Productivity Improvement through Layout Redesign
A Lean Approach Case Study

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Abstract: This paper explains how a small-size company located in the western New York region has used a lean approach to redesign its operational layout and eliminate unnecessary transportation moves to deal with financial turmoil and survive global competition. Although this is a true real world case study, the company's name is referred to as West City Vacuum Forming Inc. (WCVF Inc.) throughout the paper to protect the company privacy as they are still in business today. A couple of years ago when WCVF Inc. lost two of its major customers to competition and technology changes, the company sales were tragically impacted and severe measures of cost reductions were urgently needed in order to maintain the company in business. WCVF Inc. then decided to retrench and re-evaluate its manufacturing practices. As a result of this self assessment effort, drastic measures including a significant downsizing of the workforce and a consolidation of the space floor were addressed to save the company from financial turmoil. This paper specifically analyzes the floor consolidation aspect because it resulted into a new configuration of operational layout that improved WCVF Inc. operations, productivity, and material flow by eliminating unnecessary transportation activities. Other benefits recorded include annual operational costs saving of approximating $50,000 and a reduction in cycle times in the order of 4.8 days for some products, representing a cut of 5%.

1 INTRODUCTION

In this paper, the real name of West City Vacuum Foaming Incorporated (WCVF Inc.), the precise location of its operations, as well as the exact financial and/or operational figures of its transactions are purposely altered to protect the company business privacy. Established in the early 70s and located in the western region of the State of New York in the US, West City Vacuum Foaming Inc. is a small size manufacturer of vacuum foamed and pressure formed plastic parts serving mid and large-size companies in the general industry, medical and transportation markets. These custom made parts normally involve secondary CNC machining further augmented by additional value-added assembly work along the production lines. WCVF Inc. mainly serves markets in the United States and Canada, with a concentration of its customers in the Northeastern US (New England) and the Eastern Canada regions.

Few years ago the company lost two major customers, one as a result of moving their manufacturing operations abroad and the other as a result of changing their operational technologies and pursuing new manufacturing processes by moving away from traditional plastic thermoforming practices. As a consequence of these two losses, WCVF Inc. sales were tragically impacted to the point that severe measures of cost reduction were imperatively needed to save the company from financial troubles and potential bankruptcy. The most tragic measure was the lay-off of dozens of employees representing a significant portion of the workforce. This measure was the fastest way to save a large portion of cash liquid. However, downsizing the workforce was not enough to give WCVF Inc. the financial relief that was required to remain in business and keep a global competitive advantage at the same time. Another cash liquid improvement was needed, and therefore, deep analyses of

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manufacturing practices were urgently required.

2 THE SPCIAL CASE OF WCVF INC.

WCVF Inc. is an almost 40 year old privately owned family business. As uncommon as this may be in the manufacturing community, WCVF Inc. is a vertical manufacturing facility with interrelated operations taking place in a three floors of a four-story building, with the fourth floor being used as a mold and accessories storage room. The building is facility with floor to ceiling pillars architecture. There is one freight elevator used to move goods between floors and also as a transportation bridge to the second floor shipping door. This unusual vertical operational configuration made it not only unique but also difficult to the company to best operate economically with respect to material flow and equipment layout. WCVF Inc. experienced material handling issues that resulted in large amounts of time wasted during movement of parts between floors, hence, occasioning long cycle and delivery times.

3 COMPETITION AND ECONMIC FACTORS

Competition and operation costs are the two major factors in the manufacturing arena that have forced most companies to reassess their way of conducting operations. Companies are continually evaluating their manufacturing systems in light of increasing market competition for the purpose of growing and in some cases simply for survival in today's competitive global environment (Al-Mubarak and Khumawala, 2003).

Many firms operate at the extreme ends of Hayes and Wheelwright's (1984) product process matrix. For these firms it is easy to select which plant layout to operate under, between a job shop configuration and a flow shop configuration. Organizations are facing issues when they operate between these two extremes, i.e., mid-volume with mid-variety. In these conditions, the better option is batch processing. However, competitive forces in both domestic and global markets are challenging batch processing firms to become more flexible and more efficient at the same time (Demeyer et al., 1989). To address this dual challenge many organizations have found efficient to opt for cellular manufacturing. In order to remain competitive in the business, WCVF Inc. decided to explore lean manufacturing tools and techniques to eliminate the waste in time generated by the vertical operation process. Budget pressure required the company to rethink its manufacturing practices and reassess all the related expenses before redesigning its overall manufacturing operations. The economic and technical analyses performed by the management and engineering teams concluded that significant cost savings would be generated by taking one or more of the following actions:

- Grinding plastic at the point of its origin: This requires the purchase of one or more new grinder(s).
- Consolidating all three 5-Axis CNCs to one floor instead of having them in two different levels in the building.
- Consolidating the business tooling engineering operations and administrative offices with existing manufacturing and administrative offices in one floor.

However, it became quickly apparent that simply shrinking space by confining machines and workstations to one work space with no regard to sufficient and adequate material flow improvement was not the appropriate solution. Therefore, arranging equipment in a positive manner with respect to the operating areas became critically important for the survival of the company. The immediate solution was to eliminate one of the three manufacturing floor spaces, and consequently save money from the associated overhead and operational costs, and then, consolidate all the manufacturing operations and the administrative offices in the other two remaining floors.

4 CELLULAR MANUFACTURING

Cellular manufacturing has been long claimed to be effective for reducing the adverse effects caused by the adoption of functional layouts in job shops. Functional layouts are formed by grouping machines of similar functions into individual departments (Schonberger, 1986). In traditional job shops functional layout is adopted to increase machine utilization. Implementing cellular manufacturing requires the shop to be configured in cellular layouts comprising of cells. Each manufacturing cell is dedicated to processing a group of parts following similar sequence, and called part family. A cellular layout emulates repetitive manufacturing by allowing parts from the same family to be processed repetitively in a cell, resulting in smoother production flows (Jing-Wen Li, 2005).

Cellular manufacturing is known to promote efficient production, and therefore, extensively used in today's practice of lean manufacturing, which focus on the elimination of waste (known as muda in Japanese) in a manufacturing system. In effect, the close proximity of machines in a cellular manufacturing layout also has an advantage of reducing the waiting time, especially because its configuration allows the implementation of a practice known as operations overlapping (OPOVR) or one-piece flow. OPOVR requires moving a part to the subsequent workstation immediately of operation at the preceding workstation within a cell. Exercise of OPOVR can eliminate waiting time due to transferring parts in batches (Schonberger, 1986; Cheng and Podolsky, 1996) and thus create a smoother flow of parts and enhance control.

The second aspect of manufacturing operations in favor of several companies' alignment towards lean practices is the batch size. The batch size is an important factor that directly influences the average completion time for all parts (Shafer and Charnes, 1993). In choosing the new configuration in order to consolidate all the workstations close to one another, WCVF Inc. considered among other factors, the impact of a layout change and the batch size. The following sections describe the main steps towards the design of the cellular manufacturing using lean techniques including value stream mapping procedure as conducted and performed at WCVF Inc.

5 THE LEAN APPROACH

In a general move towards lean operations many companies today are primarily interested in the facility layout that could allow them to eliminate unnecessary transportation moves considered as a non-adding value activity (waste or muda) and that also have the drastic consequence of impairing the flow of material. Most of these companies operate in environments where product demands are not always certain or predictable. In this case, many researchers have suggested the use of virtual manufacturing cells as the most efficient operating structures. In a virtual cell, machines are dedicated to a product or a family of product as in a regular cell, but the machines are not physically relocated close to each other (Balakrishnan and Cheng, 2004).

For companies like WCVF Inc., operating on a low volume with a high variety of products, it is advantageous to operate in a virtual cell than a regular cell because in virtual cell manufacturing systems, machines in a functionally organized facility would be temporarily dedicated to a part family. In this way, jobs are routed only to those machines that are dedicated to the specific part family under current production. Another advantage of operating in a virtual cell for companies like WCVF Inc. is that no arrangement of machines needs to be done when the demand is uncertain and this results in savings on machine arrangement. Kanan et al. (1996) revealed that virtual cells act like flexible routing mechanisms.

6 THE CELLULAR LAYOUT DESIGN

This section describes the four major steps taken in designing a lean cellular configuration at WCVF Inc.:

- Determine the process family;
- Draw the current state map;
- Determine and draw the future state map;
- Draft a plan to arrive at the future state.

6.1 The Process/Product Family

A process family, also known as a product family, is a group of products or services that go through the same or similar processing steps. The intent is to look for items or parts that could be created alongside each other in a manufacturing cell. Once the part families are identified, WCVF Inc. designed and developed a cellular layout tailored to the processing of some of their typical part families.

6.2 The Cellular Layout

WCVF Inc. identified for each part-family a dedicated cluster of machines that have the complete responsibility for processing the parts identified in the family of like-parts.

The significant benefits of cellular manufacturing include reduced setup time, reduced work-in-process inventory, reduced throughput time, reduced material handling cost, improved product quality (Wemmerlov, 1997). Cellular layout is suitable for a manufacturing environment such as WCVF Inc. in which large variety of products are needed in small volumes (or batches). Once the part families are determined and assigned to specifically identified and virtually formed cells, WCVF Inc. generated a current state value stream map of the identified process/product families.

6.3 Spaghetti Diagram

The first step in creating a path towards a lean process consists of generating the spaghetti diagram to depict the flow of parts in the system. A spaghetti diagram also known and called layout diagram is a visual representation using a continuous flow line tracing the path of an item or activity through a process. The continuous flow line enables process teams to identify redundancies in the work flow and opportunities to expedite process flow (Ron et al., 2009).

6.4 Current State Value Stream Map

In general value stream mapping (VSM) combines material processing steps with information flow as well as other important related data. This tool allows users to create a solid implementation plan that, in a lean journey can be considered as the launch pad to begin identifying and improving a process family. The current state value stream map (end-to-end system map) takes into account not only the activity of the product, but the management and information systems that support the basic process. Important information provided by the current state map is the machine or work station cycle time, distance traveled, and product lead time.

At WCVF Inc., once the current state value stream map was produced and analyzed, the team identified the location of waste and then decided to produce a version of what should be the future layout of the factory and the sequence of various operations through various machines. Simulation was also used to assist the team in analyzing various "future states" scenarios.

6.5 Future State Value Stream Map

The future state map defines a direction and theoretical goal for the new work cell to aim for. In general, a future state map is almost identical to the current state map except for the kaizen events. As mentioned earlier, discrete-event simulation was used to generate and test different scenarios of future states before selecting one for implementation. In choosing the new configuration in order to consolidate all the CNC machines on the second floor, WCVF Inc. had to consider among other factors, the impact of a layout change and the batch size. The results of the move were encouraging.

7 TECHNICAL CONSIDERATIONS AND IMPLEMENTATION OF LAYOUT CHANGES

After technical considerations, the three alternatives described below were identified as candidate solutions that could contribute to waste elimination, process, productivity, and delivery time improvement at WCVF Inc. Further economical analysis determined that only two of these alternatives were immediately feasible while the third one was rescheduled for future time when and/or if better finances allow. The three candidate projects are listed and described below.

7.1 Difficulties Encountered

The major source of difficulties encountered during the lean implementation was the lack of lean principles education from the company's management. However, case studies and success stories from other prominent corporations lead the management to authorize the implementation of the new operational philosophy with less skepticism. For the engineering team, however the problem was more the lack of experience due to the fact that this implementation was really the very first lean experience for most of them. Long meetings were often necessary to overcome the divergence of opinions and reconcile ideas, which was necessary to convince both the top management and the working personnel. The latter was extremely skeptical at the beginning of the project but ended to become a positive and enthusiastic part of the effort when they finally realized that a negative attitude from their part could only harm the future of the company that could even face a potential closure.

7.2 Procurement of Plastic Trim Granulators

By acquiring a Plastic Trim Scrap Granulator the accumulation and subsequent excessive material handling of trim scrap would be avoided because all trim scraps would be immediately ground at the point of origin rather than being boxed, moved, stored in a free space (to be found) awaiting a later move to a grinding machine where an additional worker would be needed to perform the grinding operation.

Grinder costs based on a need of seven machines are shown in Table 1. The estimated costs associated with the trim scrap are displayed in Table 2. Calculations revealed that the pay-back period for the investment made to purchase the grinders is approximately 3 years as displayed in Table 3. At the time of this project, WCVF Inc. was not financially positioned to disburse $136,000 (coded data) and expect a three year return-on-investment period. Therefore, the grinder proposal was contemplated as a future project.

7.3 Relocation of All CNC Machines to One Single Floor

The second alternative project as contemplated by WCVFC consisted of relocating two Thermowood 5-Axis CNC machines (one M70 and one M67) from the third floor to the second floor where a third Thermowood 5-Axis CNC (M67) was already pre-located.

The current location of the M67 and M70 on the third floor makes it difficult for one operator to run two machines simultaneously as expected by the plant operations manager. The difficulty is centered on various factors including material storage space, CNC machine work space, downstream work space, and the operator mobility, i.e., the ability of simply moving easily, timely, and cost effectively from one machine to the other.

Placing both M67 facing each other would create a cell with two workstations that could be managed by a single operator, thus, easing the demand on manpower due to various cycle times of machining programs that allow for one operator to run both machines.

The reader is advised that pictures and drawings of various views of CVFC plant as well as of those of the second floor final layout are available upon request with a special permission of the company.

Finally, placing the Model 70 Thermwood 5-axis in a good proximity into another work cell that has excessive cycle time and close to the foaming work center would also create the opportunity for a second operator to run these two workstations (i.e., the CNC M70 and the foaming booth) in a one cell which now can afford a one-operator two- machines situation.

7.4 Relocation of Offices, Tooling, and Welding Booth to the Second Floor

The last project analyzed by the company and the continuous improvement team was the relocation of all the administrative offices, the tooling department and the welding booth from the third floor to the second floor. Before rearrangement and floor consolidation, the company functional layout was organized as follows: all the operations (manufacturing) offices were located on the second floor while the support offices (sales, marketing, and customer service) were operating from the third floor.

The new structure will combine all these services on the existing available office space on the second floor, thus, creating a more close and integrated environment where constant communications would be more on an interpersonal basis than via e-mail and phone as employees are now confined next to each other, improving the team effort spirit.

The final move consisted of relocating the tooling department and the welding booth from the third floor to the second floor, thus occasioning a 16,000 square foot of free space available for potential rent income while simultaneously eliminating more or less $50,000 of annual overhead expenses from the WCFV Inc. operating budget. WCVF Inc. wanted to target the second floor for the lean manufacturing implementation first because of the large open space in the middle of the floor that needed to be better utilized for existing manufacturing operations.

Table 1: Grinder Quote Summary (Coded Data).

Product	Price ($)	Quantity	Total Price ($)
12 x 18 Grinder	15,250.00	7	106,750.00
Accessories	4,187.50	-	29,312.50
Total	19,437.50	-	136,062.50

Table 2: Wages and Benefits Table (Coded Data).

Cost Area	Wages (*) x10^3	Wages & Benefits x10^3	Average Hourly Rate
Employee	$26	$31.2	$15.00

(*) Remarks: Wages are based on $15/h. Benefits are 20%. Data are slightly altered and coded to reflect reality)

Current process and material flow was in conflict with itself as material was moving in two directions in the same space and material cut on the M67 had to travel to the left side of the room for final fabrication. A more organized layout was needed.

8 CONCLUSIONS

A final floor plan was created using AutoCAD software. In total, this change of layout configuration had completely vacated the third flow, hence, opened a 16,00 square feet space to offer as potential rental income, eliminated more or less $50,000 of manufacturing operation expenses, moved 50 pieces of fabricating machinery, moved three 5-Axis CNC machines, and created an improved material flow, cycle/delivery times, and manufacturing work environment. The move was performed under the leadership and coordination of one of the authors with minor disruptions of operations, no loss of production time and no interruption of employee work efforts. Table 4 shows what area originally existed on the third floor and how much area was actually needed on the second floor.

Before the new configuration the shop was crowded and darker. Pictures taken before and after change of layout, although not allowed to be reproduced in this paper, are available with special permission of WCVFC Inc. Now, the second floor is brighter and better air flow is available because this floor has an air exchange system that was not available on the third floor. In addition, material flow is in the west to east direction.

The lighting on the second floor is improved over that on the third floor which was not painted and occasioning the light to be more absorbed in the room. The window wall is on the west side of the building. The elevator and shipping doors are in the east side. Additionally, work flows were altered to minimize conflicting movement patterns and make material flow one way without conflicts.

Arranging CNC machines in such a manner that accommodated one operator to run two CNC machines or one CNC and other work bench routines simultaneously has reduced operator idle time during machine cycle time, thus, eliminating non value added operator downtime. In the new configuration a single operator is able to run two machines located next to each other when prior to the move machines were located on two different floors forcing the need of one operator for each machine.

Finally, to capture the significance of the savings generated by the change in layout from the three-floor operations to a two-floor organization, two products were particularly tracked through their entire process before and after implementation of the lean changes and elimination of some non-value adding activities. A time process map showing different steps in these product processes is depicted in Figure 1 above. An analysis of the diagram reveals an improvement in cycle time and machine use. In this illustration, the string of white boxes shows the current process and the gray and yellow boxes show the future process. The future process map shows a saving of 4.8 days per year for the two products. Considering that these products represent only two of 35 to 50 varieties of products which run across these machines it can be easily seen and concluded that the potential of duplicating this saving scenario among other products is very high.

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APPENDIX

Table 3: Grinder Total Savings per Year (Coded Data).

Old Grinder	New Grinder	Issue	Annual Saving	Remarks
Highly probable to over feed and jam	Highly improbable to over feed and jam up.	Clean out time is 30 minutes + no jam time depending on the jam up, as little as 4 hours	$127.50	Cause of jams, grinder overheats plastic, melts, creates jam figure about 2 jams a year
Need for Full Time Employee	Machine Operator grinds in cycle	1 employee with benefits	$31200.00	
Clean out time is 30 minutes	Clean out time is 10 minutes	Clean out is three times less	$2,600.00	Average clean out is a day or 20 minutes a day, 5 days a week, 52 weeks a year
Grinds 1 full containers in 30 minutes	Grinds the same quantity in 20 minutes	There is a saving of 20 minutes or 1/3 hour equivalent to $4/hour	$4890	489 boxes of regrind is approximately 1956 boxes of trim scrap (4 trim scrap to 1 regrind). This will generate a saving of 10 min per box or 326 hours a year at a wage of $15 per hour
General material handling: Must move trim boxes to first floor from 3 floors	Dos not need trim scrap boxes	Reduced material handling movements	$1950.00	30 min a day 5days a week 52 weeks a year. This corresponds to moving 1440 boxes a year in average.
Requires moving boxes to the platform	No movement required	Usually waiting for a forklift skids onto platform	$3600.00	Calculated on a 10 minutes per box and 1440 boxes per year
Safety/Housekeeping requires a storage for trim scrap boxes	Needs storage for regrind boxes only	Clean up all aisles improves safety issues	N/A	Double the storage space from 25 to 50 boxes of regrind by eliminating the need to store any trims crap prior to regrind on the first floor. This will permanently eliminate any container size skids on the parameter aisle ways.
Trim Scrap Inventory	20 minutes a day	Will not be required anymore	$1300.00	Inventory/list/organize regrind path
Estimated	**Annual**	**Savings**	**$45667.50**	

Table 4: Space Usage Before and After Layout Changes.

Area	Original Space (Square Feet)	New 2nd Floor area (Square Feet)
3rd Floor Administrative Offices	3200	Absorbed into existing second floor office area
3rd Floor Tooling Manufacturing	5900	3000
3rd Floor 5-axis CNC Machine Centers	6900	2200

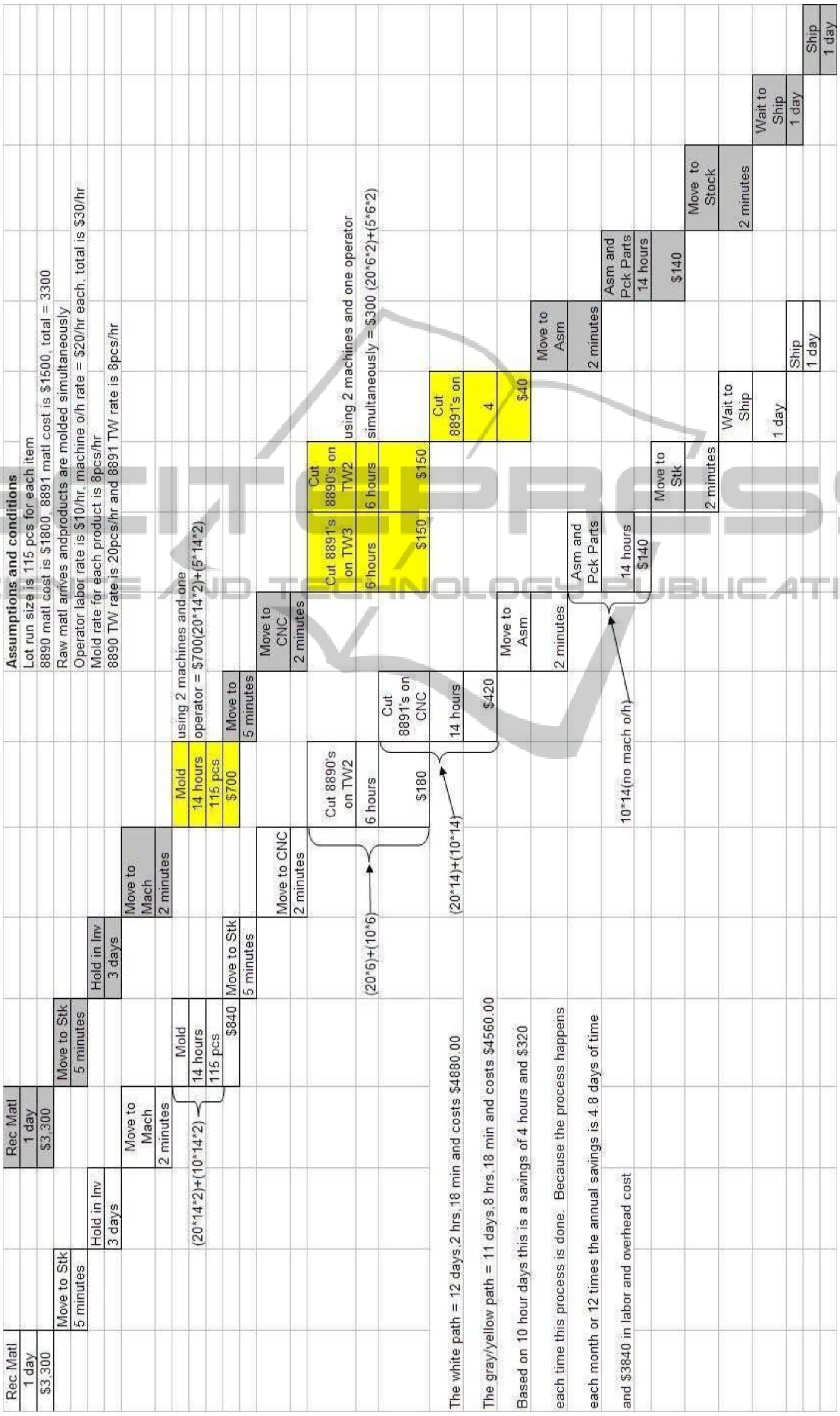

Figure 1: Process Mapping for Two Products (Product A + White Path and Product B = Grey + Yellow Path.