Spring 5-9-2010

Production Streamlining through Design, Implementation, and Analysis of Lean Manufacturing Methods

Tyler Pattison
University of Connecticut - Storrs, tyler.pattison@gmail.com

UNIVERSITY OF CONNECTICUT
STORRS, CT

Production Streamlining Through Design, Implementation, and Analysis of Lean Manufacturing Methods

Management and Engineering for Manufacturing Program
Honors Scholar Thesis

Tyler Pattison
Spring 2010

Thesis Advisor
Dr. Manuel Nunez

Honors Advisor
Dr. Robert Jeffers

Table of Contents

I. Abstract

Cellular layouts in manufacturing group machines together in such a way to, “support a smooth flow of materials and components through the production process with minimal transport or delay. “(1) Over my internship at TTM Technologies in Stafford, Connecticut, I was given the task of designing, organizing, and implementing a cellular layout on their drill department, and giving the floor a more “lean” layout. Prior to the cellular layout, many orders and materials seemed to flow throughout the floor with little guidance or clear direction as to where they should be machined. Examples of this could be seen in situations when an overdue order would be pushed aside yet again to process a rush order. There should be no need for this, and the question as to what job should be machined next should be easy to answer. Over my first three weeks at the company, I observed and analyzed the organization. It was clear that the addition of this cellular design would be extremely beneficial to their production, as long as it was done properly. The opportunity for this experience that TTM Technologies gave me will benefit not only my career but over time should help to improve their production in a department that at times could be a bottle neck.

II. Company Background

TTM Technologies is the North American leader in the manufacturing of printed circuit boards (PCBs), for aerospace and military purposes. TTM was formed in 1999 and has since grown dramatically with the acquisitions of several other companies, "that have resulted in TTM being the most diverse and profitable supplier in the PCB industry." (5)

The company's evolution began when Pacific Circuits and Power Circuits combined to form the original company. Next Honeywell Advanced Circuits was acquired, and finally Tyco Printed Circuit Group in 2006 doubling the company's size multiple times over a seven year period. Currently they have ten separate manufacturing operations throughout the world, nine in the United States with their corporate headquarters in Santa Ana, California and one in China. In these facilities, TTM owns over one million square feet and around 3,500 employees. (5)

This project took place at the TTM Technologies plant in Stafford, Connecticut. The plant manufactures a wide variety of military and aerospace circuit boards. The production in this plant has a variety of areas with opportunity for improvement. This is why the General Manager of this branch, Mr. Phil Titterton, assigned me the task of improving their machine organization to streamline the production through their PCB Drill Department. To improve production, the machines would be moved, and several other changes would be done during my time at the company and others set in motion for later completion.

III. Original Production Process and Layout

The drill floor at TTM Technologies consists of a wide variety of different machines, each with their own specifications, limitations, and capabilities. Some machines may have only one drill head, while others have six, showing the variety of machining options for one job. The machines brands are Schmoll, Hitachi, Uniline, Excellon, and Routers. Figure 1 shows the original layout of the drill floor. There are eight Hitachi machines, two Schmoll machines, two rout machines, two Excellon machines, and six Uniline machines. Each one goes by a separate number, shown in Figure 1.

Figure 1: Original Floor Layout

The machines not only vary by the number of drill heads, but also by the size of boards that can be handled. Additional variability is in the ability in some machines to do controlled depth drilling, meaning the ability to drill a hole within only a few thousandths of an inch of the correct depth without drilling all the way through a board, and others are built to only perform routing processes and nothing else. These limitations are shown in Table 1.

Machine Name	Size Capability (Inches)	Heads	Special Features
Hitachi 5	24 x 36	5	Depth Drilling
Hitachi 6	21 x 27	6	Limited Capability
Hitachi 7	24 x 36	5	Limited Capability
Hitachi 8	21 x 27	5	None
Hitachi 9	21 x 24	5	None
Hitachi 10	18 x 24 or 42 x 60	6	None
Hitachi 11	21 x 27	6	None
Hitachi 12	21 x 27	6	None
Schmoll 1	n/a	4	n/a
Schmoll 2	n/a	4	n/a
Excellon 2000 "C"	n/a	5	n/a
Excellon 2000 "D"	n/a	4	Depth drilling
Router 1	n/a	n/a	n/a
Router 2	n/a	n/a	n/a
Uniline 1	25 x 30	1	Vision System
Uniline 2	25 x 30	1	n/a
Uniline 3	25 x 30	1	n/a
Uniline 4	25 x 30	1	Depth Drilling
Uniline 5	25 x 30	1	n/a
Uniline 6	25 x 30	1	Depth Drilling

Table 1: Machine Specifications

The ideas for the different manufacturing cells were proposed at the beginning of the research. They were a "Highway Cell" for fast processing of large orders, a "Critical Cell" for jobs that must be completed quickly, an "Engineering Cell" for jobs requiring the cooperation of an engineer to complete the job, a "rout cell" for jobs that need routing, a "small lot cell", and a "sub cell" for a unique type of PCB. Though these ideas were proposed, free range was given as

far as research, ideas, and even the ability to knock down and build walls if necessary to accommodate a better plan. Additionally some other routings were taken into consideration to limit the traveling distance for the operators and to further improve efficiency.

The drilling of these boards is far more than simply drilling. The process involves various steps. First, once an order comes off of the elevator onto the floor, “kits” must be made. Kits are small plastic holders that hold the various drill bits necessary for the particular job. They are created by hand, and then placed in a plastic bin for the operator to use when it is time to put the job on. Next, the job is assigned to a particular machine, and the raw material is taken from the stock room. The panels are then placed in the machine, along with the cassettes holding the drill bits. Once the first set of panels from a job is done, a “coupon” is cut from the board with a router in the stock room. A coupon is simply a small piece of the board used as a cross section to check the drilling of the board. Next it is brought to a grinding wheel where it is smoothed, and finally it is examined. As long as it passes inspection, the rest of the job is then completed, routed by the routing machines if necessary, and then sent through the “hole check” machine. This machine automatically compares a file with the correct locations and size of the holes to those of the actual board. Once these pass inspection, the order is sent to the next step in the manufacturing process which varies with each order.

There were many problems with the original layout. Previously there was no method as to what job would go to which machine. In addition, the smaller machines, such as the grinding wheel and the small router which are used together are in different locations. The best situation would be that every job would have a specific machine, with no exceptions, and that the other machines would all be centrally located to eliminate waste of time. With lean practices, the production and income of TTM could greatly increase.

The moving of these machines can be viewed as an easy process, with pallet-jacks and man power moving them into their new location, but the process is extremely complicated. The machines weigh over 20,000 pounds, with the machining surface of the Schmoll machine made of solid granite. Outside contractors must be hired to move these machines, with a cost of $7,500 dollars per day for a crew of six. In addition, the limited space in the hall ways increases the difficulty. Lastly, each machine requires a specific type of network connection, and also different suction power to remove debris from the drilling process.

IV. Cellular Layout and Lean Manufacturing

Cellular manufacturing consists of using work stations and equipment in a layout that minimizes transport and allows fast production. (1) It is a method used to achieve lean manufacturing. Lean manufacturing is defined as follows:

> "The systematic elimination of waste from all aspects of an organization's operations, where waste is viewed as use or loss of resources that does not directly lead to creating the product or service a customer wants when they want it." (1)

In companies that have not adopted the "lean mentality," the majority of time in the manufacturing process is wasted. On occasion, waste can comprise more than ninety percent of the time. This idea originated with Hendy Ford and the Ford Motor company but became much more prominent with the Toyota Motor Company and Taiichi Ohno.

Henry Ford implemented interchangeable parts and a moving conveyor system to create "flow production" (3) Lean manufacturing was taken to the next level when Toyota travelled to America to observe what Ford had implemented and invented their own variation known as TPS, or Toyota Production System. With this system, they changed their capabilities to accommodate the necessary volume. In addition, self-checking machines improved quality, and their layout decreased changeover time. The goal of these changes was to have low cost, high quality, and rapid throughput. In the book "The Machine That Changed the World" by James P. Womack and Daniel Jones, the five principles of lean were laid out, given as follows.

1) Specify the value required
2) Identify the Value Stream for each product
3) Achieve continuous flow through the value-added steps
4) Use a Pull-System when possible
5) Continuously decrease time, steps, and information needed reducing waste and increasing efficiency

Correct implementation of these principles yield high efficiency. It is an extremely long process for companies to achieve the highest possible level of lean manufacturing. TTM is one of those companies, and is currently moving in the right direction towards that end.

V. Cellular Layout Implementation

The idea of a cellular layout was given to me, along with a suggested idea for the layout by TTM managers, but I was told to research other possible layouts for the machines. Many different approaches were used and tried before a final solution was found. These are attached in the Appendix. We considered the flow of operators, as well as the possibility of joining multi-head machines with single head Uniline machines to allow them to handle a wide number of panels seamlessly. Also, we took into consideration the maximization of space on a very cramped floor. However, each of these ideas kept reverting back to a simpler, mathematically focused layout.

Each cell has specific machines for certain types, or sizes of jobs. The "Critical Cell" remained the same, with two six head machines. This is because the point of the critical cell is to push through high priority jobs as fast as possible, and therefore should have the maximum number of heads possible, without having an unnecessary amount of machines. The "Sub Cell" consists of the two newest Hitachi drill machines, which have the largest capacity of all of these style machines. Subs are extremely large, and this is why these machines were chosen to make up this cell. The "highway," or production cell, has four machines, with both five and six heads. This allows for a wide variety of different sized jobs to be handled quickly, including very large jobs. The "engineering cell" has a machine with controlled depth drilling capabilities as well as another one that has since been fitted with that capability as well. These are placed together due to the increased supervision that engineers supply to these jobs. The small lot cell has two Uniline machines, with only one head on each, as well as a Schmoll machine to give a few choices for which machine to give small jobs to, without having a lot of unused drilling heads. The final cell was the routing cell. The routing cell received the two machines dedicated to

routing, as well as other unique drilling machines, a Schmoll and an Excellon machine, and a Uniline machine with a brand new vision system to provide for improved precision in the drilling and routing process.

In addition to these changes, two machines, a Schmoll machine and a Uniline machine would be removed, and in turn a pair of new Hitachi Machine would be brought in. Given these changes, the lack of space, and the fact that nearly every other machine would need to be moved, a very specific order had to be followed to avoid issues with being unable to move a machine because something else has gotten in the way. The specific sequence went as follows:

1. Move Schmoll Machine Out
2. Move Uniline Out
3. Stage Router to ready for move
4. Move Excellon C machine
5. Move remaining Schmoll Machine
6. Move in 2 new Hitachi's
7. Stage Unlines for move
8. Move Routers into place
9. Move Unilines into place
10. Switch around Hitachi's into place

The moving process took one day longer than expected. This problem arose while moving a Schmoll machine. It was too large to make the corner without hitting a beam so it took nearly half of a day to get it turned and moved. Once this was finally done, an

extra day was necessary, bringing the total cost up to about $28,000, $7,000 higher than expected.

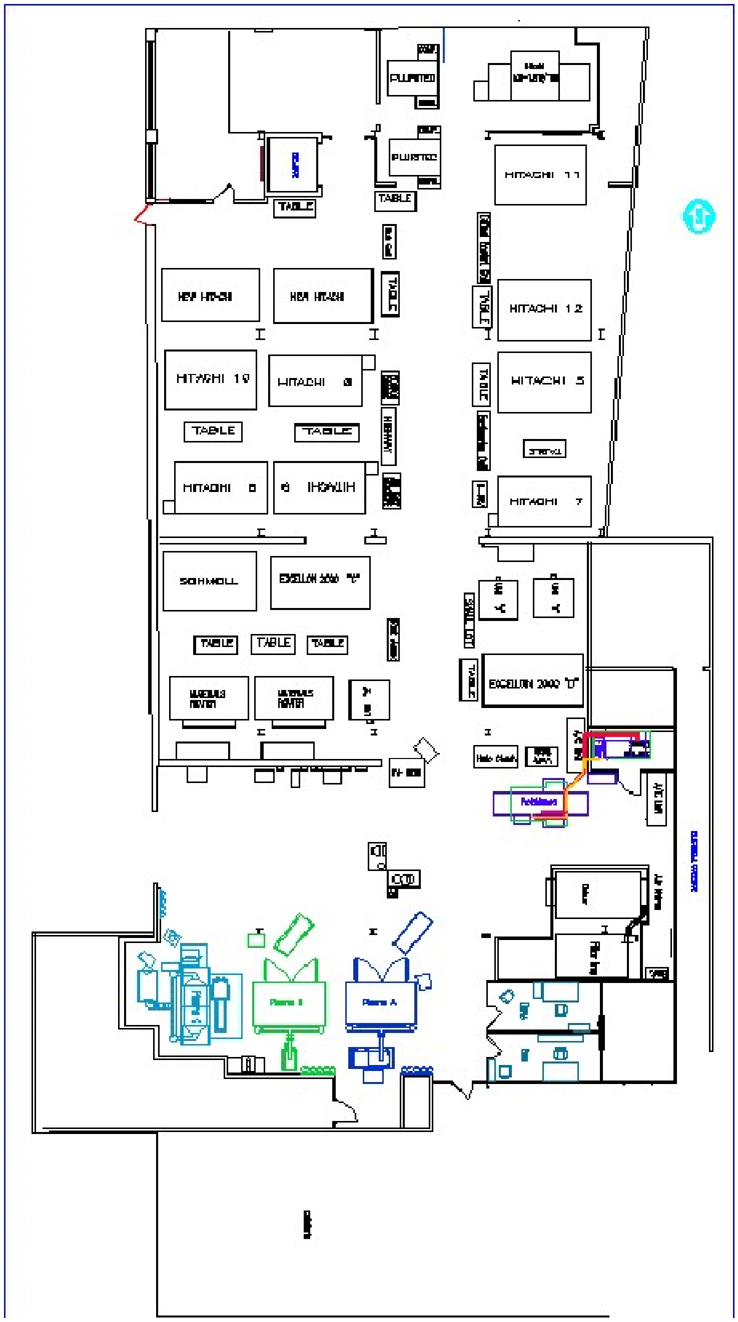

Figure 2: Final Floor Layout

VI. Finding the "Magic Number"

The "magic number" is the number of panels in a job that require it be sent to the highway cell, instead of the small lot cell. A mathematical approach was used, as well as taking into consideration the experience of operations and managers to make slight variations to the results.

Based on the new cellular layout, the ratio of heads from the highway cell to the small lot cell are 3.6667 to one. This means that the highway has nearly four times as many heads as the small lot cells. In the ideal situation, the number of panels going into each of these cells would have a four to one ratio. Using data from a past year, and nearly 7,600 jobs, the data was simplified into useable numbers.

Based on the given data, also attached in the Appendix, if jobs with ten panels or less were sent to the small lot, and jobs of eleven or more were sent to the highway, the ratio of jobs would be 4.76 to 1.08 giving a close result to four to one, while giving a slightly larger load to the highway which is appropriate. However, upon surveying both managers and operators, they felt that a slightly different value, ten and more going into the highway, would be better. Given below are the calculations used, as well as the explanation of these calculations. Table 2 shows the lot size division point solely based on mathematics.

		Theoretical Calculations	
	Desired Ratios	Theoretical Ratios	Theoretical Lot Size Division
Highway/Small Lot Head Ratio	3.6667	3.5630	11.5
Highway/Small Lot Job Ratio	1.0000	1.0026	10.5

Table 2: Mathematical Magic Number

Given the input from employees of TTM Technologies, these numbers were slightly altered based on their suggested, giving the following results in table 3.

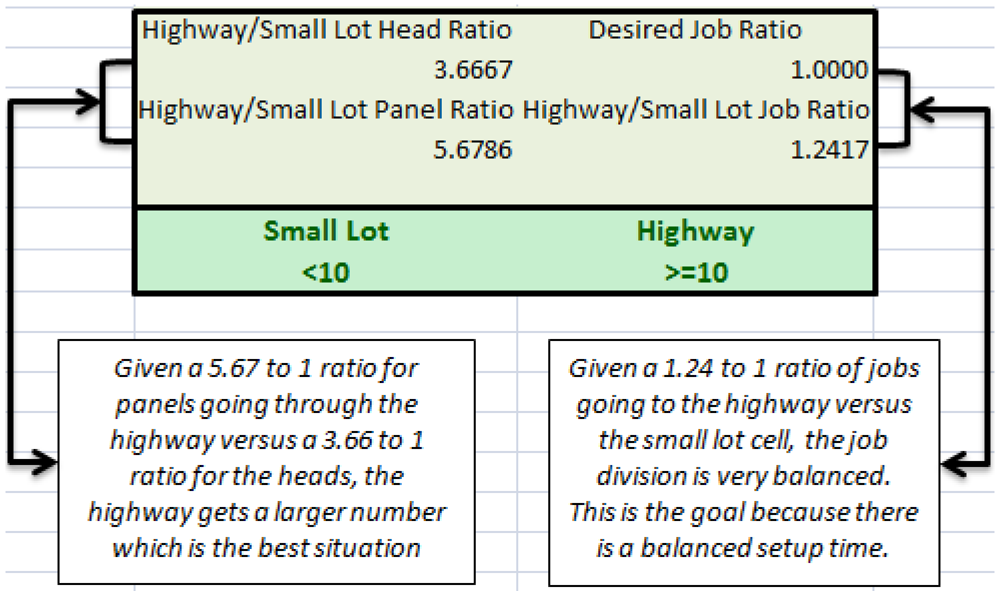

Table 3: Actual Magic Numbers

As shown above, lot sizes 1-9 will go into the small lot cell, while lots 10+ will go to the highway. The calculations to support these numbers show the following:

1) Show almost equal jobs going into each cell, therefore giving an equal setup time for each cell

2) Show a somewhat equal balance between panels going into each cell compared to the number of heads in each cell by comparing their ratios

3) Even though the ratio comparison is slightly skewed, it is supported because not only do you want a larger number of jobs going into the highway, but it would be illogical to put a lot of 10 into the small lot. Putting a lot of 10 would require 3 runs at least, where as it would only require 2 in the highway.

The theoretical calculations show, if only numbers were considered, what the "magic numbers" would need to be. These values are only supported by the numbers, not by machine design.

VII. Future Suggested Changes Towards Lean Manufacturing

In addition to the cellular layout implementation, there are several other issues that began to be addressed, but were not completed. One major problem is in one of the primary elements of lean manufacturing, and that is decreasing inventory of raw materials. As shown below in image 1, TTM Technologies has a large amount of money and space locked up in inventory.

Image 1: Stock Room Inventory

I analyzed the number of panels that were produced of each size throughout the course of one year. Based on these calculations, TTM had in some cases over a year's worth of inventory in stock. With the deal TTM Technologies has with their supplier, there is no limit to the number of orders that can be placed throughout the week, and often it will only take one day of lead time to receive and order. Given that, the inventory does not to be too high. The ideal system would be that of an automatic replenishment system. For example, set a replenishment point, and as soon as the inventory reaches that value, a certain number of packages are ordered.

Though this material is not perishable and will all be used eventually, an extremely large amount of money is simply sitting on shelves. This was being looked at when internship ended at TTM.

A second issue was simply wasting of money. In the drilling process, there are several size drill bits that are used for each panel, and they can drill a specific number of holes before they need to be changed. Often five to ten drills, or more, of one size are used on the same job. However, an issue occurs when there are an odd number of panels in a job, for example fourteen panels are going on a five headed machine. This job will take three runs on the machine, but the last set of drill bits will not be used for the last run, because only four panels will be drilled. However, these drill bit holders, known as cassettes, are set up the same for each head. Therefore, the last cassette will have unused bits at the end of the job that will be disposed of or sent away to be re-tipped in order to be reused even though they do not need to be refurbished. I completed a Microsoft Excel analysis and some calculations to figure out a system to determine which drill bits are not used, and do not need to be placed in the cassette. However, there have been many changes to the production process, and at the time, this would have resulted in more work, and may be considered later on in the future. This is another inefficiency that should be addressed.

VIII. Conclusions

Lean manufacturing techniques have been used extensively throughout all of manufacturing. Companies look to eliminate wasted money, whether it be from overstocked inventory, wasted materials, scrapped jobs or various other factors of manufacturing. With the implementation of these important principles, income can be greatly increased. The usage of a cellular layout is one of these principles. Many industries have gone lean not only to save money, but in order to contend with competitors for business, while many have only done so partially and still have much room for improvement. TTM Technologies is one of these companies.

The cellular layout now being used on the drill floor of TTM helps to streamline their production through increased efficiency and reducing error. Other lean principles, such as reduced inventory and reducing waste are also steps in the right direction for a completely lean manufacturing process. While there are still many changes to be made, no company will ever achieve completely lean manufacturing. However, the importance of constant improvements to the manufacturing process is what can make a successful company, and consideration of lean principles is something that can bring on these enhancements.

IX. Acknowledgments

The experience of completing my Honors thesis has been an extremely memorable and unparalleled experience for me. I have worked hard for four years in the Honors program. It started my first day in Shippee Hall and will end walking across the stage in Jorgensen, and those four years culminated with this research. I could have never completed it without the help of so many people, those of whom I would like to acknowledge. I would like to thank my family for their support for so long, and putting up with my highs and lows through my years at the University of Connecticut. Also, Dr. Jennifer Lease Butts who became a great mentor for me, and more importantly someone who I can always speak to about issues, and just what was going on in my life. Another large help in forming my four years here was Dr. Lynne Goodstein. Not only was she the Director of the Honors Program which helped to form my years here, but also my professor for an eye opening independent study in my sophomore year, and a friendly face to bump into throughout campus. Without the help of these people, I do not know where I would be, but I would definitely not be an Honors Scholar.

I would also thank both my academic and Honors advisors, Dr. Robert Jeffers and Dr. Manuel Nunez. The constant guidance of Dr. Jeffers helping me pick classes or figure out how to go about solving academic questions was an immense help for me and Dr. Nunez as well, not only being a resource for questions and teaching my classes, but supervising my Honors Scholar Thesis. I am extremely grateful for all of their help.

Finally, I would like to acknowledgement TTM Technologies and all of those that helped me throughout my internship there, which is simply too many to name. Phil Titterton, Daniel Delaney, Daniel Ellis, and Terry Armelin are just a few to send these thanks to. The internship

was a huge highlight of my years in the School of Engineering and will help me far more in the future than I will ever be able to understand.

The way my years here turned out are to be the result of far too many people to list, and for that I would like to send my acknowledgements and my sincerest thanks to all those who were with me for these years.

X. References

1. "Cellular Manufacturing | Lean Thinking | Lean and the Environment | EPA." *U.S. Environmental Protection Agency*. Web. 10 Feb. 2010. <http://www.epa.gov/lean/thinking/cellular.htm>.

2. "History of lean manufacturing." *Lean Six Sigma | Lean Manufacturing | Lean Six Sigma Certification*. Web. 11 Feb. 2010. <http://www.beyondlean.com/history-of-lean.html>.

3. "History of Lean Manufacturing." *Manufacturing-Works - the Wyoming Manufacturing Extension Partnership*. Web. 10 Feb. 2010. <http://manufacturing-works.com/lean/lean_history.php>.

4. "Lean Thinking and Methods | Lean and the Environment | EPA." *U.S. Environmental Protection Agency*. Web. 11 Feb. 2010. <http://www.epa.gov/lean/thinking/index.htm#what>.

5. *TTM Technologies, Inc.* Web. 10 Feb. 2010. <http://www.ttmtech.com>.

6. "TTM Technologies Reviews | Glassdoor.com." *Glassdoor.com - Company Salaries and Reviews*. Web. 11 Feb. 2010. <http://www.glassdoor.com/Reviews/TTM-Technologies-Reviews-E12135.htm>.

XI. Appendix

<u>Past Data Used (Abbreviated)</u>

autLotID	txtCustomer	txtPartNo	dtmDateOrdered	dtmCreationDate	sngPanelWidth	sngPanelLength	intNoUp	bytLayerCount
39277	TTM SS / NORTHROP	139K542G01	23-May-08	02-Jun-08	24	30	1	16
39278	Plexus / Honeywell	2715282-1	30-May-08	02-Jun-08	18	24	18	3
39279	BAE Systems	488548-02	30-May-08	02-Jun-08	24	24.5	6	10
39280	BAE	488544-02	30-May-08	02-Jun-08	21	27	6	10
39281	HAMILTON	1706847-1	30-May-08	02-Jun-08	18	24	5	8
39282	TTM STAFFORD	ENG TEST PANEL	30-May-08	02-Jun-08	12	18	4	2
39283	TTM-SS/NORTHROP	1471F60H01	30-May-08	02-Jun-08	18	24	4	12
39284	HAMILTON	813128-1	30-May-08	02-Jun-08	18	24	4	6
39284	HAMILTON	813128-1	30-May-08	02-Jun-08	18	24	4	6
39285	HAMILTON	816116-2	30-May-08	02-Jun-08	21	27	6	8
39285	HAMILTON	816116-2	30-May-08	02-Jun-08	21	27	6	8
39286	Raytheon	PWH418023 TEST2	28-May-08	02-Jun-08	18	24	6	6
39287	Raytheon	PWH418023 TEST1	28-May-08	02-Jun-08	18	24	6	1
39288	ELDEC	8-848058-01	13-Mar-08	02-Jun-08	18	24	3	17

39289	TTM-SS / Raytheon	6631778-1	30-May-08	02-Jun-08	18	24	6	6
39290	HAMILTON	816269-1	30-May-08	02-Jun-08	18	21	4	8
39290	HAMILTON	816269-1	30-May-08	02-Jun-08	18	21	4	8
39291	LOCKHEED	7400753	28-May-08	02-Jun-08	18	24	4	12
39292	Northrop Grumman	891115-1	21-Nov-07	02-Jun-08	18	24	1	22
39293	Jabil	4072822-2002	02-Jun-08	02-Jun-08	21	27	8	12
39294	BAE	H535A612-101	02-Jun-08	02-Jun-08	18	21	12	8
39277	TTM SS / NORTHROP	139K542G01	23-May-08	02-Jun-08	24	30	1	16
39278	Plexus / Honeywell	2715282-1	30-May-08	02-Jun-08	18	24	18	3
39279	BAE Systems	488548-02	30-May-08	02-Jun-08	24	24.5	6	10
39280	BAE	488544-02	30-May-08	02-Jun-08	21	27	6	10
39281	HAMILTON	1706847-1	30-May-08	02-Jun-08	18	24	5	8
39282	TTM STAFFORD	ENG TEST PANEL	30-May-08	02-Jun-08	12	18	4	2
39283	TTM-SS/NORTHROP	1471F60H01	30-May-08	02-Jun-08	18	24	4	12
39284	HAMILTON	813128-1	30-May-08	02-Jun-08	18	24	4	6
39284	HAMILTON	813128-1	30-May-08	02-Jun-08	18	24	4	6
39285	HAMILTON	816116-2	30-May-08	02-Jun-08	21	27	6	8

39285	HAMILTON	816116-2	30-May-08	02-Jun-08	21	27	6	8
39286	Raytheon	PWH418023 TEST2	28-May-08	02-Jun-08	18	24	6	6
39287	Raytheon	PWH418023 TEST1	28-May-08	02-Jun-08	18	24	6	1
39288	ELDEC	8-848058-01	13-Mar-08	02-Jun-08	18	24	3	17
39289	TTM-SS / Raytheon	6631778-1	30-May-08	02-Jun-08	18	24	6	6
39290	HAMILTON	816269-1	30-May-08	02-Jun-08	18	21	4	8
39290	HAMILTON	816269-1	30-May-08	02-Jun-08	18	21	4	8
39291	LOCKHEED	7400753	28-May-08	02-Jun-08	18	24	4	12
39292	Northrop Grumman	891115-1	21-Nov-07	02-Jun-08	18	24	1	22
39293	Jabil	4072822-2002	02-Jun-08	02-Jun-08	21	27	8	12
39294	BAE	H535A612-101	02-Jun-08	02-Jun-08	18	21	12	8
39294	BAE	H535A612-101	02-Jun-08	02-Jun-08	18	21	12	8
39295	PLEXUS / HONEYWELL	623-3940-007	02-Jun-08	02-Jun-08	18	24	12	4

The given data was a few hundred pages long, and a sample is listed above.

Condensed Version of Past Data

Lot Size (Panels)	Quantity of Each Lot Size	Total Panels (Quantity x Lot Size)	Small Lot Heads
1	31	31	6
2	303	606	
3	670	2010	**Highway Heads**
4	574	2296	22
5	428	2140	
6	439	2634	
7	310	2170	
8	415	3320	
9	218	1962	
10	262	2620	
11	285	3135	
12	231	2772	
13	158	2054	
14	238	3332	
15	286	4290	
16	193	3088	
17	133	2261	
18	99	1782	
19	111	2109	
20	142	2840	
21	93	1953	
22	99	2178	
23	127	2921	
24	157	3768	
25	105	2625	
26	70	1820	
27	90	2430	
28	250	7000	
29	96	2784	
30	116	3480	
31	71	2201	
32	80	2560	
33	85	2805	
34	55	1870	
35	62	2170	
36	49	1764	

37	33	1221
38	49	1862
39	27	1053
40	61	2440
41	17	697
42	81	3402
43	23	989
44	18	792
45	17	765
46	18	828
47	3	141
48	33	1584
49	9	441
50	21	1050
51	0	0
52	1	52
53	7	371
54	5	270
55	6	330
56	14	784
57	0	0
58	1	58
59	2	118
60	4	240
61	0	0
62	0	0
63	10	630
64	1	64
65	0	0
66	0	0
67	0	0
68	0	0
69	0	0
70	2	140
71	0	0
72	0	0
73	0	0
74	0	0
75	0	0
76	0	0
77	0	0
78	0	0
79	0	0

80	0	0
81	0	0
82	0	0
83	0	0
84	0	0
85	0	0
86	0	0
87	0	0
88	0	0
89	1	89
90	0	0
Total	**7595**	**112192**

<u>**Cellular Layout Summary**</u>

Stock Room: Before and After

Small Lot Cell: Before and After

Engineering Cell: Before and After

Before:
1 5-head machine w/ Depth Drilling
1 6-head machine

After:
2 5-head machines w/ Depth Drilling

Sub Cell: Before and After

Production Cell: Before and After

Before:
3 5-head machines
1 6-head machine

After:
2 5-head machines
2 6-head machines

Rout Annex: Before and After

Further Changes to Shelving/Tables Still Required
Better utilization of back wall area