CONVERTING FROM MOVING ASSEMBLY LINES TO CELLS

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ABSTRACT

After more than a decade of mainstream exposure, the concepts embodied in the Toyota Production System (TPS), also referred to as lean manufacturing, have sparked a great enthusiasm in companies towards converting their departmental, mass system. The enthusiasm typically stems from reports of lean that tend to stress its excellence in performance measures such as floor space savings and higher quality. Unfortunately, many of those attempting to convert quickly get lost in the exercise of physically implementing cells, while the lean concepts take a backseat. Thus, it is essential to emphasize the fundamental design differences that allow lean systems to be superior to traditional mass systems from the onset. In this way, it can be better understood that cells are not a quick or one-time solution, but rather the outcome of a thorough understanding of the lean concepts.

The work presented herein focuses on an assignment to convert a moving assembly line -- typically associated with mass systems -- into cells which serve as the building block of a lean manufacturing system. Once the cells were implemented, the two subsystems were compared in terms of 1) design process, 2) quantifiable measures, and 3) non-quantifiable benefits. The intent of this paper is to show how the measures used for system comparison, quantifiable and non-quantifiable, take root in the design phase.

Keywords: Toyota Production System, lean manufacturing, moving assembly line, cell design

1 INTRODUCTION

The use of moving belt assembly lines is a familiar sight in the final assembly areas of many mass production systems. It is also typical for the entire final assembly area, composed of several assembly lines, to be treated as a department within the larger manufacturing system. Meaning that parts enter the department in extremely large batches, are taken to entry points along the various assembly lines, and then wait to be processed. Despite the fact that mass systems operate in a batch and queue fashion, it can be argued that their moving assembly lines promote single piece flow (SPF) -- the primary reason for pursuing cells -- and thus the question of whether a conversion to cells is necessary may arise.

In an attempt to answer the question of why cells should be pursued over moving belt assembly lines, this paper focuses on the fundamental differences in the design process for both, and the benefits, quantifiable and non-quantifiable, these differences translate into.

2 THE PRODUCT'S BASICS

A common thought among those who have either failed to convert or are hesitant to change is that some products are better suited for cells than others. Therefore, it is important to emphasize that the product discussed throughout this paper was not altered in any way to make it a better candidate for production in cells. Moreover, the authors agreed to the cell design project prior to the company choosing which product it wanted to run in cells.

A description of the product seems appropriate so that one can understand that the product is not overly simple or complicated, and does not have very few or many processing steps. The product is the hose and tube assembly shown in Figure 1, which acts as a connector between the components of an automotive air conditioning system. At either end of the product there are aluminum tubes, each with a different type of end joint. In final assembly, the tubes are joined to a flexible, rubber hose by a crimping process. Other final assembly steps include attaching O-rings to the tubes, a leak test of the assembly, and placing protective caps on the tube ends for shipping purposes.

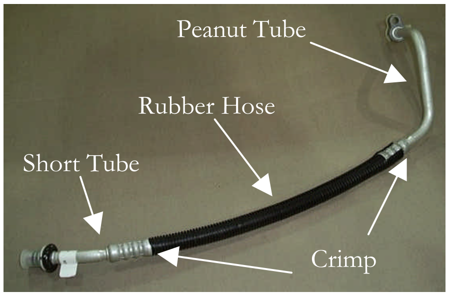


Figure 1: Connector between air conditioning components

As for customer demand, the hose has an average daily demand of 4200 pieces with rare shifts to either 3600 or 4800 pieces. Production planning always schedules these parts in multiples of 600 because it is the maximum amount a shipping container can hold. Given the high demand, the assembly line and the cells that replaced it, were both entirely dedicated to the final assembly of this single product.

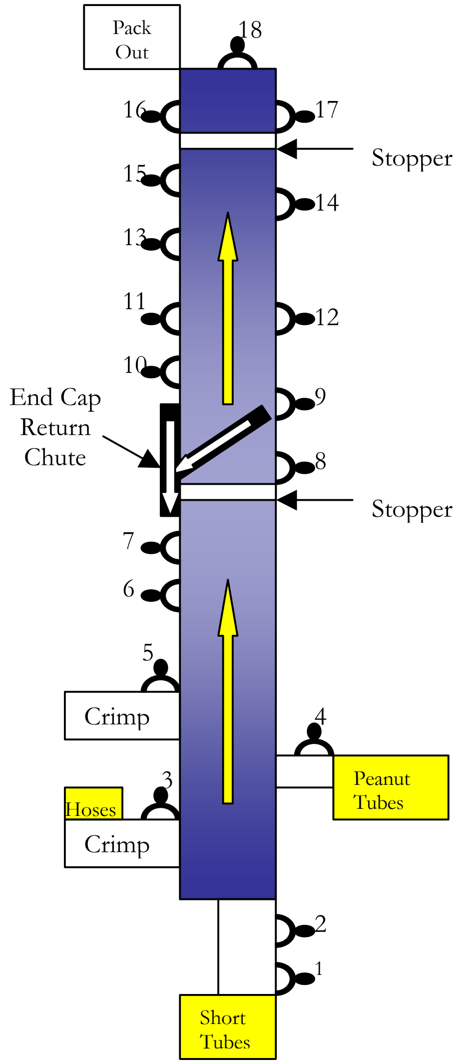


Figure 2. Layout of the assembly line

3 STATE OF THE ASSEMBLY LINE, JUNE 1999

When the project began, the assembly line which had been running the hose for close to 2 years was by all accounts mature in operation (i.e. all the "bugs" that were going to be worked out had been worked out). At this point in time, the assembly line's conveyor measured 90 ft in length and 3 ft in width, while the entire working space utilized by the line was about 100 ft by 15 ft. Also of importance, with regard to the belt, is that it ran at a fixed rate of 470 pieces per hour, meaning that 1 part should come off the end every 7.7 seconds. In order for the product to be assembled at this high speed, 18 direct and 6 indirect workers were dedicated to the line. Figure 2 shows a layout of assembly line. The length and speed of the belt, along with the number of workers manning it and their position along the line are all among the most essential variables that go into the designing of an assembly line. Thus, it is important to understand how these variables are related, and the sequence in which the design choices are made.

4 SIMPLIFIED "MASS" ASSEMBLY LINE DESIGN PROCESS

The following four steps have been identified as those taken to design a mass assembly line, and are shown in the order in which they were pursued.

1. Determine belt rate
2. Determine a standard time for each operation
3. Calculate the number of direct workers
4. Calculate the length of the belt

4.1 DETERMINING BELT RATE

In keeping with the company's work schedule philosophy, the assembly line was designed to complete production of the hose in the first shift. This design goal stems from the desire to have the assembly lines free in subsequent shifts to deal with unforeseen spikes in demand and problems that occur over the course of the day, by working overtime.

The result of wanting to complete production in the first shift, which has 8.5 hours of available working time, is that a part needs to come off the line every 6.2 seconds (this is assuming an uptime factor of 85%). However, when the line was introduced it was rated for an output of 470 parts per hour or a finished part every 7.7 seconds. Thus, when volume later increased, the fixed belt rate led to a dependence on overtime of at least one hour a day to complete production. While one hour may not seem like a lot of time, it should be kept in mind that for the assembly line to function all 18 direct workers are needed.

4.2 DETERMINING OPERATIONS' STANDARD TIMES

The operations that took place on the mass assembly line are shown in Table 1 along with their standard times. The standard times are the result of time studies conducted by the plant's Industrial Engineering Department. In some cases the worker was much faster than the predetermined work standard, and in other cases the worker could not actually meet the target time. An example, of the latter was observed in operation 11, attaching a sleeve over hose, in which the task took so long that a second operator was permanently added to the line to make sure that this operation did not disrupt the flow. These are workers #11 and #12 in Figure 2. They sit across from each other, on either side of the moving conveyor belt, and each of them picks every other part that comes down the line.

Table 1: Final assembly work standard times

Op #	Tasks completed by operator	Std. Time (secs)	# of operators required
1	Remove shipping cap, inspect, attach metal spring to short tube	7.6	1
2	Attach 3 O-rings to short tube	2.2	1
3	Crimp short tube to hose	3.8	1
4	Remove shipping cap,	3.6	1

	inspect, attach O-ring to peanut tube		
5	Crimp peanut tube to hose	4.7	1
6	Attach end cap to peanut tube	3.9	1
7	Attach end cap to short tube, and load assembly with helium	3.7	1
8	Leak Test	4.4	1
9	Unload helium and remove end cap from short tube	4.7	1
10	Remove end cap from peanut tube	2.8	1
11	Attach sleeve over hose	4.7	1
12	Attach indicator and shipping cap to short tube	4.3	1
13	Attach shipping cap to peanut tube	3.5	1
14	Attach product label	2.9	1
15	Final inspection	9.2	2
16	Package parts	1.9	1
	Total Processing Time	**67.9**	

4.3 CALCULATING THE NUMBER OF DIRECT WORKERS

In calculating the number of direct workers for a mass assembly line, the only constraint that exists pertains to the product's assembly sequence since some operations must precede others. With this constraint in mind, the next step is to group tasks so that the line is balanced, meaning that each operator has roughly the same work content based on time and that this time is less than the belt speed. The final step is the actual assignment of workers to specific tasks. This is done taking the standard operating times shown in Table 1, and dividing them by the belt speed. The answer is then rounded up, and this determines how many workers are needed at each defined operation or set of operations. In most instances each operator has a single task, and in the case of final inspection which is greater than the belt speed two workers were given an identical task. These correspond to workers #16 and #17 in Figure 2.

The obvious problem with this method of determining the number of workers is that almost all the workers, by design, have a great deal of idle time per cycle. Figure 3, a plot of the work standard times against the cycle time, shows that 50% of a part's throughtput time is spent as downtime. This loss of worker utilization is largely due to the fact that with a cycle time of 7.7 seconds, there are very few choices for combining operations.

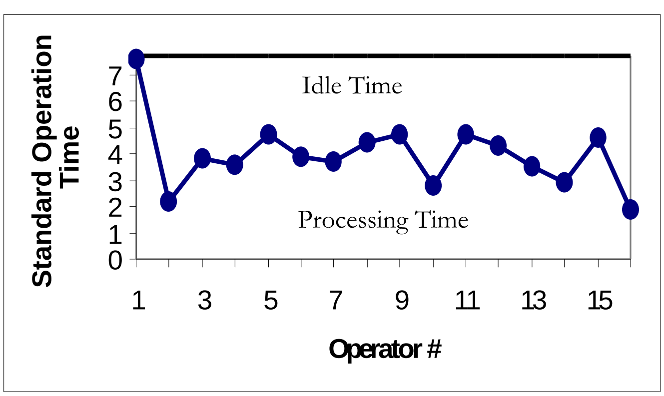


Figure 3: Downtime per part throughput time

4.4 CALCULATING BELT LENGTH

Once the number of workers needed and their position along the line are known, the last step in designing the moving assembly line is to determine the length of the belt. The length is determined by allowing sufficient spacing between workers so that they are able to keep up with the belt speed. Since the operations that actually take place on the belt, #3 through #15, all vary in time from 2.8 seconds to 4.7 seconds the spacing also varies to smooth out these differences. The typical spacing between operations along the line is about 5 feet.

5 DISCUSSION OF PROBLEMS OBSERVED ON THE ASSEMBLY LINE

Prior to the conversion of the mass assembly line to cells several different problems were observed, most of which resulted in the line stopping for varying amounts of time. In this section, the discussion will center on those problems that are directly tied to the design of a moving assembly line.

5.1 CONVEYORS CREATE THE NEED FOR FINAL INSPECTION

The most serious flaws with the choice of a conveyor belt for assembly is that a part can get past a worker. This flaw is made evident by the physical stoppers on the line before leak test and final inspection (see Figure 2), operations in which a missed part cannot be tolerated. But in fact, no part that comes down the line can afford to get by any of the operators. However, it is not feasible to put a stopper in front of each station, and thus a lengthy final inspection becomes the alternative solution. In this solution, it becomes the task of the final inspectors to check the work of the 15 people before them. As one can imagine, defective parts make it by the inspectors, who also have to respect the belt speed, on a regular basis.

Another inherent flaw with the use of a conveyor for assembly is that it is linear, and thus the inspectors' effectiveness is minimized. Meaning that if, and when, the final inspector does find a defect there is nothing he can do except pull it off the line. Take the case in which the final inspector notices that Operator #2 only put 2 O-rings on the product instead of 3. While the worker may be inclined to quickly fix the part by attaching the O-ring himself, it is not possible for him to walk 90 feet to do so, without disrupting his own work. As a result, the defective parts are batched for rework, and it may be hours or even days before the defective parts receive attention. In our example, where the entire assembly is only missing 1 O-ring, the person reworking could have difficulty relocating the defect, and may send the defective part for packing after all.

5.2 LINES ARE NEVER TRULY BALANCED

A result of trying to balance against a fast belt rate is that some operators end up with very little work content per part. As it turns out, people who are stationed at material entry points are not dependent on parts that are coming down the line, and quickly figure out they can work ahead of the belt, building up work-in-process (WIP). By doing so the workers essentially buy themselves a break. While there is nothing immediately wrong with this situation, so long as the person continues to feed the line one part every 7.7 seconds, the problems begins when the worker chooses to send the pile of WIP down the line. In this way, the fast worker now feels free to leave the area. The next operator is left with no choice but to pick the pile from the line and clutter his working area, which is a major inconvenience. However, the larger problem is that the fast operator may not return to his station in time to send more parts once the WIP runs out, and as a result the entire line will stop. With a quarter of the workers being able to build up WIP, it is a conservative estimate that at any instance there are at least 150 pieces of WIP on the line, roughly 60% more than expected by design. Consequently, the assembly line's throughput time may be as high as 20 minutes, while the belt speed times the number of workers suggest that the throughput time should be about 2 minutes.

The other issue with workers operating at several different cycle times is that a standard material replenishment cycle cannot be established. Rather the line's material handler walks the area waiting to be asked for parts. Again the length of the belt plays a role in the material handler's job since it is not uncommon for him to be far from the station that needs material. This again will cause a line stoppage. To make matters worse, there are no standard replenishment quantities to give the material handler a better feel for when to replenish. Rather the empty bins are simply filled with as many parts as possible, and the quantities vary greatly.

5.3 LOSS OF PREDICTABILITY

These sources of line stoppage, along with several others, make the output of the assembly line completely unpredictable. Once predictability is lost, the job of the supervisor becomes extremely difficult since he must take hourly production totals and if behind must figure out what to do. The supervisor knows he will probably not get to the root of the problem, and instead he spends his time on quick fixes—finding volunteers to stay overtime.

5.4 INTENTIONAL LINE STOPPAGES

One "lean" concept that has crept into the design of the assembly lines is the idea that all workers are free to pull a stop cord if there is a problem. While this concept works well within the proper system, it has few benefits on the line. When the line is stopped, several reactions take place among the line operators. Some instantly reach for their newspaper, others leave, and those in the habit of building WIP continue producing in order to gain an even longer break.

These various reactions point to the fact that the 18 direct workers on the line do not feel as though they are part of a team. Instead each worker is conditioned to only feel responsible for the operations that takes place at his station, and if the problem is not due to them, then they are indifferent. The end result is that no one is aware of what the problem was, and how it was solved. Thus, the chances of a similar problem occurring, and requiring another line stoppage, are higher than if the team worked to solve the problem.

5.5 LACK OF FLEXIBILITY

On this particular line demand increased from what the belt rate was originally designed for, and the only solution was to work overtime on a daily basis. Had demand decreased, the line is still tied to a fixed belt rate, and production would have been completed early. Thus, the 18 workers would have no work for the remainder of the shift. Lastly, it is important to reiterate that by design the assembly line requires that all 18 workers be present in order to function. Thus, the problem of absenteeism, not looked upon favorably in any system design, is an especially huge problem in the case of assembly lines.

5.6 NO CONCEPT OF CONTINUOUS IMPROVEMENT

While several of these problems are immediately evident, the fact that they persist can be attributed to the lack of continuous improvement efforts. While many fire-fighting efforts are put forth on behalf of the assembly line, the results of such activity should not be confused with continuous improvement. Instead, continuous improvement is a concept that emphasizes the fact that there are several better ways, some minor and others major, to operate the current system. Thus, on a regular basis several systems aspects are analyzed and challenged in search of these better ways. In the case of the assembly line, where basic variables such as belt speed and operator times are considered "standard" implies that they are not variables subject to analysis, and therefore leaves little room for true continuous improvement.

6 GOALS FOR THE CONVERSION TO CELLS

Upon taking on the assignment of converting the line to cells, three goals were agreed upon by the company and the authors:

1) the equipment to be used in the cells could only come from that being used on the line
2) once implemented, the cells were responsible for producing the required daily volume (i.e. the cells were not being built for experimental purposes)
3) the cells were to serve as a teaching tool for all employees.

7 SIMPLIFIED CELL DESIGN PROCESS

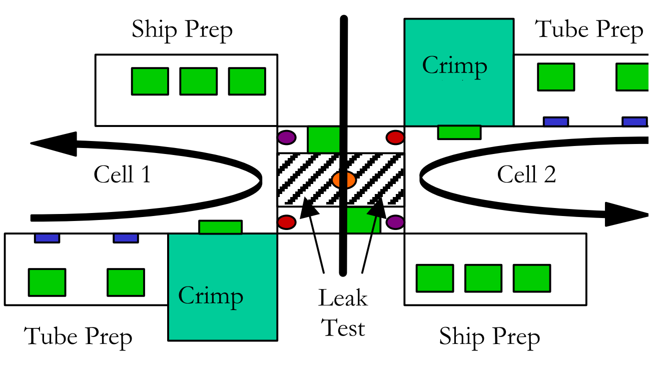
In a lecture entitled "Cell Design," Cochran identifies the following steps as those needed to design cells within a lean system.

1) Define Part Families
2) Determine Takt time
3) Standardize Process and Operator Routine
4) Is the Takt Time met? If not, is it due to operator delay or machine delay?

7.1 DEFINING PART FAMILIES

In this initial conversion to cells only one hose type was considered because of its high volume, and therefore defining part families was not relevant at this point in the project.

7.2 DETERMINING TAKT TIME



By definition, takt time is the total available working hours in a day divided by the customer's daily demand. The value arrived at is in units of time and tells the manufacturer how often a customer needs a part and thus how often to produce. While the takt time calculation is similar to determining belt rate, it is a more integral part of the cell design since a primary design goal of a overall lean system is to match production pace with customer demand (i.e. never under- or overproduce).

Moreover, both the denominator and numerator in the takt time calculation are viewed as variable in lean thinking. With takt time perceived as dynamic, a fundamental difference in the design approach of cells is that volume flexibility is emphasized from the onset. For this reason, an underlying design goal of cell design is that it be capable of running with a single person should the need arise. This goal of being able to run a cell with one person greatly affects the machine and workstation design.

A maximum of two cells could be formed because of the equipment constraint being imposed. The different takt time calculations that were considered are given in Table 2, with the available working hours per day being the only variable. The calculations are based on the following:

1) 8.5 hours of available working time in the first shift
2) 7.5 hours of available working hours in the second shift
3) an uptime factor of 85%
4) a daily demand of 4200 pieces.

Table 2: Takt Time Calculations

Work Schedule	Takt Time
a) 1cell, 1 shift (same as line)	6.2
b) 2 cells, 1 shift	12.4
c) 2 cells, 2 shifts	23.3

In order to achieve the full benefits of a cell, takt times should be greater than 30. While the option of running 2 cells for 2 shifts was pursued since it gave the highest possible takt time, ideally a third cell would have been formed. In this way each cell would have had a takt time of 35 seconds. In either case, the decision to run 2 shifts was one of many major departures from the company's traditional operating pattern.

The pursuit of two cells meant that each cell would have 1 crimp machine, and that the cells would share the leak tester, as shown in figure 4. The dotted line is intended to show the separation of the two cells. The cells' U-shape is a function of the cells needing to share the leak test equipment (shown as the dot in the crosshatched section). It is important to note that the sharing of the leak tester is not ideal, since it makes the cells interdependent. Meaning that the two cells have to coordinate such that the person leaking testing in one cell is not waiting for his counterpart to finish using the equipment in the other cell. This coordination adds a level of complexity which would preferably been avoided, if there was not an equipment constraint.

In order to place a single crimp machine in each cell, another shift from traditional operation was made in that each crimp machine would now have to crimp both ends of the product. On the assembly line, each crimp machine was dedicated to crimping only one end. The change required the design of new fixtures capable of holding the product while each end was crimped separately.

Figure 4. Layout of the two cells used to replace Line 4

7.3 STANDARDIZE PROCESS AND OPERATOR ROUTINE

The consideration that is given to the order of operations, is another fundamental difference between the design of assembly lines and cells. When designing cells, the product's assembly sequence must also be respected, but only in terms of the cell's physical layout. For once it comes to defining standard workloops, the fact that the workers are walking and multi-functional means that they do not necessarily need to follow the product's assembly sequence. For instance, one worker may be given tasks one, two, and three and then jump to tasks fifteen and sixteen in his loop. This added flexibility in forming workloops, along with the higher Takt time, provides several choices for combining operations when defining operator routines. Therefore, the only constraint in designing workloops is to have the sum of each worker's operations plus walking time be less than the takt time.

Through analysis of the hose's assembly operations, it was found that they all fit into one of three main categories -- assembly, leak test or shipping prep as shown in figure 5. The important point to gather from figure 5 is that while it is necessary that shipping prep follow leak test, and that leak test follow assembly, within each of the three categories the order of operations is not significant. For example, O-rings can be attached before or after crimping, and either tube can be crimped to the hose first. This realization offers yet another level of freedom in determining workloops, and allows for a great deal of iterations to be easily tested during the implementation phase of the cells.

The number of workers to man the cell was taken by dividing the sum of operating time as determined from assembly line standards (67.9 seconds) by the Takt time. The logic being that the time the operators spent on the line reaching for the part and returning it to the line would roughly cancel out with the walking times of the cell. In any case, this first pass calculation suggested that three workers would be needed, and that each should be given about 23 seconds worth of work to do in a loop. After several theoretical iterations it was decided that in terms of balancing the workload and minimizing the amount of non-active walking time it would be best to have

- the first worker prepare both tubes and make the first crimp,
- the second worker make the second crimp and leak test,
- the third worker remove the end caps and prepare the part for shipping.

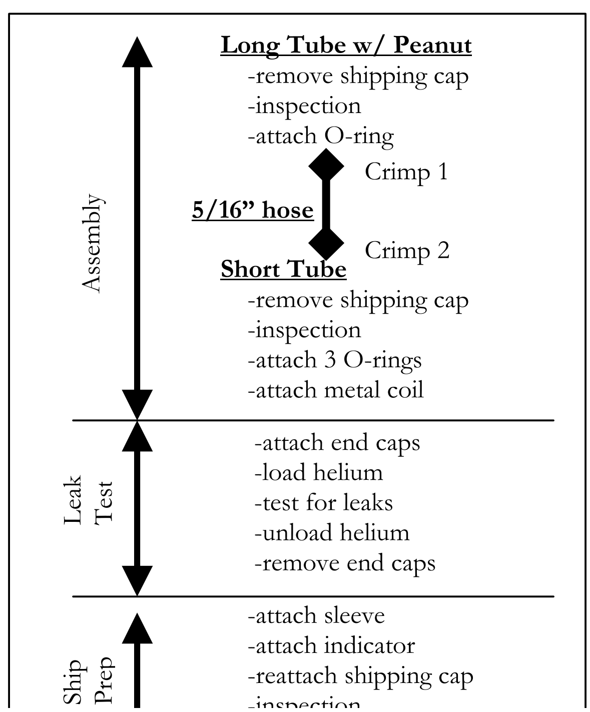


Figure 5: Breakdown of final assembly operations

7.4 CELL TESTING: IS THE TAKT TIME MET?

In the first rounds of testing, takt time was not being met, and that the sum of all manual and walking times was close to 85 seconds. Given that the machinery in the cells had a processing time well below the takt time, it was easy to conclude that the problem lay with the operators.

Upon further examination of the situation, it was realized that once the operators were asked to do tasks they were unfamiliar with, a learning curve was to be expected. Secondly, once the workers were asked to not only do a larger set of operations per workloop, but also be responsible for knowing all the operations, it was to be expected that they would not necessarily master any one task, but rather get efficient at completing their workloops.

Thus, the conclusion was that the 3 cell workers simply needed time to familiarize themselves with the new system, and adding a fourth worker to the cell was decided against. Another step taken was to make the 3 workers fully aware that as a team they were responsible for producing a finished part every 24 seconds, and then asking what we could do to help them accomplish this end. The resulting communication led to the workers becoming involved in improving their workloops, the different workstations, and identifying processing steps they felt were not essential.

Within only a few days of all the changes being implemented, the workers were very close to producing a part every 24 seconds. The one unforeseen advantage of having two identical cells placed back to back is that as the workers spoke to each other, the best practices of each cell were being adopted in both. As a result, the cells were maturing at an extremely fast pace. Therefore, after a month of running the cells it was not surprising to find that their cycle times were down to about 20 seconds.

Since the time being saved was not enough to justify the removal of a worker from each cell, a material handler was introduced to pace the cells. Keep in mind that while the system wants to meet customer demand, overproduction is not desired either. A single material handler replenishes both cells by working on a 10 minute cycle. However, since he alternates between the cells, he provides each with 20 minutes worth of parts (50 parts). The introduction of a material handler now meant that there was feedback every 20 minutes. This was made possible by having the material handler count how many parts, if any, were left in the bins when he returned after 20 minutes. This tally along with an explanation of why production was not met during a certain interval, now gave the supervisor a much clearer picture of where to concentrate his problem solving efforts. For example, it was found that in the interval before lunch, production was not being met because one worker was leaving a few minutes early. While the problem was relatively minor and easy to solve, it would most likely have gone unnoticed on the line.

8 A COMPARISON OF QUANTIFIABLE MEASURES

As stated earlier, lean systems tend to consistently outperform mass systems on several quantifiable fronts. In the comparison of the assembly line to the cells that replaced it, the results are no different. Table 3 gives a comparison of the assembly line and the two cells. The most striking of the measures comes from the 78% floor space savings, and the 45% reduction in man-hours required for production.

Table 3: Comparison of Assembly Line 4 to Cells

Measurable	Assembly Line 4	2 Cells
Floor Space	1500 sq. ft.	320 sq. ft.
Direct Workers	18	12 (3 per cell for 2 shifts)
Man-hours required	~170	96
Avg # of Defects per Month	226	2.5
% Absenteeism	4	0
Throughput time	Variable (~20 min)	72 secs
WIP	Variable (~150)	6 (3 per cell)
Incoming Material	High and variable	50 pieces/20 min
Conveyor	90 ft	none

9 DISCUSSION OF NON-QUANTIFIABLE BENEFITS OBTAINED THROUGH CELLS

9.1 VOLUME FLEXIBILITY

The most often discussed benefit of cells, which is difficult to quantify, is volume flexibility. Cells are designed such that workers can be added or removed in order to match customer demand, while the number of workers on an assembly line is fixed. Along the same lines, absenteeism is not as big of an issue to the cell as it was on the assembly lines. For even if only one cell worker is present he can still deliver some level of production. This is a significant improvement over the line in which if only one worker is absent, no production is possible.

9.2 PREDICTABLE OUTPUT EXPOSES PROBLEMS

The design of cell allows for a highly predictable output rate, which is made possible by the workers strictly adhering to standard operating procedures. The irony stemming from this benefit, is that on the assembly line standard procedures were not defined, while processing time standards were. In other words, assembly line workers were told how much time they had to complete a task, but were not necessarily told how to do it. One such example comes from leak testing, in which no one could agree on how long the process should take. Some quoted the number of joints on a product as the determining factor, others felt it was the length of the assembly, and when line workers were asked they replied that simply try to keep up with the belt.

Another problem constantly exposed by the final assembly cells producing at a predictable output is that several of the components being fed by upstream processes are defective. With the material handler delivering only 50 parts every 20 minutes defects cannot be tolerated since they prevent production from being met for that interval. On the assembly line where parts arrive in large batches, at varying time intervals, quality problems with the incoming material are hidden.

9.3 WORKERS' ATTITUDE

Among the most important benefits of cells over assembly lines, deals with workers' attitudes toward their work. Once the workers were trained to be multi-functional two things happened. First of all, it seems as though their level of interest in the work itself increased. This is evident by the fact that on assembly lines it is common for people to wait for instruction before doing anything out of the ordinary (i.e. line stop situations), while the cell workers tended to be more confident at solving problems on their own. Secondly, the cell workers were more inclined to give their opinions and constructive criticism of the cell. Such discussion was often fruitful, and it points to the workers giving thought to their job and constantly seeking improvement.

It is of utmost importance that all ideas put forth by the cell workers are taken seriously. For it is important to realize that the workers' major source of reward comes from seeing their ideas take form. If workers are content, and play a role in designing their working space, the benefits are endless. The closest gauge of the workers feeling important and rewarded comes from the sharp drop in absenteeism that was experienced when the assembly line was converted to cells.

10 CONCLUSIONS

A cell is a physical tool that integrates several system level objectives. Since the cell is never thought of in isolation from the rest of the system, but rather as a mechanism for obtaining higher level goals of the system, the thought process behind the design of one varies greatly from that of designing an assembly line. Moreover, while the primary goal of the assembly line is to meet daily production at the time of implementation, the primary goal of cells is to match their production to customer demand throughout their existence. These major differences lead to several quantifiable and non-quantifiable advantages that cells posses over assembly lines.

1) Cells have circular workloops allowing workers to correct problems they detect, assembly lines are linear and defects can only be pulled off the line
2) Cell operate with walking, multi-functional workers allowing better balancing of operations, assembly workers are often seated at a station and are limited in the number of task they can do
3) Because of 2) Cells get better utilization out of each workers than assembly lines do
4) Cells have predictable time and quality output, assembly lines deal with variation in both aspects
5) Cells are volume flexible, assembly line are fixed
6) Cells expose problems, assembly lines hide them
7) Cell workers tend to take initiative and try to solve problems on their own, assembly workers are usually not in a good position to take action
8) Cells tend to occupy much less floor space than the assembly lines

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