Material Handling Guidelines to Support Lean Cells in the Bose Production System

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Abstract

This project introduces guidelines for material handling to support lean cells as part of the Bose Production System at their manufacturing facility in Framingham, Massachusetts. We designed an insert for the material handling carts, called tuggers, to better organize deliveries to cells. We developed an organization of the warehouse and a formula for estimating the tugger capacity needed if a new cell is added. With the suggestions Bose will be able to increase the efficiency of their manufacturing facility.
Acknowledgement

We would both like to thank the Bose staff and our advisor, Sharon Johnson, for the time and effort they have put into helping us with our project. We learned real world applications through this project which we hope to instill into our futures. The knowledge and experience gained through this project will undoubtedly fuel us beyond graduation and into our professional lives.
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1. **Introduction**

The goal of this project was to develop and improve material handling at the Bose manufacturing facility in Framingham, Massachusetts, using various analytical methods to increase the efficiency, timing, and movement within the production plant. The unit of transportation for materials at the Bose facility is called a tugger. A tugger is a one person electric cart, no bigger than a golf cart, with a flatbed trailer that is attached to the back and “tugged” along. The tugger cart moves in the same pattern through the plant on half hour intervals, by starting in the warehouse and then delivering materials and picking up finished goods at the cells on the facility floor.

Bose has been embracing lean production and developing their own system based upon the principles and philosophies created by the Toyota Production System, which have been greatly successful. With the movement towards lean thinking in the Bose Production System, the tugger cart has become critical to operations. The tugger cart allows the workers to move larger sized and greater quantities of materials around the facility in a more timely and orderly fashion than what can be done by humans, but with smaller batches than a forklift. Lean production requires responsive material handling so parts are available when and where they are needed, however, there are always areas for improvement and increased efficiency, which will lead to better production.
Our initial observations of the Bose Production System led us to focus on three key components. They were the timing and handling of materials along the tugger pathways, the design of the tugger cart itself, and the setup and arrangement of materials in the warehouse of the facility. The flow of materials on the pathways was observed, including the drop off and pickup of materials and the amount of time needed to accomplish such tasks. We used this data to develop capacity formulas. We examined how the tugger carts were organized in regard to organization for the transportation of materials, and designed improvements to the cart. The setup and placement of materials within the warehouse was observed and guidelines for changes were developed.

The remainder of the report is organized as follows, to allow for a better understanding of the issues at hand and the methods used to resolve these issues. The background and literature review provide a foundation for information on the entire project. The methodology chapter explains the process used to identify issues, which
includes the numbers and concrete data that was used throughout the project. Next, the results are presented, followed by conclusions and recommendations for improvements.
2. Background and Literature Review

Through the literature review we found helpful information that pertained to the issues that Bose tried to improve. The background on Bose and their tugger system lead us to target certain articles and books that have been helpful sources.

2.1. Background on Bose

Bose has long been a leader in sound production equipment. They specialize in speakers, headphones, and microphones. (URL 2) The background will focus on the operations of Bose and the focus of their company.

2.1.1. Overview

The Bose Corporation is a private company that is based in Framingham, Massachusetts. They specialize in audio equipment and are always looking for more ways to improve the quality of sound. (URL 6) Bose’s extensive research in the fields of speaker design and psychoacoustics has led to many innovations that are used around the world today. Bose products can be found in Olympic stadiums, the Sistine Chapel, and the NASA Space Shuttle. Audio equipment that they manufacture includes speakers, amplifiers, headphones, and automotive sound systems for luxury cars. Bose’s first ever tabletop radio was introduced in 1984 and was called the Acoustic Wave® music system. This included two 2” speakers with a cassette player and an AM/FM radio. In 1993 the first Wave® radio was introduced. From this point on it would evolve with better sound and more components. By 2006 the Acoustic Wave® music system II was
released. This model added a CD/MP3 player as well as a bigger screen and improved acoustics.

Bose has also developed a line of noise reducing headphones. The idea for this product line came about in the 1950’s for helicopter and aircraft pilots. Bose came out with their first set of noise reducing headphones in 1989 called the Bose Aviation Headset Series I. Ever since, the Bose line of headphones has evolved greatly. There are a couple different types of these headphones; Bose around-ear headphones (AE), Bose over-ear headphones (OE), and Bose In-Ear Headphones (IE). Out of the three types of headphones, the OE headphones do not include the active noise reducing feature. The Bose IE headphones are also known as ear buds, similar to the headphones that come with an iPod. The Bose AE headphones are bulkier sized headphones that fit more comfortably around the head than any other.

2.1.2. Plant and Operations

The Bose manufacturing plant that we worked in is located in Framingham, Massachusetts. This plant has very recently changed over to lean manufacturing, setting up cells dedicated to particular products and using kanban cards to schedule material deliveries via tuggers. They specifically manufacture the current noise reducing headphones that are used in the military with pilots, truck drivers, and other soldiers. Recreational noise reducing headphones are also manufactured at the Framingham plant for the everyday consumer.
The plant operates on a strict schedule for the delivery and pick-up of finished and unfinished goods to lean cells. There are 2 material tuggers that go back and forth from the warehouse to the manufacturing floor every 30 minutes. These tuggers have pre-specified routes that they follow each time. While they are “tugging” around, they make stops at each cell around their route and drop off any materials that are needed based on kanban cards which signal them what material is running short. The tuggers also pick up any goods that are already to inspect and ship. Once the tuggers are done with their route and head back in the warehouse, the tugger operator must gather the materials that are needed for the next run by reading the kanban cards that were picked up. The operator then gathers these materials, and when the next half-hour arrives the tugger must follow his route again and perform the same tasks.

2.1.3. Plant Layout

The warehouse that materials are stored in is separated into sections to support each tugger. For each route, the materials for the cells that are on that route are gathered and put together. They are collected because the tugger operator has to make the best use of his time so he can stay right on schedule. All of the materials needed are assigned specific spots so he/she does not have to run around the whole warehouse looking for specific parts.
2.1.4. Tugger Operation Issues

The problems and issues facing the Bose Corporation involved improving the overall efficiency of the entire tugger production line including the warehouse organization, and the tugger cart design. We had to assess the time they were taking to do their tasks and come up with a solution on how to improve the process that they used. We needed to think about the waste that was involved with their daily tasks and how to eliminate as much of that waste as we could while keeping the process as efficient and lean as possible. We had to examine the setup of both the warehouse and the tugger cart. A formula and set of guidelines needed to be established in order to help the Bose staff assess the challenges faced with adding another cell for a new product to the production line. So the questions that we answered were as follows. Are the tuggers using their time efficiently? Is there a way that we could smooth out the movement of the tuggers delivery and pickup of materials?
The first area of concern was the addition of a new cell to the production line and the timing implications this would have on the entire line. The second problem was design of the tugger and areas of improvement that will lead to more efficient delivery and pickup of materials. Lastly, there were the areas for improvement within the warehouse which would lead to the tugger operators and all the other workers being able to find and transport all the necessary materials quicker and more efficiently. Overall we were responsible for examining the way Bose ran their tuggers within the BPS (Bose Production System), how materials were handled to and from cells, and how they could make it better.

One opportunity was to create guidelines for another cell being added to the tugger line, specifically what the Bose staff can expect in terms of time requirements. Several timed observations were obtained of the tuggers on their routes, and with the help of the Bose workers, the amount of material on each trip was recorded. Based upon these observations and recordings, a capacity estimate was created to reflect the time the tugger line would need to allow if another cell were to be added.
The examination of the handling and timing of materials on the tugger line was the initial area of focus with the thought of reducing holding time and costs as the original areas of improvement. Through a data analysis of kanban cards and the timing of the tuggers on the production line, other thoughts and ideas were contemplated which lead to one of the key areas of focus in our project, the capacity formula for the addition of a new cell. There were large areas of the manufacturing floor that were left empty and ready for use. Based on the data collected, we developed a rough formula for the expected amount of time needed to add another production cell. The information will allow Bose
management to have an expected time allotment for the addition of a new cell based on
the size and amount of material needed for the cell.
The workers at Bose presented us with a variable. Each individual works at a certain pace, and has his or her way of approaching their work respectively. The goal though, was to ensure that the current workers could understand and use the system, while maintaining a level of simplicity so a new worker could learn the system immediately. This would allow for better communication between management and the workers and also cuts down on wasted time explaining the system if a new employee were to be hired.

2.2. Literature Review

Through several sources we have compiled our foundation for applying lean manufacturing practices and techniques to material handling. The information from the literature was extremely helpful in helping us address Bose’s issues.

2.2.1. Lean Manufacturing

The principle of lean manufacturing is a relatively new practice, particularly to the United States. (Womack, 1996) Lean manufacturing originated during the middle of the 20th century in Japan with the Toyota Production System. As time passed this system became remarkably successful and as a result, companies all over the world began adopting the principles of lean manufacturing, ranging from Asia, to Europe, and then to the United States.

During the 1980s lean manufacturing really started to take off in the United States and continued to be used by companies all over the country well into the 90s. The first principles being put in place were the TQM (total quality management) and JIT (just in time). These ideas caught on, and soon many more followed. Today these initial ideas are still being introduced to new companies in various industries. There are also new ideas being developed such as POLCA, which will be discussed in greater detail later.
Lean has to be practiced religiously and implemented into the company's environment as soon as possible. The strategies take time, so the earlier the company becomes accustomed to the idea of lean thinking, the quicker they will be able to adjust. Not only do these strategies need to be implemented, but the companies need to master these strategies in order fully utilized the benefits that would result. Lean companies are always competing, whether it may be against another rival company or themselves. A lean theory is to compete against perfection. This leads to constant competition and improvement because perfection cannot be achieved. The Japanese companies and companies all over the world who have adopted these principles have been widely successful. (Kazuo, 1994) The overall function of lean manufacturing is to create a profit. It is widely accepted that creating the largest profit when moving away from lean thinking is the best approach to manufacturing.

Lean manufacturing theory dictates that the company implementing lean focus on the overall understanding of lean thinking focusing upon building skills in workers not the machines. The workers need to be taught the idea of lean thinking to the point where it is embedded in their thoughts and they just react to all situations with a lean mindset. They need to understand they are people, not robots and they are expected to think and make adjustments to contribute to lean thinking. A major contribution to implementing lean manufacturing is to ensure that everyone, management and workers, is on the same page and thinking in the same manner. Management and skilled workers need to communicate back and forth to one another so that the plant can run as smoothly as possible. Feedback from the workers is the best way to understand how well this philosophy is working for
them. This also helps management make adjustments over time. People cannot adopt the lean way of thinking overnight. It takes time, practice, patience, and persistence.

Generally speaking there are four rules that Toyota lives by in lean:

1. All work specified towards content, sequence, timing and outcome
2. Customer-supplier connection is direct. Yes-no way to send requests and receive responses
3. Pathway for every service must be simple and direct
4. Any improvement must involve scientific method, under guidance of teacher at lowest possible level (Spear, 1999)

2.2.2. Lean Manufacturing Wastes

When discussing lean manufacturing, there are eight specific types of waste that need to be eliminated, or in the worst case, controlled. (Womack, 1996) Wasted human talent is the number one offender in lean manufacturing. This damages the company and also the demeanor of the worker. Defects is the second most common form of waste as these take time to rework when they could have been done right the first time. Inventory and overproduction wastes go hand in hand as they both lead to higher holding costs. On the flip side is waiting time waste, in which there is not enough production and workers are waiting for parts or work to arrive. Motion and transportation wastes can be grouped together as they both encompass wasted human or machine movement. Processing waste is the last offender. This waste is when activities or procedures are non adding value to the final product or the manufacturing line.

Eliminating cost and creating profit is more important than applying lean thoughts when working in a manufacturing plant. (Liker, 2003) Companies should always make sure there is demand because the production rate is going to climb with the implementation of lean strategies. They cannot increase the production if there is no
demand for the product. This creates excess inventory which goes against lean principles. As inventory increases, so does the carrying cost and applying lean means trying to cut costs wherever possible. Costs can occur at several other points as well. Excess manpower increases cost twofold because the workers need to be paid and the inventory they create will also be excess leading to high holding costs. One way to prevent this is to vary the products being made. Initially, this may be difficult, but over time the workers and cells should adjust and be able to accommodate different products on the line. Having a wide array of products will cut down on holding costs for each of the products while ensuring the products will be there for the customers to pull from the line.

2.2.3. Lean Manufacturing Tools

Value stream chain mapping is a critical procedure to every application of lean thinking. (Cox, 1999) Value chain mapping involves examining the manufacturing process and analyzing each step along the way. Activities need to be divided into value adding and non-value adding categories. Then the non-value adding activities need to be eliminated while the value adding need to be focused on and improved. An example of a non-value adding activity would be anything that caused workers to wait. Waiting is waste. The managers need to find what is causing this bottleneck and eliminate the source.

Group technology is a lean strategy when it comes to placing items in a warehouse or establishing a cell. The idea behind group technology is to place similar parts together to reduce wasted movement. Grouping similar parts together cuts down on the distance one would need to travel. This will also reduce the number of employees for
it will take less people to move the required materials the distance needed. Companies need to focus on improving the skills of their employees, not increasing the numbers of them. This will again cut down on costs.

The cell module is similar to the flowline except it is grouped by family of parts instead of by production line. The machining center module places the most commonly used setup machine in the middle of the flowline. This limits setup delays and allows the making of parts within the same family. A functional layout module allows for the most flexibility but also creates the most chaos. The flow of parts and materials is random which can lead to bottlenecks and thus is not recommended. (Irani, 2000)

JIT (just in time) production revolves around the pull and kanban card system. The idea of JIT is to produce only what is needed and to limit inventory levels, which will expose production problems. Once a product is in demand it is “pulled” from the end of the line. This has a trickledown effect as parts are pulled down the manufacturing line from the previous work station until a new product is finished and ready “just in time” for the consumer.

The kanban production system is one that Toyota used many years ago and the one that Bose is currently implementing today. The kanban system is a system of signals (note cards in Bose’s) that let other workers along the line know what is needed as well as what process to start and when to start it. The kanban system requires a level schedule, which is a pattern that allows the kanban system to respond to pull signals. The formula for determining how many kanban cards to use is: (Womack, 1996)
\[ K = DL \frac{(1+S)}{C} \]

\begin{align*}
K &= \text{no. of kanban cards} \\
D &= \text{average no. of units demanded per period} \\
L &= \text{lead time to replenish order} \\
C &= \text{container size}
\end{align*}

(Loucka, 2006)

Lean manufacturing strategies want to ensure that production is steady but not predetermined. The production is dictated by the consumers pulling the products from the line. This signals a demand for that product and thus the schedule for production is adjusted. Generally freeze windows are not used with kanban systems because it puts restraints on the entire line. A freeze window means the schedule is fixed and no changes are possible. Backflush is a term often used when talking about lean thinking. Backflush is when parts are removed and accounted for based upon the number of units being produced.

The pull system is an implementation from lean that has been widely successful around the world. The pull system uses the kanban system, as the kanban cards signal when to pull material or products on the production line. Two of the major advantages of a pull system are the ease of control and the support for quality and reliability improvement. Pull systems lead to low WIP (work in progress) levels, resulting in a higher quality product. The low WIP levels allow the workers to focus more intently on the quality of their product instead of rushing the product to ensure high levels of quantity. The disadvantage of a pull system is sometimes the WIP levels means companies will struggle to adjust their product to meet customized demands.

One specific type of pull system that is being used is called the POLCA system, which is an acronym for, *Paired-cell Overlapping Loops of Cards with Authorization*. 
This mainly can be applied to cell design, but has some relevance when referring to warehouse layouts. The foundations and principles of POLCA indicate that like parts should be placed together. In a warehouse, parts that are common to all the production lines should be placed in a centralized location with easy access from several workers. (Suri, 1998)

Takt time is another measurement and tool used in lean manufacturing. Takt time is used to synchronize the rate of flow throughout the manufacturing process with the demand from the consumers. Takt time can be found using the following formula:

\[
\text{Takt} = \frac{\text{Net Available Time to Work}}{\text{Total Demand}}
\]

2.2.4. Material Handling

The transportation of materials is a cost that is not considered value added, therefore should be limited. (Shingo, 1989) Improvements within a lean manufacturing system tries to eliminate the transportation factor as much as possible. “The goal is to increase production efficiency, which is accomplished by improving the layout of processes.” (Shingo, 1989 p. 25)

An example of this is Tokai Iron Works which was a small press plant. They had a goal of increasing productivity and limit delivery delays. To fix this Tokai they rearranged the organization of the materials and also added a conveyor belt to help transport the materials to the respective cells to be compiled. As a result this limited the transport time, allowed for more space, and increased production up 200 percent.

The transportation of materials is never value added as it only increases costs. Although it is a necessity, transportation costs and time need to be limited as much as possible. Even moving from a manual transportation method to a mechanical
transportation method has not shown any returns on the investment. With this, it is key to remember layout improvements are more important then improvements in transportation. When layout improvements are no longer a practical option, then transportation improvements can be made. (Shingo, 1989)

The goal of successful material handling is to utilize the most efficient means to distribute materials and finished goods throughout the production line. This includes gathering raw materials in the warehouse, then organizing them so they can be easily distributed to the cells, and picking up the finished goods and dropping them off at the respective area in an efficient manner. Essentially, lean thinking needs to be applied to material handling in order to create and effective system.

Material handling is a significant factor in determining Bose’s success on the production floor. With efficient and successful material handling, Bose can expect to decrease the time and costs associated with waste of delivering and picking up materials. This in turn allows the Bose Production System more flexibility with the extra time allotted to them, which can be used to add a new cell.
3. **Methodology**

The goal of this project was to improve the operation of the tugger system at Bose, using various analytical methods, increasing the efficiency and timing, as well as making practical, reliable, and safe changes to better the tugger system.

The DMAIC method, part of six sigma, was used in the MQP to guide our methodology and to keep the project focused and structured (Aquilano, Chase, & Jacobs, 2009). The D represents Define, which involves defining the problem(s) to be studied. The M is symbolic for Measurements, meaning data collection to establish a baseline related to the defined issues. The A stands for Analyze, in which the measurements and data are analyzed to understand root causes and possible solutions. The I represents Improve, which involves improvements that address the problems or issues. Lastly, the C is for Control, which means how the problem is going to be controlled and the improvements sustained over time.

3.1. **Define**

In the define phase, the project was divided into several more specific sub-problems. Originally the goal was to make the tuggers more efficient. The tugger problem was then divided into three main areas of focus so details could be taken care of with the correct attention. Within each area of focus, several issues were observed in regards to the larger overall tugger issues.
3.1.3. Tugger Capacity Formula

Kanban cards for each production cell were tracked for a week. For every trip the tugger takes the total kanban cards for the trip in each cell were recorded. These were then used to help formulate an equation. This equation will solve how much more time it will add on to the tuggers trip. This can be used to figure out what the pitch rate should be. These were the initial problems associated with the inventory levels.

After more thought was put into the inventory issues, a different method for helping the production line was derived. We believed we could formulate a calculation method that would be able to predict how much time Bose would need for the addition of a new cell to the production line.
Table 14: Tier Breakdown

<table>
<thead>
<tr>
<th>Tier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>High priority</td>
</tr>
<tr>
<td>Tier 2</td>
<td>Medium priority</td>
</tr>
<tr>
<td>Tier 3</td>
<td>Low priority</td>
</tr>
</tbody>
</table>

[rest of the table redacted]
4.4.3. Material Arrangement

Safety is a very important to the workers in the workplace. Equipment suppliers should be able to provide OSHA-compliant equipment. Safe equipment doesn’t always mean you have a safe work environment. For a safer work environment in warehouses pallet racks and industrial lift trucks should be used. Most injuries are caused by focusing specifically on space efficiency and causing there to be poor layout of aisle widths for the vehicles being used. As well trained as the workforce is, narrow aisles will result in damaged vehicles, damaged workers, and damaged uprights. Risk factors to avoid would be forcing operators into awkward body postures, repetition, force, contact, stress, and vibration. Forcing a worker into the job instead of fitting the job to the worker causes one-third of all workplace injuries. This can be avoided by having the workstations be adjustable so the work can be done between the knees and shoulders.

(Tomkins, White, Bozer, Tanchoco, & J.M., 2003)
5. Conclusion

The goal of this project was to develop and improve upon the material handling at the Bose manufacturing facility in Framingham, Massachusetts, using various analytical methods, to increase the efficiency, timing, and movement within the production line.
6. References


