An Application of Lean Assessment in a Cross-Docking Distribution Center

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Abstract

In this paper, using lean principles, we assessed one of the cross-docking DC operations in the USA. Specifically, a value stream map was developed to identify existing operational areas of waste and opportunities for improvement. According to the data, collected through filed observations and analysis using the lead-time concept, several areas of waste were identified in the cross-docking operations. Waste was manifested in the long queues, poor staff planning, lack of floor supervision and direction, overproduction, shifts and breaks transitions, and in the lack of discipline and sense of urgency. These types of waste contributed to the long lead-time, in some cases as much as six hours, where a carton could have taken only seven minutes from the inbound to the outbound step.

The outcome of this study adds to the body of cross-docking operations knowledge. In addition, the study makes a contribution to the understanding of cross-docking workflow and lead-time issues, and the importance of value stream mapping in identifying waste in order to maximize throughput.

Keywords
Cross-docking, Lean Principles, Value Steam Map, Lead-time

1. Introduction

The role of Distribution Centers (DC's) in the supply chain has changed over time, evolving from serving as storage locations to becoming postponement operations for manufacturers. This is the result of strategic planning, in supply chain management, to release manufacturers from dealing with the added complexity of distributing goods to several customers, either end-users or retailers. Distribution Center operations, today, are becoming more complex than in the past. For instance, current DC operations entail receiving finished goods, in cartons, through what is known as "inbound;" then, depending on the type of operations in each DC, a variety of other processes could take place. For example, the cartons could be sent directly, on pallets and utilizing forklifts or automated conveyors, to temporary storage areas. DC's process temporary storage differently depending on their end customer requirements. There could be manual picking, case picking, pallet picking, items sorting, or cross-docking to the final shipping areas, which is known as outbound operations, or shipping, where boxes and pallets are loaded into trailers and shipped to retailers and customers. These processes, therefore, require planning and control, similar to any manufacturing operation.

The complexity of a DC's operations, in today's challenging and variable working environment, has increased under the influence of three main factors, namely; higher expectations from customers and management, cost savings pressure, and more volume processing requirements. Therefore, the management of any DC is faced with the challenge of running their operation more effectively and efficiently. In this study, we mainly focus on assessing a cross-docking DC using the lean analysis approach. The objective of our study is to identify existing opportunities in cross-docking DC's, in order to prepare for imminent changes and bridge gaps between existing capacity and actual daily production. More specifically, to assess a cross-docking DC operation using lean principles to address typical operational changes. Operational changes entail turnover of operations managers, fluctuations in volumes, learning curves of operators, productivity, and a challenging budget.

2. Literature Review

Cross-docking is considered to be one of the supply chain management optimization strategies for product flow consolidation. Cross-docking is defined in the literature as the, "… temporary storage or/and consolidation of products in DC's/warehouses where final products are unloaded through an inbound operation. (Nikolopoulou et al., 2017). The unloaded products will then either be stored temporarily (the period varies depending on the product and customer requirements), or shipped directly to different customers through an operation known as the, "outbound process." Wal-Mart is known as being the first pioneer in implementing cross-docking operations, saving an operations cost of 2% to 3% (Ladier and Alpan, 2016).

Growing interest in research literature has been reported following the success of the cross-docking strategy implementation by Wal-Mart. Some of the research reported in literature addressed many problems and issues related to the cross-docking strategy, including studies by Agustina et al., (2010), Boysen and Fliedner (2010), Stephan and Boysen (2011), Van Belle et al. (2012), and, most recently, by Ladier et al. (2016). According to the authors, more research has been carried out in the area of cross-docking, but most of the published research has been based on theoretical assumptions and is far from reflecting the actual practices of industries (Ladier and Alpan, 2016). This paper addresses the actual practice of one of the cross-docking industries in the USA. In their literature review of cross-docking research, the authors focused on cross-docking operational issues. One of the main focuses of interest in our research, supported by Ladier 2016, is storage and resource capacity, which we also support as practitioners and researchers.

Another research by Buijs et al., (2014) supported the importance in "synchronization" of the cross-docking network. However, we also emphasize the importance of synchronization within the cross-docking operation, in order to meet the necessary service levels for the logistics network as stressed by the authors (Buijs et al., 2014).

On the other hand, lean principles have been applied in DC's, as a result of their success in manufacturing, in an effort to minimize waste and increase productivity (Reichhart and Holweg, 2007). One of the effective lean tools that has been adapted, mainly in the assessment of organizations to identify waste and improvement opportunities, is value-stream mapping. A value stream map is a visual tool that illustrates, and thus helps in the understanding of, the flow of material and information as a product makes its way through the value stream. One of the related studies was presented by Mahfouz et al., (2013), where the authors assessed a tire distributor in Ireland using value stream mapping, and simulation using Java and XML technology.

3. Methodology

3.1 Data collection

In our study, we employed the field observation method to collect data from one of the crossing-dock DC's in the USA. As illustrated in Figure 1 below, our cross-docking DC has 12 receiving lanes comprised of roller and belt conveyors inclined into a "4 to 1" merge (conveyor). Thus, there are three "4 to 1" merges, which meet later at another merging point, referred to as an "8 to 2" merge. On the other side of the floor layout, there are five depalletization stations with label printers. Each depalletization station has a conveyorized lane that is connected to the "8 to 2" merge, as illustrated in Figure 1. Once cartons arrive at the "8 to 2" merge, they are moved into two separate conveyorized lanes, which then meet at a "2 to 1" merge. The "2 to 1" merge has an overhead barcode scanner which directs boxes to the right shipping/palletizing lanes. There are 40 shipping/palletizing lanes, which are connected directly to the shipping docks. In addition, there is a "trouble lane" (TL) for cartons with problems such as unreadable bar codes or unidentified destinations. There is a re-circulation lane after the shipping lanes, for use when the inclined belts of the shipping lane are full. This lane directs cartons back to the "8 to 1" merge, and then to the "2 to 1" merge, which is a long travel time on an automated conveyor. Figure 1 presents the overall flow and the cross-docking DC layout. The lines in Figure 1 represent conveyors with variant speeds. Conveyors are equipped with sensors and stop/move mechanisms. Some of the conveyors are belt-based while others are roller-based.

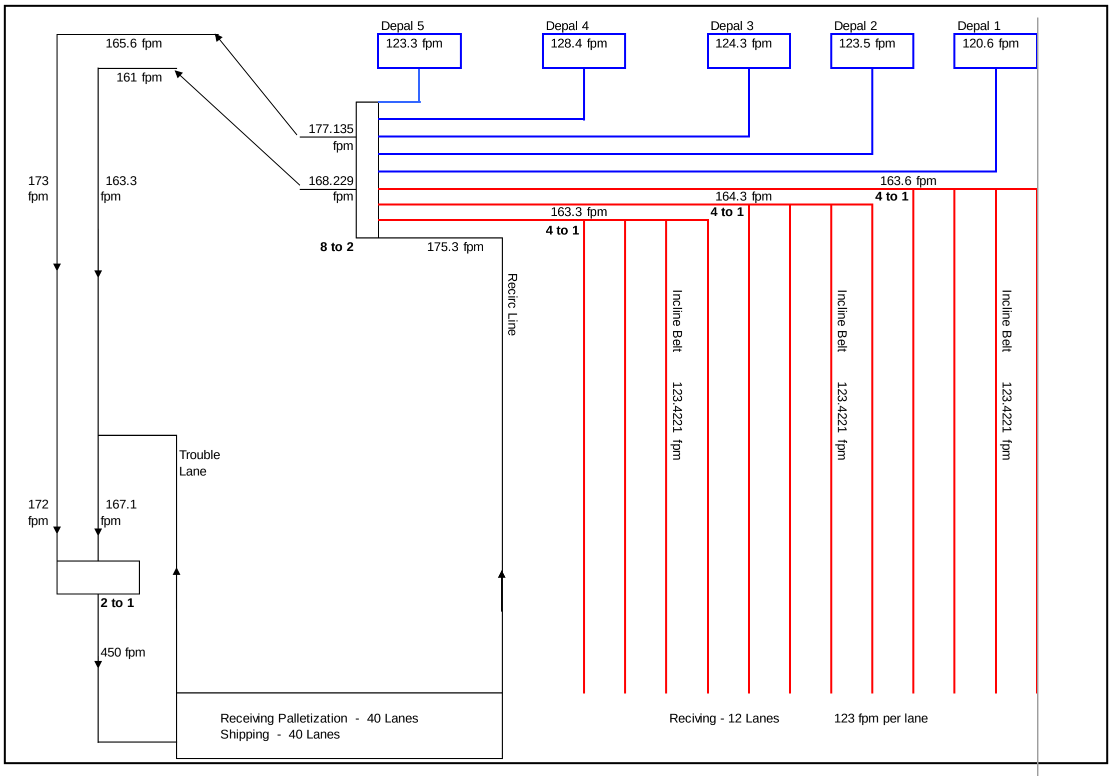

Figure 1: Cross-docking DC process flow diagram

3.2 Lead time and the Value Stream Analysis Approach

To be able to assess cross-docking DC operations, we have to establish a measurement tool to allow us to gauge the cross-docking DC performance level. One of the most effective and collective operational measures is, "lead-time." According to Monden, production lead-time is the time interval between starting and finishing a product (Monden, 2011). Lead-time is composed of queue time before processing, set up time, run time, queue time after processing, and move time. Figure 2 depicts the components of operational lead-time (Aamer and Sawhney, 2004). So, what do we mean by, "DC operational lead-time?" Lean principles consider long lead-time as a symptom of non-value added activity that must be eliminated (Nicholas, 1998). Non-value-added activities are steps and activities that do not add value to the end product. In simple terms, non-value-added activities are those that are performed but for which a customer is not willing to pay. In operations, products/cartons wait in queues, but the waiting, or temporary storage of a product in a facility, is not of value to the end-user. The value to the customer lies in the ability of operations to process the part. Only run/process time is considered a value-added activity. All other categories are considered non-value-added activities. The lower the lead-time, the more flexible the system is in responding to demands. Combining the production concept of lead-time with the cross-docking DC operations, we can represent the DC operation as depicted in Figure 3, which explains the overall operations of the DC and its relationship to value-added and non-value-added activities.

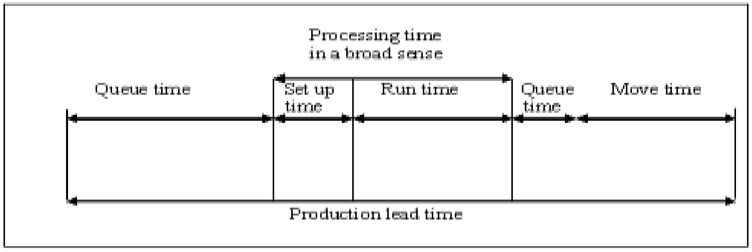

Figure 2: Components of production lead-time

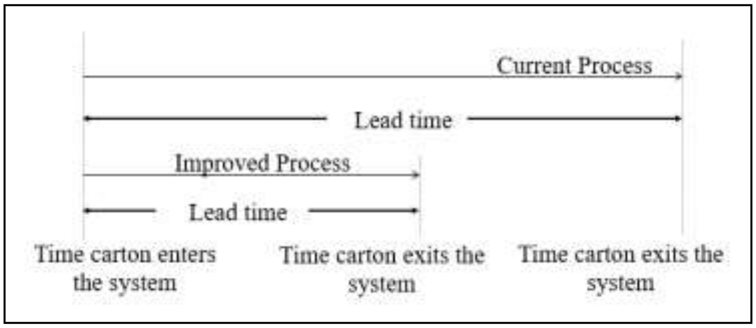

Figure 3: Relationship between lead-time and throughput

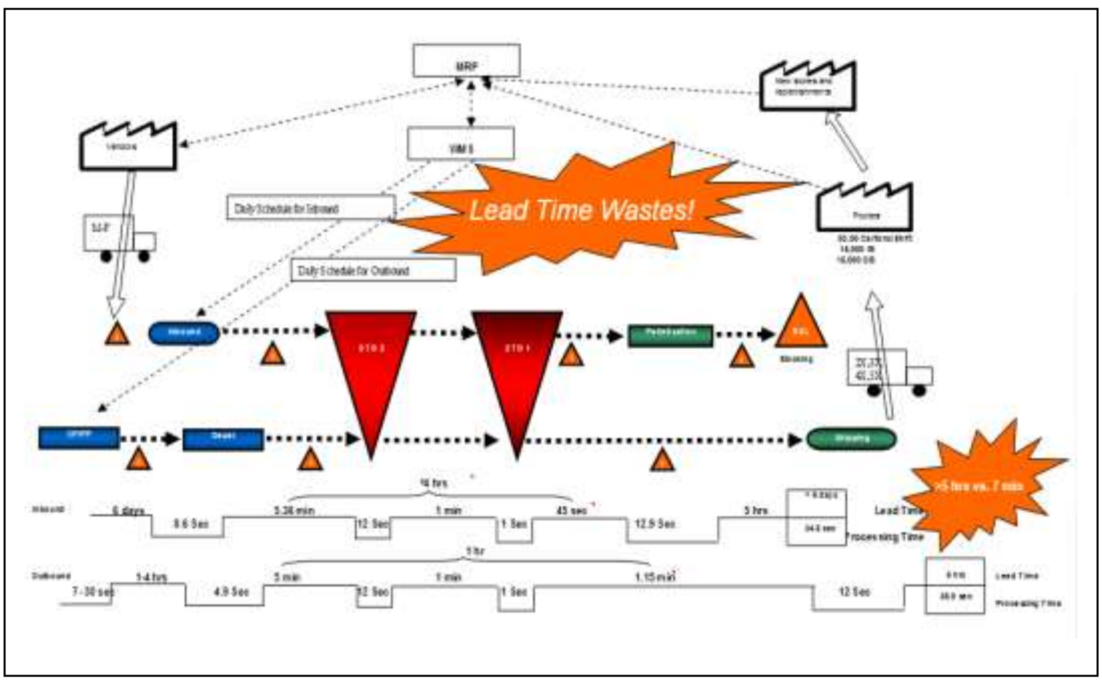

Figure 4: Cross-docking DC value stream map

To examine the cross-docking DC operations flow, a value stream map was created to identify direct and indirect activities related to operational performance. This was done by identifying lead-time components. To calculate lead time, tagged cartons were tracked throughout the value stream from receiving/storage, all the way to shipping lanes.

Each step of the flow of the cartons involved direct and indirect activities which affected the cross-docking DC operational performance. Product flow encompassed material, personnel, and information flow as illustrated in Figure 4. Figure 4 depicts the DC value stream map. A value stream map is a visual tool that illustrates, and thus helps in the understanding of, the flow of material and information as a product makes its way through the value stream. (Rother and Shook, 2003; Womack and Jones, 2003).

4. Data Analysis and Discussion

4.1 Current cross-docking DC performance

We spent over a month observing and collecting data from the cross-docking DC operations. Our data collection indicated a lower than expected throughput capacity, and there were variations in throughput results from day to day (cartons per shift). According to the data collected for five months, the average throughput was 20,273 cartons/shift, with a maximum of 33,365 cartons/shift, and a minimum of 6,489 cartons/shift. Table 1 presents the descriptive statistics of the collected data. In addition, Figure 5 presents the cross-docking DC performance over five months in terms of total throughput of cartons per shift. Figure 5 clearly shows a high variability of throughput, with a high, standard deviation of 6298 cartons per shift. We will discuss some of the root causes in the next section.

Moreover, in examining the current process in terms of the developed value stream map in Figure 4 and the relationship between lead-time and throughput in Figure 3, we can see that cartons spent an average of six hours on conveyors from inbound/carton-pick to the outbound operations, while, in fact, the processing time should not have been more than seven minutes if no bottlenecks existed in the merge operations. Also, the value stream map in Figure 4 illustrates the amount of work in progress (inventory), depicted by triangles, and the length of time each inventory waited, or queued, in the operations flow. In some extreme cases, the work in process queue could have reached five hours, as is the case with cartons waiting to be put away after the palletization process. Thus, the amount of lead-time waste existing in the cross-docking operations is clear, as are the opportunities available to improve the DC current process throughput.

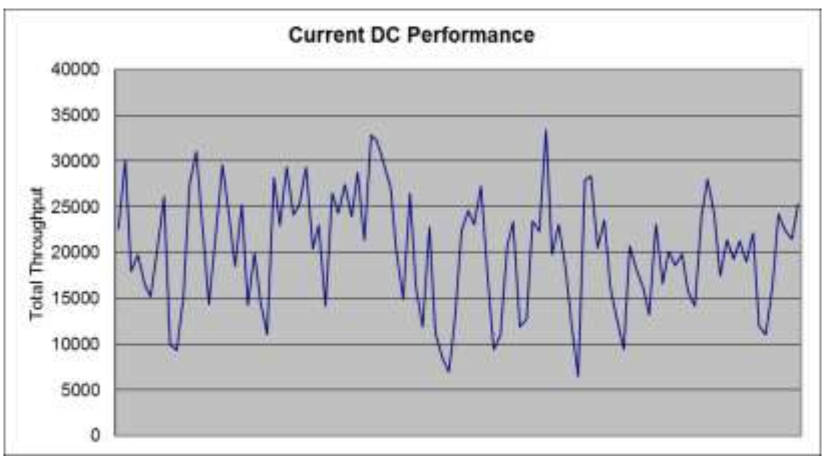

Figure 5 : Current DC performance data for 5 months

Table 1 : Descriptive statistics of DC performance

Total Throughput	
Mean	20273
Standard Deviation	6298
Minimum	6489
Maximum	33365

4.2 Why is the cross-docking DC not achieving a higher productivity?

One of the reasons our cross-docking DC is not achieving a higher productivity can be seen in the relationship between capacity and lead-time. Lead-time is the amount of time it takes a carton to move through a process inbound (receiving, palletization, case put away) to outbound (case pick, depalletization, shipping).

So, what is considered to be "waste" in a lean environment? What types of waste exist at the cross-docking DC? Types of waste could manifest in the form of shifts and breaks transitions, processing and overtime, as well as other factors illustrated in Figure 5. Waste in DC's could be categorized under three main general categories, Set-up Time, Queue Time, and Move Time, as illustrated in Figure 5. Set-up Time includes activities such as shipping-dock set-up time; Queue Time, the time spent as cartons wait for the merge to clear; and Move Time could include forklifts moving to storage and racks areas to retrieve pallets and move them to depalletization.

Set-up Time in DC operations, as represented in the shipping dock doors set-up and inbound receiving lanes set-up, could potentially increase overheads, decrease machine utilization, decrease labor productivity, and increase queue time. Queue Time (cartons waiting for the merge, or cartons at depalletization waiting for conveyors to re-start) could potentially create lost opportunities, cost of capital, greater space requirements, and an increase of DC holding costs. Excessive Move Time, such as stocking depalletization, could potentially increase material handling costs and labor.

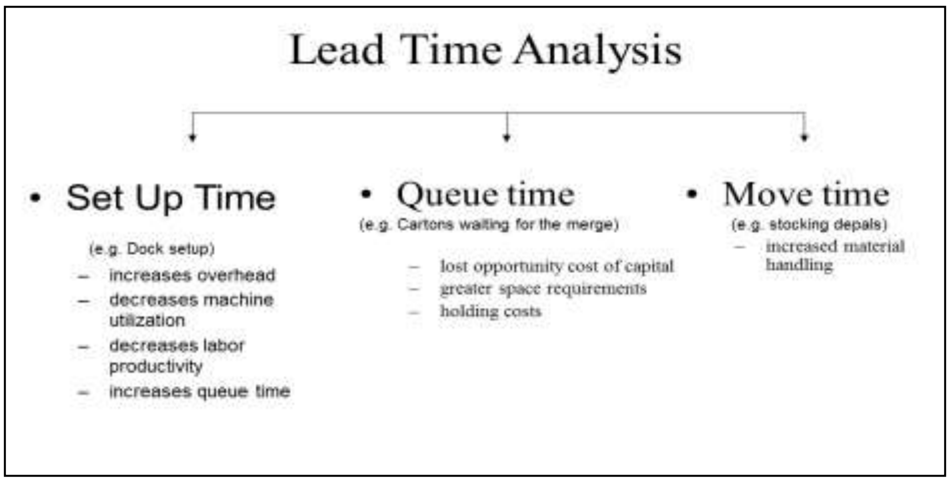

Figure 5: Lead-time analysis in DC operations

4.3 What types of waste existed at the cross-docking DC?

Among several other issues, the following represents the most critical issues in the current cross-docking DC, as related to waste:

4.3.1 Long Queues

Long queues with cartons waiting to be diverted to shipping (mainly before merges and traveling around the building on conveyers) due to a high re-circulation rate. Why does this matter? Re-circulation is a form of waste/rework as it doesn't add any value. Re-circulation occupies valuable space on the conveyors (limited resources); almost every re-circulated carton was a lost shipped or received carton; and it affected weekend work and overtime. Therefore, reducing the re-circulation rate could result in more throughput, and could positively impact cost per unit. The data result proved the negative relationship between the re-circulation rate and lower throughput (cartons diverted), as shown in Figure 6.

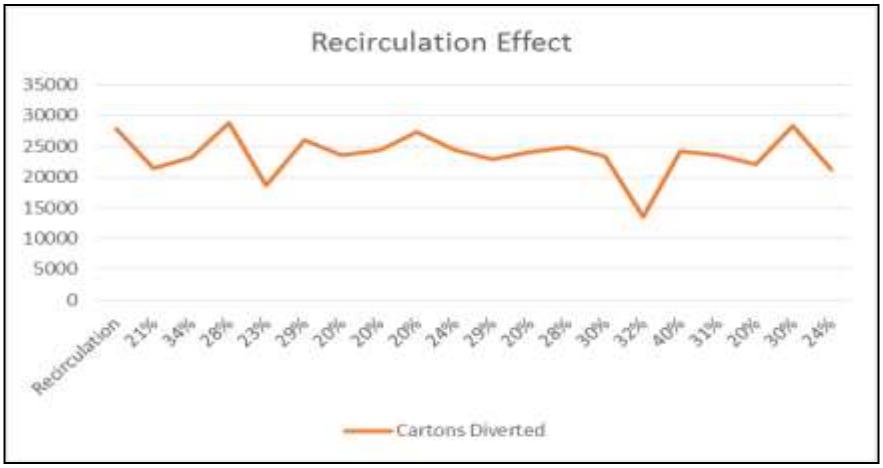

Figure 6: Re-circulation effect on throughput

4.3.2 Staffing per shift (Planning)

Staffing was based on hunches and experience. Supervisors tended to run production based on the number of people, not the required production. Therefore, operations supervisors tended to place more operators on inbound and depalletization, rather than the outbound side. The thinking was that throughput would be maximized if trucks and inventory were loaded on conveyors to shipping. However, this method created bottlenecks in the merge stations for conveyors, causing long lines of cartons queuing due to re-circulation.

Planning/staffing is by far the most critical issue in the current cross-docking DC case. Because of the unique set up of automated conveyors and sensors and its semblance of continual flow, capacity was affected significantly if lines were not balanced. There has to be a change in the supervisors' thinking paradigm of how the process should run. It was never more productive having cartons re-circulate when there were not enough operators to load or palletize. (This resulted in a loss of 108 cartons per minute).

In our conversations with the supervisors, we were told that the common practice was to keep the depalletization and receiving lanes running to get the cartons from one side of the building to the other because it was quicker to load than throwing cartons, regardless of whether they had red lights or shipping lanes not set up at the dock doors.

This approach had to change. It only took six to eight minutes for a carton to make it to the palletization or shipping side. Keeping depalletization and receiving lanes running using this common practice affected the merge and, consequently, increased indirect time significantly. There was a lack of motivation in some of the supervisors to use tools to plan the shifts. Some of the supervisors were not comfortable with using numbers and basic analysis skills to staff and run the shifts.

4.3.3 Daily Flow management

4.3.3.1 Floor supervision and directions

Operators were running the lines "their" way with minimal directions. Supervisors checked equipment out to the operators, told them where they would be working for a particular shift, and cut them loose. The situation worsened when the cross-docking DC under study, utilized temporary employees to overcome shortages. If effective directions and accountability on the floor are not in place to direct people, no improvement can be expected. Several operators on the floor had their own work priorities, and did not have any urgency, or the understanding that the first priority was to get rid of red lights first, as these were the main cause of high re-circulation rates. In fact, some operators responding to such waste, simply said, “Do not worry about red lights, I have been here for a long time and I know what I am doing…this is double stacking.”

4.3.3.2 Overproduction

Supervisors had the habit of stocking depalletization when there was no need. This created over-production and unnecessary inventory, and led to over-processing and overtime. The main objective should have been to tailor production to meet demand – not to indulge in over-production. Supervisors tended to run production based on the number of people on shift, not the levels of required production. This was done by placing more operators on the inbound and depalletization side rather than the outbound side, where the problem of recirculation was exacerbated.

4.3.3.3 Shifts and Breaks Transition

One of the areas of waste observed was caused by the fact that some operators left their stations early while others were still working. This disrupted the continuous flow of cartons and caused the re-circulation lane to fill up quickly, taking over the merge. Consequently, the move time of cartons was increased, as was the lead-time. One reason was that multiple operators were sent to break at the same time. Another was that some operators started earlier than others.

4.3.3.4 Lack of Discipline and Lack of a Sense of Urgency

More often than not, operators left their stations early while others were still working. This disrupted the continuous flow of cartons and caused the re-circulation lane to fill-up and take over the merge. Consequently, the move time of cartons was increased, as was the lead-time. The merge operator invariably left his/her station while the conveyor lanes were still running, inbound and outbound, before the incoming lanes from inbound and depalletization were cleared. This created an accumulation of cartons, and long queues, before they reached the merge stations, and caused a high re-circulation rate. This resulted in the operators in inbound and depalletization (all upstream operations) having to wait until the merge was clear, and the red lights cleared, before they could start operating again. This created a lot of wasted time before, during, and after breaks.

5. Conclusion

Cross-docking operations are becoming more complex and thus require more attention to operations planning and control. Some cross-docking DC operations employ automation in processing cartons. If not studied and analyzed thoroughly, this automation can lead to a tremendous amount of waste, and a decrease in service levels. The study at hand assessed one of the cross-docking DC operations, in the USA, using lean principles. Specifically, a value stream map was developed to identify existing operational waste and opportunities for improvement.

According to the data, collected through filed observations and analysis using the lead-time concept, several areas of waste were found in the cross-docking operations. Waste was manifested in the long queues, poor staff planning, lack of floor supervision and direction, overproduction, shift and breaks transitions, and in the lack of discipline and sense of urgency. These types of waste contributed to the long lead-time, in some cases as much as six hours where a carton could have taken only seven minutes from the inbound to the outbound step.

This study adds to the body of cross-docking operations knowledge. In addition, the study at hand contributes in a practical way to the understanding of cross-docking workflow and lead-time issues, and the importance of value stream mapping in identifying waste in order to maximize throughput.

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