Analysis of Outbound Process Defects at Amazon's ONT2 Fulfillment Center

by
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Submitted to the MIT Sloan School of Management and the Institute for Data, Systems, and Society in partial Fulfillment of the Requirements for the Degrees of

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ABSTRACT

This thesis investigated two outbound process defects that result in damaged, late, missing or wrong-item shipments, leading to a poor customer experience and concessions for Amazon. Reducing these defects will improve customer satisfaction, reduce concession and re-work costs, and improve operations for last mile carriers, including Amazon Logistics. Investigation focused on two defects 1) missorted packages and 2) SLAM kickout errors. For each area, the process was mapped, data sources determined, statistical process control analysis performed and solutions implemented. For the sortation process, sort center data provides the most complete and timely view of process performance. Using this data control charts were created, providing a historical view of ONT2 process performance, enabling comparison to other sites and justifying the purchase of new equipment. A daily missort report was created and is delivered daily to ONT2 management to enable continuous tracking of sortation performance. Accurate data to track SLAM kickout defects was not readily available, so several existing metrics were used to develop a working understanding of primary defect drivers. A training gap was identified and re-training and auditing was performed. Post-implementation, the existing metrics indicated some improvement though the presence of confounding factors makes a definitive conclusion difficult. Recommendations for future work include incorporation and analysis of equipment data to create a leading indicator for missort defects. Concurrently, retrofits on the ONT2 flat sorter should be performed to reduce equipment-induced sortation problems. To reduce SLAM kickout errors, a metric should be created to track and correct human errors, and technology should be used to both reduce the need for re-processing and verify correct re-processing.

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Glossary

Associate: An associate is the typical worker in an Amazon fulfillment center, with tasks such as picking, packing, etc.

Amazon Logistics (AMZL): AMZL is Amazon's own last mile delivery provider, currently operating in major cities. There are several AMZL delivery stations in the Los Angeles area.

Critical Pull Time (CPT): The "critical pull time". Twenty to thirty minutes after this time a trailer must be loaded and virtually departed from the FC.

Gaylord: A large cardboard box, about five feet tall, into which sorted "flat" packages are diverted. The gaylord is then loaded onto a trailer for transport.

Jiffy mailer: A yellowish envelope used to pack small items and sorted on the flat sorter.

Kickout: A package that did not "pass" the verification scan after auto-SLAM. A kickout could have a number of different defects, and will be manually re-processed by an associate.

Last mile carrier: A last mile carrier delivers packages from a distribution facility to a customer's door. Examples include UPS, FedEx, DHL and Amazon Logistics.

Missort: A package that arrives at the incorrect carrier facility or, for Amazon Logistics, at the incorrect station. For example, a package with a UPS shipping label is delivered to a FedEx facility by mistake.

Manifested Not Received (MNR): An error in which the last mile carrier virtually receives a package, but does not physically have the package in their facility.

Pallet Spur: A conveyor belt system on the outbound shipping dock that does not empty into a dock door, but rather into an empty area where boxes will be placed on pallets.

Promised Delivery Date (PDD): The PDD is the delivery date that is promised to the customer when they check out at Amazon.com.

Peak: The peak season begins in mid-November and continues until Christmas; this is the busiest time for the FC.

Received Not Manifested (RNM): An error in which the last mile carrier physically receives a package, but does not see the package ID number in their tech system.

SLAM: Stands for Scan / Label / Apply / Manifest, and refers to the step at which a shipment is weighed, the shipping method is calculated, and a shipping label applied.

Shipping Label: The shipping label is applied by the auto-SLAM machine or when a package is kicked out after the SLAM step. It contains the customer's name and address, the tracking number for the last mile carrier, and the encrypted shipment ID for internal Amazon tracking.

Sort: A delivery method that specifies the carrier and the CPT (critical pull time), by which all packages that are a part of the sort must be loaded onto a trailer.

Sp00: A barcode label applied to a box after an item has been packed. After packing and before auto-SLAM, the sp00 contains all order details for a particular shipment.

Virtual Physical Mismatch (VPM): A general term for the MNR and RNM errors discussed above.

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1. Introduction

1.1 Amazon Background

Amazon.com was founded as an online bookseller in 1994 and has since expanded into consumer goods, electronics and entertainment media. The company's goal is to be "Earth's most customer-centric company, where customers can find and discover anything they may want to buy online" (Amazon.com, Inc. History, n.d.). While Amazon has branched out into other industries, the company's primary business is still retail[1]. Most recently, Amazon has expanded into online grocery fulfillment and last mile parcel delivery services. In 2014, Amazon launched its own last mile carrier, Amazon Logistics (AMZL), with the intent to gain greater control over the shopping and shipping experience, and to reduce shipping costs (Stevens, 2014). The creation of AMZL will also enable Amazon to avoid a threat noted clearly in the company's 2014 Annual Report: "We rely on a limited number of shipping companies to deliver inventory to us and completed orders to our customers. If we are not able to negotiate acceptable terms with these companies or they experience performance problems or other difficulties, it could negatively impact our operating results and customer experience." (Amazon.com, 2014) The focus of this thesis project is closely aligned with Amazon's goals of satisfying its customers and also expanding Amazon Logistics.

1.2 Problem Statement

The goal of this thesis project was to reduce customer concessions by reducing outbound process defects at the ONT2 fulfillment center (FC). A secondary goal was to reduce the impact of these defects on last mile carriers, Amazon Logistics in particular. Outbound process defects lead to

[1] "Our primary source of revenue is the sale of a wide range of products and services to customers" (Amazon.com, 2014).

damaged, late, missing or wrong-item shipments, resulting in a poor customer experience and concessions for Amazon. These concessions are a key performance metric for all FCs and are tracked on a weekly basis. In spring 2015, ONT2 increased focus on reducing outbound process defects in order to drive down concessions and reduce problems for downstream Amazon Logistics delivery stations.

1.3 Project Approach

The approach used for this project is as follows: map the outbound FC process (Fig. 1), map the last mile carrier process (Fig. 2), determine quantitative and qualitative data sources to measure the impact of defects, data analysis, and report creation. The key steps under consideration are the SLAM and sortation steps for both "flat" packages (sorted by the flat sorter) and "dock" packages (sorted by the shipping sorter). Data sources for analysis include AMZL station feedback, AMZL package returns to ONT2, ICQA missort audit data and missort data collected at sort centers. Statistical process control tools were utilized to better understand defect root causes and quantify the current and historical process performance for the sortation step. Throughout the project, changes and re-training efforts were implemented, the results of which will be discussed in depth. Finally, a missort report was created that provides a more accurate, timely indicator of sortation performance for the managers at ONT2. Note that all numbers (axes, etc) in this thesis have been altered using a scaling factor in order to protect Amazon's confidentiality.

1.4 Thesis Overview

This thesis will begin in Section 2 with a general overview of the Amazon.com fulfillment process, and a more detailed description of the FC outbound and Amazon Logistics processes. Section 3 will continue with a literature discussion of relevant topics, including process capability assessment, control charts and continuous improvement. Section 4 will dive deeper into the package missort defect, along with the metrics used to measure performance, analysis completed and changes implemented. Section 5 will follow a similar outline for SLAM defects. Section 6 will close with a discussion of recommendations and suggestions for future work. Throughout this thesis defects will be reported in terms of defects per million opportunities (DPMO), which is frequently used to describe small defect rates. Defect DPMO has been adjusted using a scaling factor in order to protect Amazon's confidentiality.

2. Operations at Amazon.com

2.1 Amazon.com Fulfillment Process Summary

When an order is placed and assigned to an FC, the item is then assigned to a picker who picks the item from a shelving unit and places it in a tote. Next, the item is routed via tote to a packer, who packs the item into a pre-determined box or jiffy mailer (yellow envelope) as specified on the computer screen. The packaged item travels down a conveyor belt to the "SLAM" (Scan / Label / Apply / Manifest) step, where the package is weighed, an algorithm is run, and the shipping label is applied. If the package is defect-free, it is sorted on the shipping sorter if is a large box, or on the flat sorter if it is a smaller box or jiffy mailer. After sortation, the package is loaded onto a truck and then departed to a carrier facility. This process will be described in more depth below.

2.2 Overview of ONT2 Outbound Process

The focus on ONT2's outbound processes begins when the item is packed into a box. The relevant steps are illustrated and detailed below:

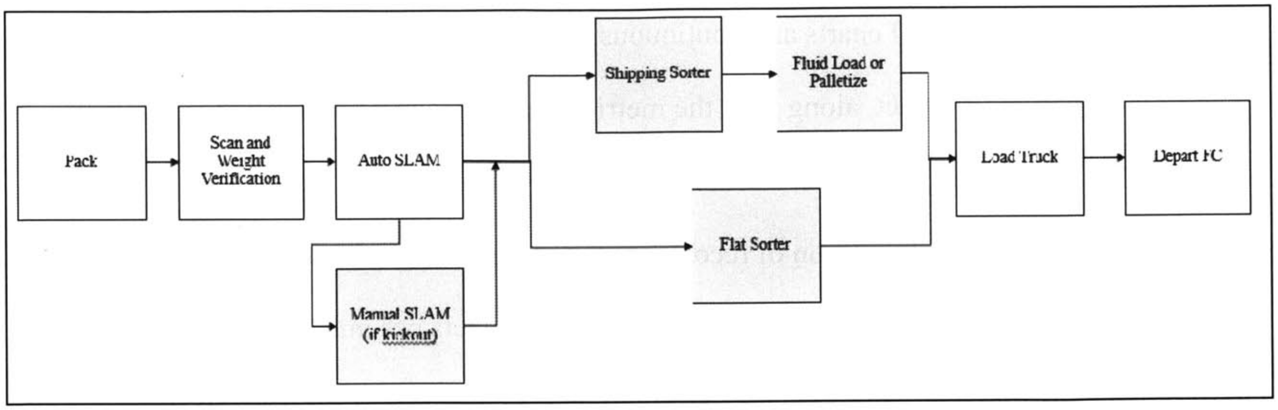

Figure 1. ONT2 Outbound Process Map

- When the item is received by the packer it is scanned, and a box or jiffy mailer size is assigned based on the item's dimensions and weight. The packer builds the box, puts in the item, and adds protective "dunnage" (air-filled plastic cushioning material). They then seal the box / jiffy mailer, scan and apply a "sp00" label, and place the package on the conveyor belt. The sp00 label now contains all the relevant information about the order, including the item in the package, the customer's address and the PDD (promised delivery date).
- The box / jiffy mailer travels down the conveyor belt until it reaches the auto-SLAM machine, which applies the shipping label. Just before the package reaches the auto-SLAM machine, the sp00 is scanned and an algorithm is run to calculate the appropriate shipping method and carrier. The algorithm takes into account when the package needs to arrive to the customer (the promised delivery date, or PDD), the destination, the weight and size of the package and finally, the cost of shipping. When the best method has been determined, the auto-SLAM machine applies the shipping label. Included on the shipping label are the customer's name and address, the carrier's name (UPS, FedEx, etc.), a tracking number and an encrypted shipment ID, and other information. The tracking

number is used by the last mile carrier for routing and sortation. It has no particular relevance to the FC, and a new tracking number is generated for the same order every time a new label is printed. This is an important point when discussing SLAM errors in Section 5. The encrypted shipment ID is used by Amazon to track the package after the shipping label has been applied. It can be decrypted and searched in several different Amazon tech systems to see where the package should be in the fulfillment process. The encrypted shipment ID stays the same no matter how many times the shipping label is printed for a single order.

- After auto-SLAM, the package receives a verification scan in which the shipping label is scanned to ensure it will be readable in later scans. If it is not, or if a number of other errors occurred during the process the package will be "kicked out", or diverted, to a station where an associate will manually resolve the error. More on this error resolution step, called manual SLAM, in Section 5.
- Packages that pass the verification scan continue on to one of two sortation processes depending on their size. "Dock" packages (those greater than three inches in height) are routed to the shipping sorter, where the encrypted shipment ID is scanned and the package is assigned to the appropriate dock door based on the sort code. Depending on the "sort", or specific departure time and carrier, dock packages will be either fluid loaded or palletized. For a fluid loaded sort, the packages are loaded directly into the back of a trailer, while packages for a palletized sort are built into a solid structure on a standard wooden pallet. "Flat" packages (those less than three inches in height) are routed to the flat sorter where an associate inducts the package onto the flat sorter equipment. When the package passes underneath one of two cameras on the flat sorter, the encrypted

shipment ID on the label is scanned, and the package is assigned to the appropriate chute based on its sort code. When the package reaches the assigned chute it is diverted into a gaylord, a large cardboard box that can hold up to 800 packages.

- Dock packages are loaded onto the trailer either via fluid loading or on pallets. Finally, the gaylords with flat packages are added to the trailer. The trailer is departed, physically and virtually, to the last mile carrier facility.

2.3 Overview of Amazon Logistics Sortation and Delivery

Amazon Logistics (AMZL) was created in 2014 to be Amazon's internal last mile carrier, providing Amazon with the opportunity to own the full customer experience. The organization's vision statement includes the following:

"The goal of AMZL is to disrupt the traditional logistics industry by providing the lowest delivery cost, highest quality and fastest delivery service, regardless of route density, to Amazon's customers globally…"

Currently, a fraction of ONT2's outgoing volume is sent to the delivery stations in Los Angeles, San Diego and San Francisco. The L.A. delivery stations were of particular interest for this project because they were close enough to visit, and managers at these sites provided important information for this thesis. Packages destined for an AMZL site are handled in much the same way as packages that are sent to a UPS or FedEx site: dock packages are either fluid loaded directly into the back of a trailer, or they are palletized and then loaded into a trailer. Flat packages are sorted into gaylords, and the gaylords are then loaded.

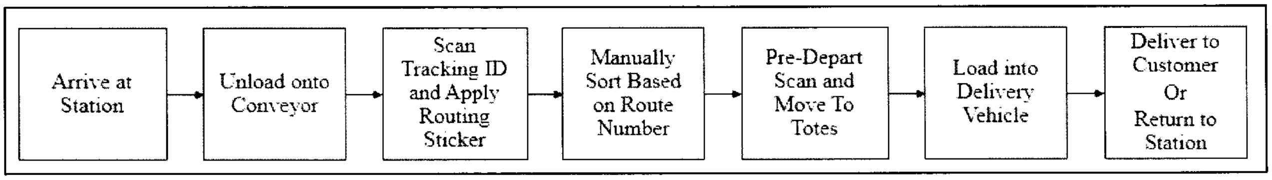

Figure 2. Amazon Logistics Delivery Station Process Map

Once a package reaches the delivery station, the general process is as follows:

- Packages are unloaded from the trailer, pallet or gaylord onto a conveyor belt. At this time, wrong carrier or wrong station missorts may be visually identified and sidelined for return to the FC.
- Packages are hand-scanned, a route sticker is applied, and they are put back on the conveyor belt. If the package is not manifested or has another defect, an "Error" sticker will print and the package is sidelined for problem solving. This will happen if there was a SLAM error that occurred in the origin FC, as will be discussed in Section 5, or if the package is a missort that was not previously identified.
- The packages are manually sorted to large racks based on their route number, given a pre-depart scan to reduce intra-station missorts, loaded into totes (or bags) and staged for departure when the delivery vehicles arrive.
- Delivery Associates (DAs) load the totes into their vehicles, depart for their route and return any undeliverable packages at the end of the day. Depending on the issue, undeliverable packages may be re-injected the same or the next day. After three delivery attempts, the packages are returned to ONT2, even if they did not originate at ONT2. Un-routable packages (those that are damaged, wrong-station or wrong-carrier missorts, have a manifest issue, or some other defect) are also returned to ONT2.

3. Literature Review

3.1 Process Capability Assessment

One of the first steps in this project was to assess the current performance of the sortation and SLAM processes. (Cachon & Terwiesch, 2009) state that when assessing process capability and using statistical process control methods, "the importance of data collection cannot be overemphasized". After data collection, current performance should be compared with performance standards (NIST/SEMATECH e-Handbook of Statistical Methods, 2013), however in this case there were minimal pre-existing performance requirements. For sortation, there was only an estimate of missort DPMO across the North American network, and SLAM defects were incorporated into the aggregate concession DPMO target.

While SLAM performance capability assessment was not achieved in the course of this project, sortation performance was determined. The literature lists several tools as being important in establishing an understanding of process performance, including histograms, control charts and regression analysis to determine the relationship between process variables and process output (Montgomery, 2009). All of the above were valuable inputs in establishing sortation process capability understanding.

3.2 Control Charts

Control charts were a critical part of this project, initially in establishing a baseline for historical sortation process performance. As noted by Haridy, the primary use for control charts is to "quickly detect the occurrence of assignable causes of process shifts" or rather, determine if the process is in control or out of control (Haridy, Wu, Lee, & Rahim, 2014). However, there are several additional benefits to control charts including determining the process mean and standard deviation, and providing a visual representation of the process performance (Cachon & Terwiesch, 2009). Montgomery continues that "use of a control chart is an excellent way to reduce variability", and that corrective action should be taken as soon as the process characteristics plot outside the upper or lower specification limits on a control chart (Montgomery, 2009).

Several different types of control charts can be used depending on the process and the parameters under investigation. The type used in this project is an attribute control chart (or p chart), as compared to a variable control chart (or $\bar{x}$ bar chart), in order to measure the proportion of defective (missorted) units. (Cachon & Terwiesch, 2009) caveat that with attribute control charts the sample size must typically be much larger than with variable control charts, especially when defects are rare. This caveat informed the choice of sample size (a day's worth of sort center volume) since missorts are somewhat rare at ONT2.

3.3 Continuous Improvement

Determining a robust data source, establishing a baseline for process performance and creating control charts to continually monitor the performance against statistically determined specifications are enablers of continuous process improvement. The benefit of using data and control charts is gaining the ability to base process improvement meetings on facts and discuss a path forward objectively (Cachon & Terwiesch, 2009). While there are many available frameworks and tools to aid continuous improvement efforts, employee engagement is one of the most important contributors to success (Brajer-Marczak, 2014). Providing a readily available data source (a missort report) and getting management buy-in were priorities for this project in order to ensure the feasibility of continuous improvement projects.

4. Sortation Analysis

Sortation defects resulting in missorted packages are one of two main areas of study for this thesis. For each section, dock package and flat package missorts will be addressed jointly when discussing general missort issues, and separately when different root causes and remedies apply. This section will first describe the dock and flat sortation processes in greater detail, then discuss the metrics used to gauge performance and the process performance at the time of study. The statistical process control techniques of interest will be described, as well as the solutions implemented and the recommendations moving forward.

4.1 Dock Package Sortation Detailed Process Description

After the auto-SLAM step, dock packages are routed to the shipping sorter, where the encrypted shipment ID is scanned and the package is assigned to the appropriate dock door based on the sort code. If the assigned lane is full (and the andon light is flashing blue, or "blue lighting") the package will recirculate on the shipping sorter a maximum of three times, at which point it will reach "max re-circ (recirculation)" and be kicked out at the "jackpot lane". The package will be problem solved by an associate if necessary and then the package will either be manually taken to the appropriate door, or re-inducted to the shipping sorter.

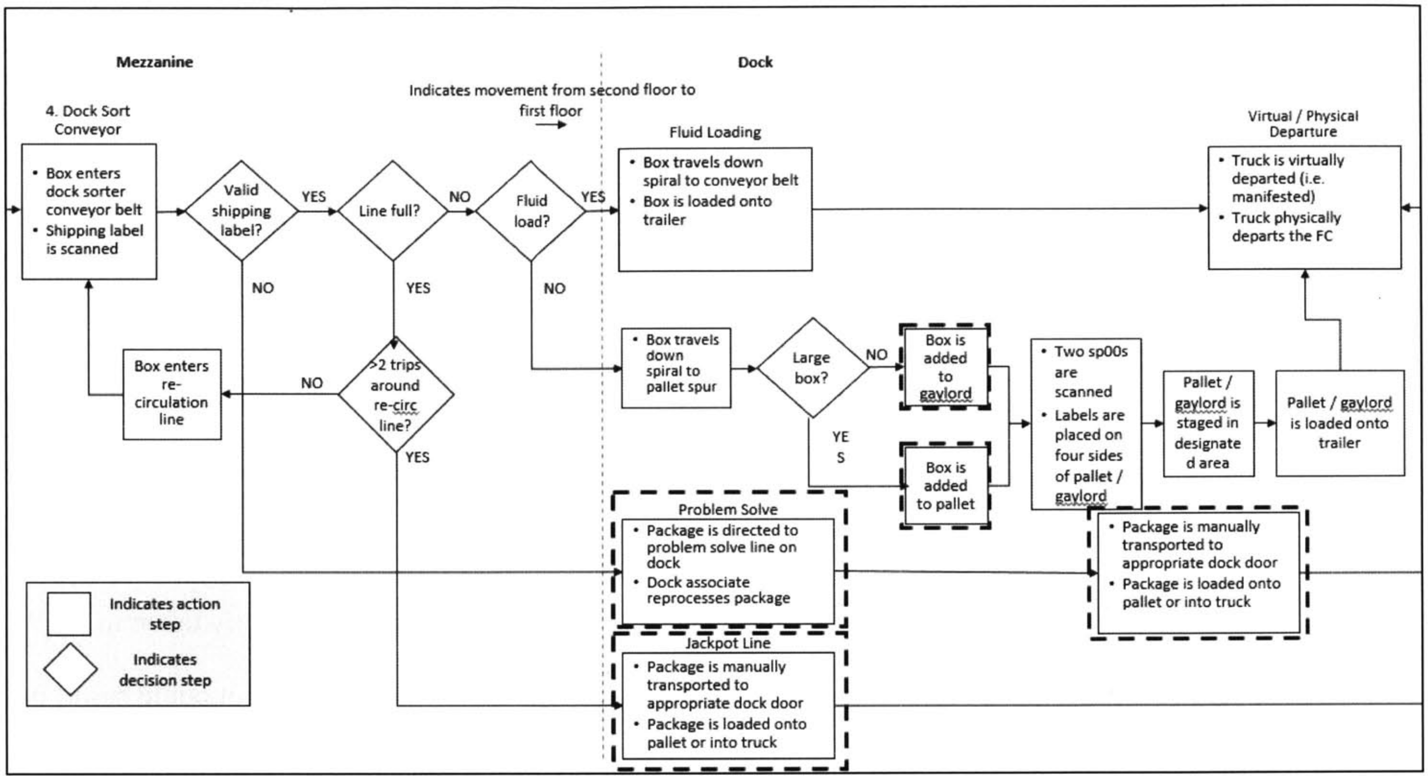

Figure 3. Dock Sortation Process Map

As noted earlier, dock packages will either be fluid loaded or palletized. High volume sorts, including one AMZL sort at ONT2 at the time of study, are typically fluid loaded. During this process, between one and three associates will build a wall of boxes to maximize the "cube" usage (i.e. volume) of the trailer. If the conveyor belt leading into a given dock door is full, its andon will "blue light" and become unavailable to the packages on the shipping sorter; packages that hit max re-circ on the shipping sorter during this time will be kicked out at jackpot. When sortation volume is heavy, associates may put boxes that should be fluid loaded in gaylords. Missorts resulting from human error occur during this step if an associate is not closely watching where they are putting each package.

For lower volume sorts, including most AMZL sorts, packages are routed to a pallet spur. Here, associates build pallets by hand scanning each package to the pallet location and placing the box on the pallet. When the pallet is full, it is wrapped in plastic to hold it together and staged in a designated area. Two sp00 labels from packages on the pallet are scanned to uniquely identify the pallet. The pallet is scanned to the staging location and then again to the trailer. Packages from different sorts may be mixed on a pallet spur, increasing the chance of mis-sortation. Sorts were mixed on at least two pallet spurs at ONT2.

There are several opportunities for missorts to occur (Fig. 3; bold dashed lines represent steps when missorts can occur). The first is after the package is diverted to the jackpot or problem solve lane. After re-processing (if needed), the package will either be re-inducted on the shipping sorter or it will be placed on a cart with packages from the same sort and manually taken to the appropriate dock door. If an associate misplaces a package on the incorrect cart, it could result in a missort as there are no further formal checks to ensure the package is in the correct place.

For those packages that are palletized and on a "mixed" pallet spur containing several sorts, there is an additional missort opportunity. Although associates must scan each package and then scan the destination location (in the form of a QR code or bar code on a pallet or gaylord) it is still possible to misplace a package when pallets or gaylords for different sorts are in close proximity.

Finally, on rare occasions entire pallets or gaylords can be "missorted" if they are placed in a trailer destined for the incorrect trailer. This is not common and was not a major focus of this project.

Although manual errors such as package misplacement may seem trivial and unlikely, associates work ten-hour shifts, with just an hour break total during that time. Fatigue, the repetitive nature of the work, and frequent process and layout changes can easily lead to mistakes. The individual root causes of the human errors that result in missorts were difficult to quantify for this project, so the focus was primarily on improving the processes that might lead to missorts.

4.2 Flat Package Sortation Detailed Process Description

After auto-SLAM, flat packages (those less than three inches in height) are routed to the flat sorter. The flat sorter is a large, oval piece of equipment, consisting of induct stations, a circulating conveyor belt, and diverts (or chutes). At ONT2 there are eighty to ninety different chutes, not all of which are in use at any given time.

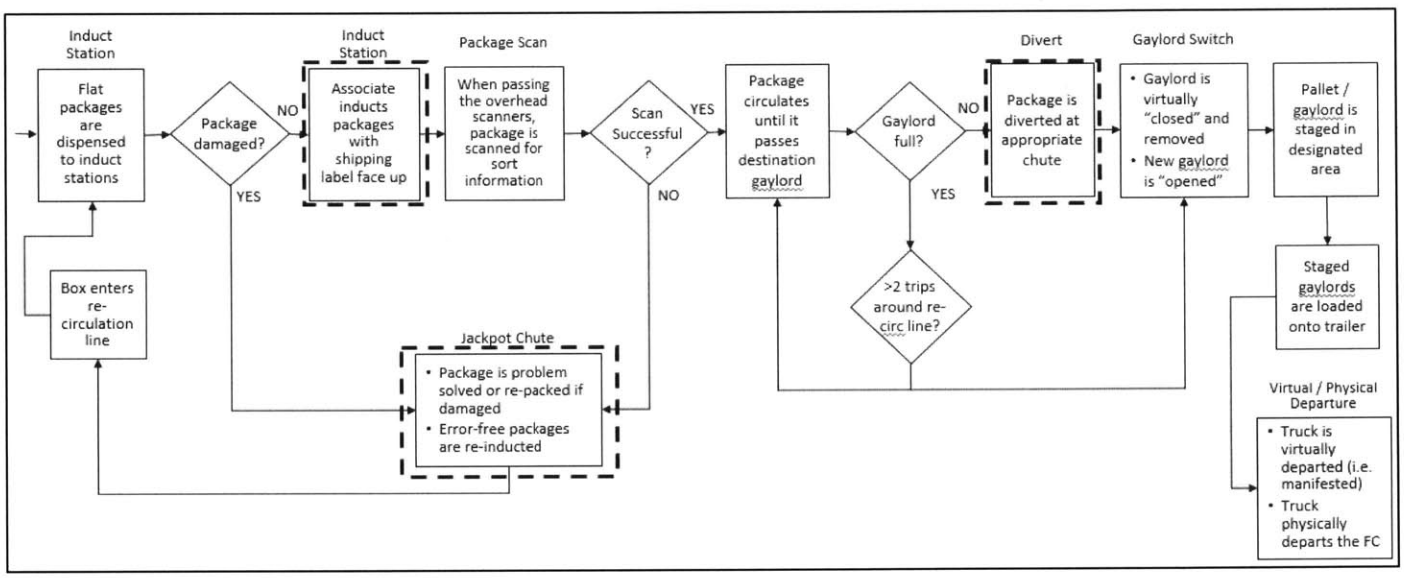

Figure 4. Flat Sortation Process Map

Packages are directed to induct stations at regular intervals, provided that the station is active and not too full, such that each station has 20-40 packages. There are four induct stations on each side of the flat sorter. At the station, an associate inducts the package onto the flat sorter conveyor belt with the label facing up. Then, the package is assigned to a position on the main part of the equipment, called a carrier plate. A carrier plate is about 18 square inches in size and consists of a conveyor belt on a metal frame. The conveyor belt will spin in order to direct the package into a chute. There are two cameras on opposite sides of the flat sorter. When the package passes underneath one of these cameras, the encrypted shipment ID on the label is scanned, and the package is assigned to the appropriate chute based on its sort code. When the carrier plate passes the chute, the belt spins and the package is diverted into the gaylord. If the appropriate gaylord is full or the chute is turned off (the gaylord is unavailable), the package will recirculate ("re-circ") a maximum of three times on the flat sorter before it is kicked out at jackpot, where packages with other defects are also kicked out. Here, the package will be problem solved and / or re-inducted. Immediately after the jackpot chute there is a device called an air knife, which will shoot a puff of air towards a carrier plate when directed. The air knife will fire if the camera detects any anomalies with the carrier plate, including a package that is not fully on the plate (and thus at risk of being mis-diverted), or a barcode that could not be read. The purpose of the air knife is to ensure that overlapping packages or very light packages are diverted to the jackpot lane.

There are several opportunities for missorts to occur in this process (Fig. 4; bold dashed lines represent steps when missorts can occur), from induct to divert, due to human, technology and mechanical errors. Typically, missorts occur when multiple packages end up on the same carrier plate (double packages) or when one package overlaps an adjacent carrier plate (overlapping packages). When packages are situated off-center on a carrier plate, they may not cleanly divert into the proper chute. If this happens, the package may fall down the adjacent chute, end up on the adjacent carrier plate, or overlap the adjacent carrier plate. When packages are doubled up on a carrier plate they may be detected by the camera and fixed by diverting down the jackpot lane. However, if the camera does not detect two barcodes, it assumes there is only one package on the carrier and both packages are diverted into the same chute. The reasons for doubled up and overlapping packages will be described according to the order in the process in which they may occur.

The first place that errors can occur is during induct. The packages that are sorted via the flat sorter have dramatically varying dimensions: the package may be a small, light jiffy mailer, a heavy box, or a jiffy mailer with an abnormally shaped item like a baseball. Although the mechanical induct system is theoretically designed to handle this variability, in practice these differences can result in a package being inducted such that it overlaps an adjacent carrier plate. Doubled up or overlapping packages can also occur due to poor or variable induct technique. When the packages are inducted, the associates doing this activity are instructed to slide the package onto the conveyor belt such that the package will be situated in approximately the same position with each induct. This technique should ensure that the packages end up squarely on a carrier plate, thereby ensuring that they are cleanly diverted into a gaylord. However, when an inductor does not follow the procedure correctly, the package ends up in a slightly different place on the carrier plate each time. Even after trial-and-error calibration of the conveyor belt speed, the controls systems engineers at ONT2 found it difficult to account for the induct technique variability.

Another instance that leads to missorts occurs when the flat sorter jams due to blockage of a photo eye (there are many on the equipment). When a jam occurs, the entire conveyor belt comes to a stop and the equipment must be manually restarted after the jam is cleared. When the conveyor belt is changing speed, packages are more likely to be inducted onto a carrier plate that already has a package on it or will overlap an adjacent carrier because the induct station belt speed is not able to adjust for the changing speed of the larger piece of equipment.

4.3 Sortation Performance Metrics

The sortation process at ONT2 has several different performance metrics, including the concessions report, a missort audit (performed four times per day) and a sort center missort report. In addition to using these measures, interviews and observations were performed, and additional insight was gained using data from AMZL station returns and from missort data collected at sort centers.

Several metrics are used to gauge the performance of the sortation processes for both dock and flat packages at all FCs in North American (NA FCs). Each of these metrics provides a window into the process performance, however each of them has notable flaws which were critical to understand in the pursuit of an accurate current state analysis.

The first of these metrics is the concessions report. As noted above, the concessions report is used to gauge performance in meeting the customer expectation for all NA FCs. If a customer has a sub-optimal experience and receives a package that is late, damaged, missing, or does not include the proper items, they can file a concession and Amazon will grant them one of a variety of different remedies. When the concession is filed, the case is assigned a reason code, such as "wrong item switcheroo", "item missing", or "damaged item", among others.

While the concessions report is a reflection of the customer experience and is published for all NA FCs on a weekly basis, it lacks clarity in several key ways. First, the concession is reported at the convenience of the customer and in many cases the customer will not file the concession until several weeks after they should have (or did) receive their shipment. For six months of concessions data at ONT2, the mean time between ship date and concession report date was eight days[2]. The histogram below (Fig. 5) shows that although most concessions are reported within a week, the delta between the ship date and concession report date can stretch past three weeks.

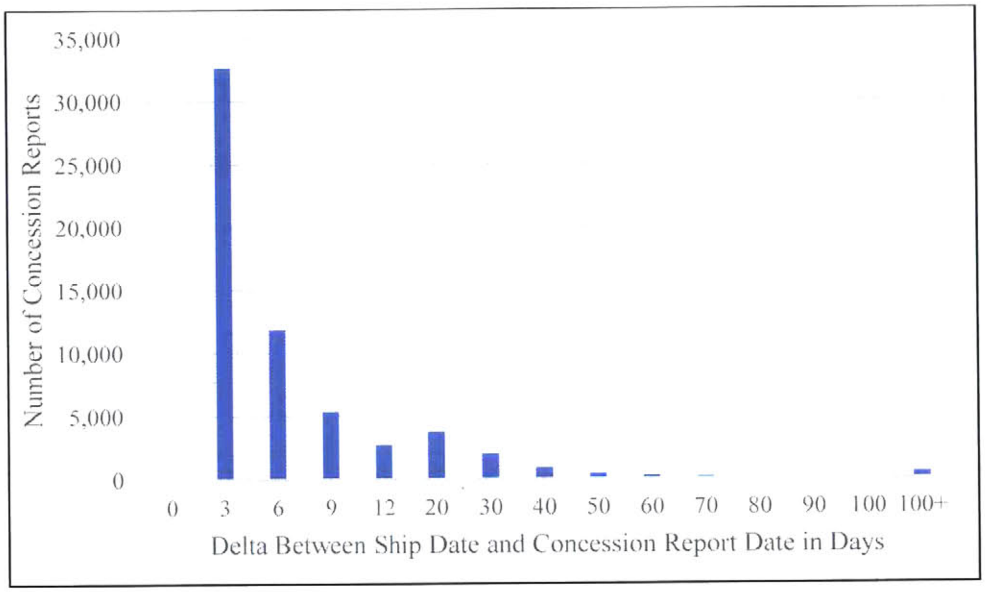

Figure 5. Delta between Ship Date and Concession Report Date

This illustrates that concessions are a lagging indicator and it is impossible to tell when all of the concessions for a given ship date have been reported. Thus, the efficacy of outbound process changes aimed at reducing concession-causing defects is difficult to determine using the concessions report alone.

Second, concessions may not be allocated to the correct reason code by the customer or the customer service representative. For example in one report a concession was categorized as a "wrong item switcheroo" although the customer commented that they "never received package", indicating that the appropriate reason code should have been "item missing". This leads to another difficulty with concessions: reason codes are not only mis-reported, they can have multiple definitions. A concession allocated to the "item missing" reason code could indicate that

[2] For 80 days of ONT2 concessions data based on date reported (7/26/2015 – 11/11/2015)

the customer never received their order at all, that they received an empty box, or that they ordered five items and only received four. The defects that lead to these different outcomes are different and impossible to ascertain using the current coding system.

Additionally, the reason codes encompass several root causes that lead to the same customer impact. For example, a wrong item switcheroo can occur when the item is picked, packed, or reprocessed by a SLAM operator.

Finally, for missorts in particular, the concession report provides a lower bound estimate for the defect rate. This is due to a "band aid" for missorts that was introduced in 2012 in which major carriers (UPS, FedEx, etc.) correct any missorts they receive by "overlabelling"[3]. For example, if UPS receives a missorted package with a DHL label, a UPS label is placed over the existing label and the package is delivered to the customer by UPS. Because the customer receives their package, a concession will not be filed for this package and the true missort rate will be underrepresented by the concessions report. While this band aid method does have a small financial impact to Amazon in the form of a per package payment to large carriers, it is about 20% of the cost of a concession[4], and typically meets the customer's PDD.

Another metric for sortation performance is the missort audit that is performed four times per day in the FC by an associate on the ICQA (Inventory Control and Quality Assurance) team. Each time the audit is performed, the associate should sample 100 flat packages, 100 fluid loaded dock packages and 100 palletized dock packages. The associate chooses which gaylords and dock lanes to audit and visually scans the packages to see if any of the shipping labels do not match the sort in that location. This audit is subjective and the thoroughness will depend on the

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[3] Conversation with Bors Vesterby, 7/15/2015
[4] Cost provided by Bors Vesterby

specific associate doing the job. A review of thirty days of missort audit data shows how a positive missort finding skews the missort DPMO. In October 2015, the missort DPMO at ONT2 according to the audit varied between 0 (for 15 days) and 1,500 (for 1 day) (Appendix I)[5]. Additionally, the sample size of 800-1200 packages per day is too small to accurately capture the missort rate at the expected DPMO. Using the sample size calculation equation[6] shown below and the estimated actual rate of missorts based on sort center data, the appropriate sample size for a confidence level of 95% and a margin of error of 0.1% is 7,700 flat packages and 2,700 dock packages.

$$n = \frac{\hat{p}(1-\hat{p})z^2}{ME^2}$$

Where n = the sample size

ME = margin of error; 0.1% used in this example

z = critical value for a specific confidence level (1.96 for 95% CI)

$\hat{p}$ = estimate of population missort proportion, with different values used for flat and dock packages

The final important metric is a report that the sort centers generate and deliver to all NA FCs every few days (Fig. 6). The report records all missorts that arrive at a sort center. While this report is the most complete and timely measure of the missort rate, this data is not tracked over time to identify trends, nor is it available to the FCs in a detailed format that would enable immediate action to reduce missorts. The report indicates the number of missorts received by

[5] Amazon's Missort Audit Portal
[6] https://www.unc.edu/~rls/s151-2010/class23.pdf

each sort center from each origin FC within the indicated time period (typically a few days). However, there is no indication of the package type, the carrier or the arrival date of the packages, information which could help identify root causes.

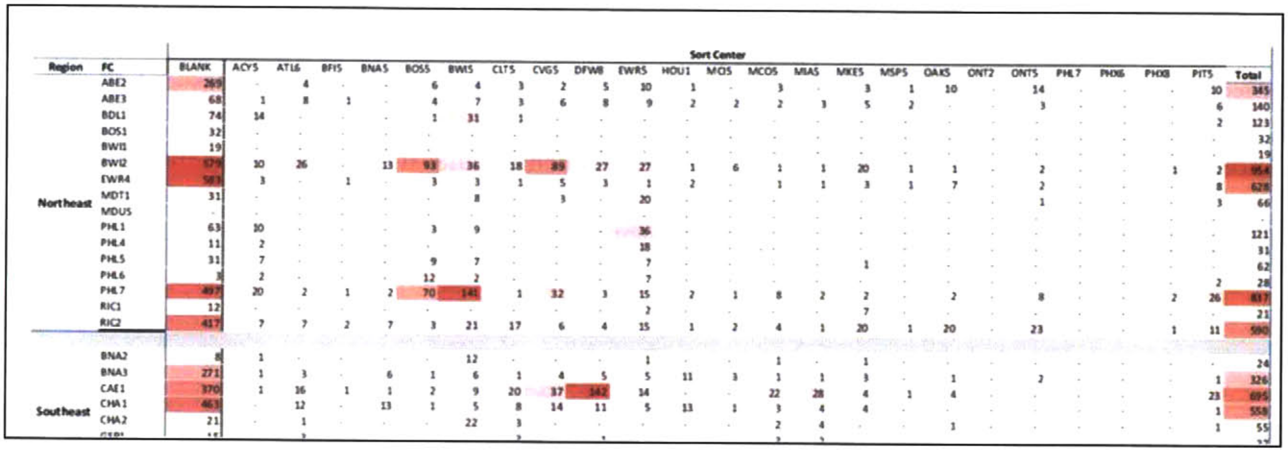


Figure 6. Sort Center Missort Report

In summary, none of the metrics described above provide an indication of current or historical process capability and they do not support continuous improvement efforts due to their lagging and high level nature. These metrics were an important starting point for this investigation, however alternative performance measures were developed and will be discussed in Section 4.4.

4.4 Current Process Performance

The current dock and flat sortation process performance was determined using the metrics above, as well as additional data collected in the course of the internship. Both quantitative sources, such as the missort report and concessions report, and qualitative sources, including interviews and observations, were used.

Several informal interviews were carried out in order to understand general process performance and barriers to achieving a zero DPMO missort rate. The initial qualitative description of the process provided by a senior manager at ONT2 indicated that the dock process "has a lower missort DPMO than the flat sortation process", though the true quantitative missort rate was unknown. This assessment was echoed by an operations manager at ONT2, and by the Outbound Dock SME (subject matter expert). In Sections 4.4.1 and 4.4.2, observations and metrics will illustrate that these hypotheses were correct.

4.4.1 Dock Package Performance

The Outbound Dock SME hypothesized that the reason for the dock sortation defect rate was primarily due to human error with palletized packages. For example, on a pallet spur with multiple sorts, it is easy for an associate to scan the package, scan the destination pallet / gaylord and then accidentally place it in the wrong destination. Observations of the dock sortation process showed that fluid load sorts were less likely to encounter the same issues as mixed, palletized sorts because the packages are loaded directly into the back of a truck.

Beginning in June, ONT2 was the dedicated returns site for packages that arrived at AMZL stations but that were un-routable (due to an FC error) or undeliverable (due to a delivery or AMZL error). Five local delivery stations sent packages back to ONT2, where the customer service team collected package identification data, including the tracking number and the encrypted shipment ID. Using this ID information, additional details about package attributes could be gathered from Amazon's Data Warehouse using a SQL query. This data enabled some preliminary conclusions about wrong carrier missort DPMO for the FCs that delivered packages to these stations. It is not possible from this data to determine which packages were wrong-station missorts. Prior to the discovery of more robust and representative data, this data was used to identify trends and approximate the missort DPMO of flat and dock packages. Figure 7 shows the wrong carrier missort DPMO for these packages. The flat missort rate is clearly higher than the dock missort rate, and the dock missort rate is relatively low, in line with the suspicions of the ONT2 managers. One caveat with this data is that not all of the packages that were returned had identification information that could be collected. And not all of the identification numbers returned detailed information from the Data Warehouse query. Detailed information for about two thirds of the returned packages was found, and it is not clear why some information was not returned. It is also not clear if there was a bias in the type of package for which information was or was not returned (flat or dock packages). However, this data was assumed to be a better approximation than the existing data sources because it provided a direct and nearly complete missort defect rate for several sorts (albeit sorts that were a small fraction of total ONT2 volume).

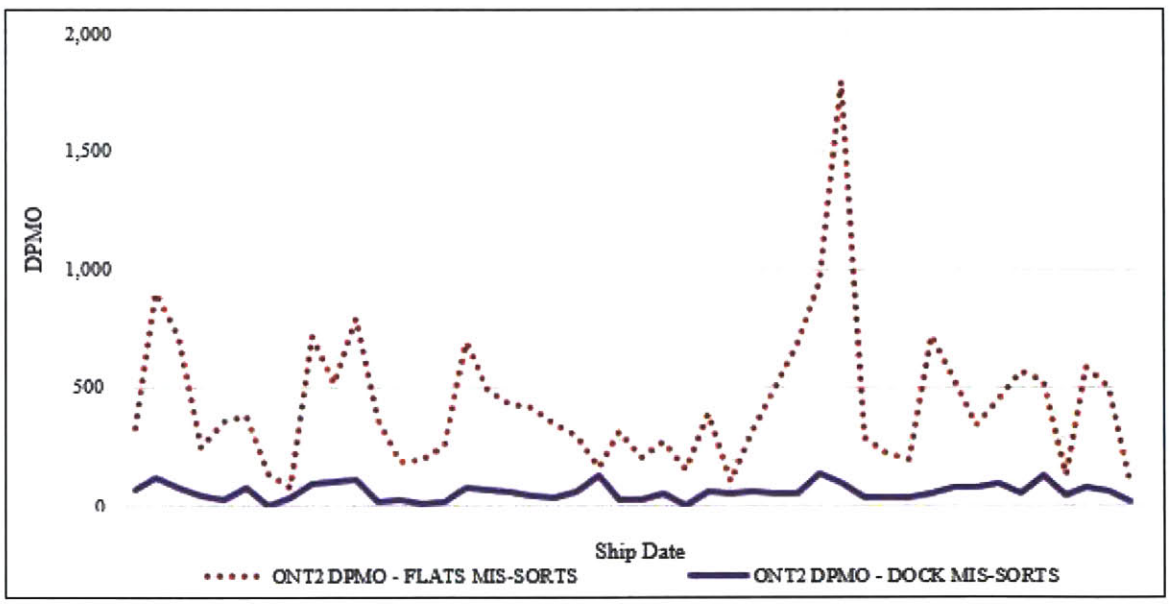


Figure 7. AMZL Returns Missort DPMO

4.4.2 Flat Package Performance Assessment

Several different observations were performed on the flat sorter in order to better understand the process, the opportunities for defects to occur, the impact of induct technique and the effectiveness of the air knife.

The first of these was an observation of the air knife, the purpose of which is to help divert poorly placed or "error" packages to the jackpot station. The air knife is designed to fire when the carrier belt spins to divert a package. The carrier diverts in response to a signal from either camera, which could be detecting two barcodes, an invalid barcode, or some other anomaly. The hypothesis was that the air knife contributes to circumstances of misplaced packages by unsuccessfully diverting the packages, and does more harm than good. This is recorded below as "air knife fired, package was not diverted", a situation in which the air knife fired and the package was not diverted and ended up poorly placed on a carrier plate. The air knife was observed for a period of thirty minutes and the following four different actions were observed and the number of occurrences as a percentage of the total number of air knife fires was recorded (Table 1).

1. Air knife fired, package was diverted	39%
2. Air knife fired, package was not diverted	7%
3. Air knife should have fired but did not	2%
4. Air knife fired on an empty carrier	52%

Table 1. Air Knife Observations

The observation indicates that for the majority of the time the air knife either contributed to the placement problem or fired on an empty carrier. Although action four (fired on an empty carrier) does not directly appear to contribute to potential missorts, it does bring into question the overall functioning of the device and how often the air knife fires when it should not.

An induct experiment was also performed, in which one hundred packages were inducted with the proper technique and one hundred packages were inducted with improper techniques. The number of "good" placements and the number of "bad" placements were recorded. With the proper technique, none of the packages were doubled up or overlapping. With improper techniques, just one out of one hundred packages ended up between carrier plates. This brief experiment seems to indicate that induct technique does not have an impact on package placement on the carrier plate. However, there are many variables that were not tested or recorded in this situation, including package dimensions and start up / shut down of the flat sorter. While a useful exercise, this experiment did not yield clear results, and a more detailed experiment with a larger sample size could yield more conclusive results.

In an effort to determine a more accurate missort rate using data that could be collected immediately at ONT2, fourteen gaylords were emptied and the number of total packages and number of missorts were counted. Additionally, the sort codes of the missort packages were recorded to determine if there was any kind of a pattern in the missortation. The average missort rate was almost eight times that of the assumed network average[7], though the rate varied from zero missorts to fourteen times the network average.

Finally, as with the dock missorts, the AMZL flat package returns were reviewed and the missort rate was plotted (Fig. 8). The plot indicates that the flat missort rate varies widely, unlike the dock missort rate. The plot does not show a clear pattern or trend, and the missort rate is up to fifteen times as high as the network average.

4.5 Cause and Effect Analysis

After mapping the processes and determining and analyzing qualitative and quantitative measures of dock and flat sortation performance, cause and effect (or Ishikawa) diagrams were created to determine the possible root causes of the missort defects. The causes were divided into

[7] Average estimated using concessions data, provided by Bors Vesterby

equipment, process, people, materials, environment and management categories, which are commonly used in manufacturing-type settings (Kollengode, 2010). The problem to be solved was defined as dock missorts and flat missorts. The key causes and the reasons behind the key causes were determined through conversations with managers and associates, as well as personal observations. See Figures 8 and 9 for the full diagrams. Further investigation was done for some of these areas, and will be discussed later in this thesis.

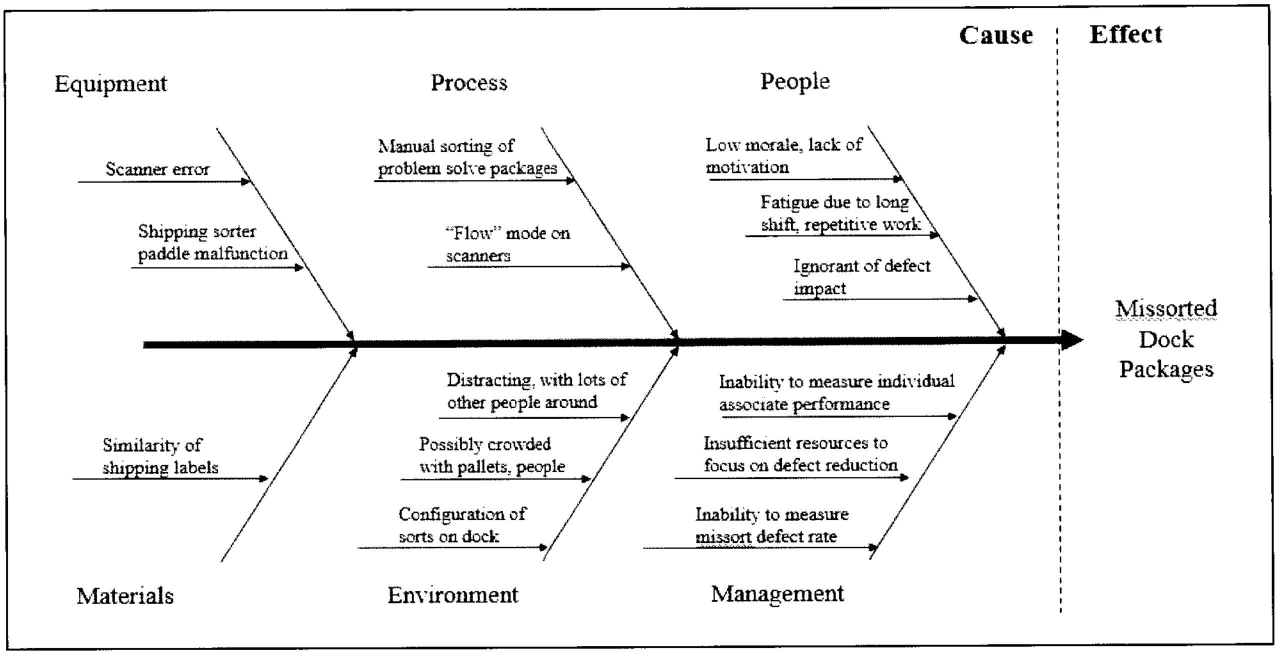


Figure 8. Dock Missort Cause and Effect Diagram

For dock packages, the primary contributors, based on data and observations, to missorts appear to be the people and the environment, with some contribution from management's inability to effectively measure associate performance.

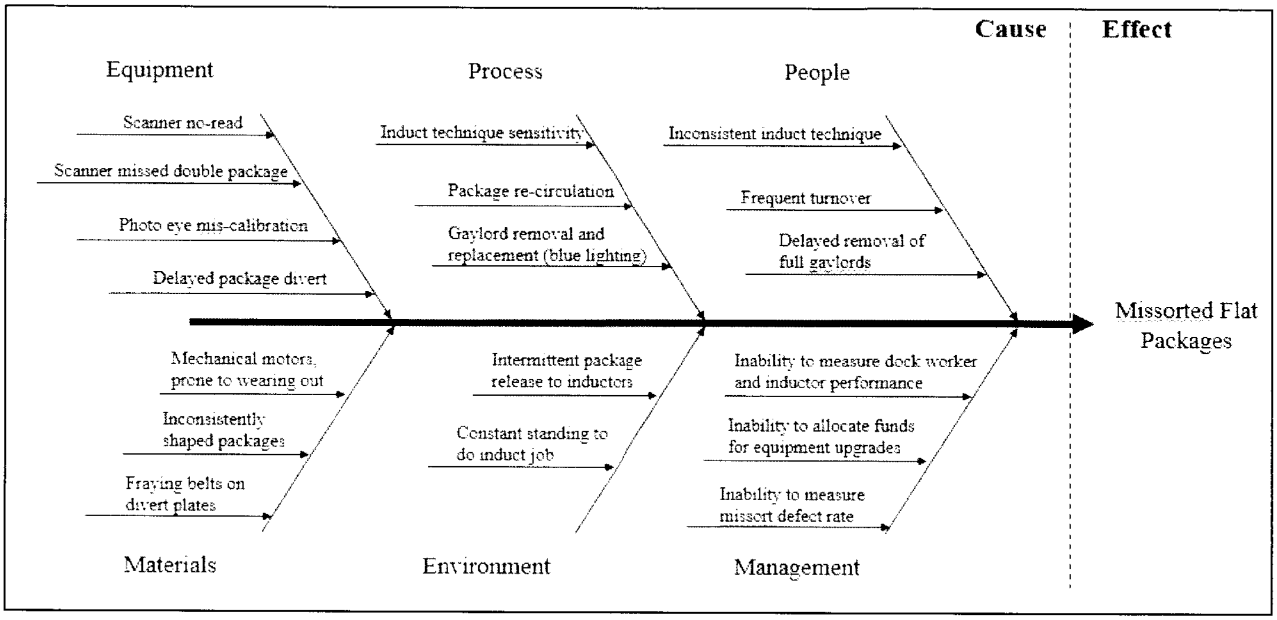


Figure 9. Flat Missort Cause and Effect Diagram

For flat packages, the primary contributors, based on data and observations, are the equipment and the materials used, as well as management's inability to measure the missort rate, as noted above.

4.5 Control Chart Creation

In order to get a more accurate and useful measure of the missort rate, the detailed missort data collected at sort centers was gathered from Amazon's Data Warehouse for analysis. By entering the shipment ID, detailed package information including the SLAM time, package type (including box size), tracking number, ship date and carrier, is returned. This data is a useful resource for understanding historical sortation process capability as well as monitoring sortation performance on a daily basis in order to correct anomalies. Statistical process control (SPC) methods were utilized to better understand errors in the sortation process for dock and flat packages and create an action plan for correcting unusual process variation.

Control charts were created to track the proportion of missorted packages compared to outbound sort center volume. These charts establish an understanding of historical and current process parameters, which has never been done for the sortation process. With the historical performance established, control charts can be used to monitor the process, identify when the process has exceeded the allowable threshold and act to bring the process back within the acceptable thresholds. Finally, once the sortation process has reached a steady state, in which only common cause variation occurs, the charts can be used to systematically decrease the sortation missort rate.

For the missort defect control charts, the sample size is the total sort center volume over the period of time in question, in this case a single day. The "defective" proportion is the number of missorted packages over the sort center volume for that time period. The scales on the control charts have been altered to protect Amazon's confidentiality and control charts were created separately for flat and dock packages. The mean missort rate and upper and lower control limits were calculated but are not provided in this thesis for confidentiality reasons.

The date used for each data point was determined by the SLAM time for each package because it is one of the last time stamps that exist for a package in the Amazon data system. It is also the most reliable measure of approximately when a package went through the sortation process. Ship time was not used because of the amount of time that can pass between sortation and shipping (up to and occasionally over twenty four hours), and because the ship time assumes the package was sorted correctly, which is not the case for these packages.

Control charts were created for ONT2, ONT6, and PHX6 to understand the historical process capability of the flat and dock sortation processes. ONT6 was used because of similar volume and sorts as ONT2, and PHX6 was added because of flat sorter equipment similarities. A p chart was utilized to capture the proportion of defective (missorted) packages compared to the sample size.

4.5.1 Dock Missort Control Charts

Figure 10 shows a control chart for dock package missorts from ONT2 for three months during the internship. The three process "stages", indicated by dashed vertical lines, are the three months that were studied. The p chart below indicates that the average proportion of missorted packages is increasing over time, and that there have been three instances of unacceptable uncontrolled variation, indicated by the red points on the plot that fall above the UCL. Figures 11 and 12 are control charts for ONT6 and PHX6. A comparison of the charts shows that dock missort rates have increased over time at all three FCs, perhaps due to new hires for the holiday season ("peak") or an increase in outbound volume.

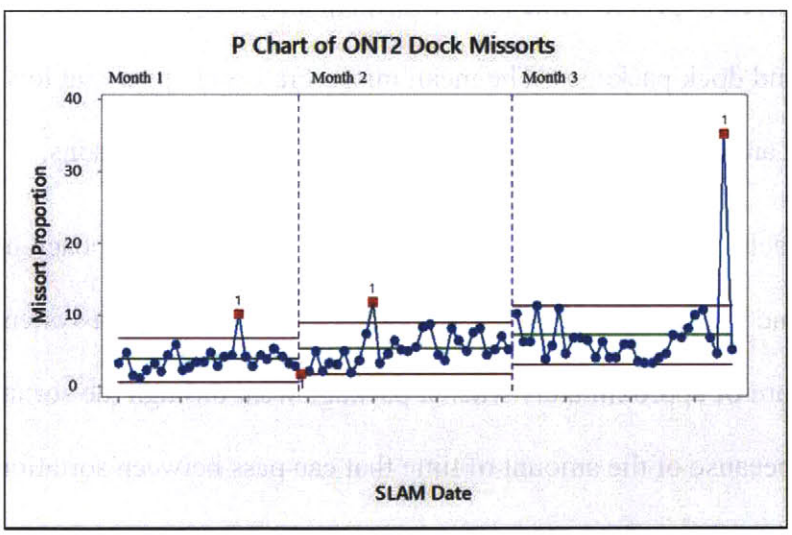


Figure 10. P Chart of ONT2 Dock Missorts

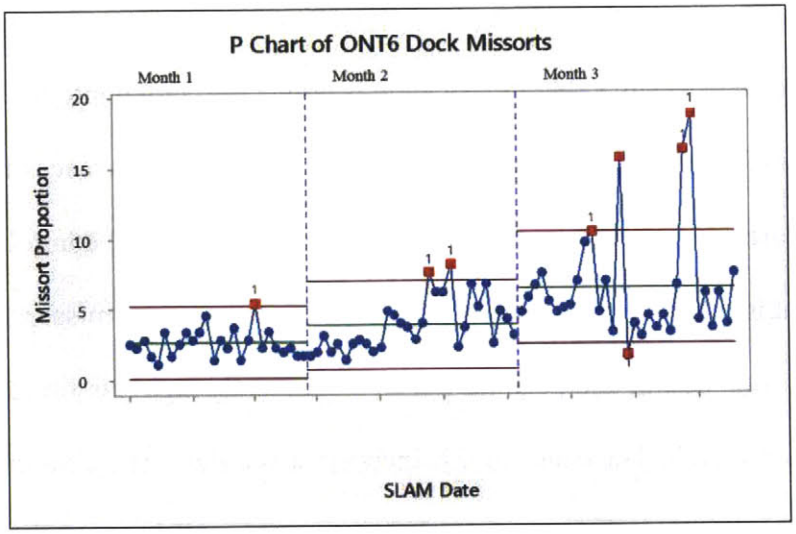


Figure 11. P Chart of ONT6 Dock Missorts

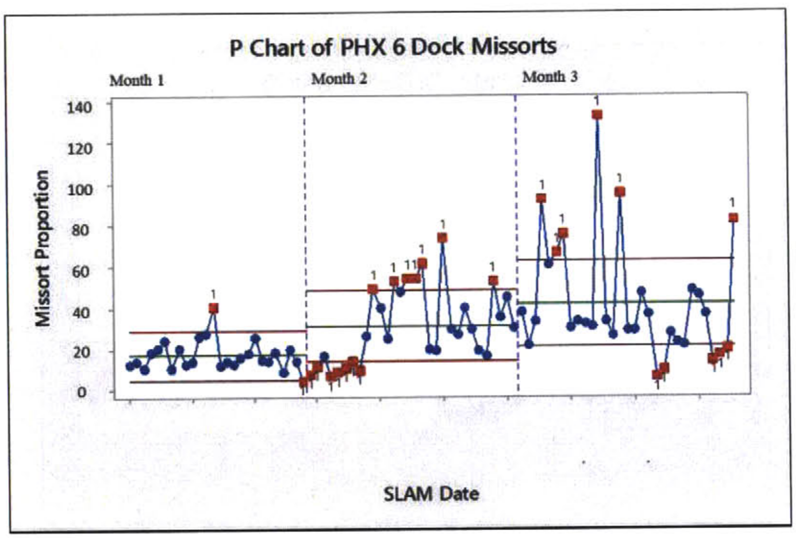


Figure 12. P Chart of PHX6 Dock Missorts

4.5.1 Flat Missort Control Charts

Figures 13, 14 and 15 are control charts of flat missorts at ONT2, ONT6 and PHX6. The ONT6 average flat missort rate is about half that of ONT2 and PHX6, likely due to equipment differences. The ONT2 and PHX6 flat sortation equipment is similar, though PHX6 scanner camera has been updated recently. At ONT2 and PHX6 the carrier plates do not adjust to re-position the package once it has been inducted onto the plate. The ONT6 flat sortation equipment has a different design, in which the carrier plates dynamically adjust to center the inducted package on the plate. This ensures that the package is properly diverted into the appropriate chute and does not miss the chute. This difference, as well as some differences in the induct stations, likely explains the lower flat missort rate at ONT6. The ONT2 control chart (Fig. 13) shows a process that is out of control, as well as an upward trend in the missort rate beginning in the middle of the second month and peaking with a dramatically high missort rate at the beginning of the third month. The cause of this increase was a flat sorter equipment malfunction that was detected on a Friday and was corrected over the course of the following week through equipment changes.

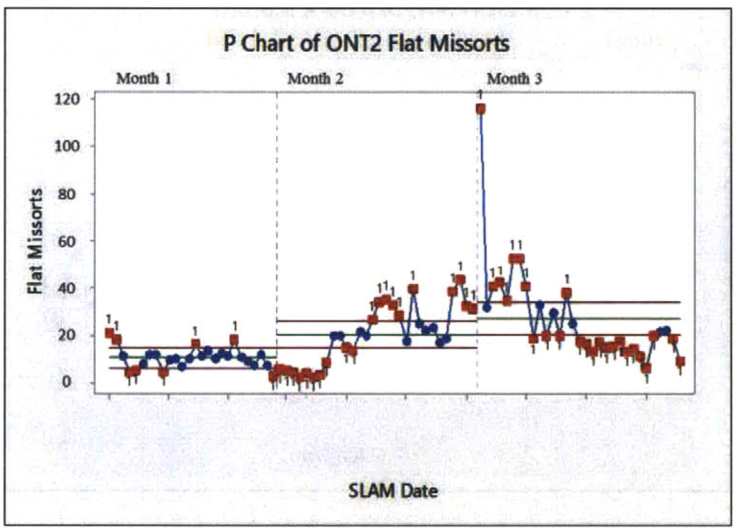


Figure 13. P Chart of ONT2 Flat Missorts

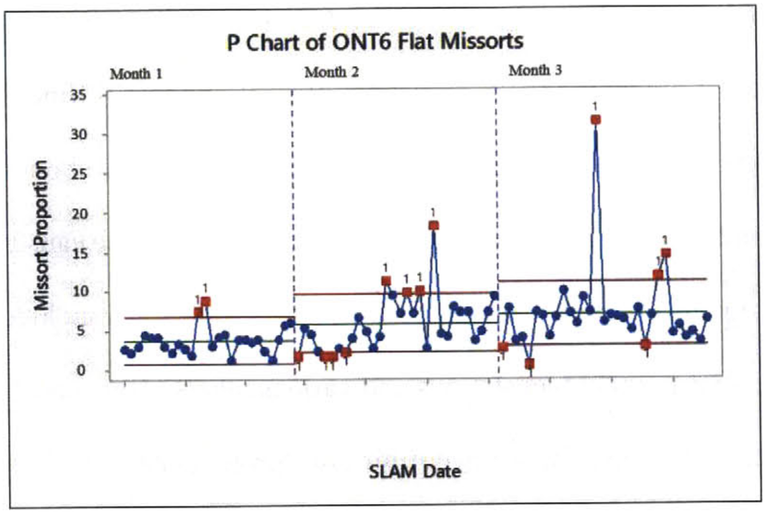


Figure 64. P Chart of ONT6 Flat Missorts

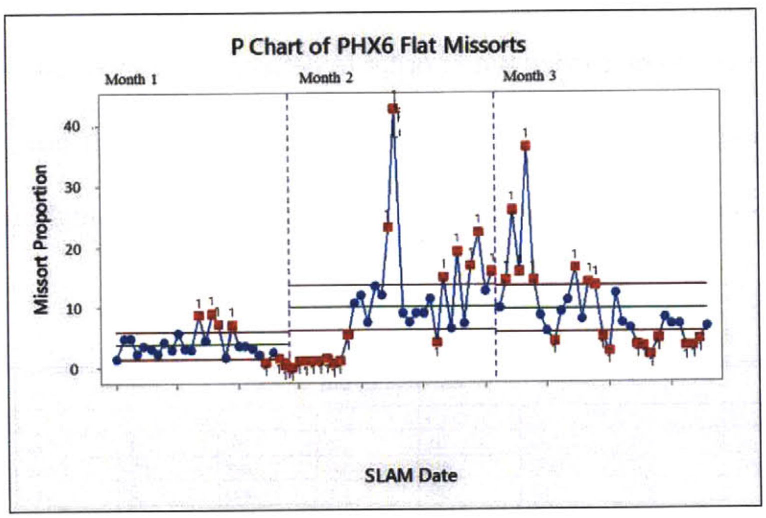


Figure 15. P Chart of PHX6 Flat Missorts

4.6 Solution Implementation

In order to provide greater visibility into ONT2 missorts, a report was created (Fig. 16 and 17) which utilizes the missort data collected at sort centers. Outbound sort center volume at ONT2 accounts for a sufficient amount of total ONT2 outbound volume that the sort center missort rate can serve as a reasonable proxy for the overall missort rate until a better data source is found or created. The report is generated on a daily basis and provides weekly missort rates for flat and dock packages over the past eight weeks, as well as daily missort rates for the past week. The report also includes a list of common root causes for missorts at ONT2, which will help to quickly correct any known issues that arise and increase the knowledge about new issues. This list can be added to and amended as necessary. For dock missorts, some causes to check for are gaylord labeling and loading. For flat missorts, some causes to look for include photo eye alignment, mechanical issues at induct stations and various others. This report will enable outbound managers to track performance over time and correct unusual variation, and this same report can be created for all NA FCs. At ONT2, managers can compare the daily missort rate to the average missort proportion from month 1 of the control charts above. Although a longer term investigation would need to be carried out in order to determine the most accurate "benchmark" rate at ONT2, the month 1 mean missort rate can be used as a reasonable proxy because it is pre-peak, and therefore should not include any unusual circumstances that might impact the missort rate.

Past Week Missorts

								% Change DoD
Dock Mis-sorts	24	162	31	19	54	18	16	-575%
Dock Mis-sort DPMO	*297*	*2,046*	*634*	*351*	*653*	*586*	*418*	-589%
Flat Mis-sorts	221	314	141	129	679	51	192	-42%
Flat Mis-sort DPMO	*2,620*	*3,261*	*2,237*	*2,044*	*6,795*	*1,383*	*3,143*	-24%
Total Mis-sorts	**245**	**476**	**172**	**148**	**733**	**69**	**208**	-94%

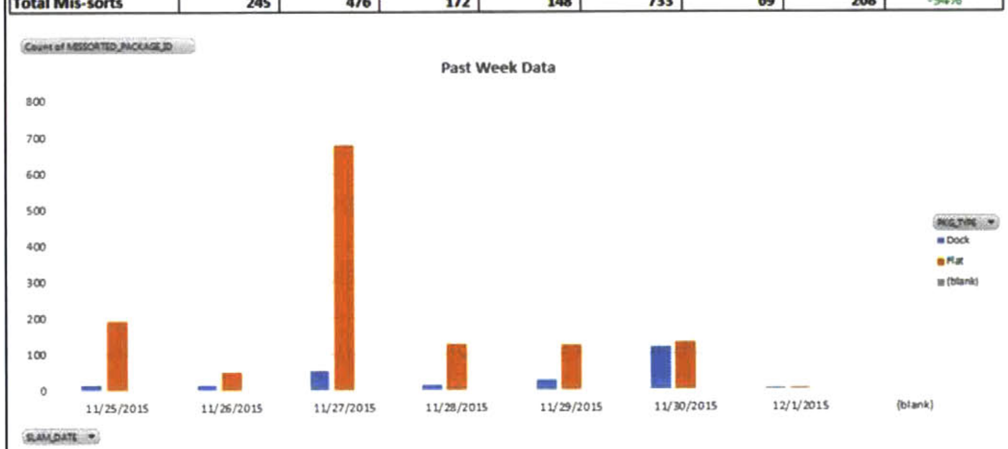
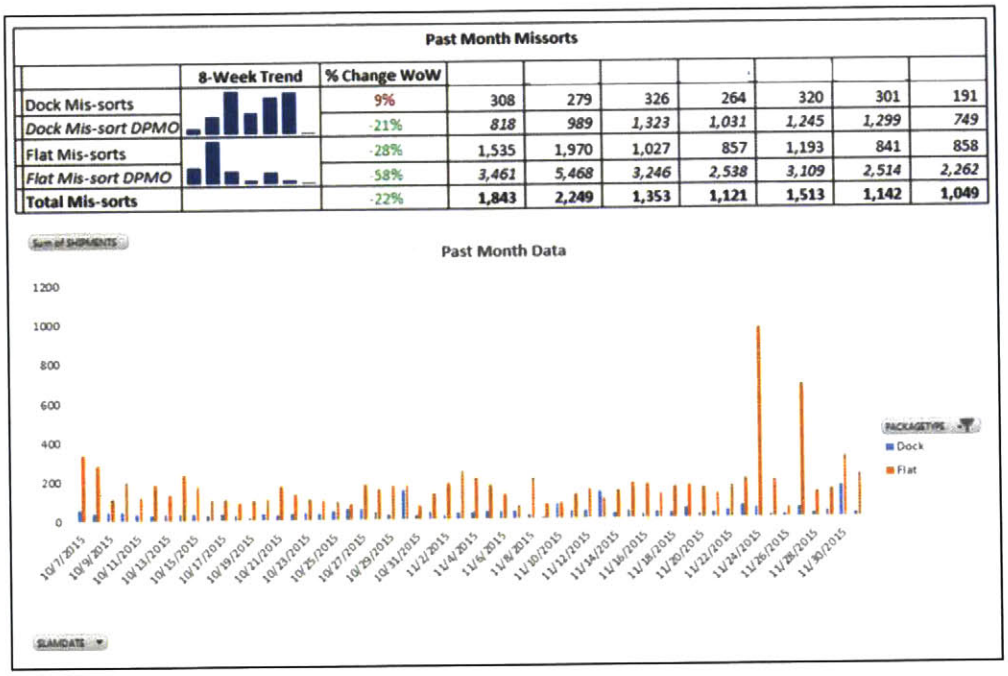


Figure 76. Missort Report – Day by Day View



Past Month Missorts									
	8-Week Trend	% Change WoW							
Dock Mis-sorts		9%	308	279	326	264	320	301	191
Dock Mis-sort DPMO		-21%	818	989	1,323	1,031	1,245	1,299	749
Flat Mis-sorts		-28%	1,535	1,970	1,027	857	1,193	841	858
Flat Mis-sort DPMO		-58%	3,461	5,468	3,246	2,538	3,109	2,514	2,262
Total Mis-sorts		-22%	1,843	2,249	1,353	1,121	1,513	1,142	1,049

Figure 87. Missort Report – Week by Week View

4.6.1 Dock Package Solution Implementation

On the outbound shipping dock, some lane configurations were changed in order to reduce the likelihood of human error leading to missorts. Specifically, the palletized sorts were spread across more pallet spurs so there were fewer spurs with multiple sorts. The missort report will enable area managers (AMs) to track their shift performance by drilling down into the detailed data provided in the report so that they can provide verbal feedback to associates.

4.6.2 Flat Package Solution Implementation

The solution implementation for the flat sorter included several different approaches including experimenting with the air knife, calibrating the photo eyes and replacing motors in the induct stations.

For one week, an experiment was performed in which the air knife was turned off. This experiment was performed to reduce the impact that the air knife has on carrier plate package placement, which is described in Section 4.4.2 above, and to test the hypothesis that the air knife causes some of the missorts that occur. During this time, the only available data source was from AMZL package returns, which did not indicate any change in the missort rate. Future work could better indicate the impact of the air knife on the missort rate.

4.7 Impact of Implemented Solutions

Dock Missorts: For dock missorts, the impact of these solutions will be seen in greater detail in coming months, as the implementation phase of this internship was occurring during the peak season, when only a few changes were realistic.

Flat Missorts: A use case for the missort report was experienced at ONT2 in fall 2016 (see Fig. 13), when the flat package missort rate spiked. Using the data displayed in this report, the missort rate was tracked over the following days to ensure that the issue was resolved. This is one example of how to utilize the report in the future.

4.8 Recommendations and Future Work

Given the limited changes that were feasible during the internship, there are several recommendations for ONT2. The first pertains to the missort report. With this report, outbound managers have a more accurate way to measure and monitor the historic and current missort rate, as compared to previous methods. Moving forward, the report should be owned and acted upon by the outbound SME and should also be provided to facilities and CSS (control system specialist) representatives, as well as the GM and senior operations team. When the missort rate exceeds the established control limits, the outbound SME should determine the root cause and correct the problem with the help of the other FC stakeholders.

This report should be rolled out across the NA FC network and bridging (i.e. an explanation for the occurrence) should be required for each site anytime the threshold DPMO is exceeded for either flat or dock missorts. The threshold DPMO for each package type should be determined after examining historical missort rates at each site, to ensure that the threshold is set appropriately. The decision tree and common causes should be customized by each site because some root causes, such as poor staging area labeling, will be common to FCs, while others will be unique due to equipment and process differences.

Future work should also include determining whether equipment process data, such as recirculation rate and scanner no read rate, is correlated with a high missort rate. If there is a relationship, this data should be tracked on a real-time basis internally in order to proactively prevent missorts by monitoring and controlling these process characteristics.

Missort data from the AMZL dashboard, Perfect Mile, could be utilized as an additional data source to reduce the impact of missorts on AMZL, and on customers who may not receive their packages. Currently, only wrong station missorts are visible in this portal. This should be changed to incorporate all missorts that arrive at AMZL stations, regardless of the carrier. These defects should be visible by the FCs, in addition to the current station-by-station view.

Lastly, a novel idea to track and then reduce missorts is to include an RFID tag on each package. If a missort defect occurred, it could be identified immediately and corrected before leaving the facility. While this technology may currently be too expensive or otherwise unrealistic, it could be used in a small pilot to help identify major contributors to missorts that are not identified in this thesis. A detailed action plan to correct defect contributors would still be needed in this situation.

Dock Missorts: With respect to the dock missorts, further action should be taken to reduce the number of pallet spurs that contain multiple sorts. Additionally, the login of the associate who was responsible for a missort should be provided in a separate report to enable tracking of these errors over time. Creating a measurement and feedback mechanism for associates will also encourage greater care when building a pallet or loading a truck.

Flat Missorts: At ONT2 specifically, new flat sorter scanners should be researched to see if this equipment change will reduce the number of mis-diverts resulting from poor scanner detection capabilities. A new scanner should identify more accurately when there are two packages on a carrier plate. When the anomaly is detected, the doubled up packages could be diverted at the jackpot chute and the missort could be prevented.

Retrofits should also be performed in order to make the conveyor belts on the induct stations more robust and better able to handle package variation. For example, observations indicated that oddly shaped packages were more likely to be disadvantageously placed on a carrier plate, increasing the likelihood of a missort. By replacing the ONT2 system with a self-adjusting system and improved camera similar to that at ONT6, the impact of this variation could be mitigated. Finally, installing flexible barriers between carrier plates would help to reduce the incidence of doubled up and overlapping packages.

5. SLAM Analysis

The SLAM kick out re-processing step is critical because it is one of the last opportunities for a defect to be corrected, but defects can be introduced in this step as well. Several defects can occur, leading to customer concessions and challenges for last mile carriers. This section will go into greater detail about the SLAM process and errors, and then discuss error analysis, implemented solutions and recommendations moving forward.

5.1 Detailed Process Summary

After an order is packed, the package is placed on a conveyor belt and moves past a scanner which scans the sp00 and weighs the package. Packages are staggered by the conveyance system at this step, so that only one package is on the scale at a time. After the scan / weigh step, the package moves directly underneath a SLAM machine, which applies the shipping label. Between scanning / weighing and shipping label application, an algorithm determines the appropriate shipping method (carrier and priority) based on the PDD, the package dimensions, the destination and the cost. After the shipping label is applied, a verification scan ensures that the barcode is readable and that the package is ready to go to sortation. If the package fails this scan, it will be kicked out so that it can be re-processed by an associate. Several kinds of defects lead to a kickout and the associate will problem solve according to the appearance of the package: the package will either have a valid-looking shipping label, no shipping label, or a label that has an error code and brief instructions on how to correct the issue (Fig. 20). The major types of kickouts are listed below.

- No label: If there is no label at all, the associate will scan the sp00 (or unpack the box in the absence of a sp00), and print a valid shipping label.
- KO label: A KO (or kickout) label will have instructions for the associate to follow (typically involving a scan of the box type barcode and the sp00). A cancelled order, system error, or a weight error can result in a KO label. A weight error occurs when the measured weight of the package does not match the expected weight based on the items assumed to be inside. This is also called an auto check weight error or ACW (Fig. 19).

Figure 98. Auto Check Weight Error Label

- Shipping label: Packages will kick out with a valid-looking shipping label if the auto SLAM machine was out of sync with the shipping labels it placed on packages, for example, when the machine put label A on package B. When this error is detected, the machine will "auto flush" several packages to ensure that the problem is corrected. Then the machine must be manually restarted by an associate.

Kickout reprocessing has the potential to introduce one of three different kinds of defects into the order process: wrong item switcheroo, in which the customer receives a different item than what they ordered; item missing, in which the customer receives fewer items than they ordered; or virtual physical mismatch (VPM), in which the last mile carrier experiences a discrepancy between the packages physically and virtually in their facility. The way that improper re-processing leads to these defects is described and illustrated below.

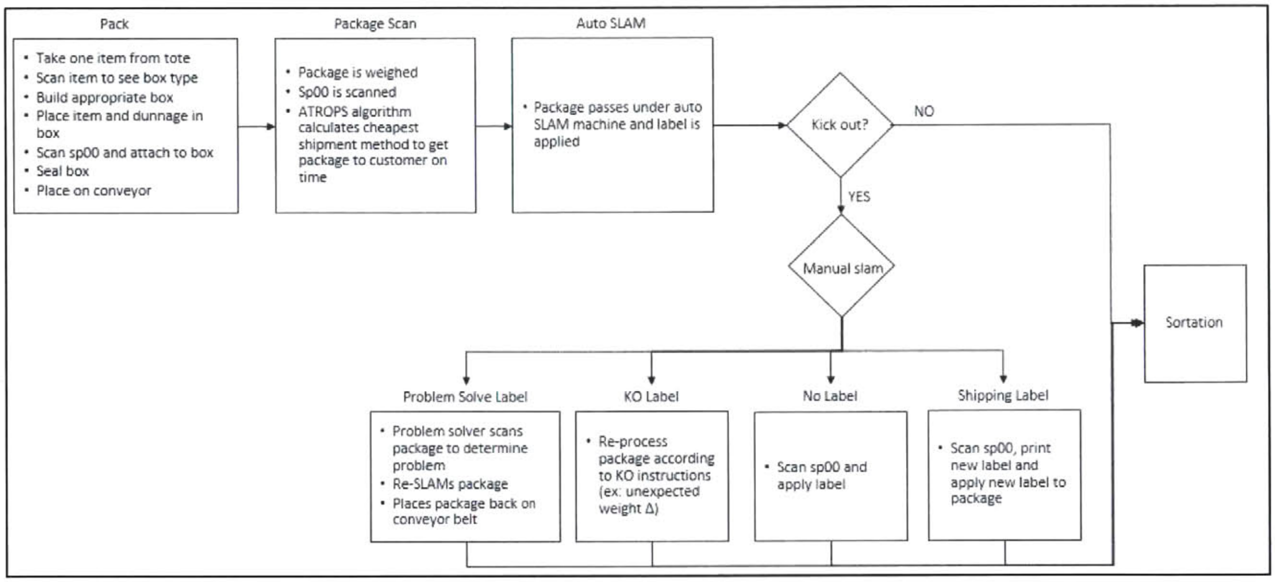


Figure 19. SLAM Process Map

- Wrong item switcheroo: This error occurs for packages that have a valid-looking shipping label, but which are kicked out after auto-SLAM. The associate uses visual inspection to verify that the barcode on the existing label is scannable by the sortation scanners. If the label passes visual inspection, they put the package back on the line and it goes to sortation. If the SLAM machine was out of sync, the package will have the incorrect label. If it was not re-labeled, this will result in a "wrong item switcheroo", and the customer will receive the wrong item(s).
- Virtual Physical Mismatch (VPM): This error occurs for packages that have a valid-looking shipping label, but which are kicked out after auto-SLAM. The associate scans the sp00 and prints a new shipping label, thus generating a new tracking number. If the recipient on the old label matches the recipient on the new label, the associate throws away the newly printed label and puts the package back on the line with the old label attached. However, the tracking number on the new shipping label is the ID that will be manifested and used for routing at the AMZL delivery station. When this package arrives

at the delivery station, the tracking number on the physical package will generate an error and the station will never physically receive the package with the expected tracking number. The impact of this defect is unique to AMZL and is the result of operator error. More specifically, when an AMZL station receives a physical package but not a virtual package the error is called "received not manifested" (RNM). The opposite, receipt of the virtual package but not the physical one, is call "manifested not received" (MNR). Collectively these errors are called virtual physical mismatch errors (VPM).

- Item missing: This error occurs for packages that have a KO label that results from an ACW error. A package that is kicked out with an ACW error is not properly checked to ensure that all of the order items are included in the package, but the associate manually "approves" the package, prints the shipping label, and sends it to sortation.

5.2 SLAM Performance Metrics

For defects that occur during kickout re-processing, there are few metrics that can be used to gauge performance, and none of them provide a reliable performance indicator. The most frequently used is the concessions report. If a package has not been reprocessed appropriately, it could be reported by a customer as a "wrong item switcheroo" or "item missing". Several difficulties with this metric were discussed in Section 4.3. Another fault with concessions appears when tracking SLAM errors: the concessions report includes the packer's login, but it does not include the login of the associate who reprocesses SLAM kickouts. This information could be used to track individual performance and provide corrective feedback.

A second metric is provided by an AMZL performance dashboard via an internal website (Fig. 20). The website tracks MNR (manifested not received) errors, some of which can be traced to kickout re-processing. While this website is accessible to the folks who work in the FC, it is not well-known or frequently used. Additionally, the performance data is not displayed in a way that is useful to the FC. For example, MNR DPMO rates are displayed for each delivery station (DLA1, DLA2, etc), but they are not broken down according to FC. Several FCs provide shipments to each delivery station and the errors are counted in aggregate, greatly reducing the usefulness of this feedback for the FCs.

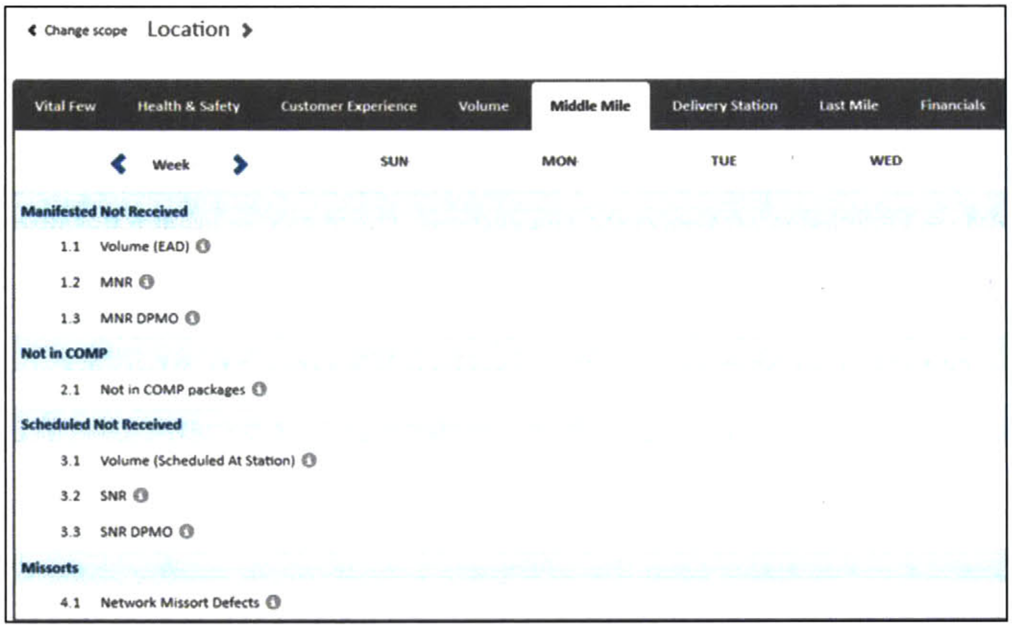


Figure 20. AMZL Performance Middle Mile Dashboard

Due to the current limitations on informative performance metrics, additional measures were developed to gauge performance. They will be discussed in more detail in Section 5.3.1.

5.3 Current Performance Analysis

The current process performance was determined using quantitative data from the concessions report and AMZL dashboard as well as qualitative feedback gathered from managers and associates at ONT2 and AMZL delivery stations.

5.3.1 Quantitative Assessment

Returned, undeliverable AMZL package data (see Section 4.4.1) was utilized to better quantify the impact of RNM errors that result when SLAM kickouts are incorrectly reprocessed. Packages with the RNM error have a discrepancy between the tracking number physically on the package and virtually in the FC system. The manually collected physical tracking numbers and virtual tracking numbers pulled from Amazon's internal database were compared. If the numbers were the same, the RNM error had not occurred. If they were different, the RNM error was assumed to have occurred. This assumption was validated by speaking to several folks within and outside the FC who had deep knowledge of Amazon's data systems. This data was used in the absence of other data sources. Based on this data, the RNM DPMO, indicated by the gray line "AMZL – SLAM Error DPMO", for ONT2 packages is approximately 60 (Fig. 21). While the magnitude of this defect rate appears to be low when compare to the defect rate for missorts and other defects within the FC, it is likely an underestimate of the true error rate, and it does not reflect the impact of the error on AMZL operations. At the time of the project, AMZL delivery stations needed all packages to be manifested (i.e. virtually departed) from the origin FC in order to run the routing software for their delivery associates. A mismatch in the packages virtually and physically received could mean the difference in adding or removing a route, and could impact staffing. Although a workaround at the delivery stations was developed toward the end of the project, it introduced an unnecessary, valueless step in the AMZL routing and sortation process. The impact of FC defects on AMZL operations is of particular importance as AMZL increases the number of packages it delivers and expands into additional US cities.

Concessions were also used to track item missing and wrong item switcheroo errors (Fig. 22). With each of these reason codes, other errors in the FC could have led to the customer concession, introducing a confounding factor into this data. However, it is still useful to see general trends because other folks in the FC were attempting to eliminate the other root causes that lead to these errors.

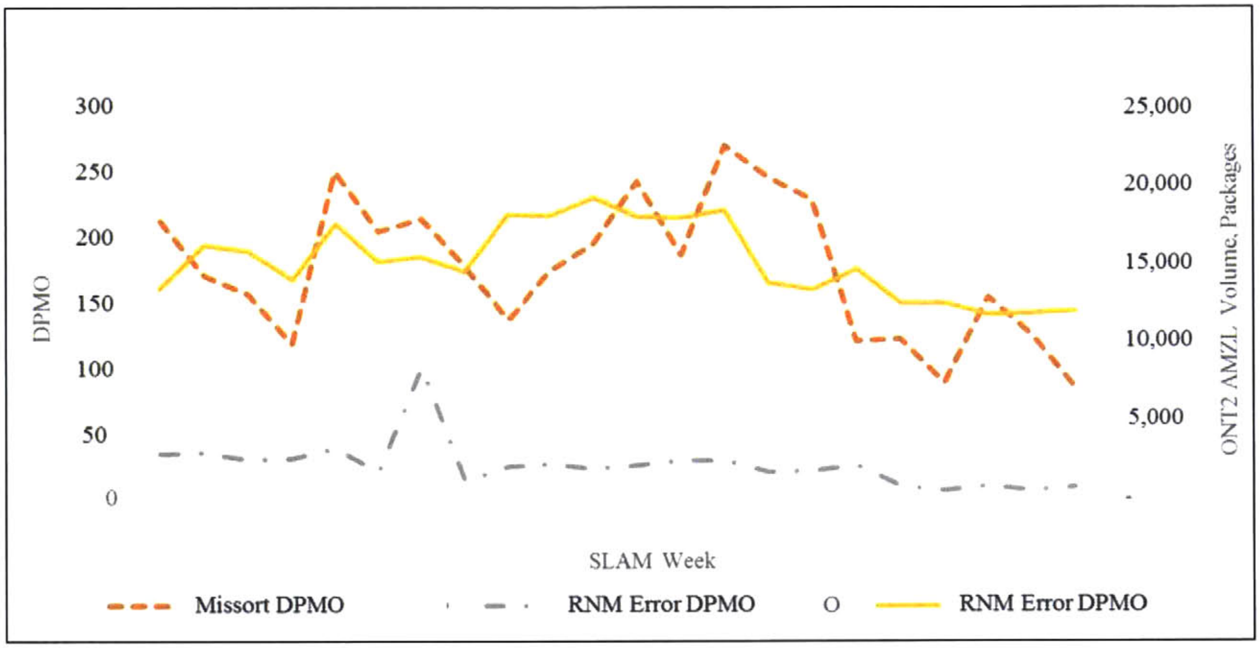


Figure 101. AMZL Package Returns

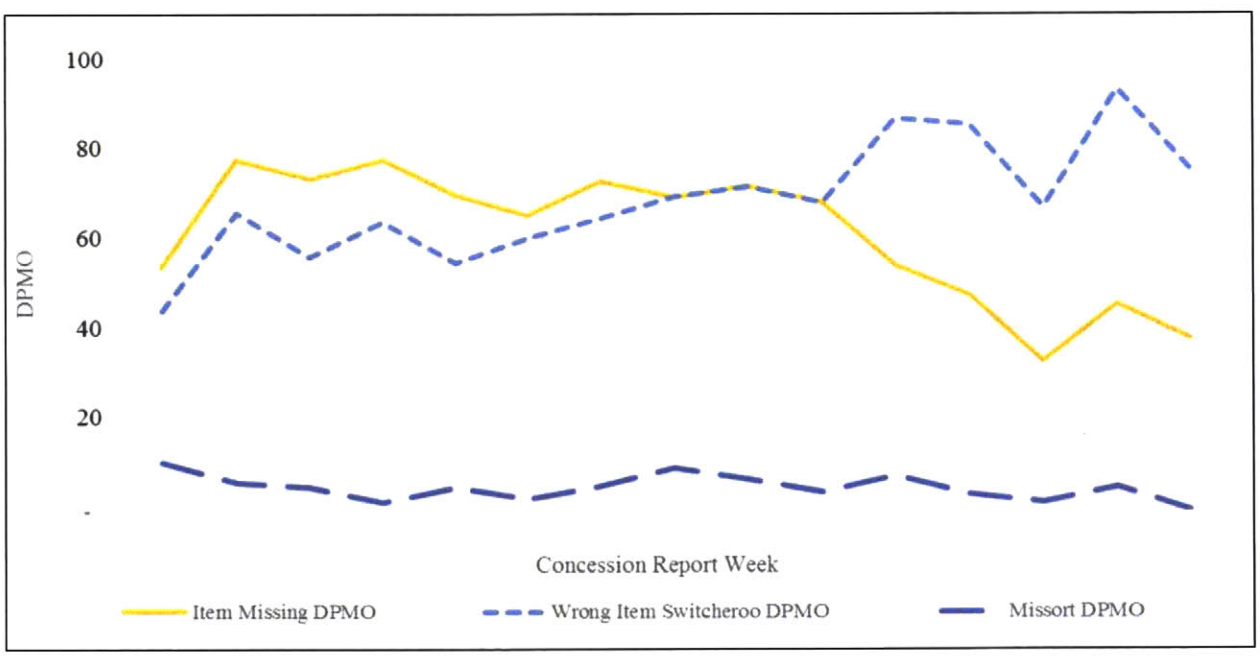


Figure 112. ONT2 Concessions, Summer and Fall 2016

5.3.2 Qualitative Assessment

Conversations with managers and associates at ONT2 were valuable in better understanding SLAM defects. At ONT2, conversations with eleven associates indicated lack of understanding of the correct kickout re-processing procedure. Five of the associates said that they were never taught to remove a valid-looking shipping label on a kickout. Further observations showed that those who acknowledged the proper technique did not follow it. The reason for this behavior could be lack of understanding of the consequences of not following the process, tendency to cut corners due to overwhelming workload, or lack of desire to do the job properly.

Managers at ONT2 stated that there was very little formal training for the kickout re-processors when the FC first opened in 2012 and several associates who started then were still doing the job in 2015. They also mentioned that because SLAM kickout re-processing is an "indirect" role (i.e. one without a required rate), it is hard to monitor and manage the performance of the associates doing this job.

5.4 Cause and Effect Analysis

The root causes for SLAM defects belong to six primary categories, equipment, process, people, materials, environment and management. The primary causes fall into the people and process categories, based on data, observations and conversations. The process is suboptimal because there are so many kickouts (due to packer errors), and they must be re-processed manually by a human, rather than being corrected using technology. Additionally, because so many different types of errors can occur, the associate doing the re-processing must understand how to correct many kinds of problems. The process does not include any kind of verification (technological or otherwise) step that checks the work of the associate, unlike other parts of the outbound process in the FC.

The people are also a major cause of defects. Only high performing associates, those who were able to work in a direct, rate-monitored role such as packing boxes, are assigned to re-process kickouts. This role is an "indirect" role, meaning that there is no rate, or quota, which the re-processing associate must meet, in contrast to picking and packing. In spite of the high performance level, these associates still appear to lack motivation, based on conversations and observations over the course of six months. For example, even after coaching on the proper re-processing technique, some associates would still return to the old, easier approach. Additionally, the associates are required to focus on a task that may require them to leave the station at which they re-process packages or wait for help to arrive if they have pulled an andon, inhibiting their ability to focus on getting the job done. Finally, many of the associates did not have sufficient training; they had a brief initial training but no refresher course when the computer system or process changed, leaving them ill-equipped to do their job well.

These and other causes coincide with the inability of the managers to measure SLAM defects, and work to reduce them (Fig. 23).

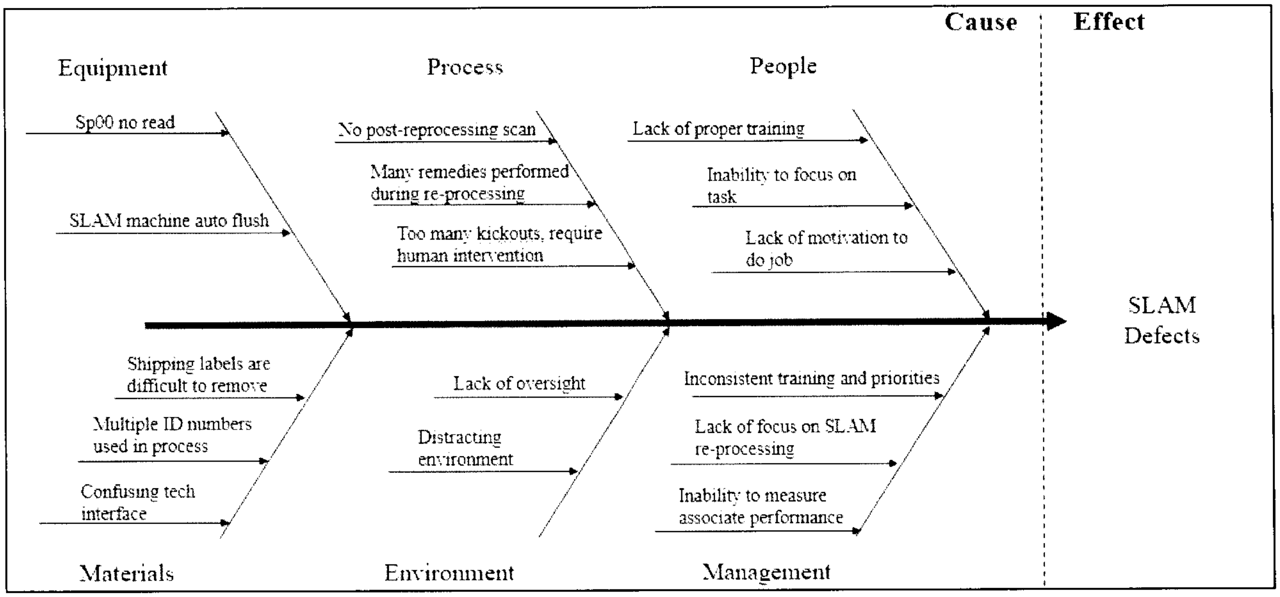


Figure 123. SLAM Defect Fishbone Diagram

5.5 Solution Implementation

Due to the lack of clear metrics, additional statistical analysis could not be performed on SLAM kickout errors. Instead, an attempt was made to find additional metrics and implement solutions.

In order to reduce re-processing errors, PMV (process) diagrams (Appendix II) were created and placed at the kickout stations to demonstrate the correct process procedure. A high performing associate spent four weeks rotating between shifts in order to re-train and audit the kickout re-processors. During this time the associate kept notes with observations and determined that 20% of the associates were not aware of proper re-processing procedures.

Unfortunately, the ramp up for the "peak" (holiday) season prevented thorough implementation of any corrective measures and also distracted the FC from the goal of reducing SLAM defects. Starting in October 2015, many new temporary associates were trained in the FC, and the operational focus shifted away from defect reduction toward efficiency and increased throughput to meet holiday demand. Several additional solutions were identified and are discussed further in Section 5.7.

5.6 Impact of Implemented Solutions

Measuring a reduction of SLAM defects was challenging due to the lack of metrics, as discussed earlier. However, several measures indicate that there were improvements, though these should be taken with caution as there are other factors that obscure the results.

Using AMZL package returns, the RNM DPMO as it can be attributed to SLAM operators appears to have decreased (Fig 21, bottom line). Using the concessions report, wrong item switcheroo conceded unit DPMO is trending upwards (perhaps due to pick errors), however item missing DPMO has decreased about 50% since the peak (Fig. 22).

5.7 Recommendations and Future Work

SLAM kickout reprocessing is a critical checkpoint to prevent wrong item switcheroo, item missing and VPM defects. Two primary aspects must be changed in order to better measure and reduce these defects: the metrics and the process. To better measure the defects, each SLAM kickout station should be given a unique identifying number in order to track the associate working at that station, and the SLAM kickout operator login should be added to concession reports to connect associates with defects that result in concessions. SLAM kickout operator performance should be tracked on a weekly basis to coach or remove those who are consistently responsible for concessions. To better measure MNR errors, the existing data in the AMZL performance portal should be provided to FCs, and should be displayed by FC in addition to the current delivery station view. RNM data should be added to the portal to enable visibility into this error.

Process changes should also be explored. SLAM operators should have an additional check performed on their work. For example, a problem solver could be required to provide a second review of auto check weight (ACW) kickouts before the shipping label can be printed, in order to reduce item missing concessions. Technology solutions can help to ensure that kick outs are properly reprocessed, for example by tracking the number of kickouts and whether each kickout was scanned for reprocessing. Currently, the scanners on the shipping and flat sorters check only for a valid encrypted shipment ID, however these scanners could also scan the sp00 and tracking number to ensure that the order details attached to the sp00 and those attached to the encrypted shipment ID match, and that the tracking number is valid (critical for AMZL). Defective packages could be kicked out at the ship dock problem solve station to be properly reprocessed. This change would help reduce virtual-physical mismatch and wrong item switcheroo defects.

To reduce the number of MNR/RNM packages and missorts that arrive at AMZL delivery stations, an AMZL team could staff the outbound shipping dock for their sorts only, and ensure that each package is individually scanned and manifested. ONT2 could be used as a test facility for this initiative as AMZL liaisons were already in place at the FC. Additionally, a few shift managers at each station could be granted the appropriate permissions and training so that they could manifest RNM packages without having to wait on action from the fulfillment center, ensuring that these packages would be sent out for delivery the day they arrive at the station.

Future work should also include examining the job of SLAM kickout operators to determine if the complexity of the role is so great that it is contributing to these errors. The impact and root cause of MNR/RNM shipments that result from outbound ship dock errors should be studied, as this was not an area of investigation for this project. Using detailed MNR/RNM data from the Perfect Mile portal, an analysis could be performed to determine if there is a correlation between MNR/RNM errors and SLAM time, package type, shift, day of the week, etc. MNR data was added to the portal only a few weeks before the end of this thesis project, and RNM data has not yet been added to the portal, making this analysis currently unfeasible.

6. Conclusions

In conclusion, there are many defects that lead to customer concessions; sortation and SLAM errors are major contributors and were the primary focus of this project.

6.1 Summary

Missort defects for both flat and dock packages were analyzed using observations and data collected at sort centers across the country. A cause and effect diagram indicated that equipment was primarily at fault for flat missorts and human error was to blame for dock missorts. Control charts were created to establish an understanding of historical and current process performance. These indicated that ONT2 had increasing levels of both dock and flat missorts, likely due to the approach of the holiday season. A significant one-time increase in flat missorts was corrected by installing new equipment. A missort report was created using the sort center data to enable managers at ONT2 to monitor missort rates (in absolute numbers and DPMO) on a daily basis and implement continuous improvement efforts.

SLAM defects that result in wrong item switcheroos, item missing orders and VPM errors are rooted in process and people issues. Re-training and auditing activities were implemented and additional measures were recommended for implementation after the peak season. In addition to process changes, better metrics need to be available for managers to better track and measure associate and process performance.

6.2 Future Research Opportunities

This project conducted an initial investigation of outbound process errors that result in customer-facing defects and challenges for last mile carriers. It also indicated room for additional research and implementation. Metrics and process knowledge can be further enhanced, as outlined below.

For both missorts and SLAM defects, metrics are lagging and lacking in needed clarity, in spite of the improvements made in the course of this project. Additional investigation should determine sources of better performance data, and this data should be used in a daily or weekly process review. Better metrics will enable more focused defect reduction efforts.

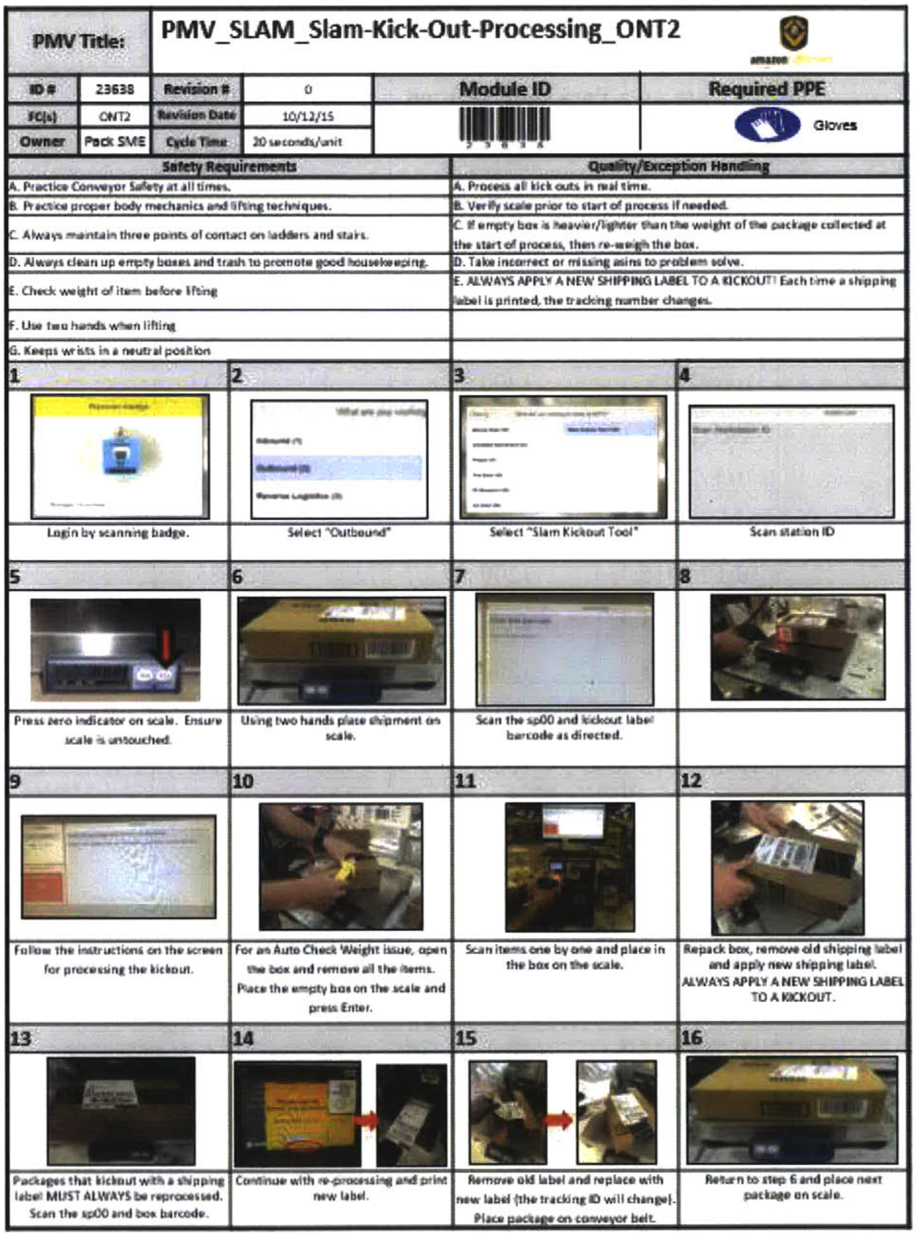
Additional research should establish a greater understanding of process performance for areas other than sortation, and should incorporate equipment data as leading indicators. This data should also be used to improve uptime and reduce bottlenecks, such as the one caused by the SLAM machines.

Appendices

Appendix I. ICQA Missort Audit Results – ONT2, October 2015

Date	Packages Audited	Missorts	DPMO
10/1/2015	900	0	0
10/2/2015	400	0	0
10/3/2015	800	0	0
10/4/2015	900	2	222
10/5/2015	1200	0	0
10/6/2015	1200	4	333
10/7/2015	1200	2	167
10/8/2015	1100	0	0
10/9/2015	1200	0	0
10/10/2015	1200	1	83
10/11/2015	900	1	111
10/12/2015	1200	3	250
10/13/2015	1200	2	167
10/14/2015	1000	6	600
10/15/2015	627	0	0
10/16/2015	900	0	0
10/17/2015	600	0	0
10/18/2015	900	0	0
10/19/2015	1200	2	167
10/20/2015	500	0	0
10/21/2015	600	1	167
10/22/2015	1300	0	0
10/23/2015	900	5	556
10/24/2015	600	9	1500
10/25/2015	900	0	0
10/26/2015	1200	0	0
10/27/2015	1200	0	0
10/28/2015	1198	2	169
10/29/2015	1200	2	167
10/30/2015	1500	14	933
10/31/2015	1300	11	846

Appendix II. SLAM Kickout Reprocessing PMV Diagram



PMV Title:	PMV_SLAM_Slam-Kick-Out-Processing_ONT2				
ID #	23638	Revision #	0	Module ID	Required PPE
FC(s)	ONT2	Revision Date	10/12/15		Gloves
Owner	Pack SME	Cycle Time	20 seconds/unit		

Safety Requirements	Quality/Exception Handling
A. Practice Conveyor Safety at all times.	A. Process all kick outs in real time.
B. Practice proper body mechanics and lifting techniques.	B. Verify scale prior to start of process if needed.
C. Always maintain three points of contact on ladders and stairs.	C. If empty box is heavier/lighter than the weight of the package collected at the start of process, then re-weigh the box.
D. Always clean up empty boxes and trash to promote good housekeeping.	D. Take incorrect or missing asins to problem solve.
E. Check weight of item before lifting	E. ALWAYS APPLY A NEW SHIPPING LABEL TO A KICKOUT! Each time a shipping label is printed, the tracking number changes.
F. Use two hands when lifting	
G. Keeps wrists in a neutral position	

1	2	3	4
Login by scanning badge.	Select "Outbound"	Select "Slam Kickout Tool"	Scan station ID
5	**6**	**7**	**8**
Press zero indicator on scale. Ensure scale is untouched.	Using two hands place shipment on scale.	Scan the sp00 and kickout label barcode as directed.	
9	**10**	**11**	**12**
Follow the instructions on the screen for processing the kickout.	For an Auto Check Weight issue, open the box and remove all the items. Place the empty box on the scale and press Enter.	Scan items one by one and place in the box on the scale.	Repack box, remove old shipping label and apply new shipping label. ALWAYS APPLY A NEW SHIPPING LABEL TO A KICKOUT.
13	**14**	**15**	**16**
Packages that kickout with a shipping label MUST ALWAYS be reprocessed. Scan the sp00 and box barcode.	Continue with re-processing and print new label.	Remove old label and replace with new label (the tracking ID will change). Place package on conveyor belt.	Return to step 6 and place next package on scale.