Technology in Logistics:

Logistics Facility Sorting, Tracking, and Packing Systems

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Applicable and Reference Documents

This report has been compiled in accordance with the Occupational Health and Safety Administration guidance, OSHA 2254-09R 2015 and Department of Defense Design Criteria Standard: Human Engineering MIL-STD-1472G.

These documents were chosen because of their direct applicability and legal implications over the work being performed at a facility such as this. Adhering to such documents is essential for THE COMPANY to avoid legal inquiry or action, as well as protect their valuable assets, and the workers themselves.

Terms and Definitions, Abbreviated Terms and Symbols

The Following terms and abbreviations will be used throughout this report:

Terms

Air Can: Specialized fuselage-shaped container designed to hold 300-3000 packages. Width and height vary, but all are 12’ long for consistent loading.

Belt: Belts are conveyor belts, usually assigned color designations for their respective routes through an air facility.

Employee ID: Seven digit unique code assigned to each employee used for log in to equipment.

Forever Bag: Zippered 3’x3’ envelope for combining smalls.

New hires: THE COMPANY employee with less than 45 days of work experience.

Package Handler: The front-line worker who directly manipulates and scans parcels moving through THE FACILITY sorting and tracking system.

THE COMPANY: The company's actual name has been redacted for this published report by request from the leadership.

THE FACILITY: The facility's actual name and location have been redacted for this published report by request from the leadership.

Smalls: Packages 8lbs or less, measuring less than 7" thick, 16" wide and 16" long.

Small Sort: Area of THE FACILITY where smalls (packages less than 16x12x4) are placed into forever bags.

Abbreviations

BCS: Belt Control Switch

UI: User Interface

EIN: Employee identification number

PPH: Packages per hour

MS: MIL-STD 1427G

SSSS: Small Sort Scanner System

Scope

Objective

This report evaluates the design and use of technology employed by THE COMPANY at The Air Facility in Orlando, Florida to track and route packages within a facility. It will address the layout and functioning of the primary nodes: functional areas and their associated displays and controls. Each of these components is examined within the framework of a parcel flowing through THE FACILITY and the package handers using the technology to ensure accuracy and accountability. I use a descriptive functional flow analysis for its comprehensibility to THE COMPANY leadership and ability to pinpoint issues and highlight solutions.

Introduction

THE COMPANY moves millions of packages around the world to facilitate online commerce, personal logistics, healthcare, defense, and other businesses. In recent years, as online purchasing has become increasingly popular for both consumers and businesses, operations at THE COMPANY have accelerated with demand. The performance of the organization is dependent on having these people move as many packages to the right place in the minimum amount of time.

A worker's ability to sort and move packages is aided by the technology on which they depend both mentally and physically. Since 2013, THE COMPANY has been spending $1 billion per year on new technology. If the technology does not work well, THE COMPANY cannot track and route the packages to their appropriate destination. Worker confusion over how to use the equipment can take up valuable time which adds up quickly when spread across an entire workforce. When a worker is required to handle 1000 packages in an hour but must spend 10 minutes fixing a technology problem or being retrained on a task, the overall system begins to

break down, and bottlenecks are created. These issues are compounded over hundreds of facilities, where THE COMPANY's 434,000 workers put in nearly a billion hours a year. Poorly designed equipment can cost the corporation millions of dollars over a year.

THE COMPANY Background

In the past, postmen read addresses on envelopes and manually placed them into bins sorted by neighborhood for delivery. Now, when a package arrives at drop off location, such as the THE COMPANY store, the address and a special barcode are printed on the label after the postage is paid. In the 1990s, THE COMPANY began using a machine-readable graphic called a MaxiCode on each label. Encoded in that graphic are information about the package's sender, destination, weight, size, kind of contents, and delivery instructions.

Figure 1. Sample label with MaxiCode highlighted.

THE COMPANY scanners and their associated devices make use of this data to track and route the packages. Either as part of a larger shipment or individually, a package or group needs to be scanned each time its location changes. It is scanned into the drop off location, scanned again when it is sorted, scanned when it is packaged, and scanned when it is delivered. Each scan updates the package's location to a central database and timestamps it. Scanners can be linked to individual employees. This provides the company information about how quickly a package handler is working in packages per hour (PPH), a key metric. It also aids it the tracking of lost packages. This practice also prevents the handlers from neglecting their duties because a poorly packed shipment or a parcel missorted to the wrong destination can be traced back to a single worker.

According to warehouse managers, a missorted package can quadruple the cost of shipment to THE COMPANY, turning profit into loss. A package sent to the wrong address takes up space that another package could fill and requires additional transport, often at an expedited pace via aircraft, which is the most expensive way to ship packages. The company may also have to pay restitution to a sender who purchased a guarantee. A lost or damaged package can be even more costly. Correctly routing the packages in the shipping facilities, even with the help from scanners, is still a cognitive task requiring vigilance, and a thorough understanding of the equipment.

The barcode scanners used at THE COMPANY come in many forms, and the information contained in the codes can be displayed through a variety of mediums. Some scanners are attached to printers that generate physical labels after reading a code; others convey information about a package with blinking lights on a console. To improve mobility and decrease time lost by workers moving a package to a scanner and then moving it back to be packed away,

THE COMPANY has been an early adopter of wearable technologies. The most flexible scanner/display setthe Company are those that use a digital screen and allow a worker to view, manipulate, and transmit data about the parcel. No matter the variety, workers must be ready to use their technology to relay information about damaged, misrouted, or canceled shipments.

Analysis Elements

In the Air Facility, two kinds of scanner/interface designs are used. The **Small Sort Scanner Station (SSSS)** is a custom-made fixed workstation that communicates with blinking lights and receives inputs from **Genovation 5887 keypads**. The **Motorola WT 4080** is a wearable computer with a small screen and keyboard used throughout the rest of THE FACILITY. This report will also briefly discuss the **Belt Control Switch (BCS).**

Scenario

The 100 **package handlers** at the Air Shipping facility use the **SSSS** and **WT4090** to receive, sort, repack and send up to 100,000 packages towards their final destinations per night. **Supervisors** oversee, check, and confirm their work using the same devices. They work in the evening and through the night with shifts varying from 3 to 12 hours. Some of the package handlers have been working at THE COMPANY for years and are very familiar with their equipment. Other workers are **new hires**, some of which have come on as **seasonal employees** in the run up to a holiday gift-giving season. Receiving, processing, and routing the packages is the overall function and requires all sub-tasks to be performed accurately and in a timely manner to run smoothly.

General System Description

Trucks bring packages to the docks and are unloaded. At each subsequent stage, another function of THE FACILITY is to ensure that no unauthorized hazardous materials (haz mats) are loaded onto aircraft. As the packages are sorted by size, each package handler performs a six-sided check for markings and indications that a package contains haz mats. Haz mat packages must be further screened for proper documentation and handled according to strict regulations. **Smalls** are directed to small sort for repackaging. There they are processed using the **SSSS** and packed into **forever bags** with other smalls bound for the same destination. **Small sort** is vital to a smoothly operating facility because it enables faster scanning than is possible using handheld devices preventing bottlenecks. Forever bags leaving small sort join the larger packages on the belts.

On a belt, such as **Red Belt,** other package handlers use the **WT4090** to scan the forever bags and larger incoming packages, loading them into air cans. Supervisors use their WT4090s to track employee performance, ensure packing accuracy, and create data on the packed cans. Sometimes, the belt must be stopped with the **BCS** to break a package jam or prevent package damage. Supervisors try to avoid that because it slows the entire facility. When cans are full, package handlers transport the cans away from the belts on specialized flooring embedded with ball bearings. They arrive at a hydraulic lift where a supervisor will check the documentation one more time. Finally, the cans are lowered and rolled into trucks which are driven to the airport to be loaded onto planes. After the shift concludes, management will review the night's metrics and report them. The key metric for THE FACILITY is packages handled per worker hour (**PPH**). By minimizing the time employees are on the clock, costs stay low. To meet this end, workers are sometimes traded between areas where they are most needed, but this is done on an ad hoc

basis and not part of the overall plan. Therefore, it is important that the workers spend their time in their areas moving and scanning packages rather than troubleshooting or reconfiguring their equipment.

Users

Package handlers and supervisors are the primary users of the facility. Package handlers can be further broken into unique groups by the area in which they work. This useful distinction in this divides users by the kind of scanner interface they use. Small sort package handlers use the SSSS and belt package handlers use the WT4090. All supervisors are equipped with WT4090s so they can move around and address issues without being tied to a physical location. To provide data for my analysis, I used interviews and direct observation of a convenience sample of 30 employees to collect user data. This revealed a wide range of experience. Five of the workers were trainees, lacking both declarative and procedural knowledge who could not even begin their tasks (16%). Twenty employees (66%) knew the procedures needed to perform their tasks, but could not use the full functionality of their devices. There were also four expert users (13%) who routinely trained the new hires and seasonal employees. There was one employee who could perform almost all functions but could not describe what he was doing as he went through the process.

For the descriptive task analysis, understanding the differences between worker responsibilities and skill levels is important. I created personas based on my interviews and observations to help keep track. Kim, a seasoned employee who has been with THE COMPANY for three years, is assigned to Red Belt where she will be packing air cans. Brian, a newly hired supervisor, will be overseeing the belt and processing air cans for departure. Aaron and Elvis,

seasonal employees with no warehouse experience and little training on the equipment, will be working in small sort.

Task Analysis

At the highest level, THE FACILITY's's task is to safely and rapidly process packages for shipment to the correct destinations. While packages can branch into different areas for diverse destinations, the task is actually linear in nature. It is particularly prone to disruptions from within, making it a mostly closed system. Such a system is best analyzed with a descriptive approach to functional flow analysis. Using a descriptive approach to understand how the workers actually behave rather than a strictly normative approach addresses the realities of the facility in context. My findings, illustrated by vignettes, will be easily understood by the THE COMPANY leadership who are positioned to make the suggested changes. The flow charts and graphics can highlight the key improvements that can be made to certain aspects of the system. The personas I use to discuss the tasks are useful to describe the flow of each task, potential failure points, and the charts provide an overview.

Small Sort

Aaron and Elvis, the small sort package handlers go to the SSSS (Figure 2). Elvis will be the sorter, and Aaron will be the bagger. Aaron logs in using the Genovation 5887 Keypad. (Figure 3). There is no indication whether it is on or off. In the absence of a LOGIN button, Aaron needs help from Elvis to remember the sequence. First, he selects, LOGOUT, then ENTER. The SWITCH key turns on login mode, and Aaron begins to enter his employee identification number (**EIN)**. Unfamiliar with the layout of the keypad, it takes him several tries. Elvis at the Sorter Station (Figure 4) tries to log in using his EIN, but he does not know which

keypad to use. Neither works, and he has to call a supervisor over. The supervisor tells him he must go into the office to pull up Aaron's file. He prints it on a piece of paper and gives it to Aaron. The process has taken 10 minutes.

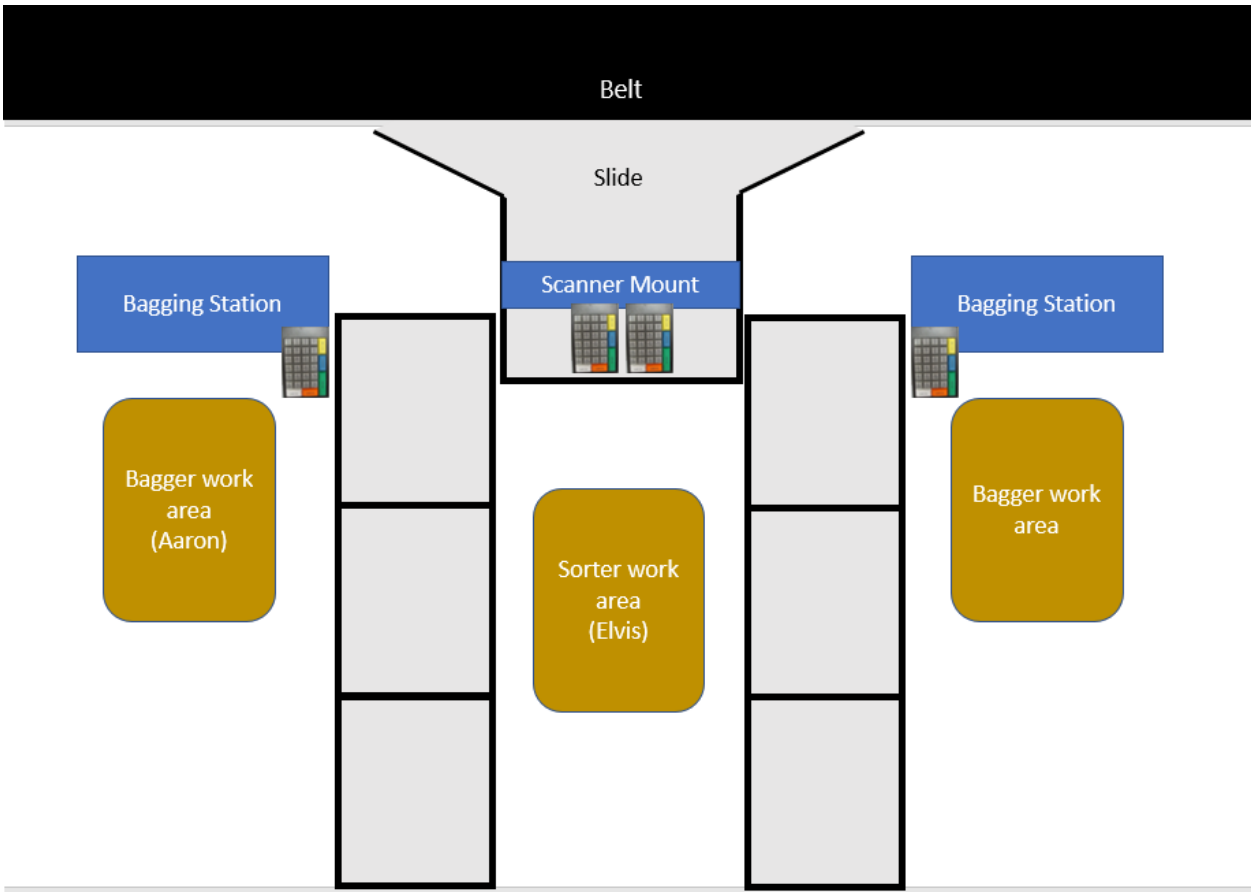

Figure 2. Small Sort Scanner System (SSSS).

Figure 3. Genovation 5887 keypad at SSSS workstations

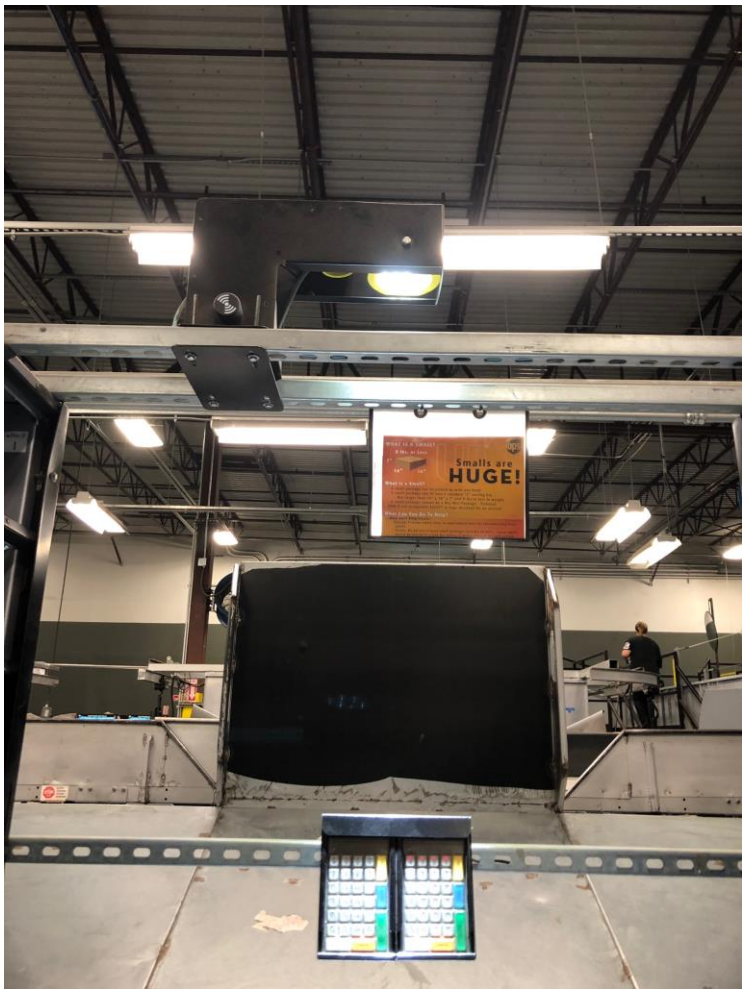

Fig. 4 Sorter Station

Meanwhile, the belt has been running. The Aaron and Elvis hurry to push packages from the small sort belt onto the slide. The slide empties into a sorting tray, where Elvis, the sorter, will retrieve the packages scan them, and put them in the appropriate slot, located on either side of him. The scanner is a camera located directly above him which shines a bright white light downward. It does not have a reticle to shine red lines onto packages, so Elvis has to guess and gradually learn where it can "see" and where it cannot. Each time he successfully scans a package, the scanner beeps, the number on the keypad corresponding to the slot begins to blink, and the 4 LEDs on the slot itself begin to blink (Figure 5). He fits the package into the slot and

scans another. The process repeats. Sometimes the system selects a full slot for a package, and Elvis has to cram it in or rearrange the packages already in the slot to accommodate the new one. Not all the slots are used, and scanning the same package twice can route it to different slots. Elvis doesn't know how or why it works that way, and his supervisors are vague about the algorithm used to group the packages.

If he cannot get the package to scan because of a damaged barcode or other error, such as a misplaced package that is not intended to be at THE FACILITY all numbers on the keypad light up and begin to blink. This is supposed to prompt Elvis to rescan. In the meantime, the previously selected slot will continue to blink. Sometimes, he thinks that a package has scanned when it has not because he imagines a beep, but the environment is noisy, so he is not certain. He might place it in the slot that was blinking for the last package because he is moving so fast to meet his PPH goals and looking for the blinking slot instead of the blinking keypad. When the package load is particularly heavy, some of the LEDs and entire slots are obscured by packages that have piled up in front of them. He has to take time away from his scanning and loading to move them out of the way. Once Elvis has had enough successful scans to get a slot full enough that he cannot fit any more packages, Elvis will press the corresponding number on the keypad, and the slot number on the bagger's keypad will begin to blink. Unfortunately, the system will

still indicate that he should load that slot, even though it is full.

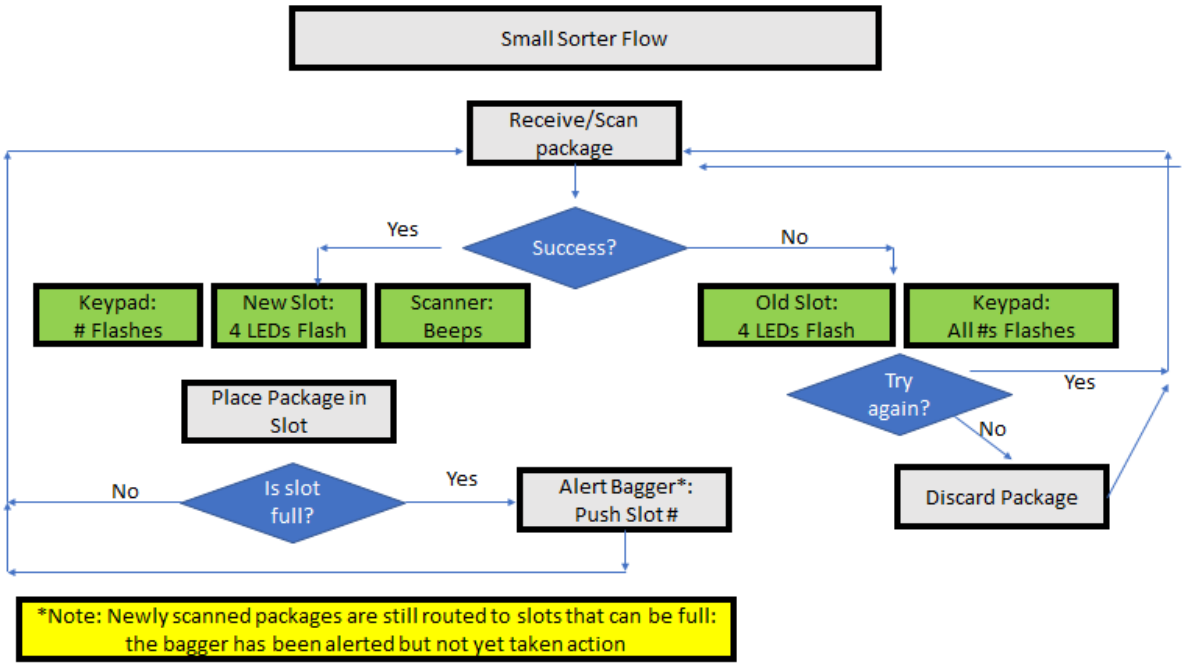

Figure 5. Intended small Sorter task flow.

Aaron, the bagger, will see the blinking light indicating a full slot on his keypad. He selects that number and empties the contents of the slot into a forever bag. He will then enter the three-digit code from within the slot and press enter. The number is only visible if the slot door is open, and most of the slots are behind him. He must look behind him while he types in the code, or try to remember it when he turns back around to look at the keypad. If the code he enters is incorrect, his entire keypad will flash, and no label will print. Sometimes this happens because he has trouble reading the numbering labels on the slots and he opens the wrong one because of the odd numbering that skips every 4th number and the mismatch between his keypad. (Figure q3). Like most new baggers, he has filled a bag with packages from a different slot than he has selected on his keypad at least once. Without an appropriate label, he has to set that bag aside

and try to remember which slot he actually took it out of while he opens the correct slot and bags those smalls in a new bag.

Figure @#$. Bagger slots with numbering.

When he matches the correct code from the inside of the slot to the number he has selected on his keypad, the printer attached to his scanner will produce a label for the bag. He pastes the label onto the bag, walks it to another belt, and returns to his part of the SSSS to repeat the process. If he has set a bag aside because he was unable to get a label for it, he must now go

back and remember the slot the packages came from and enter that code to obtain the correct label. Unfortunately, if he keeps the slot open as a memory aid, the sorter may load something into that slot while it is open. This results in packages falling to the floor, possibly being lost under the structure, or at least needing to be loaded back on the belt to re-sorted.

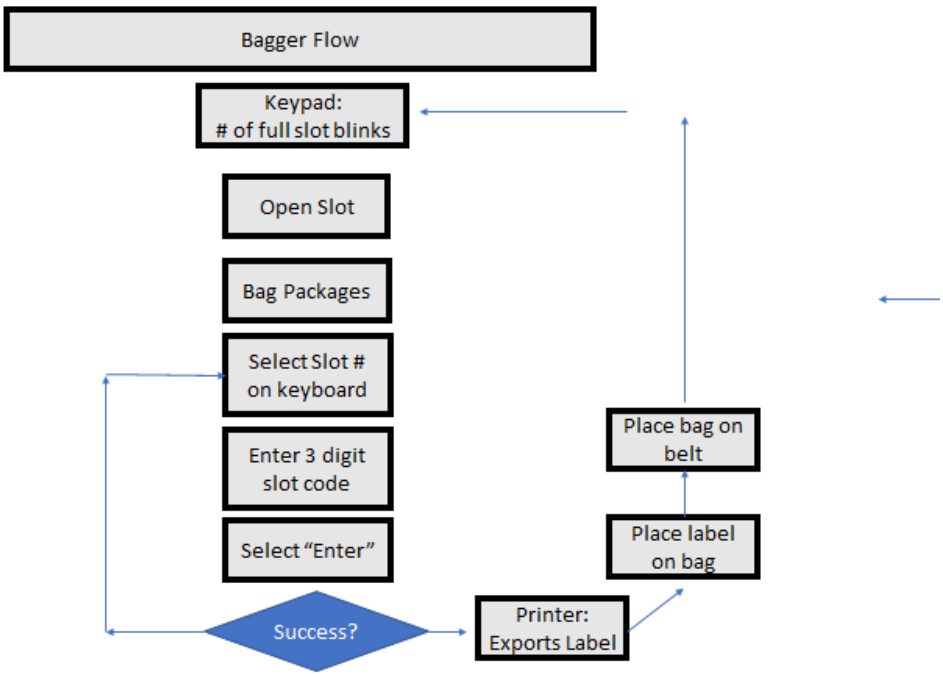

Figure 6. Intended bagger task flow.

Aaron is confused about why he keeps getting indications to empty slots that are not all the way full, so he has been partially filling bags. Partially filled bags decrease efficiency because the setup for each bag takes some of the bagger's time as well. Aaron tries to get as many packages into each bag as possible to maximize his personal PPH, the metric upon which he will receive raises or promotions. Also, supervisors who see partially filled bags admonish the baggers who "let it happen." During break, he might ask Elvis about the partially full slots. It turns out Elvis inadvertently activated those lights and had no way to turn them off. Aaron's bagger keypad will continue to blink until the slot's code is entered and a label prints. The sorter

has no recourse to cancel a previously issued command. As a backup, Elvis agrees to be more careful, but this slows down his work as he is carefully picking the keys he presses. Now, when he finishes one of the slots that he previously activated, he calls to Aaron around or through the partition. With the belts running, he has to be especially loud, leave his station and walk around, or try to catch Aaron at eye level while he has a slot open on his side. Keeping track of which slots indicators are activated and not full takes additional cognitive resources. If the bagger or the sorters had more flexibility and control over their displays, this wasteful and distracting process could be mitigated.

Figure 7. Baggers at work

Red Belt

When Kim arrives at the Red Belt where she will be loading air cans with packages as they travel on the belt to near her station, she gathers her finger scanner (Figure 8) and her WT4090. If her supervisor Brian has done his job right, the scanners will be configured for the workers to simply scan their personalized EIN associated barcodes and go to their stations around the belt (Figure 9).

Figure 8. Two views of the WT4090 associated finger scanner and the WT4090.

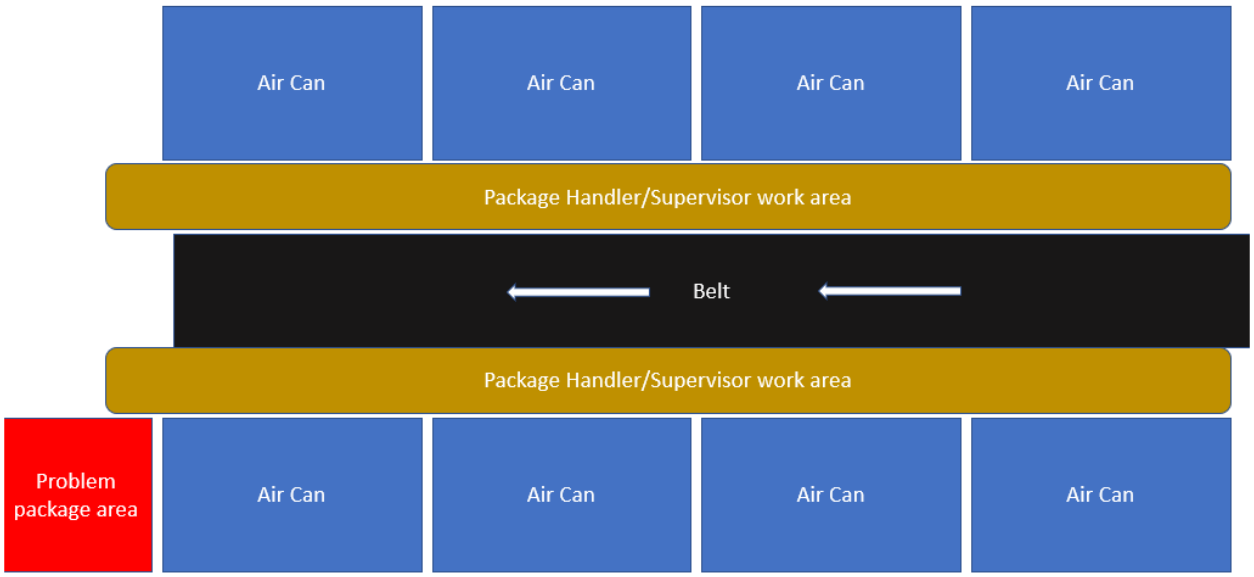

Figure 9. Layout of Red Belt

Figure 10. Workers on Red Belt.

Kim and the other package handlers can then scan the barcode at their position, scan the can that they are loading, and get to work scanning and loading packages (Figure 10), and Brian will close them as they are full. If the packages need to go to a different part of THE FACILITY or the barcode cannot be fully read, one of several error message appears, and the worker will use the enter button to clear it. Kim has to help some of the new package handlers who do not

know how to respond to a message because there are no button combinations that appear in the usual place to instruct the worker (Figure 11). They also ask her about some of the less common messages that appear and what needs to happen with the package. They carry the problem package to the problem package area at the end of the belt.

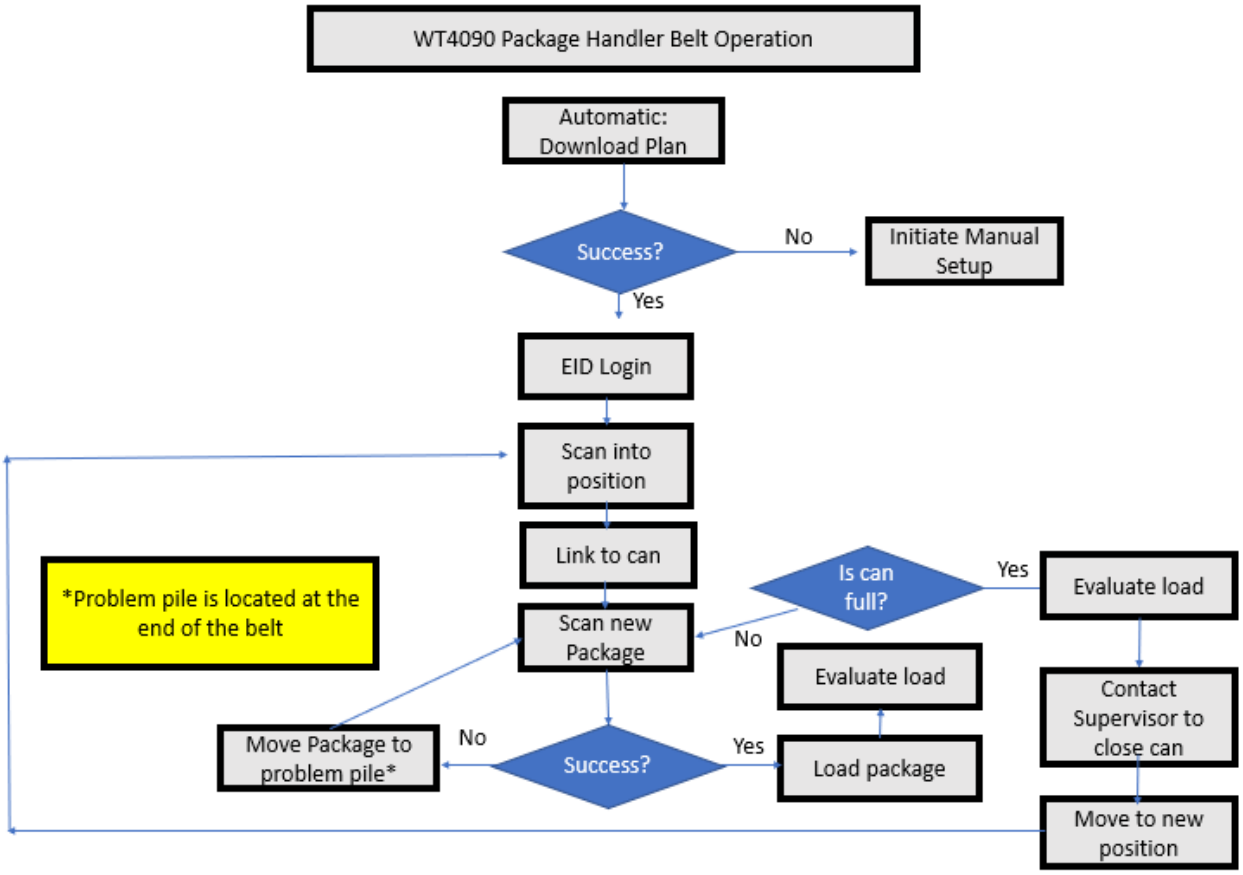

Figure 11. Red Belt workflow

Figure 12. Example error message for problem package.

If there have been delays in the setup, either due to a tight schedule, troubleshooting other scanners, or the device's failure to sync with the network, Brian and Kim may have to perform the steps manually. The most common issue is scanner disconnect. These incidents happen infrequently enough that manual setup is not routine, but often enough that they can damage a facility's monthly PPH.

Kim turns the device on with a red button on the top of the scanner. After a loading screen, a menu page comes up (Figure 13). She uses the number buttons on the right to select options, using ENTER to confirm her choice.

Figure 13. Menu for manual setup.

This is different than the usual method of confirming information, so it takes her a moment to remember how to navigate the different mode. If she gets lost in the menus, she will probably hold the red power button down and wait for a few more minutes while it reboots and she tries again. LAUNCH tries to automatically synch with the programmed plan. Usually, this would work to get her to the home screen, but if the technology is failing to update automatically, she will have to use SETUP. Other choices on the menu bring up options that only should be changed by the programmers who can alter internal settings like IP address, firmware versions, and other things that are far beyond what package handlers or even a front line supervisor can do. Kim should start by making sure her finger scanner is paired with the device by choosing 4, Associated Devices. She can then restart her scanner and when it turns on, scan the barcode (Figure 14) on the screen. Otherwise, she will have to navigate back to this menu

when she is done with the manual setup.

Figure 14. Barcode for pairing scanner.

Unfortunately, SETUP is the second option, and it is easy to forget to pair the scanner because Associated Devices is further down the list. When she navigates to the SETUP page (Figure 15), she is confronted with the need to enter a great deal of information manually and precisely without useful prompts.

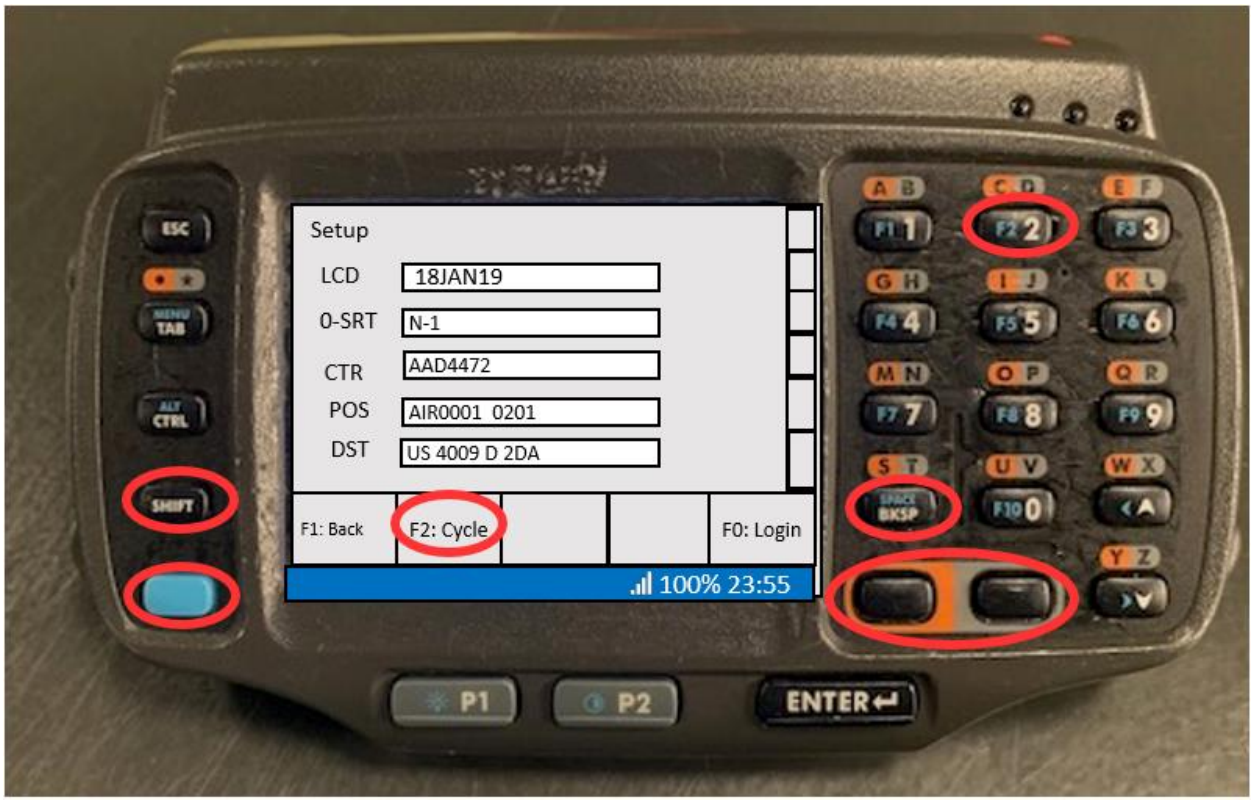

Figure 15. Setup page with relevant keys and controls highlighted and information entered in the correct format.

To move from field to field, she must select CYCLE using the F2 button. LCD is the date, and 0-SRT is the shift designation. CTR is the container she'll be working in, and if she remembers, she can use her scanner, if paired, to automatically enter that information. She receives no prompt indicating this is field can be auto-filled. POS is the position on the belt where she will be working and where the can is located, which is also scannable. DST is the destination for that container and any packages loaded into it. If she enters any information in the wrong format, she will not be able to continue to the LOGIN page. She has to use the orange and grey buttons to select the letters, and if she needs to delete a letter or number, she must press the SHIFT button and the BKSP. After several attempts, the use of a paper memory aid that Brian gives her, and a significant amount of frustration, she can finish the manual setup. Now she is

prompted to login so her EIN will be associated with the can and position, as well as any packages loaded into it. Finally, she is ready to start receiving packages. Even though she is experienced, this process has cost 10-15 minutes of productivity time.

Brian will have to configure the other workers' devices because he cannot talk each of them through it quickly enough, and many of them have no idea how to even get started. With six package handlers on the Red Belt, this process costs even more valuable time. Supervisors are only authorized to arrive 30 minutes prior to the beginning of their shifts so that they do not accumulate overtime except in emergencies, but many choose to arrive before that and wait to clock in until their designated start time. While they are ensuring the WT4090s are configured, equipped with charged batteries, associated to finger scanners, and often handling additional paperwork, they are essentially working without pay. Supervisors and package handlers are always greatly relieved when the plant engineers and programmers are able to remotely configure and update the devices for "easier" use. The screen that is displayed when ready to scan is displayed in Figure 16.

Figure 15. Ready to scan packages or close can.

After each can is loaded, Brian takes several steps to close it out and send the overall data about the can to the cloud for tracking purposes. Closing a can takes five steps on the WT4090, each requiring multiple keystrokes. Pressing FUNCTION then 0, leads to an overview screen of where the can is supposed to go, how many packages are in it, and if there are any special instructions. FUNCTION, then 5 proceeds to the package count screen. The supervisor then manually enters the number of packages. FUNCTION then 1 finishes the package count entry. Finally, the device prompts the user to confirm: Close Load. FUNCTION then 5 finishes the process.

Brian, as a new supervisor, has to learn to navigate the audit modes of the WT4090. The methods to navigate to these modes parallel the previously discussed navigation method and therefore are associated with similar navigation issues that have already been highlighted. The audits themselves entail scanning into a position and scanning packages to see which ones are going to that position. Throughout my interviews with actual supervisors, no supervisor could explain why this was a policy at THE FACILITY. In other larger facilities, these audits help can be used to find a package that may have fallen off the belt at a certain point. At THE FACILITY, however, the workspace is significantly smaller, and Red Belt packages that might fall are clearly visible on the ground around the work areas. Mentioning this part of the workflow is relevant to the overall task of THE FACILITY simply because it is not a necessary part of the task and it taxes supervisor cognitive resources, which are vital to predicting preventing bottlenecks.

There is one situation that Brian, Kim, and the other package handlers dread more than a manual setup. When packages are unloaded faster than the belt can accommodate, belt jams and package build-up bottlenecks can occur (see Figure 16). These occur nightly as unload and small

sort flood supervisors push their workers to exceed PPH goals. When a jam occurs, Brian must climb up the slide and the delivery belt to dislodge the packages. Often, a jammed belt takes more than one attempt to fix. While the belt remains motionless, the facilities' activities come to a halt. Up to 75 workers in different areas cannot do their jobs during this time. A bad jam or belt that has become strained by the weight requires removal of packages and then reloading - repetition of work that has already been accomplished. Jams inevitably result in Red Belt being overwhelmed.

Figure 16. Red Belt bottleneck.

Packages arriving all at once after a jam. They pile up, fall off, block workspaces, and get crushed or crush other packages. The sight alone overwhelms Kim and Brian and demoralizes them. While they try to keep up a quick pace, the boxes block their paths and force them to slow

down. Red Belt PPH drops further when packages that need to be loaded are wedged in by other packages and must be wrenched free. Brian can only turn the belt on or off using the BCS, the series of emergency buttons positioned at intervals along both sides of the belt. He wishes there was a way to slow the belt or communicate to the unloaders and their supervisors.

Standards Evaluation

Controls and Displays

Even for the experienced workers, the technology is sometimes confusing to navigate, and certain aspects are more laborious than necessary. Seasonal workers need continuous attention and often need multiple trainings. Training time is time not spent moving packages, which significantly decreases facility PPH. Certain changes to the controls and displays could significantly increase efficiency, prevent costly errors, and reduce recovery time from technological issues.

Genovation 5887 Keypad

This keypad is adequate for the small sort tasks, but in no way designed for it. Genovation produces customizable keypads, so it would be easy to update the numbering and key arrangement to accurately reflect the layout of the SSSS. There are 18 slots each with their own number. The keypad goes up to 24, and the location of the numbers do not reflect the location of the slots. The keypad is also arranged in such a way that it counts up starting on the right. That is, 1 is located on the left, 2 is to its right, and so on. A better layout would match western mental models of reading left to right, and it would meet MS 5.6.1.3.8 Matching layout to users' natural patterns. The numbering of the slots should also be changed to reflect the actual number of slots instead of skipping every 4th number.

New workers routinely have to get help from their supervisors to get set up at their stations. One way to mitigate that would be to change labels. The “switch” button should be relabeled “login,” and the “clear all” button should be renamed “cancel,” and moved to the top left, where people usually look for an “escape” button on a keyboard. The new layout would put more information in the world and rely less on new-worker recall adhering to Nielsen and Norman’s design heuristic of using recognition rather than recall.

A redundant, digital display should be added to the keypad, as well. This could prompt employees to login (ENTER EIN) and allow the user to know what EIN they were entering during login. The MS 5.1.1.9 requirements for Feedback state clearly that commands “entered by keyboard shall provide feedback to the user prior to entry to ensure that the keyed entry is errorless.” The digital display would also provide backup to the keypad lights, which are often dimmed or blurred by repetitive touching in a dusty, brightly lit environment. The susceptibility of the keypad display to obscuration and degradation violates the MS 4.9 for Ruggedness**.** A simple translucent rubber cover that could be removed and cleaned or disposed of would ensure continual visibility of the lights, but the addition of the digital display would negate the need for two keypads at the sorter’s position. Rather than having one or the other keypad blinking to indicate which side of the slots was required for the package, foveal vision and attention could be focused in one area, the display, to indicate the side. Presenting the task-critical information satisfies MS 5.6.1.3.12 and negates the need to attend to two different keypads. A single keypad would reduce mental workload and help prevent capture errors that occur when the package handler manipulates the wrong keypad.

The lights on the keypad display that indicate to which slot the package needs to go could be slightly modified to decrease slot identification time. According to MS 5.3.1.1.4, apparent

urgency**,** indicators on displays should match the tempo of the task. This task is rapid sorting and less than four seconds per package sorted is considered the minimum standard to meet PPH. The blinking cycle takes 1500ms seconds to cycle. This is slower than the amount of time a human needs to identify a moving target, meaning a bagger. A human eye saccade occurs in 20-30 ms, and a fixation during search lasts between 180-260 ms, meaning the eye could fixate on the target when it was off and then look away without seeing it turn back on. A more rapidly blinking light, around 200ms or 5hz would allow the eye to more quickly orient and identify the target and ensure a blink cycle during an eye fixation.

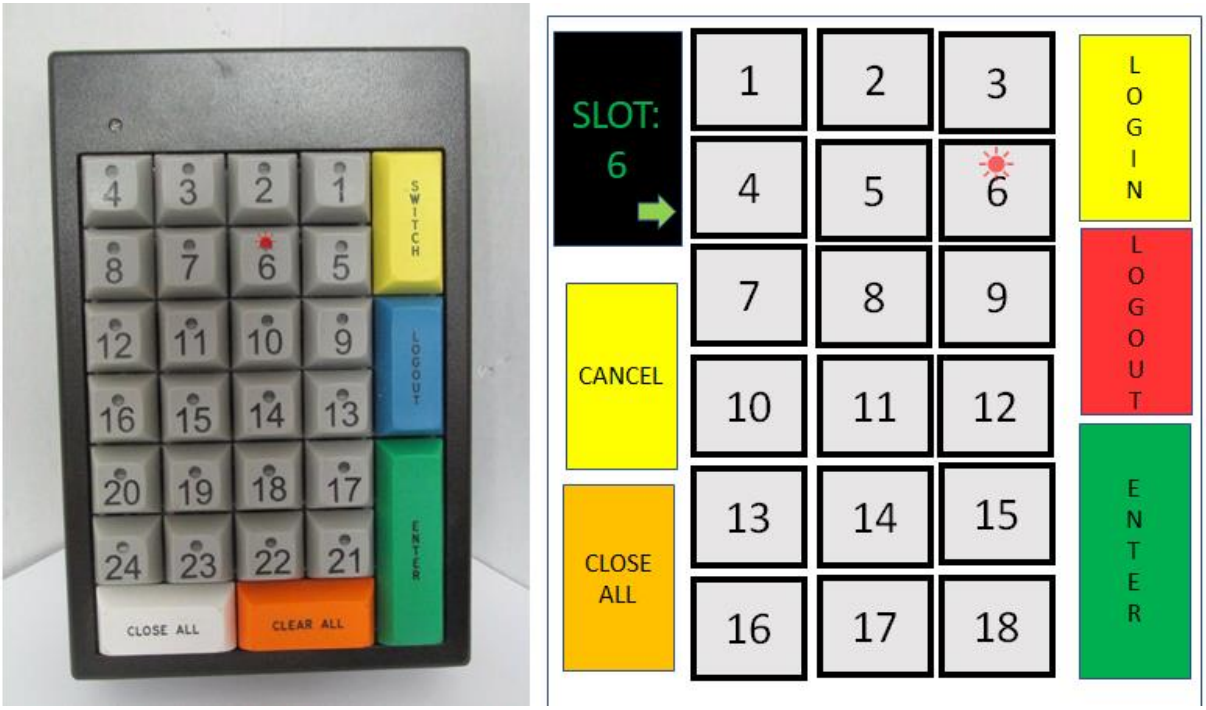

Figure 17. Current Genovation 5778 next to redesigned keypad.

The sorter's overall flow could be tweaked with a few changes to the programming and keypad to look more like Figure 17, which would likely shave time off the processing of each small. This time would add up and likely justify the cost of implementing new solutions within one holiday season. Turning off a flashing slot after an unsuccessful scan prevents costly

misloads. Preventing the system from prompting the user to fill full slots would reduce bottlenecks significantly by allowing a sorter to keep working instead of trying to cram packages into full slots.

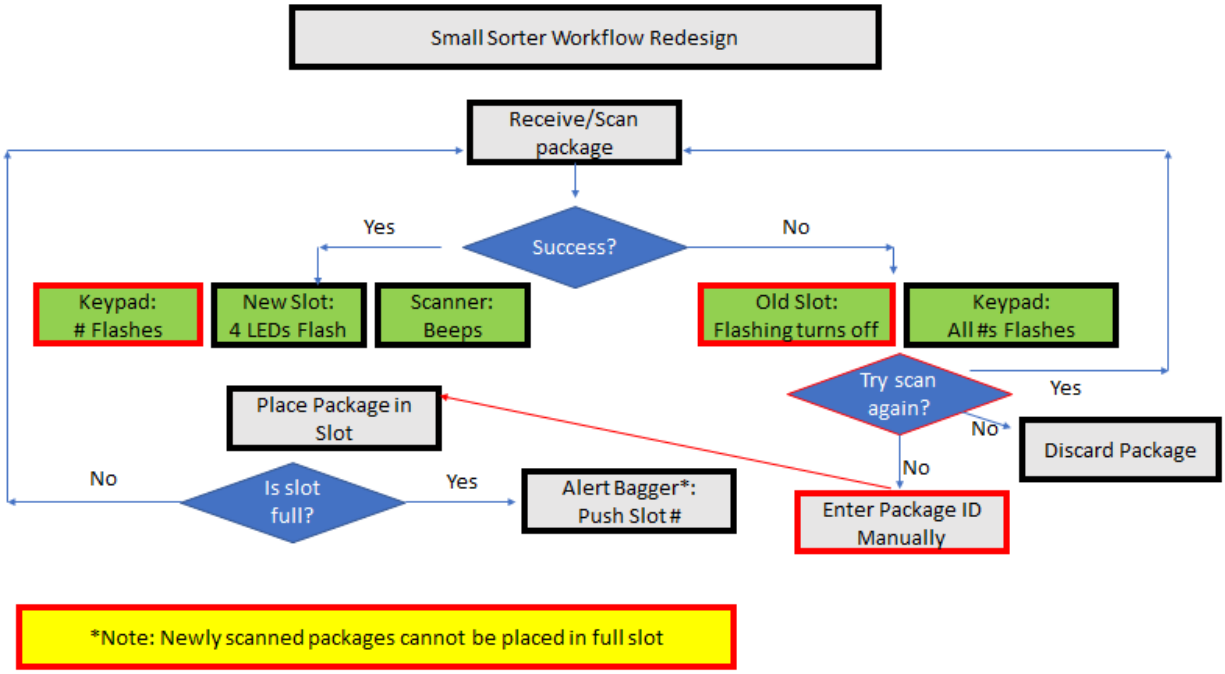

Figure 18. Small Sorter Workflow Redesign with changes highlighted in red.

Slot Controls and Displays

The slots and the indicators can be improved to prevent misloads. The odd numbering pattern fails, like the keypads, to meet MS 5.6.1.3.8 Matching layout to users' natural patterns when it skips every 4th number (Figure 19). To comply with MS 5.1.3.2.2, the layout and configuration of the keypads should be in accordance with ANSI/HFES 100.

The slot numbers are also small and can become quickly difficult to read after wear and tear. This visibility issue combined with the odd numbering scheme can result in significant lost time, especially if it leads to the wrong slot being emptied into a bag. MS 5.1.2.2.3c, Arrangement within grothe Company, simultaneous use mandates “visual display that must be

monitored while a related control is manipulated shall be located so that the user is not required to observe the display from an extreme visual angle." However, the slot codes are only visible when a slot is open, and the keypad needed to enter them and confirm an empty slot is positioned where looking at both the keypad and the code is impossible.

Figure 19. Bagging Slots

The current blue colored 4-led system also blinks too slowly. Workers who are sorting depend on their peripheral vision to know which way to turn to deposit the package. Faster blinking at 5hz would help and take advantage of rod cells' sensitivity to motion. The harsh, fluorescent lighting in THE FACILITY degrades the visibility the indicator violating the guidance of MIL-STD 5.2.1.5, Contrast of displays. Additional LEDs should be added to outline the slots clearly, or the lighting of THE FACILITY could be updated to operate in a spectrum

that would create more contrast (Figure 20).

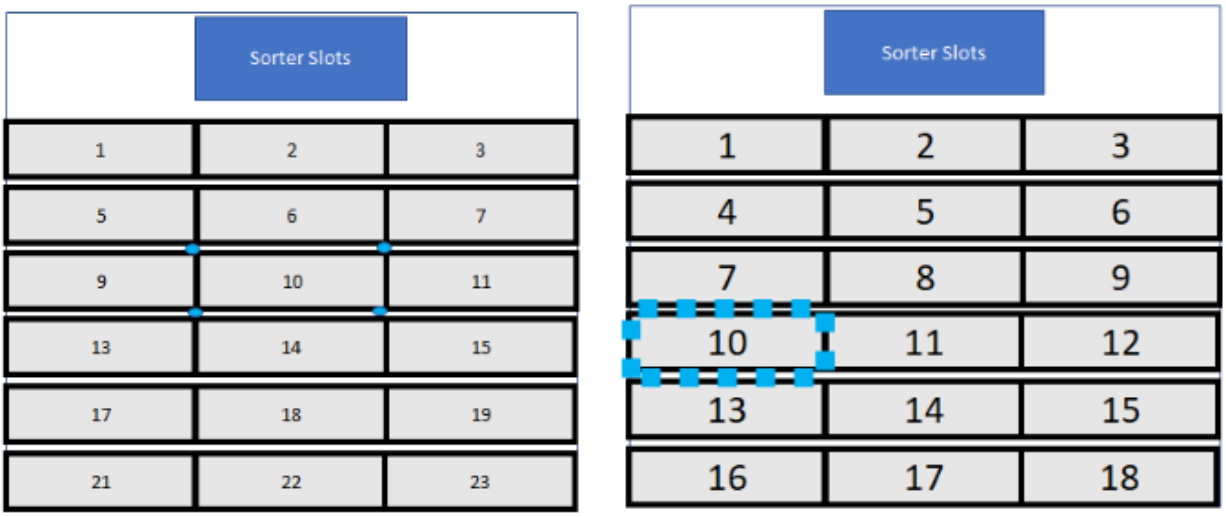

Fig. 20. Current slot layout and redesigned slot layout with numbering and flashing indicator LEDs.

While not a main focus of this report, the fluorescent cold-white overhead lighting shines in the 400-700 nm spectrum. The 400-500nm wavelengths are damaging to melatonin release, which can be disruptive for night shift workers. Replacing the lights with bulbs that shine in the 550-700nm spectrum could lessen the shift work's impact on workers' circadian rhythms.

WT-4090

This handheld computer runs Windows Mobile 5.0 CE as a base operating system and has been programmed with a THE COMPANY-specific application. It has many buttons and can perform a wide range of functions, but only a few buttons are used regularly. As highlighted earlier, setting it up manually is extremely complicated, and most workers would not be able to perform these functions. MS 5.6.1.5.2, Starting point, mandates that the beginning of any activity should be immediately understood. The LAUNCH option from the menu does create a clear starting point as long as the technology is working. If the technology is not guidance will be

needed throughout. The device/operating system interface currently violates nearly all sections of MS 4.6, which calls for Simplicity of design and minimal training. The equipment should "represent the simplest design consistent with functional requirements."

Selection of displayed options on almost all menus can only be performed using the blue FUNCTION button on the left and a subsequent button on the right. The function button is not labeled, in violation of MS 5.4.7.2.3, functional labeling. Also, single button presses could be used in place of combinations. Rather than FUNCTION then 1 to "Reject" or cancel a command, the ESC button could be programmed to reject the last command entered. Pushing two buttons to issue a single command creates an extra step, almost always forces the use of two hands to manipulate the keyboard, and violates Norman and Nielsen's consistency and standards heuristic.

New workers and supervisors often become confused when their mental models of keyboards do not match the operation of the device. On some screens, FUNCTION and then F5 accepts the entered information, but an ENTER button is clearly visible. The "Control/display relationships [that should] be straightforward and explicit," per MS 5.1.3.5.1.e, are neither. Screen glare, dust, and moisture often obscure the screen, requiring additional actions to clean, then view, then manipulate the controls. Enabling manipulation with traditionally labeled, physical keys would reduce the need to use both hands, mitigate partially obscured screens, and improve user control and freedom, flexibility, and efficiency of use**,** two more design heuristics. Using the keypad to move between fields and the enter key to make selections would be a small design change that would make navigation easier for a novice and enable single-handed operation (Figure 21).

Figure 21. Using arrow keys to navigate and enter to select options.

Both experienced and novice users navigating the WT4090 would benefit from compliance with MS 5.6.1.4.1, Consistent screen structure. Currently, information moves around from screen to screen. LCD, for example, can be found in the bottom left corner on some screens and in the top right on others. The size of fields to enter information sometimes matches the length of the information required in the field, and other times it is much longer. The menus have different appearances than the other modes, and selection instructions are different. A screen reorganization for both operating modes and menus and would solve some of these issues and leave the same functionality and feel intact. Figures 22 and 23 show redesigns for functional screens and menu screens. The Main Menu now has a description of what each choice will do to assist novice users, but the same names as before to keep continuity for experts. It also incorporates a HELP option, "in addition to labels, prompts, advisory messages and implicit aids (cueing)," which will be compliant with MS 5.2.2.7 Help guidance. Help will also be present on every screen possible, accessible by using F-6 for specific guidance on each mode or function.

Figure 22. Redesigned Menu Screen

Grouping like information per MS 5.1.3.5.3b will lessen the need for new users to search, and likely give them a better idea of what each item means. The F-6 help function will provide options to learn more and explore individually rather than asking supervisors and other workers, who may or may not even know all the functions and uses of their devices. Implementing a vertical layout matches the options to the menus and makes scrolling using the arrow buttons easier for selection. The FUNCTION + # control is retained for the expert users who do not need to look at the screen to perform their actions. Finally, the blue FUNCTION button is clearly labeled.

Figure 23. New overall WT-4090 functional screen design.

One of the interesting and underutilized functions of the WT4090 is its ability to communicate in real time to the rest of the THE COMPANY cloud within THE FACILITY. All supervisors carry these to perform audits, but another function could be to monitor and tweak

package flow and worker locations. **MS 5.1.2.1.7, Simultaneous access,** states “If more than one crewmember must have simultaneous access to a group of controls or displays to ensure proper functioning of a system or subsystem, each user assigned to control and monitor a function or group of related functions shall have physical and visual access to all controls, displays, and communication capability necessary to adequately perform the assigned tasks.” Because bottlenecks created by jams and overloading are so detrimental to the overall PPH of THE FACILITY, it behooves all supervisors in all sections to prevent them, even if it takes their area’s PPH down slightly. Ideally, the sum of the unloader PPH and the small sort bags per hour (not packages overall) should be equal to the overall belt PPH. Using the wireless communication and visual display capacity of the WT4090, THE FACILITY could maintain a constant flow of packages on the belt by easily viewing area PPHs and moving workers to balance them.

BCS

The Belt Control System, a series of binary switches, is a simple control that anyone can use. Pushing one of its buttons in turns the belt off so that a moving belt can be stopped immediately in case of an emergency. It is intended to prevent injuries from fingers or hair getting caught in pinch points, but it is also used to stop the belt to prevent damage to packages.

Figure 24. BCS Button

The buttons provided conform to all OSHA Standards in Section 1926.555 by providing a "means for stopping the motor or engine ... at the operator's station." It is also "equipped with an audible warning signal to be sounded immediately before starting up the conveyor." The package handlers work at stations along the belt, so these buttons are "provisions for stopping the motor or engine …. at the motor or engine location." The BCS stop switches are "arranged so that the conveyor cannot be started again until the actuating stop switch has been reset to running or 'on' position." Because the device can be used anywhere along the belt and it is used frequently to stem the flow of packages when a problem arises, it does conform to MS 5.1.2.1.7, simultaneous access. Altering the function of the buttons slightly so they could be used to decrease the speed of the belts without completely stopping it could be a useful tool for supervisors to make their needs known without having to communicate verbally.

Recommendations

In summary, this report has analyzed and described the task of the Air Facility: processing packages quickly and efficiently. With special attention to problem points including bottlenecks, situations that can lead to lost packages or missorts, and friction between workers and technology, the following recommendations will improve THE FACILITY's overall functioning by improving the key performance metric, the PPH. Here, I base savings on 50 new hires earning $14/hr on 8-hour shifts, working six days a week for the six weeks from Black Friday to early January, when gifts will have gone out, and most returns will have been processed for a total of over $200,000 in pay. This is a conservative estimate, considering some nights workers are on the clock for over 12 hours

Small Sort

About 25 of the new hires will work exclusively in small sort. The most simple solution to improve the SSSS is to **renumber the slots to match the configuration of the keypad**. I estimate this could cut possibly 5-10 minutes off each new worker's time to acclimate to the strange numbering each time they start a shift. This would equate to a **savings of over $2000** for the negligible cost of printing new stickers with equipment that already exists. Another easy solution would be to **provide a reticle**, even if it were a painted or taped area on the sorting tray to use as a target for scanning the packages. Reducing time per package for a scanner from 4 to 3 seconds, and saving significantly more time for packages with oddly placed or degraded MaxiCodes would yield an **increase in productivity of over 25%**, which could **save $25,000** - those seconds add up! **Updating the software to prevent overloading full slots** would require a more effort and cost but salaried plant engineering programmers already work for THE COMPANY to perform such functions. An overfull slot probably costs a sorter around 5 minutes an hour, adding up to **$8,400** for new hires, and probably even more, because new and experienced sorters alike suffer from full slot bottlenecks. **A redesign of the SSSS Genovation 5887 Keypad** (Figure 17) could potentially quadruple the cost of each pad from $100 to $400, but only three pads would be needed per SSSS instead of four, costing $2400. In conjunction with **improved slot cues (**Figure 20), more missorts would be prevented. Currently, missorts occur at a rate of 1-3/night. If it prevented 108 missorts, which can cost THE COMPANY up to $100 each to correct, an additional **$10,800 in lost profits could be prevented.**

Red Belt

Reprogramming the WT4090 with a better interface (Figures 22, 23) might only save 48 hours over six weeks at a value of less than $1000, and the programming would likely cost much more. The improvements, however, could be propagated across all THE COMPANY

facilities where WT4090s are used, and form the basis for future user interfaces, projecting time savings through training and troubleshooting far into the future. Moreover, guidance within the operating system could encourage exploration of the devices' untapped abilities, possibly resulting in further innovation and enhanced problem solving by users both experienced and new. **Enabling real-time unload and can packing statistics sharing** could benefit every area of the warehouse, leveraging worker hours more effectively through supervisor situational awareness. **Balancing the PPHs** of unloading and sorting with the PPH of Red Belt packing the cans via data sharing or **enabling variable BCS speeds** could save up to an hour of downtime each night. This represents **saving $50,000** by preventing lost productivity throughout peak without even taking damages into account.

Implementing even one of these recommendations would be a good start. The savings could be used to attempt more ambitious improvements. THE COMPANY and THE FACILITY stand to become more efficient and safer, happier facilities if they can adopt these solutions.

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