Developing a Distribution Ergonomics Research Center

Final Report

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EXECUTIVE SUMMARY

The long term objective of this research project was to address common ergonomic issues that exist across DC operations within three commodity sectors: Grocery, Apparel, and General Merchandise. In pursuit of this objective we developed the Distribution Ergonomics Research Center (DERC) at The Ohio State University, through the initial funding support from the Material Handling Industry of America (MHIA) and the College Industry Council for Material Handling Education (CICMHE). This mission of this center is to develop and evaluate ergonomic interventions (methods, tools, equipment, processes, etc.) that will allow distribution center workers to work more efficiently and safely.

This report describes how we initiated the center's activities using qualitative research techniques to identify common ergonomics issues and concerns that exist across distribution organizations within a given industry sector. In the first phase of this work, we conducted focus groups with managers and safety personnel from several grocery, apparel, and general merchandise distribution organizations in the Midwest and eastern portions of the country. In preparation for these sessions, participants were asked to interview up to three employees to help sensitize the participants to their employees' concerns regarding workplace ergonomic issues. The first part of the focus group discussion focused on issue identification, through conversations and a review of participant-supplied photographs illustrating ergonomic challenges in their operations. The participants were then given the opportunity to indicate which ergonomic issues were most important to them by attaching stickers to 4 by 6 inch cards on the wall that listed the identified issues. Table ES1 shows the key issues and concerns for each type of operation. These show considerable overlap, which suggests that there may also be the possibility that intervention concepts may crossover between industry sectors.

Table ES1. The primary ergonomic issues identified from the focus groups conducted with Grocery, General Merchandise, and Apparel distributors.

Grocery	General Merchandise	Apparel – Unload Trailers
Overhead Reaching	Overhead Lifting	Overhead Lifting
Far Reaches	Reaching to the back of a pallet	Repetitive Lifting
Heavy Boxes (i.e. Meat Case)	Heavy Oversize Objects	Heavy Cartons
	Loading boxes of items of various sizes	

The focus groups were then tasked with developing ergonomic intervention concepts that address these issues. A sketch-and-pass brainstorming method was used in which the participants were asked to sketch concepts and pass them to others working on similar issues. This approach generated considerable discussion and a number of interesting intervention ideas. The focus groups then concluded with a discussion of the usability issues associated with each of the concepts.

Using these initial concepts the research team searched websites, consulted with MHIA staff, and spoke with potential vendors to establish workable approaches to the

identified intervention concepts. Some of these concepts already exist as products that are commercially available and others were developed by working with firms who build and market this type of equipment. Table ES2 lists these concepts for each distribution sector. We believe all of these concepts address the physical ergonomics issues identified in the focus group process.

Table ES2. A summary of the concepts described in this report for the Grocery, General Merchandise, and Apparel distribution sectors.

Grocery	General Merchandise	Apparel
Pick Hooks	Pallet Breakdown Station	Articulating Belt Extension
Pallet-Jack Mounted Lift Assist (Eco-Pick)	Conveyor-mounted Lift Assist for Trailer unloading	Conveyor-mounted Lift Assist for Trailer unloading
Flow Pallet	Layer Pick Equipment for Pallet Breakdown (FrogLift)	Inclined Parcel and Polybag Conveyor
Pallet Cart	Flow Pallet	Height Adjusting Catch Basin
Elevated Pallet Jack	Pallet Cart	Slipsheet Truck
	Elevated Pallet Jack	
	Pallet-Jack Mounted Lift Assist (Gorbel Product)	
	Conveyor-mounted Lift Assist for Trailer Loading	

For the grocery sector, all the intervention concepts were aimed at the order filler or selector job. We think one of the simplest and least expensive things to do is to introduce pick hooks. But a longer term solution to bringing material forward in the slots will likely involve the flow pallets and the pallet carts. While flow pallets could be used on the ground level, pallet carts offer additional functionaltiy for sanitation crews who clean out the slots. While there were reservations regarding the Eco-Pick equipment which were expressed by the hourly employees we spoke with in small group interview sessions, the research team thinks that this product could be beneficial to employees who move heavier items, such as meat, water, juice, and produce in grocery DCs. In order to use this most effectively, the organization of the work process may have to change, such that there are dedicated Eco Pick users that create partial orders comprised of the heavier products that are often the first items selected in a given store's order. For example, once the heavier boxed meats are placed on the pallet using the Eco Pick the pallets may be handed-off to another selector using traditional equipment that completes the order with all the cases below some threshold weight. The same could be done with other starting point products such as juices, waters, bagged produce, or pet foods.

For the general merchandise sector, the intervention concepts address the needs of at least three differ jobs within a facility. On the receiving dock, there are typically opportunities to improve the way pallets of mixed freight are broken down. Clamp trucks or forklifts outfitted with devices such as the Froglift can significantly reduce manual handling and likely speed up the operation. Where floor loaded trailers are received, a conveyor-mounted lift assist (Vaculex's Parcel Lift) looks very promising. As

for the selector job, the research team thinks that those involved in the selection of large and or heavy merchandise (i.e. much of the non-conveyable merchandise) would almost certainly benefit from the type of pallet jack lift assist that Gorbel is developing. Clearly, the speed of the device is important, however, if one examines the amount of time necessary to manually lift, slide, drag, and maneuver large, heavy, and awkward objects onto a pallet, the timing issue maybe resolved. The Atlet style raising pallet jack has some merits, especially in DCs that encourage employees to pick by layer. This type of height adjustment could facilitate the sliding of large items, for example boxed furniture, from their pick locations onto the pallet jack, with little vertical displacement when filling orders with items stored above waist level. Both the pallet cart and the flow pallet may also help in this environment to reduce the reach distances required and the risks associated with stepping on pallets. As for the shipping end of the operation, a conveyor-mounted lift assist (i.e. the Parcel Lift by Vaculex) would likely facilitate the loading of heavier items up to about chest or shoulder level. Combine this with a step arrangement and the utilization would be increased.

As for apparel, the most promising intervention concept, we think, is the Parcel Lift (Vaculex). The research team think that this device would significantly reduce the biomechanical loads on the shoulders and spine, while maintaining or even perhaps enhancing current levels of productivity due reduced muscular fatigue. Receiving products on slipsheets, that could be removed and taken to breakdown stations much like that shown for the pallet breakdown concept in general merchandise, would certainly be an alternative approach. Although use of slipsheets requires the cooperation of suppliers who are often overseas. The use of Articulating Belt Extenders, or devices such as the Empticon which mechanically pull the cases onto a conveyor, are also attractive options that address the similar ergonomic concerns. On the shipping side, configuring an inclined conveyor to pile-up polybags and cartons in 3rd party shipping trailers is doable with existing products on the market. Moreover, with some additional investment, these can be set up with sensors so that they can automatically retract from the trailer as the trailer fills. The lower cost option may be to employ height adjusting catch basins that allow employees to service more conveyors without compromising their safety.

In conclusion, this report shows that there are a number of intervention opportunities available to distribution centers that can be used to address existing ergonomic issues that are common within and across distribution commodity sectors. We think that all of the intervention concepts listed in Table ES2 can help reduce the biomechanical loads experienced by distribution center employees, thereby reducing their risk of injury and potentially allowing DC employees to be more productive.

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PROJECT AIMS

The long term objective of this research project was to address common ergonomic issues that exist across DC operations within three commodity sectors: Grocery, Apparel, and General Merchandise. We sought to use a participatory approach which involved participants representing DCs located in different parts of the country and manufacturers of material handling equipment. This research was targeting Theme 7 from the 2007 Material Handling Logistics Summit: Worker-centric distribution center design as workplaces of excellence. The two specific aims of the project were as follows:

Specific Aim 1. To create a center for distribution center work that develops and evaluates interventions (methods, tools, processes, etc.) that will allow distribution workers to work more efficiently and more safely, through research focused on ergonomic science in conjunction with lean engineering.

Specific Aim 2. To develop partnerships with regional DCs and material handling equipment manufacturers to assist the DCs in achieving their goals of becoming or maintaining their status as a "workplace of excellence" through addressing challenges and discovering opportunities for improvements through research and application of ergonomic science in conjunction with lean engineering.

The charter research team included two graduate students and two faculty members from Ohio State University's Industrial and Systems Engineering Program, who possess expertise in ergonomics, work design and specific experience working with and conducting research involving distribution centers (DCs). The participatory research methodology employed is one that we have applied successfully in other industries. It is outlined in Figure 1 and is explained in detail in the Methods section of this report.

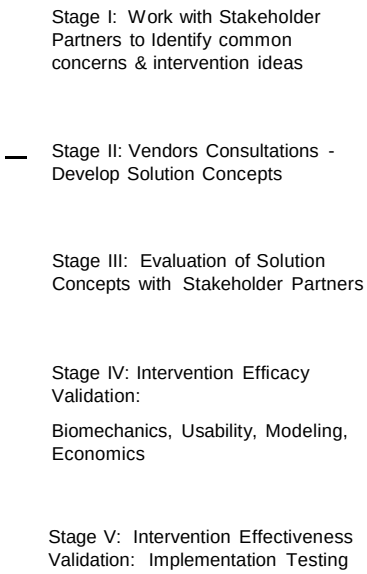

Fig. 1. Distribution Ergonomics Research Center (DERC): Research method outline.

Broader Impacts

Integrating research and education through partnerships. This project sought not only to address the needs of regional DCs, but also to provide research and learning opportunities for students. In the longer term, partnerships between the university, DCs, and equipment manufacturers will yield opportunities for individual (graduate and senior research theses) and group projects (graduate research practicum and senior capstone design courses). Additionally, experiences from the research will, as they often do, become part of the stories that are told by faculty to illustrate applications of principles that are explored in courses. Case studies may be developed from some of the development-implementation experiences generated from

this project.

BACKGROUND AND SIGNIFICANCE

The long term objective of this research is to improve DC operations, for the benefit of companies and their employees. More efficient operations benefit companies and their employees. The simplest way to represent efficiency is as follows:

$$\text{Efficiency} = \text{output/input} \qquad \text{(Eqn. 1)}$$

Efficiency is improved through manipulation of factors that contribute to a net increase in the numerator and/or manipulation of factors that produce a net decrease the denominator. The Distribution Ergonomics Research Center (DERC) that was created as part of the project is focused on seeking opportunities to affect both parts of this equation.

Ergonomics

Ergonomics discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable human use (adopted from (Sanders and McCormick 1993)). (Chapanis 1996) provided a comprehensive list of potential benefits of applying Human Factors/Ergonomics principles in the design of work systems (Table 1). It is easy to look at each potential benefit and consider how it might impact numerator, denominator, or both parts of Eqn. 1.

Table 1. Potential benefits of applying HF/E principles (Chapanis 1996)

- increase safety
- improve system performance
- increase reliability
- improve maintainability
- improve the working environment
- increase human comfort
- increase ease of use
- increase user acceptance
- reduce errors
- reduce personnel requirements
- reduce training requirements
- reduce fatigue and physical stress
- reduce boredom and monotony
- reduce losses of time and equipment
- increase economy of production
- increase aesthetic appearance

Given that our focus is on DC operations, one substantial opportunity to affect Eqn.1 is readily identifiable from reviewing recent lost time injury and illness statistics provided by the Bureau of Labor Statistics (BLS 1994-2006). For 2006, BLS reports show that Warehousing & Storage (W&S), as an industry sector, had an overall incidence rate of lost time non-fatal injuries that was comparable to Construction, and higher than private industry as a whole or that of the Manufacturing sector (Table 2). Rates for every type of injury listed are higher for W&S than for private industry as a whole. The direct and indirect costs associated with these injuries affect both parts of Eqn. 1. Injured workers may not be able to produce output at all or only at reduced rates for some time, and medical costs, workers' compensation costs, and other costs associated with an injury both increase the denominator and represent lost opportunity to make an investment in the operation.

When injury and illness data are examined by type of exposure, incidence rates are also higher for W&S, compared with private industry as a whole (Table 3). Sprain and strain

injuries constituted 49% of the non-fatal lost time injuries in W&S in 2006 (BLS, Table R1), a percentage similar to that found in a large prospective study of risk factors associated with repetitive material handling work (Craig *et al.* 2003).

Table 2. 2006 incidence rates for non-fatal lost time injuries & illnesses, by nature of injury (BLS table R5).

Nature of injury/illness (selected)	Private industry (overall average)	Warehousing & Storage (NAICS 493)	Construction (NAICS 23)	Manufacturing (NAICS 31-33)
Total cases	127.8	**220.6**	219.5	141.2
Sprain/strain	51.1	**107.5**	75.8	47.7
Fracture	10.2	13.8	**25.3**	11.8
Cut	12.4	11.9	**34.3**	17.0
Bruise	10.9	**25.3**	13.6	11.8
CTS	1.4	2.0	1.3	**3.5**
Back pain & pain except back	11.3	**17.3**	17.2	10.1
Back pain only	3.8	5.4	**5.8**	3.2
All other	21.4	31.8	**38.1**	26.7

Note that in all categories of injury/illness, Warehousing and Storage rates exceed those for private industry as a whole.

OSHA[1] provides a method for estimating costs associated with various injuries, and presents the results in terms of direct and indirect costs, as well as the additional revenue a company would need to generate, based on its profit margin, to make up for those costs. For example, OSHA estimates the average direct cost for a sprain or strain injury at $7500. The indirect cost is estimated to be 1.2 times the direct cost, or $9000. This totals $16,500. For a company that operates with a profit margin of 5%, it would require $330,300 in revenue to make up for one strain/sprain injury. When comparing costs associated with the purchase of lift tables or other materials handling aids, it is important to consider the full costs associated with those injuries that may be prevented by the investment.

Table 3. 2006 incidence rates for lost time injuries & illnesses, by type of exposure (from BLS table R8).

Exposure (selected)	Private industry (overall average)	Warehousing & Storage (NAICS 493)
Contact with objects	36.2	58.3
Falls – lower level	8.0	8.8
Falls – same level	16.4	20.3
Slip/trip	3.8	5.6
Overexertion – all	30.8	73.6
Overexertion – lifting	16.3	45.7
Repetitive motion	4.1	8.2
Transportation accident	6.1	19.1
All other	13.6	22.8

Ergonomics and DCs. There is a limited amount of research that has been published specifically addressing ergonomics in warehousing/DC operations, though much research has been published on manual materials handling, more generally. A review of the epidemiological research by the (NRC 2001) found several risk factors that are prevalent in DC operations to be positively associated with occurrence of musculoskeletal back disorders, including manual material handling, frequent bending and twisting, heavy physical load, and repetitive movements (pg 99). Upper extremity disorders were also linked to manual material handling, repetition, and force (pg 102).

[1] http://www.osha.gov/dcsp/smallbusiness/safetypays/estimator_text.html

More specifically, when NIOSH investigators performed a hazard analysis of a grocery warehouse wherein the rate of back injuries was 16 per 100 workers, they found lift loads exceeding recommended limits and rates, locations from or to which items were picked or placed to be too low, too high, or too deep, and work periods exceeding 8 hours to be points of concern (Putz-Anderson *et al.* 1993). In an earlier study of wholesale grocery order selectors, (Garg 1986) found excessive reaching postures imposed by the design of the storage systems, which, based on biomechanical modeling, he predicted would cause half of male workers and 90% of the females to overexert themselves on the job. More recently, (Lavender *et al.* 2006) studied the low back disorder risk values of 53 jobs in 7 automobile parts DCs. They found risk values ranging from about 25-75% risk; about half of the jobs studied had a risk at or above 60%, indicating they resembled jobs that were associated, in a comparison database ((Marras *et al.* 2000), with annual back injury incidence rates of 12 or greater. In a study of problematic work factors for stockers in a warehouse superstore, (St.-Vincent *et al.* 2005) identified factors in several aspects of the work system that made the stocker job less efficient and more risky. These included product and packaging characteristics (weight, lack of handles, flimsy packaging materials that did not support the weight of the product), facilities/display layout (requirements to stack product very high, deep storage bins, congestion), equipment (mismatches between pallets and pallet jacks, poor maintenance), and work organization (poor planning by management).

There are a few accessible reports specific to interventions in warehouse operations. One describes countermeasures taken by a hardware retail DC (Washington State Department of Labor and Industries 2001), that include modifications that are limited in scope (self-imposed weight limits on totes and smaller wheels on carts) and modifications that are wider is scope, including changes to their inbound receiving procedures and containerizing outbound shipments. The report specifically discusses the decrease in trailer utilization that occurred as a result, but there were also decreases in the amount of material handling performed by the loader and the driver and decreases in "product damage, fewer misdeliveries, and increased equipment utilization and labor efficiencies". This exemplifies the need to take a systems approach to the intervention process. (Ulin and Keyserling 2004) presented case studies of three interventions in automobile parts DCs. Their paper demonstrates how the intervention process involves multiple steps and may require iterations to "get it right". They also provide examples of objective means by which pre- and post-intervention conditions can be evaluated. Recently a large scale study of DC workers found only limited effects of state-of-the-art lift training on back injury prevention; results indicated that prevention efforts in DCs should focus on work and process design issues (Lavender *et al.* 2007).

In a lab-based study that simulated box handling conditions in grocery DCs, (Marras *et al.* 1999) studied effects of box size and weight, box-handle coupling, and location on pallet on spine compression and shear forces. They found box weight and location of the box on the pallet affected compression, as well as anterior-posterior and lateral shear forces. Box size affected A-P shear and the presence of handles affected A-P shear and compression. The bottom location on the pallet was particularly problematic with regards to spine compression and A-P shear (consistent with some field studies

mentioned previously). The effect of including handles was equivalent to reducing the weight of the box by about 4.5 kg.

As in many industries, some DC operations are seeing their workforce age. Reports and research studies that provide information for engineers and others on how to design work to compensate for decrements that occur in various capacities as workers age are becoming increasingly important and relevant (Shin *et al.* 2006, Haight and Belwal 2006). In a younger sample of workers, a number of personal factors were shown to be associated with injury risk in material handling operations, and therefore, provide additional opportunities for injury risk reduction (Craig *et al.* 2006).

To summarize, much is known about the risks involved with material handling activities and the injury statistics show the effects of these risks. They also reveal opportunities for improvement and innovation to reduce these risks, thereby improving operations.

OVERVIEW OF RESEARCH DESIGN AND METHODS

The preceding sections of the report identify the need for ergonomic interventions in distribution centers. Many of the work processes have elements that increase the risk of back injury and, due to the nature of the work, present challenges with regards to implementation of traditional engineering controls. Thus, this work seeks to identify ergonomic solutions to some of the challenging situations that commonly exist across this nation's distribution network. Our approach, as identified in Specific Aim 1, was to, first, create the Distribution Ergonomics Research Center (DERC). The mission of this center is to further the occupational health and productivity of DC employees. In pursuit of this mission, the center's activities, and particularly the inaugural project, focus on developing new and innovative approaches to material handling tasks based on ergonomics principles.

In this first project, we were particularly interested in addressing some of the common ergonomic issues that exist across a wide range of distribution operations. Notable examples are manual handling of material when floor loading trucks, unloading floor loaded trucks and containers, picking to pallets, or picking to belts. Our approach was (and is) to involve stakeholders in the innovation process. In this project, we partnered with several DC stakeholders representing grocery, apparel, and general merchandise distribution operations, as well as equipment manufacturers.

In developing interventions, we pursued a multi-stage process (fig. 1). To date, our efforts have been focused on the first three stages of the process. In the first stage we worked with stakeholders to identify common concerns and intervention ideas that address common and persistent needs of stakeholders. In the second stage, we initiated conversations with equipment suppliers that could possibly supply the ergonomic interventions. The third stage involved obtaining feedback from the original focus group participants, as well as hourly employees, and DC managers on the concepts. Subsequent work will include biomechanical validation of concepts for which there are questions regarding their potential efficacy, and testing effectiveness of

selected interventions in field settings.

STAGE-SPECIFIC METHODS

Stage 1: Work With Stakeholder Partners To Identify Common Concerns & Intervention Ideas.

The goals of this first stage were to ensure that (1) the DERC focused on ergonomic issues deemed relevant and important to all parties involved, and (2) innovative and usable intervention concepts were generated and developed or identified, and prioritized.

From our partnering DC organizations, we recruited participants to our focus groups who have safety and operation management responsibilities. Participants attended one of three focus groups, depending on the products their DC managed (grocery, general merchandise, or apparel). These focus groups were charged with: (1) identifying common issues related to development of musculoskeletal disorders, (2) brainstorming innovative intervention approaches, (3) conducting initial usability analyses, and (4) prioritizing solutions for further development. We view this type of focus group is a truly collaborative process, that draws upon the collective creativity of the researchers (who have biomechanics, lean operation design, and participatory design expertise), and participants from the distribution operations (who have grounded, experiential knowledge).

Focus Group Preparation. Prior to the focus group session, the participating individuals were provided with workbooks to sensitize them to the issues that would be discussed. In addition to learning about their experience level in grocery distribution, in the workbooks the participants were asked to (1) reflect on what their organizations have done to address ergonomics concerns in the past, (2) interview two employees to obtain their views of the what represented the most physically challenging components of their jobs, and (3) photograph the tasks and conditions that are physically challenging for their hourly employees. These workbooks were sent to the investigators in advance of the focus group meeting.

Focus Group Process. The investigators moderated the focus group meetings, each of which was comprised of three phases. In the first phase, the moderator initiated a discussion focusing on the issues identified in the participant's workbooks and the photographs submitted. As photographs were displayed the submitter(s) described the issue they were trying to highlight in their pictures. As issues were verbalized by the narrator or other participants they were recorded on 4 by 6 inch cards. At the completion of the issues discussion the issue cards were taped to the wall in clusters which indicated that the cards in a given cluster addressed a similar topic (theme or category of concern).

The second phase of the session employed a consensus building process regarding the issues discussed. This was done by handing each participant a set of sticky dots. The participants were asked to indicate which issues were most important to them by

placing one or more of their sticky dots on an issue. The dots were then tallied to determine the issues that were the most important to the group.

The third phase of the session comprised a brainstorming process to elicit new ideas for potential ergonomic interventions that could address the issues. We used a sketch and pass method in which the participants were placed at small tables in groups of 3 to 5 people. They were provided with large sheets of paper, pencils, and markers and were asked to sketch intervention concepts that they thought would address one or more of the priority issues. After approximately 10 minutes each participant passed his/her sketch to the participant on his/her left. At this point participants were encouraged to explain their artwork to the recipient who was, in turn, asked to augment the sketch, or if the idea triggered a new idea, sketch an additional concept on the page. After 5 to 10 minutes, the pages were passed again to the left and process repeated until the sketches completed one full cycle around the table. Once the process was completed, the sketches were placed on the wall and each one, in turn, was presented by its originator and then discussed by the entire group. The discussion focused on the purpose of the concept, it expected implementation, and potential usability issues.

In the following sections we describe the findings of this focus group process for each type of distribution operation.

Stage 2: Vender Consultations

Based upon the intervention concepts generated in stage 1 and our analysis and interpretation of those concepts and the participants' expressed needs, several equipment vendors were identified and contacted. Vendors were identified based on their production of products that were similar to the new concepts or as an organization that might be willing, given their current product line, to consider developing a product concept. Ray Neimeyer was of great assistance in helping us identify some of these organizations. Others were identified through internet searches or their expression of interest in our project following the project's announcement to the MHIA membership. In the initial conversations with these organizations, the project was described and the relevant identified needs and intervention concepts were described. Depending upon the specific intervention concept, these consultations resulted in refined concept drawings, prototypes, and/or opportunities to conduct field trials with their equipment.

Stage 3: Evaluation of Solution Concepts

The intervention concepts arrived at through the vendor consultations were evaluated using surveys mailed to each of the original focus group members. These surveys presented each of the equipment concepts that were considered viable by the research team, in the form of the sketches from the focus group, as well as potential form of the equipment concept that stemmed from the vendor consultation process. While questions on the survey varied slightly depending on the nature of the solution concept, participants were generally asked about whether the equipment concept was consistent with the initial idea, whether they thought their employees would want to use the equipment, whether it would enhance productivity, and whether it would impact work quality. The response format for each of the questions on the survey was a 10 cm

visual analogue scale (VAS). Additional open-ended questions asked about other potential benefits and barriers to use. A final visual analogue scale was used the assess the participant's overall excitement about the concept. An example of a survey page is shown in figure 2.

The opinions of hourly employees at some of the participating organization were also sampled during on-site concept review sessions ("small group interviews") using a different survey tool. In these sessions, 5 to 8 participants were assembled in a room with the researchers; managers were not present during these sessions. participants were informed by the researchers that their participation was voluntary and that they were under no obligation to participate in the session. Participants were all people who would potentially be users of the concepts, based on their current jobs. In these sessions, each concept was displayed using a PowerPoint slide and its use and function described, by the principal investigator, to the employees. There was an opportunity, then, for the employees to ask questions and discuss the concept, which generally clarified their understanding of where, when, and how the concept under discussion would be used. The employees were then handed surveys which contained questions focusing on usability, usefulness, and desirability of each of the concepts. This process was repeated for each of the concepts relevant to the given employee group. An example of the hourly employee survey is shown in figure 3. At these same sites, following the small group interviews with the hourly employees, discussions about the concepts were held with management teams, comprised of facility managers and shift supervisors. At one site, the managers also filled in the hourly employee surveys.

Figure 2. One of the survey pages used in Stage 3 to obtain assessments, from original focus group participants, of the intervention ideas and solution concepts stemming from the grocery distribution focus group (Stage 1).

Elevated Pallet Jack for Product Selection
A double pallet jack that can raise forks to waist level, thereby reducing bending when loading the bottom half of a pallet

Provide your evaluation of the new approach to addressing this need *(mark one response in each row)*:

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack would be easy to maneuver.					
2. I think changing the forks' height with this pallet jack would be easy.					
3. I imagine that most people would learn to use this pallet jack very quickly.					
4. I think that changing this pallet jack to the right height will not significantly waste our work time.					

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack can reduce the time I spend bending at work.					
2. I believe that using this pallet jack would make my work easier.					
3. I believe this pallet jack will help me perform my selection tasks more efficiently.					
4. I believe this pallet jack will allow me to be less tired at the end of each work day.					
5. I believe this pallet jack has the potential to reduce product damage.					

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet jack.					
2. I would like to try this pallet jack.					
3. I think some of my co-workers would want to use this pallet jack.					
4. I really need this pallet jack for certain products in my warehouse.					
5. I would like to see us loading pallets with this pallet jack.					

Figure 3. An example of the survey tool used during the hourly employee small group interview concept review sessions.

FINDINGS FROM GROCERY DISTRIBUTION

Stage 1- Participants. Eleven individuals representing management and safety functions from five large grocery distribution organizations participated in a single 3-hour focus group session. All signed informed consent documents before participating in the research. Experience working in distribution centers ranged from 7 to 34 years (average = 18 years). We should note that each of the participating organizations used a pick to pallet process (as opposed to a pick to belt) process.

Stage 1- Findings. Prior to the focus group meeting, individual focus group participants interviewed a total of 20 DC employees ranging in experience from 0.25 to 24 years. Collectively, the employees who were interviewed indicated the following items were most difficult to handle: meat, juice, canned food, potatoes and onions, bleach and detergents, bottled water, bags of dog food, and soft drinks. On average, just over 10 percent of the items they handled were considered by them to be "too heavy". The interviewed employees estimated 31 percent of the items they handle are picked-up or placed above shoulder height and about 30 percent of the items are handled below knee height.

The discussion of issues at the beginning of the focus group meeting exposed many of the important common challenges to target for improvement. Figure 4 shows the most important issues were "overhead reaching", "far reaches", and "meat cases".

Figure 4. The ergonomics issues brought up in the discussion. The number of dots indicates each issue's priority as assigned by participants.

In the brainstorming phase of the focus group meeting, the participants proposed solutions addressing these issues. Figure 5 shows several of the sketches created in the session. Sketches a – e focused on ways to reduce the reach distance and overhead reaching by bringing the products closer to the selector by either using turntables (Figures 5 a, b, d), by presenting products on pallets in flow-racks that could be broken down into smaller units as product is removed (Figure 5c), or by changing the organization of the warehouse so that each slot could be picked from two sides (Figure 5e). The concept of raising items in the slots by means of lift-tables or some other similar device was sketched in Figure 5f. Others focused on ways to reduce the manual lifting of heavy cases by proposing the use of automated or semi-automated case selection equipment (Figures 5g and 5i). The concept of incorporating a lift assist into a pallet jack was developed in Figure 5h. The height of the pallet jack was addressed in Figure 5j by having a pallet jack rise far enough off the floor that the bending would be eliminated when placing items on the pallet.

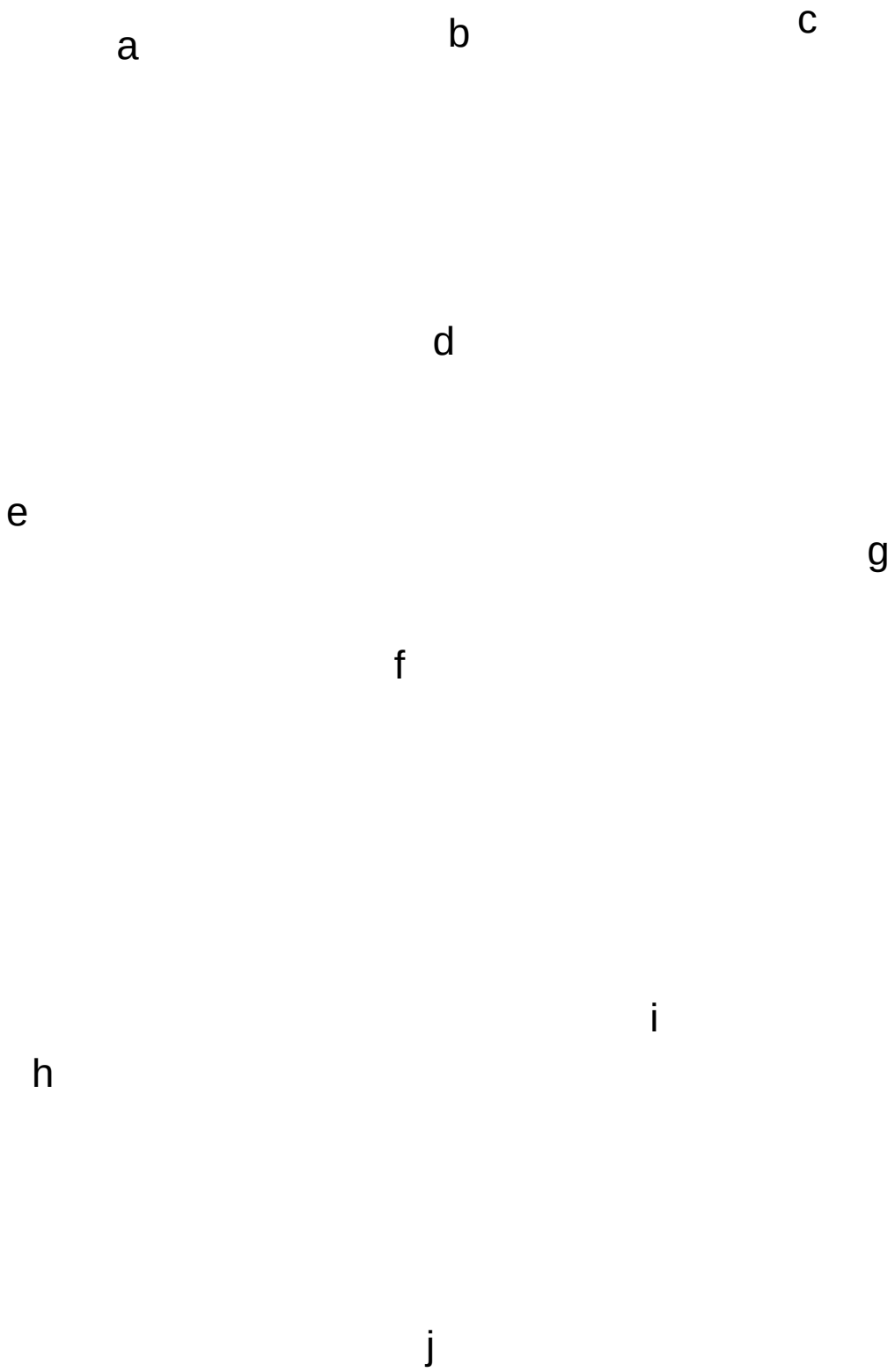

Figure 5. The concepts sketched during the sketch and pass brainstorming component of the focus group session for grocery DCs.

Figure 3. Sketches created by participants during brainstorming session.

Usability discussions indicated there could be challenges associated with each of these ideas. For example, rotating a rectangular pallet with a rack system, while desirable, is not really feasible unless the racking system is set up with excess space between pallets (racking for two pallets would need to have a 126 wide face, or in other words, nearly the space for three pallets). Keeping in mind the objective of the approach, the investigators explored different ways product could be more easily accessed. This was the basis for the pick hooks, the pallet cart, and the flow pallet concepts that arose from our analysis of the Stage 1 and Stage 2 processes. Finding ways to ease the handling of heavy material was also a theme that emerged from this session. This was the origin of the higher raising pallet jack and pallet jack mounted lift assist concepts.

Initial Concepts for Grocery DCs – Discussion and stakeholder assessment

Pick Hooks. Pick hooks are a simple tool for accessing product that is located beyond one's easy reach zone. While pick hooks are not new, they are not widely used in grocery distribution centers. We believe this is due, at least in part, to the cost of purchasing or fabricating hooks, and potential workplace violence concerns. Some facilities reported that they had previously used them, but over time they had disappeared and had not been replaced. Many of these had been fabricated out of rebar or metal electrical conduit material. We explored the use of PVC electrical conduit to make these hooks and found that each hook could be fabricated for less than one dollar. Figure 6 shows two examples of these hooks. In addition, given their plastic construction, we believe the workplace violence concerns are significantly reduced.

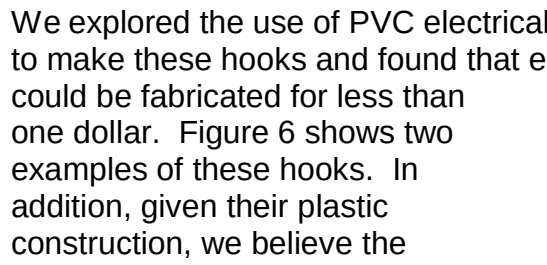

Fig. 6. Two styles of pick hooks, fabricated from electrical PVC.

Results from the survey sent to the focus group participants indicated that the pick hook concept addresses the identified need. Moreover, most of the respondents thought that workers would want to use this tool, assuming it does not adversely affect productivity. Most also thought it would facilitate quicker picks, however, there were mixed opinions as to the impact on product damage due to spillage (Figure 7).

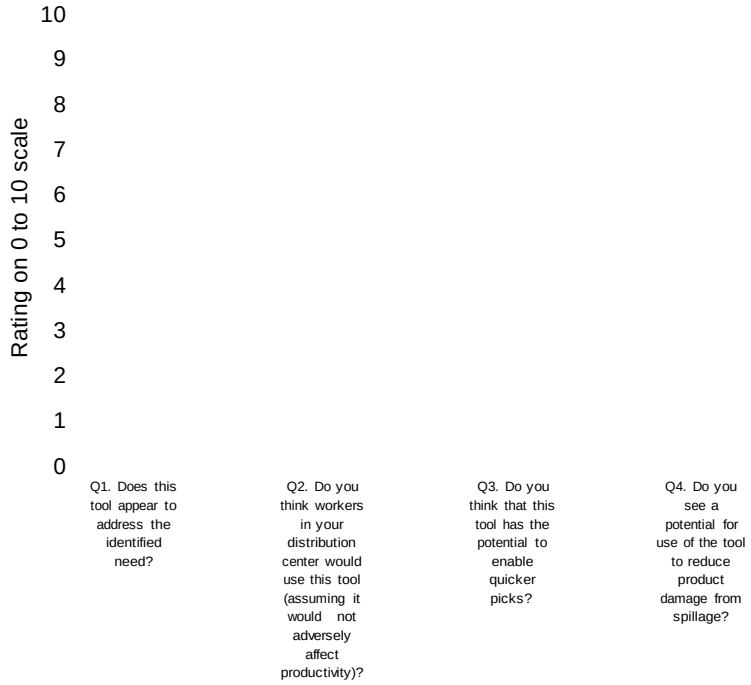

Figure 7. Survey response from focus group participants regarding the Pick Hook concept. (On the rating scale, 0=no, 10=yes).

Feedback on the pick hook from the hourly employees who participated in the small group interviews is summarized in Tables 4 and 5 for the dry grocery selectors and the perishable/meat selectors, respectively.

Table 4. Feedback on pick hook concept, from hourly employees who work as dry grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this type of pick hook would be easy to use.			*1*	*3*	*6*
2. I think the weight of the pick hook is acceptable.				*2*	*7*
3. I can comfortably grip this pick hook.				*3*	*5*
4. I think the demonstrated pick hooks are long enough.				*4*	*5*
5. I think this pick hook is durable and will work for handling our merchandise.		*1*		*4*	*3*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pick hook can reduce the time to pick products.		*1*	*5*	*2*	*2*
2. I believe that using this pallet jack would make my work easier.		*2*		*4*	*2*
3. I believe this pallet jack will help me perform my selection tasks more efficiently.		*2*	*3*	*2*	*1*
4. I believe this pallet jack will allow me to be less tired at the end of each work day.		*3*	*2*	*1*	*2*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pick hook.		*1*	*5*	*2*	*2*
2. I would like to try this type of pick hook.			*3*	*3*	*4*
3. I think some of my co-workers would want to use this type of pick hook.			*3*	*3*	*4*
4. I really need this pick hook for 2nd tier products in my warehouse.	*1*		*2*	*5*	*2*

Table 5. Feedback on pick hook concept, from hourly employees who work as meat/perishable grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this type of pick hook would be easy to use.			*2*	*3*	*5*
2. I think the weight of the pick hook is acceptable.				*3*	*7*
3. I can comfortably grip this pick hook.				*5*	*5*
4. I think the demonstrated pick hooks are long enough.			*4*	*3*	*3*
5. I think this pick hook is durable and will work for handling our merchandise.		*2*	*1*	*3*	*4*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pick hook can reduce the time to pick products.	*2*		*3*	*3*	*2*
2. I believe that using this pallet jack would make my work easier.		*2*	*1*	*5*	*2*
3. I believe this pallet jack will help me perform my selection tasks more efficiently.		*2*	*1*	*5*	*2*
4. I believe this pallet jack will allow me to be less tired at the end of each work day.	*1*		*6*	*2*	*1*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pick hook.	*1*		*3*	*4*	*2*
2. I would like to try this type of pick hook.	*1*		*3*	*4*	*2*
3. I think some of my co-workers would want to use this type of pick hook.			*3*	*5*	*2*
4. I really need this pick hook for 2nd tier products in my warehouse.			*4*	*3*	*3*

In general, these data indicate that most believe that the pick hooks made from PVC electrical conduit would be a usable, useful, and desirable intervention for use in grocery DCs. Nearly all of the hourly participants indicated they would like to try using them. Similarly, the managers and supervisors who also filled in the hourly employee survey strongly projected that their employees would find the hooks useful and easy to use. Just prior to the writing of this report, we left some sample pick-hooks at a grocery distribution operation so that they could try them out. We expect to be receiving feedback in a week or two.

Pallet Cart. As an alternative to the turntable approach proposed by some of the Stage 1 focus group participants, the research team explored the development and use of a "pallet cart". Standard pallets in lower tier slots would be placed on these 6-wheeled carts, rather than on the floor. When the front half of the material had been picked away, the cart could be easily pulled forward out of the rack, rotated 180 degrees, and pushed back into the rack (the slot), therein bringing the product remaining on the pallet also to the new front of the pallet, for easier picking. These carts, designed by Hamilton Caster (figure 8), have handles that raise and lower and which facilitate moving the cart. A set of brakes allows the cart to hold its position in the slot during product selection or pallet replenishment.

Figure 8. Pallet cart concept created through collaboration with Hamilton Caster Company.

Focus group participants' survey responses were mixed as to whether this concept met the identified need, whether their workers would want this equipment, or whether it would facilitate easier access for sanitary functions (clean-up) (Figure 9).

Responses from the hourly employees, to the pallet cart concept, are shown in tables 6 and 7 for the dry grocery and meat/perishable participants, respectively.

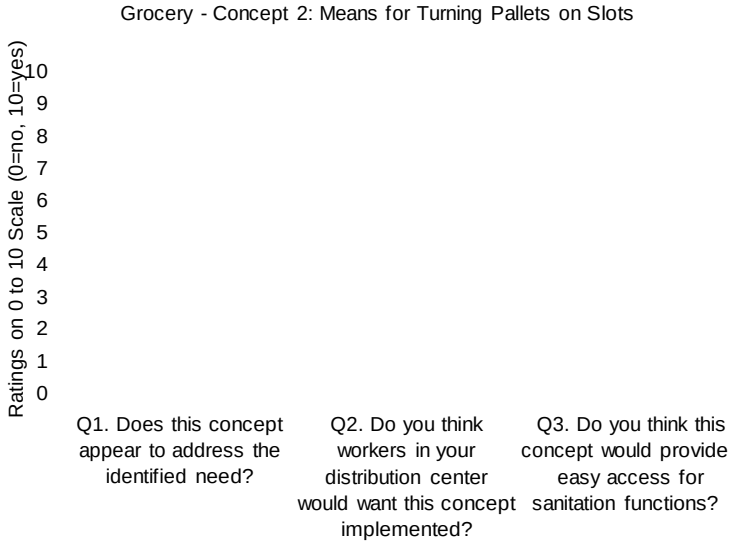

Figure 9. The survey response from focus group participants regarding the pallet cart concept.

Table 6. Feedback on pallet cart concept, from hourly employees who work as dry grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the handle is at the right height for me.	*1*	*1*	*3*	*4*	*1*
2. I think it would be easy to turn pallets on this cart.			*4*	*5*	*1*
3. I imagine that most people would learn to use this pallet cart very quickly.		*2*	*1*	*6*	*1*
4. I think this pallet cart will roll easily on our floor.			*3*	*4*	*3*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet cart would help me access boxes that are now at the back of the pallet			*1*	*4*	*5*
2. I believe that using this pallet cart would make my work easier.	*1*	*2*	*3*	*2*	*2*
3. I believe this pallet cart will help me perform my selection tasks more efficiently.	*1*	*2*	*2*	*4*	*1*
4. I believe this pallet cart will allow me to be less tired at the end of each work day.	*1*	*3*	*3*	*2*	*1*
5. I think it would be easier for people to clean the floor if this pallet cart were available.		*1*	*1*	*4*	*4*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet cart concept.	*1*	*2*	*3*	*4*	
2. I would like to try this pallet cart.		*2*	*2*	*4*	*2*
3. I think some of my co-workers would want to use this pallet cart.		*1*	*2*	*6*	*1*
4. I really need this pallet jack for select locations in my warehouse.	*1*	*3*	*1*	*2*	*3*
5. I would like to see us turn pallets using this pallet cart.	*1*	*2*	*2*	*4*	*1*

Table 7. Feedback on pallet cart concept, from hourly employees who work as meat/perishable grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the handle is at the right height for me.		*3*	*2*	*2*	*3*
2. I think it would be easy to turn pallets on this cart.			*4*	*3*	*2*
3. I imagine that most people would learn to use this pallet cart very quickly.			*2*	*7*	*1*
4. I think this pallet cart will roll easily on our floor.		*2*	*3*	*4*	*1*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet cart would help me access boxes that are now at the back of the pallet		*1*		*8*	*1*
2. I believe that using this pallet cart would make my work easier.		*3*	*3*	*3*	*1*
3. I believe this pallet cart will help me perform my selection tasks more efficiently.		*3*	*4*	*2*	*1*
4. I believe this pallet cart will allow me to be less tired at the end of each work day.	*2*	*3*	*4*		*1*
5. I think it would be easier for people to clean the floor if this pallet cart were available.		*2*	*1*	*3*	*4*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet cart concept.		*2*	*6*	*2*	
2. I would like to try this pallet cart.		*2*	*3*	*4*	*1*
3. I think some of my co-workers would want to use this pallet cart.		*1*	*5*	*3*	*1*
4. I really need this pallet jack for select locations in my warehouse.	*2*	*2*	*3*	*2*	*1*
5. I would like to see us turn pallets using this pallet cart.		*3*	*4*	*2*	*1*

Both the dry grocery and meat/perishable hourly employees reported that they thought the cart would be relatively easy to use. In general, while most thought it would be useful, there was a mixed response with regards to the desirability questions. More of the dry grocery employees were interested in trying the cart, compared with the perishable employees who were clustered around the mid-point of the response scale. Concerns expressed during the review sessions focused on who would actually be turning the pallets, and if it was the selectors, would time be allocated in the work

standards system. Additionally, given that this discussion was conducted without the benefit of a physical prototype at hand, there were questions regarding just how hard would it be to move the carts and how long would it take to complete a pallet rotation.

The supervisory staff also indicated a mixed response to this concept, again clustering around the mid-point of the scales. During the discussion there were concerns raised regarding the accuracy required by the replenishment drivers, in order to avoid damaging the cart.

Flow Pallet. The flow pallet concept was developed by the research team in response to the expressed desire, expressed by some of the focus group participants, to bring product forward in second tier slots (making it more easily accessible to selectors). While the original concepts proposed included turntables and break-away pallets, our team looked into other alternatives that might be more feasible, given productivity and space constraints. Out of this process, the flow pallet concept evolved.

The concept begins with a metal pallet that contains a wide conveyor belt built in (Figure 10). The belt is advanced with a ratcheting lever handle located on either one or both sides of the pallet. The flow pallets would be loaded at the receiving dock by shifting the inbound freight from its original pallet to the flow pallet with a clamp truck. When the pallet is in the pick slot, an employee could move product forward by pulling the ratcheted handle. It is likely that the product on the pallet would move between 6 and 8 inches with a single handle pull. A spring mechanism would keep the handle oriented so that it would not project into the pick aisle.

Figure 10. The flow pallet concept is a specialized pallet that contains a conveyor mechanism to shift product forward during the selection process. In the rack, product is shifted forward by operating a ratcheting lever located on the side of the pallet.

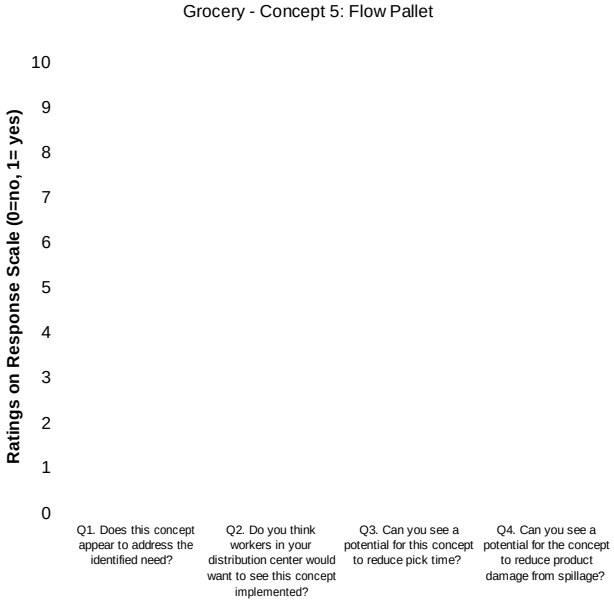

Figure 11. The survey responses from the focus group participants to the flow pallet concept.

In general most of the focus group survey respondents agreed that the flow pallet concept met the identified need (figure 11). Most though it would reduce pick times and 4 out of 6 indicated that they thought their employees would like to see this concept

implemented. There was uncertainty as to whether this concept would reduce product damage from spillage. Additional concerns focused on the how the ratchet lever will work and how this would impact work flow on the receiving dock as now a clamp truck operation will be required.

The employees in the dry grocery operation thought that the usability was would be adequate if the convey shifted product about 6 inches with each pull of the lever and that the location of the lever was adequate (Table 8). Moreover, most either agreed or strongly agreed that this concept would be useful. Likewise, most indicated a desire to use this concept. Interestingly, the employees from the meat/perishable operation were less excited about this intervention concept as evidenced by more neutral and few strongly agree scores on the usability, usefulness, and desirability scales (Table 9).

The supervisory staff's response followed that of the meat/perishable employees, with modest agreement and a majority of them indicating a neutral response. Their issues with this concept were primarily focused on maintenance and replenishment. There was concern about how much preventative maintenance would be required to keep the conveyor operating smoothly. Likewise, there were questions about how well these flow pallets would hold up to the regular use and handling that occurs in a grocery DC, in particular in the moist produce areas. The other major concern was what would be done with the pallet once it is removed during a replenishment operation. It was agreed there would probably have to be slots that served as flow pallet banks where these could be stacked and stored until there were enough to warrant a trip to the receiving dock.

Table 8. Feedback on flow pallet concept, from hourly employees who work as dry grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the location of the lever is ok.			*2*	*4*	*4*
2. I think it would be adequate if the product moved 6 inches for every lever pull.			*3*	*3*	*4*
3. I imagine that most people would learn to use this flow pallet very quickly.			*2*	*4*	*4*
4. I think ratcheting the lever would not really slow me down.		*2*	*2*	*2*	*4*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this flow pallet can reduce the picking time.			*3*	*4*	*3*
2. I believe that this flow pallet could make my work easier.			*1*	*4*	*5*
3. I believe this flow pallet will help me perform my selection tasks more efficiently.			*2*	*5*	*3*
4. I believe this flow pallet will allow me to be less tired at the end of each work day.			*3*	*4*	*3*
5. I believe this flow pallet has the potential to reduce product damage.		*1*	*3*	*3*	*3*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this flow pallet.			*3*	*3*	*4*
2. I would like to try this flow pallet.			*1*	*3*	*6*
3. I think some of my co-workers would want to use this flow pallet.			*1*	*5*	*4*
4. I would like to see us obtaining products in 2nd tier slots using this flow pallet.			*2*	*3*	*5*

Table 9. Feedback on flow pallet concept, from hourly employees who work as meat/perishable grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the location of the lever is ok.			*5*	*5*	
2. I think it would be adequate if the product moved 6 inches for every lever pull.			*4*	*6*	
3. I imagine that most people would learn to use this flow pallet very quickly.			*3*	*4*	*3*
4. I think ratcheting the lever would not really slow me down.		*2*	*3*	*4*	*1*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this flow pallet can reduce the picking time.			*8*	*1*	*1*
2. I believe that this flow pallet could make my work easier.			*5*	*4*	*1*
3. I believe this flow pallet will help me perform my selection tasks more efficiently.		*1*	*6*	*3*	
4. I believe this flow pallet will allow me to be less tired at the end of each work day.		*1*	*8*	*1*	
5. I believe this flow pallet has the potential to reduce product damage.		*1*	*3*	*3*	*2*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this flow pallet.		*1*	*7*	*2*	
2. I would like to try this flow pallet.			*4*	*6*	
3. I think some of my co-workers would want to use this flow pallet.			*3*	*7*	
4. I would like to see us obtaining products in 2nd tier slots using this flow pallet.			*4*	*3*	*3*

Elevated Pallet Jacks for Product Selection. The concept of raised pallet jacks was explored based upon an initial concept sketched during the focus group process (figure 5j). In that sketch, the focus group participant was suggesting that the two pallets be able to move independently. Our team looked into this concept and found that while this may be possible if one went with a train of pallet carts, there were no equipment vendors making independently adjusting pallets. The train of pallet carts, while possibly a viable approach, would potentially require a forklift to unload the train at the shipping dock. Alternatively, one could conceive of a system using a roller conveyor at each dock door onto which the pallets could be manually rolled, providing the pallet carts of the train and the conveyor were matched in height. If the concept was instead shifted such that both pallets are raised or lowered simultaneously, then the Atlet double pallet jack (Figure 12) could be considered a viable option. While this approach is more limited in its ergonomic appeal, compared with the independent pallet height adjustments, the Atlet option would appear to be easier to implement in an existing distribution system. That said, however, the use of the Atlet equipment is predicated on the availability of open bottomed pallets. Traditional double sided wood pallets will not work with this equipment.

Figure 12. The Atlet elevated double pallet jack.

Five of the six grocery focus group respondents indicated in their survey responses that the raising double pallet jack appears to address the identified needs (Figure 13). Most agreed the workers in their DC would want to use this equipment. However, opinions were split as to whether this equipment would help employees be more productive. In general, the respondents did not believe this equipment would reduce product damage.

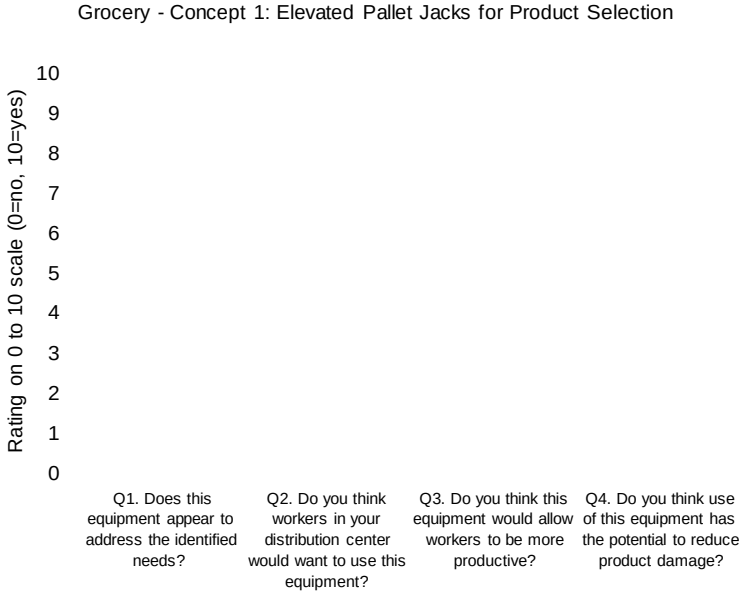

Figure 13. The survey responses from the grocery focus group participants to the elevated double pallet jack (Atlet).

Dry grocery hourly employees rated the usability, usefulness, and desirability of the elevated double pallet jack higher than their counterparts that worked in the meat/perishable

warehouse (Tables 10 and 11). With regards to usability the meat/produce selectors were more concerned about the time required to adjust the height of the forks. Both groups, however, generally agreed that the elevated pallet jack may potentially reduce the amount of bending they experience while working. Sixty percent of the dry grocery respondents either agreed or strongly agreed that the elevated pallet jack would make their work easier, whereas only 30 percent of the meat/perishable selectors agreed or strongly agreed with this same statement. While 65 percent of all the selectors across both groups indicated they would be willing to try the equipment, only 25 percent thought they would benefit from the use of this equipment. During the discussion, some expressed concerns regarding overall stability of the equipment. Others were concerned about the amount of time it might take to raise or lower the forks and where the up/down controls were located. Some thought that the elevated forks would require more walking. Since they pick both sides of the aisle, they would have to walk around the forks rather than stepping over the pallets.

The group of managers and supervisors, while rating this concept more positively than the hourly employees with regard to usability and usefulness, were clustered around the neutral scores on the desirability measures. Their concerns were largely focused on pallet flow and stability.

Table 10. Feedback on the elevated double pallet jack (Atlet), from hourly employees who work as dry grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack would be easy to maneuver.	*1*	*2*	*4*	*1*	*2*
2. I think changing the forks' height with this pallet jack would be easy.			*1*	*4*	*5*
3. I imagine that most people would learn to use this pallet jack very quickly.	*1*	*1*	*1*	*4*	*3*
4. I think that changing this pallet jack to the right height will not significantly waste our work time.		*3*	*2*	*2*	*3*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack can reduce the time I spend bending at work.			*1*	*2*	*7*
2. I believe that using this pallet jack would make my work easier.			*4*	*3*	*3*
3. I believe this pallet jack will help me perform my selection tasks more efficiently.		*2*	*4*	*2*	*2*
4. I believe this pallet jack will allow me to be less tired at the end of each work day.		*2*	*4*	*3*	*2*
5. I believe this pallet jack has the potential to reduce product damage.	*1*	*1*	*6*		*1*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet jack.		*1*	*6*		*3*
2. I would like to try this pallet jack.			*4*		*6*
3. I think some of my co-workers would want to use this pallet jack.		*1*	*2*	*4*	*3*
4. I really need this pallet jack for certain products in my warehouse.	*1*	*2*	*3*	*2*	*2*
5. I would like to see us loading pallets with this pallet jack.		*2*	*4*	*2*	*2*

Table 11. Feedback on the elevated double pallet jack (Atlet), from hourly employees who work as meat/perishable grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack would be easy to maneuver.	*1*	*1*	*6*	*1*	*1*
2. I think changing the forks' height with this pallet jack would be easy.	*1*	*1*	*3*	*3*	*2*
3. I imagine that most people would learn to use this pallet jack very quickly.			*2*	*5*	*3*
4. I think that changing this pallet jack to the right height will not significantly waste our work time.	*3*	*3*	*1*	*3*	

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack can reduce the time I spend bending at work.		*1*	*2*	*3*	*4*
2. I believe that using this pallet jack would make my work easier.	*1*	*3*	*3*	*3*	
3. I believe this pallet jack will help me perform my selection tasks more efficiently.		*6*	*2*	*1*	*1*
4. I believe this pallet jack will allow me to be less tired at the end of each work day.	*2*	*3*	*4*		*1*
5. I believe this pallet jack has the potential to reduce product damage.	*1*	*1*	*6*	*1*	

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet jack.	*3*	*1*	*4*	*2*	
2. I would like to try this pallet jack.	*2*		*1*	*4*	*3*
3. I think some of my co-workers would want to use this pallet jack.			*5*	*3*	*2*
4. I really need this pallet jack for certain products in my warehouse.	*3*	*2*	*3*	*1*	*1*
5. I would like to see us loading pallets with this pallet jack.	*3*	*1*	*4*	*1*	*1*

Pallet Jack Mounted Lift Assist. One of the concepts sketched during the brainstorming session was a pallet jack mounted lift assist (Figure 5h). The objective of this concept was to reduce the physical demands associated with grocery selection, particularly when selecting heavier products. A large part of the challenge when designing lift assists is selecting the appropriate end-effector. Different types of end-effectors were considered in the discussion following the presentation of this concept, including vacuum lifts. Questions included how well vacuum lifts would hold and how fast they would operate. Other clamp-type end-effectors were considered by the group to be slow and not really feasible, given the variety of the sizes of boxes that are handled in grocery DCs. Through MHIA, the research team was introduced to a product being developed by Gebhardt. This pallet jack mounted lift assist works by applying the lift force to the selector's arms while the products are grasped by the selector's hands (Figure 14). A thumb switch mounted on the gloves signals the unit when to lift.

The survey sent to the focus group participants indicated that most believed this equipment meets the identified need (Figure 15). However, most were unsure about whether their employees would want to use this equipment. Likewise, they were also unsure regarding the impact on product damage. Additional comments written on the surveys indicated the respondents had questions about productivity in fast-paced distribution centers and usability concerns when the equipment is integrated into an environment with racked slots, as opposed to the open slots as shown in figure 14.

When this intervention concept was shown to the employees, several expressed reservations about being tethered to the equipment, and many had questions about the control process. These questions were difficult for the research team to address because we have not yet worked with the equipment and the audio on demonstration video is in German.

Figure 14. The Eco-pick pallet jack mounted lift assist produced by Gebhardt.

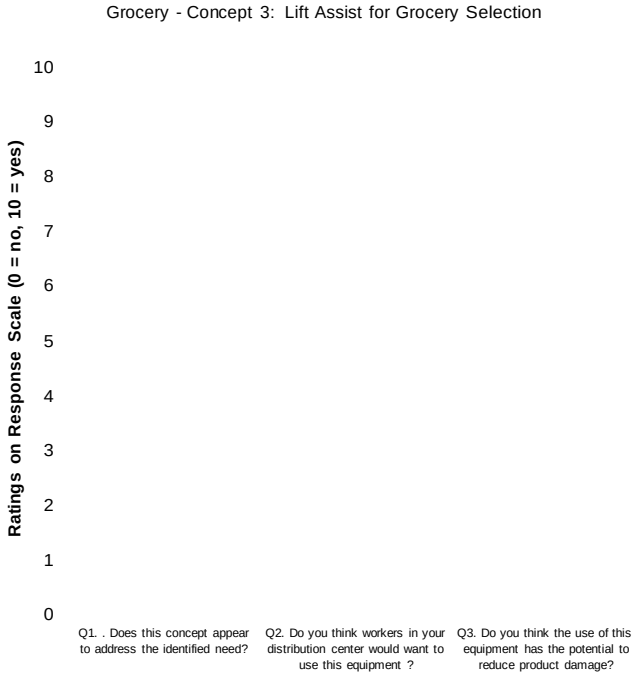

Figure 15. The survey responses from the grocery focus group for the pallet jack mounted lift assist.

Overall, most of the dry grocery selectors expressed negative reactions towards the usability, usefulness, and desirability of this equipment (Table 12). The responses were more varied amongst the meat/perishable selectors (Table 13), with more of these employees, especially those that move cases of meat, being interested in trying the concept.

The managers and supervisors tended to see the usefulness of the equipment although had their reservations regarding the usability in their environment. Hence, they ratings of desirability were clustered around the neutral response.

Table 12. Feedback on the pallet jack mounted lift assist (Gebhardt), from hourly employees who work as dry grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this lift assist would be easy to operate.		*5*	*4*	*1*	
2. I think wearing this equipment on my hands will not significantly limit my movements.	*3*	*3*	*4*		
3. I imagine that most people would learn to use this lift assist very quickly.	*1*	*8*	*1*		
4. I think this lift assist will allow me do get my work done on time.	*2*	*6*	*1*	*1*	

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I believe that using this lift assist would make my work easier.	*1*	*4*	*3*	*1*	*1*
2. I believe this lift assist will help me perform my selection tasks more efficiently.	*2*	*6*	*1*	*1*	
3. I believe this lift assist will allow me to be less tired at the end of each work day.	*1*	*3*	*3*	*2*	*1*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this lift assist.	*2*	*6*	*2*		
2. I would like to try this lift assist.	*1*	*4*	*3*	*1*	*1*
3. I think some of my co-workers will want to use this lift assist.		*3*	*4*	*3*	
4. I really need this lift assist for certain products in my warehouse.	*2*	*6*	*1*	*1*	

Table 13. Feedback on the pallet jack mounted lift assist (Gebhardt), from hourly employees who work as meat/perishable grocery selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this lift assist would be easy to operate.	*3*	*3*	*3*	*1*	
2. I think wearing this equipment on my hands will not significantly limit my movements.	*3*	*5*	*1*	*1*	
3. I imagine that most people would learn to use this lift assist very quickly.	*4*	*3*	*1*	*2*	
4. I think this lift assist will allow me do get my work done on time.	*3*	*1*	*2*	*4*	

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I believe that using this lift assist would make my work easier.	*2*	*3*	*2*	*2*	*1*
2. I believe this lift assist will help me perform my selection tasks more efficiently.	*3*	*3*	*3*	*1*	
3. I believe this lift assist will allow me to be less tired at the end of each work day.	*2*		*3*	*2*	*2*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this lift assist.	*2*	*3*	*4*		*1*
2. I would like to try this lift assist.	*1*	*1*	*3*	*3*	*2*
3. I think some of my co-workers will want to use this lift assist.	*1*	*1*	*4*	*1*	*3*
4. I really need this lift assist for certain products in my warehouse.	*3*	*1*	*3*	*2*	*1*

FINDINGS FROM GENERAL MERCHANDISE DISTRIBUTION

Stage 1 - Participants. Eight individuals representing management and safety functions from five distribution organizations participated in a single 3-hour focus group session. All signed informed consent documents. Experience with distribution centers ranged from 10 to 38 years (average = 20 years).

Stage 1 – Findings. Prior to the meeting, individual focus group participants interviewed a total of 9 DC employees with reported experience levels ranging between 4 and 31 years. The interviewed employees worked in DC's that distribute office furniture,
general merchandise for retail sales, and text books. Collectively, the employees who were interviewed indicated the heavier and bulkier items passing through their DC were most difficult to handle. These included files cabinets, heavy cases of books, swing sets, grills, boxed furniture, bikes, treadmills, and pools. On average, just over 17 percent of the items they handled were considered by these employee to be "too heavy". The interviewed employees estimated approximately a quarter of the items they handle are picked-up or placed above shoulder height and about a third of the items are handled below knee height.

The discussion of issues at the beginning of the focus group meeting exposed many of the important common challenges to target for improvement. Figure 16 shows the most important issues were "overhead lifting", "handling heavy or oversized objects – including seasonal items", "reaching to the back of pallets" and "loading boxes of various sizes".

Figure 16. The ergonomics issues brought up in the discussion at the general merchandise focus group meeting. The number of dots indicates each issue's priority as assigned by participants.

In the brainstorming phase, the participants proposed solutions addressing these issues. Figure 17 shows several of the sketches created in the session. Sketch "a" focused on providing a lifting assist on a pallet jack for helping with heavier objects that must be handled. Sketch "b" suggests ways of sliding heavy objects, such as file cabinets, into place when loading trucks. Sketches "c" and "f" introduce the concept of having a pallet jack rise far enough off the floor that bending on the part of employees would be eliminated when placing items on the pallet. Sketches "d" introduced the concept of a depalletizing station with an adjustable lift/turn table for the incoming freight. Sketch "g" shows a person loading outbound trailers on stilts, similar to those used in construction trades, so they can reach the upper parts of the trailer without having to reach overhead. Sketch "h" shows a personal lift assist device that would be worn by the worker to increase the worker's strength and lower biomechanical loads transmitted through the body. Sketch "i" shows the use of a turntable to bring product forward in a rack. Sketch "j" shows a handtruck type of device

with an extending, height-adjustable shelf that could facilitate the loading of flow racks without actually lifting the cartons. This would be particularly useful when cartons need to be lifted over conveyors or other obstructions. Sketch “k” shows the use of a tool designed to help lift heavier, awkward containers. Sketch “L” shows a vacuum lift depalletizing station used for breaking down pallets with mixed product onboard.

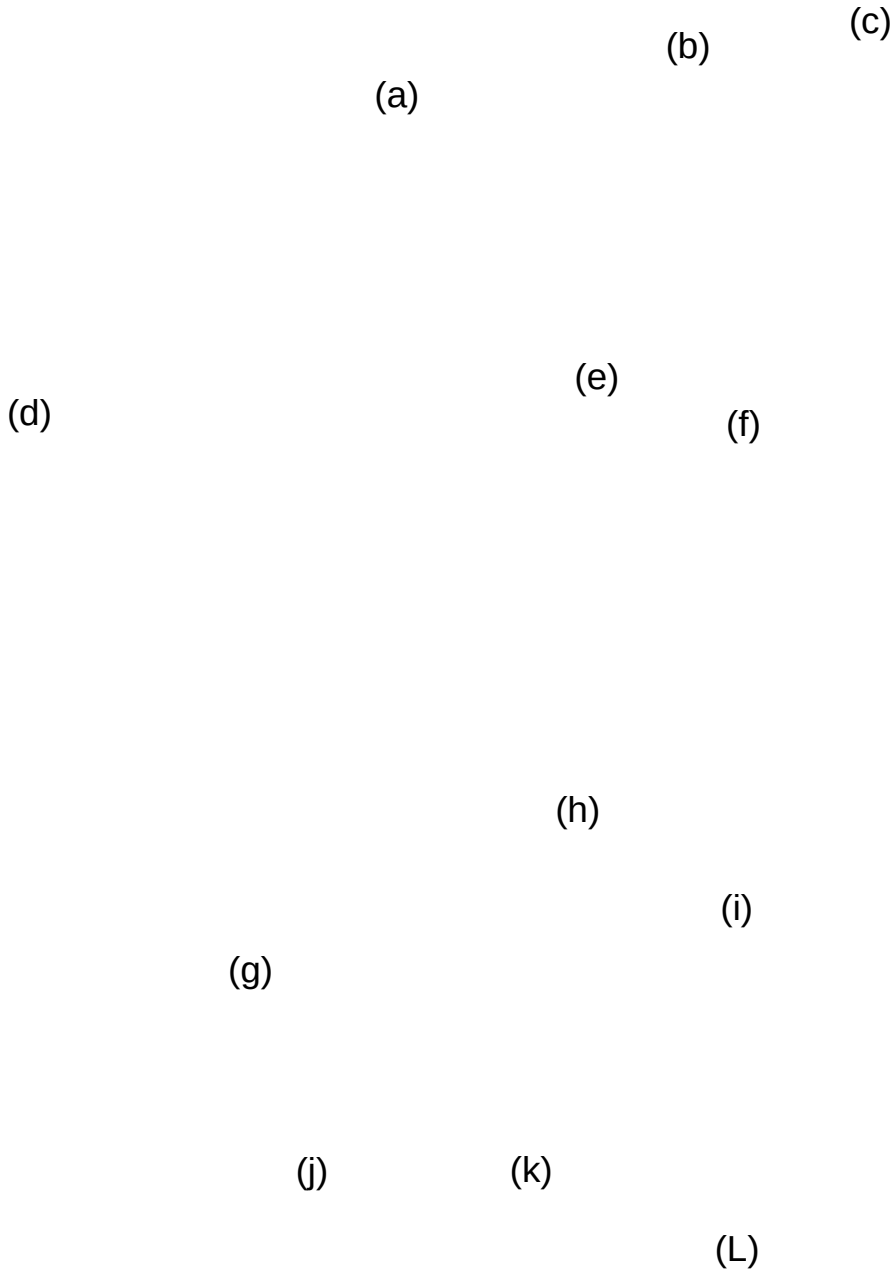

Figure 17. The intervention concept sketches created by the participants in the general merchandise focus group session.

Discussion of usability identified some of the barriers associated with the various ideas. For example, it was felt that the stilts would compromise an employee's stability during fast-paced material handling tasks, such as trailer loading. Moreover, stilts may induce a worker to twist more and step less (a poor trade-off, from a biomechanical standpoint). Other concepts, such as the personal lift assist device, may not be ready for the dynamic day to day requirement of distribution center work, although such ideas are being explored in agricultural settings to offset the strain on the tissues during prolonged flexed postures during harvests. If interested in these types of devices, the reader can look at the work of Abdoli, Agnew, and Stevenson (2006).

Based upon usability discussions and feasibility considerations we will explore, in more detail, the following concepts for handling general merchandise in DCs: the elevated pallet jack, pallet jack mounted lift assist, vacuum lift equipment for loading and unloading trailers, vacuum lift equipment for breaking down mixed freight pallets, the pallet breakdown station with lift and turn table, pallet cart, and flow pallet.

Initial Concepts for Handling General Merchandise – Discussion and stakeholder assessment

Elevated Pallet Jack. As in the grocery focus group session, the concept of raised pallet jacks was explored based upon sketches made during the Stage 1 focus group process (figures 17 c and f). Again, the Atlet raising double pallet jack (Figure 18) seems consistent with the expressed concept. As a reminder, pallets with open bottoms are required to accommodate the scissors mechanism.

Figure 18. Pallet jack with adjustable height currently in the market by Atlet Company.

The evaluation survey mailed to focus group participants showed that most of the respondents believed the elevated pallet jack met the identified need. Those who thought so also thought their workers would want to use this equipment. Four of the six respondents anticipated positive effects on productivity and product damage, while the other two were neutral in their expectations (Figure 19).

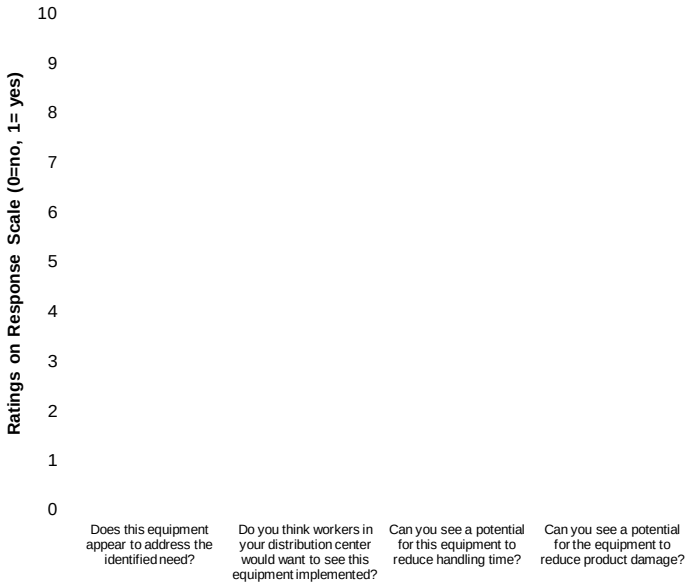

Figure 19. Survey response from focus group participants regarding the Elevated Pallet Jack. Rating scale: 0=no, 10=yes.

Hourly employees' assessments of this concept were obtained from employees working in the non-conveyable area of a large retail general merchandise DC. Their evaluations are summarized in Table 14. Approximately 2/3rds of the 16 participants in these small group interviews agreed with the survey's statements regarding the elevated pallet jack's usability, including the ease of use. About the same proportion indicated that this equipment would make their work easier. Approximately ¾ of the employees perceived that this equipment would help reduce their bending and would lessen their fatigue at the end of the day. A similar proportion indicated they would like to try this pallet jack.

Table 14. Feedback on the elevated pallet jack, from hourly employees who work as non-conveyable product selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack would be easy to maneuver.			*6*	*5*	*5*
2. I think changing the forks' height with this pallet jack would be easy.			*4*	*6*	*6*
3. I imagine that most people would learn to use this pallet jack very quickly.		*1*	*1*	*6*	*8*
4. I think that changing this pallet jack to the right height will not significantly waste our work time.	*1*		*3*	*7*	*5*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet jack can reduce the time I spend bending at work.		*2*	*1*	*2*	*11*
2. I believe that using this pallet jack would make my work easier.		*2*	*4*	*2*	*8*
3. I believe this pallet jack will help me perform my selection tasks more efficiently.	*1*	*1*	*6*	*5*	*3*
4. I believe this pallet jack will allow me to be less tired at the end of each work day.		*1*	*1*	*6*	*7*
5. I believe this pallet jack has the potential to reduce product damage.		*1*	*5*	*3*	*7*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet jack.		*1*	*8*	*1*	*6*
2. I would like to try this pallet jack.			*4*	*3*	*9*
3. I think some of my co-workers would want to use this pallet jack.			*2*	*6*	*8*
4. I really need this pallet jack for certain products in my warehouse.		*1*	*5*	*2*	*8*
5. I would like to see us loading pallets with this pallet jack.			*7*	*3*	*6*

A discussion with the managers yielded several interesting comments. The biggest concern were the reverse logistics issues associated with getting plastic (bottomless) pallets returned to the DC. Most acknowledged that sliding (the advantage predicted by the hourly employees) could be better than lifting, especially with some of the heavier items. There were also concerns about the stability of the pallet jack when the forks are raised. It is important that the jack can accommodate two pallets at once, as the products handled by non-con employees sometimes do not fit on a single pallet.

Pallet Jack Mounted Lift Assist. Consistent with the sketch concept shown in figure 17a, the research team explored options for a pallet jack mounted lift assist. Rather than the Gebhardt equipment described in the grocery intervention section of this report, a vacuum lift was considered to be a better alternative due to the weight and size of the products handled by non-conveyable selectors. Gorbel offered to assist us in further developing this concept. This device would be attached to a double pallet jack and should still enable the transport of two pallets (Figure 20). It would be powered by the pallet jack's battery. The double-jointed support arm would allow the lift to reach anywhere in the two pallet region and up to 6 feet to either side of the pallets. Clearly speed is important for this type of equipment. However, one must compare this with the time it takes, currently, to load the more physically challenging items, such as swing sets, grills, furniture, treadmills, and large televisions.

Figure 20. Pallet jack mounted lift assist. concept created through collaboration with Gorbel Company.

Focus group participants, responding to the evaluation survey, indicated that the proposed equipment appears to meet the identified need (Figure 21). Moreover, most respondents indicated that their employees would want to use this type of equipment. While opinions about handling time were generally favorable, most of the respondents indicated that the lift assist would likely reduce product damage.

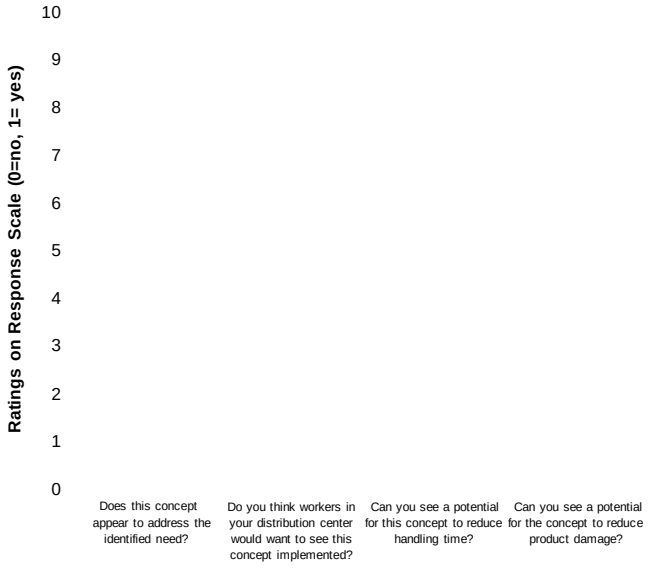

Figure 21. Survey response from focus group participants regarding the Pallet Jack Mounted Lift Assist.

Approximately 2/3^{rds} of the hourly employees who participated in the small group interviews thought the equipment would be usable (Table 15). A majority indicated that they thought the equipment would be useful, however, there were many respondents

who were unsure. As for desirability, there was generally a positive response, again, though with several individuals being unsure. The follow-up discussion indicated that their biggest reservation was the amount of time it might take to use this equipment. However, they thought that 30 seconds would be acceptable for some of the heavier items that they handle. If this is longer that the time allocated in the current work standards, then perhaps the standards would need to be adjusted to reflect the use of this type of equipment. There were also concerns about cardboard quality and questions regarding how well the device would work with the different grades of cardboard the DC receives.

Table 15. Feedback on the pallet jack mounted lift assist (with vacuum end-effector), from hourly employees who work as non-conveyable product selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this lift assist would be easy to operate.		*2*	*3*	*5*	*6*
2. I think the vacuum lift will be capable of lifting most of the items we ship.		*3*	*3*	*5*	*5*
3. I imagine that most people would learn to use this lift assist very quickly.		*1*	*6*	*4*	*5*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I believe that using this lift assist would make my work easier.	*1*	*2*	*4*	*5*	*4*
2. I believe this lift assist will help me perform my selection tasks more efficiently.		*3*	*6*	*4*	*3*
3. I believe this lift assist will allow me to be less tired at the end of each work day.	*1*	*1*	*4*	*4*	*6*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this lift assist.		*4*	*5*	*2*	*5*
2. I would like to try this lift assist.		*2*	*5*	*3*	*6*
3. I think some of my co-workers will want to use this lift assist.			*7*	*3*	*6*
4. I really need this lift assist for certain products in my warehouse.		*1*	*6*	*3*	*6*

The assembled management team also had questions about the speed of operation. Like the hourly employees, they brought up concerns about cardboard quality. Although, it was recognized that if a sheet of plastic is packed in the box, directly under the cardboard, then the equipment should still work well. Other issues raised included how well the equipment would work with dusty packages, and as stated above the pallet jack still needs to accommodate two pallets due to the size of some items.

Pallet Cart. The concept of rotating pallets for better access to product was introduced in the brainstorming session by a participant who drew a turntable device that could be mounted in the rack (Fig. 17i). The research team proposed the use of the same pallet cart concept, introduced in the grocery section of this report, for the product handled in the non-conveyable section of a general merchandise operation. The cart concept being developed by Hamilton Caster is shown in Figure 22. Pallets with heavier items that are located either in lower tier or full slots could be placed on a 6-wheeled carts that can be pulled out of the rack, rotated 180 degrees, and pushed back into the rack (the slot) when approximately half of the product has been removed (the front half). This reduces the reach distance and allows for quicker and easier product selection. These carts have handles that raise and lower facilitating pushing and pulling. The cart also has as a set of brakes that allow it to hold its position in the slot during product selection

Figure 22. Pallet cart concept created through collaboration with Hamilton Caster Company.

or pallet replenishment.

Focus group participants generally agreed (mean = 6.2) that this concept met the identified need (Figure 23) and that most likely their employees would want to see this concept implemented. However, there was uncertainty (a mixed range of ratings) as to whether this concept would aid productivity and reduce product damage.

Responses to the pallet cart concept from small group interviews with hourly employees who work as non-conveyable order selectors are shown in Table 16. A majority indicated that they believed the cart would be easy to use. Slightly more than half either agreed or strongly agreed with the statements concerning the

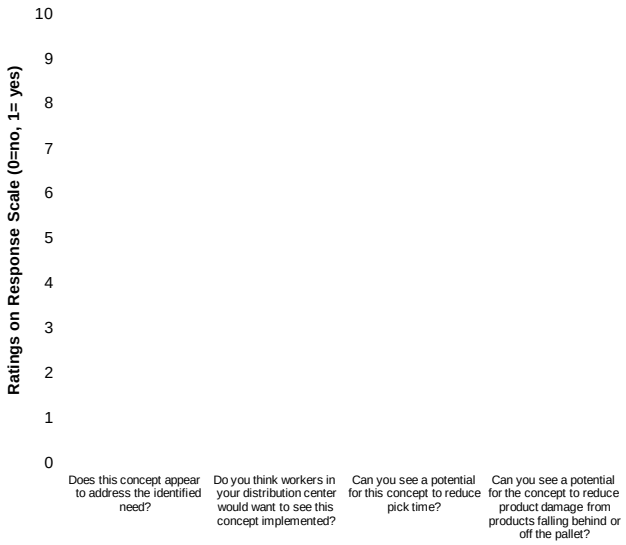

Figure 23. Survey response from focus group participants regarding the pallet cart concept. Ratings scale ranges from 0=no to 10=yes.

usefulness of the cart. Many were unsure of the cart's utility. As for desirability, many more of the participants agreed with the desirability statements than disagreed. However, about half of the participants were undecided.

Table 16. Feedback on the pallet cart concept, from hourly employees who work as non-conveyable product selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the handle is at the right height for me.	*1*	*1*	*7*	*3*	*4*
2. I think it would be easy to turn pallets on this cart.		*1*	*5*	*7*	*3*
3. I imagine that most people would learn to use this pallet cart very quickly.		*1*	*5*	*2*	*8*
4. I think this pallet cart will roll easily on our floor.	*1*	*1*	*3*	*4*	*7*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet cart would help me access boxes that are now at the back of the pallet	*2*		*2*	*6*	*6*
2. I believe that using this pallet cart would make my work easier.	*1*	*1*	*5*	*4*	*5*
3. I believe this pallet cart will help me perform my selection tasks more efficiently.	*1*		*7*	*5*	*3*
4. I believe this pallet cart will allow me to be less tired at the end of each work day.	*1*	*1*	*5*	*5*	*3*
5. I think it would be easier for people to clean the floor if this pallet cart were available.	*1*	*1*	*4*	*5*	*4*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet cart concept.	*1*	*1*	*7*	*3*	*4*
2. I would like to try this pallet cart.	*2*		*5*	*3*	*6*
3. I think some of my co-workers would want to use this pallet cart.			*6*	*5*	*5*
4. I really need this pallet jack for select locations in my warehouse.	*1*	*2*	*4*	*2*	*7*
5. I would like to see us turn pallets using this pallet cart.		*1*	*7*	*4*	*4*

The supervisory staff also indicated a mixed response to this concept. Their concerns were focused on who will do the turning and how hard would it be to turn the cart. Clearly this depends upon the weight of the product sitting on the cart. There was agreement that the brake mechanism is an important component.

Flow Pallet. The flow pallet concept was developed by the research team in response to the expressed concern about reaching and the racked turntable concept from the brainstorming session (Fig. 17 i). While originally conceived for 2nd tier slots, this intervention concept could be used in lower (1st tier) slots, as well as full slots. The concept is based upon a metal pallet that contains a wide built-in conveyor belt (Figure 24). The belt is advanced with a ratcheting lever handle located on either one or both sides of the pallet. The flow pallets would be loaded at the receiving dock by shifting the inbound freight from its original pallet to the flow pallet, using a clamp truck. When the pallet is in the pick slot, an employee could move product forward by pulling the ratcheted handle. It is likely that the product on the pallet would move between 6 and 8 inches with a single handle pull. A spring mechanism would keep the handle oriented so that it would not project into the pick aisle. The length of the handle could be longer for lower or full slots.

Figure 24. The flow pallet concept is a specialized pallet that contains a conveyor mechanism to shift product forward during the selection process. In the rack, product is shifted forward by operating a ratcheting lever located on the side of the pallet.

In general, the most of the focus group survey respondents agreed that the flow pallet concept met the identified need (figure 25). Four of the six respondents indicated that they thought their employees would like to see this concept implemented. Only half thought there would be any productivity benefits, although all respondents generally agreed this concept could reduce product damage from spillage.

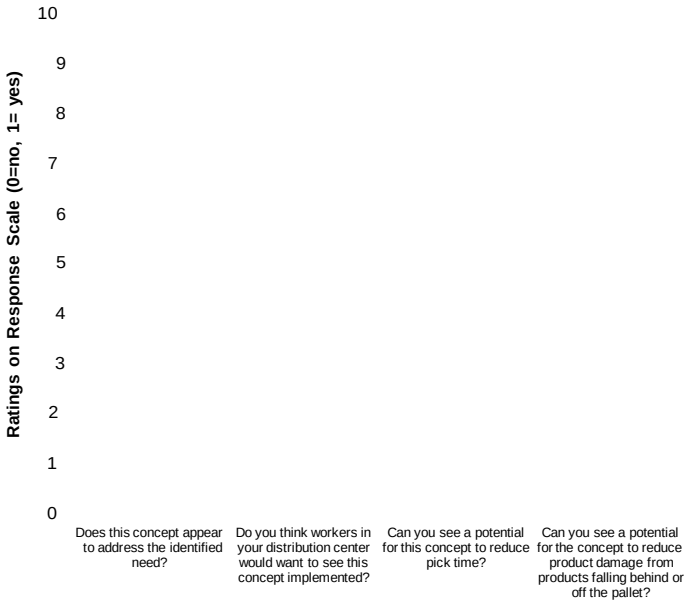

Figure 25. Survey response from general merchandise focus group participants regarding the Flow Pallet. Ratings scale range is 0=no to 10=yes.

Approximately 2/3rds of the sampled employees indicated that they thought the flow pallet was a usable concept (Table 17). A similar percentage indicated that they thought the concept would be useful to them by making their work easier and less fatiguing. Eighty percent of the sample indicated that they would like to try this concept.

Table 17. Feedback on the flow pallet concept, from hourly employees who work as non-conveyable product selectors. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think the location of the lever is ok.		*2*	*3*	*4*	*7*
2. I think it would be adequate if the product moved 6 inches for every lever pull.		*3*	*1*	*5*	*7*
3. I imagine that most people would learn to use this flow pallet very quickly.		*1*	*3*	*4*	*8*
4. I think ratcheting the lever would not really slow me down.		*3*	*3*	*5*	*5*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this flow pallet can reduce the picking time.		*3*	*3*	*5*	*5*
2. I believe that this flow pallet could make my work easier.		*1*	*3*	*3*	*9*
3. I believe this flow pallet will help me perform my selection tasks more efficiently.		*1*	*4*	*6*	*5*
4. I believe this flow pallet will allow me to be less tired at the end of each work day.		*2*	*2*	*5*	*6*
5. I believe this flow pallet has the potential to reduce product damage.	*1*	*1*	*3*	*4*	*7*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this flow pallet.		*2*	*2*	*3*	*9*
2. I would like to try this flow pallet.		*1*	*2*	*2*	*10*
3. I think some of my co-workers would want to use this flow pallet.		*1*	*4*	*3*	*7*
4. I would like to see us obtaining products in 2nd tier slots using this flow pallet.		*1*	*2*	*5*	*7*

Managers and supervisors indicated concerns about the reverse logistics of returning the flow pallets back to the receiving dock. One of the key questions was how the pallets would be removed from the rack. If this is used in a flow rack the total weight needs to be about the same as existing wooden pallets. If it is heavier, then this may increase injury risk in itself if it is manually handled. In non-flow rack applications the pallets could be removed using fork lift equipment and placed in a nearby designated storage slot. A delivery run to the receiving dock would occur when enough flow pallets would accumulate in the storage slot. There was also a concern regarding the

additional labor that would be required to transfer product using the clamp truck. However, nearly all agreed that this could be useful for selected products. Finally there was concern about how fragile the mechanism would be and whether it could be easily damaged during normal handling and anticipated mishandling.

Layer Pick for Pallet Breakdown. Three concepts sketched during the brainstorming session focused on the breakdown of inbound pallets containing mixed product. The concept sketched in figure 17L showed a vacuum lift device being used to sort inbound freight. While there are several vacuum lift and gantry devices that could be readily purchased they have limited flexibility in that they need to remain in a fixed location. One alternative is to use a clamp truck to remove one or more layers from a pallet. This provides an easy way to ensure the equipment is located at the dock door where it is needed. However, the clamp truck may be more challenging for smaller products that arrive with many different SKU's on a pallet. As an alternative, the Froglift attachment is designed to pick a single layer using a multi-port vacuum system. In contrast to the clamp truck, using suction on the top of the layer prevents excessive lateral compression of the boxes.

Figure 26. Froglift layer picker currently in the market by Layer Tech Pty Ltd.

As seen in Figure 27, the focus group participants who responded to the evaluation survey agreed that this concept met the identified need (mean response = 8.0). Five of six indicated that they think their employees would want to see this equipment implemented. Most though this equipment would reduce handling time relative to manual methods and would likely reduce product damage.

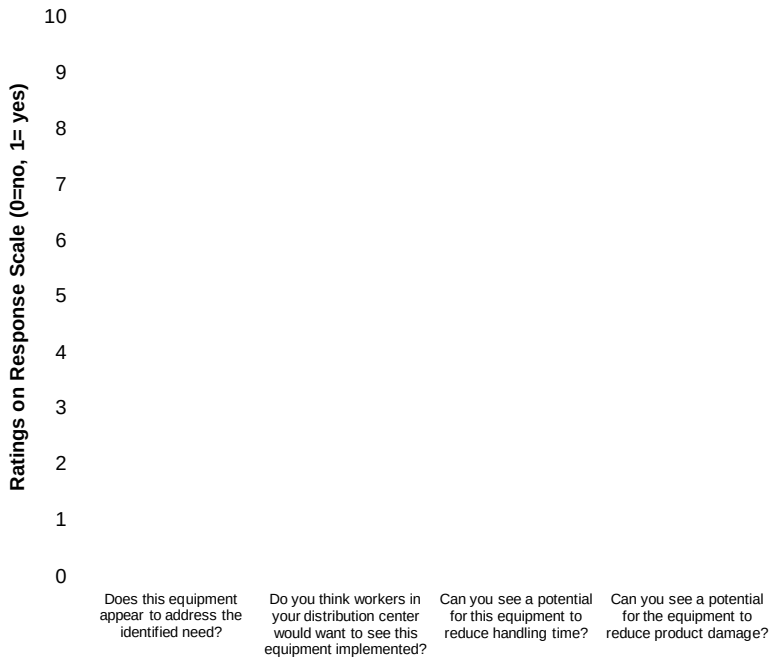

Figure 27. Survey response from general merchandise focus group participants regarding the Frog Lift Layer Picker. Ratings scale ranges from 0=no to 10=yes.

The small group interview concept review session with receiving dock employees indicated that, based upon the promotional video shown, the majority perceived the device would be relatively easy to install, and easy to learn how to

use. Most did not think using it would slow them down. The judgment on usefulness was mixed as the sampled employees have access to a clamp truck that can perform a similar function. However, the conversation suggested that there were smaller items for which this equipment would be useful. This is likely the reason that 5 out of 8 agreed that they would like to try this type of equipment.

Table 18. Feedback on the FrogLift layer picker, from hourly employees who work on the receiving dock. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this layer pick can be easily mounted on our forklifts.		*1*	*1*	*3*	*3*
2. I think the equipment would not significantly disrupt my line of sight.		*1*	*1*	*3*	*3*
3. I imagine that most people would learn to use this equipment very quickly.		*1*	*2*	*2*	*3*
4. I think using this equipment would not significantly slow me down.		*2*	*1*	*1*	*4*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this layer picker can reduce the handling time.		*2*	*2*	*1*	*3*
2. I believe that this layer picker could make my work easier.			*4*	*1*	*3*
3. I believe this layer picker will help me perform my selection tasks more efficiently.		*3*	*1*		*4*
4. I believe this layer picker will allow me to be less tired at the end of each work day.		*1*	*2*	*3*	*2*
5. I believe this layer picker has the potential to reduce product damage.		*1*		*1*	*6*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this layer picker.		*2*	*2*	*1*	*3*
2. I would like to try this layer picker.		*3*		*1*	*4*
3. I think some of my co-workers would want to use this layer picker.		*2*		*2*	*4*
4. I would like to see us breakdown pallet using this layer picker		*2*	*1*	*1*	*3*

Managers and supervisors at the participating retail general merchandise DC were concerned about the limited usefulness of the FrogLift in their operation given they already had a clamp truck. There were also concerns about the quality of the box material and how effectively the vacuum mechanism would work.

Parcel Lift. One of the concepts sketched in the apparel distribution brainstorming session was that of a conveyor-mounted lift assist that could be used when manually unloading freight from trailers or containers. Vaculex manufactures a product, called the Parcel Lift, which the research team thought might have application in the receiving or possibly the shipping operations in general merchandise DCs. The Parcel Lift is a vacuum lift device supported by a lightweight carbon fiber boom. The height of the boom is controlled by sensors that can detect the height of a trailer or container. The length of the extendable vertical uprights supporting the boom are then self-adjusted to maintain the boom at the highest height possible in the truck or container. The vacuum hose is led horizontally under the boom to a large pulley that changes the hose's orientation to vertical. This arrangement allows the vacuum lift to travel from near to ground level to very near the top of the trailer or container.

Figure 28. Parcel Lift currently in the market (Vaculex Company).

Figure 29 shows that the survey respondents from the focus group were unsure whether this equipment would address the identified need (mean response = 6). Moreover, these respondents were unsure whether their employees would want to use this equipment (mean response =5.3). They did not believe this equipment would help productivity (mean response=3.4).

The hourly employees indicated they thought this device would be easy to operate and that they could learn to use it quickly. However, there was uncertainty as to whether it would be fast enough for their work flow. Overall, most agreed that the Parcel Lift would make their work easier, less fatiguing and allow them to work more

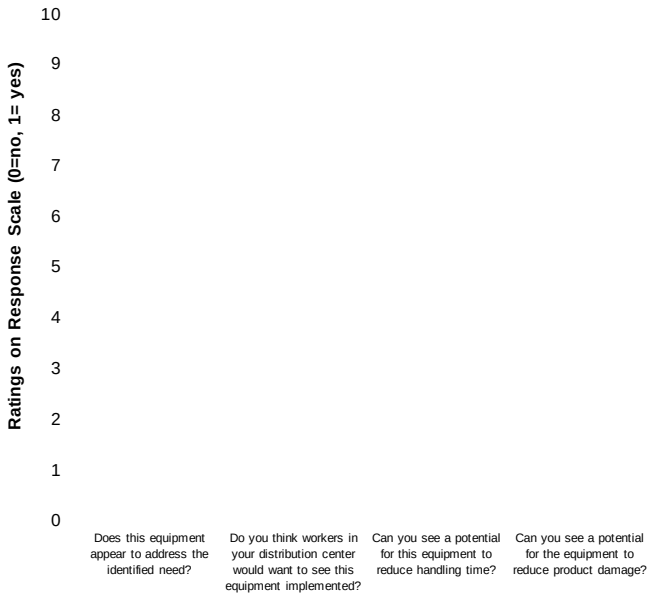

Figure 29. Survey response from general merchandise focus group participants regarding the Parcel Lift.

efficiently. While only 4 out of 7 participants agreed that they would benefit, 6 out of 7 participating employees indicated that they would like to try this equipment.

Table 19. Feedback on the Parcel Lift, from hourly employees who work on the receiving dock in a general merchandise DC. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this lift assist would be easy to operate.			*1*	*4*	*3*
2. I think the vacuum lift will be capable of lifting most of the items we ship.			*4*	*1*	*3*
3. I imagine that most people would learn to use this lift assist very quickly.			*2*	*1*	*5*
4. I think this lift assist would be fast enough to allow me to keep up with the work flow.		*1*	*3*		*4*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I believe that using this lift assist would make my work easier.			*1*	*4*	*3*
2. I believe this lift assist will help me perform my loading or unloading tasks more efficiently.		*2*		*4*	*2*
3. I believe this lift assist will allow me to be less tired at the end of each work day.		*1*	*1*	*2*	*4*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this lift assist.			*3*	*2*	*2*
2. I would like to try this lift assist.			*1*	*3*	*3*
3. I think some of my co-workers will want to use this lift assist.			*1*	*1*	*5*
4. I really need this lift assist for certain products that we ship or receive.		*1*	*4*	*1*	*1*

The managers and supervisors thought that the pace of the work shown in the Parcel Lift video seemed adequate. However, they acknowledged that there would likely be a learning curve to get employees up to speed. They thought it would need to be capable of lifting at least 75 lbs, so that larger items, such as grills, could be handled. During the discussion they identified two other jobs that could benefit from this equipment within their operation.

Pallet Breakdown Station. One of the concepts sketched during the brainstorming session focused on the design of a work area that would reduce the physical demands on employees who manually breakdown pallets of incoming freight. The original sketch showed a lift/turn table that would keep the work at a height that does not require bending and a turntable that does not require reaching. The concept shown in figure 30 used a lift/turn table that has roller conveyor on the top. This allows employees to load the lift/turn table with full pallets that are waiting on a roller conveyor without the need of a forklift or other material handling equipment. Product in this scenario is depalletized to a conveyor, however it could also be sorted onto other skids that would also be on lift/turn tables.

Figure 30. The concept of a pallet breakdown station. Picture on the bottom left is a lift/turn table with adjustable height that is available in the market.

Figure 31 shows that the focus group participants who responded to the survey strongly agreed that this concept addressed the identified need (mean response = 8.0). Most agreed that their employees would want to use this concept. In fact, some of the respondents indicated that they have similar stations set up in some of their DCs. One respondent strongly disagreed and wrote in the comment section that the units they had tried were mechanically slow to adjust and required too much maintenance. With the exception of this individual, the rest of the respondents thought this concept could enhance productivity and reduce product damage.

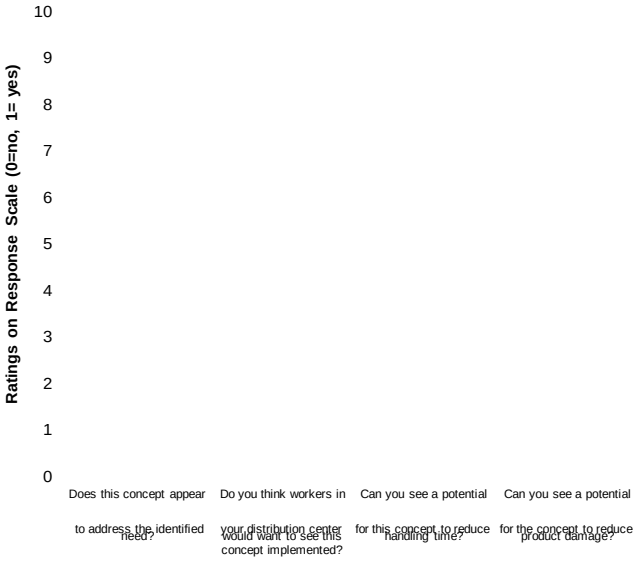

Figure 31. Survey response from focus group participants regarding the Pallet Breakdown Station. Rating scale range: 0=no, 10=yes.

Feedback from the hourly employees was mixed (Table 20), with about half rating it fairly high and the other half rating it fairly low. Some respondents told us that they already set-up makeshift breakdown stations, using forklifts or stacks of pallets.

Table 20. Feedback on the pallet breakdown station, from hourly employees who work on the receiving dock in a general merchandise DC. Italicized numbers in each cell are response frequencies.

Usability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think we have enough space for this arrangement in our warehouse.	*1*	*2*	*2*	*1*	*2*
2. I think turning around the turn table would not significantly slow me down.	*1*	*2*	*2*	*1*	*2*
3. I think adjusting the height of the turn table would not significantly slow me down.	*1*	*1*	*1*	*3*	*2*
4. I imagine that most people would learn to use this pallet breakdown station very quickly.		*1*		*4*	*3*

Usefulness	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I think this pallet breakdown station can reduce the handling time.	*1*	*2*		*3*	*2*
2. I believe that this pallet breakdown station could make my work easier.	*1*	*2*		*2*	*3*
3. I believe this pallet breakdown station will help me perform my selection tasks more efficiently.	*1*	*2*	*1*	*2*	*2*
4. I believe this pallet breakdown station will allow me to be less tired at the end of each work day.	*1*	*1*	*1*	*2*	*3*
5. I believe this pallet breakdown station has the potential to reduce product damage.	*1*		*3*	*2*	*2*

Desirability	Strongly Disagree 1	2	3	4	Strongly Agree 5
1. I would really benefit from the use of this pallet breakdown station.	*1*	*2*	*1*	*2*	*2*
2. I would like to try this pallet breakdown station.	*1*	*3*		*1*	*3*
3. I think some of my co-workers would want to use this pallet breakdown station.	*1*	*2*	*1*	*1*	*3*
4. I would like to see us breakdown pallet using this pallet breakdown station.	*2*	*2*		*1*	*3*

FINDINGS FROM APPAREL DISTRIBUTION

Stage 1 - Participants. Eight individuals representing management and safety functions from three apparel distribution centers participated in a single 3-hour focus group session. All signed informed consent documents. The participants had worked in distribution operations from between 3 and 20 years, with an average of 14 years of distribution center experience.

Stage 1 – Findings. A total of 15 employees in apparel distribution centers were interviewed by individual focus group participants prior to the focus group session. The interviewed employees were mostly material handlers and loaders, with work experience ranging from 1 to 15 years. Several unifying themes were identified throughout these interviews which often described the handling of large, heavy, and non-traditional shaped boxes. The way the boxes were stacked and the uneven distribution of weight inside the boxes were also issues for some of the interviewed employees. Moving boxes above shoulder height and below knee height were estimated to occur 20% and 30% of the time, respectively.

The discussion of issues at the beginning of the focus group meeting exposed many of the important and common ergonomic challenges found in apparel distribution work. Figure 32 shows that most of the material handling related issues occurred during the loading and unloading of trailers and shipping containers. These issues included “overhead lifting”, “repetitive lifting”, and “heavy cartons/boxes.”

Figure 32. The ergonomics issues identified by the apparel focus group participants The number of dots indicates each issue’s priority as assigned by participants.

In the brainstorming phase, the participants proposed and sketched solutions to address these issues. Figure 33 shows the concept sketches created during this session. Figure 33a shows an inclined conveyor for delivering polybags to UPS trailers. In conjunction with this conveyor, a panel could be used to restrain the slippery plastic bags in front of the conveyor, facilitating the piling up (rather than spreading out) of the bags as they fall off the conveyor into the trailer; the conveyor is retracted as the trailer fills. Figure 33b shows a vacuum lift concept that could remove many cartons from a trailer at once. Figure 33c shows a portable lift assist that can be rolled into a trailer that is being unloaded; the lift assist is then positioned along side the conveyor. Figures 33d and 33e show a lift assist mounted to the end of an extendable conveyor. Figure 33f shows a possible job rotation scheme that could help with an aging workforce. Figure 33g shows an extendable conveyor with an end effector that can pull boxes directly onto the conveyor. Figure 33h shows a conveyor system controlled by photocells so material can be delivered to the end of the conveyor

without falling on the floor if the operator is working more than one trailer. Figure 33i is uses a slipsheet truck to remove layers of cartons from trailers of inbound freight. Figure 33j is a system in which the whole load is removed from the trailer or shipping container and delivered to a height adjustable workstation where it can be shifted onto

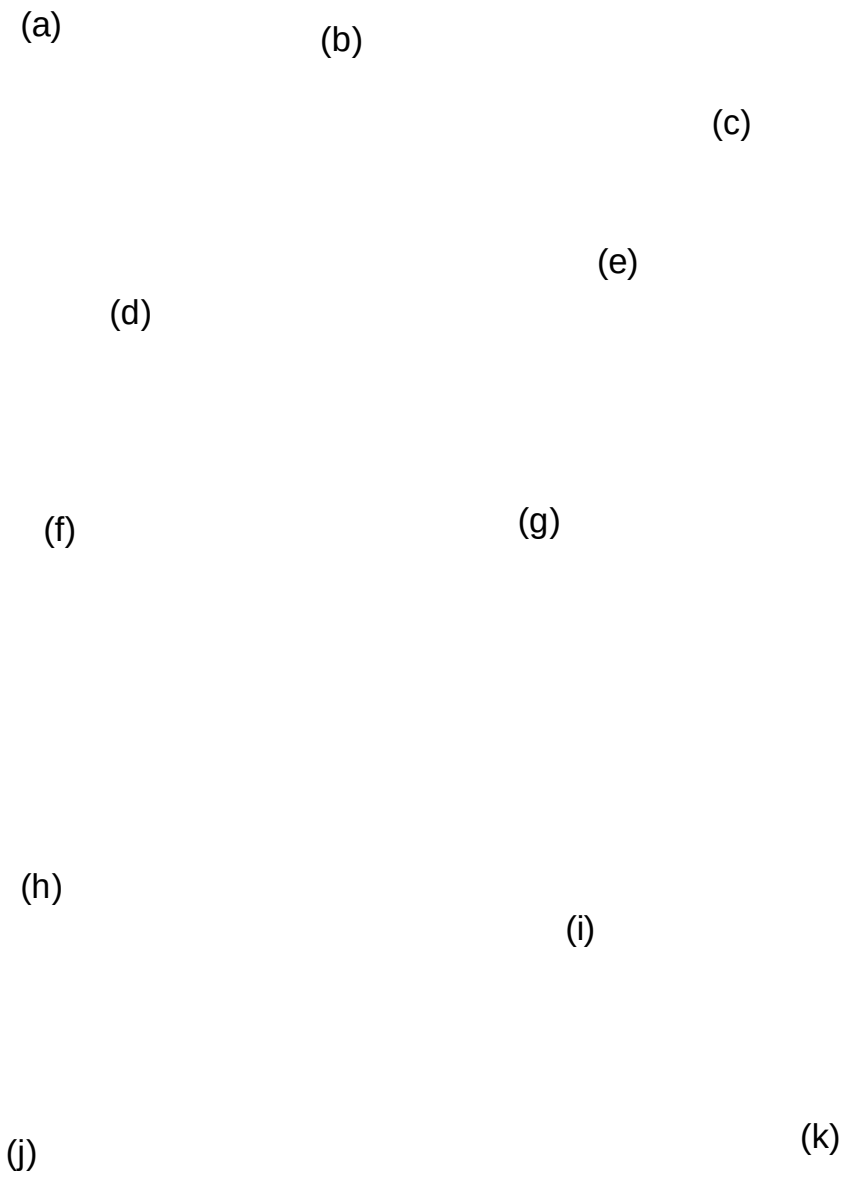

Figure 33. The intervention concepts sketched during the brainstorming portion of the apparel focus group session.

the appropriate conveyors. Figure 33k is a system that elevates the operator along with the extendable conveyor when unloading trailers or shipping containers. There is a

product already marketed by Caljan that essentially performs this function.

The following sections explore some of these concepts in more detail. Specifically, we describe the articulating belt extension conveyor, the use of the slip sheet truck for unloading freight, the inclined parcel and polybag conveyor, the use of a height adjusting catch basin for shipping trailers, and the conveyor mounted lift assist for trailer unloading.

Initial Concepts for Apparel Distribution – Description and stakeholder assessment

Articulating Belt Extension Conveyor. An articulating belt extension (ABE) is an additional attachment at the end of a belt conveyor that can be adjusted in height and length. By extending, adjusting the height, and laterally shifting the ABE to the boxes being unload, it should ideally allow parcels to be slid, rather than lifted, onto the conveyor. As a result, the biomechanical loads experienced by the operator are reduced, thereby reducing fatigue and lowering the risk of employee injury.

There are several ABEs on the market, such as those manufactured by Univeyor and Caljan (figure 34). The Empticon has an automated system to pull cartons onto the conveyor in a manner that is consistent with the concept sketched in figure 33g.

Figure 34. Articulating Belt Extension Conveyors currently in the market by Caljan Company (left) and Univeyor (right).

The survey sent to apparel DC focus group participants showed that the articulating belt extension generally addressed the identified need, which is reducing the amount of manual lifting (Figure 35). The survey respondents also indicated that they thought their workers would want to see this type of equipment implemented in their DCs. However, the survey participants were generally uncertain if the articulating belt

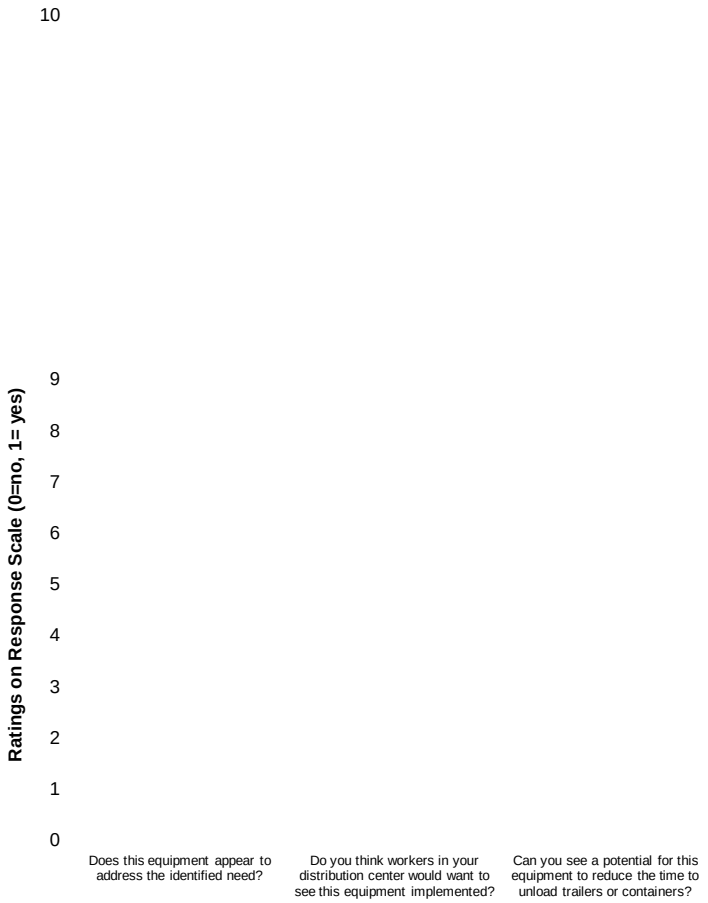

Figure 35. Survey response from the focus group participants on the use of articulating belt extensions. Rating range: 0=no, 10=yes.

extension would reduce trailer unloading times. Comments written on the surveys indicated that they believe it has the potential to reduce the risk of shoulder injuries, and would be cost effective if the extension is highly adjustable. In general, the survey participants gave an average of 7.8 out of 10 points scale in their level of excitement over this equipment.

Use of a Slip Sheet Truck. The original idea proposed during the brainstorming session (Figure 33i) was to use the flat blade surface of a slip sheet truck to remove layers of apparel product from at least the rear part of the trailer. It was indicated that the current slip sheet rigs, such as the one shown in figure 36, would not be able to raise high enough once inside the trailer due to the height of the vertical backstop. Nevertheless, it was thought that the blade could be wedged between layers and the product could be removed without the manual lifting currently required.

As an alternative the research team proposed that slip sheets could be inserted in floor loaded trailers or containers when they are being loaded (figure 36). At the receiving dock, a slip sheet truck would be used to unload batches of product, and transport the product to an appropriately designed workstation for induction. The benefits include removing of overhead and low level lifting in the trailer and, perhaps, eliminating much of the manual lifting from the job, as a whole, if products can be pushed or slid onto the system's induction conveyor. The slip sheet attachment already exists in the market, and most of it should be compatible with the forklift trucks found in most apparel distribution centers. However, it should be noted that implementation of this concept requires cooperation with product suppliers, in that they have to include the slipsheets in their shipping process.

Figure 36. Slipsheets replacing traditional wooden pallets (left) and slipsheet truck (right).

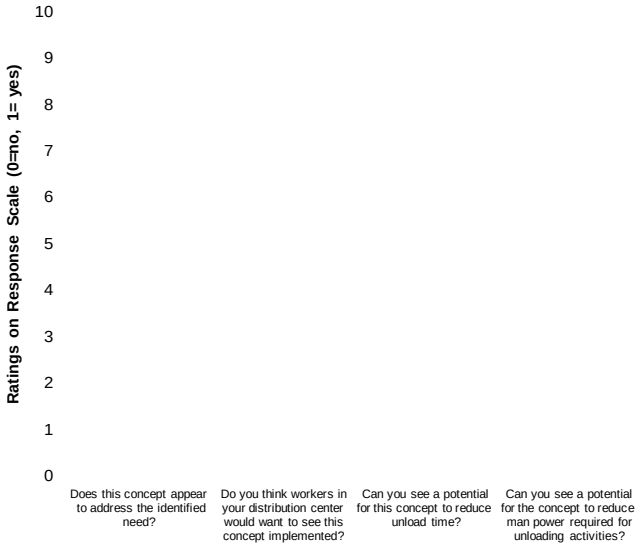

Figure 37. Survey response by apparel focus group participants to the use of slipsheets and a slipsheet truck. Rating scale: 0=no, 10=yes.

Focus group participants were unsure if this concept met the identified needs (mean response value of 5.1, with

range of 1 to 9) (Figure 37). The mean response of 2.8 on the implementation question suggests that the respondents did not believe employees would find this approach favorable. The questions of the concept's potential to reduce handling time and reduce manpower were also met with a mixed response with ratings that ranged between 1 and 9 points.

Written comments on the survey form respondents suggest that one of the limitations of this concept is its ability to work with mixed sizes of product. On the other hand, the respondent who gave the higher ratings sees the potential for more efficient loading pattern and more effective utilization of the truck or shipping container.

Parcel and Polybag Conveyor. The concept of a specialized inclined conveyor positioned at the end of an existing extendable conveyor (figure 38) provides an alternative to minimize manual handling of the polybags and boxes inside the truck and was based on the sketches "a" and "h" shown in figure 33. The concept allows for a partial or fully automated loading process for outgoing direct sales merchandise. Many of these products are shipped in plastic polybags or small cartons and currently loosely stacked in trailers bound for third party shipping organizations. In a partial automated system scenario, an operator would control the conveyor retracting rate (the system will be retracted as the items were piled up at the end of the truck). A fully automated system would work similarly, with sensors replacing the need for manual control. A net or physical barrier would be incorporated on the far part of the conveyor to prevent items from falling outward and under the conveyor system. This concept would minimize the manual handling of these materials and should allow a single employee to cover additional dock doors.

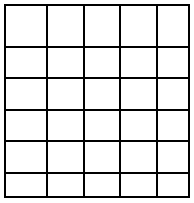

Figure 38. The concept of the inclined parcel and polybag conveyor.

Result from the surveys from the focus group participants (Figure 39) showed an inconsistent response as to whether the concept address the identified need. Similarly, the question on implementation of this concept was also met with a mixed

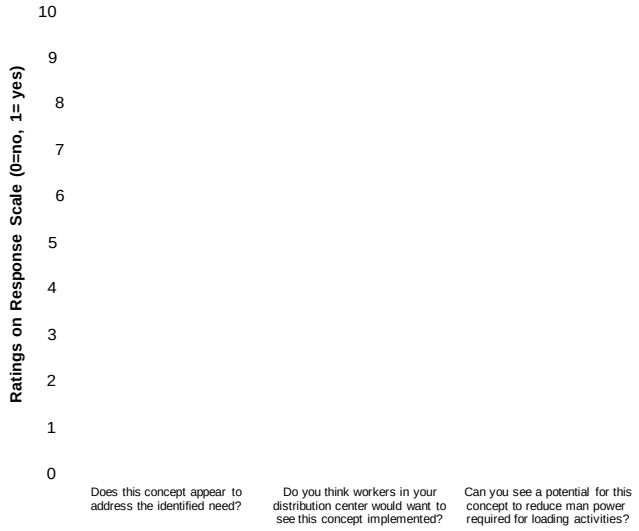

Figure 39. Survey response from focus group participants regarding the Parcel and Polybag Conveyor. Rating scale: 0=no, 10=yes.

response. Most of the survey respondents disagreed with the statement that this concept would reduce the manpower required.

Other concerns written on the survey on included the amount of time to set up, and the possibility that the pile will get "uncontrollable". It was suggested that set up time could offset the benefits of loading time, and the possibility that the pile falls out from the designated space would cause additional problems for the hourly employees.

Height Adjusting Catch Basin. Another issue that was raised in the focus group session was that, in some operations, employees have to pick up items that accumulate on the floor at the end of an unattended shipping conveyor. This prompted the concept of photoelectric eyes (Figure 33h) to shut down the conveyor if product is not removed by the operator. As an alternative, the research team proposed the concept of a height adjusting catch basin that could be placed at the end of an unattended conveyor. This would allow the conveyor to keep running while the employee may be working at an adjacent dock door. A prototype catch basin was developed by the research team (Figure 40) which included a passive means to automatically adjust the height of catch basin, which minimizes the distance that the merchandise falls, and more importantly, minimizes the bending of the operator when he/she returns to move the accumulated merchandise into the proper location on the trailer.

Figure 40. A prototype concept model of a height adjusting catch basin developed at The Ohio State University.

Figure 41 shows that the focus group participants who responded to the survey were mixed as to whether this concept met the identified need, with the ratings ranging from about 2 to 9, and a mean rating of 5.2. Likewise, the question on desirability of implementing this concept in their distribution centers generally showed a negative response from the survey

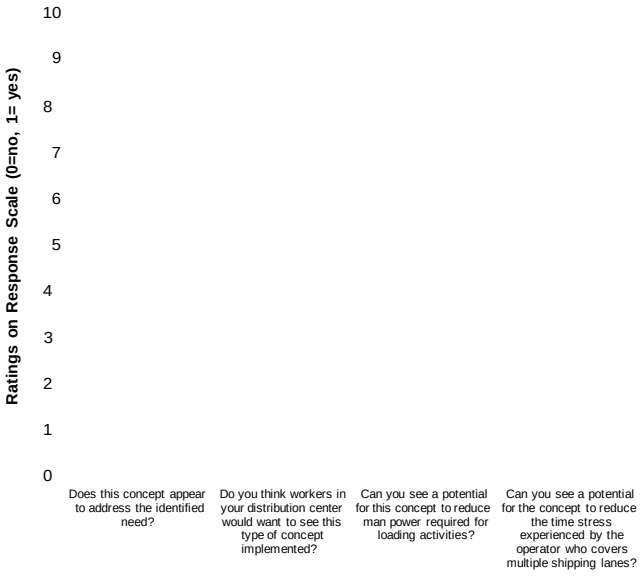

Figure 41. Survey response from focus group participants regarding the height adjusting catch basin. Rating scale: 0=no, 10=yes.

respondents. The respondents tended to be consistent in their disagreement concerning benefits from the equipment in the form of reduced manpower or time stress.

Written comments on the survey indicated concerns about the use of additional equipment in a congested space and that it might be in the way when the employees are not using it.

Lift Assist for Trailer Unloading. The concept of a lift assist attached to the end of an extendable conveyor was drawn by two participants in the brainstorming session (figures 33 d and e). As described in the general merchandise section of this report, Vaculex manufactures a product, called the "Parcel Lift", which is designed for unloading trucks and containers and is designed to be mounted on an extendable conveyor system (Figure 42). The Parcel Lift is a vacuum lift device supported by a lightweight carbon fiber boom. The height of the boom is controlled by sensors that can detect the height of a trailer or container. The length of the extendable vertical uprights supporting the boom are then self-adjusted to maintain the boom at the highest height possible in the truck or container. The vacuum hose is led horizontally under the boom to a large pulley that changes the orientation of the hose to vertical. This arrangement allows the vacuum lift to travel from near ground level to a vertical location very near the top of the trailer or container. While in this example the lift assist is attached to an extendable conveyor, it could also be used as a standalone device to assist an employee with lifting tasks outside the trailer or where extendable conveyors are not used.

Figure 42. The parcel lift currently marketed by Vaculex Company.

The apparel DC focus group participants who responded to the survey agreed that the equipment addresses the identified need (figure 42). Moreover, 3 of the 5 survey respondents indicated that workers at their facility would want to use this tool, while the other two were unsure. A similar breakdown in the respondents was found with regards to whether the device would enhance productivity, which was defined as reduced time to unload a trailer. All of the surveyed focus group participants thought the equipment would potentially be beneficial in their shipping operations as well as their receiving operations.

Other feedback received from the survey respondents indicated concerns about the speed of the device and concerns about how it would work with some of the poor quality boxes their vendors provide. Others recognized that it may help shorter individuals and may help with the tightly packed containers in which it is difficult to pull the first boxes in each row.

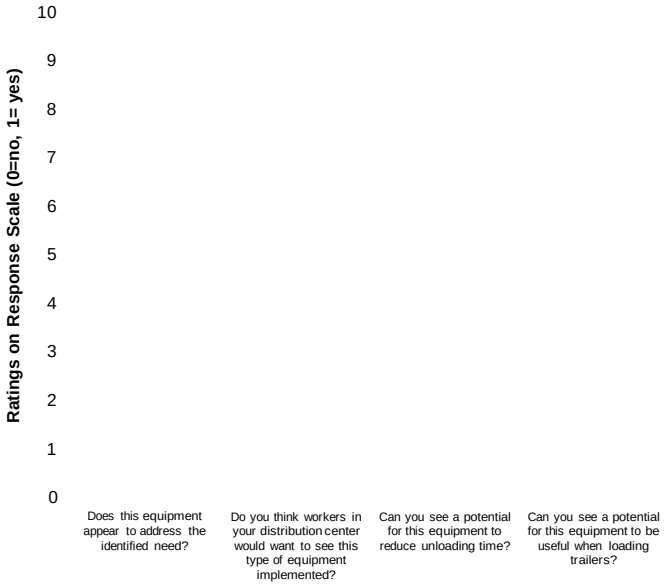

Figure 42. Survey response from focus group participants regarding the lift assist for trailer unloading. Rating scale: 0=no, 10=yes.

SUMMARY OF STAGES I THROUGH III

Several different concepts were identified through the focus group brainstorming process. Some we consider to be "low hanging fruit" that could be implemented with little investment, for example the pick hooks and a job rotation scheme. Others, while essentially ready to go, would require some capital investment. A third group were essentially "blue sky" ideas that could shape material handling systems in the future. We have reviewed what our research team believe are the most promising equipment-based concepts, in the preceding sections of this report. Table 21 lists these concepts for each distribution sector. We think that all of these concepts address physical ergonomics issues identified in the Stage 1 focus group process.

Table 21. A summary of the concepts reviewed in this report by distribution sector.

Grocery	General Merchandise	Apparel
Pick Hooks	Pallet Breakdown Station	Articulating Belt Extension
Pallet-Jack Mounted Lift Assist (Eco-Pick)	Conveyor-mounted Lift Assist for Trailer unloading	Conveyor-mounted Lift Assist for Trailer unloading
Flow Pallet	Layer Pick Equipment for Pallet Breakdown (FrogLift)	Inclined Parcel and Polybag Conveyor
Pallet Cart	Flow Pallet	Height Adjusting Catch Basin
Elevated Pallet Jack	Pallet Cart	Slipsheet Truck
	Elevated Pallet Jack	
	Pallet-Jack Mounted Lift Assist (Gorbel Product)	
	Conveyor-mounted Lift Assist for Trailer Loading	

For the grocery sector, all the intervention concepts were aimed at the order filler or selector job. We believe one of the simplest and least expensive things to do is to introduce pick hooks. A longer term solution to bringing material forward in the slots would involve the flow pallets and the pallet carts. While flow pallets could be used on the ground level, the pallet carts offer an additional advantage to sanitation crews who clean out the slots. While there were reservations regarding the Eco-Pick equipment expressed by the employees, the research team thinks that this product appears to have a potential to be beneficial to those who move heavier items, such as meat, water, juice, and produce items in grocery DCs. In order to use this most effectively, the organization of the work process may have to change such that there are dedicated Eco-Pick users that create partial orders comprised of the heavier products that are often the first items selected in a given store's order. For example, once the heavier boxed meats are placed on the pallet using the eco pick the pallets may be handed-off to another selector using traditional equipment that completes the order with all the cases below some threshold (such as 35 lbs). The same could be done with other starting point products such as juices, waters, bagged produce, or pet foods.

For the general merchandise sector, the intervention concepts address the needs of at least three different jobs within their facilities. On the receiving dock, there are typically opportunities to improve the way pallets of mixed freight are broken down. Clamp trucks or forklifts outfitted with devices such as the Froglift can significantly reduce the manual handling and may speed up the operation. Where floor loaded trailers are received, the conveyor-mounted lift assist (Vaculex's Parcel Lift) looks very promising. As for the selector job, the research team thinks that those involved in the selection of large and/or heavy merchandise (i.e. much of the non-conveyable merchandise) would almost certainly benefit from the type of pallet jack lift assist that Gorbel is developing. Clearly, the speed of the device is important. However, if one examines the amount of time necessary to manually lift, slide, drag, and maneuver large, heavy, and awkward items onto a pallet, the timing issue maybe resolved. The Atlet style raising pallet jack has some merits, especially in DCs that encourage employees to pick by layer. This type of height adjustment could facilitate the sliding of large items, for example boxed furniture, from their pick locations onto the pallet jack, with little vertical displacement when filling orders below waist level. Both the pallet cart and the flow pallet may also help in this environment to reduce the reach distances required and the risks associated with stepping on pallets. As for the shipping end of the operation, the conveyor-mounted lift assist (i.e. the Parcel Lift by Vaculex) would likely facilitate the loading of heavier items up to about chest or shoulder level. Combine this with a step arrangement and the utilization would be increased.

As for apparel, the most promising intervention concept, we think, is the Parcel Lift (Vaculex). This device would likely significantly reduce the biomechanical loads on the shoulders and spine, while maintaining or perhaps enhancing current levels of productivity due the reduced muscular fatigue over the course of a day. Receiving products on slipsheets that could be removed and taken to breakdown stations, much like that shown for pallet breakdown in general merchandise, would be an alternative approach. An important constraint is that this requires the cooperation of suppliers, who are often overseas. The use of Articulating Belt Extenders or even devices such as the Empticon, which mechanically pulls cases onto the conveyor, are also attractive options that address the same ergonomic concerns. On the shipping side, configuring an inclined conveyor to pile the polybags and cartons in 3rd party shipping trailers is doable with existing products on the market. Moreover, with some additional investment, these can be set up with sensors so that they can automatically retract from the trailers as they fill. The lower cost option may be to employ height adjusting catch basins that allow employees to service more than one conveyor simultaneously and without compromising their ergonomics.

GOING FORWARD - STAGES IV AND V: INTERVENTION EFFECTIVENESS AND IMPLEMENTATION TESTING.

The fourth stage of the proposed project (refer to fig. 1) included, where necessary, testing of the effectiveness of selected interventions in a laboratory setting to validate that the biomechanical loads on the body are, in fact, reduced. As it turns out, for many

of these intervention concepts there is no need to conduct this level of testing. We can clearly expect that devices which reduce bending (pallet break down stations, elevated pallet jacks, height adjusting catch basins), reach distance (flow pallets, pallet carts, pick hooks), or remove the manual handling altogether (layer pick equipment) or reduce the load significantly (the parcel lift or pallet jack mounted lift assists) will reduce tissue loads when products are handled. Surely the exertions required to move the flow pallets and to turn the pallet carts are of interest, however, these might be better assessed in field testing with actual product. Likewise, the usability of these interventions would be a concern as we move forward.

With regards to Stage 5, at the time this report was written (summer of 2010), the research team is continuing to pursue field trials of selected concepts including the Vaculex Parcel Lift, the Eco Pick Device, and the Gorbel Equipment when a testable version is developed. We are currently testing the electrical conduit pick hooks with a grocery DC to see how well they hold up over time and their perceived usefulness.

For these investigations we plan to use pre-trial and post-trial surveys, a post-trial group interview, and obtain productivity assessment measures. The pre-trial survey is designed to capture background information on the participants and initial attitudes regarding the intervention and willingness to change work procedures. The post trial survey will assess the degree to which they found the intervention easy to use, useful, and their subjective assessments regarding the change in effort their job requires with the intervention. The post-trial group interview is designed to elicit usability issues and normative attitudes towards the intervention. Our analysis will focus on the factors likely to affect end-user adoption (i.e. perceived ease of use and perceived usefulness) and productivity.

Clearly training of the participants is a critical component of the intervention assessment process. Participants will be trained in the use of the new equipment by vendor representatives. The new equipment will be accompanied by an instructional video so that we can be confident a consistent training program is received.

The product of this stage of the project will be qualitative data showing how end users of the intervention(s) respond to them and quantitative data showing impact on productivity.

Dissemination Plans. At the time of this report, one paper has already been accepted for presentation this fall (September 2010) at the Human Factors and Ergonomics Society Annual Meeting. Associated with this is a conference proceedings paper. At least one manuscript describing the study, will be prepared and submitted to a peer-reviewed journal.

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