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Exploratory Study in Container Loading Embraer 190 Aircraft

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Approved by Major Professor(s): Denver W. Lopp

Approved by: Richard Fanjoy 04/16/2014

Head of the Department Graduate Program Date

EXPLORATORY STUDY IN CONTAINER LOADING EMBRAER 190 AIRCRAFT

A Thesis

Submitted to the faculty

of

Purdue University

by

Ryan H. AuYeung

In Partial Fulfillment of the

Requirements for the Degree

of

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West Lafayette, Indiana

For Al AuYeung, Mae Edyth Au, Genevieve AuYeung Kiley, my friends and my brothers of Pi Kappa Phi Fraternity. I am eternally grateful for their support of my dreams and aspirations in aviation.

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My Committee: Professor Denver Lopp (Chair), Professor Tim Ropp, Professor John Young.

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ABSTRACT

AuYeung, Ryan H. M.S., Purdue University, May 2014. Exploratory Study in Container Loading Embraer 190 Aircraft. Major Professor: Denver Lopp.

Since the dawn of aviation, cargo loading on aircraft has remained virtually constant. A person and a baggage cart together have been the primary method of loading baggage on to aircraft, and this practice has virtually remained unchanged, especially for narrow body aircraft. This study explores the question of whether a loading device, designed for Embraer 190 aircraft, can increase economic efficiency by reducing aircraft turnaround times, increasing aircraft utilization and reducing work hours. In the course of designing a theoretical loading device for an Embraer 190, various literature ranging from elaborate articulating conveyor belts, to the use of LD3-45W containers in Airbus 320 aircraft were analyzed. In the pursuit of understanding ground operations with containers, the study looked at the Boeing 767-300 and the Boeing 777-200LR to analyze the timeliness in which containers can be loaded and unloaded from an aircraft. With the goal of using common narrow body ground support equipment, time trials were done with a Purdue University baggage belt loader to see if loading a container on a conventional belt loader was feasible. To create a theoretical working container design, the LD3-45W boundaries in relation to the Airbus 320 aircraft cargo walls was scaled to match the Embraer 190s. With this scale, a container size could be derived, as well as volume, capacity, tare weight and maximum weight. In determining these various parameters, the amount of baggage that could be placed in 11 loading device containers was determined. With these figures an extensive comparison between loading baggage by hand and loading baggage utilizing containers, was analyzed.

CHAPTER 1. INTRODUCTION

This chapter provides a foundation and overview of this research study. The chapter also establishes the significance of the subject of aircraft loading problems as well as their ramifications.

1.1 Statement of the Problem

In the airline industry one of the concepts that is understood is aircraft only make money for the airlines when they are flying. Since that financial paradigm has been established, operations analysts have long studied how to minimize aircraft ground times. Everything from maintenance times to more efficient ways to load and unload aircraft have been explored in great depths. To minimize ground time, it is natural that any company would attempt to maximize the labor force in place.

The issue of maximizing ground labor however, was exacerbated when in the year 2007, oil reached its highest point of $145 a barrel (Hamilton, 2009). To recover the great economic losses to flights, the airlines aggressively “unbundled” the inflight experience, charging for checked baggage. With passengers consolidating their personal belongings on aircraft, the airlines saw a dramatic drop in baggage being checked, and thus a lower utilization of the infrastructure. The reduction in bags, according to Christine

Negroni of The New York Times, has led to a reduction in the amount of lost baggage and baggage handler injuries (Negroni, 2010).

Whether it has been airlines hauling the mail in the 1930s to carrying passengers on DC3s, there has always been baggage carts and someone to pack the baggage into the aircraft's cargo hold. With travel needs rising, especially in developing countries such as Asia and South America, Boeing estimates that the need for narrow body aircraft will increase from 13,040 in 2012 to 29,130 in 2032 (Boeing Commercial Airplanes, 2013,). Narrow body aircraft in contrast to their widebody counterparts have had the least amount of technological development in terms of cargo loading technology. For widebody aircraft, packing bags involves handlers to sort baggage into pallets and loading device. Those containers will be loaded onto the aircraft by scissor lift and are sculpted to fit inside the cargo hold of an aircraft with greater ease on the part of the handler as rollers can assist in moving these heavy pallets.

In contrast, narrow body aircraft still require handlers to sort baggage on to carts, as well as sort them inside cargo holds of aircraft to efficiently utilize the entire compartment. The utilization and placement of every bag is left to the judgment of the handler inside the cargo hold. This handler is also the individual most likely to be injured on the job due to working in confined spaces and having to exercise much heavy lifting. With the lack of development in technology to improve narrow body baggage handling, and the greater risk to on the job injury, the question is posed: is there a method to load baggage onto a narrow body aircraft that can utilize modern day infrastructure such as traditional belt loaders and LD3 Containers that would result in faster aircraft turnaround times.

1.2 Research Question

The research question to be explored: Can a new loading process utilizing containers and existing ground support equipment be developed that will result in faster turnaround times for Embraer 190 narrow body aircraft?

1.3 Scope

This study will focus only on Embraer 190 jet, a popular aircraft in the modern airline fleet. The primary focus will be on the technical data specifying the ability for the ground crew to turn around the aircraft within the manufacturer's specified guidelines. This research is focused on the commercial aviation industry and the current operating procedures of airlines in loading baggage on narrow body aircraft. This study attempts to relate current practices of loading baggage on Airbus 320 aircraft, and apply similar methodology to Embraer 190 ground operations. The analysis of narrow body ground loading operations will only attempt to show the benefits of using containers as a method of loading and provide benefits from the perspective of better economics in faster turnaround times.

1.4 Significance

In order to launch a single flight, airlines must employ massive labor forces to load their numerous narrow body aircraft, which for aircraft like the Boeing 737 can average a turnaround time of 40 minutes (Boeing 2007b). The revenue margins the airlines face are commonly razor thin and the ability for an airline to gain back time while on the ground can make the difference between losses and gains on a particular flight. By studying the ability of an aircraft to load baggage via a container versus loading by hand, this study will seek to study whether containers will be able to increase turnaround time for operators of the Embraer 190.

1.5 Definitions

Narrow body aircraft- Single aisle passenger transport aircraft such as the Boeing B717, B727, B737, McDonnell Douglas DC9, MD83, and MD87 and Fokker F28 & F100, as well as all commuter aircraft seating up to around 150 passengers, that are designed to have the baggage loaded in bulk, one item of baggage at a time. (Dell, 2007, *p.193)*

1.6 Assumptions

The following assumptions are inherent to the study:

- The base line loading time to load baggage into an Embraer 190 aircraft is similar to that of Boeing aircraft with comparable cargo volume.
- Injuries occur during the loading process of an aircraft.

1.7 Limitations

The following limitations are inherent to the study:

- This study is limited to the technologies listed in the literature that is reviewed beginning at Chapter 2.
- The primary data analyzes technologies that currently exist.
- The research assumes that materials for containers are those approved by the global aviation regulatory bodies.

- Numbers and figures are based from a review of literature and no container was designed or built for testing.

1.8 Delimitations

The following delimitations are inherent to the study:

- This study does not take into account any technologies currently under development.
- This study does not take into account any loading mechanisms that will be added to future aircraft.
- This study does not analyze the effects of security and screening on the time it takes to load an aircraft.

1.9 Chapter Summary

This chapter establishes the foundation of this study. Included are descriptions of the background, problem, research question, scope significance, assumptions, limitations and delimitations. The next chapter reviews in detail the existing literature that develops that context in which narrow body aircraft are loaded.

CHAPTER 2. LITERATURE REVIEW

2.1 Narrow Body Definition

According to Geoff Dell, a narrow body aircraft is defined as:

> Single aisle passenger transport aircraft such as the Boeing B717, B727, B737, McDonnell Douglas DC9, MD83, and MD87 and Fokker F28 & F100, as well as all commuter aircraft seating up to around 150 passengers, that are designed to have the baggage loaded in bulk, one item of baggage at a time (Dell, 2007, *p.193)*

In addition to Dell's analysis, it is important to also add a series of other narrow body aircraft as specified by Riley (2009), which include aircraft with similar loading methods as defined by Dell. These aircraft include:

> The Airbus 320 family of aircraft (A318, A319, A320 and A321) within our definition as well as some others that meet the single aisle criteria. An alternative description of this group of aircraft would be 'regional airliners'. We also include the Boeing 757 family of aircraft as these are common in the low cost sector and are routinely bulk loaded with passengers' baggage at regional airports. A 757-200 can seat over 220 passengers. (Riley, 2009, p. 1)

2.2 Narrow Body Work Environment

According to a study conducted by Korkmaz, Hoyle, Knapik, Splittstoesser, Yang, Trippany, Lahoti, Sommerich, Lavender, and Marras of The Ohio State University in 2005 air transportation injury rates are higher than that of agriculture, mining, and construction (Korkmaz, 2005). In a survey conducted by Salomon (2004) of the New Jersey Institute of Technology, out of 156 baggage handlers, 110 stated that inside a narrow body aircraft, baggage compartments were the most likely place to cause back injury. This is in stark contrast with the eight individuals who found wide body aircraft to be a likely area where back injuries can occur. These injuries have resulted in financial hits for the airlines.

For baggage handlers the overall rate of incidence is about 3.5 times the rate for other industries as a whole, and on average one in 12 baggage handlers will suffer a back injury in a year, costing companies $1.25 million dollars annually between 1992-1994 (Korkmaz, 2005). According to Dell's (2007) study, of the 16 airlines and their rates of back injury, the various airlines took a financial loss of "$US17,639,857 in 1992 to $US 23,697,170 in 1993 and $US 21,710,953 in 1994" (Dell, 2007, p.182). In addition to cost, the 16 airlines detailed in Dell's report also lost time for injury frequency raters. These injury frequency rates calculated per million hours worked, equaled 42.5 for 1992, 41.5 for 1993 and 43.5 for 1994 (Dell, 2007).

2.3 Design Obstacles

With this foundation laid, Dell (2007) continues to detail that despite the high-risk operation of loading narrow body aircraft, manufacturers have yet to deal with the serious work environment that causes baggage handler injury (Dell, 2007). One of the obstacles that stops aircraft from developing new systems is the steep development cost, yet many ergonomics specialists indicated that the long term costs of not intervening at the design stage have contributed significantly more to injuries than anticipated (Dell, 2007). One of the greatest challenges to developing any new system on an aircraft is the plane's ability to meet its payload and range targets (Dell, 2007). Manufacturers and designers who have intimate knowledge of their aircraft's payload and range equations are heavily opposed to adding unnecessary weight to the aircraft for competitive performance purposes (Dell, 2007). But the biggest obstacle to environmental changes in the underbelly of narrow body aircraft is due to the shear fact that airlines are consistently not profitable (Dell, 2007). It is this consistent unprofitability which drives the airlines' desire to reduce turnaround times, and streamline the baggage loading process.

According to The Boeing Company's process maps for Terminal Operations for a Boeing 737 (2007b), the company has budgeted that the task of loading and unloading a Boeing 737 -300/400/500 series would take approximately 35 minutes to complete a turnaround (Boeing, 2007b). In the span of 35 minutes, handlers are required to unload a total bulk cargo load equivalent within the range of 756 cubic feet to 1,852 cubic feet (Boeing, 2007a). For narrow body aircraft, handlers commonly are the individuals who are required to stack bags inside the cargo hold of the aircraft and make judgment decisions on placement of baggage. With this archaic method of loading, the industry has developed multiple ideas to remedy the issue, and reduce turnaround times with lower labor hours.

2.4 Airbus A320 Family LD3-45W Loading

One idea that has been pushed with the introduction of the Airbus 320 family of aircraft has been the use of containers, similar to that of widebody aircraft. What makes the Airbus 320 cargo holds different from other narrow body aircraft are the fact that they "are wider and deeper than any other single-aisle aircraft"(Airbus, 2013, p. 1). The Airbus is also able to accommodate these containers because the cargo doors "open outward to avoid reducing available volume inside the hold. These doors also give protection during operations in bad weather, helping to reduce damage to baggage and freight" (Airbus, 2013, p.1). The ability to load cargo into the cargo hold is accomplished by using a "mechanized bulk loading system" (Airbus, 2013, p. 2013). In applying the mechanized loading system, Airbus has effectively "applied the traditional wide-body" aircraft solution to narrow body aircraft, however the manufacturer has also indicated that "only 60% of their customer airlines have purchased aircraft with the mechanical loading

Figure 2.1 Airbus Container Loading (Airbus, 2013).

system fitted" (Dell, 2007, p.137). This is unfortunate in the eyes of Dell (2007) as he deems the A320 container system as "the only system presently available which offers" the opportunity to eliminate "manual handling, including the mechanical loading of containers in the baggage room" (Dell, 2007, p. 159).

With Airbus offering the ability to install mechanized loading, Boeing has begun to offer sliding carpets on their Boeing 737s, which can reduce "loading crew size, loading time, baggage damage, cargo lining wear" and the popularity of the product has been endorsed by 30 airline customers on more than 1,100 of the Boeing 737 type airplanes (Boeing, 2006, p. 4). "The sliding carpet has major relevance on aircraft such as the Boeing B737, B717 as well as the Douglas DC9, MD 80 aircraft." (Dell, 2007, p. 147.). What makes these planes unique are their "inward opening aircraft baggage compartment doors" that increase the likelihood of back injuries to baggage handlers (Dell, 2007). However, despite the installation of the sliding carpet system, Boeing 737s are still unable to take any form of container unlike its widebody counterparts (Boeing, 2012).

2.5 Sliding Carpets

These sliding carpet loading systems are marketed as SCLS Telair International and the Air Cargo Equipment Telescopic Baggage cargo system, which is also known as the Telescopic Bin System (TBS)(Riley, 2009). According to Riley, both of these sliding carpet systems provide a "moveable bulkhead and hold floor that can be positioned near a baggage compartment door" (Riley, 2009, p. 7). The benefit of these sliding carpet systems include "eliminating one of the baggage handling" personnel, making the loading and unloading of the aircraft a two person operation (Riley, 2009). The sliding carpet cargo system is a device kept on the aircraft, which does not require specialized equipment (Riley, 2009). Yet despite the reduction in work force, the use of mechanized loading systems does not reduce the "manual lifting and handling operations associated with the stacking and un-stacking" of baggage within the Boeing 737 (Riley, 2009, p. 7). A downside to the sliding carpet system is the additional weight that is added to the aircraft. In some instances, airlines have removed mechanized loading systems "in order to reduce the aircraft weight and therefore improve fuel efficiency" (Riley, 2009, p. 7). According to Telair International, the TBS system has a weight penalty of 160kg to 250kg, per cargo hold but has a reliability factor of "99.96% (Riley 2009, p. 7).

In contrasting the SCLS and TBS systems, Dell cites a study in which 17 Boeing 737s operating with Scandinavian Airlines utilized the SCLS system. In one year of operation, Scandinavian Airlines saw "a 25% reduction in baggage handler sickness absences as well as a small reduction in baggage handling staff resource" (Dell, 2007, p. 147). However in responding to Dell's experiment, Riley states in his personal opinion that the "expected reduction in resources should be greater since one worker is eliminated from the usual team of three or four" baggage handlers (Riley, 2009, p. 8). Riley also cited studies conducted by Johansen of Braathens SAFE airline, who reports that there was "no measureable increase in fuel consumption after installing the SCLS system" with the Scandinavian Airlines fleet (Riley, 2009, p. 7). For Geoff Dell (2007) he concludes that the "sliding carpet [has] eliminated […] the transfer of baggage from the doorway of narrow body aircraft to the person stacking baggage within the compartment" (Dell, 2007, p. 179). But a concern that Dell (2007) expressed is the fact that the sliding carpet system never solved the task of the baggage handler of manually stacking the bags within the hold (Dell, 2007).

As it has been established that the sliding carpet is not the optimal idea for reducing back injuries, the question is posed by the Scandinavian Airlines experiment whether a sliding basket could be used with the sliding carpet system (Dell, 2007). The system of baskets was manufactured out of fiberglass and were staged with baggage in the baggage make up room and then transferred to the aircraft for loading via a standard belt loader (Dell, 2007, p. 158). Despite the idea being conceived, the system was never produced. According to Dell (2007), "from a manual handling injury reduction viewpoint, the system had a combination of solutions that still have not been achieved by any other single system in airline operations today" (p.158). Dell (2007) continues by stating that with the basket sliding carpet system:

> *all manual handling of baggage in narrow-body aircraft baggage compartments was eliminated using the system, manual handling of bulk baggage outside the aircraft was eliminated and the baskets were open-topped which facilitated the use of mechanical lifting aids for loading baggage into the baskets inside the terminal. (p. 158-159)*

Scandinavian Airlines Belly Loading's design is by far the most comprehensive design utilizing multiple technologies, yet the challenges of development and funding stand as a massive obstacle to making the product a reality.

2.6 Unique Loading Methodologies

Aside from the sliding carpet feature, other ideas that have been floated as solutions for baggage include the RTT Longreach system. Designed by Telair, the RTT

Longreach is a "belt loader based device" whose purpose is to "deliver the baggage items to the position and level that it has to be stacked" (Riley, 2009, p. 8). In theory, this method would minimize the "amount of manual handling required from stacking" (Riley, 2009, p. 9). In a study documented by Riley, investigating "the use of the SCLS with the RTT" it was discovered that "both assistive devices were found to be beneficial in reducing the frequency of occurrence of hazardous postures" (Riley, 2009, p. 8). The combination of both devices leads to a 7.5% decrease in a baggage handler's average heart rate (Riley, 2009). In a similar examination of the RTT Longreach by Dell, his reports cites that "the difference was most noticeable for the worst case lift when lifting from below the waist, at floor level, to above head height when stacking in the top row" (Dell, 2007.p. 9). Dell completes his analysis for the RTT Longreach by stating that in a similar study conducted with the airline Qantas with 32 other baggage handlers, the use of the RTT Longreach resulted in a reduction of baggage handler manual handling risk (Dell, 2007). From the studies both conducted by Riley and Dell, it is noted that the RTT Longreach is compatible with multiple of the mechanized loading systems and is highly versatile, being able to be used in narrowbodies such as Boeing 737s down to smaller regional jets such as Embraer ERJ 145s (Riley, 2009).

While the RTT Longreach may be one solution to the ergonomic challenges of the narrow body aircraft, another device that has also been introduced to aid in the loading of single aisle aircraft is the task of the Rampsnake.

As defined by Riley (2009), the Rampsnake is “a piece of ground handling equipment that has been designed to reduce and assist with the manual elements of bulk loading” (Riley, 2009, p. 10). The Rampsnake effectively “replaces the conventional belt loader” and provide features such as allowing baggage items to be “transported directly between the worker at the stack in the hold and the worker at the baggage cart, and vice versa” (Riley, 2009, p. 10). On the side that is placed within the cargo hold, the Rampsnake provides an “adjustable raising section of conveyor (up to 0.8m) to assist with the transfer between belt and stack” along with the device’s ability to provide a

Figure 2.2 RTT Longreach (TelAir, n.d.)

conveyor belt that can be height adjusted and extended (Riley, 2009). The Rampsnake

Figure 2.3 Rampsnake (CPH Design, n.d.)

was tested by KLM Royal Dutch Airlines at Schipol Airport in Amsterdam, and was used regularly by the ground loading staff and during use various functions such as heart rate, Borg, RPE, Working Posture, and push/ pull force measurement were taken. In the study, it was discovered that when using the Rampsnake, the average heart rate was reduced due to the reduction in physical exertion as opposed to those operating conventional belt loaders. (Riley, 2009). In a time based video footage study, taken every 15 seconds, Riley (2009) notes that the "incidence of lifting is significantly less with the Rampsnake (5% of samples) than it is when working with conventional aides (28% of samples)" (p.11).

However in tasks involving pulling action, the Rampsnake did not provide any form of relief to the baggage handlers (Riley, 2009).

In addition to the Rampsnake, the Powerstow device is another conventional conveyor belt loading derivative product that looks to complete similar tasks to that of the Rampsnake. According to Riley (2009), the Powerstow is an "EBL type device" and provides an "extending powered conveyor from a belt loader type device running in through the hold door, right to the working point within the hold" (Riley, 2009, p. 11). The device can be fitted to existing belt- loader platforms however to complete such an attachment the extending conveyor requires an upgrade to allow an increase in weight (Riley, 2009). Similar to that of the rampsnake, the EBL is a less technologically

Figure 2.4 Powerstow (International Airport Expo, 2011)

advanced piece of equipment, which allows airlines to utilize existing belt loaders, without having to scrap them for devices such as the Rampsnake. However, as of the time Riley's (2009) literature review was conducted, the Powerstow device did not include the ability to be adjusted by height for its conveyor belt (Riley, 2009). As a result of this, the risks of lifting baggage are identical for the Powerstow as would be for a conventional belt loading device.

2.7 Chapter Summary

In this chapter, various forms of aircraft loading, designed to increased turnaround time and decrease labor hours and labor injuries were reviewed. The favorite form of aircraft loading amongst the various forms of literature was the Airbus 320, as it was the only form of baggage loading that completely removed the need for any heavy lifting. However the design of the Airbus 320 loading system is unique to the aircraft specifically due to the design of the cargo door which swings outward as opposed to inward similar to that of the Boeing 737 and McDonnell Douglas doors. In response to the Airbus design, Boeing has advertised to its customers the use of a sliding carpet. This carpet while improving the ease at which baggage can be positioned within the cargo hold, does not alleviate any form of lifting what so ever for baggage handlers. However with the sliding carpet has come a host of ideas and combinations. An example of a combination was a study done by Dell who followed Scandinavian Airlines in a project to incorporate fiberglass "baskets" to load baggage into and slide via the loading process down the carpet. However lack of interest and funding ultimately would cause the project to cease. The final technologies covered were various forms of articulating belt loaders. The RTT long reach, was a belt loader that allowed the end to turn and articulate in a more ergonomically friendly position for the baggage handler to receive the bag. The second derivative of the belt loader was the Rampsnake, with a longer extension at the aircraft loading end that can articulate further inside the aircraft than that of the RTT long reach. The final derivative of the belt loader discussed was the Powerstow, which possess a greater belt extension that can reach deep inside aircraft cargo holds. However the drawback amongst each of the various belt loading derivatives was the consistent criticisms that RTT long reach, the Rampsnake, and the Powerstow did not change the fundamental action of heavy lifting and stowing for baggage handlers.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

This section outlines the type of research that was performed, how the study was conducted, and how the data was analyzed.

3.1 Research Type and Framework

This thesis was an exploratory study utilizing qualitative methods to explore the idea of utilizing containers for loading Embraer 190 without the use of mechanized loading systems and opting for common ground support equipment such as standard belt loaders and baggage carts.

3.2 Sample

The technical data and sample times being used in this study were based Embraer 190 technical documentation. This aircraft was chosen due to its wide appeal with airlines, its operational profile as a regional jet to accomplish fast turnaround times, and its outward hinging cargo door that is conducive to allowing containers in the cargo hold (similar to that of the Airbus 320).

3.3 Data Collection

The data used in this study was collected from a variety of technical and journal sources. Having narrowed the focus of aircraft to the Embraer 190, technical data was provided by the manufacturer, Embraer. From these technical documents, limitations on the aircraft's cargo hold environment were established. As Embraer does not publicly disclose turnaround times, data provided by Boeing for similar mission profile aircraft, such as the Boeing 737 were extrapolated to make assumptions on ground handling and loading speeds of baggage per minute. As Boeing details the approximate turnaround time for each aircraft and provides process maps, this information provides a foundation to base turnaround times for the Embraer 190.

3.4 Testing Method

In exploring the development of containerized loading processes for an Embraer 190, the goal was to develop a process that would provide a working environment that would allow for faster turnarounds, with minimal technological changes to existing ground support equipment. In addition, a successful container would minimally reduce the useable baggage area of the aircraft's cargo and not pose a great weight penalty upon the aircraft. To demonstrate the benefits of a loading device for an Embraer 190, the loading times for larger aircraft that utilize containers were analyzed. In an effort to ensure standard belt loaders could be used for loading, time trials were done on a belt loader at Purdue University Airport. From this information, process maps of the loading process and of the overall turnaround process were developed to gauge the use of amount of labor hours and the prospect of reducing the labor force required to undertake the task of loading an Embraer 190. By comparing the time to load an aircraft in a process map to the labor hours, this framed a contrast between the two loading methodologies from a labor hour cost perspective. As there is only one other narrow body aircraft, the Airbus 320 that incorporates a pallet and container system, some of the benefits, such as ergonomics are assumed from data provided by Airbus. In addition to the Airbus data, the use of Boeing's extensive start up database with loading times and terminal operations was used to formulate a turnaround schedule for an Embraer 190. In analyzing the cost of materials for a new type of loading device for a regional jet, this study assumed that materials that are acceptable for existing containers would be acceptable materials for the stated hypothetical Embraer load system and weights could be scaled down to the size of the Embraer 190 container. The study assumes that the hypothetical design of a container would be able to operate on a belt loader as well as a scissor lift if necessary. The study also assumes that the man power to load the aircraft remains constant as container loading was not tested in this study.

3.5 Chapter Summary

This chapter describes the important variables used in the research and the method of designing and testing a hypothetical container. It also described the data used and the testing method determined.

CHAPTER 4. DATA AND FINDINGS

This chapter describes the steps and findings that led to the development of the Regional Loading Device or RLD as it will be referenced herein. This chapter will review the sources that justify the RLD's dimensions, tare weight, loaded weight and the process under which these were calculated. In addition to the RLD's specifications, this chapter will contrast the difference in capacity in Embraer 190s using RLDs versus hand loading which demonstrates the time it takes to load and unload the aircraft.

4.1 RLD Dimensions

In the process of scaling a loading device that would be able to fit into the Embraer 190 aircraft, much inspiration came from the design of the LD3-45W and the LD3 containers. As the LD3-45W is the only container that is used currently on narrow body aircraft, much of the design was taken into consideration for the RLD. Referencing figure 4.1, the dimensions of the LD3-45 W, which are designed to fit inside the Airbus 320 aircraft are at a top container height of 96 inches, a height of 45 inches. Base width of 60.4 inches and a base length of 61.5 inches.

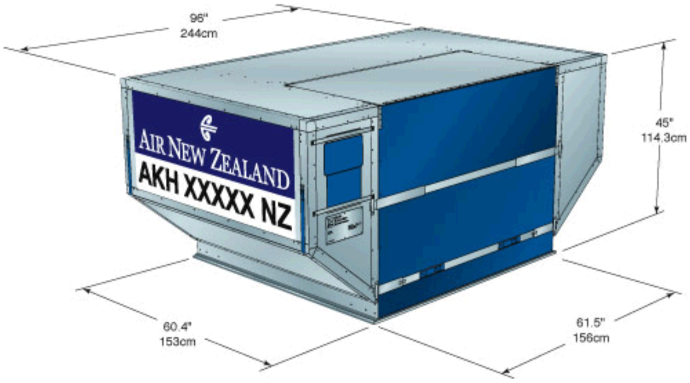

Figure 4.1 LD3-45W (Air New Zealand Cargo, n.d.)

Taking into account the Airbus cargo hold as shown in figure 4.2, has a base width of 55.91in, height of 48.82 inches and a max width of 103.94 inches. To be able to hold the LD3-45W, the study assumes that the left on board rollers, which allow cargo handlers to push containers throughout the hold, is fixed to the aircraft and occupy a height of three inches (Airbus, 2013, p. 2-5-0). This height would allow the container to fit into the cargo

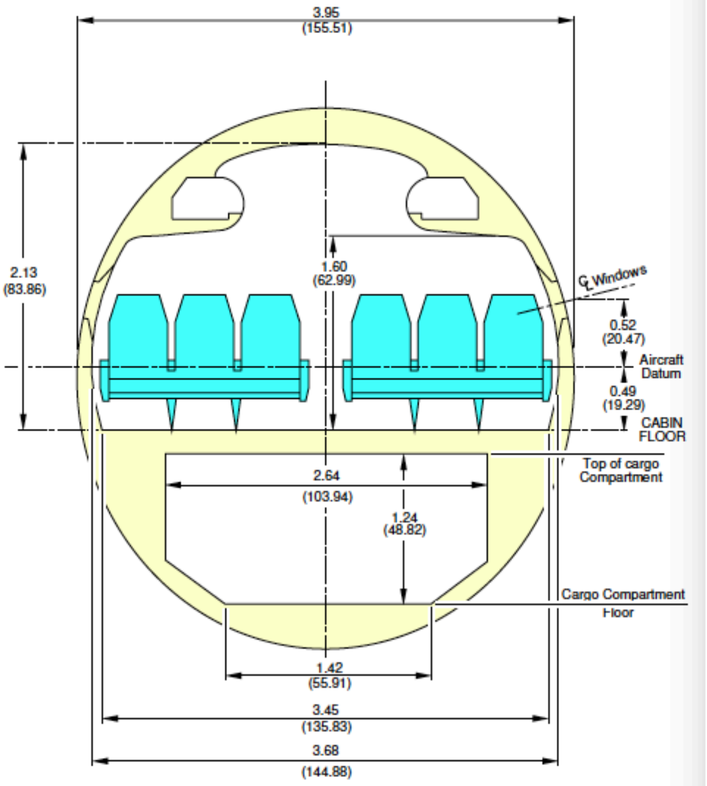

Figure 4.2 Airbus Cross Section (Airbus, 2013)

hold with a 2 inch clearance on the top and a 4.47 inch clearance on the width. Translating these same parameters to the RLD container that must be able to fit within the space of an Embraer 190 cargo hold as shown in figure 4.3, this resulted in a container able to fit within the contour of the Embraer 190 cargo hold. Maintaining the same spatial separation as the Airbus 320 container, this would therefore give the RLD container a height of 35 inches, base width of 29 inches, and a length of 35 inches. At the widest point of the cargo hold, the container is able to have a maximum width of 99 inches, while maintain a 4 inch margin on either side between the side wall of the RLD and the wall of the Embraer 190 cargo hold. Unlike the Airbus 320 container, where it must be raised 2 inches for the roller

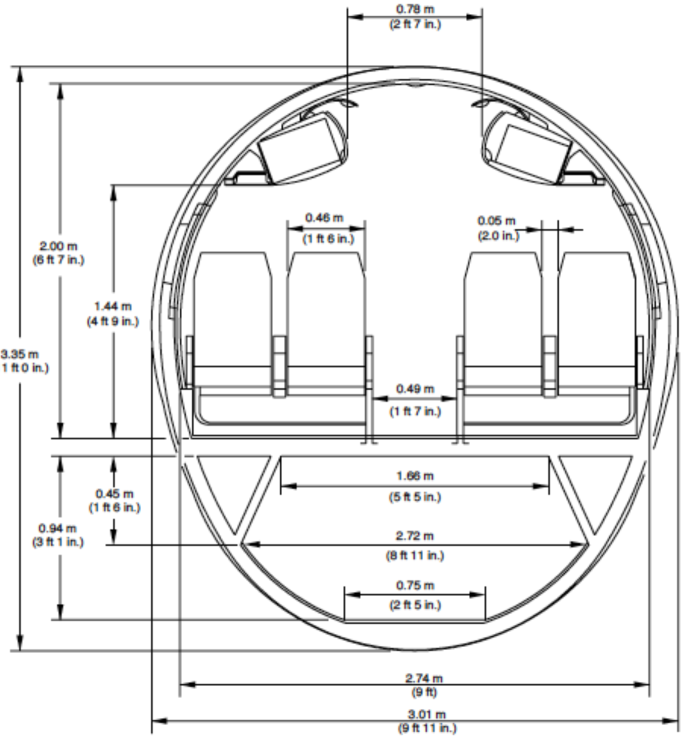

Figure 4.3 Embraer Cross Section (Embraer, 2013)

system, the RLD assumes a movement ability with slide pads, that eliminate the need for a “left on board” roller system, which is used on all aircraft that utilized loading device containers (Boeing 2009, p.33)

4.2 RLD Tare Weight

The tare weight of the RLD was conceived by taking into account the surface area of the container and scaling the empty weight of the LD3 to the RLD.

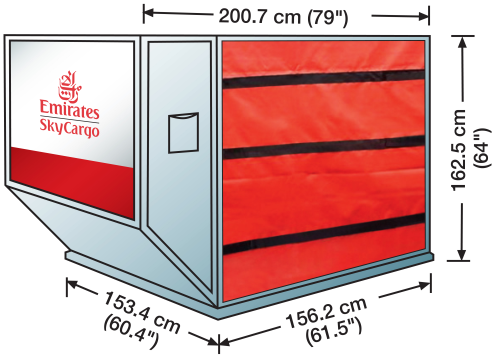

Figure 4.4 LD3 AKE Contoured Light Weight Container (Emirates Sky Cargo, n.d.)

For the LD3 lightweight containers as specified by Emirates, the total volume of the container is equal to 151.85 cubic feet and has a tare weight of 145.505 pounds (Emirates Sky Cargo). To determine a tare weight for the RLD, the surface area of each component of the LD3 was taken. This resulted in the total surface area equaling 26,698.52 square inches. For the RLD dimensions, the total surface area equaled 13,997.29 square inches. Comparing the RLD to the LD3, the RLD resulted in being 52% of the LD3. With the LD3 having a tare weight of 145.505 pounds, this would place the RLD to have a tare weight of 76.284 pounds. The weight of the container assumes that the RLD will be made with the same materials as the LD3, as the study assumes that those materials have been approved by global regulatory bodies for use in aircraft.

4.3 Loaded Weight

To determine the maximum weight that the RLD would hold multiple factors were taken into account. The first assumption that had to be made was to determine the average bag dimensions and weight that would be loaded into an Embraer 190. To develop this figure, three primary factors were taken into account. The first was the average bag size that is loaded into a cargo hold. According to Boeing, in developing the process maps for the Boeing 737 Ground Operations manual, the company assumed an average bag size of 3.0 cubic feet (Boeing, 2007b, p. 363). The second factor that was taken into account was the FAAs required weight of 30 pounds for checked baggage (FAA, 2005, p.19). The third factor that was considered was the Embraer 190s maximum payload. The aircraft's cargo holds have a maximum weight restriction of 4,078 pounds for the forward hold and 3,638 pounds for the aft hold. From these parameters, it was determined that the RLD's maximum capacity at the average FAA weight of 30 pounds and 3 cubic feet per bag was 14 bags per container. With 14 bags at 30pounds apiece, this brings the total content weight of the RLD to 420 pounds. If the tare weight of the RLD at 76.284 pounds were to be considered as well, the total weight of the 11 RLD's would be 839.124 pounds.

4.4 Cargo Hold Payload

In factoring the loss of baggage space due to the use of a container, the study took into account the total space of the Embraer 190 cargo hold, and the maximum amount of bags the hold could handle if the space was hand loaded versus loaded by container. According to Embraer's aircraft specifications, the forward cargo hold has a volume of 438.26 cubic feet and a total max loading weight of 4,078pounds. The aft hold has a total volume of 360.93 cubic feet and a maximum loading weight of 3,638 pounds. In applying the defined standard checked bag of 30 pounds at 3 cubic feet, a total bag count was conceived for both hand loading and container loading the Embraer 190. When hand loaded, the Embraer 190 is able to hold 135 bags in the forward fold and 121 bags in the aft hold. This brings the total to 257 bags at 3 cubic feet per bag at the FAA weight of 30 pounds in the Embraer 190. When the aircraft is loaded by RLD the forward hold is able to hold 8 containers and a total of 112 bags within those containers. The aft cargo hold is able to hold 3 containers with 42 bags in the combined containers along with 71 bags that are hand loaded in the very rear of the aft cargo hold. This would bring the total baggage in the rear hold to be 113 bags. When loaded using RLDs the Embraer 190 is able to hold 228 bags at 3 cubic feet per bag at 30 pounds each. The difference between hand loading and RLD loading is a difference of 31 bags or a 12% loss of space loaded with the RLD. When loaded by hand, the aircraft is able to hold 7,680 pounds of baggage. When loaded by RLD the Embraer 190 is able to hold 6,750 pounds of baggage. It should be noted that when loaded by RLD each RLD has a tare weight of 71.6 pounds. With a maximum eleven containers able to be loaded in to the Embraer 190, the total tare weight of all containers is equal to 787.6 pounds. In comparing hand loading and RLD loading 225 bags, the RLD loading will add 547.6 pounds of weight to the aircraft when comparing to the hand loading method.

4.5 Hand Loading Times versus Container Loading Times

To determine the loading efficiency of containers versus hand loading, two pieces of data had to be determined. The first is determining the speed at which ground handlers are able to fill an aircraft such as the Embraer 190. The second is identifying the time it takes to load containers into an aircraft. In determining the time it takes to load an Embraer 190, a comparable aircraft with similar mission profiles was used, the Boeing 737-600. According to The Boeing Company's guide on ground operations for the Boeing 737-600, the baggage loading rates were established at 15 bags per minute for unloading and 10 bags per minute for loading (Boeing 2007b, p.361). The Boeing 737-600 has a cargo hold capacity of 756 cubic feet (Boeing 2007b, p.361). This is similar to the Embraer 190 which has a total cargo capacity of 799.18 cubic feet (Embraer 2013, p.2-10). Using these figures, it was determined that the Embraer 190 at 100% capacity of

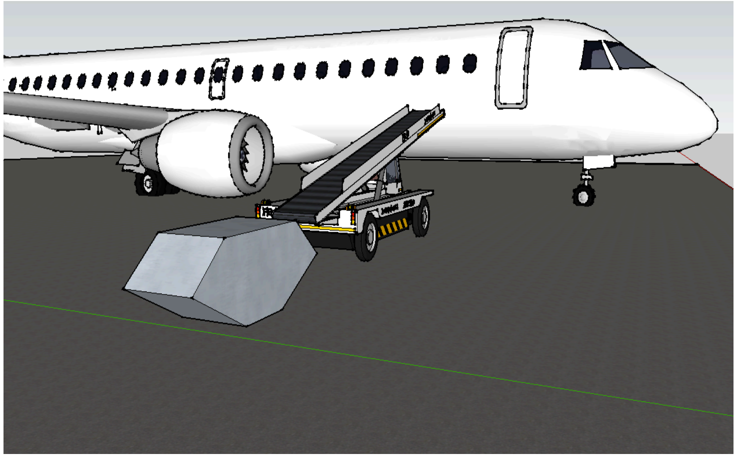

Figure 4.5 RLD CAD Image

hand loaded baggage would be able to unload 257 bags and load 257 bags in a total time frame of 24 minutes as shown in figure 4.5.

To determine the time it takes to load RLDs for the Embraer 190, consideration had to be given to aircraft that utilize loading devices for reference. Because the only narrow body that uses containers, the Airbus 320, does not publish the time it take for loading and unloading containers, widebody aircraft loading had to be considered. When considering widebody aircraft, the two planes analyzed were the Boeing 767-300 and the Boeing 777-200LR. According to Boeing's ground handling manual, the Boeing 767-300 is able to load and unload both the forward and aft cargo holds which combined hold either 30 LD2 containers in a total of 30 minutes or 8 LD3s and 5LD4s in the Aft cargo hold in 30 minutes, plus bulk cargo (Boeing 2005, p.125). The Boeing 767 -300 loading capability is seen in figure 4.7. This is equivalent to a container a minute for unloading and a container per minute during the loading process. To compare the times in which loading devices can be loaded and unloaded from an aircraft, the Boeing 777-200LR was also used as a guide. For the Boeing 777-200LR, the forward cargo hold is able to hold 18 LD3 containers, and the aft cargo hold is able to hold 14 LD3 containers (Boeing 2009b, p. 88) To unload both cargo holds simultaneously is equivalent to 18 minutes for the forward hold and 14 minutes for the aft hold. For the loading portion, Boeing determines that it take 18 minutes to load the forward holds and 14 minutes to load the aft hold. As

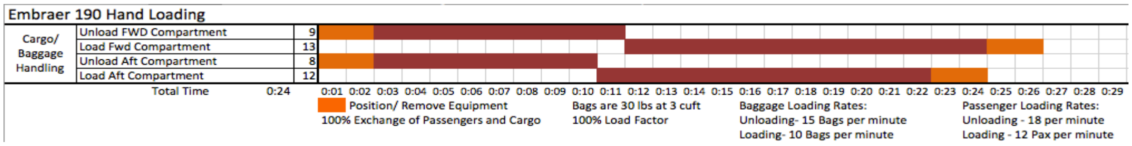

Figure 4.6 Embraer 190 Hand Loading

both loading and unloading of both holds is done simultaneously, it is determined that both loading and unloading can be done in 18 minute sections each which is equivalent to a container a minute for loading and unloading. To ensure that a similar container loading profile could be taken from a scissor lift, which is used to load wide bodies, a time trial was done on a belt loader at Purdue University Airport to ensure that a one-minute loading time could be achieved. In conducting the time trial, an object traveling the Purdue University Airport belt loader, with a surface 23ft 10 inches was able to make the journey in 33.78 seconds. The Purdue University Airport belt loader is also able to handle a maximum weight of 2,000 pounds.

Taking into account the loading data from Boeing and the Purdue University belt loader, it is believed that for ground crews loading RLDs into Embraer 190s, it is feasible to achieve a 1 minute load and 1 minute unload time per RLD container, which would translate to an unloading time of 7 minutes for the forward hold and 7 minutes for the aft hold. While the aft hold is only able to hold 3 containers, the 7 minutes excess is calculated using the metric of 15 bags per minute for unloading and 10 bags per minute

Figure 4.7 United Airlines 767-300 container loading (Airchive, 2011)

for the loading and unloading of bulk baggage that is placed in the aft cargo hold, due to lack of space for a fourth container. In total using the RLD process, an Embraer 190 could be unloaded and reloaded in 20 minutes, in contrast to a 24-minute time frame when hand loaded. The difference between hand loading and unloading baggage to the RLD process results in a four minute reduction in baggage tasks. The RLD loading time can be seen in figure 4.8.

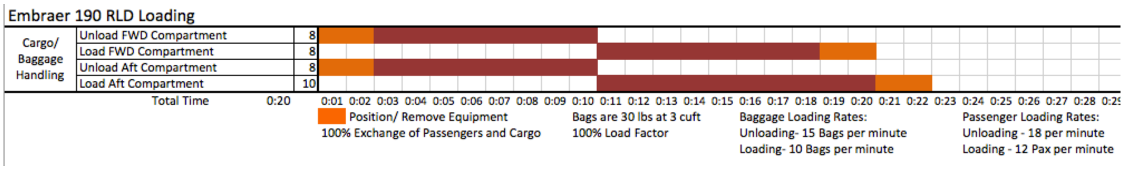

Figure 4.8 Embraer 190 Regional Loading Device

4.6 Mobility of RLD Containers

As addressed in the previous chapters, the Airbus 320 aircraft has the ability to have cargo rollers installed to allow for the movement of LD3-45W containers within the hold. As rollers are a fixed product to an aircraft and in most cases, add severe weight penalties, it is proposed that the RLD will have fixed slip pads attached to the bottom of the containers. This will allow the RLD to be loaded using existing ground loading

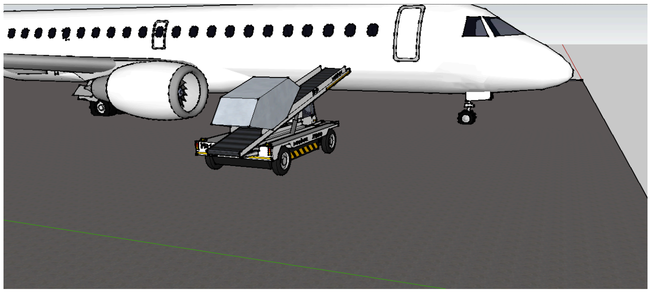

Figure 4.9 RLD loaded into E190 using belt loader.

equipment such as conventional hand loaded baggage conveyor belts as seen in figure 4.9 or even universals for pallets. The use of slip pads will allow for RLDs to not require extensive overhaul to aircraft cargo holds and will allow for hand loaded baggage in the same hold should the need for a container be unavailable. While slip pads are experimental in nature as they are not approved by the Federal Aviation Administration (FAA) as an acceptable method of moving containers, it is assumed that at some point a zero friction pad can be developed to facilitate an RLD like device

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the conclusions derived from the data that is set forth in the previous chapter.

5.1 Conclusions

From the data that was presented in the previous chapter, it can be concluded that it is possible for a loading device or RLD for an Embraer 190 to be designed, that would have minimal impact on the way current Embraer 190 ground handling is conducted and would allow for ground handlers to stage baggage within RLDs, load and unload RLDs from aircraft in a more timely manner. The ability for ground handlers to pre stage containers before loading would give carriers the flexibility to have more buffer time for loading. However, while the data has shown that the loading process can be accelerated, this study does not look into other ground procedures, which remain constant.

In figure 5.1, all turnaround processes for the Embraer 190 are shown including the hand loading of baggage. Within the 28 minutes it takes to turn around an Embraer 190 today, of this time 24 minutes requires hand-loading baggage. In contrast to the hand loading method, the RLD results in a 20 minute baggage loading time. However when factored with other processes, the Embraer 190 still completes a turnaround in 28 minutes as shown in figure 5.2. In the end while a four-minute savings was achieved in loading, the overall turnaround time was unaffected. It should be noted that this study factors that the

RLD will be able to be placed in the cargo hold using slip pads or similar zero friction surface that is to be adhered to the RLD as opposed to the aircraft itself. While this is not an approved material by the Federal Aviation Administration (FAA), it is assumed that a similar product or zero friction surface can replace a roller system. This study also to decrease labor hours and reduce cost by increasing turnaround times and increase aircraft utilization. But ultimately while the time savings from loading are evident, the end product does not materialize into increased aircraft utilization or reduced labor hours.

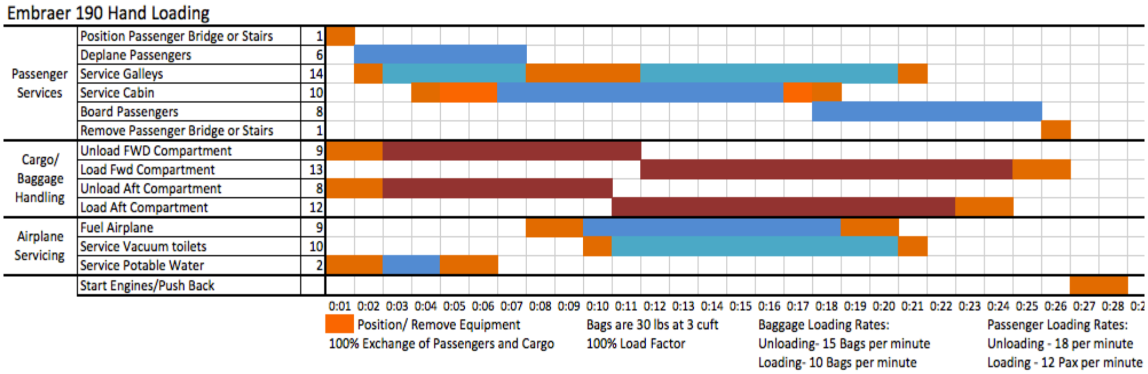

Figure 5.1 Embraer 190 Hand Loading Process Map

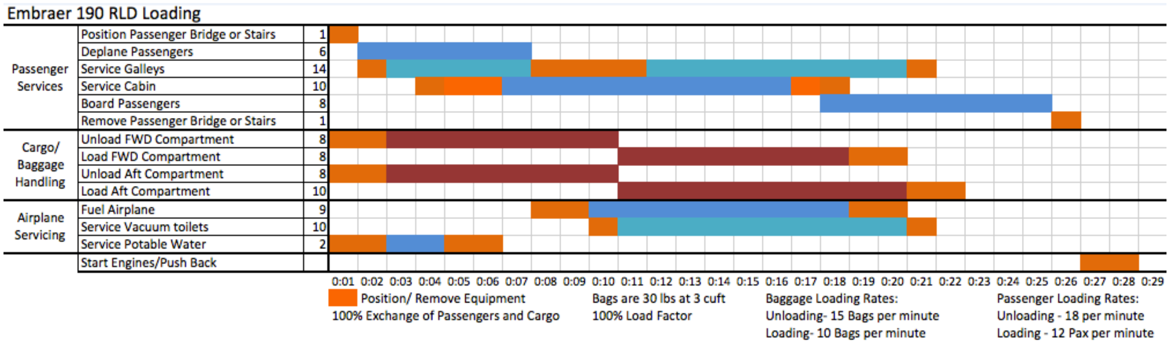

Figure 5.2 Embraer 190 RLD Process Map

5.2 Recommendations

Based on this study, it is evident that containers for narrow body aircraft are a possible product for future development. As stated in the review of products used for baggage loading, aircraft such as the Airbus 320 family have the ability to hold a unique container, the LD3-45W. Products like these are major options for airlines, allowing handlers the ability to presort baggage and allow for faster turnaround time, as opposed to sorting transiting or origin and destination baggage while trying to turn an aircraft around. While this is a new realm of design that is to be considered and much of the mechanics must be certified by global regulatory bodies, the elimination of heavy fixed rollers would allow for lighter aircraft, regardless of model. This study has allowed airlines to evaluate operations to reduce other task in the boarding process, which can allow a 4 minute reduction in baggage loading to positively benefit the entire boarding process.

5.3 Future Study

For RLDs to be a viable product, it is necessary that slip pads or similar zero friction surfaces be investigated as means to replace fixed roller systems that are conventionally used for loading device containers. What makes the RLD possible, is the Embraer 190's cargo door. The Boeing 737, despite being a workhorse to the global aviation fleet, could not be considered in this study as its cargo door is a plug type door instead of an outward moving door like the Embraer 190 and the Airbus 320. In addition to exploring practical RLDs, lighter materials would allow for increased loads as the weights of the RLD would be lighter. This study does not directly explore the ergonomic strains of hand loading baggage and container loading baggage, however the assumption that injuries do occur during loading and the loss labor due to those injures can be taken into account under future studies. It is also believed that the ability for a baggage handler to sort baggage directly into a container and load a unit into the aircraft's hold would result in a more ergonomically friendly environment, this speculation must be explored through human testing and product development.

5.4 Summary

This study explored the possibility of developing a loading device for an Embraer 190 that could result in improved economic benefits of faster turnaround times and reduced labor hours. The study outlined various technologies that have been used to increase aircraft loading efficiency as well as reduce injuries that occur in the process of loading aircraft. In establishing a precedent for the creation of such a loading device, attention was given to the LD3-45W, a container that is used by the Airbus 320 aircraft, and containers that are used on common widebody aircraft, specifically the Boeing 767-300 and the Boeing 777-200LR. To create a theoretical working container design, the LD3-45W boundaries in relation to the Airbus 320 aircraft cargo walls was scaled to match the Embraer 190. With this scale, a container size could be derived, and the surface area of an LD3 container could be evaluated from a surface area perspective to determine a weight for the new RLD container. In determining these various parameters, the amount of baggage that could be placed in 11 RLDs was determined by following the 30 pound rule by the FAA and the measurement of 3 cubic feet per bag by the Boeing charts for the 737. From the baggage weights and volume, maximum amount of baggage could be determined between hand loading and RLD loading. The result showed a 41 bag penalty when loading with RLD when attempting to load the cargo hold to maximum tonnage. The study also shows that when loading equivalent amounts of baggage, the RLD on average will add 547.6 pounds to the aircraft. However the RLD results in a four minute reduction in baggage loading time, assuming the man power to load the Embraer 190 is kept at the same staffing level as defined by Boeing for the 737. Yet, despite the reduction in loading time, the four minutes are overshadowed by other task in the boarding and turnaround process. In concluding this study, recommendations and future topics of study were proposed, such as evaluating the ergonomics of containers and adjusting other task of boarding to achieve the four-minute reduction.

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