DECISION SUPPORT SYSTEM FOR EXCEPTION MANAGEMENT IN RFID ENABLED AIRLINE BAGGAGE HANDLING PROCESS

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Abstract— This paper attempts to investigate methods through which RFID-enabled technologies may be used to streamline and improve airline baggage handling processes. The current process for airline baggage handling relies heavily on the use of barcodes and is highly unreliable. Even though the value of RFID-enabled technologies, in handling passenger bags, is generally accepted in the industry, the adoption of these technologies is hindered by concerns relating to inadequate return on investment on them. In this paper, we attempt to address this issue by highlighting scenarios in the baggage handling process where RFID-enabled technologies may be uniquely positioned to create value. In particular, with the help of fault trees we identify exceptions that commonly arise in the baggage handling process and identify RFID-enabled solutions that may be implemented to manage these exceptions. We also discuss the design of a decision support system that can be implemented to automatically handle baggage handling exceptions using RFID tag information.

Index Terms—Radio Frequency Identification (RFID), Airline Baggage Handling Systems, Fault Trees, Case-Based Reasoning

I. Introduction

Radio Frequency Identification (RFID) is a recent technological development that harnesses wireless and information technologies to automatically identify products, items, resources and assets using devices called RFID tags. In particular, RFID-enabled solutions have in the recent past offered a number of very innovative and exciting applications in the supply chain arena. Specifically, Walmart, the retailing giant, and the Department of Defense of the USA (DoD) are spearheading its application in retail and supply chain tracking and visibility. As a result it is estimated that the RFID market will grow to around \$ 11.7 Billion (Source: Forrestor) in 2010 and save Walmart alone \$8.4 Billion per year in supply chain costs (Source: Sanford C. Bernstein & Co. analyst report).

Within the airline industry, the adoption of RFID tags for baggage identification and tracking has been aggressively pushed by some airlines, airports and the International Air Transport Association in recent months. There has been a considerable amount of literature highlighting how the fast read rates and near 100% accuracy in read-rates of RFID tags are superior to those barcode tags currently being used to track passenger bags. However, simultaneously there have also been reports of airlines and airports abandoning RFID system implementations and pilot tests due to the lack of demonstrateable return on investment on such projects.

In our opinion the reason most of these projects failed to demonstrate the needed financial return was because they focused primarily on increased labor productivity in the baggage scanning process, instead of considering other more valuable applications of RFID-enabled technologies, such as the savings in time, money and effort from the avoidance of costly baggage handling exceptions. Literature Review

There are several white papers written on the merits and return on investment for use of RFID in retail, transport and logistics, pharmaceutical supply chains and a host of others. It would be difficult if not impossible to survey all that literature here. An internet search will throw an enormous number of papers. Most of them are either descriptions of trial runs and mere specifications.

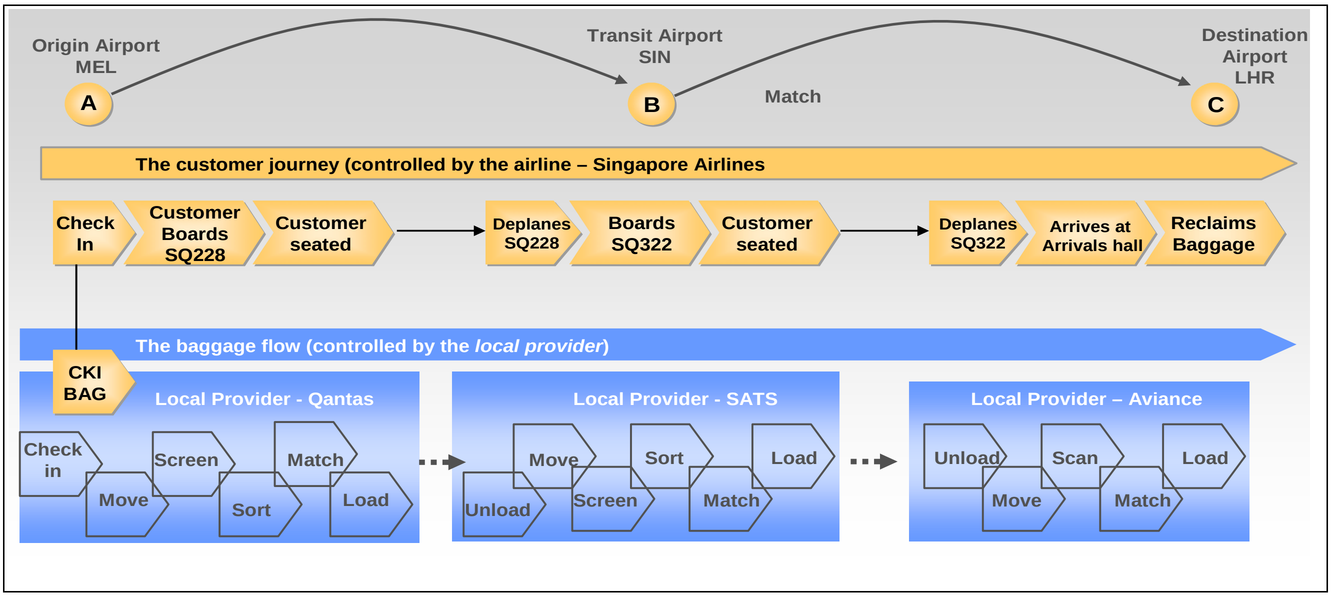

Fig1:.Illustrating the Players in the Baggage Handling Process

A. Organization of the Paper

In the following sections, we will begin by providing an overview of the airline baggage handling process and describe the process flow and problems involved therein. In particular, we will focus on flight delays and incorrect routing of bags due to baggage handling processes. Subsequently, we shall look at some technological solutions, such as RFID and case-based reasoning, that can be deployed to minimize these problems. Eventually It will end with a Decision Support System incorporating Case-Based Reasoning, and how, when coupled with RFID technology will give a holistic solution to the baggage handling process Current Barcode-based Baggage Handling Processes

The current baggage handling processes are heavily dependent on barcode-based baggage tags for baggage identification and to provide routing information. To provide details on the baggage handling process the baggage flow from an origin A to a destination C through a transit hub B is mapped in Figure 1. Also, for ease of illustration and explanation, we discuss the specific case of a passenger traveling from Melbourne (MEL) to London Heathrow (LHR) with Singapore Airlines (SQ) and transiting through Singapore (SIN). In the specific example considered we assume that the passenger boards SQ228 at 1600 in MEL, arrives in SIN at 2040 and connects to SQ322 leaving SIN at 2315 to reach his final destination LHR at 0530 hrs the next day. The passenger has a connect time of 2 hours and 35 minutes in SIN, between his two flights. Except for the transit times and flight schedules the baggage handling process being discussed will remain pretty much the same.

The carrier airline, Singapore Airlines in this case, evidently has full control over the fulfillment of the customer's journey from Melbourne to London. However, unlike the case of passenger flows, the baggage handling in each airport is in the control of individual local ground handling companies. These ground handling companies in turn often rent out the needed airport and baggage handling infrastructure from the local airport authority. The presence of such a large number of stakeholders in the journey of a single back, consequently leads to a large number of handovers and limited visibility and information sharing in the baggage handling chain. Furthermore, as a result of the large number of handovers involved in the end-to-end journey of the baggage, an error or inefficiency in any single handover can result in the bag not reaching the destination along with its owner. A detailed description of the baggage flow is presented below.

B. Departing Baggage/Check in

In Melbourne, Qantas is the ground handling agent for Singapore Airlines. During passenger check-in, the Qantas customer service agent issues the boarding pass to the customer and tags each bag with the luggage tag of the final destination, including a 10-digit bar code, which is unique to the bag. This is where the customer and her bags part ways. The baggage is then security-screened for hazardous material, in a process known as "Hold Baggage Screening" (HBS).

C. Screening

Given the increasing vulnerability of the airline system to a variety of nefarious activities, such as terrorism and smuggling, all bags are screened at the origin to detect and prevent such activities.

D. Baggage Sortation

On passing the security screening, the bags are typically loaded onto conveyors that transport them to an automated baggage sortation system. The arrival of the bag into the sortation system is read by a bar-code scanner array that is arranged in a circular manner around the conveyor, providing an almost 360 degree coverage of the space within the array... However, sometimes the bag tag is not visible to any of the scanners within the array. Typically 75 -90% of the barcode tags are accurately read by the scanners. The reading of the barcode tags not only acknowledges the location of the bag in the sortation system but also provides information on the departure flight the bag is destined for. Through a database look-up in the sortation system, the controller in the baggage sortation system is able to route the bag through a series of pushers and automated conveyor systems to the appropriate staging area/gate for the specific bag as per its departure flight information.

At the staging area, the baggage handlers, load the baggage into the plane. As bags are loaded their barcodes are scanned to acknowledge their loading and to provide an audit trail. For smaller aircrafts the bags are often loaded directly as "bulk cargo" and secured using harnessing nets. On larger planes the bags need to be loaded into containers called Unit Load Devices (ULD) that are loaded and secured in the belly of the aircraft. Priority bags for First Class, Business Class and other special passengers are identified manually by "priority tags" hung round the bags at check-in. Bags that are making a transfer after a flight ("transfer bags"), are loaded into ULDs separate from ULDs for bags that will be arriving at the same final destination as the flight ("direct bags"). In fact transfer bags might be further segregated into different ULDs based on their final destination. This strategy presorts baggage at the origin itself according to clusters containing any number of destinations (Robuste and Daganzo).

E. Loading

Once the ULDs are filled up they are loaded into the cargo hold in the belly of the aircraft, at different locations such as the front cabin and the back cabin. This activity typically takes place 15 to 30 minutes before flight departure. On completion of the loading the responsibility for the baggage is transferred over to the carrier airline. For the example considered, this suggests that responsibility for the baggage is handed over from Qantas to SIA. Also, as a matter of ensuring security, the baggage for passengers who check-in for a flight and subsequently fail to board the plane is removed from the flight.

F. Arriving Baggage/Transit Baggage

In a transit airport like Singapore, responsibility for baggage handling is now transferred from the carrier, SIA in our example, to the local ground handler, Singapore

Airport Terminal Services (SATS). On the arrival of the plane at the gate, SATS agents unload the bags and ULDs and take charge of the baggage.

As mentioned earlier bags arriving into an airport might be transfer bags or direct bags, and consequently, depending on their destination they are handled differently. Direct bags are offloaded from the plane and carted to the baggage carousels in the arrival section of the airport. On the other hand, depending on the connect time available for the bag, a transfer bag is either carted directly to the gate of the connecting flight or carted to a staging area for subsequent dispatch to the appropriate connection gate. Bags with limited connect times are referred to as "hot bags" and those with ample connect times are known as "cold bags". Once the connecting plane is ready to depart all the transfer bags on that flight, along with the locally originating baggage, are once again loaded onto the plane as bulk cargo or in ULDs. On completion of the loading of the plane the responsibility for the baggage once again transfers from the ground handler to the carrier. So, in our illustrative example, SATS unloads the bags from SQ228 and delivers them to connecting gate corresponding to flight SQ322. The loading of bags onto SQ322 coincides with the transfer of responsibility from SATS to SIA.

G. Bag at Final Destination

Finally, on the landing of SQ322 at LHR, Aviance, the ground handler at Heathrow assumes responsibility of the bag when it receives the aircraft. They unload the bags from the flight and cart it to the luggage carousel in the arrivals area of Heathrow, for eventual pick-up by the passenger.

H. Baggage Management Systems

One of the key supporting tools in the process described above is the Baggage Management System (BMS), which manages and coordinate the activities of the ground handler at most airports. The BMS typically holds information about all the arriving bags, and their routings, on a particular flight. Some of this data may be held in the form of aggregate numbers such as the Number of Transfer Bags, Total Bags Misconnected, Illegal Connections and Bags Misconnected within Minimum Connecting Time (MCT) for each flight. This information is employed to determine which bags are loaded on a plane, which are transferred at a hub and which are dispatched to the arrival hall. In addition, the connection times for transferring bags may also be available through the BMS. However, due to legacy issues and the resulting designs for these systems, most do not maintain information on the specific location of each bag in the plane belly.

In addition these systems also provide some reporting functionality, wherein they report useful statistics such as the "Percentage Misconnected", "Passengers arriving without Bags" (PAWOBs) and the "Bags Misconnected with Connecting Times in Excess of MCT".

II. Issues with Current Baggage Handling Process

A number of issues exist in the current baggage handling process that frequently contribute to the loss of passenger bags or their delayed arrival at destination airports. In addition, these inefficient processes also result in significant flight delays, further contributing to customer dissatisfaction. In better understanding these issues we particularly focus our efforts on understanding the outcomes resulting from the drawbacks of barcode technology and consider two specific exceptions that may result from the set-up of the current baggage handling processes: 1) Baggage handling anomalies resulting in flight delays 2) Bags not reaching their intended final destination due to baggage mishandling.

A. Drawbacks of Barcode Scanning

The use of barcode scanning for sortation and tracking in the baggage handling process is a significant contributory to handling inefficiencies and exceptions. Firstly, as a result of the folding and creasing of baggage tags, the read-rate of baggage tags in sortation machines has been noted to fall from 85-90% to as low as 65% in some cases (as reported at Tokyo's Narita airport). In addition, since flight arrival and departure frequencies are bursty in nature, and not uniformly distributed over the 24 hours of each day, read rate errors can increase during peak traffic periods when there is a deluge of incoming transfer bags. Since mis-read bags tend to stay within the sortation system, such an increase in the mis-read can lead to an exponential growth of outstanding bags in the sortation system and can lead to a gridlock of the system, when the total number of bags in the system surpasses the holding capacity of the system. Once a gridlock occurs it often takes a few hours to get the system started again. Consequently, flights are forced to take delays or leave without the bags.

In addition, high read-error rates necessitate the deployment of additional personnel to manually handle, sort and screen misread bags. Furthermore, bar-coded baggage tags loose their reliability when the bags, which have missed their connections or were unfortunate to be on cancelled flights, need to be re-routed through another flight. In these scenarios the rerouting information is typically hand-written on the existing tag or the barcoded tag is replaced by a handwritten tag. As a result the updated baggage routing information is no longer machine readable, hence requiring manual identification and sortation at each of the down-line process steps. This also increases the chances of the bag being lost or getting delayed in reaching its destination.

Also, barcode technology due to its limitation does not in anyway help expedite the offloading of bags belonging to no-show passengers or identify bags that need a quick transfer to a connecting flight. The primary reason for this is that barcode technology does not provide any information on the location of each bag in an arriving aircraft or on the dynamically changing status of each bag with respect with its current available connect time.

B. Fault Tree Analysis of Baggage Handling Anomalies Causing Flight Delays

There are two primary ways in which handling anomalies may result in flight delays. Firstly, if a checked-in passenger does not board the flight his baggage needs to be offloaded, often at the last minute, leading to departure delays. Secondly, departing flights might be delayed if an arriving flight, carrying connecting passengers bound for the departing flight, is delayed and the bags of these connecting passengers cannot be identified and transferred from the arriving flight to the departing flight within the available time. In such scenarios the departing flight might have to wait for the bags of the connecting passengers to be identified and transferred. The fault tree for the exception of a delayed flight resulting from baggage handling exceptions is discussed below and presented in Figure 2.

1) No Show Passenger – Baggage to be offloaded from Aircraft

A closer look at the fault tree suggests that for the base event of a no show passenger, the lack of information on the specific location of a particular bag or its ULD, coupled with the inability of bar-coding technology to spatially locate a given bag leads to a manual hunt for the bag, contributing to the top level event of a delayed flight departure.

2) Late Arrival of Flight Carrying Connecting Passengers

Airlines routinely delay an outbound flight from their hub if an inbound flight with a significant number of connecting passengers arrives within half an hour of its scheduled time of arrival. Ideally, the baggage would have been pre-sorted in their ULDs at the origin station of the arriving flight as mentioned earlier. This would enable quick identification of the bags at the hub when the flight arrives, thereby allowing for a "rush" transfer of hot bags to their outbound connecting flights. The fault tree for flight delays demonstrates that in the event of errant sorting of baggage at the airport of origin, the unavailability of tools for quick identification of hot bags coupled with an absence of information on the specific location of these hot bags contributes to a departure delay of the outbound flight.

C. Fault Tree Analysis of Bags not Arriving at Final Destination

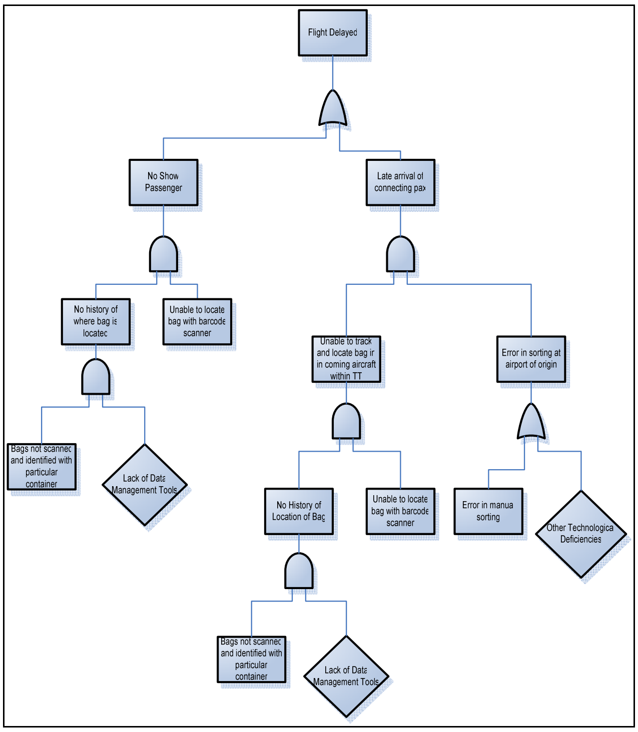

Figure 2: Fault Tree Analysis of how Baggage Handling Anomalies Result in Flight Delays

There are a number of reasons why bags might not reach their intended final destination along with the passenger. Such scenarios often prove costly to the carrier since it has to compensate passengers monetarily for the inconvenience, even though the bags may eventually be united with their owners. However, the two primary reasons why a bag may not reach its destination on time are the incorrect dispatch of the bag to the wrong destination and the inability to load the bag in a timely manner at the origin airport itself.

1) Bag at Wrong Destination

Referencing the example discussed earlier, a bag can end up at a destination different from its intended destination either because it was incorrectly put on the wrong flight at either the origin (MEL) or at the connecting hub (SIN). This problem typically arises when bags bound for two different destinations are sorted and packed into the same ULD container and there is a failure in barcode scanning that is not corrected or detected by the manual sorting process at either the origin or the connecting hub. For e.g. if some SIN and LHR bound bags are packed together in the same ULD in MEL for a MEL-SIN flight, there is the possibility that if the presence of the SIN bags in the ULD with LHR bags in not detected in SIN, the SIN bags may be mistakenly forwarded to LHR along with the rest of the ULD. In fact, it is possible that an entire ULD might be wrongly sent to the wrong destination if the ULD is not properly identified and sorted. Furthermore, the probability of such an exception arising at a hub airport is significant because of the large volume of transfer bags and frequent last-minute gate changes that are necessitated by operational deviations resulting from spiky flight arrival and departure schedules

2) Missed Connection at Transit Hub

The bags will not make it to their intended destination if the arriving flight at the hub reaches later than the departure of the connecting flight.

3) Failure to Load Bag at Airport of Origin

Another reason the bag may not reach its destination on time is that it is not loaded at the airport of origin. Such a situation may arise if the passenger checks in late or alternatively if the baggage is not cleared through security in time.

III. Proposed Technology Set-up to Better Manage Baggage Handling Process

The baggage handling problems and exceptions discussed in the previous sections can be easily managed to a significant extent through the smart use of technology. In particular, RFID technology holds a lot of promise in being able to provide superior efficiency and reliability in the baggage handling process. Used in conjunction with case-based reasoning (CBR) systems RFID technologies can prove to be even more impactful.

Our discussion of how technology may be applied to better manage the baggage handling process assumes the availability of the following technology set-up in the airline and the airport. The two key aspects of this set-up that we shall investigate further are the applications of RFID technologies and that of CBR-based decision support systems.

A. RFID Technology

RFID technology has been proposed as an alternative to barcodes for the purpose of data capture. This technology can be used to track, identify and detect a wide variety of objects. The two basic components of an RFID system are a tag and a tag-reader. A tag is made of an embedded chip processor and an antenna. A tag typically stores up to 96 bits of information as compared to the 10 bits that are encoded in a barcode. Tags may also incorporate read/write capabilities using embedded programmable memory chips. Information encoded in the reader is accessed through a radio-enabled device that communicates with and interrogates the tag for reading and writing. The significant benefits derived from RFID systems are that they do not require a line of sight for data capture, and consequently can capture a greater amount of information (nearly 10 times that of the barcode) in a shorter period of time.

In the context of RFID implementations in airline baggage handling, RFID tags can be embedded in the bag tags that are appended to the bags during check-in. The RFID tags can be coded with data uniquely identifying the bag through information on the airline code, flight number, passenger reservation number and itinerary. This information can be accessed by placing RFID readers at various points in the baggage sortation system. More importantly, the information accessed by the readers can be transmitted to the baggage management system to keep track of the bag location and to provide context-specific and actionable routing plan for each bag.

1) *RFID Tag Creation*

The RFID tags might be based on a design such as the Parallel Integrated Chip Assembly (PICA), which has been proposed by Symbol. A PICA machine with one head can produce 1.2 million tags per hour. In addition, the machine is small enough to be placed at airport check-in counters.

2) *RFID Readers at Conveyors*

After check-in, bags are routed into conveyors where their RFID tags can be read by appropriately placed RFID readers. As the tags are read, they can be routed to their correct flights for subsequent sorting and uploading to their ULDs. The routing and sorting system can be based upon the principles described by Charles Cadieu et al. Here, each router consists of a computer with three RFID readers, a mechanical arm that detects the presence of a bag, and another mechanical arm, which pushes the bag into the correct output conveyor belt. Upon detecting the presence of a bag, the incoming baggage is scanned by the 3 readers and the router decides which tags are actually present by a vote on the 3 RFID outputs. This voting system minimizes the effects of false reads and malfunctioning hardware. Also, since line of sight is not required the tags are accurately read even if the tag is lying under the bag. Additional readers need to be placed at each junction to determine which route the bag should take. The routing itself will depend on the flight information read from the tag and the gate information for a flight stored in the Airport Database. In addition, RFID tags can be used to identify fragile or odd-sized baggage (which are currently identified by physical labels) and routed automatically in the sortation system to conveyors specifically designed to handle such special baggage. Special RFID tag writers can also be positioned at selected locations to erase and write new data into existing tags, in the event of rerouting or correction of a mishandled bag

3) *RFID Readers on ULDs*

RFID readers can also be placed on each ULD to identify individual bags that are loaded. The reader will read the tag of each bag that is loaded in, and send the information back to the airline's central database. This will enable 100% visibility of all bags in the aircraft, which will enable the ground staff at the flight's destination airport to pinpoint the locations of each individual bag on the flight.

4) *Hand-held Scanners*

Hand-held scanners will need to be used for bags that either have a destroyed RFID tag or those that come from airports that do not use RFID tags. The barcode on each bag is then scanned by hand and an RFID tag is placed on it. These handheld scanners will need to connected to a central server and the airport database and decision support tools.

With this system, the airline will have full visibility on all its bags. Every step of the bag's movement from check-in to loading will be recorded. Misplaced bags can be read with hand-held readers and information regarding the bag will be instantly available from the baggage database through the airline or airport's LAN system.

B. *Case-Based Decision Support System for Baggage Handling*

The RFID solutions described earlier no doubt address a number of problems in the baggage handling process. Nevertheless, their true potential can only be leveraged if the data captured by the RFID readers is processed through a smart decision support system. One implementation of such a system can be rooted in the Case-Based Reasoning approach.

IV. Application of Technology to Better Manage Problems in Current Baggage Handling Process

The proposed technology set-up described in the previous section no doubt provides a number of ways in which it can be applied to solve problems in the current baggage handling process. However, to better understand the manner in which these technologies can improve the baggage handling process we shall refer back to the specific issues we discussed in Section 3 and describe how RFID and CBR technologies can be used to address them.

A. *Baggage Screening Process with RFID*

During baggage screening, RFID technology can be used to successfully read close to 100% of bags sent through the screening process. As a result, the number of bags that require Level 3 screening subsequent to Level 1 screening, because of bag tag mis-reads, is minimized greatly. Consequently, the average screening time and resources expended for bags is greatly reduced.

B. *RFID solutions to minimize Flight Delays resulting from Baggage Handling Anomalies*

RFID technologies can be readily applied to address both of the key issues in flight delays resulting from baggage handling anomalies, which were discussed in the previous section. The "absence of technology to identify bags in a quick manner" is a common contributing problem to delays, both when passengers do not board and when inbound connecting flights are delayed. In fact, the adoption of RFID technologies can provide a convenient means to quickly and easily detect the presence and location of specific bags within the belly of the plane, thereby allowing their quick offload. In the event of a no-show passenger, RFID technology can allow an airline to instantaneously access information on the location of the particular passenger's baggage, reducing the time needed to locate and subsequently offload it. Similarly, when an incoming connecting flight is delayed, RFID technology can help identify the presence and location of hot bags and thereby minimize the unloading time of these bags making it easier for them to make their connections.

C. RFID solutions to Lower the Risk of a Bag not arriving at its Intended Destination

The risk of bags not arriving at their intended destination can also be minimized using RFID technology.

Firstly, using RFID technology it is possible to quickly and easily read the destination information for each arriving bag on a flight. Consequently, even if bags bound for different destinations are mixed in the same ULD, using RFID readers it is possible to immediately and easily identify their presence. While not directly preventing mishandling in the labor-intensive sorting process, RFID technology will enable the ground handler to recognize the presence of bags bound for specific destinations in each ULD and accordingly sort them. For e.g., the ground handler receiving an arriving aircraft from MEL will know through his reading of RFID tags of bags inside ULDs that ULD1 contains transit bags to LHR and Paris (CDG) and needs to be sorted, whereas ULD2 contains bags of passengers terminating in SIN and needs to be sent to the arrival hall. This ability can minimize instances where ULDs are mistakenly sent to the wrong destination.

Secondly, RFID accuracy read rates approach 100% as compared to 85% for the best-case barcode tagging system. Hence, due to the enhanced tracking and logging capabilities of a complete RFID system, manual handling of bags is significantly reduced and incorrectly routed bags can be redirected, through a quick RFID read of destinations of bags inside a ULD being loaded, before they are loaded onto wrong flights and lost. This avoids the additional cost associated with recovering a missing bag and compensating the passenger. Finally, as mentioned earlier, the use of RFID technology can minimize the average time taken to screen bags. As a result, the possibility of a bag missing a flight at its origin due to screening delays is minimized.

V. CONCLUSIONS

This paper has introduced and charted the baggage handling process for both departing and arriving baggage as is practiced using present barcode systems. The concept of RFID technology as a barcode replacement was then introduced, and Fault Tree Analysis was conducted on various problems that compound baggage handling operations today. For each of the base issues, their solution through the use of RFID Technology was discussed. The role of decision support systems built using case-based reasoning methodology in further harnessing the potential of RFID systems was also discussed.

We believe that RFID technology in baggage handling can prove to be very powerful only if airlines and airports look beyond RFID's role as a mere replacement for a barcode to its ability in reengineering and streamlining their processes, such as in the baggage rerouting system discussed in this paper.

Undoubtedly, there are some challenges as well in the adoption of these technologies. In particular, different countries use different standards for RFID technology implementations. Nevertheless, the potential for RFID use in baggage handling and terminal management is enormous. The potential use of RF tags could extend to having the tag capture the weight of each bag, which would aid in loading algorithms. These functionalities need to be studied further.

In conclusion, we hope that our analysis in this paper has established a strong operational case for the use of RFID technology in baggage handling

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