THE NEW DESIGN OF AUTOMATED BAGGAGE LOADING AT AIRPORT

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ABSTRACT

Since the dawn or society, man have dreamt of aviation. The first known form of man-made flight came in the form of paper kites originating from China. But it was only in the 18th century were hydrogen balloons invented and the Montgolfier brothers discovering the hot air balloon. Within the same century of the Wright brothers' single man wooden plane, large commercial planes capable of carrying in the hundreds is flying over our oceans on a daily basis. As the number of flights and air travelers increases year on year, so does the amount of baggage they bring on board. The barometer used to gauge an airport operator's service quality is often the efficiency and quality of their Baggage-Handling-System. Due to the highly competitive nature of airport operators, it is of great importance they have the state-of-the-art systems. The aim of this research is to find out if an automated Unit Load Device for passenger baggage is capable of providing advantages in terms of cost, manpower and time efficiency. The design of the system focuses on the loading of baggage from the airport's conveyor or storage onto the plane and the unloading of them at the destination airport. This is done by the introduction of built-in conveyors in the Unit Load Devices that allows baggage to be loaded into them directly from the airport conveyors without the need of workers to do so. The Unit Load Devices would then be driven to the airplanes loading bay by automated Dollies. The ULD's built-in conveyor would unload the baggage onto the plane. The reverse process is then done to transfer the baggage off the plane and into the destination airport's baggage system. The performance of the system is evaluated by comparing them to general baggage systems that are currently in use through a series of simulations.

Keywords: Automation, baggage handling system, simulation, unit load device

1. INTRODUCTION

Manned flights today are no longer myths and fantasies, instead it is now our reality and for some a necessity. Modern day commercial air planes can take passengers in the hundreds at a time. Worldwide air travel is experiencing a continual growth year on year. According to Schmidhuber (2003), the number of air passengers increased by more than 4 folds from 1980 to 2018. Meanwhile the situation in Germany also follows a similar trend with a staggering growth of more than 5 folds across a similar period of time.

Among the biggest and toughest challenges an airport operator could face is the handling of baggage and it is a major indicator of their service quality, Frey (2014). Failure to meet standards often causes a huge drop in passenger and airline satisfaction levels. The highly competitive nature between airport operators for passengers as well as airlines makes service quality a vital aspect of the business. Baggage handling systems with a characteristic of short transfer times for the baggage from passenger to flight (outbound baggage), flight to passenger (inbound baggage) or flight to flight (transfer baggage) are attractive to prospective airlines and also encourages the return of passengers in the future. The rise of technology has seen more fully automated and highly intelligent sorting devices being implemented in more and more airports throughout the world. However, the loading and unloading of unit load devices and the transport link between narrow-bodied aircraft and automated baggage sorting systems remain outdated.

Traditionally all baggage handling task and resources are managed and assigned by senior workers called dispatches. Dispatchers receive colossal loads of data and information, and have to churn them within a very limited timeframe. Dispatchers would then assign the available resources to carry of the needed task. Their responsibilities are enormous and often do not have any other tools to call upon other than their own experience and manual planning. This often results in the dispatchers to come up with very poor solutions in regards to the utilisation of the available resources at hand. It is very much apparent that a heuristic mathematical solution would be able to better manage the resources. Inefficient utilisation of the resources run up an unnecessary high operating cost. Tošić (1992) suggest this often leads to temporary workers being employed in order to carry out the additional work or expensive extensions to the current infrastructure.

Baggage handling services performed by manual labor often brings about a few problems. The working area are often not fully protected from the weather and at times treacherous to the health of the workers. This means that fewer number of people would be inclined to do such work. Leading to more man-power needed for the work and at a higher cost. Open baggage carts or semi-covered baggage carts are often used to transport the baggage. The baggage is at a risk of facing damage or getting lost during the transport, further increasing the cost to the airport operator. Major congestions often occur are important airside roads due to the train of baggage carts. This is time-critical to the aircraft turn-around time and transfer flights. The problem of open baggage carts to airport and aircraft security. Open baggage carts form a considerable hazard in the security of airports and aircraft. These has led to studies into various new designs and concepts. In recent years, a number of new concepts have been studied, resulting in a focus on fields of research: the automation of baggage handling in and out of ULDs Wallien (2003); the mechanization/automation of baggage handling between sorting systems and narrow-body aircraft Jerkovic (2000).

Airports are split into two sections, landside and airside. The landside includes all public and private access roads headed into the airport, parking area, public transport stations if there are, the check-in halls and the shop lots. The airside of the airport is made up of all areas with direct access to the aircrafts, this includes ramps, taxiways and flight runways. The connection between the landside and the airside part is the terminal which contains the baggage handling system (BHS), the central infrastructure for baggage handling. The BHS is an automated baggage transportation system that also provides a storage to temporarily buffer baggage. Bags can enter and leave the BHS from either landside or airside.

All baggage at the airport can be split into four categories. Frey (2014) The category a baggage belongs to is dependent on where the baggage enters the airport from and where is it headed to. The four categories are as follows:

a. Outbound baggage: Baggage leaving the airport at the airside

b. Inbound baggage: Baggage leaving the airport at the landside
c. Check-in baggage: Baggage entering the airport from the landside
d. Transfer baggage: Baggage entering and leaving the airport at the airside

Extensive research have been conducted baggage handling systems at airports throughout the years. The notable early works can be found as early as in the nineteen sixties with Tanner (1966) suggesting a simple deterministic model to study the arrival pattern of passengers and baggage from the check-in counter. The application of production theory to baggage handling and sorting was done by Parsons (1979). This included activities such as ticketing, check-in and baggage collection, reconciliation and claims. Studies have also suggested that transferring certain baggage sorting functions away to the check-in counter could prove advantageous. A reduction in baggage handling cost and transfer time using pre-sorting strategies based on the flight destination according to Robusté (1992).

While baggage handling systems have been the subject on many researches, there seems to be a neglect with regards to the link between the development baggage sorting and the loading and unloading of unit load devices and the transport link between narrow-bodied aircraft and automated baggage sorting system until recent years. Ottjes (2004) suggest that considerable cost and time savings can be achieved when scheduling method and the introduction of a new prototype automated loading and unloading vehicle is utilised. With all that taken into account, this paper aims to introduce a new system or method of loading baggage into ULDs. The system includes the introduction of an automated ULD with built in conveyors within it for it to load and unload baggage easily. Conventional dollies are replaced with automated guided vehicle (AGV) to boost scheduling and provide an unmanned solution. The design combines technology that are already available today.

Figure 1. Example of proposed design

2. METHODOLOGY

2.1 Case study of current baggage transfer systems

The initial step is to first start with case studies of current baggage transfer systems. This is to better familiarise with the industrial standard and to evaluate for strengths and weaknesses. The research is to conducted through online research as most books are not up to date and very limited in the topic of current baggage transfer systems. Amsterdam Schiphol Airport and London Heathrow Airport are selected as the subject of the case study.

Amsterdam Schiphol Airport is the busiest airport in the whole of Europe in terms of aircraft movement and the third busiest airport in terms of passenger traffic. Amsterdam Schiphol Airport was recently voted as the best airport in Western Europe for the year 2020. Meanwhile, by passenger volume London Heathrow airport is ranked as the busiest airport in Europe and second busiest in the entire world. It is one of the six international airports in the London area. In 2019, London Heathrow airport handled a record 80.8 million passengers. These two airports are selected as they are among the biggest and best in Europe and the world. A study of the best would better realise the goal of the study, to create introduce a state-of-the-art system.

2.2 Modelling and Simulation

The proposed design will be evaluated using a simulation software, Anylogic is the selected choice. The simulation will be used to evaluate the performance of the proposed design of the automated Unit Load Device in terms of capital cost, operating cost, manpower and the time needed to transfer the baggage. A similar simulation is also used to evaluate the same work being done by manual labour in order to create a standard to compare against.

The simulation is modelled with the goal of loading baggage into the respective Unit Load Devices and transported to their flight gates. Both designs are subjected to similar input flow of baggage. As categorised by IATA (2004), category A and category B baggage flow rate is used, less 1000bags/hour and 1000 bags/hour – 4999 bags/hour respectively. Automated baggage systems for category A baggage flow rate is deemed by IATA as not necessary while a semi-or fully automated system is recommended to be implemented at the airport.

There are two types of Unit Load Devices, container and pallet. Only the container type is used for passenger baggage. The most commonly used Unit Load Device that’s being used for passenger bulk baggage is the LD3-Unit Load Device. Only the LD3 will be used for the simulation and from here on, all Unit Load Devices are referring to the container type LD3-Unit Load Device. It is estimated that a standard LD3 can hold about 40 baggage. However, the conceptual automated Unit Load Device is estimated to hold only about 32 due to the conveyors within it. Three cases are constructed, case I is the proposed automated ULD design with double-sided loading station and in-feed, case II is the conventional manual design and case III is also uses the automated ULD design but with a single -sided loading station and in-feed. Each case will perform both task in the simulation including the different baggage flow rates for the loading.

In the matter of case II, focusing on just the loading and walking of baggage to the ULD, four baggage handlers are responsible. In addition to that, one baggage handler will be in charge of scanning the barcodes of each baggage. An automatic scanner is used in both case I and case III. The only difference between case I and case III is the former allows loading and unloading on both sides of the station, that means two automated ULDs can be loaded and unloaded at the same time.

2.3 Cost

The capital cost of the existing tugs used to tow baggage carts/dollies and other resources are not included in the capital cost for the manual model. It is the assume that current airports do already have such resources on site and do not need to be added further. The research also focuses more on the incentive of existing airports to switch to the new concept. The cost of the dollies is also neglected for both designs as it is already present at the airport.

However, the cost of Unit Load Devices for both cases are taken into account as the existing Unit Load Devices are rather easily damaged and frequently need to be changed. The average cost of a standard Unit Load Device is 930€ each according to IATA. Since the proposed design is still only conceptual, an estimate has to be used. The added equipment calculated in the capital includes the conceptual Unit Load Device, the unmanned tug and potential changes to the in-feed and outlet of the baggage sorting system at the airside.

The operational cost will take into account cost resulting from factors such as manpower and maintenances. Fuel cost is neglected as there is insufficient data for either configuration. The salary of each baggage handler is taken from a survey done by Bradley (2010) sourced from Cowper A (UK Airport), Dolye H (American Airlines), Stewart D (IATA), Shortland (Airport Operational Committee Heathrow Airport) and Taylor (Air Canada). As the survey was conducted 10 years ago, growth to the salary through inflation has to be accounted. Since certain cost are not fully taken account in the study, a more appropriate comparison in cost between the two systems would be to use relative cost. The relative cost is compared over a period of time to investigate how soon could the benefits be reaped from the proposed design.

2.4 Baggage Loading Times

The time taken to scan and load each bag are estimated based on IATA's manual for the loading of baggage onto Unit Load Devices. In addition to the time taken, the capacity of the Unit Load Device of the two different configurations have to be taken into account.

3. RESULTS & DISCUSSION

3.1 Baggage Loading

The results of the model analysis of the loading task used in the research are presented and discussed in this section. The task of loading the ULDs with outbound baggage is subjected to two different conveyor in-feeds in accordance with IATA's categorisation of baggage flow, as showed below.

Table 1. IATA baggage flow categorisation

Category	Baggage flow rate	IATA recommendation
A	< 1000 bags/hour	Automated BHS not necessary
B	1000 bags/hour – 4999 bags/hour	Semi- or fully automated BHS recommended

Table 2. Time of completion: Category A

ULD number	Time of completion (seconds)		
	Case I	Case II	Case III
1	370.178	439.756	291.361
2	696.155	679.756	577.361
3	721.486	949.756	863.361
4	1032.515	1221.802	1149.361
5	1215.413	1311.802	1435.361
6	1271.413	-	1545.361

The results of the simulation for the baggage flow rate of category A can be seen in the table 2 above. There are only 5 ULDs needed for Case II due to their higher capacity. The ULD in case II has a capacity of 40 baggage while the automated ULDs in case I and case III have a lesser capacity of 32 baggage.

Table 3. Time of completion: Category B

ULD number	Time of completion (seconds)		
	Case I	**Case II**	**Case III**
1	275.025	304.644	267.644
2	304.505	614.644	553.644
3	561.025	904.644	839.644
4	593.025	1134.644	1125.644
5	671.025	1224.644	1411.644
6	933.025	-	1521.644

Similarly, only 5 ULDs are used for case II. The time taken does not differ much from category A flow rate for case II and case III. However, a significant drop in the time taken to complete can be seen for Case I.

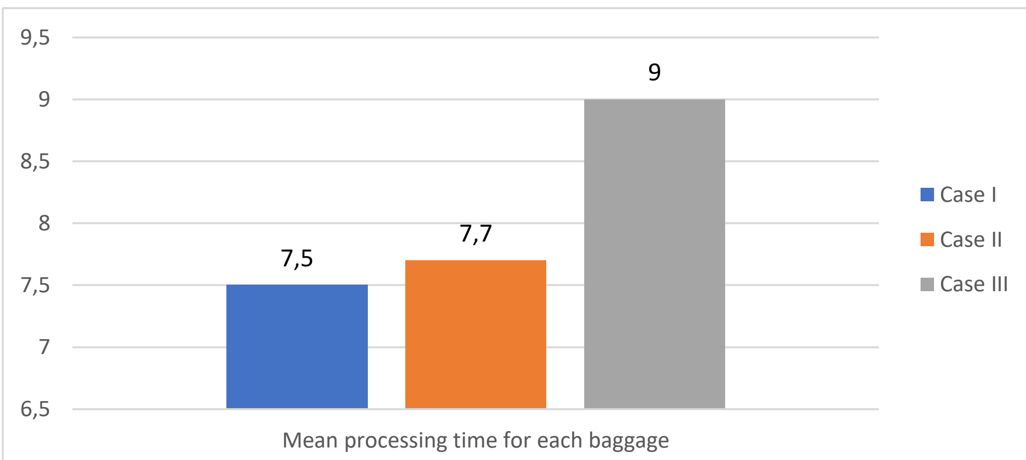

Figure 2. Mean processing time for each baggage: Category A

Figure 2 shows the mean processing time for a single baggage. Case I and case II takes a similar amount of time to process each baggage. While case III takes 1.3 seconds or about 17% longer than case II.

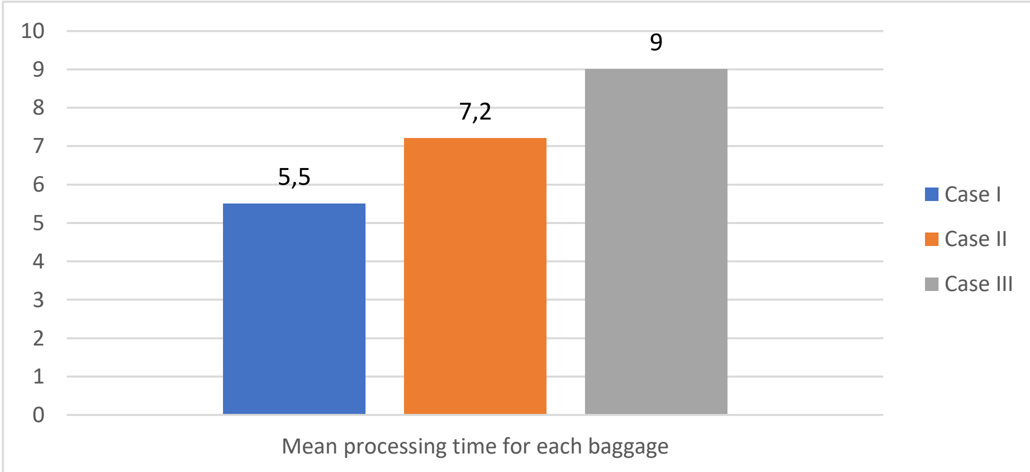

Figure 3. Mean processing time for each baggage: Category B

The time taken to process each baggage in case I drops considerably from flow rate category A to category B. There are no impactful changes for case II and case III across the different flow rates.

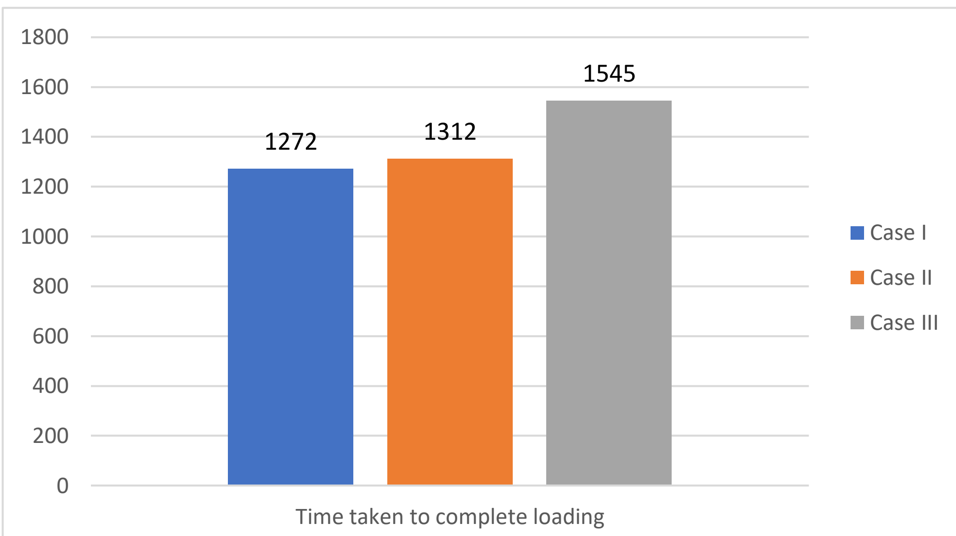

Figure 4. Time taken to complete loading: Category A

From Figure 4, it can be seen that there are no significant benefits in the usage of the automated designs for a category A flow rate. In fact, case III takes a longer time to complete the loading.

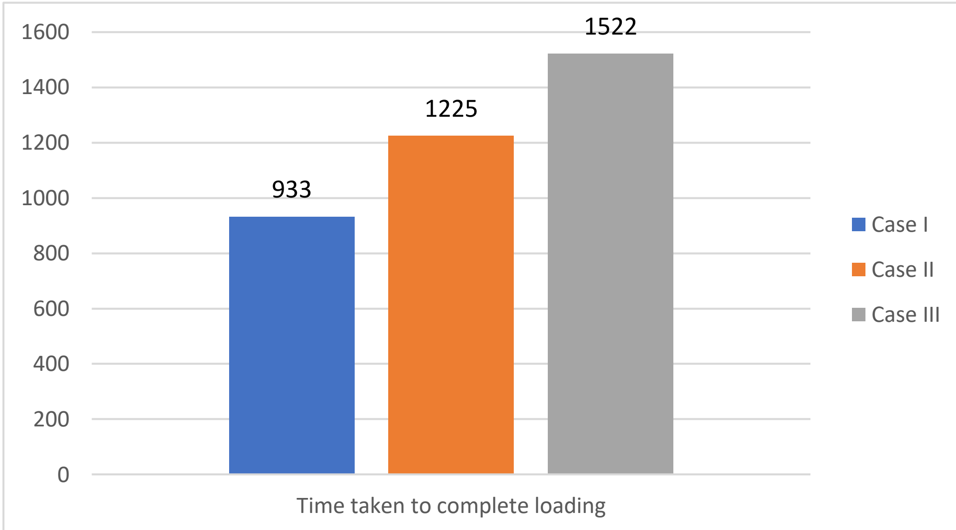

Figure 5. Time taken to complete loading: Category B

As illustrated in Figure 5, it takes 23.84% less time to complete the loading of 170 baggage into ULDs for case I when compare to case III. Meanwhile, case III takes 24.24% longer to load the baggage when compared to case II.

There is significant reduction in the time taken for case I in flow rate category B when compared to category A. The small decrease in times for case II and case III is too small to be noteworthy.

3.2 Baggage Unloading

In this section the results of the simulation for the task unloading are presented. The activities simulated in this task account for the time taken to unload the ULD and switching ULDs. Case II also requires the additional activity of walking the baggage.

Table 3. Baggage Unloading Completion Time

ULD number	Time of completion (seconds)		
	Case I	Case II	Case III
1	64	90	64
2	64	217	158
3	158	344	252
4	158	471	346
5	208	528	440
6	252	-	490

The results of the simulation are tabulated in Table 3. Case I and case III are essentially the same but case I allows two automated ULDs to unloaded simultaneously at the in-feed. This can be seen in the time taken to complete the first ULD is the same for ULD number 1 and 2 in Case I, and ULD number 1 in case III.

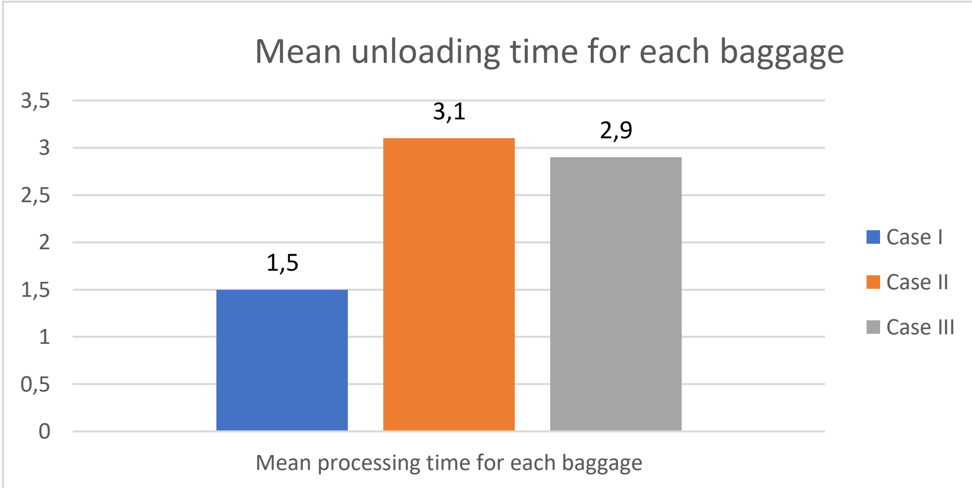

Figure 6. Mean processing time for each baggage

Figure 6 illustrates the mean time taken to unload a single baggage. There does not appear to be any significant advantage in this area for case III. However, in case I it takes 1.6 seconds less to process each baggage, or 51.61% quicker than case II.

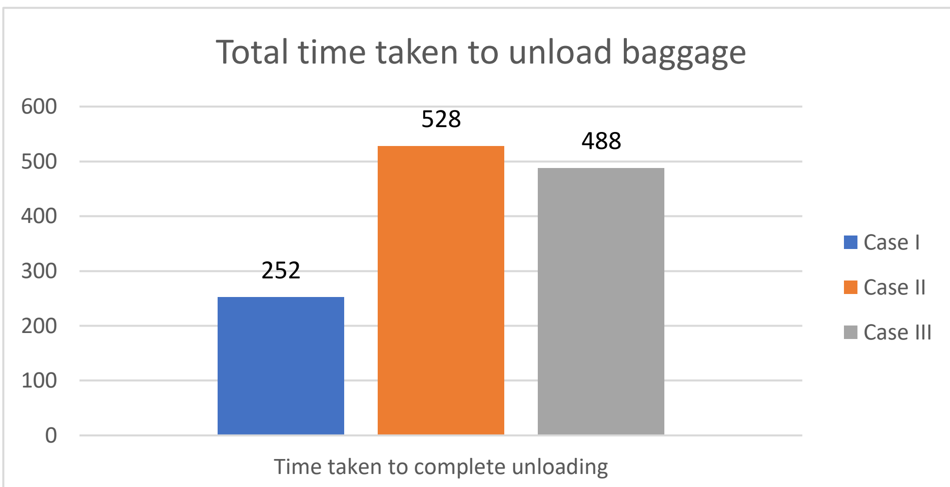

Figure 7. Time taken to complete unloading

The total time taken to complete the unloading of 170 baggage from ULDs into the BSS for each case is shown in Figure 6. When compared to case II, case III takes a slightly shorter time (7.58% shorter) than case II. Case I displays a superior 52.27% quicker time in contrast to case II.

3.2 Cost

In this section the results of the cost analysis are presented. The cost analysis is aimed to compare the potential savings per year in cost of case I and case III when compared to the manual configuration of case II. The comparison is done using relative cost.

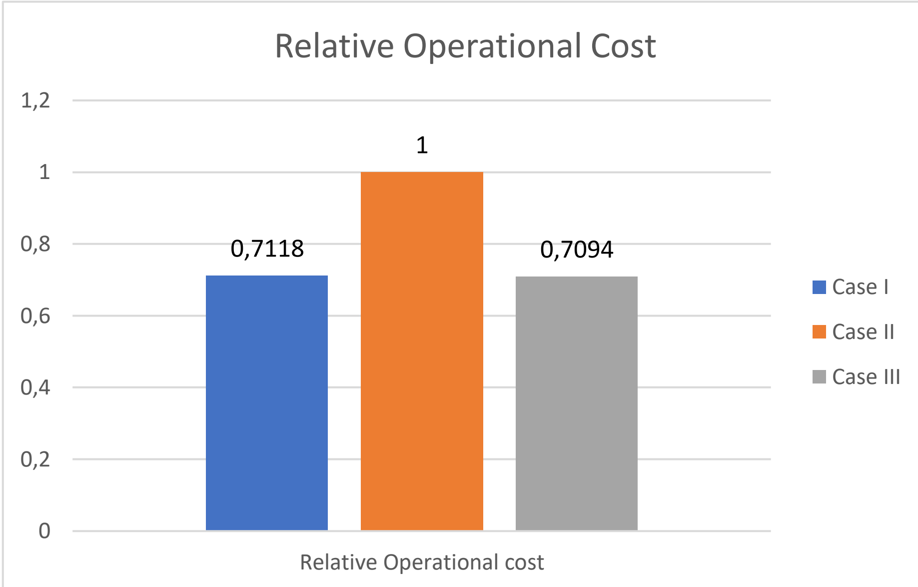

Figure 8. Relative Operational Cost

Figure 8 illustrates the relative cost of case I and case III with respect to case II. The cost of case II is set as the benchmark by holding it to a value of 1. Relative to case II, the cost of case I and case III are 0.7118 and 0.7094 respectively. Both designs are nearly 30% cheaper than case II. The 28.82% saved in operational cost is projected to be able to pay of the initial capital cost in the implementation of case I after 3.21 years. Meanwhile, the potential savings is expected to pay dividends after 3.10 years.

4. CONCLUSION

Under Category A flow rates there isn't much difference in the time taken to complete the loading for Case I and Case II. However, under category B flow rates there is an improvement of 23.84% in the time for Case I. This reinforces IATA's recommendation on the implementation of automated baggage handling systems at the aforementioned flow rate. The results gathered suggest the proposed design of a double-sided loading/unloading station is capable of superior loading/unloading times. This is done at a cost that could see savings when in the third year (3.21 years) of utilisation. The idea of the proposed design should be pursued further with the initial promising results.

The cost calculation in this study is completely specific and accurate as it fails to take into the many complex indirect cost involved in the operation of baggage handling systems. Further study is recommended for better accuracy. A prototype test run would also help determine the exact times for each activity as this study had to use estimated durations for each activity in the simulations in the absence of available exact data.

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