The Optimization of Beirut Airport's Check-in and Luggage System

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Beirut Rafic Hariri International Airport's ground handling processes lack efficiency. This inefficiency leads to high cost, low productivity, and low customer satisfaction. Therefore, we will tackle two major operations at the airport: the check-in and the luggage handling systems. This paper will present different tools and techniques used to analyze the current systems, and propose some improvements that aims to optimize the processes. According to several studies, an improvement in the airport processes can help boost tourism which is one of the most developed sectors in Lebanon. This can in return positively impact the Lebanese economy. In addition, the luggage operators carry excessively heavy loads for long periods of time, leaving them prone to injuries. Our team decided to study these operations which will consider the worker's safety and will make every traveler's life easier. Finally, this project would help our country achieve lower operations costs, and higher tourist's revenues.

I. Introduction

Any traveler going through Beirut International Airport (BIA) will have to wait in line for hours and deal with the congestions and inefficiencies of the poorly designed processes. The nature of the problems that happen in the airport are closely related to industrial engineering fields since these problems generally include optimizing queues, layouts, and interfaces. The two major problems that travelers face are in the check-in area, where they sometimes spend more than two hours in queues just to collect a boarding pass, and in the luggage system, where they have to wait around the conveyor for long minutes before being able to collect their bags. The motive behind this study is not only to ensure a better experience for travelers, but to consider the workers' safety and help boost the Lebanese economy by increasing the passengers' airport expenditures. In fact, the lower the time spent at the counters (e.g., check-in counters, security check…) the more time the passengers have to spend on shopping and restaurants which would lead to an increase in the airport's revenue [1]. This paper will introduce two main areas of Beirut International Airport that have a wide room for improvement, it will discuss different tools and methods used and will show how the mentioned processes were optimized.

II. Objectives

The goal of our project is to optimize two different processes at BIA:

A. *Objective 1: Optimize the airport's check-in process*

- Aim 1: Simulate the check-in queues
- Aim 2: Determine the optimal number of check-in counters
- Aim 3: Propose lean improvements to the customer's experience

B. *Objective 2: Enhance the luggage handling system*

- Aim 1: Improve the manual handling of luggage
- Aim 2: Conduct a cost analysis for the automation of the luggage sorting system

III. Background

The recent years have witnessed an ongoing growth in the aviation industry which seemed uncontrollable and unlimited. Numerous international airports have shown a tremendous increase in the number of passengers [2]. This growth endlessly challenges the overall experience of the passenger. Delays occur everywhere: parking your car, screening, security checking, checking-in at the counters, dropping your bags and boarding the aircraft. In fact, customer satisfaction is measured by the amount of time spent in the overall process. The luggage system at the BIA consists of four conveyor belts, two for each terminal (east and west). Each conveyor belt is linked to around 20 counters serving at most three flights at a time. Once the bag is dropped, its respective conveyor belt takes it through a 360° degree bar code scanner, saving all the passenger's information (i.e. Name, address, number, arrival destination etc.). Then, the bag goes through a security-check machine (X-ray scanner) monitored by a controller room. The first check is done by the machine itself and the second by the controller room personnel. The bag can face two scenarios: either gets accepted and continues its direction towards the containers or gets rejected. In case of rejection, the conveyor belts will automatically change lanes and drop the bag in the controller room where it will be checked for any unacceptable items. Unacceptable items will be removed and the affected traveler will be contacted. Once re-accepted, the bag will re-join the initial luggage lane toward the containers. In fact, each flight will have different containers for luggage sorting: one for priorities (the first to come out) and includes first and business class, and others for economy class which is divided by transit and local, depending whether the bags have to be unloaded at the arrival airport, or should be put back in another flight that the passenger will take. Workers will sort the bags using a barcode scanner, and will manually place the luggage in the corresponding container. In fact, to protect human welfare, the airport management team increased the height of the conveyor belt so that the worker does not bend to pick up the luggage (workers pick on average 400 bags/day according to BIA representative).

To achieve objectives similar to ours, researchers all over the world used a wide array of tools and techniques.

A. *Data gathering and data analysis tools and techniques:*

Researchers from the University at Buffalo [3] and the University of Naples [4] spent many hours at the Buffalo Niagara International Airport and Naples International Airport Terminal 1 collecting manually the arrival times, service times, time spent in a queue, party size (which is the number of people in a group travelling together), the number of bags carried, number of open check-in counters, and flight departure times. The researchers also used the check-in software to gather data, such as total number of passengers for different flights, as well as the number of people who checked-in online. ANOVA (analysis of variance) statistical model was used in order to determine the importance of party size, number of bags and the impact they have on service time. Findings showed that the best approach to use for the Buffalo airport simulation was to fit distributions to sets of data differentiated by the party size only. The ANOVA analysis also showed that there are no difference in service time for passengers who had checked online and the ones who had not [3]. In addition, at Copenhagen airport, questionnaires were given to the workers working in the luggage system (n=3092) and a reference group (n=2478) in other unskilled job with less heavy work, in order to assess the relationship between heavy manual baggage handling and musculoskeletal disorders [7].

B. *Mathematical and simulation models*

According to Beirut Airport's 2018 yearly report of commercial air traffic, congestion increased within a year by 7.37%. This is due to the increase number of passengers and the low investments of airlines in check-in systems and self-service counters. Similarly, a vast number of international airports are facing the same issue which has led to the development of many optimization approaches that aim to minimize this congestion. In an attempt to solve a similar problem, two researchers from the international Kansai airport in Japan [5], and researchers from the University of Naples [3] conducted a simulation analysis using Arena software, to reduce the waiting time of passengers in queue. For Kansai airport, unavoidable delays resulted in passengers missing their flights. Analysis showed that passengers spend 80% of their time at the check-in desks; the output highlights that check-in should be considered as a bottleneck [5]. On the other hand, relationship between baggage handlers and musculoskeletal symptoms were analyzed using three different models. In model 1, only age was taken into consideration for the differences in musculoskeletal symptoms between the workers and the reference group. In model 2, researchers further included seniority with the reference group labeled as 0 years of experience. Then analyzed the likelihood ratio test to estimate if seniority can be fitted as a linear effect. In model 3, they further included general health split into excellent, very good, good, fair and poor health conditions [7].

C. *Improvement strategies and workers' welfare*

The main objective of the Amsterdam Schiphol Airport Study was to reduce queuing time in order to increase customer satisfaction. The aim of their study case was to gain insights on substitute check-in methods [6]. Airlines can use common check-in or dedicated check-in. Common check-in is when passengers of different flights can check-in at the same counter. However, dedicated check-in serves passengers of the same flight. By simulating both scenarios, Joustra and Van Dijk found that common check-in leads to lower average queuing time than dedicated check-in. Another important factor was the ideal time a check-in counter should open prior to a flight [4]. At Beirut Airport, all counters open three hours before a flight. In the study of Schiphol airport in Amsterdam, it was revealed that 60% of the passengers arrive more than three hours before their flights' departing time. That is not the case in Beirut Airport but a simple data collection can be used to validate this result. In our case, 141 people in total checked in to the flight and only seven people (~5 %) were in the check-in queue prior to the start-of-service. In addition, according to Bern et al, musculoskeletal disorders are disposed to increase in six anatomical regions with increasing seniority for the baggage handlers. The same apply for the cumulated heavy listings done by the workers working in luggage system [6].

IV. Methods

Many tools and techniques were used in order to optimize the airport's processes.

A. *Objective 1: Optimize the airport's check-in process*

The tools and techniques used to achieve this objective can be divided into 3 categories:

1) *Data gathering tools and techniques*
2) *Data analysis tools and techniques*
3) *Simulation and Analytical tools and techniques*

The above objective includes three main parts (aims): each requiring different tools, techniques and methods.

For the simulation part, data needed to be gathered, and that was done by the mean of a wide spectrum of techniques.

TABLE I. TABLE OF DIFFERENT TECHNIQUES USED TO GATHER DATA FOR THE SIMULATION

Data Type	Tools / method used
Flow chart of the entire process	Observation of the process, and interview with employees and managers at MEAG (Middle East Airlines Ground Handling)
Service times at the counter	Mobile application called TimeStamp, as well as observation and manual note taking

Data Type	Tools / method used
Arrival times of passengers	Mobile application called TimeStamp, as well as observation and manual note taking
Number of open counters	Observation
Waiting times in queue for different passengers	Stopwatch

After gathering the data, analysis needed to be done in order to fit distributions. The data was first cleaned using basic MS Excel tools, and then distributions were fitted using Input Analyzer software.

The simulation was done using Arena software. Inputs to the simulation included the process flow chart and the distributions fitted to the gathered data. The simulation's results and outputs were analyzed using Output Analyzer software.

In order to come up with an optimal policy (i.e. how many counters would be open at different intervals of time), we used analytical concepts of queuing theory (1), as well as Little's law (5).

$$W_q(M/M/c) = \left(\frac{a^c}{c!(c\mu)(1-\rho)^2}\right) p_0 \quad (1)$$

Where: c represents the number of open counters
μ represents the service rate
λ represents the arrival rate of passengers

$$a = \lambda / \mu \quad (2)$$

$$\rho = \lambda / c\,\mu \quad (3)$$

$$p_0 = P\{0\ customers\ in\ system\} = \left(\sum_{n=0}^{c-1}\frac{a^n}{n!} + \frac{a^c}{c!(1-\rho)}\right)^{-1} \quad (4)$$

Little's law:

$$L = \lambda\, W \quad (5)$$

Where:

λ represents the arrival rate of passengers

W represents the average time a passenger will spend in queue

L represents the average number of passengers in the system

By plugging (2), (3), and (4) in (1); we were able to calculate the mean waiting time in queue while varying c (which represents the number of open counters). The arrival rate of the passengers and the service rate were determined from the data gathered previously at the airport. The formula was recalculated for every 30 minutes interval because the arrival rate of passenger was variable throughout time. Fig. 1 shows different arrival rates of passengers as a function of time.

This technique outputted different waiting times for different numbers of open counters, and using a survey and literature, we were able to determine the optimal number of counters that should be open.

Lean techniques were used to improve customers' experience. This includes 5S for organizing the counters (work stations) where passengers would check-in, as well as Ishikawa diagram to trace down the main issues that cause delay and confusion in the check-in area.

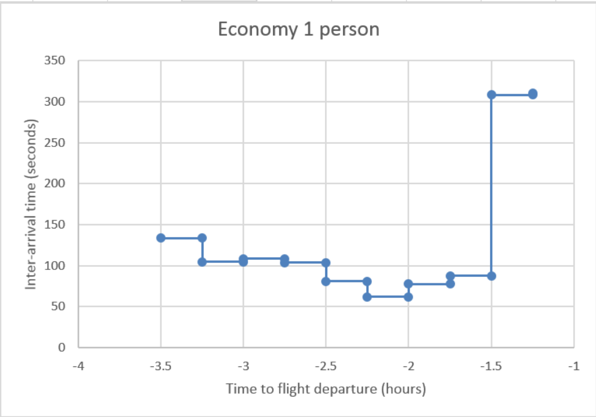

Fig. 1. Graph showing the mean inter-arrival time as a function of time for individual passengers travelling in economy class using 15 min time intervals

B. *Objective 2: Enhance the luggage handling system*

Many tools and techniques used in the above objective will also be used in this objective. This objective is still under study. The part done so far include data gathering and data analysis tools. Data collection tools include observations and interviews with representatives of MEAG. In a later stage, NIOSH (National Institute for Occupational Safety and Health) lifting equations will be used in order to determine and to improve the ergonomics of luggage handling at the airport.

V. Results

A. *Optimize the airport's check-in process*

The results obtained through Arena provide information regarding waiting times, number of passengers in queue, servers utilization etc. The arrival rates of the passengers to the check in area vary as a function of time. Fixed arrival rates were recorded for each 30 minutes interval. Service times are affected by two main variables: number of bags checked in and party size. As the number of bags increase the service times increase since the operator spends additional time weighing and attaching tags on each bag. The same applies for the party size. When the party size increases, the operator issues more boarding passes which leads to a higher service time. There is a positive correlation between the party size and the number of bags.

TABLE II. AVERAGE SERVICE TIME AS A FUNCTION OF NUMBER OF BAGS AND PARTY SIZE

Average service times (sec)					
Party size	Bags				
	0	1	2	3	>3
1	93	132	166	167	-
2	148	246	212	220	318
3	-	650	-	501	326
>3	-	-	-	418	-

After running the simulation on arena, it was found that a passenger spends approximately 5 minutes in queue waiting to get served. The number of people in queue reaches its maximum two hours before the scheduled departure time of the flight. This result comes as no surprise since people usually rush to the airport during that time. The operators are busy 67% of the time and the average number of operators busy is 2.1.

Using queuing theory, the optimal number of check-in counters was found.

TABLE III. DYNAMIC COUNTER ALLOCATION AS A FUNCTION OF TIME FOR ECONOMY CHECK-IN COUNTERS

Time until departure (hrs)	Number of counters	Waiting time in queue (min)
3-2.5	3	4.3
2.5-2	2	6.6
2-1.5	4	3.5
1.5-1	2	3.5

The maximum number of counters required using this dynamic allocation is 4. This should take place for a 30 minutes interval starting 2 hours prior to the scheduled departure. During that time approximately 35% of the total flight passengers check in making it the busiest out of all the other times.

In order to improve the customer's experience in the check in area of the airport, we looked at the main wastes and problems related to that area. The latter lacks directions and guidance to the passengers. Once they reach the check in area, they randomly choose the east or west side without necessarily taking into consideration the location of their respective counters. Hence, they might spend additional time walking between the 2 sides. Therefore, some lean measures were undertaken: (1) the installation of screens in the entrance area that show counters allocation. By doing so the passengers will not spend unnecessary time walking erratically looking for their corresponding counter. (2) The addition of screens next to each check in queue that indicate the estimated time in queue allows passengers to set expectations once they stand in line. (3) The allocation of kiosks for automated boarding pass printing decreased the congestions in the queues and in the check in area. Finally, (4) the addition of information desks to help and guide lost passengers in their journey at the airport.

B. Enhance the luggage handling system

For the improvement of the luggage handling system, a cost analysis of the annual spending on damaged bags was conducted. A damage statement may be the result of baggage that has been sent to the wrong destination, baggage that has disappeared, been delayed, damaged or stolen. The airlines estimate that each of the damage statements amount to USD 130 to 150 on average. In order to find the amount spent by MEAG on damaged bags per year, some assumptions were taken. Based on the data provided by MEA (Middle East Airlines), the total number of passengers that departed from BIA is 1526624. Based on the sample we got from our previous study, each passenger carries on average 1.16 bags (819/708). The total number of bags carried by middle east is 1526624*1.16= 1765968 bags rounded to the nearest whole number. On average, 3 per thousand bags are damaged based on our discussion with a MEAG director. The total number of damaged bags for MEA is 1765968*0.003= 5298. So the total amount spent on damaged bags by MEA per year is in this interval [688,740; 794,700] USD. Since MEA represents only 10% of MEAG's total operations, then the total amount spent by MEAG per year on damaged bags falls within this interval [6,887,400;7,947,000] USD.

VI. DISCUSSION

A. Optimize the airport's check-in process

After having gathered data regarding the current process, analyzed the current system, and simulated the check-in queues; we were able to find an optimal policy, i.e. how many counters should be open at any interval of time. The results we got are similar to the ones that were previously found by researchers from the international Kansai Airport in Japan [5] as well as from the University of Naples [4], and thus validating our work. There are however some limitations to the results we got and that's because the data we gathered is for an Airbus a 320 and a Boeing 777 which are the two most common aircraft flown in the world and particularly in Beirut Airport. The optimal counter allocation would not result in extra costs for the airport, because the personnel is there, but the issue lies with the schedule of operation.

The lean improvements proposed in order to make the check-in area an optimized space resulted in a better customer journey. The screens implemented at the entrance of the airport, and that show which airlines are located in the east terminal and which are located in the west terminal reduced passengers confusion and reduced the time a passenger usually waste trying to locate which counter he or she should head to.

Implementing the remaining proposed improvements, as well as the dynamic counter allocation, to all the counters will result in an optimal flow of passengers throughout the system. No more confusion would exist among passengers, and the maximum waiting time in queue would be decreased to 6.6 minutes (this will occur 2 hours prior to departure time), which will lead to satisfied customers, and more time to spend shopping in the duty free area, which will increase the airport's revenues.

B. Enhance the luggage handling system

Although the objective is still not fully developed and analysis is still going on, we were able to determine how much MEAG is spending on damaged bags. We will be proposing an optimization for the system that will result in less money spent on damaged bags, as well as a system that takes into consideration the welfare and health of employees. Automation of the system will also be studied, and the results of the cost benefit analysis regarding the implementation of a fully automated baggage handling system will be presented soon.

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