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Optimising the management of arriving baggage at a Kuwait Airways passenger terminal using mathematical programming and simulation

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Abstract

Handling luggage systems is a critical component of a passenger terminal's operations. The proposed study attempts to find the optimal solution for a manually operated terminal concerning the luggage offloading process from arrival flights carried by a limited number of ground handling agents. Handling agents start the offloading process from the aircraft to the cargo luggage containers carried by a cargo car that will take the containers' trolleys to the cargo area to offload them into the reserved luggage belt carousel. This study aims to improve airport service quality by minimizing the baggage handling process time for arrival flights which leads to minimizing passenger waiting time in the baggage claim area. We proposed both a deterministic and stochastic approach. The integer programming method is provided to minimize the total number of flights assigned to the belt carousel under the realistic constraint of minimizing the luggage load on each belt carousel. Simulation tools were used so that the offloading process could be modeled to study the effects of various parameters such as the number of ground handling agents for different flights with different amounts of luggage.

Keywords: *airport terminal, ground handling, baggage handling system, integer programming, simulation*

1. Introduction

Passenger terminals have been processing an increasingly larger inflow of international travelers as major ports in a country, which has inadvertently resulted in long queues within the airport. The baggage handling system (BHS) at an airport is a key process in an airport terminal's landside activities, involving both the airlines and their passengers. Poor management of the BHS may result in luggage arriving damaged, late, or never, with consequent harm to the airlines' public image. This is particularly true during the high season and peak hours when the number of flights rises dramatically, in some cases to

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levels beyond the terminal's design capacity. Most major world airports today have automated BHS. Movement of baggage within the terminal is automated but the sorting, distribution, and aircraft loading operations are carried out manually. Several ground handler companies provide baggage-handling services at the airport. The ground handling tasks are defined and contracted between the airline and the provider using a service level agreement that defines the scope of duty, price, and quality level desired and key performance indicators as well. IATA (International Air Transport Association) called for the ground-handling industry and international airports to adopt the IATA Ground Operations Manual (IGOM) to define ground-handling procedures for airlines and ground service providers to ensure ground operations activities are accomplished safely, efficiently, and effectively. Procedures in IGOM reflect the minimum standards as identified by the aviation industry, striving to reduce operational complexity, training requirements, injuries, and ground damages. Enhancing service performance to achieve passenger satisfaction is one of the crucial objectives for every airport. Several air transport agencies proposed level of service (LoS) standards for airport passenger terminals such as Airports Council International (ACI) and IATA [9]. These agencies have joined forces to provide an objective and unbiased analysis of the LoS at airport terminal facilities. The joint assessment will determine the best possible solutions to optimize the LoS for the whole airport community. Table 1 shows six levels of services that were defined by IATA.

Table 1. International Air Transport Association (IATA) level of service framework in the ninth edition of the manual [9]

Level	Flow	Passenger comfort	Delays
Excellent (A)	free	excellent	no delay
High (B)	stable	high	very few
Good (C)	stable	good	acceptable
Adequate (D)	unstable	adequate	acceptable for short periods
Inadequate (E)	unstable	inadequate	unacceptable
Unacceptable (F)	crossflows, system breakdowns	unacceptable	unacceptable

The IATA Airport Development Reference Manual [9] explains concepts of LoS that aim to optimize expenses and increase the speed, quality, and efficiency of service. It defines the service levels by analyzing both space and waiting time in four kinds of subsystems such as over design, optimum level, sub-optimum level, and under-provided level. The over-design level is a high service level with very limited waiting times for passengers in various control processes. The optimum level indicates an adequate level of service and stable conditions in the various operating subsystems. It corresponds to service level C (Table 1). The sub-optimum level is not desirable as it is related to areas that are undersized concerning the flow of passengers to be served with higher than the acceptable waiting times values. Finally, the under-provided level indicates a condition where there are uncomfortable and crowded spaces and unacceptable processing and waiting times. LoS related to the arrival [9] lists some of the surface areas and waiting times to adapt the terminal level of service to demand (Table 2).

The scope of this current research concerns the baggage handling process for the arrival passenger flights at Kuwait Airways terminal T4 which is a part of Kuwait International Airport (KIA). The process starts after the landing process and the airplane reaches the assigned gate or apron. Then, one cargo car will reach the airplane and the ground handlers will start offloading the luggage from the airplane to the cargo luggage containers.

Table 2. Maximum waiting times for each terminal subsystem and each LoS [min]

LoS guidelines		Economy class			Business/first class/fast track		
		Over design	Optimum	Sub optimum	Over design	Optimum	Sub optimum
	immigration control	<5	05-Oct	>10	<1	01-May	>5
Baggage claim	narrow body aircraft	0	0/15*	>15	0	0/15*	>15
	wide body aircraft	0	0/25*	>25	0	0/15*	>15
	custom control	<1	1–5	>5	<1	1–5	>5
	public arrival hall		n/a			n/a	

[a] The first value relates to "first passenger to first bag", the second one to "last bag on belt".

After the offload process is finished, the cargo car will take the container's trolleys to the cargo area to offload them into the assigned luggage belt carousel that was previously reserved for that airplane which is located inside the baggage claim area. The main objective of this study is to minimize the baggage handling processes that lead to minimized passenger waiting time in the baggage claim area and to minimize the baggage queue length during the offloading process from the aircraft to the final stage in the baggage claim area. This study attempts to find the optimal solution for the flight to belt carousel assignment problem at the passenger terminal and the assignment of ground handling agents for the luggage offloading process.

Kuwait Airways operates international flights and launches flights to many global destinations across Asia, Europe, North America, and the Middle East destinations. Their plans focused on expanding the flight network to new markets across the globe, by operating to 17 new destinations during 2022 [1]. Furthermore, currently, Kuwait Airways uses around 48 aircraft fleets and recently received 30 new aircraft fleets such as Airbus A330-200, A330-800neo, A320neo, and Boeing B777-300ER. There has been a rapid development of passenger movement statistics for Kuwait Airways and Kuwait International Airport in general in the past few years. Previous studies such as in [3]. The study has anticipated a growth in the number of air passengers in KIA by comparing different time series forecasting models.

2. Literature review

Solutions for baggage handling system case problems are proposed in many studies using optimization techniques. Jacobson et al.[15] used integer-programming models to obtain optimal deployment of baggage screening security devices for a set of flights traveling between a given set of airports. For an outstanding overview of baggage handling at airports, we refer to the comprehensive theses by Barth [5] and Frey [11]. Different variants of the baggage belt assignment problem have been studied in the literature. Barth [6] studied the assignment of incoming flights to baggage belts. They model the problem as an extended assignment problem and present a detailed verification study with sensitivity analysis. Many study methods to solve problems in BHS are analytical models or mathematical models and algorithms or scenarios that give good solutions for different study objectives. However, the baggage handling system process in the airport is a stochastic process that involves multiple variables. The simulation approach is an important tool for obtaining solutions for different case scenarios in BHS when the related factors are random. Determining the optimal expansion of baggage claim capacity was discussed in [18] by considering future passenger arrival patterns and using a simulation technique for estimating passenger waiting time and a cost-benefit analysis.

Delonge [8] used a constraint programming approach to minimize the variance of load distribution throughout belts. The airport baggage unloading zones assignment problem is modeled as a stochastic vector assignment problem (SVAP) to minimize the total expected system cost over the planning horizon [14]. A hybrid heuristic combining a greedy randomize was proposed in [12] to the baggage handling process. The results of the mathematical model compared with the solutions of the hybrid heuristic and the solutions. Cavada et al. [7] proposed simulator software for the baggage handling problem which tool generates evaluations of hypothetical operating scenarios based on real data whose results could be used to design operating protocols for both normal conditions and contingencies. The work of Alsyouf et al. [4] implemented a six-sigma methodology to improve the baggage flow in a BHS by identifying the causes of mishandled baggage and deriving solutions to enhance BHS performance. Other studies using simulation models [16] modeled the inbound process to enhance the performance of the system to reduce passengers' waiting time at baggage carousels using a discrete event model of inbound baggage handling. Identifying and analyzing factors that have significant effects on the key performance indicator (KPI) were discussed in [13]. The objective of this work is to minimize the percentage of failed bags in the BHS. Pisinger and Scatamacchia [17] formulate the baggage belt assignment problem that matches the arrival time of bags with the expected arrival time of passengers. A solution algorithm is presented based on branch-and-price using dynamic programming. Fay et al. [10] used simulation platforms to visualize and validate baggage-handling processes involving robotic handling systems and human operators.

Automated baggage handling and robot system design is also proposed by Aktas and Kabak [2] who used a binary integer programming formulation to determine the number of baggage robots which is an alternative element for baggage system automation. Most major world airports today have automated BHS. In some airports, baggage handling is not completely automatic. For example, the movement of baggage within the terminal is automated but the sorting, distribution, and aircraft loading operations are carried out manually. In other airports, which is the situation in our case study in research, the baggage movements and other BHS operations within the terminal are carried out manually by ground handlers agents. Since the ground handler company has a specified capacity of manpower for BHS process, job assignments should be applied to BHS operations. The scientific contribution in this research is on the decision variables and BHS operations policy where baggage loading operations are carried out manually with a limited number of resources to minimize the processing time compared with the actual procedure in our case study. Input conditions are variables that are used as decision variables in many research works. This research will focus on the baggage belt assignment and BHS operations policy for inbound baggage. Various studies for these problems have been discussed but there is no research for manual BHS operations with variate and limited total number of ground handler agents job assignments. Two solution stages have been proposed in this research. Stage I deals with the assignment of flights to luggage belt carousels. Stage II concerns modeling the BHS system by a simulation approach. The correctness of the model was tested using non-parametric test statistics.

3. General overview of aircraft ground operation at Kuwait Airways terminal

We apply our model to the baggage handling process for the arrival passenger flights in the Kuwait Airways T4 terminal. T4 has nine aircraft gates and ten apron stands where the passenger will be transferred to the passenger terminal using a bus.

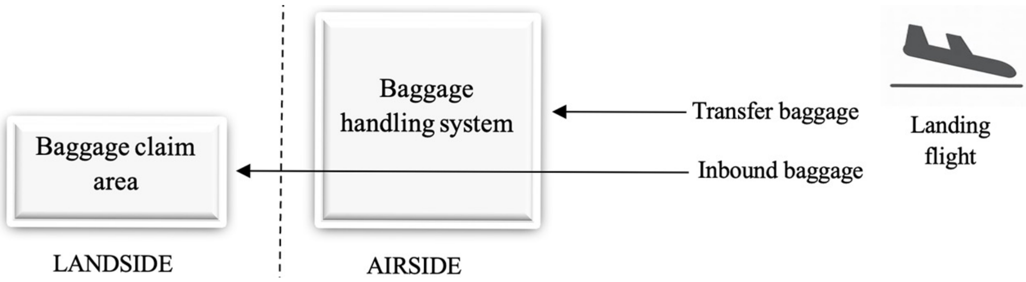

Figure 1. Transfer and inbound baggage handling processes

Figure 1 illustrates the inbound baggage handling processes. There are two airline flight schedule seasons, winter and summer schedule. Destination routes and flight frequencies increase in the summer season. Therefore, the collected data is from the summer schedule. The collected data is one week based since the airline flight schedule is repeated every week during the season schedule. 269 arrival flights for a week are operated by Kuwait Airways that departed from 53 different destinations with 58,665 total inbound baggage. Kuwait Airways passenger flights are handled by the Kuwait Airways ground handlers. After an airplane landing process is complete at the assigned gate or apron, ground handlers should start offloading the luggage from the airplane to the cargo luggage containers. From the collected information, the offloading process will take on average between 15-17 minutes. In the T4 terminal, the longest distance from the farthest gate or apron to the cargo area is 700 m. The number of luggage containers needed depends on the number of bags in the airplane and how the ground handlers will organize the bags inside the container. The cargo car will take the container trolleys to the cargo area for the offloading process. This process will take on average 5–7 minutes. Some transfer baggage should be transferred to other flights or inbound baggage that will be offloaded into the reserved luggage belt carousel. Inbound baggage will pass by the X-ray security check attached for each belt carousel and there is an inspector to manage the process. If the bag is clear, the belt will move the bag to the baggage claim area. This process will take on average between 18–22 minutes. In the T4 terminal, there are four luggage belt carousels. The capacity of each luggage belt carousel is 650 bags.

The number of ground handlers needed for each flight depends on the amount of luggage. From the collected data, a total of 892 ground handlers were assigned to do the baggage handling processes for a week. It is important to note that a ground agent could be assigned to multiple flights in one day. In other words, from the total of 892 ground handlers, there are repeated duties to the same ground agents to do baggage handling processes. This duty assignment is currently prepared manually at the Kuwait Airways terminal. It was noticed from the collected data that some cases are unreasonable involving the number of assigned ground handlers. For example, in one case, there were 3 ground handlers assigned to handle a flight with 184 luggage. However, another flight with 309 luggage but only 2 ground handlers were assigned. In this research, we used simulation tools to model the offloading process and baggage handling system to compare different scenarios to evaluate the number of ground handling agents that should be assigned to each flight. Therefore, the minimization of the passenger waiting time in the baggage claim area within the limited resources could be achieved. Flight baggage to belt carousel assignment one-week actual baggage report was analyzed. If the BHS is operated manually with a fixed number of ground agents, clearly the flight with more luggage will take more time to process its luggage than the flight with less luggage.

Thus, a flight with more luggage needs a longer time interval to be assigned to a belt carousel than a flight with less luggage. From the collected data for the Kuwait Airways passenger terminal that involves time duration for the whole process from the aircraft arrival time to the first bag out in the baggage claim area, we have estimated the time duration to assign a belt carousel to a given number of bags. Table 3 shows the estimated time in minutes. For example, by using this table if a flight carries 350 inbound baggage, then the assigned belt carousel will be reserved for 105 minutes for this flight to process BHS and X-ray security system to the baggage claim area.

Table 3. Waiting times for each terminal subsystem and each LoS [min]

Number of bags	Time
Less than 100	60
101–200	75
201–300	90
301–400	105
401–500	120
501–600	135
More than 600	150

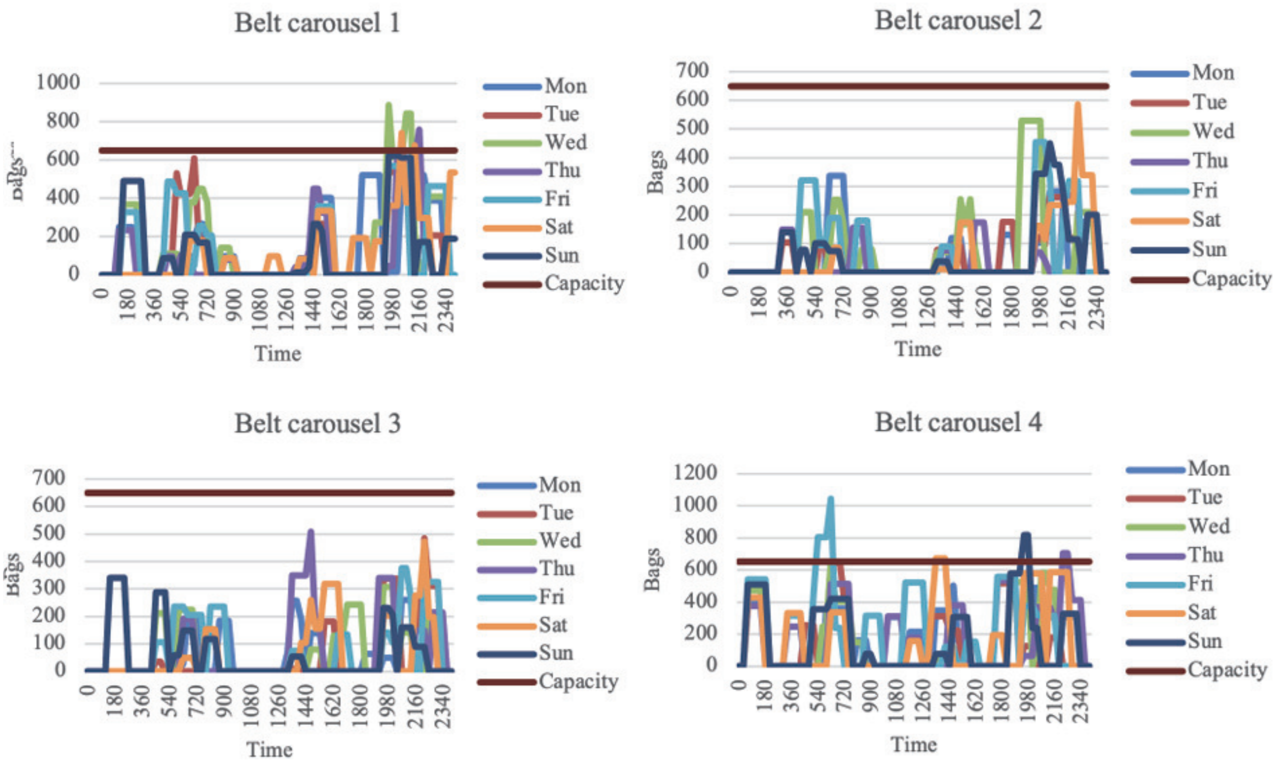

Figure 2. The current baggage assignment to the four belt carousels for one-week data

Figure 2 describes the current situation for baggage assignment. On some days, it can be noticed that the number of baggage exceeds the capacity for belt carousel number 1 during the evening period. Moreover, the same situation can be noticed in belt carousel number 4 during morning and evening periods.

4. Problem formulation

We consider the number of ground handling agents for each arrival flight to process luggage offloading from arrival aircraft from the assigned gate or apron until moving the inbound luggage to the claim area. The flight arrival times and number of luggage are known. Times that will take ground-handling agents to process inbound luggage in different situations will be estimated. Finding the optimum assignment for flights to luggage belt carousels and the number of ground-handling agents requires both a deterministic and stochastic approach. In the operations research approach, the optimization essentially involves two stages:

Stage I deals with scheduling and thus deterministic nature which is an optimization (minimization) of the total number of flights that are to be assigned in one luggage belt carousel to achieve balance involving an amount of luggage under realistic constraints such as belt carousel capacity.

Stage II objective is to build a stochastic decision-making model by using the output information for flight assignment to luggage belt carousels in Stage I. Stage II deals with queuing and thus stochastic aspects that is a computation and optimization of the number of ground handling agents and amount of luggage for an individual flight to meet a specified service level in terms of waiting times and queue length. The stochastic approach was used since it would be the best lead to feasible planning for the baggage handling system.

4.1. Stage I. Flight to luggage belt carousels assignment

According to Kuwait Airways terminal officials, each luggage belt carousel can accommodate at most 2–3 flights simultaneously. We let the value α represent the maximum number of flights that can be accommodated in a belt carousel at the same period. We have also introduced the variable β which represents the average number of bags per week. This variable was introduced to balance the number of flights that should be assigned to one luggage belt carousel. Distributing flights equally to the luggage belt carousel will minimize the possibility of delay in luggage processing in the BHS resulting in any technical problem that may cause an arrival flight. Such as delay of arrival, X-ray security system breaks down. In addition, distributing flights equally to luggage belts will give more area space between passengers in the baggage claim area if any of the above-mentioned problems occur. Furthermore, belt carousels have a limited space to accommodate a certain amount of luggage at a time. Thus, the space and available number of belt carousels must be used optimally. For this purpose, we have introduced an integer programming formulation to solve the assignment problem.

For every season during the year, the airline flight schedule is repeated every week starting from Monday and ending on Sunday. We will let the value t represent the time by half an hour for a day d. It takes the values from 1 to 48. $t = 1$ refers to time at 00:00 AM. For example, $t = 8$ and $d = 2$ refers to Tuesday at 03:30 AM. The notations that will be used to represent the integer programming model are as follows:

i – flights

j – belt carousel

t – time

d – day

$B_{d,t,i}$ – the number of bags on day d at time t for flight i

$A_{d,t,i}$ – operation of flight i on day d at time t; $A_{d,t,i}$ takes the value 1 if flight i is operated on day d at time t. otherwise, $A_{d,t,i} = 0$

c – the maximum capacity of the luggage belt carousels

α – maximum number of flights that can be assigned at any belt carousel

β – average number of bags per week

The binary variable for the model is defined as $X_{i,j}$. It takes the value of 1 if flight i is assigned to belt carousel j, otherwise, $X_{i,j} = 0$.

The proposed integer programming model may be written as follows:

$$\min \sum_i \sum_j X_{i,j}$$

s.t.

$$\sum_i A_{d,t,i} X_{i,j} \leq \alpha, \quad \forall d,\, t,\, j \tag{1}$$

$$\sum_i X_{i,j} \leq \beta, \quad \forall j \tag{2}$$

$$\sum_i B_{d,t,i} X_{i,j} \leq c, \quad \forall d,\, t,\, j \tag{3}$$

$$\sum_j X_{i,j} = 1, \quad \forall i \tag{4}$$

Here, the goal of the objective function is to minimize the total number of flights i assigned to belt carousel j. The constraint (1) ensures that the number of flights that can be assigned at any time t and day d for a belt carousel j should not exceed the allowed limit $\alpha = 3$ flights. Constraint (2) ensures that the total number of assigned flights in each belt carousel j should not exceed the average number of bags β. In this project, the collected number of flights was 269. Therefore, the average on four belt carousels will be around $\beta \approx 68$. Constraint 3 ensures that the amount of luggage for all flights assigned to belt carousel j at any time t and day d should not exceed the maximum capacity of the luggage belt carousels $c = 650$. The last constraint (4) ensures that flights i should be assigned to only one belt carousel.

4.2. Stage II. Simulation approach

The BHS in the airport is a stochastic process that involves different variables. Baggage handling timings vary over travel season at daily and even hourly levels. Depending on the time scale of capacity and baggage handling planning before the actual operations, for example, at monthly or hourly levels, this variability is to be regarded as subject to uncertainty (stochastics). We considered the BHS planning problem at the level for which the number of baggage on each arrival flight is known. Here, we considered the weekly BHS timing of the Kuwait Airways flights. Nevertheless, several aspects remain uncertain as the agent's ground handling times to process inbound baggage.

In the simulation process, we compared the results of the proposed integer programming model with the actual results using different scenarios involving several ground handlers for each flight to process BHS. The following are taken into consideration: i) the luggage as individual entities, ii) the opening and closing time for each belt carousel for each flight, iii) the actual amount of luggage for each flight, and iv) the required number of ground handlers for each flight. The simulator consists of three basic interconnected components: aircraft arrival, offloading process and moving containers to the cargo facility, and X-ray security check. The three are interconnected and operate in order starting from the aircraft arrival process until the X-ray security check process. Each one consists of several routines as shown in Figure 3. Excel spreadsheets have been used to run the simulation model. Initially, the necessary data have been collected to look for the appropriate data distribution for baggage handling times. In the first process, the flight's actual arrival time (touch down) for each aircraft is recorded and then this time is added to the fitted random distribution which is assumed to be normal ($\mu = 15, \sigma = 2.5$ minutes) Which is the estimated time for the aircraft to reach the assigned gate or apron stand.

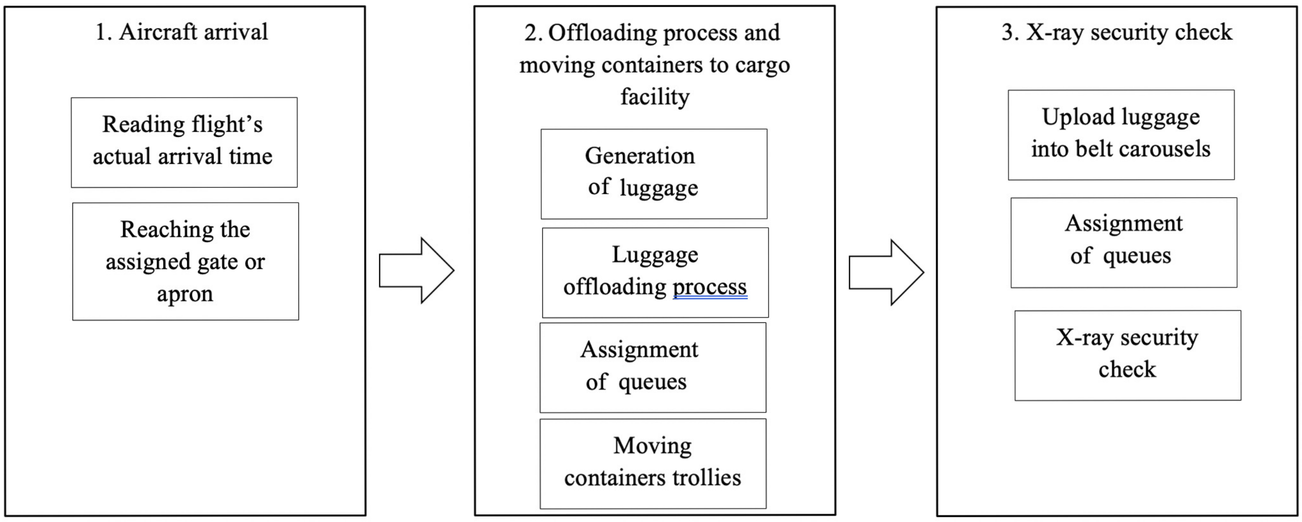

Figure 3. Schematic diagram of simulator operation for inbound luggage

In the second process, the total amount of luggage in each aircraft is recorded and then luggage individual entities are generated. Here luggage offloading from the aircraft process is handled by several assigned ground agents in a queuing system. The estimated process time for one ground agent to process one luggage is assumed to be normally distributed ($\mu = 0.85, \sigma = 0.032$) minutes. The next step in this process is moving luggage containers to a cargo facility. In the simulation model, this step starts when all inbound luggage is finished offloading. The starting time to move the containers to the cargo facility is equal to the estimated time for the last luggage from the offloading process. Moving luggage containers to a cargo facility is assumed to be normally distributed ($\mu = 6, \sigma = 1$ minutes). In the last process, the simulation for each entity starts when inbound luggage containers reach the cargo facility, where ground agents should put luggage in the assigned belt carousel. This step is also assumed to be normally distributed ($\mu = 0.85, \sigma = 0.032$ minutes) that takes one ground agent to process one luggage. Finally, the processing time for an X-ray security check was modeled in a one-machine queuing system. This process follows a fitted random distribution which is assumed to be normally distributed ($\mu = 0.10, \sigma = 0.05$ minutes) for each bag to pass the X-ray machine and reach the luggage claim area.

The Wilcoxon signed-rank test is used to examine the significance of the correctness of fit for the previously mentioned distributions in each given process. Since the distributions of the collected data in each flight's inbound baggage process are positively skewed, the use of a parametric test is not appropriate. In addition, we are concerned with finding if there is no significant difference between the flight's actual processing time data and the given random distribution for processing time for the same flight. Therefore, the Wilcoxon signed-rank test seems to be an appropriate test to use.

Table 4. Wilcoxon signed-rank test results for each inbound baggage process

Inbound baggage process	Positive ranks		Negative ranks		Test statistics	p-value
	N	Sum	N	Negative		
1. Aircraft arrival	159	18827	110	17488	-0.524	0.600
2. Offloading process and moving containers to cargo facility	129	15825	140	20490	-1.826	0.068
3. X-ray security check	145	16465	124	19850	-1.325	0.185

Table 4 shows the test statistics results for the inbound baggage process using the Wilcoxon signed-rank test. The positive ranks indicate that the randomly generated values are greater than the actual data values. While the negative ranks indicate that the actual data values are greater than the randomly generated ones. We can conclude that there is no significant difference between the two paired groups if the p-value for a given test statistic is greater than the significant level of $0.05(\alpha = 0.05)$. According to the test statistics results for the three inbound baggage processes, there is no significant difference between the actual processing time data and the fitted random distribution since the p-values are 0.600,0.068 and 0.185 for the three processes, respectively. In the first test, the time duration for all collected flights $(N = 269)$ from aircraft arrival until reaching the assigned gate or apron was paired with the time duration for the fitted random distribution to each flight. To calculate the total process time duration in each flight in the second process, which is baggage offloading and moving containers to the cargo facility, individual random entities for luggage are generated. Then, by using the given fitted random distribution, the total process duration of each bag is calculated. Thus, the process time duration for each flight is calculated by adding all luggage process duration, i.e., taking the process duration sum from the first bag to the last bag in each flight. This process is dependent on the number of inbound baggage and the number of ground handlers. The previously generated individual random entities for luggage were also used to find the total time duration for the X-ray security check for each flight. From the given fitted random distribution, the total process duration in the X-ray security check is calculated for each bag. Finally, the process duration for each flight is calculated by adding all luggage process duration.

5. Experimental results

5.1. Results of Stage I

For experimentation, in Stage I, the integer programming model was implemented by using GAMS modeling software. We implemented our model to the collected 269 arrival flight data for one week with 58,665 total inbound baggage. Table 5 and Figure 4 show the output for the assigned number of bags to each belt carousel after solving the IP model. The comparison between the actual situation and the IP model for flight to luggage belt carousels assignment is shown in Table 5. As mentioned previously

(Figure 2), the actual assigned data exceeds the maximum capacity in belt carousels 1 and 4. The IP model minimized on average 9% of the maximum assigned bags to the belt carousel.

Table 5. The actual situation and IP model for flight to luggage belt carousels assignment

Carousel	Total flights		Number of bags assigned		Maximum assigned bags	
	Actual	IP model	Actual	IP model	Actual	IP model
1	68	68	16,497	14,402	886	621
2	65	68	9,332	15,811	586	649
3	65	65	10,119	13,780	507	636
4	71	68	22,717	14,672	1,046	610

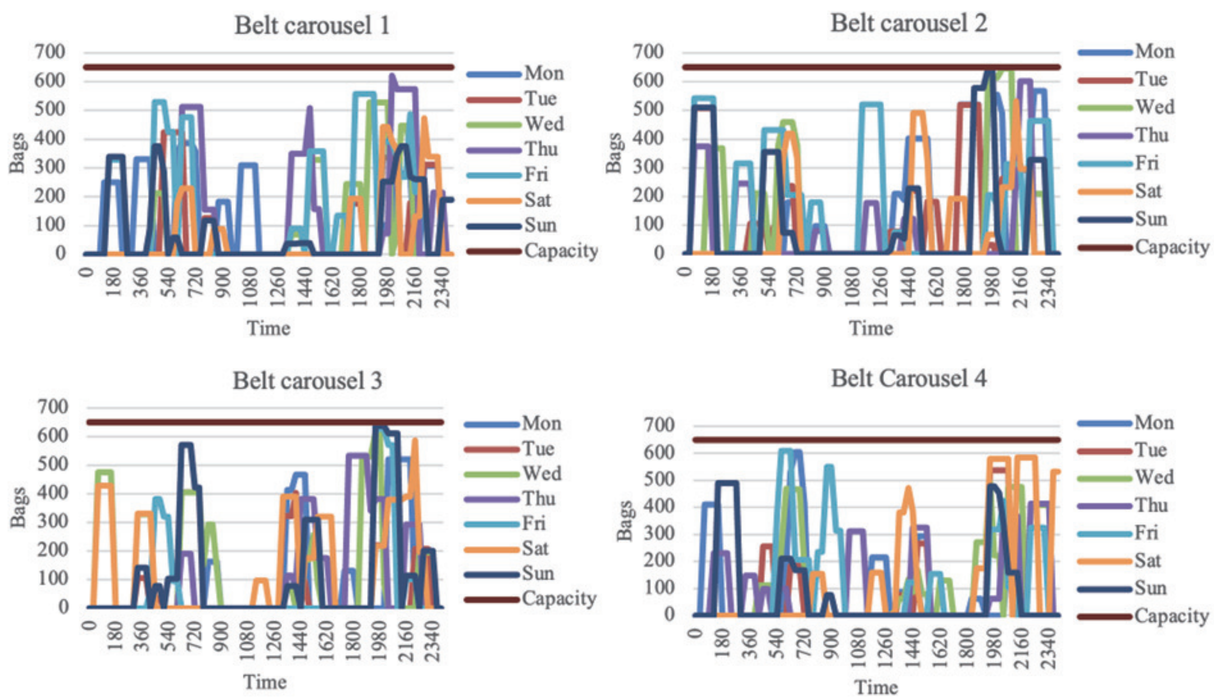

Figure 4. Assigned number of bags to each belt carousel after solving the IP model.

5.2. Results of Stage II

The total inbound baggage of 58,665 operated by 269 flights for one week was simulated for the actual flight to luggage belt carousels assignment. Table 6 shows the output of this simulation by analyzing each bag queue waiting time and bag queue length for the whole system from the offloading process from the airplane until passing the X-ray security system to reach the baggage claim area. The bags average waiting time for the whole terminal is 00:53 and the maximum waiting time 02:06. Furthermore, the average queue length for the whole terminal is 158 bags and the maximum queue length is 612 bags.

Table 6. Simulation results for actual flight to luggage belt carousels assignment

Carousel	Total flights	Total bags	Bags queue waiting time		Queue length	
			Average	Maximum	Average	Maximum
1	68	16,497	1:02	2:06	219	612
2	65	9,332	0:37	1:12	146	458
3	65	10,119	0:30	0:52	83	260
4	71	22,717	1:04	1:57	184	516

In Stage II, the output result for the flight to luggage belt carousels assignment in Stage I was used to run the simulation model to compare between different scenarios. Due to the limited capacity for ground agents, a maximum of six agents with a minimum of two agents can be assigned to one flight. The explanation of each comparing scenario is explained in Table 7.

Table 7. The proposed number of ground agents to be assigned to handle a specified number of bags range

Scenario	Number of ground handlers				
	2	3	4	5	6
Base	current assignment				
1	≤ 50	51–150	151–250	251–350	351
2	≤ 100	101–200	201–300	301–400	401
3	≤ 150	151–250	251–350	351–450	451

The base scenario is the same number of assigned ground agents in the actual data for Kuwait Airways to handle the offloading process and BHS for each flight. Other proposed scenarios divided the number of bags into different categories. Each category has several ground agents that should be assigned to handle this category. For example, if we are using scenario 1 and an arrival flight with 270 inbound baggage, then five ground agents should be assigned to handle this flight baggage. However, four ground agents should be assigned if we are using scenario 2 or scenario 3. Two ground agents should be assigned to handle less than or equal to 50 bags in scenario 1 and scenario 2 is shifted to 100 and 150 in scenario 3. From the collected data, the cases that assigned only two agents to handle more than 150 bags are considered extreme cases. There are four cases, from the one-week data, where only two ground agents handled flights with 150 bags and above. Other scenarios are not considered about the number of bags since they give almost the same results as the scenarios mentioned in Table 7.

It is important to verify the correctness of the simulation model, with different scenarios, and the correctness of the estimated time duration to assign a belt carousel to a flight with a given number of bags as explained previously in Table 3. To check if there are no overlapping cases for flight-to-belt carousel assignment in the simulation model, we compared the time difference between these times for belt assignment with the generated total process duration for inbound baggage from the fitted random distribution. For example, if a flight is assigned to use a belt carousel for 90 minutes to process BHS with a generated total time duration of 75 minutes. This total time is estimated by using the random fitted distribution that will start from flight arrival time until the time for the last luggage to reach the passenger baggage claim area. Therefore, 15 minutes is the remaining time for this flight. In real life, BHS process a delay could have occurred. Therefore, the remaining time or buffer time between the proposed time for belt assignment and the estimated total process duration is recommended to avoid long waiting baggage queues from other flights. In each proposed scenario, we used the Wilcoxon signed-rank test to verify that each flight has a buffer time as previously explained (Table 8).

The result of this test statistics shows that the proposed time duration to assign a belt carousel to a flight is significantly higher than the randomly generated total time duration (p-value < 0.001). Positive ranks in this test statistics refer to the case when the proposed flight time duration for belt carousel assignment is greater than the randomly generated total time duration. It can be noticed that there is a sum of three flights in the base scenario that have negative ranks which leads to a negative buffer time as shown in the

Statistics for the time difference part. Here, the minimum value for buffer is –18.9 minutes which may cause overcrowding in the luggage claim area. The other scenarios (1, 2, and 3) give better results than the "base" scenario due to the effectiveness of the proposed number of ground agents to be assigned to handle a specified number of bags for flight. In addition, the median buffer time value for scenarios (1, 2. and 3) is greater than the median buffer time for the base scenario with a minimum value above 10 minutes and less than 55 minutes.

Table 8. Wilcoxon signed-rank test result to verify the difference between the assigned and the simulated total duration [min]

Scenario	Statistics for the time difference			Positive ranks		Negative ranks		Test statistics	p-value
	Median	Minimum	Maximum	N	Sum	N	Sum		
Base	14.9	–18.9	54.4	267	22,366	3	27	–14.196	<0.001
1	16.7	13.1	52.2	269	36,315	0	0	–14.217	
2	15.9	12.3	46.5	269	36,315	0	0		
3	15.5	10.8	39.3	269	36,315	0	0		

Table 9 shows a summary result for the improvement percentage from the current situation concerning the bags queue waiting time in the whole processing system with bags queue length. Reassigning flight to luggage belt carousels using IP model minimized the luggage processing time in general for the base scenario and scenario (1, 2, and 3). Scenarios 1 and 2 give the best improvement percentage. However, the total number of ground handlers is more than the ground handlers in the current assignment from the collected data. Scenario 3 gives positive improvements for all criteria. The assigned number of ground handlers is 871 (2.4% less than the current situation).

Table 9. Simulation results for improvement percentage from the current situation [%]

Scenario	Ground handlers	Bags queue waiting time		Queue length	
		Average	Maximum	Average	Maximum
Base	892	0:42	1:14	130	615
	0.00	20.90	34.20	17.70	–0.30
1	1,087	0:35	1:08	117	519
	–21.90	33.60	45.00	25.30	15.30
2	972	0:36	1:10	117	520
	–9.00	30.80	43.80	25.60	15.20
3	871	0:38	1:13	114	520
	2.40	27.50	41.40	27.20	15.20

To verify if there is a significant difference between the scenarios about the bag queue waiting time and bag queue length, first, we have estimated the average and the maximum for both bag waiting time and bag queue length for each flight and each scenario using the simulation approach. Then we used the Wilcoxon signed-rank test to examine the difference between the scenarios within the same flights. The test statistics indicate that there is no significant difference between all scenarios about the average and the maximum for bag queue waiting time. However, there is a significant difference between the base scenario and scenario 3 concerning the average bag queue length and the maximum queue length (p-value = 0.012). Although the total number of assigned ground agents in the base scenario is higher than the total number of assigned ground agents in scenario 3, the above result shows the effectiveness of the luggage belt carousels using the IP model and the reassignment for the number of ground handlers for each flight.

The suggested LoS standards for maximum waiting time (min) in Table 2 are equivalent to the level of Service C – Good (Table 1). The suggested maximum waiting time after reaching the luggage claim area is 25 minutes for wide-body aircraft and 15 minutes for narrow-body aircraft. In this research, we run a simulation model for the flight's luggage from the offloading process until the luggage X-ray security checking area and luggage claim area. Kuwait Airways terminal T4 is considered a supportive terminal to the main Airport (T1). Therefore, the size of the terminal is considered small and the walking distance for arrival passengers from the aircraft gate to passport control is short. The previous testing at T4 was done in 2018 by the operational readiness activation and transition (ORAT) team. Approximately, it takes on average 7 minutes and a maximum of 10 minutes for a passenger that departs from a gate to reach passport control. The optimum waiting time suggested by IATA [9] is 5–10 minutes in the passport control area. Therefore, the maximum time for a passenger to reach the passport control area from the arrival gate is approximately 20 minutes (10 + 10). From the simulation results in Tables 5 and 7, the maximum waiting time for a passenger in the baggage claim area in the current situation is about 01:46 (subtracting 2:06 by 20 minutes). For the LP model scenarios are about 0:54, 0:48, 0:50, and 0:53 which are the base scenario, scenario 1, scenario 2, and scenario 3, respectively. Due to the limited number of ground handler agents, scenario 3 is the recommended procedure in this current research since it minimizes both passenger waiting time and the number of ground handler agents for flight assignment. Scenario 3 minimizes about two times the passenger maximum waiting time in the baggage claim area compared with the current situation results.

6. Discussion and conclusion

The quality of service and passengers' experience during the baggage claim area determines the overall quality of the airport. Therefore, the primary goal of the airport terminal service involves passenger satisfaction which involves the passenger queue length and waiting time. According to the operations department at Kuwait International Airport (KIA), there is a critical and urgent need for service improvement in the Kuwait Airways terminal T4 to improve the quality of service at the airport. In this paper, our focus is on improving passenger satisfaction in the baggage claim area. For this purpose, here we have proposed an optimization approach to improve passenger satisfaction. The proposed approach is divided into two stages. In Stage I, we tried to optimize the total number of flights to achieve an optimal allocation of flights to luggage belt carousels assignment in the baggage claim area. The solution of Stage I is supposed to solve baggage processing time and queue length problems at peak times and it was simulated in Stage II. In Stage II, simulation analysis was performed by considering different stochastic aspects, e.g., managing the number of ground handling agents for each flight from the luggage offloading process from the aircraft to the luggage X-ray security checking area.

The empirical results demonstrate that the proposed approaches generate better results from the actual situation concerning the optimization of flight to luggage belt carousel allocation and the number of luggage handling agents for each flight. However, the output results in Table 8 do not satisfy the optimum waiting times for LoS that were explained previously in Table 2. Many issues cause the delay, such as:

- small size of the terminal T4,
- shortage of the ground handler agents,

- a problem with one of the luggage belt carousels will cause overload on the others, especially if many airplanes are arriving at the same period,
- sometimes the X-ray inspector takes time to process the inspection on the bags.

BHS is one of the most important components for security and baggage processing in any airport. Therefore, mishandling the baggage system will cost the air transport industry a huge amount of money annually. Correct baggage handling not only reduces costs but also contributes to facilitation and passenger comfort. Kuwait Airways terminal T4 operators suggested some solutions for the current BHS problem, such as:

- increasing the number of ground handlers in the offloading process and the cargo area,
- changing the luggage belt carousels to bigger belts to hold more bags,
- making the offloaded process from the airplane automated.

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