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Robust model for the assignment of outgoing flights on airport baggage unloading areas

Edward Huang[a,*], Irene Liu[b], James T. Lin[b]

[a] Systems Engineering and Operations Research Department, George Mason University, Fairfax, VA, USA
[b] Department of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, Taiwan, ROC

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ABSTRACT

One of the major functions of airports is to handle the baggage of customers from check-in counters to aircrafts. To have an efficient baggage handling system (BHS), the assignment of flights on unloading areas must incorporate uncertainties. We develop a robust optimization (RO) model to find a robust plan with constant performance stability in terms of future uncertainty realization. We construct a BHS simulation model to compare different assignment models. The results indicated that the total number of manually handled baggage using the robust plan is 58% lower than that using the current assignment.

1. Introduction

One of the key performance indicators in ranking the performance of airports and commercial air carriers is the number of mishandled baggage. Mishandled baggage, such as delayed, damaged, or pilfered baggage, have resulted in loss of money and reputation of airlines, as well as passenger dissatisfaction (SITA Baggage Report, 2016). In 2007, the number of mishandled baggage reached 45 million across countries, which impelled airports worldwide to commit to reduce the number of mishandled baggage (SITA Baggage Report, 2016). However, the 2016 Air Travel Consumer Report (U.S. Department of Transportation, 2016) still ranked baggage mishandling second in the complaint category, followed by flight problems. Therefore, timely and accurate loading of baggage in airplanes should be conducted by airports and air carriers.

To improve the efficiency of baggage handling, most airports have applied automation technologies called Baggage Handling Systems (BHS) to streamline the baggage handling process. The BHS transports the baggage of passengers from check-in counters to unloading areas (Lin et al., 2015). The BHS replaces manual baggage sorting performed by ground crew, which is usually labor intensive, costly, and has a high error rate. Through BHS, the baggage of customers is sorted by flights and then transported to corresponding unloading areas where they are collected by the ground crew.

The main responsibilities of BHS are the movement, control, screening, sorting, and storage of passenger baggage from check-in counters to aircrafts. The detailed process of BHS is introduced as follows: After the customers check their baggage, the baggage is carried by conveyors and passes through an X-ray screening machine for security check. The baggage are sent to the barcode or radio-frequency identification (RFID) scanner where each piece of baggage is identified and assigned with the corresponding destination, which is either an unloading area or a buffer area determined by the control system. If the baggage is checked in before an unloading area is assigned for its departing flight, then it will be transported to a buffer area to wait for reassignment. Otherwise, the baggage will be transported to the corresponding unloading area where it will be collected, loaded in carts, and transported to the airplane by the ground crew.

* Corresponding author at: Room 2238, Nguyen Engineering Bldg., University Dr., Fairfax, VA 22030, USA.
E-mail address: chuang10@gmu.edu (E. Huang).

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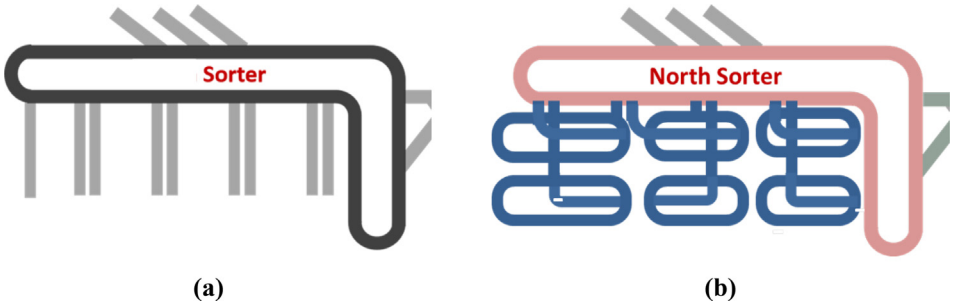

Fig. 1. (a). Sketch of lateral chutes; (b) sketch of carousels.

The equipment used in an unloading area can be either a carousel or a lateral chute. Fig. 1(a) and (b) shows sketches of a carousel and a lateral chute, respectively. Carousels or lateral chutes consist of several conveyors. Usually, a lateral chute can be assigned to only one flight at a time due to its limited capacity (Ascó et al., 2014). By contrast, carousels have a large capacity; baggage for more than one flight can be stored and processed on the same carousel at a time.

Ideally, BHS should be able to handle all baggage on a daily basis. However, this condition is not constantly the case. BHS construction is a long-term investment. During the construction, the actual trend of future demands is difficult to predict. Once BHS is constructed, expanding its capacity to anticipate future demands will become difficult. In addition, the number of flights and baggage usually have seasonal patterns and may vary on days of the week. For example, the number of baggage is usually higher in summer and winter than in spring and fall. Depending on the passenger profile, the number of baggage during weekends can be significantly different from that during weekdays. Furthermore, flights may be delayed or cancelled due to weather or mechanical conditions. These situations must be incorporated by BHS. Considering that the number of flights and passengers (Airports Council International, 2015) have increased annually, the efficiency of BHS should be improved to handle all baggage in a timely manner.

In this research, we investigate the assignment of outgoing flights on airport baggage unloading areas by considering flight uncertainties due to flight mechanical problems or weather changes. The assignment problem is a two-stage decision making problem. In the first stage, which is usually the night before the date of flight departure, airport staff assign each flight that departs the next day to an unloading area and reserve a certain baggage picking period. This process is called the assignment plan. In the second stage, which is on the date of flight departure, the status of flight arrivals changes in real time. Replanning on a real-time basis is impossible. Thus, if the assignment of a flight is not feasible, then airport staff have to change the assignment manually, that is, the flight should be reassigned to another available unloading area or be assigned to a manual sorting area. Either process is labor intensive because airport crews cannot use their regular schedule, and these processes can result in a high baggage handling error rate.

The objective of the proposed assignment problem is to minimize the expected number of unassigned flights and the changes between the plan of assignments and actual assignments. We develop a deterministic model and a robust optimization (RO) model, the solution of which performs in a constantly stable manner in terms of future uncertainty realization. The remainder of this paper is organized as follows: Section 2 formulates the flight-to-unloading-area assignment problem. Section 3 develops the deterministic model and extends it to the RO model. Section 4 presents the modification and acceleration methods. Section 5 shows an airport case study and its numerical experiment. A comparative study is provided. Section 6 discusses the conclusions along with topics for future study.

2. Related work

The assignment of outgoing flights to airport baggage unloading areas has attracted significant attention in the literature. Airports have a limited number of unloading areas, which are proportionally distributed among different air carriers on the basis of their number of outgoing flights (Frey et al., 2010; Barth, 2012; Barth et al., 2013; Abdelghany et al., 2006; Ascó et al., 2014). Abdelghany et al. (2006) presented a model that efficiently assigned scheduled flights of an air carrier to available chutes in BHS to maximize the utilization of available chutes and satisfy different operating requirements. Ascó et al. (2014) discussed the issue of assigning available baggage sorting stations by considering several objectives, such as maximizing the number of assignments on baggage sorting stations and minimizing the gap between assignments. Shih (2015) studied the carousel-based assignment problem and showed a case study at Taiwan Taoyuan International Airport Terminal 2 (TPE). Considering that a carousel can handle multiple flights at a time, the objective of the proposed model is to minimize the overlap time of flights on each carousel to reduce the workload of ground crews in the unloading process. Huang et al. (2016) proposed an assignment model to minimize the total costs, including the assignment, overlap, and changeover costs.

Most existing approaches that address the flight-to-unloading-area assignment problem are heuristics based. Abdelghany et al. (2006) used a greedy algorithm. Ascó et al. (2012, 2014) used constructed algorithms, such as order by starting time, to sort the order of flights and first-in-first-out rules for baggage sorting station selections. Shih (2015) applied the simulation optimization techniques, i.e., integrate optimization techniques into simulation analysis, to identify a good flight-to-unloading-area assignment. Due to the complexity of the simulation, it is usually expensive to evaluate the objective function among all different assignments. To reduce the

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