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A simulation approach to modelling baggage handling systems at an international airport

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ABSTRACT

The baggage handling system is a critical component of an airport's operations, coordinating many different elements and agents in different areas of the facility. Due to the complexity of their interrelationships, an effective analysis of the impact of different operating strategies on the system must consider these elements and agents not in isolation from each other but rather as an integrated whole. This paper presents a microscopic simulation model for a baggage handling system that fully integrates all baggage-related subsystems. These include passenger arrival to check-in queues, baggage check-in, security screening, sorting, transport to the aircraft and loading. Under this approach, not only the individual subsystems but also their interactions can be simulated and studied. The proposed simulator is applied to the case of Santiago International Airport in Chile where passenger demand has grown beyond the existing baggage handling system's operating capacity. The principal contributions of this study are the extension and adaptation of a vehicle traffic simulator software to the baggage handling problem and the development of a platform that models baggage handling as an integrated unit. The tool is applied to the analysis of the overall system and its components under a number of different real-world scenarios. In this application, the movement of bags and their interactions with the rest of the system are simulated in great detail for a given period. This level of granularity permits the simulator to analyse accurately the effects of different scenarios and how they are propagated through the system.

1. Introduction

The baggage handling system (BHS) at an airport is a key process in an airport terminal's landside activities, impacting both the airlines and their passengers. Poor management of the system may result in luggage arriving damaged, late or never, with consequent harm to the airlines' public image. This is especially true during the high season at peak hours when the number of flights a BHS must process at the same time rises dramatically, in some cases to levels beyond the terminal's design capacity.

Most major world airports today have automated baggage handling systems. At the international airport terminal in Santiago, Chile (SCL by its airport code), the BHS, though relatively advanced, is not completely automatic. Movement of baggage

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within the terminal is automated but the sorting, distribution and aircraft loading operations are carried out manually. Baggage handling services at the airport are provided by a number of ground handler companies, one of which accounts for more than 80% of supply.

SCL's capacity was last expanded in 2001 and is currently estimated at 9.5 million passengers per year. However, with the explosion over the last 10 years in Chile's domestic air travel market, this figure was already surpassed in 2010 when more than 10 million passengers were carried. As of 2014, the annual number had risen to 16 million [1].

In this scenario the pressure on all of the airport's systems has reached unprecedented levels, leading to long passenger queues, delayed flights and a growing potential for damage or loss in the baggage handling process. The BHS in particular, which handles all of the terminal's luggage, is suffering under the strain. Yet no significant infrastructure investment is planned to remedy the situation in the short term, in part because priorities are focussed on the construction of a new terminal to handle 30 million passengers that is slated to open in 2019.

In light of this situation, there is a clear need to find ways of improving baggage handling at SCL in the short and medium terms through the optimization of operations, processes and usage of available resources in order to support the increased intensity of demand in an infrastructure scenario that has little prospect of upgrade at least for the next two years.

The present article presents a simulation platform for modelling the whole SCL baggage handling process from the moment a passenger joins the check-in counter queue to the loading of the baggage onto the aircraft. As will be seen in the following sections, the BHS is made up of multiple subprocesses that are strongly interrelated. This results in an overall process that is highly complex to model and calls naturally for the use of simulation as an approach to its analysis. The proposed platform will enable us to make a thorough study of BHS operations for both the domestic and international terminals, and identify its critical processes and their impact on the rest of the system.

The contributions of this work are twofold: 1) a simulation platform is developed that integrates various airport operation systems (counters, baggage conveyor network, baggage loading area, security screening, etc.) so that both the systems themselves as separate entities and their interactions can be studied, and 2) the simulation of the conveyor belts is built by extending a vehicle traffic microsimulation software.

From a practical application standpoint, this simulation tool generates evaluations of hypothetical operating scenarios based on real data whose results can be used to design operating protocols for both normal conditions and contingencies. The arrival baggage operation was not included in this study but it should be considerably simpler to address than the departure baggage operation that is the focus of our analysis.

The remainder of this paper is organized into six sections. Section 2 briefly reviews the state of the art in baggage handling system modelling for airports; Section 3 describes the workings of SCL's departure baggage handling area, focussing on the movement of bags from the check-in counters to the departing aircraft, as well as the adaptation of a traffic simulation software for simulating conveyor belts; Section 4 details the structure of the simulator; Section 5 sets out the results of a number of experiments in modelling realistic BHS operating scenarios; and finally, Section 6 presents our conclusions, the current state of the simulation development and some tasks for the future.

2. Literature review

Although many published works have attempted to model the different systems for airport terminal processes as separate entities, relatively few have tried to construct an integrated formulation of a BHS. Among the earliest efforts are [2] and [3]. The latter study analyzed various configurations for the design of baggage conveyor systems and tested a number of operating schemes, but due to the technological limitations of the time it was not possible to experiment with real scenarios.

Integrated models have, however, been developed for facilitating the decision-making process in airport planning and design [4–7]. Other models diagnose the global performance of an airport terminal or parts of one [8–10]. These formulations concentrate on passenger flow (check-in, customs, security screening, departure lounges, etc.), leaving baggage handling in the background.

As regards modern baggage handling systems, the consensus is that they are complex and difficult to model and thus require elaborate tools of analysis to be managed correctly [11–14].

Broadly speaking, the available models and tools for airport process analysis may be divided into three categories: macroscopic, mesoscopic and microscopic, depending on whether the level of detail is low, medium or high, respectively.

Macroscopic models are used primarily to support strategic decisions. They operate at a high level of aggregation and therefore omit much important detail [15]. Prominent among these is SLAM [8], an analytical model for estimating the approximate capacity of passenger terminal systems. It consists of a set of modules, one for each terminal area, that estimates capacity and expected service levels, and was used as the model base for the development of OPAL (Optimisation Platform for Airport including Landside) [16]. SLAM cannot, however, model the possible interactions between the different terminal elements, nor can it handle stochastic effects that might impact general system performance, and therefore fails to capture the full complexity of a terminal's processes.

Microscopic models, on the other hand, are designed to incorporate a large number of operating considerations, require much information to be implemented and tend to be expensive to develop. They are usually based on simulation and have been developed for specific airports or limited to certain terminal processes [17].

A well-known general microscopic model was developed by Abdelghany et al. [18], who propose an algorithm for planning which flights should be processed in each zone of an airport. They analyzed the impact of grouping the departures of