A System Dynamics Approach for Airport Terminal Performance Evaluation

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Abstract. Performance modelling of highly complex large-scale systems constitutes a challenging task. The airport terminal is a highly dynamic and stochastic system with a large number of entities and activities involved. In this context, developing models/tools for assessing and monitoring airport terminal performance with respect to various measures of effectiveness is critical for effective decision-making in the field of airport operations planning, design and management. The objective of this paper is to present the conceptual framework for the development of a generic, yet flexible tool for the analysis and evaluation of airport terminal performance. For the development of the tool, a hierarchical model structure is adopted, which enables a module-based modelling approach, and System Dynamics is used as the theoretical basis.

1 Introduction

Performance modelling of highly complex large-scale systems constitutes a challenging task. The airport terminal exhibits dynamic behaviour in space and time and is characterized as a highly complex system, since it involves a large number of entities, a large variety of types of services, complex interrelations between processes, variability and stochastic events. Airport stakeholders and policy makers involved in airport strategic planning and operations face challenging decision-making problems with significant trade-off's between resource utilisation and customer service fulfillment [9]. To address these requirements, several models/tools have been developed to analyze and model airport terminal operations [1], [3], [6], [9] but no single model provides the capability of fully addressing the peculiarities of airport terminal domain, and being easily customisable to local conditions of any airport. Currently available models are either too macroscopic, failing thus to capture the complexity of airport terminal processes, or models of specific airports. Consequently, there is an urgent need for adopting a new approach to develop a generic tool for modeling airport terminal operations, that will also provide the flexibility to adapt to the specific characteristics and conditions of any airport terminal in a user-friendly way. The objective of this paper is to present the conceptual framework for the development of a generic, yet flexible and easily customizable tool for the analysis and evaluation of airport terminal performance.

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2 Airport Terminal Domain Modeling Approach

The conceptual framework developed is based on: i) domain modeling, to address the need for having a generic way of analysing the requirements of any airport terminal, ii) simulation and System Dynamics (SD), since they provide a framework to understand the operations of complex dynamic systems and view the impacts of any decision on the entire system [5], [7], and iii) a module-based modeling approach, to address the design requirement for flexibility, which in turn influenced the adoption of a hierarchical structure for the model. The tool is structured into two hierarchical levels: the first level of the hierarchy reflects the airport terminal system decomposition into a set of airport functional areas; at the second level, the functional areas are decomposed into service facilities (modules) of the airport terminal, e.g. the check-in facility. Figure 1 provides a total insight into the model architecture, its hierarchical structure, and the relationship between hierarchical levels. In the same figure, an example of a departing passenger flow throughout the various facilities of the airport terminal is graphically illustrated (with the grey arrows).

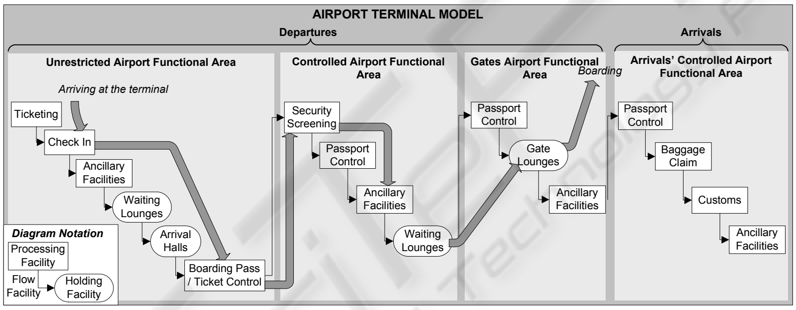

Fig. 1. Model Hierarchical Structure.

The modeling process of the tool was based on the meta-model depicted in Figure 2. The facilities modeling process is based on a general typology of the facilities involved into processing, holding, and flow facilities [1], [2]. In processing facilities, processes providing some type of services, e.g. check-in, security check, etc., to a variety of customer groups take place; holding facilities provide passengers with the required space to wait over a period of time; and flow facilities are used to accommodate the movement of passengers between the various holding and processing facilities of an airport terminal [2]. Overall demand for services is determined by the airport flight schedule, which determines arrival and departure patterns of the various customer groups at the terminal. As customer groups get processed through the system, the demand for downstream facilities is determined by the outflow of preceding facilities. The capacity of a facility is expressed though: i) the number of passengers served per unit time, for processing facilities, ii) the maximum number of passengers accumulated per unit area, for holding facilities, and iii) the maximum customers' flow through a particular flow facility per unit time, for flow facilities.

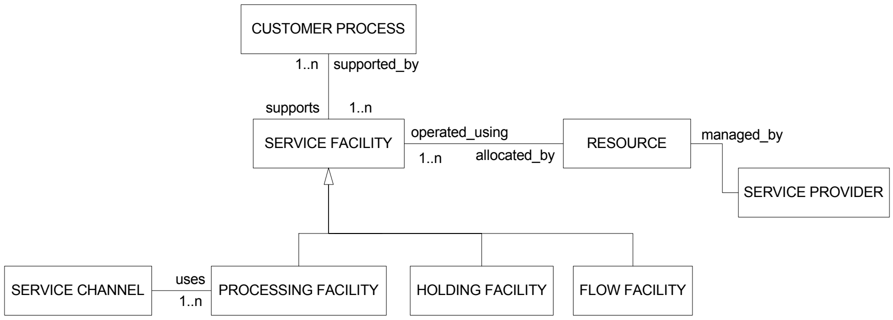

Fig. 2. The Simulation Metamodel (modified after [2]).

The services offered by the various facilities are represented by stocks (rectangles) and flows (pipes) and are controlled in terms of information feedback and process parameters (converters). Stocks represent the state of a process, e.g. passenger accumulation in queue for ticket counters, whereas flows the rate of change of this state, which is determined by variables controlled by the user, e.g. passengers per ticket counter per min, and number of open counters. A fragment of the model representing a processing facility, e.g. Check-In facility module is shown in Figure 3. Example of flow facilities are also contained in Figure 3 for the estimation of "walking time between Unrestricted Area & Check-In Hall" converter. To represent and capture the complexities of the model, each facility includes three elements. This modelling approach is adopted to allow for the same type of facility to exist in different locations of the terminal, which implies different distances travelled and different flows.

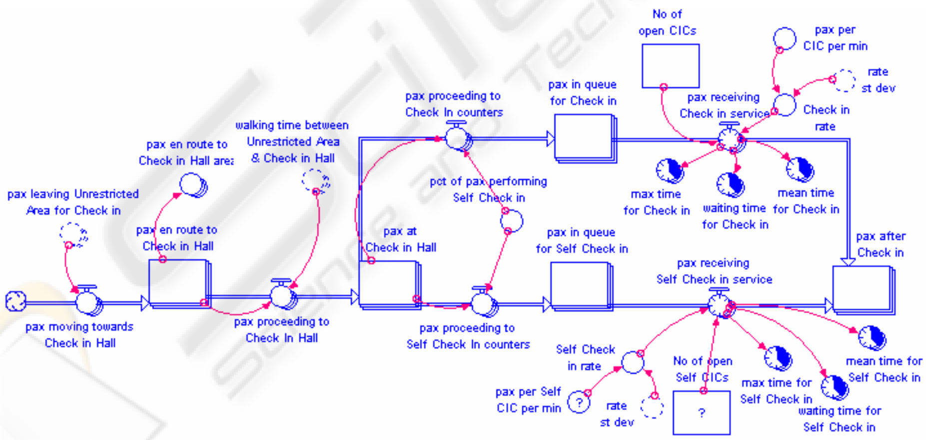

Fig. 3. Check-In Facility.

In every facility there are three points of connection driving facilities' composition into functional areas, which relate to the following: i) a stock representing "passengers available in the associated functional area for free circulation" is defined for every functional area. The initial inflow and the final outflow of a facility begins from and terminates respectively to this particular stock; ii) Demand placed upon a service facility is determined taking into account: a) passenger availability in the associated functional area (the stock defined in (i)), and b) the demand placed upon other facilities of the functional area; iii) The estimation of walking times between a service facility and the elements of the associated functional area is based on a pedestrian flow model which considers speed, flow, and density relationships, between all elements of all facilities pertaining to this specific functional area [4], [8].

To complete the design of the airport terminal model, functional areas are interconnected through a specific facility which acts as the interface between them. For example, the interface between Unrestricted Functional Area and Controlled Functional Area is the Boarding Pass facility, as this is the last facility in Unrestricted Area passengers pass through before entering Controlled Area. Accordingly are connected the remaining airport functional areas.

A conceptual framework for the development of a generic, yet flexible airport terminal simulation tool has been presented. The proposed tool is intended to support effective decision-making in airport terminal operations planning, design, and management, with respect to performance evaluation. The work underway for the completion of the tool development includes validation and implementation of the simulation model.

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