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ANALYSIS AND SIMULATION OF PASSENGER FLOWS IN AN AIRPORT TERMINAL

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ABSTRACT

As human behavior is often thought to be hard to define in models, simulations of processes with people involved are less common than industrial simulations. Nevertheless simulation has been very valuable in passenger logistics to study bottlenecks and test potential solutions. This paper describes a project concerning the analysis and redesign of passenger handling at an airport, in which dynamic modeling played an important role.

Simulation has been applied here to gain insights into the relations between the distinguished processes, the presence of bottlenecks and their causes. With the simulation models future situations were represented, through which long-term expectations can be posted. In this way critical aspects in the passenger flow through the airport terminal have been explored and studied. All potential bottlenecks have to be suppressed by apt arrangements. These can consist of an expansion of the availability of resources or floor space, but many times improving the processes can be a more effective or more efficient solution. Several supposed measurements have been tested in a quantitative way, to examine whether they fulfill the expectations, are robust and do not create new problems.

The overview of bottlenecks and the comparison of measurements formed the required results of the simulation project. However, some other effects of the study turned out to be just as useful. As detailed simulation studies require exact descriptions of processes and representative data, a large amount of information had to be collected and laid down. Process control and management will take advantage of it. Furthermore the modeling of he complete chain of processes supplied an increased insight in the dynamics and the intra-organizational relations. So in the future sub-optimal solutions can be avoided and communication improved.

1 INTRODUCTION

The airport concerned is one of the major European airports, accommodating over 33 million passengers annually. On busy days 120 thousand people arrive at and depart from the airport. Approximately half of them will transfer to a connecting flight to resume their journey. Having short connection times between the individual flights is a key selling point for the airport.

Another key selling point is a secure operation, free of disturbances. The traveler should be able to catch his flight on time, while still having enough time to do some shopping and other pleasant time killing activities. Therefore performance of the different handling processes is important and monitored. The time passengers have to spend on queuing at check-in, walking, security-check, boarding, etc will be compared with the service levels agreed upon. Furthermore different quality levels for waiting areas and maximum throughput are defined.

Due to the annual growth of passengers and flights, terminal capacity is imposed to heavy performance. So in order to manage the handling process and the present facilities, a new method had to be found to ensure that future requirements can be met.

Especially as the airport does not only suffer the consequences of the growth, but also has to cope with many social and political changes that have an impact on the passenger handling. For instance the development of the European free trade zone, the Schengen zone, and new flight patterns partly due to increasing attention to noise reduction and environmental effects of air traffic.

To be able to deal with the impacts of an expanding market and many other developments in time, it is necessary to evaluate critically and constantly the gearing between the current organization, the available infrastructural capacity and future needs. With this in mind a few years ago the project Logistics Development Terminal (in Dutch: Logistieke Ontwikkeling Terminal, LOT) has been started and Incontrol Business Engineers was asked to join in the studies.

2 PROJECT GOALS

The LOT project has been initiated for two main goals (Gatersleben et al. 1996):

1. Identification of logistic bottlenecks in the passenger handling within a time scope of five years.
2. To provide integral solutions for these bottlenecks, which support the process of making decisions about future airport developments.

The search for logistic bottlenecks in the passenger handling comprised a study of both the passenger flow and congestion in the buildings and the staying time in waiting areas or recreational facilities. In this study exact locations of bottlenecks and their causes had to be pointed out. Furthermore the needed amount of airport resources like immigration desks, check in counters and baggage reclaim belts have to be estimated.

The intention to provide integral solutions was stated as another important goal, because changes in any process may influence the total performance and quality of the passenger handling. It had been proven in the past that it was difficult to gain a clear understanding of the integral consequences of modifications.

Other, less explicitly stated, but not unimportant objectives concerned gaining commitment of all parties involved and the possibility to reuse the developed approach, method and tools. The commitment is required to reach consensus with the involved about the results of the project and its settings. In that way resistance against consequences will be reduced and communication simplified. Since the airport is exposed to air traffic developments and external influences, it is desirable to validate and repeat the project results frequently, which creates the wish to reuse the methods and tools.

For all those reasons it was decided to use modeling and simulation in the project.

3 APPROACH OF THE PROJECT

The first step in the project was to understand and describe the current situation completely, as it is yields as a reference for model validation. All processes involved with passenger handling have been analyzed and the numbers of resources estimated. Process times, waiting times, queue lengths, numbers of people in all areas, etc have been measured and compared to the information supplied by airport experts. Furthermore the general human behavior in the airport had to be examined, to determine how long before departure time passengers arrive at check in, why passengers prefer certain routes, for what reasons they spent a certain time in shops, etc.

This is a necessary phase, but it turned out to be very intensive and time-consuming, for only few data were available and there was hardly any insight in the exact dynamical process characteristics and facility usage. Right from the start experts of several departments and directly involved companies were invited to participate in the analyses in order to assist the project team and to support the chosen approach and the final results.

In the following phase all expected trends, future developments and infrastructural building plans were mapped and discussed with experts. This was just as intensive as the previous phase, particularly as special tools had to be developed to translate the acquainted knowledge into usable data. Correct data is essential to get valid and valuable results about bottlenecks in future situations and to define relevant scenarios and moments of timing. A self-developed new software tool generates future flight schedules, with expected flight characteristics and numbers of passengers, based upon various growth-related parameters. With these schedules the impacts of air traffic growth and other developments can be evaluated.

Complementary, all international enforced service levels and all quality levels the airport wants to comply with were collected. For a selection of the most prominent performance indicators had to be determined if the performance of the future handling process would meet these levels.

In discussions with experts of the passenger handling process, the aspects that were critical already or that were expected to become critical in future were drawn up. Such aspects, like congestion in walkways, long queue lengths or walking distances got extra attention in the several tools and models that had to be built to perform the calculations and the evaluation.

4 MODELING

4.1 Classification

The subjects of investigation have been divided into two categories. First the airport resources that can be assigned to airlines or specific flights, e.g. gates, check in counters and baggage reclaim belts. Second the flow related and non-assignable facilities, for example immigration desks, shops or lounges. The relation between both types of aspects is a result of passenger routings and facility location and reveals it self by presenting planning results of the first to the latter.

4.2 Static Modeling

Airport resources that can be assigned to flights or airlines are planned on a daily basis in an operational planning. On behalf of the LOT-project static modeling tools have been built to represent the function of planning, as it was not possible to use the existing instruments in completely modified situations with a redesigned Terminal building, new infrastructure and future flight schedules.

The static model produces a future resource planning and demonstrates whether the process control and the foreseen equipment are sufficient to guarantee a qualitative passenger handling. Figure 1 provides the result of the computation model for check in counters.

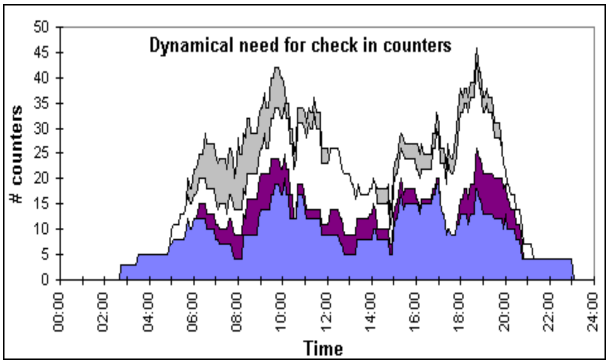

Figure 1: Check in Counter Computation Model.

4.3 Dynamic Modeling

Analyses of the passenger flow through the Terminal building and the utilization of non-assignable facilities have been carried out using simulation models. Several reasons led to the decision to use simulation as the method to look for bottlenecks in the future operation:

- Process interdependency: The processes at an airport can not to be treated as fully individual. They form a chain of processes that must be geared for one another to create a smooth handling of the passengers within limits. Taking into account the process interdependencies it is possible to notice influences and to avoid sub optimization.

  In simulation these interdependencies can be showed and quantified. Also the integral effects of a modification of one element can be easily judged. In the past insight in the quantitative aspects of these interdependencies was lacking. Every departments had its own interests and tried to perform as well as possible, what resulted in local improvements and moving bottlenecks.
- Dynamics: As the airport is transfer oriented, the flight schedules are set up in a way to create short connection times. These short connections cause peaks in arriving and departing of planes. On its turn this implies a strong time-dependency of the number of passengers walking through parts of the Terminal building. This dynamical behavior can be seen in a simulation model, which makes it possible to find the right combination of process organization and infrastructure, for even in peak situations it must be achievable to get to your plane on time.
- Future scenarios: During the phase of collecting building plans and flight data it became obvious that there were many uncertainties about future developments. It is no option to wait until a bottleneck comes into being, then it often takes a long time to react through altering the processes or increasing capacity. To leap on possible effects of the number of passengers and other developments efficiently, effectively and on time requires timely insights in these consequences and proactive acting.

  By building scenarios for several combinations of potential developments, situations with minimal, maximal and expected passenger flow and the resulting occupation of accommodations can be created. The range to expect for future logistic performances is provided by the simulation models.
- Evaluation of solutions: If the simulations indicate that some bottleneck will occur in the passenger handling, this should be solved. Every potential solution must be evaluated on influencing logistic performance and the integral effects. Simulation is known as a fine method to compare different strategies for problem solving and estimate the robustness of a solution in a quantitative way.
- Changing the way of thinking and acting: A less habitual reason for the application of simulation models in the LOT-project was the intention to change the way of thinking and acting, concerning dealing with problems regarding the capacity of the Terminal infrastructure. The traditional method existed of translating a specific percentage of growth of passengers into an equivalent percentage of required additional capacity, without studying more efficient handling methods. Growth can express itself in various ways however, with various effects. Besides, existing handling methods can be obsolete or redundant. In that case adding extra capacity is no efficient solution. So the lack of clear

insight in the dynamics of the passenger flow and the impossibility to calculate the integral effects could result in a very expensive manner to deal with these subjects.

Through the simulation models the insights should be gained. This makes it possible to change this habit and handle both growth and environmental developments by thinking about ways to do more with the available resources in stead of implicitly expanding the existent situation.

5 CONTENTS OF THE SIMULATION MODELS

5.1 Demarcation

The complete passenger flow in the terminal building, from check-in to boarding and from deboarding to baggage reclaim, as seen in Figure 2, has been modeled into the simulation environment ARENA. Three subsystems have been distinguished, based on the origin and destination of the passengers:

- Departs: This subsystem starts with the description of entering the departure hall at a certain time before departure and walking to the check in desks. Hereafter passengers have to pass immigration to get into the lounge and pier areas. These areas were hard to describe in a model, since passengers have a number of options, like shopping, walking or waiting in several locations. The decision depends on remaining time, type of flight, etc. Finally, the passengers go to boarding and leave the airport.
- Arrivals: After aircraft arrival and deboarding passengers walk through the piers and lounge areas in the direction of the immigration. If passengers have to collect their baggage, they will walk to the reclaim area. Otherwise they will directly go through customs. In the simulation model, the doors of the arrival hall indicate the end of the process arriving.
- Transfer: The transfer process contains elements of both arriving and departing. From deboarding till walking in the piers and lounge areas is equal to the arrival process. Starting at this point, transfer passengers are in the same state as departing passengers.

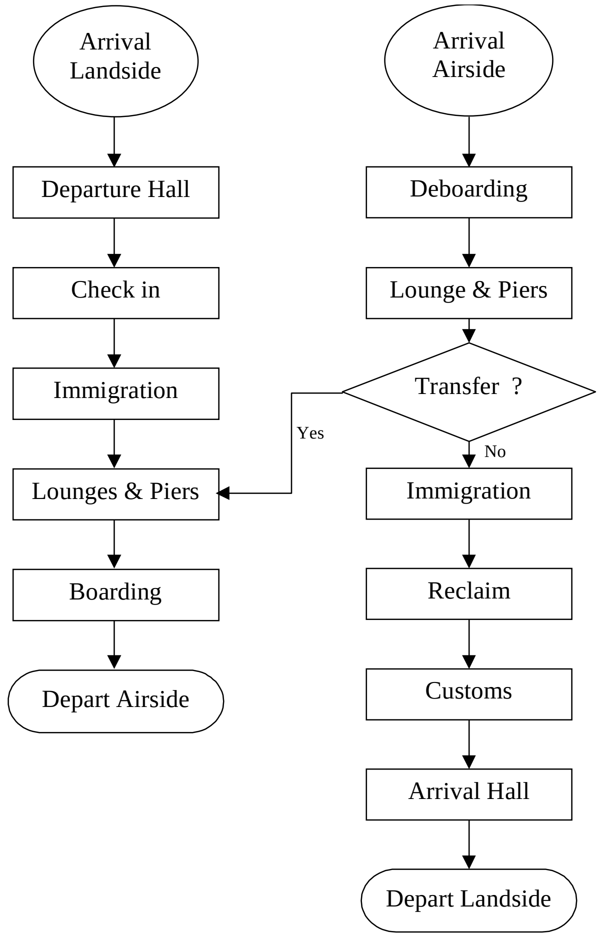

Figure 2: The Processes in the Passenger Handling.

5.2 Realization

On its way to an aircraft or airport exit a passenger has to experience several processes, which are represented by restricted resources. The required throughput times are a result of process times and potential delays, which might exist if queues arise. As process times and process capacities are often time-dependant, they are modeled as variable parameters. Other elements of the handling process, for example immigration, are subject to the characteristics of the individual passengers or their flight. In that case individual properties will cause different behavior.

In the model information about resource utilization, the number of passengers in all waiting and shopping areas, process times, waiting times and queue lengths is collected. This information will serve as performance indicators for the passenger handling.

Links interconnect the process locations and all distinguished sections. At arriving time, every passenger is assigned a route, connecting the origin and the final destination. This route is composed of several links. After completing a process step or at the end of a section, the route contains information about the succeeding link. Entering a process or a period of waiting implies a temporary interruption of the route, but after processing the passenger will reenter its route to the final destination.

The length of the link and the passenger speed determine the travel time in a link. This speed is varied according to natural variation in walking speeds and is dependent on the calculated number of passengers in the segment at that time. The total travel time, the route length and the passenger flow per minute in a link are also performance indicators.

For several stages in the development plans separate models were built. New elements were added to the model of the previous situation, others were modified. Also the number of possible routing paths had to be altered and expanded. In this way new infrastructural models of future situations were created and represented in the animation of the model (see Figure 3).

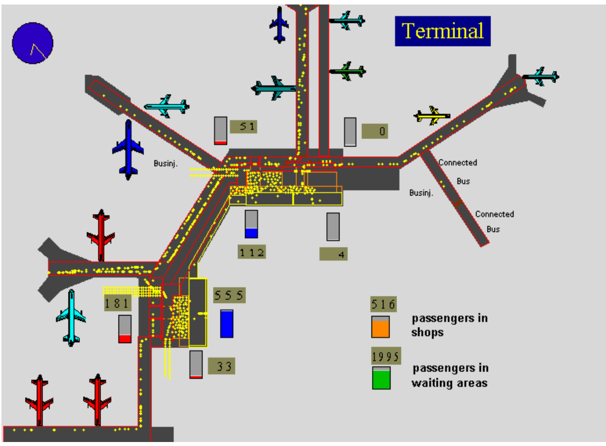

Figure 3: The Simulation Model: Overview of the Terminal Building.

Experts of the airport organization, airlines and handlers were also consulted during the modeling process, to provide their opinion and expertise about the quality of the passenger handling and to help validate the models. These comments and ideas were incorporated into the models and caused model modifications and the introduction of extra performance criteria.

Finally, every resource planning and all developed flight schedules files have been combined and these packages were added to the models. This is repeated for every distinguished future scenario.

6 RESULTS AND EFFECTS

The models resulted in huge quantities of output, which were translated into overviews of flows, resource utilization, waiting times and all other performance criteria. Since information about the performance indicators is written to output files continuously, time-dependant graphs of throughput, utilization and waiting times are set up. This shows the dynamics in the passenger handling and the variance between the occupation of the segments of the terminal building. From these overviews and graphs the bottlenecks and their urgency for solving, expressed in the extent of exceeding a quality level, were distilled. By comparing the results of the different scenarios, the likelihood of an arising bottleneck can be judged. This also estimates the boundaries between which the performance of the passenger handling is considered to vary.

In experiments combinations of solutions have been proved subsequently. This provided quantitative insights in both the consequences of solutions for the bottleneck and the side effects for other components of the integral passenger handling, as a result of the interdependencies. Some proposed solutions turned out to be very effective, whereas others showed no effect or resulted in major disadvantages.

This quantitative information serves as supporting material in making decisions about the development of the airport. Expectations for the future quality of the passenger handling are now available. Furthermore the timing of arising bottlenecks and corresponding solutions can avoid premature of even inconvenient arrangements, which can reduce risks and investments.

Other aspects coming with the study were also valuable. With respect to the reusability all collected process information was documented and a template for building similar models was developed based on the simulation models. This template, PaxSim, consists of several building elements that contain logic structures as used in the original models and simplifies future simulation studies.

As several departments were involved in the study from the beginning it was relative easy to gain commitment about the results and to apply them to the operation. The animation accompanying the simulation model was an extra support in simplifying the communication.

7 CONCLUSIONS

The LOT project, regarding analysis and simulation of passenger handling at Schiphol Airport, turned out to be quite successful. The successes could be attributed to a large extent to the employed approach including simulation.

First of all insight in the present and future situations was gained and solutions for bottlenecks were judged on their simulated improvement of performances. These insights make pro-active measurements possible in order to prevent future bottlenecks.

Furthermore the experts involved learned about their own and dependant processes, as they all are part of the complete handling chain. The simulation models and the results of it acted as independent referee in discussions about performances and causes of problems. The animation played a very important role in this communication between different parties. The “live” visualization showed clear the problems that had to be encountered. As a result, all parties accepted the solutions found and supported the overall view needed to keep performance up. Also performance indicators and process management was adapted based on new information concerning the handling process.

The simulation models and information gathered during the study is well documented for future use. Several projects enclosing simulation succeeded the LOT, including repetitions of this study. Since models, tools and information are ready to be used again, the necessary time can be reduced dramatically, which decreases expenses and increases the profits.

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AUTHOR BIOGRAPHIES

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