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NEW CONCEPTS IN BAGGAGE OPERATIONS FOR NARROW BODY AIRPLANES

A Simulation Study

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Airport, baggage, discrete simulation

ABSTRACT

In this paper new concepts for baggage transport to and from narrow body airplanes are presented. The concepts are simulated and applied to a part of Schiphol Airport Amsterdam. The current baggage transportation is labour intensive and bares the risk of damaging or losing bags. Moreover it is time-critical because of the tight flight schedules used. An alternative scheduling method as well as the application of a partly automated baggage loading and unloading vehicle are investigated with simulation and reported. It appears that a considerable saving is possible when using both the scheduling method and the new baggage vehicle.

INTRODUCTION

Amsterdam Airport Schiphol is a so-called "one terminal" airport. It consists of one building for the passengers with short connections to the gates. Figure 1 shows the current and planned future situation. The B-, C- and part of the D

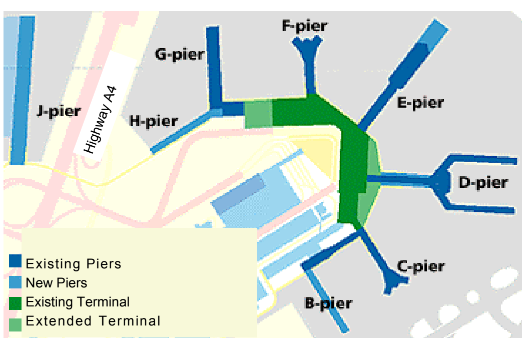


Figure 1: Current And Future Outline Of Schiphol Airport

pier form a separated "Schengen area" for destinations in the European Union. Schiphol handles about 40 million passenger per year 42% being transfer passenger just changing plane at Schiphol. It is anticipated that air traffic via Schiphol will grow 4 to 5 % per year in the next decennium. This will have serious consequences for baggage handling such as congestion on the infra structure and heavy load on the baggage sorting systems. The existing piers are rather close to the baggage sorting system but distances to new piers such as the J-pier will become considerably larger. Moreover changing regulations concerning irregular labour schemes and heavy physical working conditions are expected to cause difficulties in manning the baggage handling service.

BAGGAGE OPERATIONS

Baggage for wide body aircrafts is contained in containers. Narrow body planes, for example the Boeing 737, are too small for standard air containers (ULD's) and are loaded by hand, bag by bag into/out of the belly, see figure 2.

Figure 2: Unloading of a Narrow Body Airplane onto a Baggage Cart.

This paper is restricted to baggage flows to and from narrow body planes.

Current Procedures

Currently baggage for narrow body airplanes is transported using trains consisting of up to six baggage carts pulled by a manned truck. This system is flexible and, provided there are enough baggage cars available, the number of pull-trucks can be minimized. Some disadvantages of the systems are a low velocity (loaded up to 15 km/h), a certain risk of losing or damaging baggage and labour-intensive and physically heavy work with respect to loading and unloading. (Jerkovic 2000)

Arrival
If an airplane arrives, a central coordinator assigns a vehicle (train) and a handling team to the gate of the arriving plane. The team unloads the arriving baggage assisted by the truck driver. The train is then driven to the transfer and the reclaim inlet. The loading team returns to its base to get further instructions. Only if the turn around time of the plane is short enough, the loading team remains at the gate to load the plane before departure.

Departure
At a certain time before scheduled departure the central coordinator sends a baggage train to the baggage sorter outlet assigned to the departing flight. There the baggage is loaded onto the baggage train and transported to the proper gate. The coordinator is also responsible for directing a loading team to the gate. The loading team, assisted by the driver, loads the baggage into the plane piece by piece.

CONCEPTS

In this paper three aspects will be studied, (Snick 2002)

- Introduction of a baggage truck (Oosterhuis 2002)
- Improving scheduling of personnel and equipment by dynamic planning.
- Influence of distance between baggage outlet and gate.

The Baggage Truck

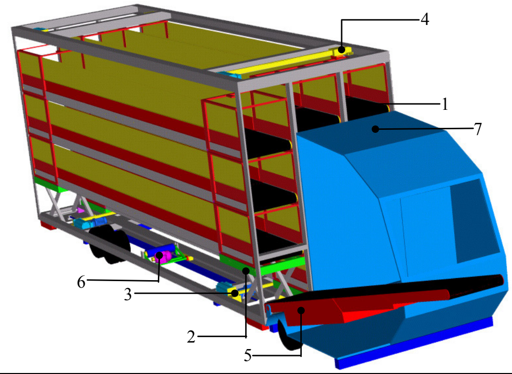
The design of the baggage truck is shown in figure 3. Baggage transport per baggage truck offers the next features:

- The baggage truck can be loaded/unloaded automatically at the sorter outlet and reclaim and transfer inlet respectively.
- It lifts its baggage outlet to the level of the plane-belly entrance. There the baggage has to be stowed into the plane-belly by hand. Arriving baggage has to be retrieved manually from the belly, but from that point the further procedure is automated again.
- The load and unload rates are rather high and all baggage of one narrow body plane fits in the baggage truck.
- Connection with existing landside systems is possible.
- First In First Out (FIFO) loading and unloading per belt conveyor is possible.
- Odd-size baggage can be transport separated from regular baggage with the same truck.

Improving Scheduling

In the current practice there is no communication between central planning and labour teams and vehicles during operations. After each job completion personnel and drivers go to their base called the "buffer" and report to the central planner.

In the concept of dynamic planning (un)load teams as well as equipment drivers have radio contact with the planner and are assigned to jobs without physically moving to the buffer. A procedure has been applied to reduce the total equipment travel time, maintaining the punctuality and service rate, see table 1. For each combination of job and



Part List		Characteristics
1.	Belt Conveyor	Max. 175 bax
2.	Lifting mechanism	20 bax/min loading
3.	Shifting mechanism	36 bax/min unloading
4.	Shifting mechanism	Max. 80 km/h
5.	Elevating conveyor	12 m length
6.	Conveyor drive	4 m hight
7.	Storage odd-size bax	2.6 m wide
		0.2 m ground space

Figure 3. Baggage truck for transport and handling of baggage from and to airplanes. Patent Nr: 1022640 pending

available vehicle a time factor $t_{i,j}$ is calculated being the sum of the next three times: 1: time to next job. 2: penalty time if the vehicle comes from the buffer. 3: penalty time if the vehicle will arrive too late at its destination. The jobs are sorted in decreasing due-time so that the most urgent jobs are on top. The objective in the scheduling process is to reduce the sum of the time factors over the job-vehicle combinations and to maintain punctuality of service. A

Table 1: Scheme of Time Factors for each Job-Vehicle Combination. Jobs are Sorted in Decreasing Due-Time.

Vehicle Job	1	2		j		m
1	$t_{1,1}$	$t_{1,2}$		$t_{1,j}$		$t_{1,m}$
2	$t_{2,1}$	$t_{2,2}$		$t_{2,j}$		$t_{2,m}$
i	$t_{i,1}$	$t_{i,2}$		$t_{i,j}$		$t_{i,m}$
n						

simple heuristic approach has been applied. For each job the vehicle with the smallest time factor in its corresponding row is assigned starting with the first job. In that way the most urgent jobs have the best choice of

vehicles. The schedule is refreshed after each job completion and plane arrival. The same approach is applied for the scheduling of the individual labour teams to the loading and unloading jobs of airplanes.

Influence of Distance

In the Schiphol situation the distances between terminal and gates are rather short as a result of the compact way of building and the "one terminal" concept. This situation changes if the airport is expanded with for example the new pier J at the other side of highway A4, see figure 1. In order to study the consequences a short distance situation (pier D) as well as a long distance situation (the future pier J) have been simulated. The distances between pier D and sorter outlet and baggage reclaim inlet are in the order of 100 m. For the J pier the distance to sorter outlet and baggage reclaim amounts up to 1500 m.

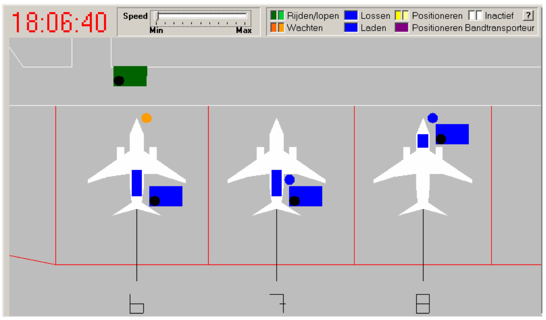


Figure 4: Part of the Animation Screen showing three Planes being handled at Gates 6,7 and 8 at the D-pier

MODELING

The process interaction method is applied. In that method relevant element classes are distinguished (Zeigler 2000; Veeke 2000; Ottjes 2002). An element class may be passive or active in the simulation. In the latter case the class owns a process, describing the activities of the element as a function of time. The main classes distinguished are:

- gate
- gate planner
- flight
- job
- vehicle (baggage train or baggage truck)
- vehicle scheduler
- loading team
- loading team scheduler

Each class owns its specific attributes. The flight class for example is characterized by the next attributes:

- Airline
- Flight number
- Planned gate
- Planned and real arrival time
- Planned, expected and real time of departure
- Number of arriving baggage units, split up into originating and transfer baggage
- Number of departing baggage units, split up into originating and transfer baggage

The model input provides information regarding:

- Flight schedule and all specific information per flight such as statistics of number of bags arriving and departing, driving time to and from assigned gate, initial arrival delay.
- Pier configuration: Lay-out, number and location of gates
- Locations of baggage sorter outlet , reclaim and transfer inlet.
- Distance matrix
- Number of available baggage vehicles as a function of time and specifications
- Number of available load teams as a function of time and specifications.
- Penalty factors used in scheduling algorithms
- Factors characterising the level of congestion as a function of time
- Run control information

EXPERIMENTS AND RESULTS

Comparing the Concepts

Table 2 shows the experimental set up resulting in 8 different concepts to be investigated.
Concept 0 represents the current situation: short distances, baggage train, no dynamic scheduling.
The objective of the simulation project is to compare the 8 concepts on the basis of logistic performance indicators and costs.

Table 2: Eight Investigated Concepts

Distance to gates	D (short)				J (long)			
Means of transport	Train		Truck		Train		Truck	
Dynamic scheduling	N	Y	N	Y	N	Y	N	Y
Concept Nr	0	1	2	3	4	5	6	7

The logistic performance and service levels are represented by a number of indicators:

- Gate occupation
- Vehicle utilization
- Personnel and equipment
- Departure delay
- Transfer times
- Reclaim times

The performance indicators are combined in a weighted judgement. Because this is an arbitrary measure, the weighing factors are model-input and the sensitivity with respect to the factors can be investigated. One simulation run covers a period of 24 hours and is conducted with a real flight schedule. For every concept 10 runs with different random streams for the distributions are carried out and averaged. The standard deviation for the average delay is in the order of magnitude of 25%. All performance indicators are directly generated in the simulation experiments. Figure

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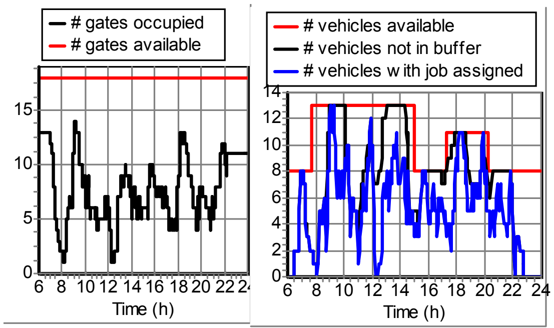

Figure 5. Gate-Occupation and Vehicle-Use as a Function of Time for Concept 3, with the New Baggage Truck on the D-pier using Dynamic Scheduling

4 shows a part of the animation screen of the model. Next some examples of model results will be shown.

Gate occupation and vehicle utilization
Figure 5 shows the gate occupation and vehicle use as a function of time for concept 3. It can be seen that the gate occupation is rather low with the current time schedule. This is the consequence of the flight schedule used. The vehicle availability has been adapted to the expected work load of the system in order to reduce labour costs.

Delay due to baggage operations

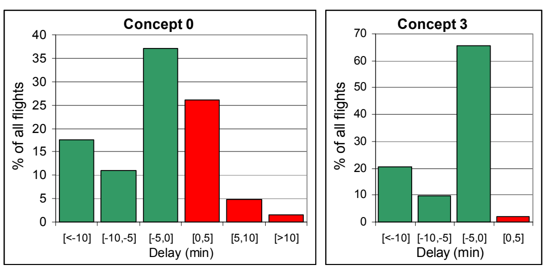

Figure 6: Contribution of Baggage Operations to Flight Delay. Green bars show a "negative" delay, to be interpreted as "ready earlier than planned", and red bars are positive delays.

Departure delay is a result of arrival delay and possible extra delay due to gate operations. Figure 6 shows the net departure "delay" of airplanes due to overrunning the schedule of the baggage operations. The net departure delay is corrected for initial delays at arrival of the flights. If the flight arrives too early the initial delay is set to zero. Mind that the net departure delay may be negative, or in other words it is possible to catch up an initial delay by handling the baggage faster than the standard handling time. It is concluded that the baggage truck performs better than the present train system.

Influence of number of personnel and equipment.
The model can be used to investigate the influence of the available people and equipment. This influence can for example be expressed in terms of departure time delay. Figure 7 shows the average total departure delay as a

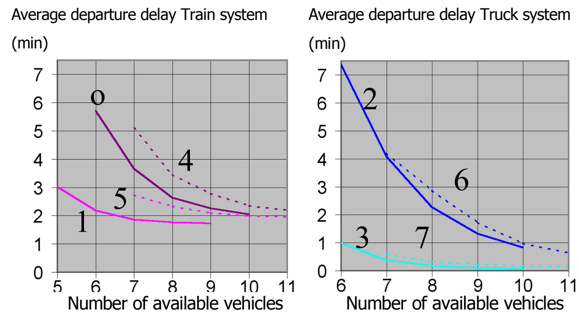

Figure 7: Average Total Departure Delay for All Concepts as a Function of the Number of Vehicles Available.

function of the equipment available. The concept numbers are indicated in the figures. The influence of dynamic scheduling is clear in the case of decreasing number of vehicles, if comparing for example concepts 0 and 1 for the baggage train and concepts 2 and 3 for the baggage truck.

Transfer and reclaim time
Transfer and reclaim times are the times needed to complete transportation of arriving baggage from the plane to the transfer inlet and the reclaim inlet respectively. The general trend is that the truck variants perform best.

Logistic Evaluation Using Weighing Factors

Figure 8 shows the weighted performances of all concepts. Although the weighing is arbitrary, the results indicate that the concepts 3 and 7 (truck with dynamic scheduling at pier D and J respectively), prevail over the train concepts. The difference between train and truck system is most pronounced in the J-pier case. The reason for that is the advantage of the higher velocity of the baggage truck and the longer distances to be covered. The improvement of dynamic scheduling is significant.

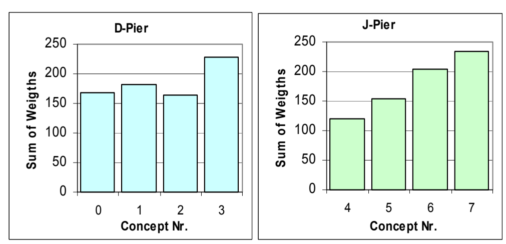

Figure 8: Weighted Logistic Performances of All Concepts

Costs

Costs are directly proportional to the number of employees and number of equipment used and to the length of working time and the distance travelled. The only uncertain factor is introduced by the costs attributable to the baggage truck that is only in the design state. An estimate of the cost of the baggage truck was made. The number of people needed as well as the number of vehicles needed is strongly related

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to the required punctuality of the baggage handling system as can be concluded from figure 7, In which the relationship between number of vehicles available and the average departure delay is shown for all variants. Costs are therefore influenced by the required service level. In figure

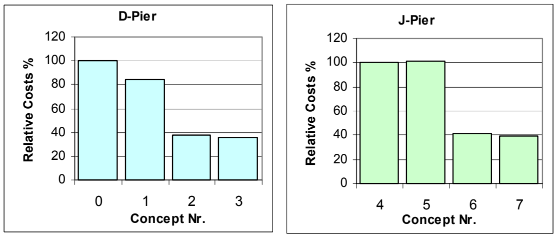

Figure 9: Relative Costs for All Concepts. The costs of the current operating procedure, concepts 0 and 4, are set to 100% for the D-pier and the J-pier respectively.

9 the costs of all concepts are shown. The conclusion is that for both D- and J-pier cases the costs of the truck concepts are down to more than 50% of the costs of the concepts using baggage trains.

ADDITIONAL EXPERIMENTS

In the simulated cases the gate occupation has been low (fig. 5). In a number of additional experiments the load of the system is increased to determine the maximum pier-capacity. The reslults of the experiments will be mentioned briefly.

Short fixed turn around times

The cases described up till now are derived from real time schedules. Only a small percentage of the flights have short prescribed turn around times. In order to investigate the influence of fixed small turn around times the original flight schedule was simulated again assuming that all turn around times are fixed to 30 minutes. So the same planes are simulated but each with a restricted turn around time of 30 min. The departure delay times measured appear to increase because they are related to the planned time of departure. Peaks in the delay times appear to be much lower when dynamic scheduling is applied. Further it was observed that short turn around times induce lower gate occupation, thus increasing the capacity of the pier. This experiment automatically leads to the question what is the maximum pier capacity.

Determination of maximum capacity

To that end a fictitious very busy flight schedule was composed. All flights are assumed to be conducted with planes of the largest narrow-body category. The prescribed turn around time was set to 30 minutes and the number of equipment and personnel was set unlimited. It was concluded that only the concepts using the baggage truck perform satisfactory. It appears that the maximum capacity of the pier is almost a factor 3 higher than the capacity needed for the current flight schedule.

CONCLUSIONS

The existing baggage operation system using trains of baggage carts is compared with a system equipped with a new designed baggage truck. Further a scheduling heuristic was applied to assign jobs to loading teams and transport vehicles dynamically. These two approaches have been applied to a nearby pier and a pier with a long distance to the baggage sorting centre. It is concluded that the logistic performance of the baggage truck is better than that of the baggage train system. The truck-concepts show a potential saving of more than 50% when compared with the baggage train concepts.

REFERENCES

Jerkovic, M., 2000., *New concepts for baggage transportation between baggage sorter and airplane at Schiphol Airport.* (in Dutch) Delft University of Technology, Faculty of Mechanical Engineering and Marine Technology, Section Transport and Logistic Technology, report Nr: 2000.LT.5363, July 2000.

Oosterhuis, E.J., 2002, *Functional design of a baggage truck for mechanized handling of narrow-bodies*. (in Dutch) Delft University of Technology, Faculty of Mechanical Engineering and Marine Technology, Section Transport and Logistic Technology, report Nr: 2001.TT.5543, July 2002.

Ottjes J. A. , Veeke, H. P.M., , 2002 "*Prototyping In Process Oriented Modelling And Simulation"*,
Proceedings 16th European Simulation Multiconference ESM 2002, pp 20-26, ISBN 90-77039-07-04, Darmstadt, Germany

Snick B.M., 2002, *Baggage Transportation at Schiphol Airport.* (in Dutch) Delft University of Technology, Faculty of Mechanical Engineering and Marine Technology, Section Transport and Logistic Technology, report Nr: 2002.LT.5674, October 2002.

Veeke, Hans P.M., Jaap A. Ottjes, 2000. Tomas: Tool for Object-oriented Modelling And Simulation. *In proceedings of Advanced Simulation Technology Conference (ASTC2000).* April 16-20, 2000, Washington, D.C. pp. 76-81. The Society for Computer Simulation International (SCS), ISBN: 1-56555-199-0

Veeke, Hans P.M., Jaap A. Ottjes, 2002. TomasWeb: web site: www.tomasweb.com

Zeigler B.P., Praehofer H and Kim T.G., 2000. "*Theory of Modelling and Simulation* 2nd Ed. Academic Press, San Diego.