Future airport turnaround ground handling processes

How to reduce the turn around time of aircraft at the airport

TRAIL Research School, Delft, October 2008

Author(s)

Wouter Beelaerts van Blokland, Roeland Huijser, MSc, Robin Stahls, MSc, Prof. mr. dr. ir. Sicco Santema.

Faculty of Aerospace Engineering, Delft University of Technology, The Netherlands.

Contents

Abstract

Abstract

KLM and Airport Amsterdam Schiphol (AAS) are both interested in reducing the turnaround time of both narrow- and wide body aircraft by improving the turnaround ground handling processes. A shorter turnaround time could improve the punctuality of the departing KLM narrow- and wide bodies at AAS, making both KLM and AAS more attractive for passengers as airline-airport combination.

This research is focused to define infrastructural and operational design specifications of turnaround ground handling processes to reduce the turnaround times of narrow- and wide bodies, for the Boeing 737-800 and the Boeing 747-400 Combi aircraft. The research gives input to the design of the future airport from a turnaround ground handling perspective. The research method applied to this research is the Theory of Constraints followed by a case study on Arlanda Airport in Sweden towards the automation of turnaround ground handling processes. A Group Decision Room brainstorm session was held to identify all involved processes and to generate suggestions for improving the turnaround ground handling processes.

Keywords

Turn around time aircraft, critical path aircraft ground handling processes, design specifications

1 Introduction

The fierce competition in the European air transportation market and an economic recession that might be coming up, an increased focus on costs can be attributed to the soaring oil prices. These events put pressure on the competitive positions of both KLM and Amsterdam Airport Schiphol (AAS). The recently introduced “ticket-tax” in the Netherlands increases the pressure even more.
Therefore, both KLM and Amsterdam Airport Schiphol (AAS) try to maintain or even improve their competitive positions by cooperation. Especially due to cooperation in improving airport processes, much more can be achieved then when each company separately tries to improve their part of such an airport process. This research is focused on the turnaround of aircraft once landed and arrived at the gate of the airport to unload and load passengers and supplies. Turnaround ground handling processes are enabling these unloading and loading processes. The total involved process is named “turnaround ground handling process”.

When looking to the turnaround ground handling process as such, it seems to be unchanged for decades. There have been improvements in turnaround ground handling sub processes, like replacing boarding stairs by passenger bridges, however these improvements can not be regarded as “radical” improvements. Plans to improve the total turnaround ground handling process by developing an innovative and integrated infrastructural and operational ground handling concept, the “total concept”, has only been realized at Arlanda Airport. This concept however, went out of use due to a change of Terminal building by SAS.

A reduction in turnaround time could have multiple advantages for KLM: costs could be saved due to higher utilization rates (more “up-time”) of aircraft. Another option might be to use the turnaround time to catch up arrival delay in the schedules. The punctuality of the departing KLM narrow- and wide bodies at AAS could be improved, making both KLM and AAS more attractive for passengers as airline-airport combination.

Furthermore, the safety at the ramps could be improved by reducing the busyness at the ramps which has a positive impact on the number of incidents occurring at the ramps. Transparency and security could be increased too. The interest of KLM and AAS has led to the following research question:

“What infrastructural and operational changes in the turnaround ground handling processes are required to reduce the turnaround time of aircraft?”

2 Research method

To research the turnaround ground handling processes, the following research methods are used.
1) Analysis will be used for identifying the constraints in both the narrow body and wide body ground handling processes. Design tools are defined for finding the design specifications for the ground handling processes. In a vision and implementation plan interpretation will be given to the design specifications. Finally some concluding remarks will be given. The Theory Of Constraints (TOC) was introduced in 1984 by Eliyahu M. Goldratt in his book “The Goal”. TOC states that every organization/process has at least one constraint at any time(Rahman, 1998; Goldratt, 2004; The research question is a typical constraint problem due to a number of activities taking place at the same time, interacting with each other, which causes bottle necks. For instance the cabin cleaning activity starts after cabin catering services; can these activities be deployed at the same time to improve the turnaround ground handling processes? The Theory Of Constraints (TOC) is an appropriate method the to analyze the processes to find out what the optimal sequence of activities is from a aircraft turnaround perspective. As part of the TOC, critical path Steyn, 2002). This constraint limits the (organizations) performance to achieve its ultimate goal. In order to manage the performance of the system, the constraint must be identified and managed correctly. The constraint will change due to managing the previous constraint successfully or because of a changing environment. Therefore the organization should repeat the steps continuously. This research could also make use of the five steps of the theory. The five steps are: 1) identify the constraint(s), 2) decide how to exploit the constraints, 3) subordinate the non-constraints to the decision on exploiting the constraints, 4) elevate the constraints, 5) if any of the previous steps a constraint is broken, repeat from step 1. Do not let inertia become the next constraint. The primary objective of this research is to reduce turnaround time.
Case research towards the automation of ground handling processes at Arlanda Airport in Sweden. This case gives relevance to the experience of other airports optimizing turnaround ground handling processes by using automation.
A Group Decision Room (GDR) session has been organized to generate ideas and get inspiration for the determination of design specifications, a brainstorm session with industry experts from KLM, Schiphol, TU Delft, AZ Exclusive Travel and Aeolus Aviation is performed using a GDR. A GDR-session can be considered a modern way of brainstorming with use of smart web based tools. For the preparation of the session a complete overview of the ground handling processes was made to identify the sequences of activities within the various processes.

3 Turnaround ground handling processes

The turnaround handling process can be divided in two sub-processes: a gate-/cabin process and a platform process. The gate-/cabin processes can be divided in:

- activities that take place above the wing and inside the aircraft
- activities that take place under the wing of the aircraft, the airport processes.

The following activities can be distinguished in the aircraft turnaround handling process above the wing:

- (Dis-)connecting passenger bridge(s) and/or boarding stairs
- (De-)boarding
- Catering/cabin service
- Cabin cleaning
- Cabin security check
- Cabin check

The activities making up the turnaround handling process below the wing are:

- Connecting Ground Power Unit (GPU)
- Placing/removing the wheel chocks at the landing gears, nose and main (NLG) and (MLG)
- (Un-)loading baggage/freight (containerized/bulk)
- Water service
- Toilet service
- Fuel service
- Placing/removing safety cones
- Push-back handling

The following definition is developed to describe and define the turnaround ground handling process: ‘*all the handling activities taking place in and around an aircraft between the moment the aircraft comes to a complete standstill at the aircraft stand this is named: (BLOCKS ON) till the aircraft is push-back from the gate for departure, this is named (BLOCK OFF)*’.

Literary the aircraft is put between blocks at the wheels to provide the aircraft from moving during the turnaround handling processes. After the finalization of the turnaround handling processes the blocks are moved so the aircraft can depart from the airport gate.

3.1 Critical path analysis

Critical path analysis will be used to determine the activities that need to be shortened in order to reduce the turnaround time of both the narrow body – and wide body ground handling process. Critical path analysis is a generic name given to techniques that focus on analyzing the interrelationships between the activities or tasks that have to be executed to complete a (complex) project [Moder, Philips, Davis, 1983]; techniques for planning, scheduling and controlling [Meidan, 1981]. A critical path could be defined as the longest sequence of direct dependent activities that takes the greatest time to complete [IATA, 2007]. If one activity on the critical path is delayed, the entire project will be delayed, unless one or more activities following the delayed activity are completed earlier such that the entire project is completed in time. The activities determining the critical path have zero slack. Slack can be defined as the difference between the earliest and latest allowable start- or finish-times of an activity [Willis, 1985].

A process map of all the aircraft ground handling activities and its interdependencies of a narrow-body aircraft is given in figure 2. A process map for a wide body aircraft is given in figure 3. For the determination of the activity duration means, standard deviations and variances, two data sources were used: data which has been acquired from archival KLM data; and from video measurements at the platforms. The archival KLM data comes from a great number of time measurements which have been taken of both the 747-400 Combi and 737-800 turnarounds. After some preliminary work, histograms of the activity durations were made from which a mean, standard deviation and variance was retrieved for each activity.

Video measurements are used for two reasons: The first reason is to acquire missing data, because not for all activities in the turnaround ground handling process is KLM data available. The second reason is validation of archival data from KLM. Two video cameras were used to record a total of 6 KLM 744 Combi’s turnarounds and 9 KLM 737-800 turnarounds. The two video camera’s were positioned such that the turnaround ground handling activities at either side of the aircraft were captured. After the measurements, the videos were played back and the start- and stop-times of the activities were determined. Furthermore, at other important happenings in the turnaround, times were written down, such as the moment the aircraft stops at the aircraft stand (BLOCKS ON), or the moment the high-loader stops at the cargo door.

For the activities, which were video measured, a mean, standard deviation and variance calculation has been made by using the PERT method. This methodology is used because the number of video measurements is too small to make proper histograms of the activity durations. In both processes nine different paths can be distinguished. Each path has a unique duration time, because the time it takes to complete a path depends strongly on the activities in the paths and when these activities take place in time. An important theorem used as part of the (stochastic) critical path analysis is the Central Limit Theorem (CLT).

When summarizing the activity duration means of each activity for each of the 9 paths in both process maps, one can obtain the critical path. For confidentiality reasons, only the critical paths will be given, and not the durations. The critical paths for the B737-800 and the B747-400 Combi are shown in figure 1 and figure 2.

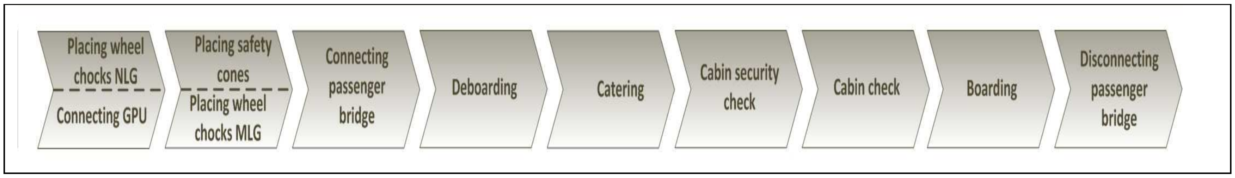

Figure 1: Critical path 737-800

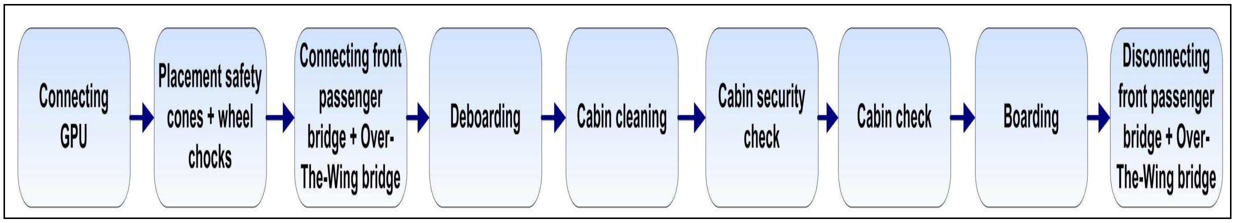

Figure 2: Critical path 747-400 Combi

Besides the activities that contribute to the critical path there are some “critical” activities, not lying on the critical path, which could make other paths critical. To determine which activities these are use is made of the 68-95-99.7 rule, also known as the three sigma rule. This rule states that for a normal distribution almost all values lie within 3 standard deviations of the mean. So both the activities lied down in the critical path and the critical activities identified with this rule need to be shortened, the activities are:

- Connecting Ground Power Unit (GPU)
- Placing/removing the wheel chocks
- Placing/removing the safety cones
- (Dis-)connecting passenger bridge(s) and/or boarding stairs
- (De-)boarding
- Catering/cabin service
- Cabin cleaning
- Cabin security check
- Cabin check
- (Un-)loading baggage/freight
- (containerized/bulk)
- Fuel service
- Water service (747-400 Combi only)
- Toilet service (747-400 Combi only)

Now it is known which activities need to be shortened, the design specifications have to be found. Further research has been made by a case study and a Group Decision Room (GDR-) session.

3.2 Case study Arlanda Airport

At Stockholm's Arlanda airport, the aircraft stands at Terminal 2 have all been equipped with pop-up units, which were built by the privately owned Swedish firm of Fabriksmontering i Trelleborg (FMT) Aircraft Gate Support Systems AB. The pop-up units are a set of fully automated, high-tech ramp modules and "pop up" from the ramp in order to supply fuel, potable water, air, electricity, toilet service, and cabin heating or air conditioning to the parked aircraft. The system has several advantages. Turnaround times become shorter and more reliable. The airline SAS claims that the faster turnaround times made it possible to take off one aircraft of its Stockholm-Gothenburg shuttle without cutting the daily 18-flight schedule [Gibson, 1998]. The system saves equipment and manpower. Certainly when the system is combined with an automatic "push-back" pilot, which replaces the manned tractors, more than 80% of the vehicles required on the ramp (and manpower) can be eliminated, according to a spokesman of FMT [Gibson, 1998]. Other advantages are: reduced emissions, as there are less vehicles at airside; and improved safety at the ramps.

In two year time Arlanda Airport recouped the capital investments associated with building-in the units, due to lower labour and vehicle costs of 25% per annum [Gibson, 1998].

The critical path analysis showed that the cabin process deserves the most attention (and not the platform processes) when short turnaround times have to be realized for both the narrow body and wide body turnaround ground handling process. An automated fueling system, which can be erected out of the ground, is an interesting turnaround ground handling concept developed by Arlanda Airport. This system seems to have only advantages if: reducing turnaround time (if the total duration of the turnaround can be influenced by at least one platform activity that could pop-up), reducing emissions, reducing congestion, increasing transparency (and therefore security), reducing safety. Furthermore, in the case of Arlanda Airport the investments were earned back in two years.

The question rises why this has not been developed and built at other airports. The answer is simple: most airlines will have a critical path in the cabin processes. Furthermore, if this is developed and implemented in a short period of time, ground handlers and self handlers will have to depreciate/sell their ground handling equipment in the same short period of time and they also have to find alternative jobs for a lot of employees involved in ground handling (within their organization). If a concept requirement comes fort out of this system, or part of it, care has to be taken by the making of an implementation plan to cope with the mentioned issues.

3.3 Group Decision Room

A Group Decision Room (GDR) session has been organised to generate ideas and get inspiration for the determination of design specifications, a brainstorm session with industry experts from KLM, Schiphol, TU Delft, AZ Exclusive Travel and Aeolus Aviation has been performed using a GDR. A GDR-session can be considered a modern way of brainstorming. The GDR allows for structured and anonymous collaboration between the participants which contributes to a free exchange of thoughts. It also ensures that ideas are valued on content and not on who contributed them. Furthermore the electronic environment enables everybody to speak and make sketches (by means of smartboards) at the same instant, saving valuable time and the minutes are stored automatically for future reference.

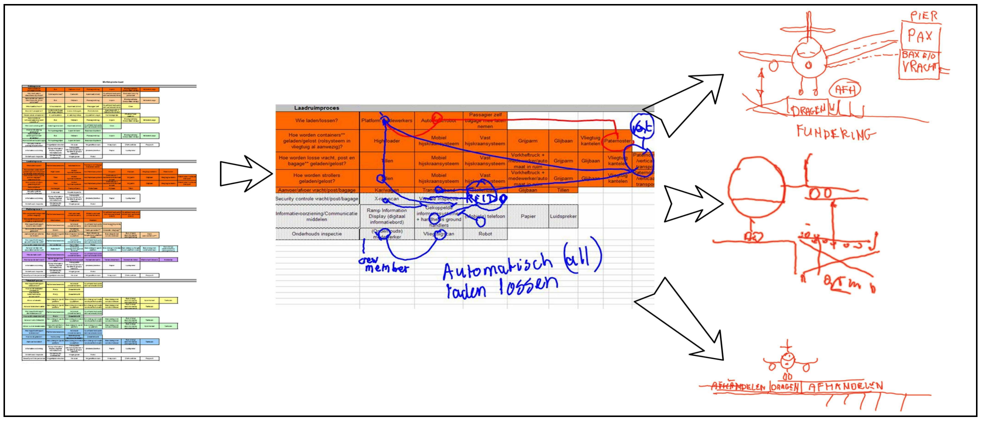

Figure 3: Procedure of the GDR-session for the cargo hold process

The required input for the GDR session was a morphological map. On the vertical axis of a morphological map, all process functions are stated, and on the horizontal axis all options/ways to carry out a function can be filled in. The 14 participants of the GDR-session were asked to check the morphological map on its completeness in terms of missing functions and missing possible solutions. The next step consisted of combining the solutions for the different design groups. The idea behind this is to pick one solution from each process function (each row in the table) and integrate them to create a complete concept. The procedure of the generation of ideas for each of the 4 design groups is given in figure 3. At the end of the session all the generated concepts have been presented by the design groups and judged by the participants on their specific benefits and drawbacks.

Table 1: Turnaround ground handling process design specifications for a new narrow body turnaround ground handling concept for the 737-800

Activity	**Specification**
Deboarding	- Use aircraft left front and left aft door.
Boarding	- Use aircraft left front and left aft door. - A passenger flow rate of 18 passengers/minute
Catering	- Parallel catering of front and aft galley - A change / flow rate of 2 trolleys (or containers)/minute - Extra resources
Catering	- Put up a partition in the galleys
Cabin cleaning	- Extra resources (twice as much)
Cabin check & cabin security check	- Cabin security check by cabin crew (combined)
Unloading & loading of baggage/freight	- Continuous and smooth supply of baggage / freight - A loading flow rate of 8,91 pieces/minute and unloading flow rate of 7,93 pieces/minute - Tail tipping prevention
Fuel service	- Fixed fuel system at the ramp - A refuel flow rate of at least 1100 liters/minute - Digital communication system for sending fuel note - Connecting bonding cable together with placing wheel chocks
Fuel service	- Use aircraft left front and left aft door for deboarding to start earlier.

Table 2: Turnaround ground handling process design specifications for a new wide body ground handling concept for the 747-400 Combi

Activity	Specifications
Deboarding	3 door connections, with flow rate of ≈ 24 pax/minute/door
Cabin cleaning	13 cleaners (5 extra in comparison with current situation)
Cabin security check	Security training of crew members
Cabin check	
Boarding	3 door connections, with flow rate of ≈ 12 pax/minute/door
(un)loading catering / cabin supply	Sufficient capacity equipment for loading forward galley with transport rate of 1,00 minute/FSTE
	Sufficient capacity equipment for unloading forward galley with transport rate of 0,75 minute/FSTE
Fuel service (two dispensers)	Connection of at least 2 aircraft doors
	Fixed connections with underground fuel network
	Automated (dis)connection electricity wire, both in 0.5 minutes
	Digitalization ‘Fuel Order’, sending in 0.25 minutes
Water service	Equipment that can simultaneously perform toilet and water service
Toilet service	
Unloading Lower-deck cargo	Equipment for parallel unloading, with rate of 1.4 minutes/unit
	Equipment for avoidance of tail-tipping
Loading Lower-deck cargo	Equipment for parallel loading, with rate of 1.7 minutes/unit
	Equipment for avoidance of tail-tipping

4 Design of turnaround process specifications

The activities lying on the critical path and the critical activities of both the 737-800 and 747-400 Combi have been investigated for improvements by making use of the design tools of the previous paragraph. This has resulted to the specifications shown in table 1 and table 2. As one can see, there are no design specifications for the activities which had such a small contribution to the turnaround time, that improvements would have an unnoticeable effect.

With the design specifications for both the 737-800 and the 747-400 Combi, implementation plans can be made. For the implementation plans, interpretation has been given to the design specifications such that a fit with the current layout at AAS could be made. Furthermore, not all design specifications can be implemented at once. The most important reason for this is the large investments and the long development time that will be required for some of the interpretations. Therefore implementation plans have been made which show the design specifications that need to be implemented in time, to reduce the turnaround time for the B747-400 Combi as well as for the B737-800.

The main focus of the implementation is to reduce the turnaround times by shortening the activities on the critical path. When the activities are shortened (enough), other paths can become critical. This will be a next phase. Both implementation plans consist of four phases of 5 years each. Besides shortening the critical path activities, also environment, safety, security and flexibility have been taken into account.

- Environment: focus mainly on the CO_2 emission, NO_x emission, and particulate matter ($PM_{2,5}$ and PM_{10}).
- Safety: The chance on incidents at platforms reduces when less ground handling equipment is involved in the ground handling process.
- Security: When less vehicles and persons are needed to perform the ground handling activities more transparency can be achieved at security restricted areas.
- Flexibility: The ideal ground handling concepts have to be equipped in such a way that also aircraft of the future can be handled by this concept.

The implementation plans for both the B737-800 as well as B747-400 Combi is shown in table 3 and table 4 respectively. For the Boeing 737-800, the turnaround time can be reduced with 42% due to the concept specifications. For the Boeing 747-400 Combi this is 38%.

Table 3: Implementation plan for a new narrow body turnaround ground handling concept based on the737-800

Phase	Initial critical path	concept design turnaround specifications	Turnaround time reduction
1 (2009-2014)	“Catering service” (cabin)	-An extra catering truck -An extra catering employee -Galley partition -Four extra cabin cleaners -Combining cabin security check & cabin check -Fixed wall electricity	20%
2 (2014-2019)	“Unloading/loading baggage and freight” (platform)	-A new baggage and freight sorting and distribution system -A supporting strut	10%
3 (2019-2024)	“Cabin cleaning” (cabin)	-A second passenger bridge -An extra passenger handler -An extra boarding pass control device -Automated passenger bridge system	12%
4 (2024-	“Cabin	-A fixed fuel pop-up system	0%

2029)	cleaning” (cabin)	-A fixed water- and toilet service pop-up system	
			Total: 42%

Table 4: Implementation plan for a new wide body turnaround ground handling concept

Phase	**Initial critical path**	**concept design turnaround specifications**	**Turnaround time reduction**
1 (2009 – 2014)	“Cabin cleaning” (cabin)	- Number of cleaners - Combining security check with cabin check - Two passenger bridges - Boarding technique - Start of fuelling - Dedicated area for storage of safety cones + wheel chocks - Replace GPU by fixed wall electricity system - Replace old equipment with new zero emission equipment - Supply of baggage and cargo pallets - Use of tail support	15 %
2 (2014 – 2019)	“Catering service” (cabin)	- Increase capacity of catering equipment forward galley - Perform fuelling with two dispensers instead of one - Combining water service with toilet service	8%
19 – 2024)	“Catering service” (cabin)	- Deboarding and boarding by three aircraft door connections - Parallel catering and deboarding - Create a (un)loading flow for catering trolleys - Automated bridge connection and disconnection	14.5%
4 (2024 – 2029)	“Catering service” (cabin)	- Automated fuelling - Automated aqua service - Underground supply of baggage containers, cargo pallets, and catering trolleys	0.5%
			Total: 38%

5 Conclusions

The Theory Of Constraints and critical path analysis showed that in the current situation, the duration of cabin activities determines the total turnaround time for both the Boeing 737-800 and the Boeing 747-400 Combi.
With other words, the critical paths lie in the cabin. These activities, and some other critical activities which could potentially let other paths in the process map determine the turnaround time due to delay, were investigated for improvements.

Other methodologies used within this research are a case study and a GDR brainstorm session used as basis for developing suggestions and possible solutions to improve the turnaround ground handling processes. The result of the GDR session with concept design specifications are presented in table 1 and 2 were the results.

A vision and implementation plan for both aircraft types was made to show how the specifications could be implemented, having a continuous focus on (a shift in) the critical path. This vision made clear that for the Boeing 737-800, the turnaround time can be reduced in phases with a total of 42% compared with the current turnaround time due to the design specifications. For the Boeing 747-400 Combi this is 38%. The measured times of the various processes can not be published for reasons of confidentiality.

6 Recommendations

It is recommended to obtain more measured data that can be analyzed and used to get more insight in the variability of the activities involved in the ground handling process of narrow body as well as wide-body aircraft. Lean Six Sigma is a method to analyze how the “mean” of the various identified processes can be reduced to improve the turnaround processes.

This research has focused mainly on the aircraft ground handling processes of the B747-400 Combi and the B737-800. Although, the aircraft ground handling processes of other aircraft types are very similar it is likely that the found design specifications will give slightly other results than for the B747-400 Combi and the B737-800. Therefore it is recommended to investigate also other narrow body and wide-body aircraft types on the same basis as this research has been performed to get a good benchmark.

Next, it is recommended to investigate how and by whom the investments need to be made, to implement the design specifications as shown in table 3 and table 4.

GREENFIELD SITUATION

When a new airport will be designed the turnaround ground handling infrastructure should incorporate the following criteria:

- Creation of activity flows and prevent crossing flows of above the wing activities with under the wing activities
- No ground handling vehicles at the platforms anymore → improves safety, transparency, and environment.

- All under the wing activities are performed with in-ground handling equipment
- Flexible ground handling process → possibility to handle all types of wide-body aircraft.

References

Cox, A. (1999), *Power, value and supply chain management*. Supply Chain Management: An International Journal, Volume 4, Number 4, pp 167-175

Gibson, M. (1998), *Green scene: Latest products to protecet the environment*. Scandinavian Review, Winter 1998/1999

Goldratt, E.M. (2004), *Het Doel*. Het Spectrum, Zeist, p 258

Hampson, I. (1999), *Lean production and the Toyota Production System - Or, the case of the forgotten production concepts*. Economic and Industrial Democracy, Volume 20, Issue 3, pp 369-391

IATA (2007), *Airport Handling Manual.* IATA, Montreal, 27th edition

ICAO (2008), *Overview of Trends and Developments in International Air Transport*, ICAO, Montreal

Meidan, A. (1981), *Marketing Applications of Operational Research Techniques*. Management Decision, Volume 19, Issue 4/5

Moder, J.J., Phillips, C.R., Davis, E.W. (1983), *Project Management with CPM, PERT and Precedence Diagramming*. Van Nostrand Reinhold Company Inc., New York, Third Edition

Rahman, S. (1998), *Theory of constrains: A review of the philosophy and its applications*. International Journal of Operations & Production Management, Volume 18, Issue 4, pp 336-355

Ranky, P.G. (2007), *Eighteen “monozukuri-focused” assembly line design and visual factory management principles with DENSO industrial examples*. Assembly Automation, Volume27, Issue 1, pp 12-16

Steyn, H. (2002), *Project management applications of the theory of constraints beyond critical chain scheduling*. International Journal of Project Management, Volume 20, Issue 1, pp 75-80

Willis, R.J. (1985), *Critical path analysis and resource constrained project scheduling-Theory and practice.* European Journal of Operational Research, Volume 21, pp 149-155

Womack, J.P., Jones, D.T., Roos, D. (1990), *The Machine That Changed the World.* Rawson Associates, New York