Scheduling vehicles in automated transportation systems

Algorithms and case study*

Matthieu van der Heijden, Mark Ebben, Noud Gademann, and Aart van Harten

University of Twente, Centre for Production, Logistics and Operations Management, Faculty of Technology and Management, P.O. Box 217, 7500 AE Enschede, The Netherlands (e-mail: m.c.vanderheijden@sms.utwente.nl)

Received: June 21, 2000 / Accepted: January 22, 2001

Abstract. One of the major planning issues in large scale automated transportation systems is so-called empty vehicle management, the timely supply of vehicles to terminals in order to reduce cargo waiting times. Motivated by a Dutch pilot project on an underground cargo transportation system using Automated Guided Vehicles (AGVs), we developed several rules and algorithms for empty vehicle management, varying from trivial First-Come, First-Served (FCFS) via look-ahead rules to integral planning. For our application, we focus on attaining customer service levels in the presence of varying order priorities, taking into account resource capacities and the relation to other planning decisions, such as terminal management. We show how the various rules are embedded in a framework for logistics control of automated transportation networks. Using simulation, the planning options are evaluated on their performance in terms of customer service levels, AGV requirements and empty travel distances. Based on our experiments, we conclude that look-ahead rules have significant advantages above FCFS. A more advanced so-called serial scheduling method outperforms the look-ahead rules if the peak demand quickly moves amongst routes in the system.

Key words: Freight transportation – Vehicle scheduling – Simulation

* We thank the Dutch Centre for Transportation Technology (CTT) for their funding of the simulation study that has been the basis of our research results. CTT is initiator and coordinator of the project to design and develop the underground logistics system around Amsterdam Airport Schiphol that has been used as a case study in this paper.

Correspondence to: M. van der Heijden
1 Introduction

As in many countries, traffic congestion is becoming a severe problem in the Netherlands, causing delay to both private and commercial transportation. Aiming to be a main hub for Western Europe, this forces the Netherlands to search for solutions in order to guarantee rapid processing of transportation orders within and through the country, particularly when the freight supply keeps growing as has occurred in the past decade.

One of the options currently considered is to move part of the freight underground via a fully automated transportation system. In several governmental studies, the technical and economical feasibility of such a system has been established. As a next step, a pilot system is currently developed, focusing on the processing of time-critical products between Amsterdam Airport Schiphol, the flower auction in Aalsmeer and a future rail terminal in Hoofddorp (cf. van der Heijden et al., 2000). All three locations are situated in the western part of the Netherlands. An example of time-critical transportation is the supply of flowers to the auction in Aalsmeer, which have to arrive in time in order to be processed the same day. Also, the transportation of export flowers to Amsterdam Airport Schiphol is critical, as delay may cause that the cargo arrives when the plane has already left. Because the automated transportation system should be rapid and especially reliable, a competitive advantage on other transportation modes, such as traditional door-to-door road transportation, can be obtained.

Such an automated transportation system consists of a number of terminals, connected by an underground tube system (see Fig. 1). The situation in Figure 1 is the primary layout option at the time of our research for the automated transportation network around Amsterdam Airport Schiphol. Automatic Guided Vehicles (AGVs) carry cargo between terminals in standardised load units (air pallets, flower mid boxes). Order patterns are usually time dependent and may vary over days in the week and over hours on a day. Each terminal consists of a number of docks where vehicles can be loaded or unloaded. Transportation is constrained by arrival times and due times. These due times can be met by a combination of sufficient resources (vehicles, terminals, docks) and a set of logistics planning and control rules. Of course, both issues are interrelated, because efficiency gained by clever planning and control rules leads to reduced capacity requirements. On the other hand, simple myopic or look-ahead rules are usually easier to implement, require less information exchange and are more robust to disturbances.

The network as shown in Figure 1 consists of three main locations, namely Amsterdam Airport Schiphol (AAS) in the north consisting of five terminals, Aalsmeer flower auction (VBA = “Verenigde Bloemenveiling Aalsmeer”) in the east consisting of two terminals and Rail Terminal Hoofddorp (RTH) in the southwest consisting of one terminal. AGVs that are not needed for a while or for which there is no room in the local parking are dispatched to a central parking that is located just south of Schiphol Airport, close to the intersection. All terminals and the central parking will be located at the surface, while just the tube system is underground (about 15 meters below the surface). Therefore slopes are planned between each terminal entrance / exit and the tube system. AGVs drive slower on these slopes.