A demand-driven logistics concept for the fully automated rail system NBP

W. Dangelmaier
M. Fahrenholz
H. Franke
B. Mueck
Heinz Nixdorf Institut, University of Paderborn
Business Computing, especially CIM
Fürstenallee 11, 33102 Paderborn
Germany
E-mail: {whd, markusf, franke, mueck}@hni.uni-paderborn.de

Introduction
To free rail traffic from its lethargy, a noticeable improvement of customer use is absolutely necessary. Passengers do not want to wait for a train at a station, which stops at many other stations, which are of no interest to them. The passenger loses time unnecessarily. And this is still a good case scenario. Often, the passenger travels on the train to a station to which they do not wish to go, only to have to wait there for another train that will perhaps take them to their destination.
The same is applicable to goods traffic. Single goods wagons, that are shunted, lose a lot of valuable time, in which they nor the track on which they stand produce transport efficiency, that causes costs.
From the view point of the operators, the situation is no better. Through large vehicles, that are planned for long distances, they are unable to react with flexibility to transport needs. Trains are overfilled or not used to capacity. Transport goods are not always transported on the shortest route. The available transport capacity is therefore only used sub optimally.

The NBP Environment
Today in the planning of vehicles, it is either attempted to lower the seat-kilometre-price or to reach higher maximum speed of vehicles. The New Train Technology Paderborn (Neue Bahntechnik Paderborn NBP) follows the principle of not aiming at higher travel speeds, but focuses more on the implementation of mechatronics and modern logistics to increase the flexibility and comfort and reduce the consumption to a minimum. The transport times should be significantly shortened through a direct orientation on the transport needs.
NBP proposes small driverless wagons (shuttles).
From a technical viewpoint, the shuttle is of modular construction. The wagon / shuttle therefore consists of a body, two driving modules with the three functional sub-modules of the drive and brake module, the track and direction module, and the suspension/tilt module, as well as the build-up and the payload module [Liu00].
NBP Modules

A linear motor for the driving and braking in combination with an actively steered axle with independently rotating wheels reduces the consumption to nearly zero [Hen99, Hen00]. An active spring-incline module increases the comfort of the customer and allows higher speeds on bad tracks and in bends/curves. Despite the innovations, the shuttles should be able to travel on modified traditional railway networks. A mixed operation between normal track traffic and NBP is an integral part of the concept and significantly reduces the necessary investment costs. Through this, substantial acceptance problems of this new technology can be overcome and a transition phase in the mixed operation is possible. This and the flexibility of the individual transport units, builds the foundation for a new, attractive train system, which can overcome the separation of goods and passenger transportation [Lüc99,Lüc00].

The Logistics Concept

While in traditional track traffic with large units (whole trains), that have to bundle the transport need of different customers, are planned, the NBP Concept proposes small, driverless units – shuttles – whose size meets the transport needs. In passenger transportation this means that as not often groups of more than four passengers travel together, shuttles in the capacity of a van (4-6 passengers) are foreseen. According to customer needs, the shuttles provide various equipment. That means, business class shuttles with desks and air conditioning as well as family wagons with for e.g. entertainment electronics are foreseen. If a transport demand arises in the system, an exact wagon for the demand is deposited. The wagon loads the transport goods (passengers or goods) at the start point and takes these via the shortest possible route to the destination. If the wagon cannot be used for the further transport of goods, it is automatically deposited in the nearest depot awaiting the next assignment. The wagon is used only if there is need. If there is no transportation need, the wagon remains stationary. With this system, a timetable is completely replaced with a needs-directed system. Unused travelling wagons therefore do not occur in the first place.

From the point of view of a passenger (passenger traffic) the system presents itself as follows: If a passenger wishes to travel from Paderborn to Munich (about 540 km), he advises the customer interaction module of the departing place, the destination station, the wanted time and shuttle type (business, tourist class etc.) and the number of travelling passengers. The
customer interaction module provides the customer with various offers from the provided resources (tracks, wagons, station capacity) and a price finding procedure. The customer decides on an offer and books bindingly.

The shuttle will then be available for the customer at the given time at the train station in Paderborn. As soon as the passenger is seated in the shuttle, it begins to move and increases its speed on the acceleration track to 160 km/hr in order to couple to a convoy. Without the shuttle being stopped, and a constant speed of 160 km/hr, maintained, the customer reaches the destination Munich in about 3 hrs and 30 mins. For the same distance on the Autobahn / highway with a car would require an average 6 hrs travelling time. Even by plane, a reduced gross travel time is not reached due to the check-in and out procedures. A short travel time is not inevitably reached through a higher maximum speed, but through a higher average speed. This and the flexibility of the individual transport units build the foundation for a new, attractive train system, which can overcome the separation of near and far travel and lead to individual travel on the tracks.

The lower travel speed and the therewith related relatively lower energy consumption and the few empty drives, lead in total, in many scenarios, to an economically attractive system.

**Convoy Building**

If each wagon was to travel by them self, it would have to travel within braking distance. As the wagons are relatively small and the brake distance in track travel is long, an unsatisfactory situation is created.

To overcome this problem, the shuttles dynamically couple into convoys. The shuttles only move out of the convoy at stations at which transport goods must be loaded. The majority of shuttles continue through without stopping. For this, travel-through tracks, that can be travelled on with travel speed have to be planned.

At forks / branch outs the convoys disconnect or join together with other convoys. To guarantee this at full travel speed, new types of passive points are required. These points are currently in development stages. Concepts are already available.

The convoys are not physically coupled, but due to the absence of relative speed of the shuttles within a convoy they are as safe as ordinary trains.

A further advantage of convoy travel is the reduced air resistance and the therewith lower energy consumption for the individual shuttles.
**Modul Concept**

Each shuttle consists of two drive-guidance modules and a build-up consumption module in-between. While different build-up consumption modules exist for different shuttle applications, the drive-guidance modules remain the same for all wagons. This leads to a high number and therefore to lower costs in mass production.

The modularity goes so far, that the wagons can still be reconfigured after delivery (of course needs-directed). This leads to further flexibility of the system [Lüc00].

**Control**

To keep the efficiency of the system scaleable and restrict interferences to regional consequences, a completely decentralised design (agent system) is followed. The system is divided into four classes of agents: the wagons, the stations, the tracks, the depots and the customer interaction module.

The customer interaction module collects the transport enquiries from customers and creates offers through the communication with other parts of the system. If a combination booking is made, one assignment is created for one wagon. The assignment is assigned on time to one free wagon.

The wagon receives the assignment and sequentially travels the route of the assignment. Through communication with the track elements it searches for the most time efficient route. If track elements are overfilled, specifically blocked, alternative routes are automatically generated. If the customer should change their route direction while underway, the shuttles can replan the route dynamically.

The depots always have enough wagons available. They calculate a prognosticated supply from prognosis and the bookings. If a short supply is indicated in a region or if particularly many are required (e.g. at the end of a sports match), other shuttles from other areas are requested.

Various depots with more or less national significance exist for the various task of a depot (storage of wagons, maintenance, repair). They organise their storage and maintenance areas themselves, but must be able to meet their promise to the customer interaction module of the actual available shuttles.

Stations coordinate the allocation of transport goods to wagons. The necessary operation means to load and unload the shuttles (for e.g. platforms for passenger traffic) must be available. The correct allocation must be guaranteed. For the control of these tactical sequences and the implementation of the detailed processes, an agent system is in development.

**Validation of the processes**

To test the technical innovations (active track guidance, active spring / incline module, linear motor drive on the tracks) and the logistical basic functionalities (convoy building, load and unload) of the NBP, a test track is under construction at the University of Paderborn.

If higher logistic functionality shall be analysed, complex connections that cannot be analytically analysed will quickly occur. Such questions are for e.g., the research of different layouts for train stations and depots or interferences, which occur through the mixed operation of normal track traffic and the NBP on the same tracks.

Such systems are analysed with simulations. Simulation tools for track traffic are often too track traffic specific so that they can be implemented in this context. On the contrary, simulation systems that originate from the simulation of production systems, offer a high degree of flexibility and adaptivity. An adaptation of this module of one of these systems will lead to a simulation tool, with which proper statements to the above mentioned questions can
be made. Various train station and depot layouts are being investigated and compared. The system can therefore be analysed regarding the impact of interferences.

**Conclusion**
The NBP Project is a new concept, that encompasses the complete traffic system. It tries to counteract the development of the track to the road with modern Mechatronics and a needs-directed logistics concept. The combination of the individuality of road traffic and the safety of the tracks from which an economically operated transport method is to be generated, is being tested. On the basis of the existent track infrastructure, the aim here is to offer the customer a possibly house to house traffic which has only been possible with the road so far. Thereby, the advantages of track traffic and the advantages of road traffic should consequently be coupled in order to reach a high and particularly quick acceptance with the enquiries for and offers from the traffic capacity. A deciding innovation hereby, is the driverless operation of individual needs-directed driving units.

**References**


[Hen00] Henke M; Grotstollen H.: Modelling and Control of a Longstator-Linearmotor for a Mechatronic Railway Carriage. 1st IFAC-Conference on an Mechatronic System, Darmstadt, Germany, 2000, P. 353-357

