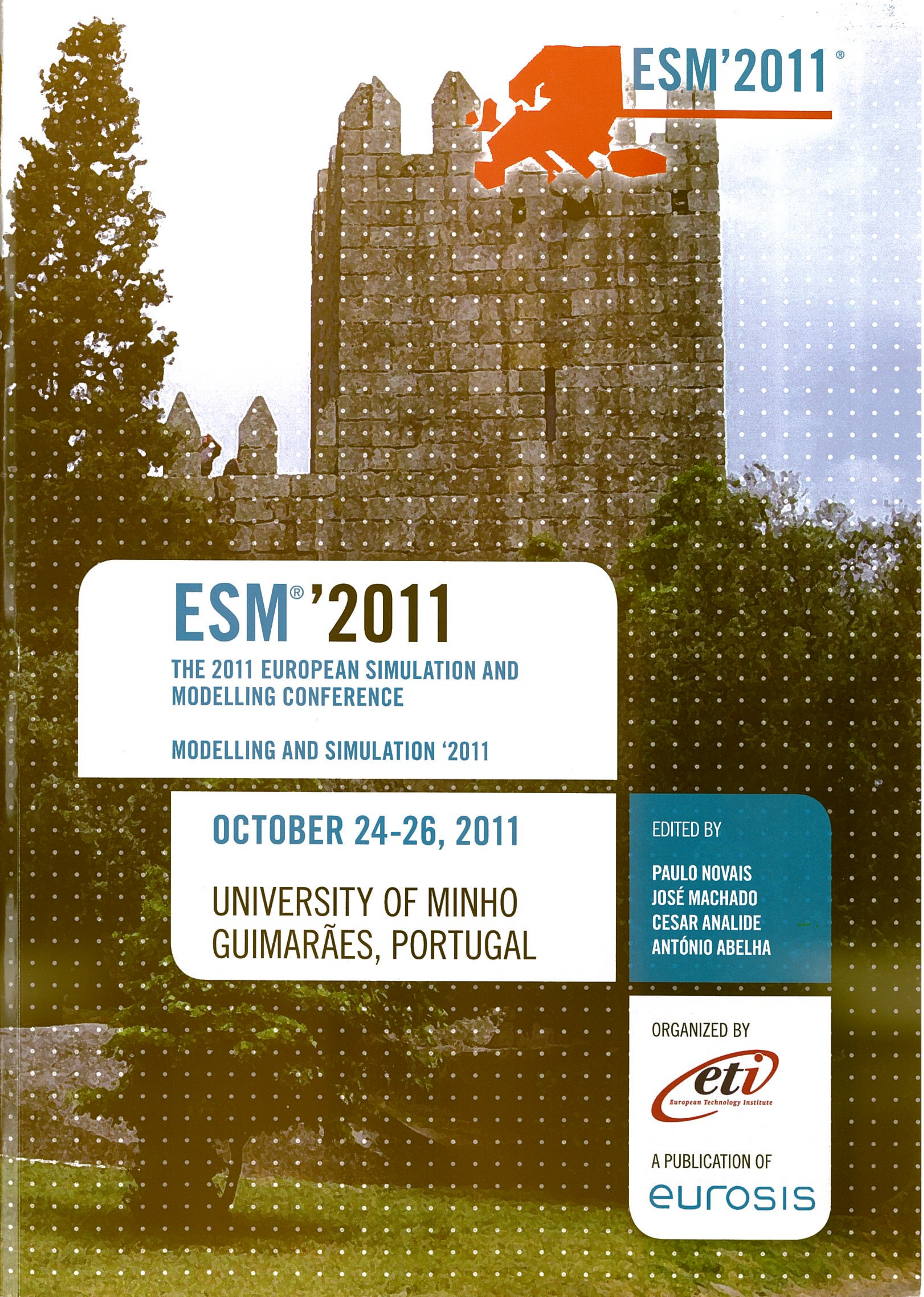

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GPS-BASED REAL-TIME TRANSPORT CONTROL FOR PRODUCTION NETWORK SCHEDULING SIMULATION

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Event-oriented, Network, Production, Real-time, Scheduling.

ABSTRACT

Nowadays, supply chains or production alliances are characterized by several different partners with different functions within these associations. Important for reaching the common goal of added value is the connection of these networks. Therefore it is important to secure an efficient flow of materials as well as an efficient flow of information. Innovative logistics service providers can tackle these tasks by providing new technical solutions, for example offering the benefits of a real-time GPS track and trace system based on GPS. This paper shows an approach how to use GPS tracking data to identify discrepancies of standards in transport processes and to support flow of information reducing synchronization problems between different partners within a production environment characterized by low stock levels, short cycle times and the challenge of on-time delivery under these requirements. A piloting example using the ild GPS.LAB in the logistics cluster of Duisburg/Germany highlights the possible uses and profits by GPS-based real-time transport control information and dynamic production scheduling.

PROBLEM DESCRIPTION

A production network is characterized by different players and their connections. Such associations are often described with nodes and links how it is displayed in figure 1 (Kumar and van Dissel 1996): Nodes standing for companies (e.g. production plants); links representing connections, generally as flow of material and flow of information.

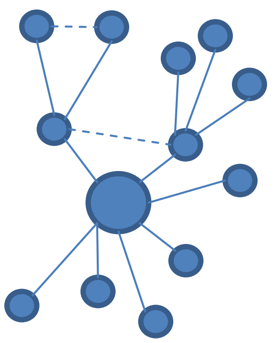

Figure 1: Production network with nodes and links

The production control within such a node is often self-organized by the individual company. Therefore the goals of primary production planning can be controlled by use of a real-time control system, e.g. by analyzing performance indicators. The Association of German Engineers (VDI) provides several guidelines with performance indicators for logistics systems as VDI-Guideline 2525 which provides logistics performance indicators for small and medium enterprises or guidelines 4400 with logistics performance indicators for procurement, production and distribution (Weigert et al. 2010).

But how to control the flow of material in such a network? These logistics processes are often bottlenecks and important for the smooth and fluent run of production because delayed or interrupted supplies may cause shutdown of production if the worst comes to the worst. But it is a challenge to control these processes because they were often executed by sub-contractors and the control of bottleneck steps have always been important for the whole process (Hopp and Spearman 2001). To control these processes and to have a possibility to react to discrepancies, the implementation of a forwarder independent real-time GPS track and trace system within a production network is suggested.

CARGO TRACKING IN PRODUCTION NETWORKS

Stock-keeping in the shop floor has to be minimized to cut capital lockup in the form of material, which also supports a reduction of cycle time. Therefore it is necessary to safeguard just-in-time supply of material. In times of globalization, global supply chains with local separation of production plants and long transport routes in between are usual. An important problem is that a delay involves troubleshooting in production scheduling to avoid an interruption of the production process. A reliable flow of information is a basic requirement for today's dynamic and flexible production and logistics activities. In fact this should be included in any software for supporting the production process (Meers et al. 2010). Telematics or cargo tracking in production alliances support the flow of information and improve the production system by reducing cycle-time, especially if tracking data is generated automatically and is transmitted in real-time to analyse data and to perform necessary actions in time (Brewer et al. 1999). Tracking data has to be continuously available at any time independent of transport mode and company boundaries, reliable and secure as well as easy to transmit and cost-efficient for the producer (Stopka 2009). The problem of using a tracking system within a supply chain is the holistic integration of one system, especially if actors within the supply chain vary from time to time. So for these short-term multi-company networks an independent forwarder tracking solution is needed. By this idea the main difficulties of software integration could possibly be solved (Kärkkäinen et al. 2004). This could be a battery powered GPS tracking system. By tracking shipments or vehicles many information and features are offered or can be estimated to control and schedule production processes in real-time (figure 2). Similar research has been put forward in transportation research regarding personal transport and urban travel systems (O'Connor 1997; Wolf 2006; Tsui and Shalaby 2006; Wolf et al. 2003; Wolf et al. 2001; Wolf 2000).

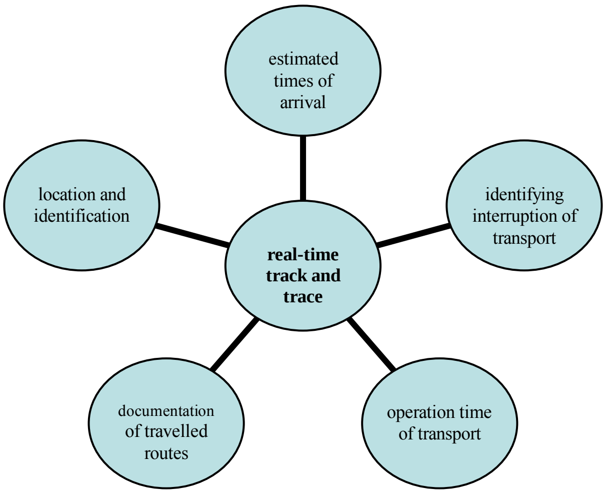

Figure 2: Benefits of cargo tracking

To summarize the benefits production planners get a better support to synchronise the delivery of material and preliminary products with the production scheduling and get a longer time period to reschedule the production if needed.

REAL-TIME TRANSPORT CONTROL

The flow of material within a network can be displayed in a network plan. Such a plan offers planning and controlling possibilities of projects by dividing whole projects into small and single activities. Every activity is described with a defined start, an operating time and a defined ending. Because of upstream, downstream and parallel activities buffer times can be estimated (Domschke and Drexl 2005).

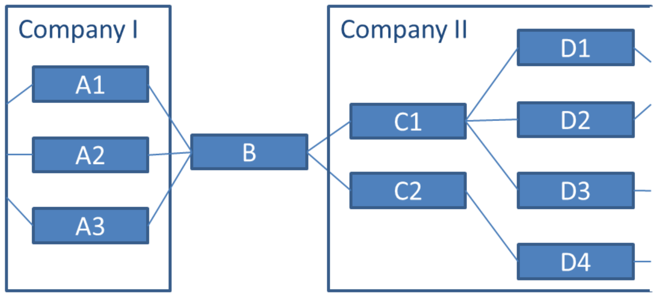

Figure 3: Section of a network plan

Figure 3 shows a section of a network plan: Operation B displays a transport process. Company I passes shipments at a defined finishing time to the forwarder. As a result the forwarder gets a time window for pick up the shipments and another time window for delivering the shipments to company II, which results from the predefined starting time of operations C. According to both, time windows and the operating time, the forwarder's buffer time can be estimated.

The planned operating time of a transport process can easily be estimated with the help of route planning software to set up the transport processes within the network plan. By running the activities the planned times have to be controlled to analyze if the production process is in time and the planned due date can be reached. With the help of a real-time track and trace system the operating time of a transport process can be controlled by executing following algorithm:

1 **For** every transport process **do**
2 Request of actual position of shipment/vehicle
3 Route planning from actual position to destination
4 Comparism of planned arrival time (starting time downstream process) and estimated time of arrival (result route planning step 2)
5 **If** estimated arrival time is equal or less than planned arrival time **then**
6 Next request
7 **Else**
8 Production Re-Scheduling
9 **End If**
10 **End For**

This algorithm is based on the idea of supply chain event management and has to be executed automatically and continuously to safeguard delivery times and because of that production process.

INTEGRATION OF REAL-TIME TRANSPORT CONTROL IN PRODUCTION PLANING

Since this year the **FOM ild - Institute for Logistics and Service Management**, Essen/Germany, operates a GPS based track and trace system by AIS Advanced InfoData Systems GmbH, Ulm, partly funded by the Ministry of Innovation, Science, Research and Technology of the German State of North Rhine-Westphalia. To use the system and to analyse the results, a laboratory has been installed under the name of GPS.LAB. One GPS tracking device has three major parts and is shown in figure 4:

- A GPS black box as central part of the system. The module is equipped with a GPRS SIM card for transmitting tracking data in real-time to a server. Transmission intervals can be set individually.
- A high performance GPS antenna for strong receiving power to calculate the run-time of signals even with low signal strength or inside of trailers and containers. This was already tested and is working very stable inside steel boxes and trucks.
- A high powered rechargeable battery for an independent electrical powering of the GPS module. With a fully loaded battery the GPS module can be operated at least 72 hours.

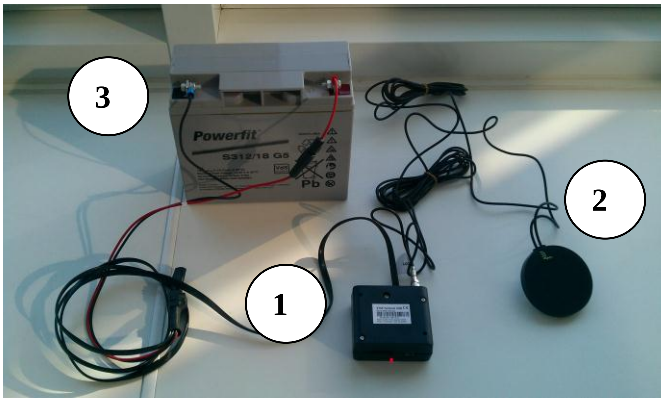

Figure 4: GPS tracking device components

By reason of the above mentioned specifications the GPS.LAB makes it possible to track goods down to the level of pallets, cases, cartons or ideally items during the whole transport to retrace the logistic process in detail and to analyse the performance of supply chains.

By the use of the software map & guide by PTV Planung Transport Verkehr AG, Karlsruhe, the GPS performance data can be mapped as a basis for further analysis and calculations. In fact, with the help of such a system logistic processes can be analysed well-founded as the data is verified by real transport and not by simulation. Figure 5 shows the system setup.

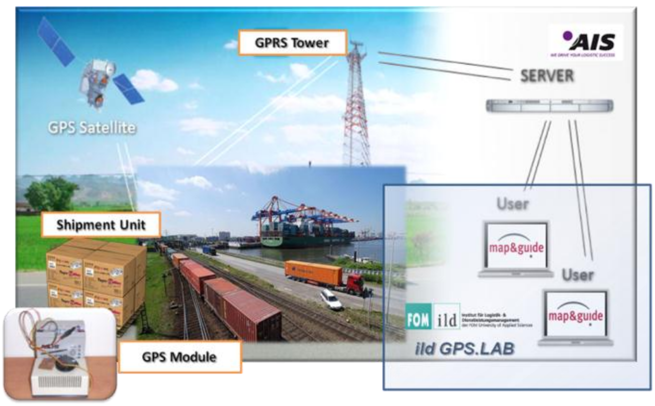

Figure 5: GPS.LAB system components

The GPS.LAB will be used to test the idea of real-time transport control within production networks. Therefore transport processes in real production environments will be tracked to check whether the results are useful to integrate them into production planning systems as shown in figure 6.

Figure 6: Holistic integration of a GPS track and trace system within a supply chain

TESTING EXAMPLE LOGISTICS NETWORK

A business example in the logistic services industry was tested with DB Schenker in Germany (Kandel et al. 2011): In fixed route scheduled transport networks in groupage freight real-time information about delays and disruptions in transport schedules are of high value (Friedrich et al. 2001). Because subsequent transports as for example last mile transports after the longer main haul transportation usually during the night shift depends on on-time arrival at the inbound depot (Polyvyanaya 2011) as depicted in figure 7.

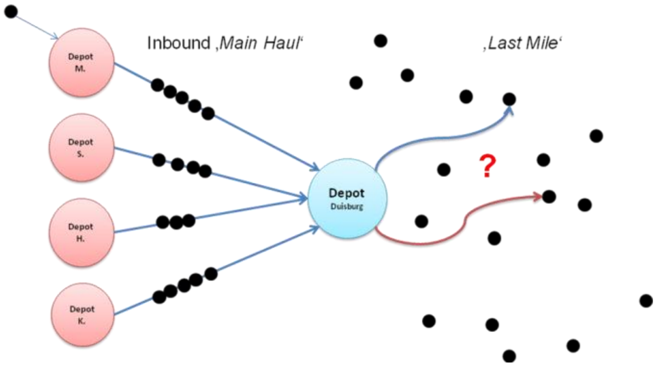

Figure 7: Last mile tour planning problem as path-dependent problem from main haul in logistics

Therefore the local depot (here: Duisburg in Germany) has the important scheduling problem of planning local transport tours without the real-time information about transport processes (main haul) destined towards the depot from other depots in Germany as for example Munich or Kassel (Lefebvre et al. 2007; Ramming 2002). This problem up to today is solved by simply allocating specific routing areas to fixed routes as shown in the following picture as standard routes A and B starting from the depot in Duisburg (Balsys et al. 2007; Daganzo and Sheffi 1977; Prato 2009).

In the here described testing case the inbound transport from the Kassel depot was delayed 55 minutes with several shipments for tour A and five shipments for tour B. in the traditional setup both trucks for boths tours A and B would have waited one more hour for the truck from Kassel to arrive in Duisburg (figure 8).

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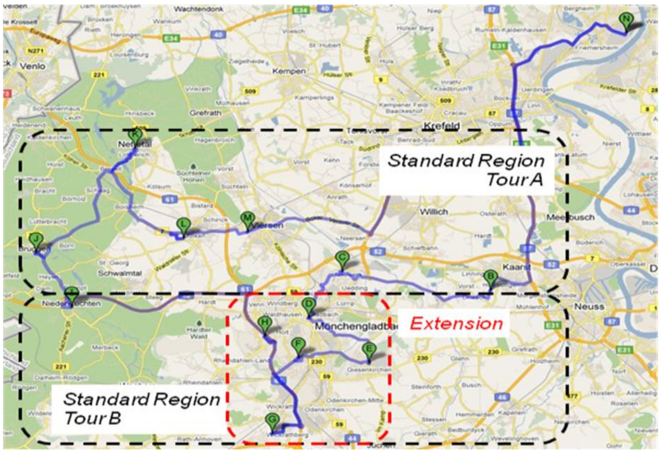

Figure 8: Real-time transport control based dynamic change in last mile routing

The new – dynamic – situation with the availability of real-time transport control information (Liao et al. 2007; Ran 2004) would lead to the new scheduling option of extending the first tour A with the five missing shipments from the inbound Kassel truck. This would support an increase in overall productivity as the second truck for tour B could already start one hour earlier and therefore be able to deliver more goods on this same day (Ogle et al. 2002).
Though many different influences and factors have to be included into such transportation and routing decisions (Bovy 2009), this still shows very obviously that in such cases dynamic production scheduling would greatly profit from the described GPS-based real-time transport control data.

CONCLUSION AND OUTLOOK

The sooner an information about a delay reaches the production planning system the longer there is still time for rescheduling: If an information about a delay in the above described context is already known when it occurs, there is enough time for a more efficient re-planning. So a continuous tracking system with an automatic data integration would support the ideas of supply chain event management and real-time production control in a context of lean management. It has to be defined in which way an access towards tracking data can be realized and used as input data for management execution systems or as performance indicators for controlling tools (Auld et al. 2009).
The paper at hand shows the general idea and possibility of integrating transportation processes control based on GPS track and trace within production networks into scheduling algorithms. Therefore further research and modeling as well as software integration of GPS-based transport control tools is strongly recommended, focused on integration of constinously available real-time data, in order to approach the described ideal solutions of dynamic scheduling in production and logistics networks. A first idea of an algorithm is presented. This would also help to overcome expected problems in a GPS mass application scenario (Marchal 2005). On top further testing of GPS applications in logistics and dynamic scheduling is needed and also most welcome awaiting the European GPS system GALILEO in order to support new value added services based in this new and more exact service in the future.
Further applications as for example a suggestey mystery shipping concept (Klumpp et al. 2011) or with dangerous goods transport (Batarlienė 2007) or within other fields in the logistics industry (Forster 2005) as well as in mobile service applications (Batarlienė and Baublys 2007) could lead to additional benefits for production networks such as recognition and mitigation of typical transport disruption points in order to avoid delays in transport and production flows in such networks and to identify shortest and therefore most efficient routes (Azevedo et al. 1993; Jarašūnienė 2007) for cargo traffic in a dynamic setting.
Also further steps in the expected integration of GIS, GPS, GSM and RFID technologies and services (Derekenaris et al. 2001) will bring important development and application options for the production and logistics sector, for example the integration of transport planning, warehouse management and production control based on 'smart materials', also known as 'intelligent cargo', in the supply chain.

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BIOGRAPHY

MATTHIAS KLUMPP studied economics and business administration after a vocational degree in logistics (Speditionskaufmann IHK, 1996) at University Leipzig and the IECS Strasbourg from 1995 to 1998 (Diplom-Kaufmann, Diplom-Volkswirt). Parallel to his professional consultant career in strategy management, logistics and education (zeb/, conoscope) he also obtained a PhD at University Leipzig in 2007 and started as a professor at FOM University of Applied Sciences.
He founded the Institute for Logistics and Service Management (ild) at FOM in 2009. He is member of the scientific committee for the German national excellence cluster "LogistikRuhr" funded by the German national ministry for research (BMBF) and has done research or EU ERASMUS teaching stays in Australia, China, Finland, France, Netherlands, Norway, Spain, Turkey and the USA.

CHRISTOF KANDEL studied industrial engineering at University Duisburg-Essen since 2005. After achieving the bachelor degree he started the master course in 2008 with major courses in 'product engineering' and 'technology and operations management'. He finished in 2010 with the degree 'Master of Science'. During his study he worked at VOITH paper in Krefeld in the department of project management and afterwards at SIEMENS Energy in Duisburg in the department "procurement & logistics".
After his studies he began to work at institute for logistics & service management at FOM in December 2010 as research assistant. His research interests are real-time production control, green logistics in particular green manufacturing and green routing as well as the calculation of CO_2 emissions and tour planning of e-vehicles. In addition, he is responsible for the GPS.LAB at ild.