

## NANOTECHNOLOGIES AND INTERMODALITY IN INTELLIGENT TRANSPORT SYSTEMS

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### 1. Nanoscience development

Nanoscience as a new step in technologies gives remarkable possibilities in development of various intellectual controlling systems. Transport systems need such technologies for navigation devices, road movement controls and transport means control (without driver participation). These tasks solve modern electronic devices, sensors, optical and acoustic signals' receivers, amplifiers and transmitters on the base of solid state and bio-nanotechnologies [1]. Thus, the interest to nanotechnologies is enormous (see Table 1).

Table 1. Examples of public funding for research and development (R&D) in nanoscience and nanotechnology (source: European Commission 2004)

| Country | Expenditure on nanoscience and nanotechnologies   |
|---------|---|
| Europe  | Current funding for nanotechnology R&D is about 1 billion euros, two-thirds of which comes from national and regional programmes.   |
| Japan   | Funding rose from \$400M in 2001 to \$800M in 2003 and is expected to rise by a further 20% in 2004.  |
| USA     | The USA's 21st Century Nanotechnology Research and Development Act (passed in 2003) allocated nearly \$3.7 billion to nanotechnology from 2005 to 2008 (which excludes a substantial defence-related expenditure). This compares with \$750M in 2003. |
| UK      | With the launch of its nanotechnology strategy in 2003, the UK Government pledged £45M per year from 2003 to 2009.  |

## 2. Nanoscience and applications

As nanoscience and nanotechnologies cover such a wide range of fields (from chemistry, physics and biology, to medicine, engineering and electronics), we have considered them in four broad categories: nanomaterials; nanometrology; electronics, optoelectronics and information and communication technology; and bio-nanotechnology and nanomedicine. This division helps to distinguish between developments in different fields, but there is naturally some overlap.

Where possible, we define the development of future applications as short term (under 5 years), medium term (5–15 years), and long term (over 20 years). It may be that some of the potential applications that we identify are never realized, whereas others that are currently unforeseen could have a major impact. We also identify potential in environmental, health and safety, ethical or societal implications or uncertainties.

## 3. Nanomanufacturing and the industrial application of nanotechnologies

The use of bottom-up and top-down techniques in manufacturing is reflected on the Figure 1.

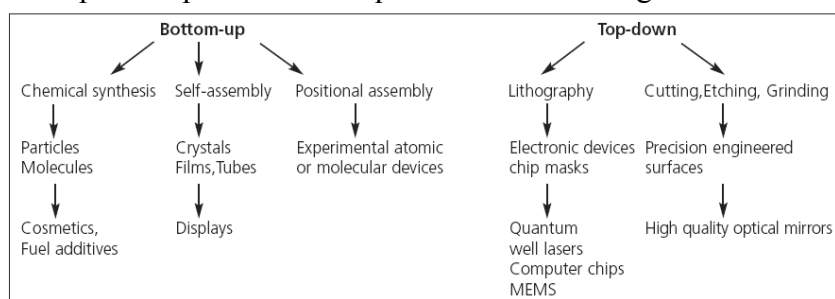


Figure 1. Basic nanotechnologies techniques

Estimated global production rates for various nanomaterials and devices based on international chemical journals and reviews (2003–2004), and market research (BCC 2001). These rates are intended for guidance only, as validated numbers are commercially confidential.

Table 2. Estimated global production rates for various nanomaterials

| Application                            | Material/device  | Estimated production rates (tonnes/annum)  |                                 |
|--|--|--|---------------------------------|
|  |  | Present<br>2011-2020                       | 2005-2010                       |
| Structural applications                | Ceramics, catalysts, composites, coatings, thin films, powders, metals                         | 10<br>10 <sup>4</sup> -10*                 | 10 <sup>3</sup>                 |
| Skincare products                      | Metal oxides   | 10 <sup>3</sup><br>10 <sup>3</sup> or less | 10 <sup>3</sup>                 |
| ICT                                    | Single wall nanotubes, nano electronics, optoelectronic materials                              | 10<br>or more                              | 10 <sup>2</sup> 10 <sup>3</sup> |
| Biotechnology                          | Nanoencapsulates, targeted drug delivery, bio-compatible, quantum dots, composites, biosensors | less than 1<br>10                          | 1                               |
| Instruments, sensors, characterization | MEMS, NEMS, SPM, dip-pen lithography, direct write tools                                       | 10<br>10 <sup>2</sup> -10 <sup>3</sup>     | 10 <sup>2</sup>                 |

|               |                           |  |                 |
|---------------|---------------------------|--|-----------------|
| Environmental | Nanofiltration, membranes | 10<br>10 <sup>3</sup> -10 <sup>4</sup> | 10 <sup>2</sup> |
|---------------|---------------------------|--|-----------------|

The convergence of top-down and bottom-up production techniques is presented in Figure 2.

#### 4. Nanoscience cycles

Ecological cycles show all necessary technologies transformations of principles, ideas and products (Figures 3). This means **IDENTITY**(*Unique effects created through Nanoscalar & Nanostructural Behaviour*)-**CHARACTERISE**(*Synthesise, Measure, Model, Simulate*)-**PROCESS**(*Fabricate functional materials through new ground breaking technologies*)-**PRODUCT**(*Create sustainable value adding advanced functional materials*) ecological cycle.

#### 5. Intellectual systems conceptions

The system theory approach formulates general ideas and conceptions of any intellectual system (see, Figure 4). Such system includes means of information processing, system's language, control language, controlling systems of data bases and knowledge bases. But the main question is: how is this system clever? There are some criteria which allow to judge about the system's intellectuality. The threeagramme of a system's demonstrates Boulding Complexity (BSL), system's language level (SSL) and controlling language level (CLL) (see Figure 5). The frequency criterion is the most convenient for system's functionality testing (Figure 6).

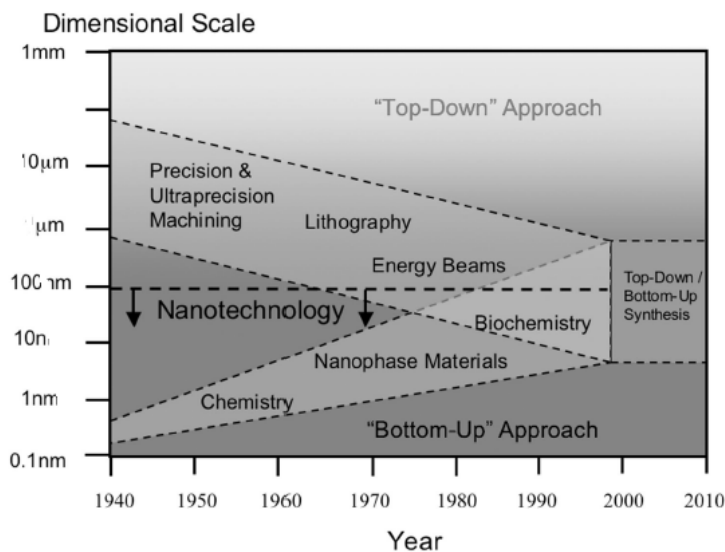


Figure 2. The generic steps that are undertaken to manufacture nanomaterials, from identification of properties through to production



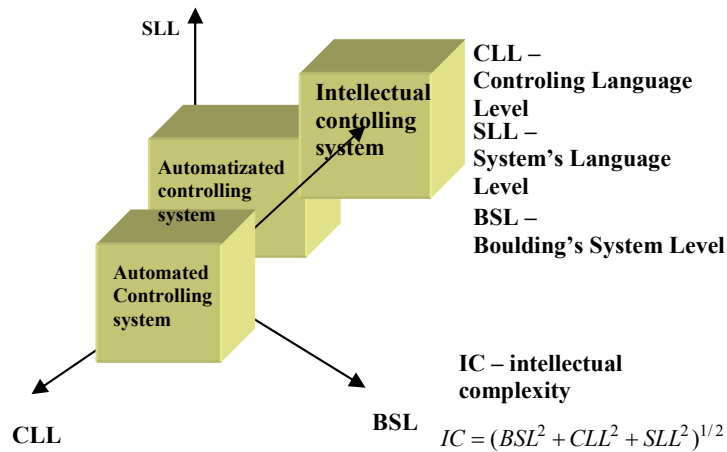
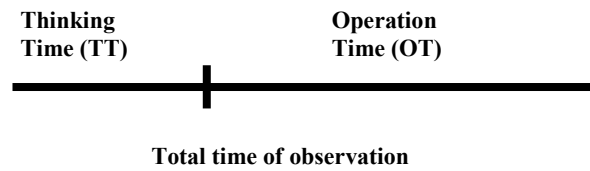


Figure 5. Threegramme of system's complexity



Frequency Intellectuality (FI):

$$FI = TT / (TT + OT) \quad \text{OR} \quad FI^* = TT / OT$$

Figure 6. Frequency estimation of intellectuality

## 6. Agent-based Planning and Simulation of Combined Rail/Road Transport

### 6.1. IDEA OF SIMULATION

A simulation model of the flow of Intermodal Terminal Units (ITUs) among inland intermodal terminals is presented (Figure 7). The intermodal terminals are inter-connected by rail corridors. Each terminal serves a user catchment area via a road network. The terminal is modelled as a set of platforms, which are served by a number of gantry cranes and front lifters. Given the schedule of train connections among the terminals, an agent-based system, the Intermodal Transport Planner (ITP) books ITUs on trains and assigns trucks to deliver them to the source terminal and to pick them up in the destination terminal. The terminal and rail corridor simulation software has been implemented as a discrete-event simulation model, using MODS1M 111 as development tool [2-10].

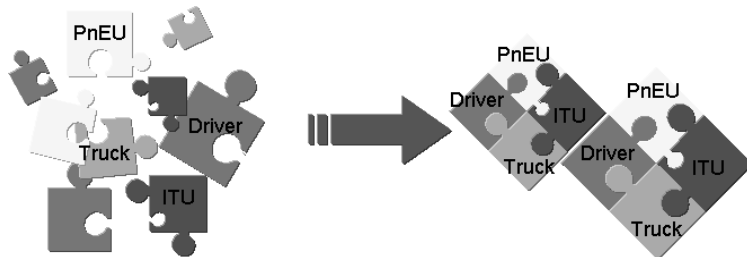


Figure 7. 'Puzzle' intermodality – the way of effective logistics

### 6.2. PLATFORM PROJECT

the aims of the PLATFORM project was the implementation of a simulation environment for the assessment of impacts produced by the adoption of different technologies and management policies to enhance terminal performances. To achieve this objective, the project needed to encompass all the phases of an intermodal transport of an Intermodal Transport Unit (ITU), a requirement for the comparison of the performance of intermodality against road-only based transport [11-16].

The basic terminology: ITU – intermodal terminal unit; ITP – intermodal transport planner; ITT – intermodal transport task; MODSIM III – discrete-time simulation software; IPnEU – intermodal planning; TS – terminal simulation. An intermodal terminal can be regarded as a node in a network that models the connectivity of the origins and destinations in the supply chain.

### 6.3. PLATFORM ARCHITECTURE

The PLATFORM architecture consists of two subsystems: intermodal transport planner (ITP) that manages the planning of the whole intermodal transport chain from origin to destination for an ITU; the simulation system (composed by the road simulation, rail simulation, and terminal simulation modules) that models and simulates the ITU Transport process, both assessing the feasibility of the plans generated by the ITP and evaluates the performances of intermodal terminals, thanks to a detailed description of the intra-terminal processes.

### 6.4. ITP (PLANNER) & ITT SIMULATIONS

- Intermodal Planning and Execution Units (IPnEU) - for planning the whole IIT of an ITU. They split the IIT into its three main parts, the initial and final leg on the road and the main leg by train.
- Forwarding Agents - for planning and booking the IIT of the ITU by truck. These agents are responsible for the planning of delivery ITUs to and their pick-up from terminals.
- Booking Agent - for booking the ITT of the ITU by train. This agent checks for availability of places on scheduled trains, checking which bookings are possible.
- Road Simulation - simulates the transport of the ITU by truck, as delegated to forwarders. It simulates the flow of incoming and departing trucks at each terminal in the corridor.
- Terminal Simulation - simulates the loading, unloading of ITUs from trucks and trains as well as storing of ITUs in the intermodal terminal. Terminal equipment, loading platforms, yard areas and gate procedures are simulated, in order to demonstrate functionality of the terminal procedures and potential for improvement.
- TVain Simulation - simulates the flow of trains within the chosen rail corridor. According to the train time-tables, the flow of trains from and to the terminals is simulated, focusing especially the train flow within the chosen corridor.

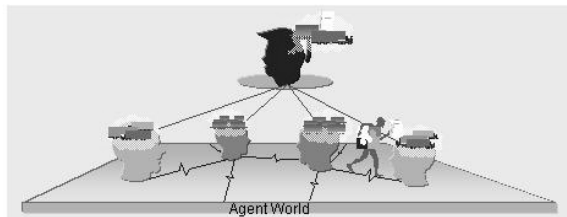
### 6.5. THE INTERMODAL TRANSPORT PLANNER

The planning of intermodal transports is performed by means of an agent-based model of the intermodal transport chain. The transport service operators are represented by individual, intelligent software agents. Each of these agents is equipped with task- and domain-specific planning and scheduling abilities as well as models of their local resources in

terms of time, load capacities etc. This approach allows for the distribution of the tasks to be solved in the processing of intermodal transport orders. Multi-agent systems are highly suitable for distributed problem solving as they offer the possibility to divide the main task into small sub-tasks.

## 6.6. AN AGENT FOR INTERMODAL PLANNING AND EXECUTION

Intermodal plans are usually generated as the result of the interaction between the forwarders and the terminal companies. We represent the knowledge in intermodal transport planning for each transport operator, by encapsulating it into the IPnEU which is an agent associated with an intermodal order. This means the IPnEU plans and executes the plans for all the goods to be delivered within the same order and not only for a single ITU, as it does the PnEU in the standard TELETRUCK system. If an order contains more than one ITU, it may be splitted over several vehicles. Yet only one IPnEU is supervising the transport execution. The IPnEU plans and negotiates the intermodal transport of the ITUs it represents



and then monitors the execution of the plan, eventually migrating to other software systems, while the ITUs are in transit (Figure 8).

Figure 8. The IPnEU planning and migrating

## 6.7. COMMUNICATION AND COOPERATION: NEGOTIATING INTERMODAL ORDERS

Customers and transport agents communicate to negotiate the contract for the execution of intermodal order. The customer at the origin requests an ITT to the forwarder of her choice. Figure 9 shows the details of the negotiation and planning phase.

The forwarder recognizes that the order requires an intermodal transport and activates an IPnEU to provide for intermodal planning. The IPnEU splits the order into three parts: the rail-based main leg order which constrains the orders for the initial and final road-based legs. The main leg order, on rail, is passed to the booking agent of one or more terminals, who then engage in planning it. The result of this activity, the main leg plan is communicated back to the IPnEU. Planning the initial and final legs involves the usual TELETRUCK planning and scheduling activity, which results in a holon for every vehicle. The Intermodal Planning and Negotiation Protocol is an application-specific extension and nesting of several classical Contract Net Protocols

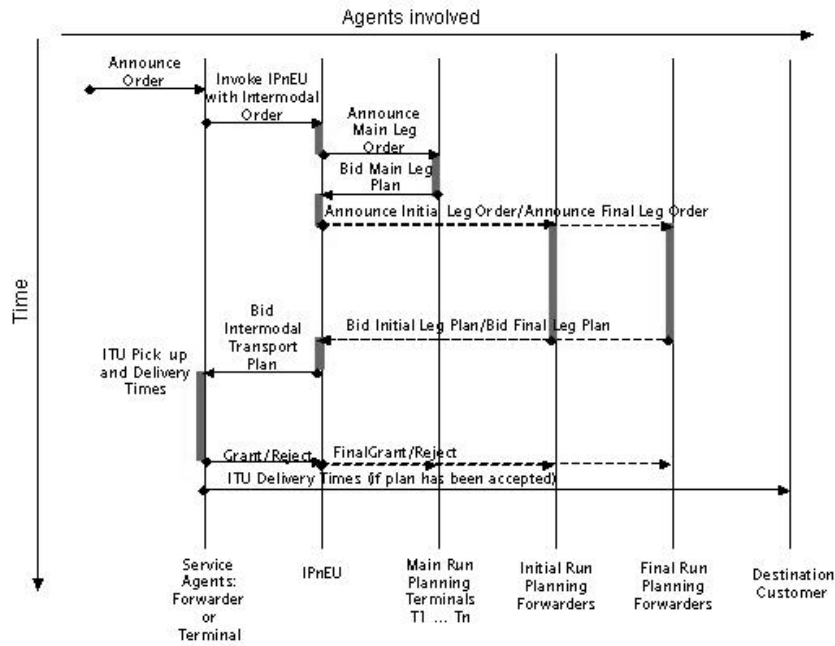


Figure 9. The intermodal planning and negotiation protocol

## 6.8. RESULTS OF NEGOTIATION AND PLANNING PHASE

The negotiation and planning phase generates an intermodal transport plan. Such a plan is a composition of plans for the different transport legs. The intermodal plan is composed of two road-based transport plans and one rail-based plan. The road-based plans implement the TELETRUCK approach, that is, for each vehicle a holonic structure is generated. Each structure is dominated by a PnEU. The IPnEU participates to each one of these holonic structures.

## 6.9. THE ROAD NETWORK SIMULATOR

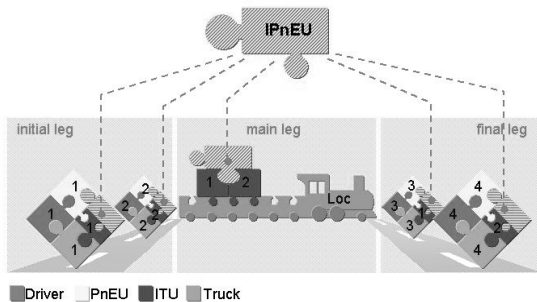


Figure 10. A holonic intermodal transport chain with two road holon and a rail holon

## 6.10. THE TERMINAL SIMULATOR

The terminal simulator (TS) has been developed in MODSIM III, a commercially available object-oriented and process-oriented simulation language. The adoption of the object-oriented paradigm allowed software components to be defined that correspond to their real-world counterparts and with a similar behavior. The terminal components modelled in the terminal simulator are:

- the road gate, where trucks enter and leave the terminal; the rail gate, where trains enter and leave the terminal.
- the rail gate is also connected to the rail tracks inside the terminal;
- the platforms, each composed by a set of rail tracks and by a buffer area;

- the storage area, a longer term (usually 24 hours) area to park ITUs.

### 6.11. EXECUTIONAL PROTOCOL OF AN INTERMODAL ORDER (MESSAGE AND CONTROL)

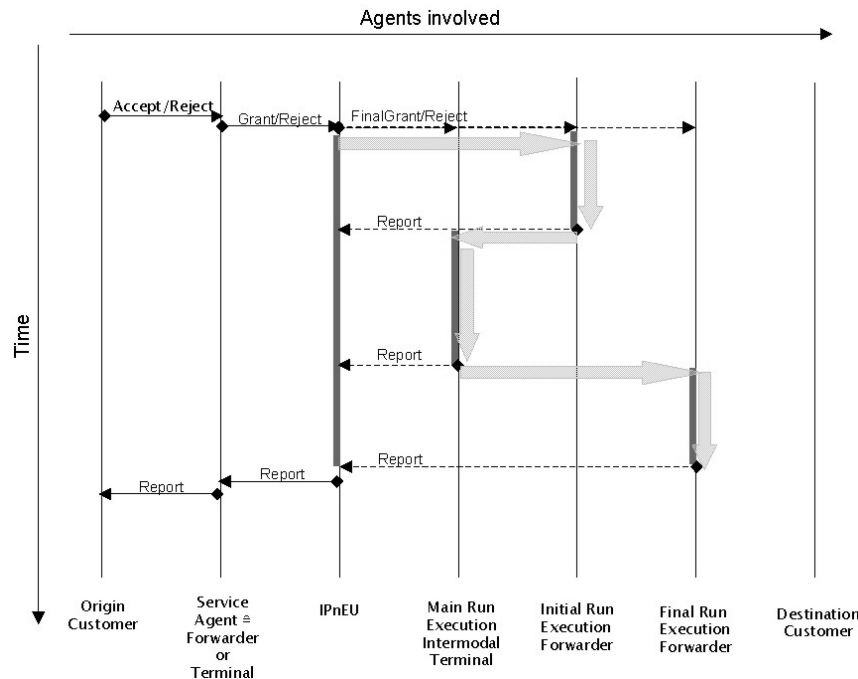


Figure 11. Execution protocol

### 6.12. ITU ARRIVALS AND DEPARTURES

When a truck with an ITU arrives at the terminal, it joins a First In First Out queue at the road gate. Each road gate is represented by a FIFO queue. The service time of the road gate is a parameter set by the simulation user, who can also decide how many road gates are used in the simulation. When the truck has been processed by the gate and enters the terminal one of these three cases is given: a) the ITU arrives well ahead of the deadline (the time when the train on which it was booked must leave); b) the ITU arrives just before the deadline; c) the ITU arrives after the train has left. In cases a) and c) the ITU is placed in temporary storage areas, in case b) a direct transshipment on the platform is performed: the truck is directed to a queue associated with the train loading process and the ITU is directly loaded on the train. From the point of view of the crane, this kind of operation has a high priority.

### 6.13. TRAIN LOADING/UNLOADING

The proposed modelling approach for train loading/unloading operations is platform-centred. A platform scheduler is associated with each platform, which assigns operations to the available cranes. The storage area is managed via a FIFO queue which accesses the pool of front lifters. Trains are modelled as sets of ITUs to be moved. Each move is an operation and a sequence of operations is a job.

### 6.14. RAIL CORRIDOR AND RAIL NETWORK SIMULATION

A rail corridor is a privileged point-to-point railway connection between two terminals, and it enables intermodal transport to try to compete with road-only transport not only in terms of cost, but also in terms of time. From the modelling viewpoint it consists of the allocation of appropriate time slots on the rail network. A corridor is thus an abstract representation of a path in a complex rail network.

#### 6.15. INTERCOMMUNICATION SIMULATIONS

The PLATFORM terminal simulation (TS) module has been designed in order to work in cooperation with the IPnEU agents. The aim of the IPnEU agents is to synchronize the truck arrivals in the terminal in order to minimize waiting times and reduce the queue length at the gates. If the planning of transport on the road network is well planned, the trucks would arrive in the best order, so the crane is making incremental moves, which are time efficient, and the required time to load/unload a train would decrease. If the planning is poor, the crane will probably travel back and forth to serve unexpected trucks, thus increasing the average service time. Thus, the advantage of planning the road network is that it is possible to improve the crane performance, since a better synchronization of the truck arrivals would transform most operations in direct train/truck transshipments.

#### Conclusions

Nanotechnologies provide the development of intellectual transport systems. But their intellectuality depends on the general system qualities, which characterize them. Intermodality principle is expanded not only on the intellectual controlling system, based on the modern nanotechnology's electronics, but also on the transport devices and vehicle themselves.

An agent-based planner and simulator for intermodal transport, developed in the framework of the PLATFORM project are presented. The software architecture is divided into the Intermodal Transport Planner, and in the simulation system. The former is an agent-based application which takes care of organizing transport planes for the dispatching of Intermodal Transport Units along the various stages of an intermodal transport, from origin to destination. The latter is a discrete-event based simulator that has been designed and implemented to verify the feasibility of these plans and measures their performances. The simulator also focuses in the detailed modelling of the internal terminal processes in order to let the terminal managers evaluate the impact of new technologies and infrastructures on existing terminals.

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**J. Šušins. Nanotehnoloģijas un intermodalitāte intelektuālās transporta sistēmās**

*Nanotehnoloģijas nodrošina jaunas perspektīvas intelektuālajām transporta sistēmām. Sistēmu teoriju likumi un nolikumi atļauj formulēt attiecīgas prasības. Piedāvātais intermodāla transporta specializētais plānotājs un simulātors uz projekta PLATFORM pamata tiek analizēts. Tiek aplūlots arī Jaunais 'puzzle' loģistikas tips .*

**Yu.N.Shunin. Nanotechnologies and intermodality in intelligent transport systems**

*Nanotechnologies provides new prospective for intelligent transport systems. The system theory laws and rules lead to formulations of corresponding requirements. An agent-based planner and simulator for intermodal transport, developed in the framework of the PLATFORM project are presented. The new type of 'puzzle' logistics are also considered.*

**Ю.Н. Шунин. Нанотехнологии и интермодальность в интеллектуальных транспортных системах**

*Нанотехнологии обеспечивают новые перспективы для интеллектуальных транспортных систем. Законы и положения теории систем приводят формулированию соответствующих требований. Специализированный планировщик и симулятор для интермодального транспорта на основе проекта PLATFORM представлены и анализируются. Новый тип 'puzzle' логистики также рассматривается.*