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INFORMATION MANAGEMENT SUPPORTING MULTIMODAL TRANSPORT UTILIZATION IN VIRTUAL CLUSTERS

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Abstract
Companies are facing problems regarding reduction of their logistics costs. Good organization of transport processes can bring a lot of profits both economical and environmental. Companies participating in transport processes more often prefer to create temporary relations and form virtual cooperation networks than to keep traditional long-term contracts. The paper first defined problems of multimodal transport. The obstacles to development of virtual transport clusters are described. The main problems and requirements of the virtual cooperation in the area of transport processes are identified. The aim of the paper is to present the scope of information needed for the coordination of virtual transport clusters. Author describes approach to information management in virtual cluster based on agent technology.

Keywords
multimodal transport processes, cooperation, information management, clusters, infrastructure, transport policy.

Introduction

Transport is an important element of everyday business operations. At the same times transport operation are generating a lot of externalities to the society like: green house gases emissions, noise, fatalities. The rising congestion on the most of European roads gives impulse to the governments to introduce alternative ways of transport operations organization. During last two decades transport sector has greatly increased its activity. At the same time the efforts made in order to reduce the energy consumption and greenhouse gases emission (GHG) were insufficient. According to data from the European Environment Agency, transport is accounted for close 20% of total GHG emissions (19.5%) and 23.1% of total CO_2 emissions in the EU-27. As presented in Fig. 1 railways, maritime and inland transport have better CO_2 performances than road transport. Taking in consideration that the road transport is dominating, the emissions dispersion is negative.

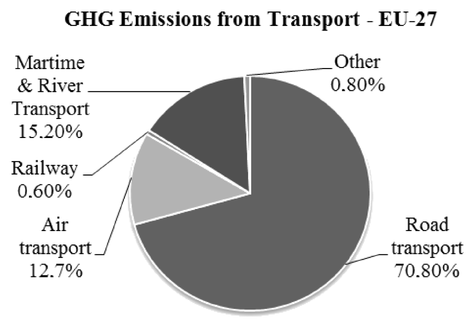

Fig. 1. GHG Emissions from Transport – EU-27 Million tonnes CO_2 (Source: based on data from [2]).

In order to change this negative trend since 2006 the concept of co-modality has been introduced, which requires efficient use of different modes on their own and in combination, resulting in an optimal and sustainable utilization of resources [1]. During last two decades a big progress has been made in achieving the main goals of the transport policy: secure, safe and environmentally friendly mobility. The main goals for improvement are highlighted in number of European Commission documents like:

1. White Papers of 1992, 2001, 2011;
2. Logistics: Keep Freight Moving (2007);
3. Greening Transport (2008);
4. Future of transport (2009).

In March 2011 the European Commission has published new White Paper on Transport. The new transport policy supports also the development of multimodal transport. These goals can be divided into main four directions [3]:

1. reduction of the greenhouse gases emission by 60% by 2050 comparing to the 1990 level;
2. efficient core network for multimodal intercity travel and transport;
3. clear urban transport and commuting;
4. creating global hubs in the European Union for long-distance travel and intercontinental flights.

In order to achieve these goals the European Commission the following action should be taken [3]:

- Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO_2-free city logistics in major urban centres by 2030;
- Low-carbon sustainable fuels in aviation to reach 40% by 2050; also by 2050 reduce EU CO_2 emissions from maritime bunker fuels by 40% (if feasible 50%);
- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors;
- By 2050, complete a European high-speed rail network. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail;
- A fully functional and EU-wide multimodal TEN-T 'core network' by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services;
- By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system;
- Deployment of the modernized air traffic management infrastructure (SESAR) in Europe by 2020 and completion of the European Common Aviation Area; Deployment of equivalent land and waterborne transport management systems (ERTMS – European Rail Traffic Management System, ITS – Intelligent Transport Systems for road transport, RIS – River Information Services, SSN – the EU's maritime information systems SafeSeaNet and LRIT – Long Range Identification and Tracking of vessels). Deployment of the European Global Navigation Satellite System (Galileo);
- By 2020, establish the framework for a European multimodal transport information, management and payment system;
- By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. EU should be a world leader in safety and security of transport in all modes of transport.

The above mentioned actions support the optimization of the performance of multimodal logistic chains. They should also increase the efficiency of transport services and infrastructure's utilization with application of the new schemes for information management.

Multimodal transport operations are carried out in the units codified by the railways of the European countries. These units are: containers large bodywork, car bodies, semi-trailers for semitrailers. At presents over 98% of goods are carried in containers. An essential element of the multimodal transport system is efficient transport infrastructure. The development of multimodal transport requires the consolidation of large volumes for transfers over long distances. Regarding multimodal freight it requires solutions relying on waterborne and rail modes for long-hauls. Integration of network should result in linking of airports, ports, railway. The physical infrastructure should be connected to online information and electronic booking and payment systems in order to facilitate multimodal travel. The multimodal transport is at present often not economically attractive for shippers, especially for short distances. The challenge is to improve the economical attractiveness and service quality for maritime, inland and rail transport in order to take a significantly greater proportion of medium and long distance freight. By 2050, all core airports should be connected to the rail network (high-speed if possible) and all core seaports should be sufficiently connected to the rail freight and, where possible, inland waterway system. For freight transport, an intelligent and integrated logistics system which support multimodal transport are needed.

This paper research highlights concentrate on:

- Identification of the main barriers to the multimodal transport development,

- Analysis of the state of the development of the multimodal transport in Poland,
- Identification of requirements for information management by organization of the multimodal transport especially by small and-medium sized companies,
- Overview of communication standards applicable in the conditions of virtual clusters,
- Identification of the information gap by information exchange by organization of multimodal transport within virtual clusters,
- Examination of the potential of agent based systems for coordination of virtual multimodal transport cluster,
- Proposal of standard messages implementation for information management in virtual multimodal transport cluster.

Barriers of multimodal transport

The importance of the multimodal transport is highlighted by a number of legal documents at the European and national level but still a number of barriers exist. The main of them are presented in Fig. 2. The problem tree analysis was applied to find the causes and effects of relatively low development of the multimodal transport in European Union and Poland. The advantage of problem tree analysis is the possibility to break down particular complex issue into manageable and definable chunks. This enables a clearer prioritization of factors and helps focus on objectives.

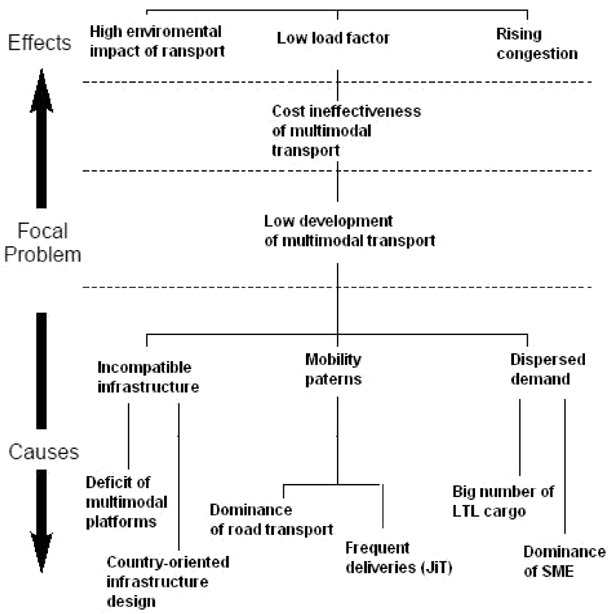

Fig. 2. Problem tree analysis- low multimodal transport development.

Most of the existing transport infrastructure has been designed to serve national rather than European economy. There is the lack of comprehensive standards on infrastructure design, power supplies, traffic management and data exchange, that result in cross border bottlenecks that constrain the movement of goods. In last decade the application of Cohesion Fund and European Regional Development Fund has helped to developed Trans-European transport networks (TEN-T). The cost of EU infrastructure development to match the demand for transport has been estimated at over € 1.5 trillion for 2010–2030. The completion of the TEN-T network requires about € 550 billion until 2020 out of which some € 215 billion can be allocated to the removal of the main bottlenecks (based on data from [3]). There is still need for additional investment in the infrastructure in order to create co-modal logistics chains which optimize the use of the different modes. The main shortages appear in the following infrastructure:

- multimodal nodes for rail and sea or air transport;
- IT infrastructure supporting intermodal transport.

The efficient transport system requires integration and interoperability of the individual parts of the network within Europe. There is deficit of platforms integrating different modes of transport. Crucial in achieving this result are the logistics centres which play the role of the network's nodes. Nowadays there is still scarcity of multimodal and transhipment platforms which can consolidate and optimize passenger and/or freight flows in the urban areas in order to avoid frictions. A big problem is disconnected planning at national and European Union level. According to the Impact Assessments analysis performed by elaboration of the new transport policy the following inefficiencies appear [4]:

- lack of joint traffic forecasts leading to differing investment plans;
- incompatible technical characteristics of new infrastructure;
- inadequate joint management of cross-border infrastructure projects.

The main challenges regarding the infrastructure development for multimodal transport include:

- creating platforms connecting airports and ports with efficient rail services;
- establishing the framework for a European multimodal transport information, management and payment system attractive frequencies, comfort;
- incentives for companies for usage of intermodal transport;

- easy access to services;
- smart inter-modal ticketing, with common EU standards.

The mobility patterns are based mainly on the road transport for freights especially on short and medium distances. Entrepreneurs, without the improvement of their financial results, are not interested in using alternatives to road freight transport. According to the European Commission the share of road transport in total freight is at the level of 76.9%. At the same time the share of rail is only 17.6%. The current capacity of transport networks is not able to meet the growing demand, what causes congestion in urban areas and on the key transit roads. The journey times lengthen and reliability suffers due to the fact that the effective organization of the transport processes is more and more difficult. It is a challenge to persuade the entrepreneurs to move traffic from the road onto rail, inland waterways or short-sea shipping. The multimodal solutions include for example road-rail transport, where on the main part of distance is used rail transport, while road transport is used only for cargo delivery from rail siding to the final recipient. The modern logistics trends based on frequent deliveries, like for example just in time (JiT), also discourage the application of multimodal transport. According to the data from the Office of Transportation (UTK) the average distance of multimodal freight in Poland was 415 km [5]. In short distances the multimodal cargo is usually cost- inefficient.

Intelligent mobility and transport demand management solutions might help to lower the congestion. There is still lack of the cooperative systems based on vehicle-to-vehicle and vehicle-to-infrastructure-communications that might in the longer term improve considerably the efficiency of traffic management and alleviate congestion [1].

Among European companies over 99% are small and medium sized enterprises. This situation leads to the dispersion of demand for transport services and a big number of the LTL (less than container load) shipments. Research conducted in the last decade by the European Environment Agency has indicated that in most countries of the European Union use of available capacity of operated means of transport is low. According to EU statistics the average use of available capacity of vehicles is at 54%. For rail transport, this value is 48%.

A challenge is to find solutions which might help to encourage the SMEs to cooperate in order to integrate the dispersed demand.

State of on multimodal transport in Poland

Poland is second biggest market for rail cargo volume in Europe and the fourth biggest regarding the length of the rail network, but despite this fact the share of multimodal transport freight is very low. At the end of 2011 the share of multimodal transport in rail transportation was 4.53%. It was one of the lowest results in the whole European Union. In countries where there is efficient State aid for greening of transport, intermodal rail freight exceeds 20%, and in some countries, such as. Netherlands, Spain, Belgium, fluctuates at 35–38%. Lower share than Polish intermodal market, is noted only in countries with poorly developed network rail infrastructure: Estonia, Finland, Latvia and Lithuania.

In recent years Poland has one of the highest rates of growth for multimodal freight. It was significantly higher than in most of the European countries. In Poland in the years 2009-2010 increase of traffic amounted to about 30% in the same period, comparing to less than 12% in Germany 5.4% in Belgium and in Netherlands at 0.4%. The average growth rate in all European countries in the years 2009-2010 has been fluctuating at 10.8% [5]. However the basis for this growth was very low. In the year 2009 the multimodal freight in Poland was 1449 million ton-kilometers (1888 million tkm in 2010) comparing the Germany 27 918 millions ton-kilometers (31 126 million tkm in 2010) at the same time.

In 2011 in Poland were 28 containers' terminals suitable for intermodal transport [7]. Terminals belong to the different operators, like: PKP Cargo S.A. and CargoSped Sp. z o.o. or PCC Port Szczecin and ACIS Holding S.A.. Some additional terminals are operated by the local companies. At the same time 26 of them were actively used by rail to shipped approximately 800 thousand units of the TEU in 2011. Four maritime containers' terminals in Swinoujscie, Szczecin, Gdansk and Gdynia reloaded 1357 577 TEU (twenty feet equivalent unit).

Main limitations for the increasing of the multimodal freight are poor technical conditions of the terminals mainly due to low capacity of warehousing space, the poor quality of the surface of reloading places, the lack of appropriate handling equipment and insufficient railway infrastructure, for example the lack of a suitable length of track for and landing facilities (above 600 m trains). The biggest disadvantage affecting significantly the volume of multimodal transport is also the lack of a sufficient number of national and regional centers. The next problem is the low speed of such services. Average speed of rail freight services in 2011 was 25 km/h and an intermodal container transport was around 35 km/h. In Germany for example the average speed for multimodal freight services varied between 60–70 km per hour.

Due to the high costs of transport by rail, road transport and poor quality of disproportionate to the parameters of the railway lines (including the average commercial speed), the carriage of containers on short distances are uneconomic. Intermodal transport increase profitability along with the distance of carriage. Most of intermodal services performed by Polish companies are international (about 80%). The domestic multimodal freight is about 20%.

The problems identified in the previous section also applied at multimodal transport in Poland. In the next section some solution regarding the aggregation of the demand and improvement of the infrastructure are discussed.

Virtual clusters – basic definitions

The European Union promotes cooperation among small and medium-sized enterprises (SMEs), which usually have less money for infrastructure expenses. SMEs have usually worse position in the negotiation regarding multimodal freight conditions due to the small volumes of cargo. Consortia of the small shippers consolidating their shipments may reach much better freight rates thus becoming much more attractive partners for these carriers [8]. Internet gives SMEs possibility to built temporary networks. Open web-based solutions don't require investments in infrastructure. Access to the broadband Internet usually is the only limitations to use them, and it is easy to overcome.

Traditionally clusters are understood as geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field that are present in region [9]. Virtual logistics cluster can be defined as a temporary network of individual companies, which aims to gain the benefits of economy of scale by joint execution of goods transfers to (or from) the particular geographic region.

By creations of the virtual clusters the SMEs can benefit from lower costs by assuring frequent deliveries. The additional benefit is limitations of externalities like GHS emission, noise and congestion reduction by elimination of empty routes or increased load factor.

The virtual logistics clusters have following characteristics:

- they should be technology independent by data exchange;
- they should be able to exchange information in visible and secure way;
- they should be opportunistic by network configuration – any time companies evaluate the benefits of participation and are able to reconfigure the network by each contract.

The temporary nature of the cooperation requires low-cost, technology independent common standards for data exchange and communication.

The standardization and interoperability problems are described in the next section.

Information management by multimodal transport

Multimodal transport organization involves usually transport service providers (supply side), transport service clients (demand side) and coordinators of multimodal services. The information requirements are different:

- transport service provider (TSP) – searches for additional orders to increase load factor;
- transport service client (TSC) – searches for freight rates, delivery times, payment conditions and reliable transport providers;
- multimodal transport coordinator (MTC) – searches for current offers and orders to match demand and supply side.

The typical information systems used for transport planning and execution can be divided into:

- transport exchanges;
- transport routes planners,
- intelligent transport systems,
- internet platforms for demand aggregation or transport mode choice.

The multimodal transport organization requires search for a combination of different modes, in order to meet the minimal transit time or transport cost. Also the structure of stakeholders is a rather complex. For example transport service providers (TSP) in order to use all modes of transportation applied very often sub-contracting. Beside direct carriers owning owners of transport modes there are numerous companies who are integrators and offer door-to door transport service subcontracting selected carriers on particular sections of the route.

There are more and more examples of Internet platforms which support the multimodality. One of such examples is Logit4see [8] tool which helps to make optimal multimodal choice. This tool [8, p. 8-9] provides the optimization of a multimodal supply chain according to the following basic logistics processes:

- Operational Planning – selecting the optimal transport chain regarding delivery time or cost
- and booking loading surface with them;
- Transport execution – after acceptance of transport order system allows to monitor transport progress and to reschedule the chain when deviations appeared;
- Freight transaction completion – after accepting Proof of Delivery by a receiver it allows possible claims settling , invoicing and payment.

One common problem which appears by information management is lack of interoperability. The number of interactions by multimodal transport organization requires the electronic data exchange. Cooperating companies both TSP and their clients need common set of electronic messages and common identifiers. Standardization is a must, otherwise it would be difficult to cooperate in virtual logistics cluster and meet requirements of ICT systems interoperability. Standards are understood, as predefined and agreed structure and content of messages/documents regarding booking of resources and services as well as reporting status on the performing of transport services.

Pedersen [10] has indicated: standardization organizations describe their electronic documents through specifications and implementation guidelines. Interoperability is defined in this chapter as: "the capability to run business processes seamlessly across organizational boundaries. Interoperability is achieved by understanding how business processes of different organizations can interconnect, developing the standards to support these business processes efficiently and by specifying the semantics of messages exchanged between the organizations to support these business processes in a scalable way" [10].

Interoperability of information systems enables formulation of virtual networks. It is chance for small and medium sized enterprises to implement and connect to and to be part of efficient multimodal logistics networks.

Communications standards

In the field of logistics many standards are already defined. There are over 400 standardisation initiatives recorded in the world [11]. In Europe big sized companies more and more often use the Logistics Interoperability Model (LIM) by GS1 [16]. Small and medium companies (SME) still search for the other solutions that might be suitable for them. Standards define mainly format and structure of information which is exchange among cooperation companies.

One of the recent initiatives regarding standardisation of logistics is a Common Framework for ICT in Transport & Logistics. It provides interoperability and consists of roles, business processes, ontology and messages to support interoperability in the main logistics processes, providing the information infrastructure to support mode-independent transport planning, compliance, cargo consolidation and visibility [10]. The Common Framework has a vision to become an umbrella of all major existing communication standards. Table 1 presents the most common messages used in Common Framework for communications when organizing multimodal transport services.

Table 1
Examples of standard messages in transport process developed within Common Framework

Name	Purpose	Scope
TSD (Transport Service Description)	TSD is used for a description of transport services suitable for automatic detection. It applicable for transfer of, operations in terminals, discharging, and additional services.	Description of service including: – scope of services, – prices, – type of cargo (food, electronics, ADR ect.), – type of packing units (pallets)
TEP (Transport Execution Plan)	TEP describes all the information needed related to the execution of a transport service between transport user and transport provider.	
TES (Transport Execution Status)	TES provides information about the progress of the transport and of the cargo condition	Remarks about the execution of the transport service, special conditions, delivery time, delivery location
GII (Good Item Itinerary)	Provides information on the movement of goods on the whole way including transhipments	Description of the complete itinerary for a given goods item, including planned, estimated, and actual times for departure and arrival for each service.
TOS (Transport Operation Status)	TOS assists in establishing the best possible arrival time estimates.	Reports on transport execution status including deviations from planned routes and timetables.
TNS (Transportation Network Status)	TNS points out traffic, including information from the different transport modes.	Information on vehicle movements, obstacles, traffic jams.

The communications standards are recognizes mainly by big companies. The small and medium companies used mainly the standards of big companies they cooperate with. The pilot survey was conducted among group of about 30 companies from SME sector. The companies represent both transport clients and transport providers. The research highlights the information exchange between the transport service client and transport service provider. The group of respondents was asked about the application of common standards. The results are presented in Fig. 3.

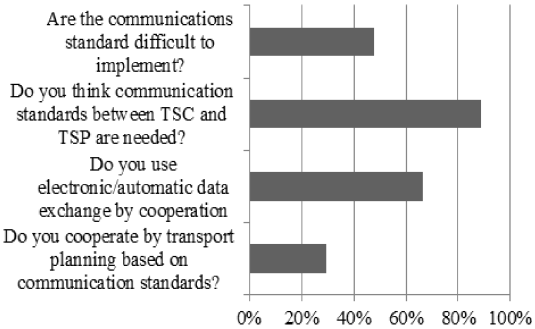

Fig. 3. Positive answers regarding the implementation of common communication standards.

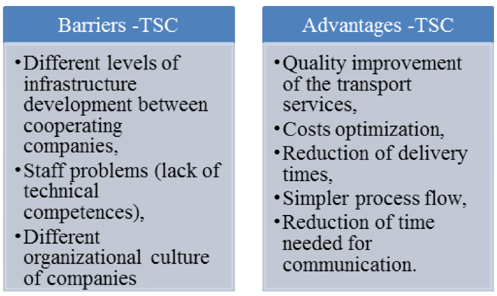

Fig. 4. Implementation of the communication standards from Transport Service Clients (TSC) perspective.

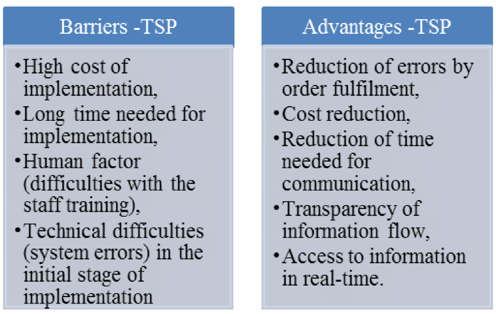

Fig. 5. Implementation of the communication standards from Transport Service Providers (TSP) perspective.

The companies are not very familiar with communication standards (c.a. 30%). At the same time most of companies (almost 90%) have declared that common communication standards are needed. The most common is electronic data interchange (c.a. 65%). In Figs. 4–5 are identified main barriers and advantages of communication standards implementation.

Information management in virtual cluster

The information management within virtual cluster aims to enable companies to achieve synergy effect leading to increased efficiency comparing to the independent activities. Moreover due to the temporary nature of cooperation and opportunistic behavior of the companies participating in the cluster it requires the flexibility and ability to adjust to changing situations.

The main functions of tool for information management for multimodal transport within virtual cluster are: freight aggregation, multimodal transport chain planning; electronic tender for intermodal transport services; offers consolidations and networking.

Information gaps regarding organization of multimodal transport within virtual cluster are presented in Table 2.

Often problem is a lack of the coordination and integration between the information systems working between virtual cluster members. Moreover the transport demand is not constant. Agents' technology is useful in case of changeable events management. It can be stated that following characteristics are typical for multimodal transport coordination within virtual cluster:

1. data, control and resources are inherently distributed,
2. the system is regarded as society of autonomous cooperating entities,
3. the components must interact with other to reach whole system goals.

Table 2
Information gap by information exchange by organization of multimodal transport within virtual clusters.

Information gap	MTC	TLC	TSP
Availability of multimodal infrastructure	X	X	
Status of multimodal network	X	X	
Current multimodal transport demand	X	X	
Current multimodal transport offers	X		X
Possible multimodal partners (capacities overview)	X	X	
Possible demand aggregation	X		X

Agent technologies can be used to facilitate and control the scope, the time, and the frequency of information sharing based on specific arrangement of each partners. The characteristic of agent technology suits well to perform planning and coordination in a multimodal virtual cluster where we can observe [12]:

- heterogeneous environment
- open and dynamic structure
- interoperability of components
- need for scalability.

The distributed multi-agent system is suitable to perform inter-organizational planning of multimodal transport processes.

Agent technology is the preferable technology for enabling a flexible and dynamic coordination of spatially distributed entities [13]. The mentioned above characteristics suit well to requirement for planning and coordination of intermodal transport process. In an agent-enabled environment, the multiple transactions and exchanges of information that drive material flow can be managed by software agents that maintain visibility across the network [13].

Agent-based system architecture provides an interesting perspective for integration of the companies in virtual clusters because agents are able to generate, process, filter, broadcast, and correlate information for real-time coordination. In this paper an agent-based system is understood as a multi-agents system that's utilizes databases of business applications implemented in cooperating companies. An agent is defined as "computer system situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives" [14]. Agents are reactive, proactive and have social ability [14].

Interoperability is needed in virtual clusters in order to safely exchange data between the different information systems. The data should follow predefined structure in order to create useful information. Communication between IT systems is possible independently of programming languages, platforms and operations systems they use, and applied information exchange standard [15]. All the above mentioned features make the semantic web suitable for application the in virtual networks. The access to the semantic web does not require application of any specialized IT systems. Information can be process in format that is readable and understandable for computer and any user. This solution gives SMEs a better possibility to capture information and exchange them within particular enterprises' network, as well as it helps to build up business relations [15].

A feasible and low cost solution for information management in virtual cluster is application of web platform. Suitable solution might be an hybrid of web-services and agent technology. Simplified schema of such tool is presented in Fig. 7. The solution includes agent representing different roles:

- Multimodal transport service coordinator agent (MTCA) - it is responsible for cooperation, communication, negotiation on behalf of cooperation entities. It delegates collecting of predefined information scope about potential business partners. It makes decisions regarding follow-up actions. Coordination Agent cooperates with groups of all agents.
- Transport service client agent (TSCA) – it is responsible for issuing the demand for transport service and it defines criteria for acceptable transport chain scenarios, as well as potential cooperation scenario with other clients.
- Transportation Service Providers Agent (TSPA) – represents companies which offer particular transport services, it defines structure of transport offers and possible/potential scenarios to create transport chain.
- Informing Agent (IA) – it is responsible for sending information to MTCA about new attractive offers available, as well as for informing transport clients agents and transport providers agent about the possibility of starting cooperation with MTCA after fulfillment of defined criteria. It makes semantic verification of information placed in the web by cooperating entities.

The communication between agents and user is asynchronic, so the confirmation of message by receiver is not required in order to continue the process execution [15]. Agents and users are informed automatically about any new event e.g. new offer arrival.

In Fig. 6 the schema for information exchange between network participants is described.

Application of the agent-based system and semantic web allows the improvement of organization of the multimodal transport process. The procedure below presents the process of multimodal transport planning by agents (see Fig. 6):

1. Transport service clients order their agents (TSCA) to issue demand and to define acceptable chain for multimodal.
2. MTCA collects the offer and aggregate them in orders to create virtual cluster.
3. MTCA sends the cluster formulation proposal for particular multimodal transport service to TSCA.
4. MSCA sends to TSPA join demand definition for multimodal service.
5. MTCA through hyperlinks finds ontology defining key words. Then it communicates with TSPA representing potential service providers and collects their offers and passes them to MTCA for analy-

sis. MTCA receives to the inquiries offers for the whole route or to the part of it.

6. Before offer choice MTCA questions providers agent TSPA whether the offer is still valid. If not, then the whole procedure needs to be repeated. If the offer is still valid, then the appropriate resources are booked. MTCA can book multiple carriers, and form multimodal transport chain (cluster at the providers side) in case when individual carrier is not able to provide multimodal transport service. Particular TSPA can create intermodal transport cluster or act separately in case they offer multimodal services
7. If the negotiations are successful, then the cooperation starts and agents sign the commission of service purchase on behalf of companies they represent. When the transaction is finished, MTCA stores the scenario of acceptable multimodal transport chains in its database. Collection of scenarios helps to simplify the negotiation process in the future.

As mentioned before a interoperability is needed by usage of predefined messages structure. Application of Common Framework messages (see Table 1) for the model is presented in Fig. 7.

Presented in Fig. 7 approach allows to plan and execute multimodal transport services in virtual cluster. Due to the standardization of message structure and format they are easy understandable by any system and user. So it allows fulfilling the requirements for technology independency. The company might benefit from dynamic reconfiguration of cooperation network by organization of multimodal transport.

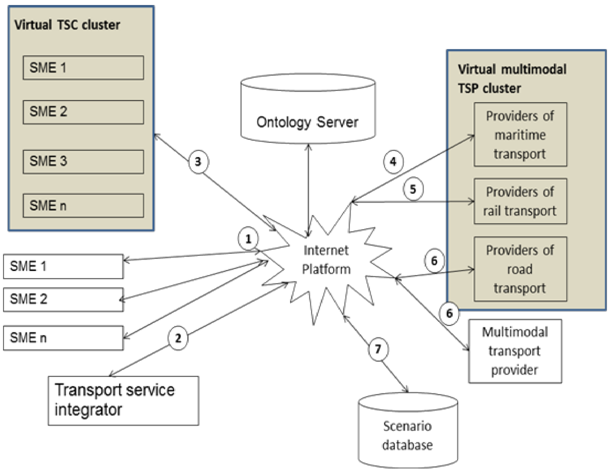

Fig. 6. Model of multi-agent system based on the semantic web (source modified from [15]).

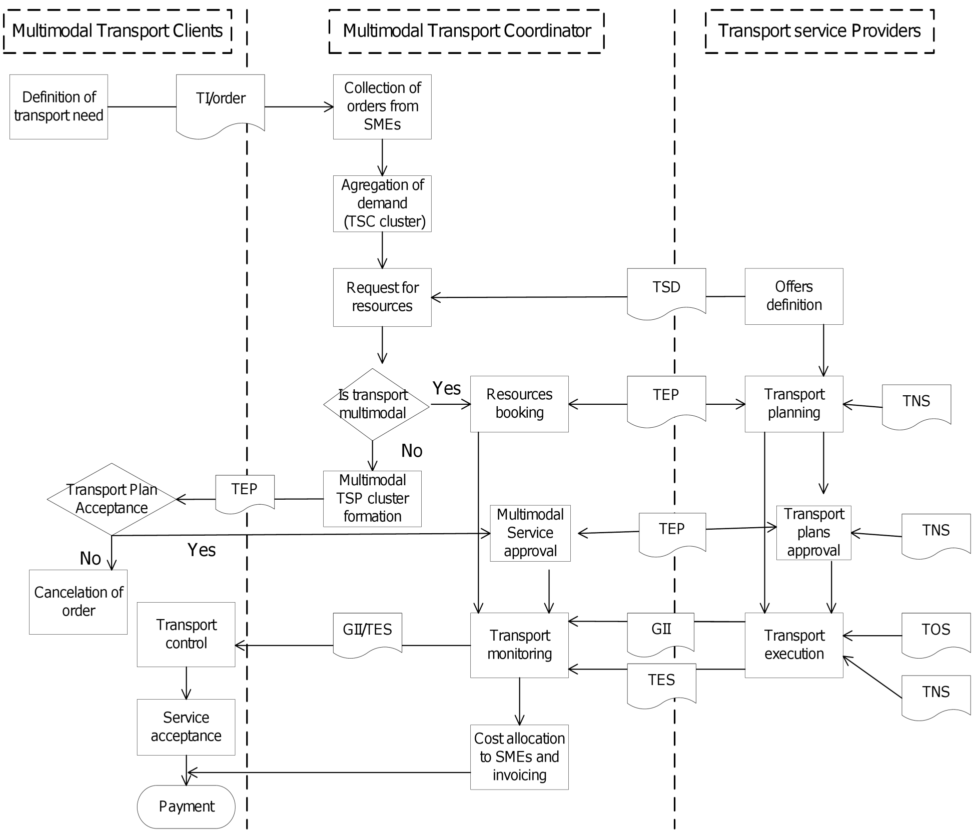

Fig. 7. Example of standard messages implementation for information management in virtual multimodal transport cluster.

Conclusions

The paper presents the problem of virtual clusters formulation by organizing of multimodal transport. The main research findings are:

- identification of the obstacles to development of virtual transport clusters,
- detailed description of the problem of standardization of information in transport processes especially by small and medium sized enterprises,
- elaboration of the concept of application of agent-based model with usage of standard messages for information management in virtual multimodal transport cluster.

Author highlighted how the lack of consistency of business process performed by particular entities and the variety IT systems used by companies, cause problems with automatic partners networking. As mentioned before small and medium sized companies have usually weak negotiation position by multimodal transport booking. Also at the supply side some transport service providers are not able to offer multimodal service on the whole route. The advantage of virtual cluster is the opportunistic approach of the participating companies so different transport chain scenarios can be created, including wide range of transport options offered by all modes of transport. Proposed model provides stakeholders with an extensive knowledge by automatically configuring multi-modal operable supply chains. Proposed solution enables efficient creation and automatic collection of data about companies and their resources published in the Internet. It facilities the establishing of the temporary cooperation network named as virtual logistics clusters. Agents representing particular companies coordinate and establish cooperation's conditions, in order to reach common goal of cost effectiveness.

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