An Approach for Ensuring Data Flow in Freight Delivery and Management Systems

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***Abstract*—**This research aims at developing the approach for more effective freight delivery and transportation process management. The road congestions and the identification of causes are important, as well as the context information recognition and management. The measure of many parameters during the transportation period and proper control of driver work became the problem. The number of vehicles per time unit passing at a given time and point for drivers can be evaluated in some situations. The collection of data is mainly used to establish new trips. The flow of the data is more complex in urban areas. Herein, the movement of freight is reported in detail, including the information on street level. When traffic density is extremely high in congestion cases, and the traffic speed is incredibly low, data transmission reaches the peak. Different data sets are generated, which depend on the type of freight delivery network. There are three types of networks: long-distance delivery networks, last-mile delivery networks and mode-based delivery networks; the last one includes different modes, in particular, railways and other networks. When freight delivery is switched from one type of the above-stated network to another, more data could be included for reporting purposes and vice versa. In this case, a significant amount of these data is used for control operations, and the problem requires an integrated methodological approach. The paper presents an approach for providing e-services for drivers by including the assessment of the multi-component infrastructure needed for delivery of freights following the network type. The construction of such a methodology is required to evaluate data flow conditions and overloads, and to minimize the time gaps in data reporting. The results obtained show the possibilities of the proposing methodological approach to support the management and decision-making processes with functionality of incorporating networking specifics, by helping to minimize the overloads in data reporting.

***Keywords*—**Transportation networks, freight delivery, data flow, monitoring, e-services.

I. Introduction

THE recent actions are planned by avoiding the gaps of measures for freight delivery processes and our efforts are forwarding for development and application of intelligent transport systems, by promoting the best practices for increasing the usage of multi-modal freight's transportation, and by supporting the new kinds of “green” transport corridors for freight deliveries [1]. Countries support freight movements by roads, including some other types of land transport. For example, the European Union (EU) expects that 30% of freight by road transport exceeding 300 km should switch to rail or different transport modes by 2030. Also, EU poses new challenges by obliging Member States to take measures until 2050 to increase the capacity of autonomous transport by more than 50% and to develop the infrastructure of transport corridors with new communication possibilities. These objectives guide and consolidate the efforts of all involved to develop a higher level of efficiency in the management of transportation processes while achieving lower levels of emissions and significantly reducing pollution in freight transportation [2]. On the other hand, overall freight transport is expected to increase by around 50% until 2050. The average distance for freight delivery by a vehicle is around 600 km, but some trips exceed 2000 km. Even digitalization of the sector of freight transportation will become a serious problem in the upcoming years. Subsequently, the European Commissioner for Transport on March 22, 2017, stressed: "that digitalisation will be vital for the transport sector's functioning" [3].

We are seeking to assess the complex infrastructure of freight's transportation processes by providing the necessary support of smart services and integration of information systems and data warehouses in a complex management process. Our previous results in works for the implementation of semi-automatic service provision in trips organization [3], and assessment of infrastructure of heterogenic service provision in cargo transportation [4], [10] are continued in this research. The aims and objectives of Digital Strategy will help us in supporting all efforts for development and assisting in the needful and standardized multi-layering infrastructure of information and communication technology (ICT).

The new Digital Strategy largely integrates the policy instruments of the Digital Agenda for Europe 2021 until 2030; as well they are reflected in the new EU-Central Asia strategy, which is regrouped according to the original objectives.

Several significant innovations in the strategy are important for our research area of freight's transportation management, i.e., the state-of-the-art ambitions correspond for:

- a strong focus on artificial intelligence;
- implementing services of cloud computing;
- applications of block-chain technology;
- using supercomputers and quantum technologies;
- developing platforms for the Internet of Things (IoT).

The aims of new research projects follow new requirements in the processes of establishing of new kinds of ICT, system applications and by developing of innovations. EU initiatives influence the significant investments in direct programs of developing infrastructure, which are recognized as important tasks, in particular for activation of strategies at the national levels of countries of the EU and with integrating activities with countries of the EU-Asia region.

The most important obligations and opportunities for ICT

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development are created by the following:

- Single Digital Gateway;
- Free movement of data, protection of personal data;
- Cybersecurity.

For the effective provision of digital services, the important requirements became the attractiveness for consumers, the creation of a trustful technological platform for well-organized provision processes and data collection. The development of smart transportation services is on-going, particularly for those functions which take priority, including:

- The development of smart, user-oriented, invisible, proactive, paperless services accessible to all;
- An increase of the use of data analytics tools, especially in the development of smart services;
- Encouragement of the development of a new generation of communications (5G and 100 Mb/s Internet access), which will primarily enable the wider implementation of various innovations for the needs of business and the population (e.g. IoT).

Horizontal assumptions that enable digital transformation are particularly important in the development of systems for decisions support working on–line and monitoring of transportation processes in real-time.

The development and renewal of mass public digital services are important, including the implementation and improvement of interoperable solutions and key enablers. The solutions of grant data analytics became important, which are based on artificial intelligence technologies. The subsidies for the creation, development and renewal of complex public services are important as well. Developing process of such services includes digitization of the institution's internal and external processes, which are required for the provision of e-services. Due to limited financial resources of individual countries and individual companies, the investments are needful from EU funds, which are strategically significant for developing of the unified, complex infrastructure of the provision multi-composite services in transportation.

Development and implementation of big data analytics tools (using artificial intelligence technologies) and subsidies for the performance and improvement of basic infrastructure (e.g., State Information Resources Interoperability Platform for service accessibility technologies) influence the possibilities for the development of more effective smart transport services.

Our research area is concerned with multi-modal transportation infrastructure. The approach for providing e-services for drivers by including the processes of estimating data flows is proposed. The aim of our research is forwarded for assessment of smart services, which are generated in freight delivery processes following the network types. The construction of the proposed methodology is based on transportation network evaluation methods and structure of organizational and managerial procedures in order to evaluate data flow conditions and overloads, and to minimize the time gaps in data reporting during transportation processes of freight under multi-modal transportation conditions.

II. Related Works

Research works for the development of smart services on the base of investigations in the vehicle to infrastructure (V2I) components are reviewed.

In EU, the focus is on the development of Cooperative Intelligent Transport Systems (C-ITS) [5]. Such systems (C-ITS) are recognized as a way to improve traffic safety, efficiency and comfort. Multiple EU financing mechanisms may show the support developments of different components of C-ITS for research and development of necessary infrastructure. On each of them, the various communication technologies were selected such as digital audio broadcasting (DAB), Infrared light, General Packet Radio Service (GPRS), Global Standard for Mobile Communications (GSM), and others. Some services based on the C-ITS Platform [5] are important for our consideration:

- Safety services – accident warning, incident warning, wrong-way driver warning, weather condition warning, roadwork information, lane banning, lane-keeping, auxiliary lane accessibility, legal speed limit, traffic congestion warning, recommended speed limit;
- Convenience services – international service handover, road charging, estimated journey time, recommended next link, map updates.

The implementation covers various aspects from the building of an in-vehicle platform, to the whole safety system architecture and the needed infrastructure including the business, legal aspects [5]-[7]. Services provisioned by vehicular applications were grouped into clusters:

- Side collision – road junction safety, lane change maneuver, safe overtaking;
- Longitudinal collision – head impact warning, rear impact, speed limit and safety distance, frontal collision warning;
- Exit from the road – road condition - slippery road, warning about the curve;
- Vulnerable road users – identification of vulnerable road users and revision.

The development of new kind of services and technological platforms, which can support the relation and communication of vehicles with information infrastructure (V2I) and between vehicles (V2V) can help in increasing of road safety and management efficiency [4], [6], [7]. The service platforms are based on wireless networks, new kinds of communication protocols and services provided for vehicles and infrastructure. These services can be grouped into the following:

- Cooperative Urban – that are related to traffic management and router planning in urban scenarios.
- Cooperative Inter-urban – that support drivers' awareness of the road.
- Cooperative Freight and Fleet – that are elements for professional drivers and fleet managers, like rest area parking, loading space booking, dangerous goods transport monitoring and others.

The development of e-services is prioritized and grouped (as listed in Table I):

- "Day 1 services" – which have societal benefits and expected to be in the short term.
- "Day 1.5 services" – which are desired by the market.

TABLE I
C-ITS SERVICES

Day 1 Services		Day 1.5 Services
Hazardous location notifications	In-vehicle signage	
Slow or stationary vehicle(s) & traffic ahead warning; Road works warning; Weather conditions; Emergency brake light; An emergency vehicle approaching; Other emergency messages	Vehicle speed limits; Signal violation/ junction safety; Request for the priority of traffic signal for designated vehicles; Green Light Optimal Speed Tip (GLOSA); Probe the vehicle data; Shockwave; Damping	Information on fueling & charging stations for alternative fuel vehicles; Vulnerable road user protection; On-street parking management & information Off-street parking information; Park & Ride information; Connected & Cooperative navigation into and out of the city (1st and last mile, parking, route advice, co-ordination of traffic lights); Traffic information & Smart routing

Day 1 Services are specified at large-scale in urban and extra-urban environments. The services to be provided are grouped into bundles:

- Bundle 1: urban efficiency;
- Bundle 2: infrastructure to vehicle safety;
- Bundle 3: traffic efficiency;
- Bundle 4: vehicle-to-vehicle safety;

C-ITS used various communication technologies, but most common are cellular (GPRS/3G/LTE) for wide-area connections with IEEE 802.11p protocol based for short-range communications (see Table II).

TABLE II
COMMUNICATION TECHNOLOGIES APPLIED IN C-ITS PROJECTS [5], [8]-[11]

Technology	COOPERS	CVIS	SAFESPOT	C-MobILE
Bluetooth			+	
IR	+	+		
DAB	+			
GPRS	+	+	+	
IEEE 802.11p		+	+	+
3G		+		
WiMAX				
LTE				+

Currently, we see that there is a consensus about C-ITS services. C-ITS "Day 1 Services" reflect this. The project focused on the evaluation of technologies to implementation on large scale services, and demonstration benefits to communities. Also, the emphasis is put on standardization and harmonization between separate projects since they are implemented in different EU member states. Currently, communication technologies combine modern cellular (LTE, 5G) communication (long-range) based on IEEE 802.11p (for short-range). "Among the outcomes of the C-ITS Platform, the common technical framework necessary for the deployment of C-ITS and the "legitimacy" of the deployment of C-ITS platform are created. The deployment of C-ITS can be justified and fostered at all levels and international cooperation" [5].

III. Detection of Infrastructure for Multi-Modal Transportation of Freights

The combined transportation can be considered as a dynamically changing and complex technology. The essential feature of combined (multi-modal) transportation is the integration of several types of transport into the process of freight transportation. It is important to organize and coordinate the activities of objects and agents participating in multi-modal transportation. A separate cycle of freight transportation of dispatch can include road haulage, rail freightage, as well as water transport.

The problem of expression of behavioral aspects arises in the multi-modal transportation domain, such as temporal relationships of process interaction and their determination in time, synchronization and inclusion of decision-making processes with the large volume of information processing, communication between objects. At the stage of analysis and evaluation of needs of performance of such types of transportation, the construction of a meta-model could allow to:

- Recognize what changes in the environment can lead to changes in decision-making goals and operational decision making;
- Decide when the situation is appropriate for the actual application of existing rules or not;
- Indicate the process for identifying possible actions and alternatives and control the choice of a specific option for these actions, assessing the attractiveness of the consequences of each step.

The environment of the transport process is also characterized by the fact that it is dynamic, has several and possibly contradictory goals and has incomplete information. The exact structure of the data due to their time and geographical interfaces must be constructed and made available to all objects involved in the process. Temporary aspects of knowledge representation are primarily of interest to the decision-making context when it comes to retrospective analysis and forecasting. For predicting the further evolution of the target area and the behavior of the system, it is important to create an appropriate system simulation model [12].

A. Requirements for the Decision Support System

Decision making has to be performed considering a lot of various factors: evaluation of technological infrastructure of multi-modal transport, organizational components, comparison of reports with the real situation, monitoring of processes, and so on.

Our consideration is focused on the representation of several features of multi-modal transportation:

- The goods are transported by the same transport unit using several different modes of transport;
- Several subsystems with their complex mechanisms interact as internal or external parts;
- Complex connections are investigated between individual

transport chains;
- Time and geographical dependencies are important in the relationships of processes.

B. Representation of the Infrastructure of Freight Transportation

An environment of freight transportation is characterized by the change space of states, where any state is steady in a short-run period. For the rapidly changing application domain of freight transportation, we have extracted the critical features for the analysis and representation:
- The complexity of process structures;
- Multiple subsystems with their complex mechanisms that interact as internal or external parts;
- Time and space (geographical) dependencies;
- Large amounts of data from the process;
- A multi-criteria decision making.

The interaction of objects for road, rail and water transportation is considered in this study. The structure of freight transportation objects, which can interact in such a process is presented in Fig. 1.

Each layer reflects the different closely interrelated function of the activities:
- The physical-technical system consists of:
  - The network of roads of landscape automobile transport;
  - The network of sea routes;
  - The network of railways.
  - The infrastructure of terminals involved in the organization and processes of reloading;
  - Manufacture – production, storage and the product distribution system.
- An extra activity is insurance setup for the freight delivery.

The co-ordination system must ensure the synchronous and coordinated activities of work from senders, forwarding agents, terminal operators, sea ferry bridges, ships, trains, and motor–transport drivers.

The layer of co-ordination of the organizational system of agents participating in the transportation process	Sender of freight	Forwarding agent(s) who organize freightage by dispatch terminal			Forwarding agent(s) who organize freight transportation out of the terminal				Receiver of freight
			Operators of combine transport						
	Owners of production and storage systems	Owners of transport means		Owners of sea ferry –boats, ships		Owners of railway wagons	Owners of transport means		Owners of distribution systems
		Transporters of land auto-roads	Terminal operators	Transporters by marine transport	Terminal operators	Transporters of railways	Terminal operators	Transporters by land auto road roads	Distributors
The layer of main multi-modal processes	Production and storage logistics	Transportation by land auto roads	Reloading	Transportation by water networks	Reloading	Transportation rail freightage	Reloading	Transport by land auto roads	Distribution
Layers of networks	Production-storage system	Motorway network	Infrastructure of terminal	Sea (river) roads	Infrastructure of terminal	Railway network	Infrastructure of terminal	Moto way networks	Distribution – storage system
The layer of IS, computer-based data flows and e-services	Smart services, e-services, geographical positioning systems (GPS), geographical information systems (GIS), enterprise resource planning (ERP) systems, client relationship management (CRM) systems, supply chain management (SCM) systems, business intelligence (BI), Traffics, planning systems, forecasting systems, data warehouses, cloud computing services								
The layer of Communication networks	Communication computer and wireless networks, communication protocols, sensors, controllers for transportation process monitoring, and roadside equipment								

Fig. 1 Illustration of layers of the interoperable infrastructure of participating components in multi-modal transportation processes

IV. More Detailed Description of Types of Networks

The network is used to describe the structure, either physical or conceptual. Networks include elements: the set of points and the set of lines which are connecting these points. Most studies [7], [14] have mathematical representation, presented as a two-link network or network of multiple links. Mathematical programs are used for the analysis of network equilibrium. One of the methods used to determine balance flows for transportation network is the Frank-Wolfe method. Programs are more useful in case the size of the network increases. Besides the equilibrium, authors search solutions for capacity restrictions of the network [15] and the shortest and longest routes in the network among the same points (solution delivered [16]).

The works of scientists fall into several directions, such as the design of transportation networks and the geography of these networks. The design studies are dedicated to the structure of networks itself. In case the network is overloaded in one direction, the delay of scheduled flows in the opposite direction increases. This effect requires much more attention to freights' flows. Also, the data flow management applying big amounts of data, service-oriented architectures, augmented reality, and visualization is important for future delivery networks [14]. Besides, long-distance delivery network, last-mile delivery and mode-based delivery aspects are important. Herein, the latest information on dynamic events (for example, traffic congestions, transport mode breakdowns, incoming requests, and route blockages), and transport mode fleets (for example, current position and current state of each transport unit) in the transportation network are mapped in a centralized database, which monitors the execution of the transport plan in the network constantly [6].

A. Long-Distance Delivery Model

Long-distance delivery models are classified into two cases: full truckload and less than a truckload. Also, these types of models may incorporate terminals in the network, which was first studied in 1960. After 1980 new possibilities emerged, such as that of fleet sharing [14].

In a long-distance delivery model, freight transport companies often cooperate to reach efficiency from sharing. For such way of working, information sharing and common decision making among the different stakeholders, improving transportation activity, and reducing fuel consumption, are indeed actual. This concept considers routing behavior, including multiple long-distance delivery operators that interact on the same physical network.

For choosing an efficient time solution, trips are planned between points (primarily, from where to where) to find the shortest trip. For less than a truckload case, it is important to revise the characteristics of physical network, line operations, and load planning.

Routing strategy could be selected among direct loads or loads via terminal. Trips, which are not accommodated by the shortest route, between origins and destinations, must be viewed over the larger physical network.

B. Last-Mile Delivery Model

In a last-mile delivery model, freight transport companies still rarely share a homogeneous transport mode.

The last-mile delivery model is devoted to home delivery. Last-mile delivery and data flow models are the two main complementary and synergic concepts for future logistics. Authors introduced the idea of the last-mile delivery model as "a rich conceptual framework for designing a transportation network that is significantly more efficient and sustainable" where data flow concepts are introduced [15]. However, for the future, we expect that logistics service providers share their infrastructure and delivery services, to decrease costs and maximize gains in the last-mile delivery model.

There are several scenarios which are implemented after the decision-making process in a concrete situation:

- A transport operator performing standard last-mile deliveries shares part of the transport capacity with other operators and modifies the routes by small amounts to satisfy the demand of the customers of the second operator;
- Other logistics operators share the transport with the last-mile transport operator.

These scenarios provide a new way of connecting routes and increasing the capacity in last-mile delivery [16]. In transport operations, this means that data flow helps to reach efficiency improvement in truck filling rates, which can be achieved with information sharing [7].

C. Mode-Based Delivery Model

The mode-based delivery model includes heterogeneous transport (road, rail, and maritime transport) and inter-modal objects (ports, freight terminals, inland custom's warehouses) as components [17], [18]. All these components are important for the establishment of the efficient mode-based delivery model [19]. The highlighted model influences the choice of transport modes or a combination of certain types of movements. Authors also present networks with different configurations [20]. An integrated configuration for freight delivery is critical, in terms of information connectivity, where 20% of journeys are performed by rail in overall inland transport, which is used for freight delivery. This model could also help make logistical trade-offs, e.g., those that are between speed and costs. The mode-based delivery model refers not only to the transport mode but also to other factors causally related to transit time and distance [21]. For this reason, data management in such type of network is at the highest complexity. But due to the use of contemporary communication technologies, all preliminary information is available in real-time, even in the mode-based delivery network [6]. For that, in terms of bandwidth (capacity of delivering parcels), end-to-end delay (time required to provide packages) and jitter (variance of the time needed to deliver parcels) must be continuously mapped for data flow management.

V. Results of Analysis of Data Flows in Mode-Based Transportation Networks

A. The Methodology of Empirical Research

Under empiric research, we would like to define the processes of estimating data flows, which are generated in freight delivery following the network type. The data related to goods deliveries via road and rail networks are analyzed for 53 countries (ES28, Asia, US, NVS and other countries) and 49 time-periods (1970-2018). The data are retrieved from the OECD statistics database [22].

For this study, we perform the covariance and co-integration procedure. This method makes it easier by considering the dynamic nature of the selected variables representing networks. The framework combines time series analysis procedures with the concept of equilibrium and facilitates the analysis of long-term relationships between non-stationary variables. The co-integration analysis is based on the observation that variables often reflect the overall behavior of trends. The combinations of these variables merge over a period towards a general equilibrium, although individual time series change over time. Also, the vector error correction (VEC) model is implemented with the appropriate backlog structure because variables affect each other. In this paper, we additionally consider the case of multiple co-integration relationships. Thus, the evaluation of implemented VEC model is not limited to long-term relationships in β-vectors. Instead, the adjustment process (α-vector) and cross-vectors are also taken into account. Also, an approach that considers the data management in the field of VEC model can explore relevant channels that are responsible for the adjustment process after deviations from long-run equilibrium.

B. Results of Analysis

Covariance analysis shows the relationship between goods deliveries by road and rail networks (Table III).

TABLE III
COVARIANCE ANALYSIS

Probability	Rail	Road
Rail	1	
Road	0.72	1

The co-integration procedure facilitates the determination of the static nature of the time series. Nevertheless, both procedures implemented show that freight flows by rail are, in the long run, primarily driven by their road deliveries rather than the opposite way (Figs. 2-4).

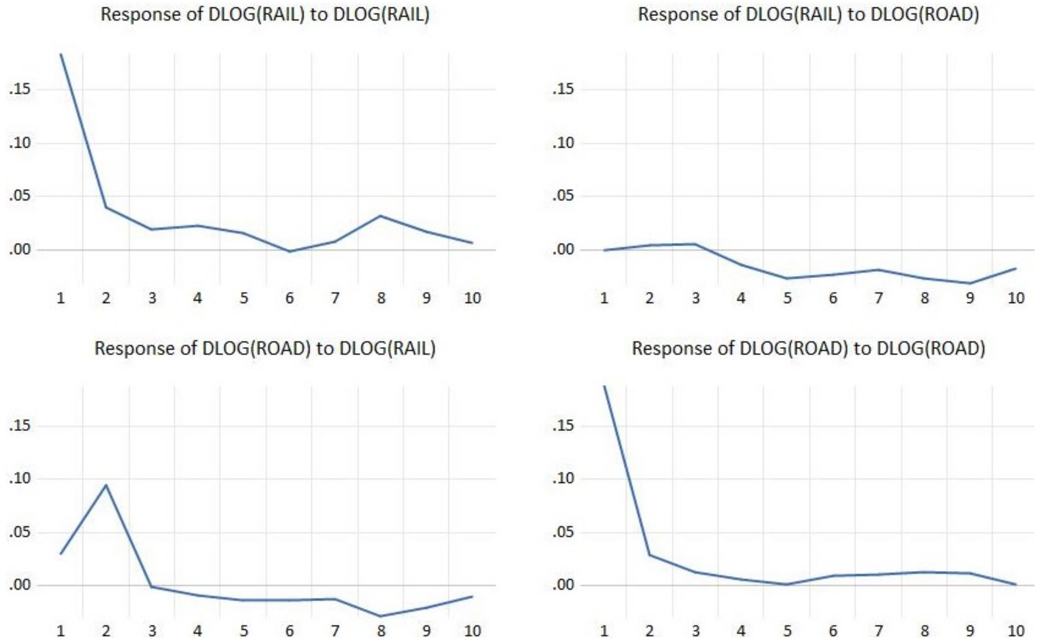

Fig. 2 Response of goods deliveries by road network of tons-kilometers to goods deliveries rail network and vice versa

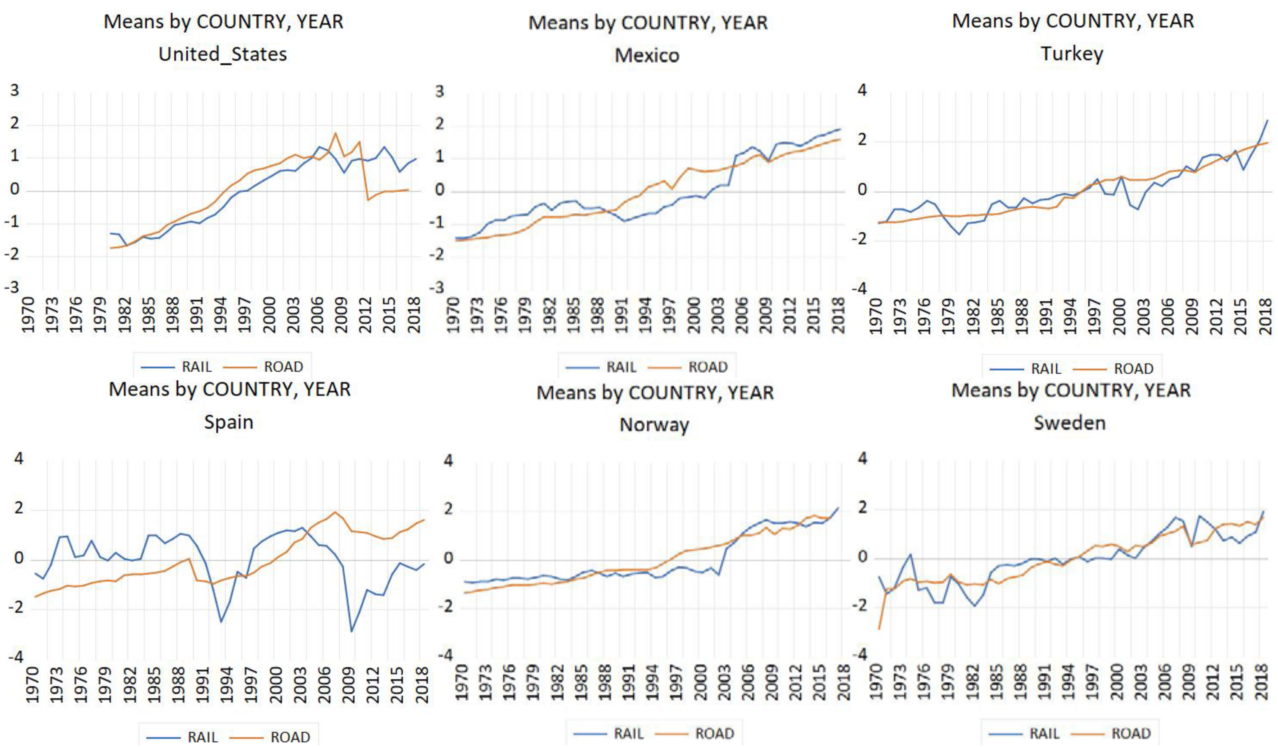

Fig. 3 Samples of analyzed North and South America, South Europe and Scandinavian countries: Long term effect between good deliveries by road and rail deliveries (red color – goods deliveries by road (t-km), blue color – goods deliveries by rail (t-km))

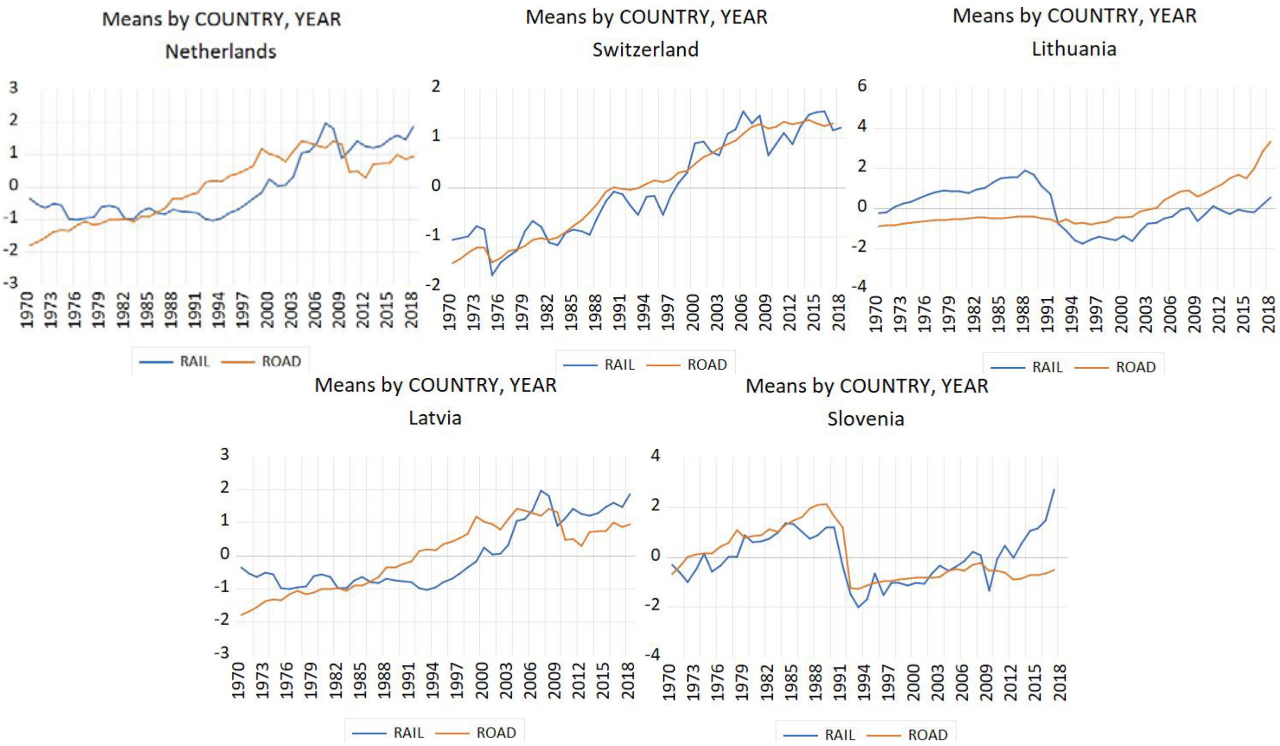

Fig. 4 Samples of analyzed other Western European countries: Long term effect between good deliveries by road and rail deliveries (red color – goods deliveries by road (t-km), blue color – goods deliveries by rail (t-km))

The use of time series guarantees that the loss of information will be avoided due to the first differences' normal use. An error correction model can represent the dynamic adjustment process of the variables towards the long-term balance path. In this way, long-term balance relationships are combined with short-term dynamic corrections. These results support the idea that data flow between road and rail goods deliveries is more important than data flow between rail and road deliveries. By estimating the data flow, we highlight that data from road network are transferred to the rail network.

VI. Conclusions

Our provided approach represents the assessment of multi-component infrastructure needed for delivery of freights by requirements of sustainable and safe transportation. The complexity and dynamicity of such phenomenon are described under the development of possibilities of more effective transportation of freights by integrating multi-modal transport means. The provided framework supports innovations of ICT with activation of developing of smart services needed for such multi-modal transportation components. The proposed framework extracts and integrates some important layers which are needed to support the management of multi-modal transportation. The illustrative interactive structure is presented with a large spectrum of provided infrastructural components. It is aimed at helping smart serviced and going forward to take more attention to the development of more green corridors for transportation.

The transport networks are interlinked together, especially in the mode-based delivery model and in the management of data flow among the components participating in multi-modal transportation processes which interconnect the networks of roads, railways, and sea roads. The implementation of data management for e-services connecting various transport modes is under development, even though the focus to digitalization is vital for the functioning of the transport sector.

For data reporting needs, empirical research is delivered to define the transportation networks specifics. From delivered covariance and co-integration analysis, it is evident that the relationship between networks exists and network specifics indication could help minimize the overloads in data reporting. The study using time-series helps to identify that in the long-term, data flow between road and rail goods deliveries is more important.

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