Article

Integration of Context-Aware Services in Smart System Based on Wireless Sensor Networks for Sustainable Cargo Transportation

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Abstract: The issues concerning the development of the smart systems for the management of freight transport are related to many factors which are influencing by properties of such a complex process and ICT development. We are concerned with the recognition of a wide spectrum of services and provision specifics under conditions of wireless communication networks. Also, we are investigated for the adequate provision of context data with problematic of a definition of such context data and with possibilities to apply formalized artificial intelligence methods for recognition of this context information needs for transportation. In this stage of application of the smart system, we are solving the problem of priority of provision of possible providing services, ensuring of quite optimal quality of data supply channels and restriction of flooding of wireless communication channels. The proposed methodology is based on methods of indication of context-aware situations and integration of such data into the situation recognition algorithms. The constructions of smart service provision system are developed for more safety management of transportation. The experimental results are demonstrated on analysis of heterogeneity of smart services, construction of schemas for service provision priorities, and extension of potential of intelligent transport with intellectual recognition possibilities of context-aware information in the transportation process.

Keywords: smart system; context aware services; wireless sensor networks (WSNs); information communication technologies (ICTs); cargo transportation.

1. Introduction

Nowadays researchers are concerned with problems of integration of digital transformations into the development of smart systems, which can be applicable for the management of cargo transportation processes [1,2]. Transport management processes became very complex. The flows of goods by different kinds of transportation extremely grow. Important issues arise in the development of advanced tools based on the upcoming information and communication technologies (ICTs), which have the potential to adapt to the heterogeneity of communication infrastructure and the diversity of vehicle automation tools [3,4]. New issues are concerning the development of smart services by implementation of data from wireless sensor networks (WSNs) [5,6]. The means for development of intelligent transport systems (ITS) require the adaptability of the heterogeneous infrastructure of WSNs.

The aim of our research is forwarded for development of smart system that corresponding to requirements of usefulness, adaptability, safety and performance of such working regime without flooding of wireless communication channels. Our objectives are related with the stages of creation of the smart service delivery system with functions of monitoring and context recognition that can respond to the needs of cargo transportation processes. The development of the smart system with the integration of context-aware services in the complex transportation processes became an issue. The platform for the development of a smart service provision system is based on the infrastructure of wireless sensor networks (WSNs). The recognition of obtained information must be applicable for implementation in the stages of transportation and provide possibilities for more sustainable cargo transportation management.

An approach is based on constructional methods for componential architecture development of the smart adaptive service delivery system (IASDS). The results obtained earlier are implemented in the development of such system [4,7,8] by hoping that our investigations will be helpful for development of autonomous transport infrastructure with extensible heterogeneous communication channels and equipment, which will help in supporting more safety processes.

New Digital Agenda for Europe until the 2030 year [9] formulate some important objectives, which are influencing the development of ITS. Such objectives are affecting the cargo transportation processes and have a relation with the goals of the Sustainable Development Agenda until the 2030 year [10]. The new Strategy for ICT development until 2030 year [9] formulate several significant innovations, i.e., state-of-the-art ambitions, which influence a strong focus on artificial intelligence (AI), cloud computing and blockchain technology by implementation of supercomputers and quantum technologies, and the means for Internet of Things (IoT). The most important obligations and opportunities are formulated as follows:

• The efforts must be forwarded for the development of the Single Digital Gateway (SDG) [11]; that means that SDG Regulation impose an obligation on all EU Member States to provide access for information of new kind public services (they are formulated as 21), while e-mail services under the seven life events will have to become fully digital (i.e., the whole service delivery process takes place online and cross-borders).

• To support efforts for implementation of free movement of data, protection of personal data [9]. Strict obligations for the EU Member States are created by the General Data Protection Regulation, and the Open Data Directive [12].

• New means have been appearing for development of cybersecurity, by objectives of the Networks and Information Systems Directive [13,14]. Stronger attention for the cybersecurity objective imposes the obligations on the Member States to achieve an appropriate level of preparedness against the cyber-attacks.

All these means influence opportunities for development of an infrastructure for intelligent service provision. The most important requirements for the development of ITSs are such that they have not distracted drivers from the road during the transportation process. The transport management system should provide the required services to the users in the right place and at the right time, and it should be properly adapted to the needs of the users, making only such interventions, which are needful for safety of transportation process.

The main way for increasing the autonomy and efficiency of user-vehicle interaction is the constructional supporting of understandable processes of current and past situations in the AI-based systems and anticipate in the future situations. The ICT infrastructure includes variety of new kinds of wireless communication channels and WSNs [5-8]. The possibilities to integrate the heterogeneous services in the platform of geographical information system (GIS) with online recognition of coordinated moving objects can help in the development of smart system as well. The possibilities to integrate data from sensors into the monitoring process of moving vehicles and helping in forecasting of the processes by assessing the data about surroundings, inspired to support the development of smart system's structures. But problems arise in the restriction of unnecessary information, prioritization of service provision process, limit the flow of information due to excess data transmission focusing on safe driving.

The structure of this article is divided into Introduction and Chapters. Chapter 2 is devoted to reviewing related works according to the research investigations in the context-aware processes and systems development for achieving the important context-aware purposes. The possibilities of smart system development are analyzed in Chapters 3-5, by paying more attention to approach development issues. The architecture of our proposed smart system is presented in Chapter 4. The possible conflicts in scheduling processes and possibilities of resolution are described in Chapter 5. Our proposals of restriction of unnecessary information for drives and mathematical methods for decision support for priority assessment in smart service provision processed by presenting the evaluation algorithms are described in Chapter 6. Experimental results obtained by simulating unsuspected events during the transportation process and context aware service provision are illustrated in Chapter 7. The unsolved questions and limitations of our research are presented in the Section of discussions, with the presentation of our further plans. In conclusions, the summaries and scientific novelty extractions are presented.

2. Related Works

Development of new kinds of services for transportation support is related to the development of ITS with the spread implementation of the advancing functions of ICT [4,15]. The new kinds of wireless sensor systems, equipped in road sites and vehicles are applied for the management and control of transport means [16-21]. But adaptable interaction between transport means and infrastructure of road site units (RSU) requires new investigations. Especially we would like to pay more attention to smart and autonomously working subsystems. In the ICT infrastructure can be integrated the vehicle Ad Hoc Networks (VANET) [20]. VANET can be deployed in some ways and one of them is over long-distance communication, based on mobile protocols such as 4G, 5G or 6G networks [22-24]. The short-range technology such as Wi-Fi and/or DSRC is used.

Various types of sensors can be integrated into vehicles for engine monitoring, sensors for monitoring of human health, and the environment, and became providers of monitoring data. Sensors became the information gathering sources, which can be used to sense the context which can be related to the cargo transportation and management processes.

The integration of heterogeneous types of sensors can be included in the monitoring system of the cargo transportation process:

- Physical sensors of environment monitoring;
- Sensors for monitoring of working regime of vehicles;
- Human health monitoring sensors.

The possibilities for integration of functionality of sensors in development of adapters for integration of smart subsystems with functionality of Geographical Positioning System (GPS) and Geographical information system (GIS).

This approach is backgrounded by the methods of recognition context-aware data by classifying sources that are obtaining from speed measures, accelerators, temperature measures, radar positioning systems, video provision, etc. Sensors of the infrastructure of RSUs help in monitoring traffic information, hazard warnings, recording of interaction with other cars, e-calls for warning information provision, and more. In the field of research for the development of advanced systems, the authors are offered several solutions for the development of adaptive service systems [3,7,8].

The problems of information gathering from environmental and dissemination in dynamic environments are presented in [25]. Monitoring data have to be directly linked to a higher level of representation by the level of ontology and other mechanisms of and knowledge extraction. Questions, how to understand the context arise in many research works [18,21,26]. The definitions of context diverse and short review of such analysis are presented in Table 1. Some authors similarly define the context, but with some interpretations. The concept of "context" is very broad.

Table 1. Review of analyzing aspects of the context applicable in transportation area

The domain of analysis of the context	Definition and analyzed aspects of the context in transportation	Works of authors	Level of influencing components for the smart system development [range from 1-5]
Surroundings and people factors	Location and identity of surrounding, people and objects and its object changing	[26]	[4-5]
Localization and meteorological data recognition	Location, the identity of people around the user, time of day, time of year, temperature, etc.	[27]	[4-5]
Conceptual definition	Set of entities which interested physically in conceptual states	[28]	[3-4]
Application factors	Application settings	[29]	[1-2]
Environmental surroundings	Environment reification, or anything that describes the surrounding environment in which the system performs	[30]	[4-5]
Environment factors	Time, environment, product and company information	[31]	[4-5]
Circumstances factors	Set of circumstances of facts that surround a particular event or situation	[32]	[3-4]
Circumstances triggers	The circumstances triggering the event, a claim, or the idea, which allow it fully to understand	[33]	[4-5]

Some problems arise in V2V communication service provision, i.e., assessment of quality of gathering information and problem of flooding of wireless channels [32-35]. A wide spectrum of communication protocols can be chosen in the architecture for gathering, transmitting, and dissemination of information. But we have restricted our consideration and do not analyze variety of communication protocols. In possibilities of communication channels are paying more attention to solving the problem of flooding of wireless channels by providing services. The approach concern evaluation of priorities for service provision with the purposes of ergonomics, safety for transportation, needfulness, and adaptation.

The concept for "Context Quality" – QoC was established by [33] and has interpretation as "a set of parameters that reflects the quality requirements and properties of context data [34]. We are concerned with inter-disciplinary concept, and interpretation of it for construction of AI systems have had possibilities to combine as well as the methods from behavioural science, operating and embedded systems, communication networks, and other fields.

This creates a huge gap between the high requirements due to the complexity of working for mobile systems, services, and operations and the context that is derived from the environment. The requirements for IoT application involve several aspects such as describe adaptability, ingenuity, and flexibility [35].

Following conditions of the heterogeneity of devices, a high level of mobility and changing topology requires the high quality of management of context information and this is extremely complex, and the errors and partial information can be significant in this area.

Applications take context information from the context-aware modules and adapt their actions following the changing context [36]. The management of context which specified by using fast-changing topology under the environment such as vehicular communication networks is a challenge due to several factors [37]:

- Context becomes important due to the high mobility of nodes. Context information is intricately linked with physical locations. But it may be challenging to update this information due to the repeating disconnection of nodes from the source of context.
- Relevance of temporary context is caused by dynamic changes. Context gets temporary importance due to dynamic situations.

Especially in services of V2V communication (when the Ad-Hoc networks can be created), the context can become ambiguous and redundant, because the service provision process in Ad-Hoc network it is difficult to regulate the flow of context information. Such problems were described in [38] works, where the context state is analyzed as the collection of current sensor readings. The reasoning methods for recognition of context information have properties of multi attributing and multi-dimensionality. We can mention the MAUT as the multi-attribute utility theory that was proposed by [39] for integration of heuristics rules and expert's experience. In decision support systems became popular the implementation of the methods of weighting of parameters, when it is possible to describe the dynamically appearing situations. Using the MAUT the space of situations can be expressed in the model and under the recognition of adequate one, the information is provided from the model (e.g., the state of the context and the description of the situation space expressed) and calculates the degree of confidence that the situation has occurred. The calculated reliability is compared with the confidence limit (a comparison of the calculated reliability with an individual situation of a certain threshold, which allows comparing the results calculated for different situations).

The dynamic properties of transportation are analyzed in many research works by revealing important properties of the context data [40]. By transportation and recording of information from dynamic objects, we are deal with heterogenic communication structures, with context which can have different importance of real-time updates. The situation assessment is concerning with evaluation, not from one individual sensor, but it will try assessing the broader spectrum of given data.

3. The Hierarchy of Decision Support for Sustainable Management of Cargo Transportation

The objectives of the research are related to developing the infrastructure of the system for smart service provision for drivers in cargo transportation processes by helping to avoid accidents, accident investigation afterwards, or to avoid traffic congestion. Investigations in development of services in the areas of vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communication are important for our proposed approach as well. Such processes are related to decision support processes which are concerning some levels of hierarchy in cargo transportation by sustainable requirements.

The decision support processes are introduced in the system using AI and are related to advance services and can help in the improvement of the whole management process. The stages of development of smart service provision system are analyzed by including the transportation scheduling issues and recognition of priorities of information transferring for drivers during the whole cycle of transportation.

Important characteristics of goods are recorded in CARNET-TIR cards (i.e., e-documents and their management system issued according to the Transport International Router and data recognition on TIR cards). Such e-cards are reflected information on the specifics of the goods and transportation legislation.

The hierarchy of decision-making is presented in Figure 1. It is assumed that at the planning stage, cargo transportation targets are set based on contractual agreements and projected delivery requests, and decisions are made in the planning phase. In the planning phase, the cargo transportation sequence is determined and transmitted to the control phase in the form of target / defined points. In the collection phase, performance variables are included, ensuring tracking of the set values of infrastructure, driver, and vehicle. In the control and response phase taking decisions on conflicts is settled:

- Leave the primary plan ("Leave plan");

- Change the primary plan ("Change plan");
- Remove the original plan ("Remove original plan");
- Remove the incompatibility ("Remove incompatibility").

Real-time measurements of process variables and information on failures and disturbances can be returned to the planning phase to inform transformation decisions.

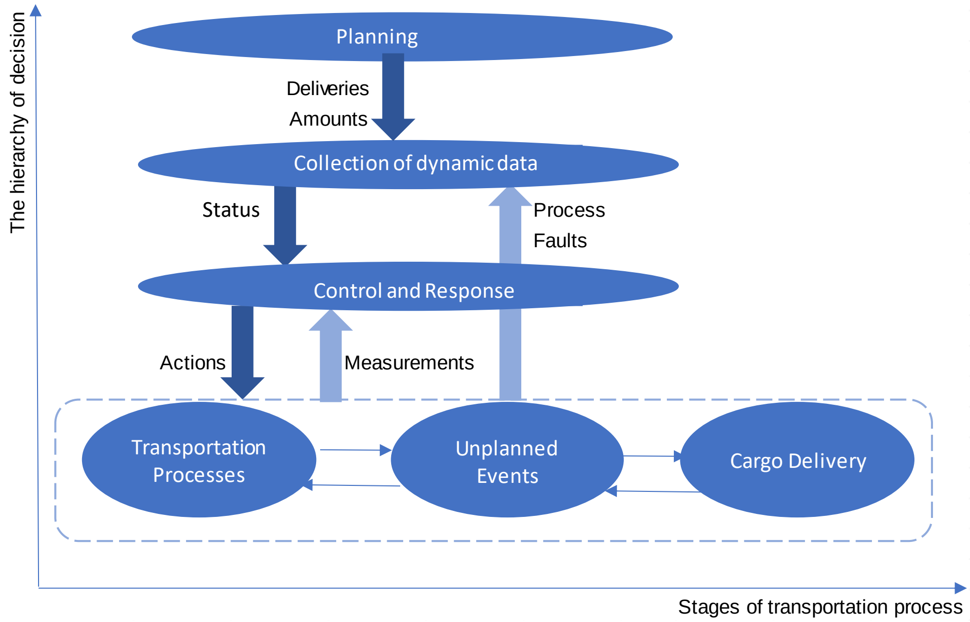

Figure 1. The hierarchy of decisions provided for cargo transportation processes

The original plan can be scheduled due to some reasons and can be incompatible - equal likelihood for the change of the original plan or cancel it. Make the decision, it is likely to be room to modify, relocate by setting a new time or leave without changes. If there is no possibility to shorten or relocate the initial plan when it is possible to shorten its duration.

4. Requirements for Construction of the System Infrastructure for the Heterogeneous Service Support for Cargo Transportation

For enabling the developments of systems that can organize the transportation in the manner of safer, more reliable, more economical, and more comfortable vehicles it is needful to implement the achievements in the field of many fields and especially follow the requirements and possibilities of adoption of DSRC (Dedicated Short-Range Communication) and IEEE 802.11p [41,43] as standards for Wireless Access in the Vehicle Environment (WAVE) [18-20]. Such protocols allow achieving a new level of service delivery. Services are arranged in-vehicles on the base of DSRC and WAVE allow to achieve requirements of ITS development and try to help in achieving road safety, more optimal traffic management, and more comfortable services for drivers. The connection between the vehicle and the roadside units (RSU) became communicative and create the needful communication. In vehicles, it is possible to equip with an onboarding unit (OBU) and several units dedicated for application (AU) [23,41,42]. The Ad Hoc domain consists of vehicles equipped with an OBU. Vehicles communicate with other vehicles that make up MANET, which allows a fully distributed vehicle to communicate with precise coordination. In the field of infrastructure, RSUs can connect to infrastructure by networks or by Internet providing OBU access to the infrastructure network [19,20,23,41,42].

The attention is drawn to different types of transportation scenarios (in cities, across rural areas, crossing border points, uploading at terminals, etc.). Especially for construction of identification algorithms for recognition of different situations and their importance in transportation management at the on-line regime. These methods are sprightly influence the service provision process for drivers.

By analyzing warnings, we have construct algorithms that consist of the assessment of conditions of some unpredictable situations of warning (collisions, lane changing, or others) including the emergency video transmission possibilities and other prediction of event and going forward for construction of systems with ability of more predictive properties of transportation management. Such assess information has be disseminated and smart system can have possibility to choose the way of information provision by sending it directly to drivers or by receiving it into the automatic active safety system.

Services providing for comfort and entertainment category are referred to that category which is not related to safety. Such a type of service aims to improve the comfort of drivers (and/or passengers). Service of the comfort area can provide meteorological and traffic information, as well as details of the location and prices of the nearest petrol station, service station or hotel.

The taxonomy of VANET can be divide in:

- The field-level planning;
- Control in which the processes are performing operatively and proceed during transportation processes.

5. Proposed Architecture of Intelligent Adaptable Service Delivery System for Cargo Transportation Process Management

The development of an intelligent adaptive service delivery system (IASDS) requires the integration of immediate environmental identification and data management techniques.

A more detailed conceptual architecture of the smart service provision system is proposed in our previous works [3,7,8]. Recently, a special attention has been paid to the field of changing the topology of mobile networks and providing information restrictions. In vehicles, drivers are facing with increasing flow of information. Special AI methods must be integrated into such type systems by solving major problem for obtaining useful knowledge from data sources, expert practices from knowledge base (KB).

Important question arises in construction of KB - how to adapt and how to construct the tailor-mode of service provision in real-time, based on the knowledge gained from the context. In provision of such services raises a few issues:

- To recognize - which information is linked with the response field and its importance in a prioritized way;
- To decide - what services have to be provided priory for the users (drivers of managers) which are interested in providing support;
- Express in the control models such mechanisms of the customization of service provision according to user questions and behavior analysis;
- To identify which security services should be provided automatically and recognize their priority.

What raw data are included in the acquiring processes from different types of sensors are presented in (Table 2).

Table 2. Types of sensors that can be equipped in transport means and RSU for context assessment

Types of sensors that can be equipped in vehicles (inV)	Virtual equipment	From other vehicles	Road site units (RSU)
Video cameras	Smartphone/ Tablets	VANET	RSU for speed recognition
GPS	Calendar	Services provided from Ad-Hoc Nets	Dynamic RSU for traffic regulation
Microphones	Reminder	Reminders	Dynamic info black-boards
Movement dynamics	Information from social networks	V2V communication services	Monitoring and info about conditions of roads
Sensors providing vehicle engine working parameters/ fuel assumption	CARNET/TIR mark equipment		Sensors for meteorological conditions
Power hit sensors			Info from road directions
Temperature measurements (inside and outside)			

The structural architecture of proposed intelligent service delivery system (ISDS) is presented in Figure 2. We are using the means of componential representation of packages and components by implementing the Unified Modeling Language (UML) notation.

Two main packages for data monitoring are created as the *Context data acquisition subsystem* (it integrates data monitoring functions obtained from sensors) and *Data dissemination subsystem*. The data from acquisition subsystem are provided for evaluation modules, i.e., subsystems, which can provide context acquisition and dissemination functions of context data. There are working mechanisms of classification of services, which detailed description is presented in next Chapter. The monitoring data are collected in data-warehouses (DWs) which are working in real-time applying cloud computing possibilities and gathering raw data from available sources.

The *Chanel quality management subsystem* enables the performance and pre-processing of data by enabling to reduce noises. Part of interfaces plays an important role as adapters for gathering data from different type of heterogeneous sensors and can help in integration of data to conceptual structures of repositories of DWs. The data for processing are transmitted through the components of part of interfaces, which have different components of embedded systems, from which data and are transmitted for the *Context evaluation subsystem*. The algorithms of such systems can use the clustering method and formulate requirements for information flow in the *Situation's identification subsystem*.

The data for context acquisition is obtained from some kinds of sensors (Table 2 and Table 4) and can be divided in locally or/and globally arranged. Locally arranged sensors can provide information about the vehicle environment. Data from other vehicles have mixed character. Data from sensors are flowing, classifying, and are passing from the *Subsystems of service support* (Figure 2).

The KB include the multi componential structure of such parts:

- Computer based ontology of application domain of transportation;
- Rules of management of transportation processes;
- Identification of situations that have to be important;
- Extra organization of decision support and control under the conditions of unsuspected events.

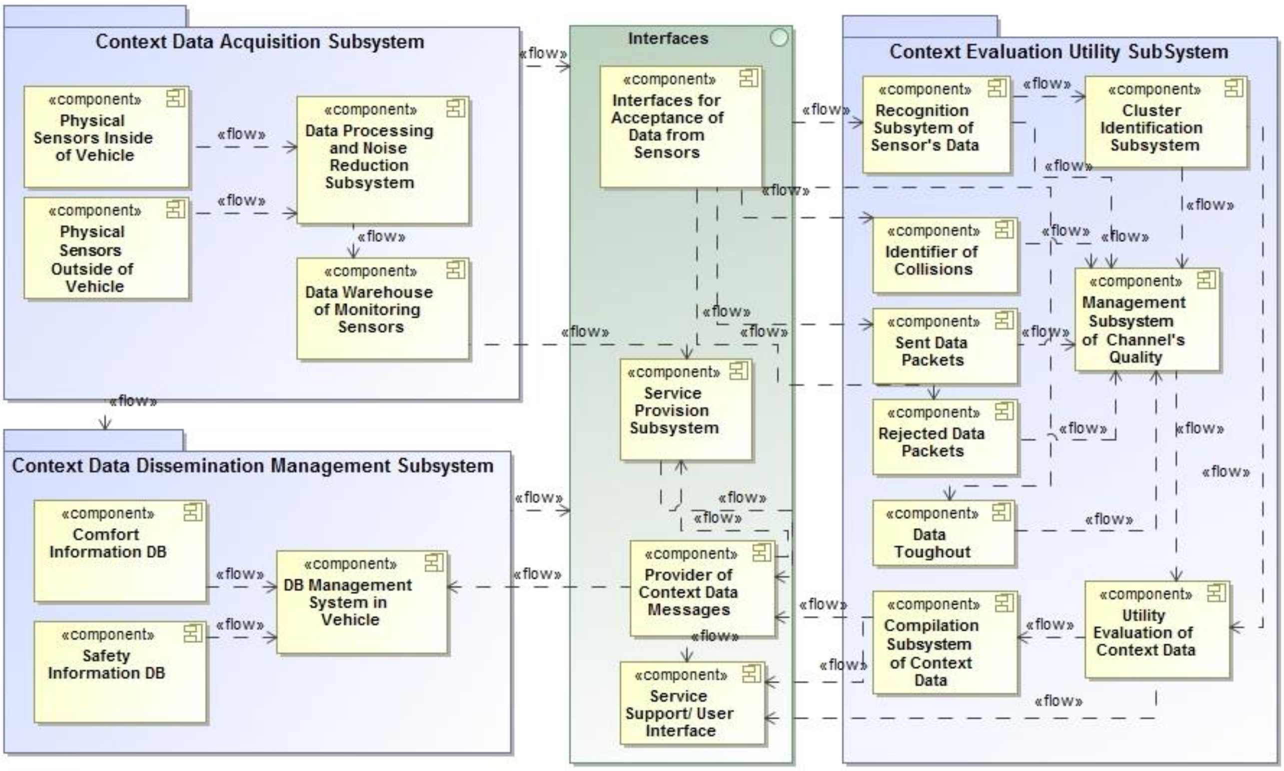

Figure 2. The architecture of proposed IASDS for service support by recognition of data from sensors

Any identified situation implies a certain mechanism to be used for the different transmission of information. The *Subsystem of situation identification* implies provision of different services, which are selected through the possibilities of remote cloud service platform. The subsystem of interfaces of service support is important parts, but we have restricted the consideration no more detailing the description of this part.

5. Conflicts' resolution in the actual scheduling process

The initial step is the identification of the real conflicts that have arisen in creating the scheduling process. Operational incompatibility happens when a new unplanned situation occurs. It is important to notify that there are cases that are not generally considered as conflicting but as individual multifunctional work.

Once the existing conflicts in the data set have been collected, the response is necessary helping to decide which strategies to use to solve them. To proceed, father, the revision step is used to determine whether a modification of the conflicting activity is in effect. For each conflicting couple, if one of the activities was an activity, other modifications activities determined the type of resolution. If neither activity was carried out, there were modifications to both activities monitored to determine possible resolve. Finally, when both activities are resolved out, the incompatibility is deleted in the list of identified conflicts. In addition, all conflicts that were not caused by operational changes to properly resolve the primary incompatibility for overlapping in time situations are eliminated from the list of conflicts and are taken for re-planning.

Theoretically, there are a lot of possible activities that contradict the activities now planned activity that the user will not enter the scheduler because it will be rejected directly and never planned. For this reason, the elimination of conflicting activities is not considered an option in the decision making, but rather the default choice in case any resolution strategy fails.

To create a *conflict resolution model*, the key attributes that should affect the conflict resolution process were first identified. The key attributes could be classified into such groups [43]:

- Driver-related characteristics. Such a group covers driving behavior and personal temperament. Driver-related characteristics show the socio-economic orientation of the vehicle's driver that is expected to affect cargo delivery needs and the ability to re-plan certain activities.
- Performance-related characteristics. These include things like the trip duration, vehicle location, fuel consumption, the aim of the trip and the constructed route information. Performance characteristics define activities and generally reflect how much is needed and the degree of flexibility.
- Conflict-related characteristics. This group represents the type of conflicts, the initially planned activity is overlapped and waits until the activity is realized. It is thought that these symptoms listed above may have the greatest impact on driver expression behavior. The conflict-related characteristics determine the results of conflict resolution and priorities that are settled in repeating situations.

The main descriptive statistics about conflicts and decisions are used in the model's construction.

Compared to social and demographic variables, the signs of conflict they selves have an important role in making decisions. When the number of overlapping initial activities increases and the number of deleted activities also increases and the number of modifications of activities decreases. However, the time available seems to have less impact on the decision selected, only a small model reduces the likelihood of modification of the initial activity and increasingly deletes activities that seem the opposite.

The specifics of the conflict activities were expected to have a significant impact on the resolution strategy chosen. In general, the original activity, which is characterized by greater flexibility, was likely to be only slightly more likely to be replaced. For example, original activities with more flexibility (leisure flexibility or driver personal flexibility only) have a higher modification percentage and a lower percentage of deletion. However, the results are not so clear to those in conflict activities. As for time horizon planning, it was generally observed that this is the time horizon of both planning as original and controversial activities increase (i.e., more are planned), activities are likely to be changed slightly.

The duration of the performance is the final characteristic of the activity. There is a noticeably clear pattern, gradually decreasing deleting activities and increasing modification of activities with increasing duration. For example, modified only one-third of short initial sessions (duration <2 h) compared to two-thirds of long sessions (> 6 h); whereas one-third of short-term activities have been deleted, compared with half of the long-term activities. This has been expected for so long-duration trips are also priority activities that cannot be easily carried over to the next day or missed. The tendency is less clear for conflict activities but is also much higher for exceptionally long conflict activities modification observed compared to deletion.

Frequency distributions of discriminatory strategies show some common patterns of interest, but interactions between variables and their relative importance cannot be determined in this way. For resolutions of represented conflicts some cases are analyzed. The model is expected to show similar trends as noted above but will do so capture in more detail the impact of each variable, in addition to the driver and time flexibility of the variables and their presence which have not been considered before.

The scheduling of vehicles is the research subject for the last four decades. Many authors investigate routing and planning aspects. While there are many surveys on the topic of vehicle planning, there are none that considers the latest research on modelling and decision methods. Because a lot of new research has been done over the last few years, the authors make an overview of recent models. These models could be sub-divided into:

- Models, which take into consideration relevant metrics, targets or combinations of targets;
- Models, which follow the integrative optimization of routes for further business decisions;
- Models, which investigate more accurate and more pronounced aspects.

The most often scheduling models to consider costs as the main objective, but such models miss other important criteria, which are additional objectives. These criteria could be broken into such categories:

- Performance: level of services, quality, penalty, navigation; congestions;
- Planning: work and drive balance, number of drivers, timing, duration of operations, number of uncertainties;
- Routing: locations, the quality of infrastructure, speed, type of freight, lancet, road taxes;
- Reliability: the probability of failure, truck readiness, driver behavior;
- Sustainable and environmental factors: fuel consumption, emission, safety criteria.

Mentioned criteria may appear as the objectives (in a weighted, hierarchical, or multifunctional formulation) or as separate variables.

6. Integration of Methods for Recognition and Processing of Context Data for Transportation Processes in IASDS

For the cargo transportation process, it is needful to build the services with adaptation properties. The intelligent adaptable smart service delivery system (IASDS) under development can be constructed for the autonomous provision of such services for drivers. We must construct the algorithms, which are used for defining the priority of service provision, when it is right at right time and the right place. The system is aware of the surrounding environment and can help to identify the current, past, and likely future situations by the whole trip duration and help in choosing the right direction.

The infrastructure of road equipment has support with a variety of sensors. The information (data) is provided from a wide spectrum RSU and can help in monitoring transport and other types of context data during the whole journey. Sensors' data can be used for situational awareness. Such monitoring data during the transportation process are highly complex. The data structures can have different provision modalities, different measurements can have huge volumes, and can have different kinds of complex interdependencies between sources.

For the IASDS development, the important part is the identification of situations by understanding relationships between them, their context, and manage these situations, because otherwise, the system may function incorrectly and not properly adapt to the needs of the user. The system should be aware of several simultaneous situations or the fact that they cannot occur simultaneously, e.g., a car cannot be parked and driven on a highway at the same time. It is a difficult task to have complex operating conditions of the system, high level of dynamics, heterogeneity of sensors, inaccuracy of sensors and other circumstances. The situation is influenced by cancer movement scenarios. Differentiation appears if transport rides by highway, city, country or it is inbuilt.

By analyzing our subject, some questions arise:

- How to obtain contextual information,
- How to connect and disseminate them in-vehicle networks.

We are following the definition of term of context as it is "*any information that can be used to describe an entity's situation, whether the entity is a person, place or object the interface between the user and the system, including the same user and system*" [31].

The part of the system that rejects some parts of not useful information can help in reducing network loads, but without losing data quality and without reducing the efficiency of the road safety in the multimodal system. To address these, an intelligent adaptive approach can be proposed that allows the use of environmental context information, including location, time, environment, user status, vehicle dynamics, information from other cars, considering network conditions, available resources for data packet formation and transmission solutions.

Considering the identified environmental parameters, it is proposed to create a subsystem of the context assessment (based on a software system), which would evaluate the usefulness of each contextual message. The data warehouse DW of sensor's data is extending by meta-model and is being formed for local storage, by implementing of the mathematical background for forming of algorithm structure that can provide a more formal description of data transmission procedures which have to initiate the information transferring to other nodes, and/or transmission procedures to the server.

The matrix M_L is constructed for evaluation of the usefulness of each data message which can be expressed as Cartesian product. The values express the usefulness of messages of local context, where the first index i of d_{Lij} express the data form message obtained from the sensor (s_j) which index is j.

$$M_L = \begin{pmatrix} d_{L_{11}} & d_{L_{12}} & \dots & d_{L_{1n}} \\ d_{L_{21}} & d_{L_{22}} & \dots & d_{L_{2n}} \\ \dots & \dots & \dots & \dots \\ d_{L_{l1}} & d_{L_{l2}} & \dots & d_{L_{ln}} \end{pmatrix} \quad (1)$$

The predictive usefulness of the concrete context data message is weighted by a function that assigns values to each data message (m_i) from sensors (s_j). The values of items of matrix M_L are calculated according to the following formula (2):

$$d_{L_{ij}} = (Ty_j + H_j + Ex_j) m_i cr_i Pr_i,\ i = 1,\dots,l,\ j = 1,\dots,n \quad (2)$$

In formula (2) the Ty_j express values of importance of the context data type, which are assessed from the range of [1-3]. The means of such range are: value 1 is assigned for expression of messages from comfort area; 2 is assigned for messages of mixed type of comfort and safety are, and 3 is assigned for messages from security area. H_j is the set of parameters indicating the importance of message for future decisions, which values are from the range [0-1] and are indicating whether the message should be stored for a longer time, and such values will be used for historical assessment needs, i.e. the assignments for messages are equal to 1; if the messages are not important for future decisions the assignments are equal to 0. The parameter Ex_j express the data exchange area and digital values are assigned from the range [1-4], by indicating such cases: 1 – when the message is from the type of communication of *Vehicle to Manager (V2M);* 2 – when the message in local environment of vehicle (*INV*), 3 – when the message is from communication of *Vehicle to Infrastructure (V2I)*, 4 – when the message is from *Vehicle to Vehicle (V2V)*, and set of parameters Cr_j express the coordinates from which the data message was generated at the real time point t_i and such values are expressed as $cr_j{}^{t_i}=\{cr_j{}^{t_i,latitude};\ cr_j{}^{t_i,longitude}\}$.

The message priority can be calculated by $\Pr_j = 1 + \frac{I_j}{A_j}$ and values are assigned according to the normalized values of the set-in interval of [1, 2, 3]:

If assignment for message became $Pr_i := 3$, it means that the message $m^{tj}{}_i$ priority at the moment ^{tj} is critical and must be sent immediately for driver and stored in the corresponding DW; if assignment for message became $Pr_i := 2$, it means that the message $m^{tj}{}_i$ at the moment ^{tj} has a medium priority; and if assignment for message became $Pr_i := 1$, it means that the message $m^{tj}{}_i$ at the moment ^{tj} is not important and could be rejected.

The importance of the message can be assigned in the set range [0, 1], where 1 is with the safety related message and 0 is a comfort / information message.

I_j is the function for expression of the message age with normalized values, which can be chosen from the set of values from the interval [1-3], which is calculated according to the algorithm that is expressed by (3), where T_M is the difference between the current time moment and the time moment when the message was created.

$$A = \begin{cases} 1, \text{if } \mathrm{T_M} > 5s \\ 2, \text{if } 1 < \mathrm{T_M} < 5s \\ 3 \text{ if } \mathrm{T_M} < 1s \end{cases}$$

For more detailed description of types of communication under analysis, the infrastructure of communication between vehicles and RSUs can consist of three areas: the INV is communication of the local area of vehicle that involves onboard unit (OBU) and several application units (AU). The Ad-Hoc area consists of cars equipped with OBU devices and communicating directly with each other, thus forming the MANET, i.e., Mobile Ad-Hoc Network, which ensures fully distributed, decentralized communication. In the area of infrastructure, the RSU can connect to the infrastructure of wireless networks or communicate by the Internet, thus allowing the OBU to access possible infrastructure objects.

The devices of OBU can be classified as WAVE are usually placed in the car local area, and used for exchanging information between the RSU and other cars. It has *Resource Command Processor (RCP)* and can explore the resources with reading/writing memory that are used for storing data in DW. The devices of OBU use interfaces that are dedicated to that type of communication that can connect the vehicle with network devices and other OBU devices by using radio technology, by covering the IEEE 802.11p standard.

Extra devices could follow other radio technologies, like IEEE 802.11a / b / g / n / ac / ad, and others. The mobile access protocols such as 4G, 5G and upcoming 6G, can be used as well as the LTE, and others.

The devices of OBU can be connected to the RSU or other OBU via a wireless connection using the channel IEEE 802.11p for radio frequency, which is responsible for communication with other OBU and RSU devices and provides communication services to the application device. OBU covers such main functions: Wi-Fi access, Ad-Hoc and geo-location-based routing, network load management, reliable messaging, security, and IP mobility [21].

AU is the device that a car is equipped with. With this device, the service provider provides services using the capabilities of the OBU. An AU can be a device dedicated to specific security programs or a regular device, such as a smartphone or tablet that provides Internet services. The distinction between OBU and AU is often logical [41-42].

RSU is facility of WAVE devices that are installed near the road or in other specially designated areas, e.g., at intersections or parking lots. This device is equipped with short-range wireless technologies such as IEEE 802.11p or others that connect it to the network infrastructure. According to [41-42], the main functions and procedures associated with RSU are:

• Extend the distance of the Ad-Hoc network by forwarding information to other OBUs or RSUs;

• Run safety programs such as crash warnings, road surface information, etc., using V2I mode and acting as a source of information;

• Provide OBU Internet access.

Areas of automotive communication

The In-Vehicle domain consists of an OBU and one or more of AUs. OBU and AU can be realized as one device. In the automotive field, contextual information is collected from installed sensors and stored in a database [41-42].

V2V domain is the area of an Ad-Hoc type networks which is consisting of cars equipped with an OBU. The cars communicate with each other via the OBU, thus forming a MANET that provides communication in a fully distributed decentralized manner.

Cars can communicate directly with each other, if the direct wireless communication between them is possible, by forming one-jump car-to-car communication (V2V). If direct communication is not possible, the data is transferred to other cars as intermediaries until the addressee is reached. These forms of a multi-hop relationship are described in [21].

Infrastructure of the domain is related to all these parts and especially for the RSUs connecting infrastructure of networks or by the Internet by providing OBU access to that network. OBU devices communicate with various nodes by providing non-security services using other mobile technologies (GPRS, GSM, 4G, HSDPA, UMTS, and WiMax) [41-42].

The componential architecture of the service delivery subsystem and connection with other components and packages is presented in Figure 3.

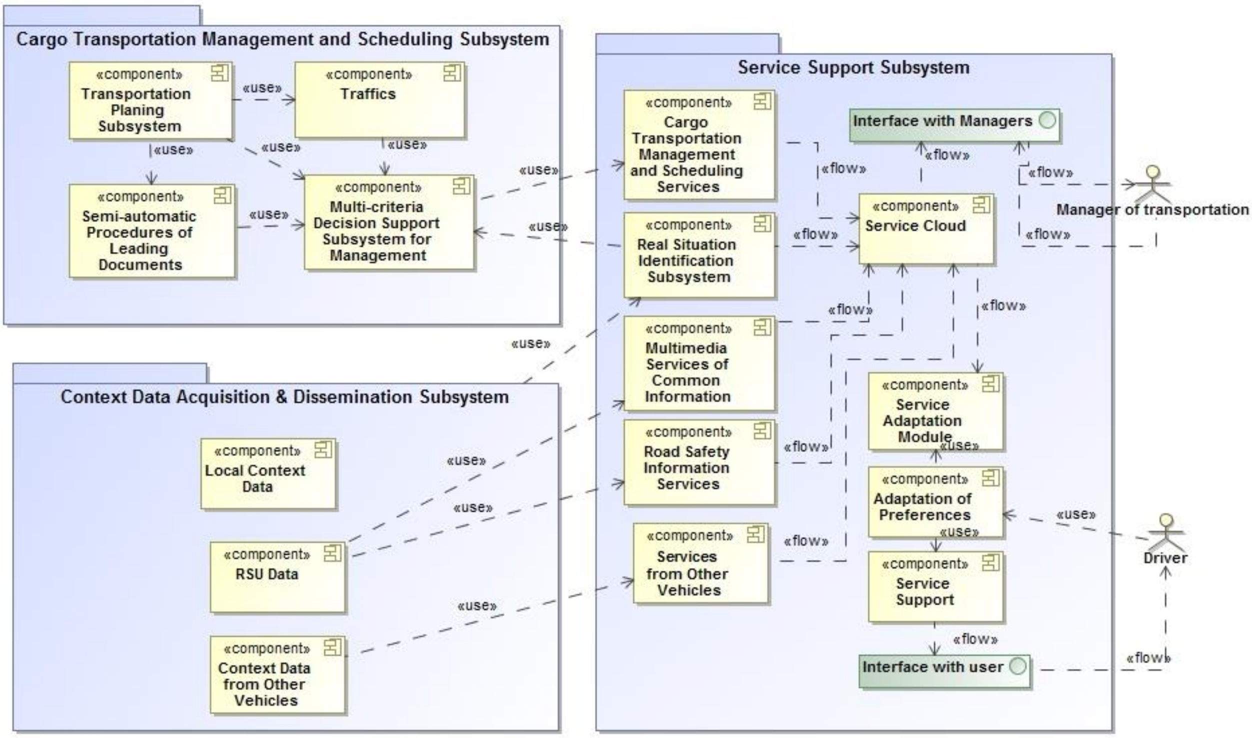

Figure 3. The architecture of proposed IASDS for service delivery by recognition of data from sensors

To reduce the amount of data transitions we are provide the structure and obtaining algorithms which can help achieve better efficiency in provision of selected messages. The matric M_O is used for storing the context utility values. The items d_{oln} of matrix M_O, where indicate importance of the data, where l index indicate the data from message (m) provided for n car (v) (4).

$$M_O = \begin{pmatrix} d_{o_{11}} & d_{o_{12}} & \cdots & d_{o_{1n}} \\ d_{o_{21}} & d_{o_{22}} & \cdots & d_{o_{2n}} \\ \cdots & \cdots & \cdots & \cdots \\ d_{o_{l1}} & d_{o_{l2}} & \cdots & d_{o_{ln}} \end{pmatrix} \qquad (4)$$

The predictive usefulness of a contextual data message is weighted by a function that assigns value m_l to each message to be transmitted to the vehicle (car) v_n. The values of items of matric M_O are calculated according to formula (5), which can be expressed as Cartesian product:

$$d_{o_{ij}} = (Ty_j + Exc_j + Z_j)m_i cr_i Pr_i n_i,\ i = 1,\ldots,l,\ j = 1,\ldots,n \qquad (5)$$

Where Exc_j is a parameter of a special non-confidential data set, which assignments are chosen from the range [1-4], indicating the data exchange area (1 - V2M, 2 - INV, 3 - V2I, 4 - V2V), n indicates the number of cooperating cars in the cluster, Z_j is the communication channel quality prediction indicator that can be calculated based on (6) formula:

$$Z_t = \frac{1 + \left(\frac{C_t + D_t}{2}\right)}{Tr} \qquad (6)$$

Where C_t is the collision parameter calculated by formula: $\mathrm{C} = 1 - \left(\frac{1}{1 + \mathrm{c}_{t\text{-}1}}\right)$, The D_t is a packet of rejection parameters, which could be calculated according to the formula: $D = 1 - \left(\frac{1}{1 + d_{t-1}}\right)$, and Tr is the bandwidth parameter calculated according to the formula: $Tr = 1 + \left(\frac{tr_{t-1}}{100}\right)$.

The context data for exchange with a hybrid VANET cloud subsystem have the context utility values, which are stored in structure by representing the matrix (M_c), there index l express the values of data of messages (m_j) for recipient entities (r_i) by presenting such matrice as (7):

$$M_C = \begin{pmatrix} d_{C_{11}} & d_{C_{12}} & \cdots & d_{C_{1n}} \\ d_{C_{21}} & d_{C_{22}} & \cdots & d_{C_{2n}} \\ \cdots & \cdots & \cdots & \cdots \\ d_{C_{l1}} & d_{C_{l2}} & \cdots & d_{C_{ln}} \end{pmatrix} \quad (7)$$

The values of usefulness of the context data messages are predicted and can be espressed by the weighing function that assigns the values to each message that is to be passed to the recipient entity. The values of such stucture can be calculated according to formula (8) express as Cartegian product:

$$d_{C_{ij}} = (Ty_j + Hx_j + Exc_j + Z_j) m_i cr_i Pr_i,\ i = 1,\ldots,l,\ j = 1,\ldots,n \quad (8)$$

Where Ty_j is the set of reduced parameters Ty_j assigned by values form the range [1, 2], where value 1 is assigned for messages from comfort area, value 2 is assigmed for messages from comfort and safety area, Hx_j is a parameter for a special non-confidential data set from which values are assigning in the range [0, 1], by indicating whether the data should be stored historically or not.

7. Illustration of Experimental Results by Simulation of Functionality of Prototype System of ISDS

For the cargo transportation process, it is needful the integration of services with adaptation properties. The prototype of intelligent adaptable smart service delivery system (ISDS) was developed, and some series of experiments of prototype system was carried out by using simulation methods and packages for these purposes. One of them, allow us to analyze the adaptability and efficiency of the data aggregation, by trying to evaluate the adaptability of provided algorithms.

The constructed algorithms were simulated by using simulation modelling and numerical methods. The package NCTUns (National Chiao Tung University Network Simulator) was chosen for the simulation purposes by recommendations of [45]. Package has possibilities to express the high-precision of extensible integrated network and mobility, as well as has a modelling tool and emulator that allows modelling of a wide variety of protocols used in both wired and wireless networks. It is based on a modern kernel reentering method that provides NCTUns with many unique advantages not found in widespread tools, e.g. ns-2 with OPNET. An intuitive user interface is used, which eliminates the need for complex script writing, and key benefits of NCTUns and later version Estinet by [45], received particular attention from ITS researchers when it developed support for ITS automotive networks in NCTUns versions 4.0 and 5.0. Package supports: basic driver behavior patterns, basic road network design, RSU modelling, OBU imitation that can be equipped with wireless IEEE 802.11 (b) infrastructure mode, Ad-Hoc mode, GPRS, 802.16

(e) modelling of mobile WiMAX communication technologies, DVB-RCST satellite communication, or all possible wireless access methods. Because this modelling environment is tightly integrated, it can be used to investigate complex ITS situations that require changes in the car's driving behavior after receiving certain messages from the network. NCTUns version 5.0 introduced important enhancements to VANET network modelling: efficient node mobility management, ultra-high volume automotive communication networks, automatic road network construction from SHAPE format map files and most importantly, full IEEE 802.11 (p) / 1609 standards for automotive communication networks support.

According to the purposes of the experimental research, 2 stages of simulation process were created for different scenarios generation. One scenario can help to simulate the network model for expression of processes, which create messages in which data are transmitted from the vehicles to the hybrid VANET cloud server by storing appropriate information in adequate structures of repositories of data warehouse (DW). The network consists of the DW server, some types of 802.11p RSU units are implemented in simulation laboratory, and during such scenario we can simulate from 1 to 10 units of 802.11p type of OBUs.

For such scenario performance we obtained the statistical data about parameters of transmission requirements of messages (Table 3).

Table 3. Assessment of data transfer parameters for heterogeneous service support in vehicular communication networks

Activity and/or service type	Required amount of transfering pacage (B/s)/ bandwidth (KB/s)	Possibility of influence of packet loss	Frequency of transmitted data	Tolerable delay (in micro seconds)
Types of actions related with traffic safety in transportation process				
Changing the lane	~100 / 1	Average	Event	~100
Information for traffic light control system	~100 / 1	Average	Periodical	~100
Warnings about hazards	~100 / 1	High	Event	~100
Multimedia services	~100 / 1	Average	Periodical	~100
Multimedia services from comfort area				
IPTV	~1300 / 500	Average	Periodical	<200
VOIP	~100 / 64	Average	Periodical	<150
Exchange of video/audio pacages	The higher	High	Periodical	-
Games	The higher	High	Periodical	-

Source: data are prepared according to work [46]

The second simulation scenario helps in analysis of data flows by transferring them in two directions: from vehicle to the DW server and from the DW server to vehicle. The types of sensors that are classified for application in such experimental scenario is presenting in Table 4.

Table 4. Classification of sensors by types, which are applied for the recognition of situations in cargo transportation

Clasification of sensors by types of applicability	Update rate (High – H, Average – A, Low – L)	Clasification of types of row data sources	Types of data exchange
Physical sensors inside of the vehicle			
Speed measurement	H	Data from vehicles	INV
Acceleration measurement	H	Data from vehicles	INV
Temperature measurement inside the vehicle	L	Data from vehicles	INV
Temperature measurement outside the vehicle	In case of needfulness of such conditions	Data from vehicles and RSU	INV
Fuel level measurement	L	Data from vehicles	INV
The number of passengers measurement	L	Data from vehicles	INV
Vision	H	Data from vehicles	INV
Transmission of voice given commands	Average	Vehicles	INV
Millimetre-wave radar system	H	Data from vehicles	INV
Physical sensors outside of the vehicle			
Global location position (GPS)	H	Data from vehicles	INV, V2I
Quality of Wireless Sensor Networks (WSN)	A	Data from environment	V2I
Information about wireless interface	L	Wireless interface equipment	INV, V2I
Virtual additional types of equipment			
Calls	L	Data from smartphones	V2M
Calendar information	L	Data from smartphones	V2M
Notification of reminders	L	Data from smartphones	V2M
User preferences	L	Data from smartphones	V2M
Information about road	H	Data from vehicles, governmental institutions, and environment	V2I, V2M, V2V
Notification of warnings	H	Data from another vehicles, governmental institutions, and environment	V2I, V2M, V2V
Information about V2V communication	A	Data from environment	V2I, V2M, V2V

The durations of data transferring cycles start from 60s. The data transfer speed was chosen as 27 Mb per second and the size of packet was approximately 1000 MB. In the experiment was included the algorithm for defining the priority assignments of service provision described in previous Section. The prototype system is simulated for purposes and has functionality of aware of the surrounding environment.

Another group of experiments was delivered aiming to identify the effectiveness of the methods which were developed to collect data. The trends over-time (in seconds) of parameters such as accumulated value, predicted utility Exc_j, normalized Z_j, and reduced Ty_j are shown in Figure 4.

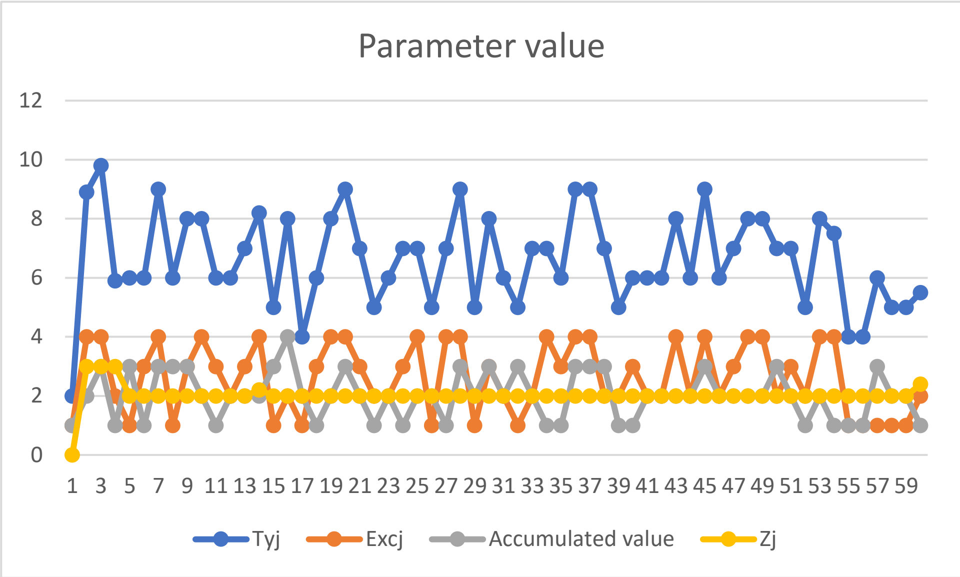

Figure 4. The illustration of experimental results by accumulated predicted utility, for Exc_j, and normalized Z_j and Ty_j parameters variation in time

These results demonstrate that the performance of the changes of accumulated value over time, depending on the parameters of channel quality, including collisions, the bandwidth of the channel, and the number of dropped packets providing the possibility to apply provided method.

The functions of prediction can help to identify the current situation by evaluating past situation, and likely predict future situation, at the stages of the whole trip duration. The algorithms on how to choose the right direction at possible points (nodes) of multimodal transportation were presented in our work [47].

6. Discussions

The processes of cargo transportation must be equipped with new ICT and possibilities of communication by using wireless sensor networks (WSN), by implementing the platform of IoT technology. The development of adaptable smart service provision systems is related to considering of complexity of such processes.

The authors provide an approach for integration of heterogenic sources of monitoring data during cargo transportation processes and help in provision needful information by analyzing the methods of context aware information recognition and scheduling issues. The algorithms are developed which are expressed the methodology of such methods are applied. Review of related works helps in understanding how such data can be applied for context aware information recognition.

The presented approach can intend to develop the adaptable system for cargo transportation with some extended properties of integration of context aware services. The prioritization methods are included in algorithms of service provision with possibilities of restriction of unnecessary information. The architectural structure of the smart service provision system developed on the base of WSN and communication channels by developing the possibilities for more adequate creation of delivery systems of smart service provision. The development of adaptable smart service provision systems is related to considering of complexity of such processes. The on-line decision-making processes involve the assessment of all infrastructure of components that are required for monitoring cargo transportation by ensuring the implementation of needful equipment.

Our future research investigations will address the more complex scenarios for accident event recognition and provision of prediction of future unsuspected situations. In the future, the classification of infrastructure components according to different type of wireless technologies and the transfer of context-oriented data for specific smart service design will be implemented to reduce the number of accidents and unsafe situations.

7. Conclusions

The paper deals with the description of the main components of infrastructure for the provision of intelligent services in cargo transportation processes. A revision of literature proves research investigations in the context-aware processes and systems development for achieving the important context-aware purposes.

In the paper, the authors proposed the structural architecture of the proposed intelligent service delivery system, for which development the identification of situations by understanding their context, and management of these situations is important. To address the challenge an intelligent adaptive approach can be proposed that allows using of environmental context information, vehicle dynamics, and information transmission from other vehicles, considering network conditions and the evaluations of the effectiveness of data messages.

The prototype of the control system of the automotive communication network infrastructure has helped to reduce the amount of useless contextual information, which must be transmitted in automotive communication network without losing context data quality, network filtering and aggregation techniques.

The authors provided the classification of sensors by types, which are applied for the recognition of situations and delivered results for the identification of the effectiveness of the methods which were developed to collect data. The results delivered in this paper help to illustrate the functioning of an intelligent service delivery system.

The study has some limitations that could be researched in future studies. The typology of unplanned events is not presented. The authors demonstrated the number of road accidents that touched heavy vehicles, but there are other cases, such as the damages of tires, the unexpected vehicle's repair needs, policy stops, traffic jams at customs, and route mistakes.

Author Contributions: the architecture and conceptualization of the ISDS, methodology and algorithms for prioritizing of services, experimental research - D. Dzemydienė; analysis of scheduling and investigations - A. Burinskienė. All authors have read and agreed to the published version of the manuscript.

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