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WORLDWIDE APPLICATIONS IN ELECTRONIC TOLL COLLECTION SYSTEMS

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The paper refers to some problems of worldwide applications in electronic toll collection systems for motorways and expressways. According to Directive 2004/52/EC, these systems should use one or more of the following technologies: satellite positioning, mobile communications using the GSM-GPRS standard (reference GSM TS 03.60/23.060) and 5,8 GHz microwave technology. Authors have analysed systems which meet these requirements, especially the states as follows: The United State of America, Japan, Taiwan, Austria, Czech Republic, France, Norway and Germany. As a result of the analysis, it has turned out that only system using satellite positioning technology and mobile communications (GSM/GPRS) is the best toll solution of unique capabilities and this kind of technologically sophisticated system should be implemented in Poland.

Keywords: *electronic toll collection (ECT), GSM/GPRS standard, microwave technology, on-board unit (OBU)*

1. Introduction

Electronic Toll Collection (ETC) is a fairly mature technology that allows for electronic payment for motorways and expressways. An ETC system is able to determine if a car is registered in a toll payment program, alerts enforcers of toll payment violations, and debits the participating account. ETC is fast becoming a globally accepted method of toll collection, a trend greatly aided by the growth of interoperable ETC technologies. Some of the benefits of ETC include:

– fuel savings;

– reduced mobile emissions by reducing or eliminating deceleration, waiting times, and acceleration;

– possible reduced drain on public monies, if the system is more self-sustaining or if the system is built/run via a public-private partnership arrangement.

The EC's target is for all vehicles to be equipped with an ETC box, linked to a standard contract for the owner/operator. At the end of each billing period, a single invoice would be issued, covering journeys through any of the member states.

All new electronic toll collection systems brought into service on or after 1 January 2007 shall, for carrying out electronic toll transactions, use one or more of the following technologies: satellite positioning, mobile communications using the GSM-GPRS standard (reference GSM TS 03.60/23.060) and 5,8 GHz microwave technology.

The above mentioned conditions are included in Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community [3].

The requirements of that directive will be implemented in Poland based on the Act from 28 of July 2005 on changing act of public roads and some other acts [10]. It stressed that toll collecting charge institutions should be able to carry out electronic toll transactions from date as follows:

– 1st of January 2011 – to the carriage of goods where the maximum permissible mass of the vehicle, including any trailer, or semi-trailer, exceeds 3,5 tones, or of passengers by vehicles which are constructed or permanently adapted for carrying more than nine persons including the driver.

New electronic toll systems brought into service after the adoption of this Directive should use the satellite positioning and mobile communications technologies.

The Working Group No 1 (WG1) of Technical Committee 278 (Road Transport and Traffic Telematics) established in 1991 is responsible for electronic toll collection systems in European Union. ISO/TC 204 is the partner of CEN/TC 278 in ISO, responsible for the international standardisation of transport information, communication and control systems.

It is recommended to implement National Automated Toll System for highways and expressways in Poland. Authors have carried out the analysis of some systems functioning all over the world to choose the best one for Poland.

2. Characterization of Electronic Toll Collection Systems

A toll collection system can be either closed (cordoned) or open. The closed system requires entrances and exits based on toll booth (a booth at a tollgate where the toll collector collects tolls). In an open toll system, toll stations are located along the facility. It is the collection of tolls on toll roads in three or more adjacent lanes without the use of lane dividing barriers or toll-booths. The major advantage to open system is that cars need not stop nor even slow down for payment.

DSRC is typically used as the primary method of charging where a charge is to be applied at one of a discrete number of specific points, such as a toll plaza (an area where tollbooths are located) or a location on the open highway.

The Rationale for Electronic Toll Collection ETC systems take advantage of vehicle-to-roadside communication technologies (traditionally via microwave or infrared communication, more recently via GPS technology) to perform an electronic monetary transaction between a vehicle passing through a toll station and the toll agency.

Electronic Toll Road Systems in USA and some European Member States using microwave technology have functioned independently. The telematic systems are implemented in some states, an example being Hitachi System (Japan), as well as Barouh System (Taiwan), which provide the function of electronic road toll for highways and expressways and additionally function of transferring data from digital tachographs. Toll Collecting System in Germany is a modern solution for the mentioned scope.

2.1. Electronic Tall Collection Systems Using Microwave Technology – DSRC

Electronic Toll System using microwave technology is an element of ITS, which allows for non-stop toll collection and traffic monitoring. It is to uniquely identify each vehicle, electronically collect the toll, and provide general vehicle/traffic monitoring and data collection. New technologies and infrastructures provide the necessary capabilities for future applications such as incident management, alternate route guidance, and travel demand management. Properly implemented, system can reduce congestion, increase operating efficiency, improve travel time, reduce pollution, and improve safety of the roadway facility and surrounding corridors. All electronic tall systems using microwave technology all over the world have the same structure, which utilizes vehicles equipped with transponders (electronic tags), toll and control gantries, in-road/roadside detection and classification sensors, computerized system (hardware and software) and wireless communication (5,8 GHz nearly all over the world, only 5,9 GHz in USA), as well as enforcement technologies (Fig.1).

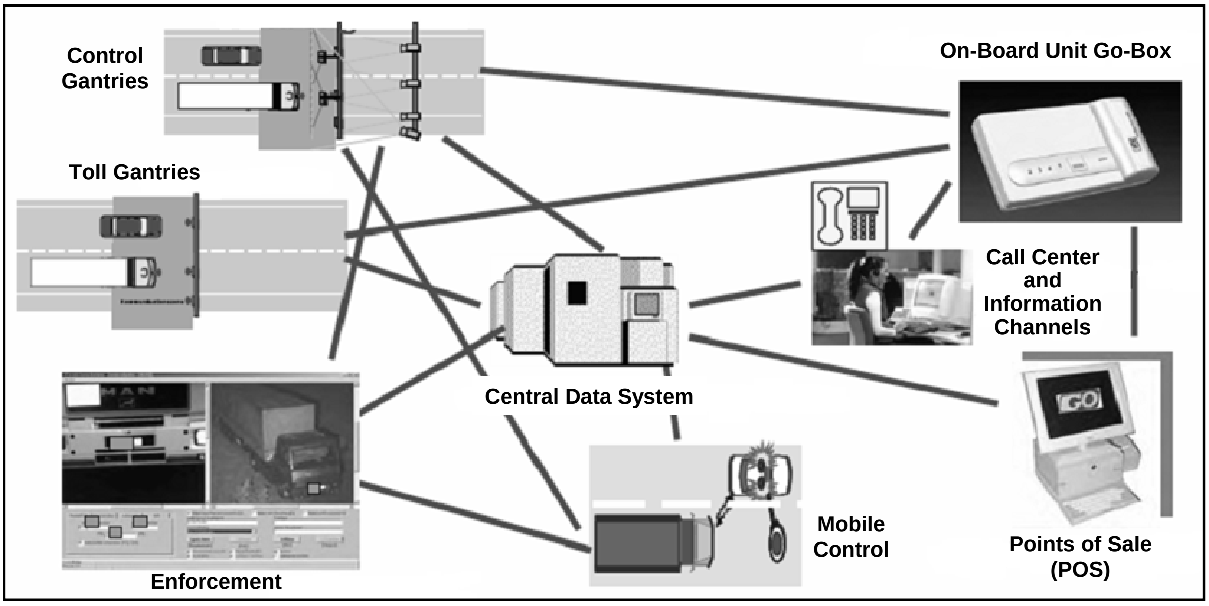

***Fig. 1**. An example of Electronic Toll System in Austria [6]*

The elements of toll system like transponders (tags) mounted on the vehicle's windshield, have got the same dimensions (box of cigarettes), but for every kind of system the vehicle should be equipped with different transponder (Fig. 2), for example Go-Box in Austria, Premid in Czech Republic, Passango in France. The antennas carried by gantries communicate with transponders (On Board Units, OBU). Users can get the OBU at a high number of points of sale 24 hours a day. OBU is equipped with a switch for the change of the vehicle class for instance in case of an additional trailer.

Fig. 2. *Electronic transponders mounted on the vehicle's windshield*

In June 2002, ASFINAG (Autobahnen und Schnellstrassen-Finanzierung AG) Austria’s national road authority charged with planning, financing, building and maintenance of the highway network, awarded a contract for the installation and operation of a fully electronic nationwide toll system for heavy goods vehicles with a maximum permissible laden weight of 3,5 tones to Autostrade S.p.A. with Kapsch TrafficCom AG [1] as the turn-key system supplier. The toll system is an open system with one gantry for toll communication in each sector between exit/entry-points. More than 800 gantries (420 for each driving direction) had been implemented in the entire network. Users who rarely drive on the tolled road network can choose to pay the toll using the pre-pay procedure. This procedure is similar to that of a prepaid telephone card; the user charges the Go-Box with toll credit up to a certain maximum limit and the toll is then deducted from this credit as required by the toll system. According to this procedure, the owner of the vehicle registers with the system and provides an authorized means of payment, which is later used to pay the toll as required. The money is collected by the relevant card issuer (Maestro card, petrol card or credit card).

Toll-enforcement which is one of the most important parts of an electronic toll system without barriers executed on the one hand by stationary toll-enforcement-gantries and portable enforcement equipments and on the other hand by a mobile control unit (“toll-enforcement-officers”). 100 permanent enforcement gantries are spread over the network primarily in the parts of higher traffic density. They consist of equipment for automatic vehicle classification by laser scanner. Vehicle class video cameras take a picture of the vehicles front. The license plate is then read by automatic character recognition and sent to the enforcement office.

Electronic toll has been paid by vehicles weighing 12 tons and more on 970 km of motorways and express roads in the Czech Republic as of January 1 2007. Kapsch TrafficCom AB contracted the system in Czech Republic, but the transponder is different and called Premid. It is the brand name for a product line of microwave-based communication links for dedicated short range communication, DSRC, between fixed Roadside Equipment and mobile units. Kapsch TrafficCom AB has supplied this DSRC Link technology to a large number of traffic applications in over 20 countries all over the world.

The third generation of the system, Premid, is compliant with the current European CEN TC278 standards for Dedicated Short Range Communication, DSRC, as well as to the international ISO standard for Electronic Toll Collection (ETC).

The term TIS-PL refers to the new French electronic toll system for class 3 and 4 HGVs. Modelled on the "Liber-t" system designed for light vehicles in France, the TIS-PL is a badge which is fitted to the windscreen and which simplifies toll payments (motorways, tunnels, bridges etc.). Launched at the beginning of 2007, it has since replaced the CAPLIS toll card as the method of toll payment in France.

AutoPASS is an electronic toll collection system used in Norway. It allows collecting road tolls automatically from cars. It uses electronic radio transmitters and receivers operating at 5.8 GHz (MD5885).

The system involves the installation of a radio transmitter on the windscreen of a vehicle, and signing an agreement with one of the toll collection companies in Norway. Tolls are charged at toll plazas as before, but cars can drive past in up to 80 km/h. The system is administrated by the Norwegian Public Roads Administration. 23 of the 45 toll roads in Norway use the system, in addition to tests for use of the system on some car ferries. The primary reason that some projects don't support AutoPASS is that they charge both for the car and for passengers, which the system cannot support. All projects using AutoPASS can only charge per car. All systems with Autopass also have manual payment methods, though not necessarily manned.

The tolls in the United States are typically collected using RFID (Radio Frequency Identification). It is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is an object that can be attached to or incorporated into a product, animal, or person for the purpose of identification using radio waves. Chip-based RFID tags contain silicon chips and antennae. Passive tags require no internal power source, whereas active tags require a power source.

Example of mentioned system is the E-ZPass electronic toll collection system used on most toll bridges and toll roads in the eastern U.S. from Virginia to Maine, and recently extended into Illinois; Houston`s EZ Tag, which also works in other parts of the state of Texas, California's FasTrak, Illinois` I-Pass, Florida`s SunPuss, and more recently Indiana`s I-Zoom (Fig.3). Traffic in these special lanes can move well with minimal slowing. Toll roads have been only in 26 states as of 2006. The majority of states without any turnpikes are in the West and South [2, 4].

Fig. 3. *Types of ETC Systems in the USA*
Based on: www.transcore.com.

Operation principle of the system is the same in Europe (Fig. 4). As a car approaches a toll plaza, the radio-frequency (RF) field emitted from the antenna activates the transponder. The transponder broadcasts a signal back to the lane antenna with some basic information. That information is transferred from the lane antenna to the central database. If the account is in good standing, a toll is deducted from the driver's prepaid account. If the toll lane has a gate, the gate opens. A green light indicates that the driver can proceed. Some lanes have text messages that inform drivers of the toll just paid and their account balance. If the vehicle does not have a transponder, the system classifies it as a violator and cameras take photos of the vehicle and its license plate for processing. If the license plate is registered as belonging to toll system user, the account is debited only the toll charge, and no penalty is charged.

E-ZPass tags are battery powered RFID transponders; they communicate with reader equipment built into lane-based or open road toll collection lanes. The most common type of tag is mounted on the inside of the vehicle's windshield behind the rear-view mirror. Some vehicles have windshields that block RFID signals. For those vehicles, an externally-mountable tag is offered, typically designed to attach to the vehicle's front license plate mounting points. Most E-ZPass lanes are converted closed toll lanes and must have fairly low speed limits for safety reasons (5 and 15 mph are typical). In some areas, however (typically recently built or retrofitted facilities), there is no need to slow down, as E-ZPass users utilize dedicated traffic lanes ("Express E-ZPass") outside the toll booth (Delaware Route 1, Virginia's Pocahontas Parkway, the Garden State Parkway's express lanes, and the Pennsylvania Turnpike's Warrendale and Mid-County (I-476) Toll Plazas).

The E-ZPass Interagency Group (IAG) was formed in 1990 with three states (NY, NJ & PA) and seven agencies. The first deployment of E-ZPass was on the New York State Thruway at the Spring Valley barrier on August 3, 1993. The IAG currently has over 9 million account holders who utilize more than 16 million transponders operating electronic toll collection for 23 agencies in 12 states. The nine million account holders reside throughout North America with thousands in each state and province including the States of Hawaii and Alaska.

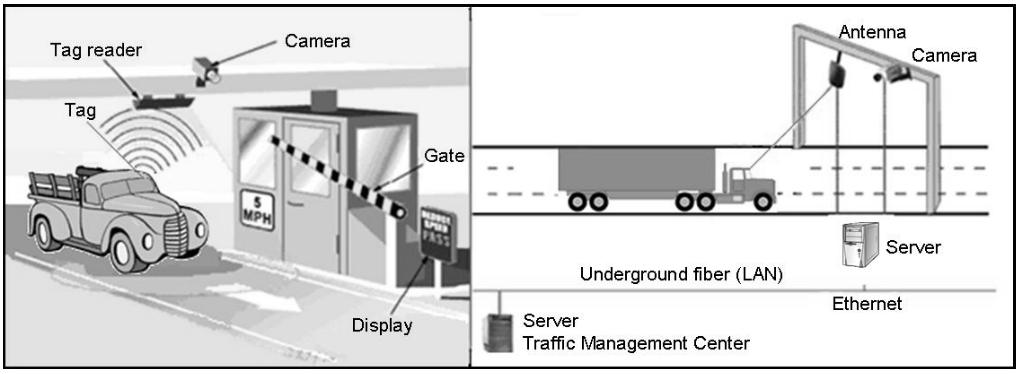

Fig. 4. *E-ZPass System (on the left - closed road line, on the right - open road line)*
Based on: http://www.garamchai.com/askadesi/ask13.htm; http://www.calccit.org/itsdecision/serv_and_tech/list.html

Another system in USA is FasTrak. It is used state-wide on all of the toll roads and bridges along the California Freeway and Expressway System.

As with other ETC systems, FasTrak is designed to eliminate the need for cars to stop to pay at toll booths, thus decreasing the traffic traditionally associated with toll roads. Its use of technology to improve transit is in line with the U.S. Department of Transportation's Intelligent Transportation Systems initiative.

FasTrak uses RFID technology to read data from a transponder placed in a vehicle (usually mounted by Velcro strips to the windshield) moving at speeds that may exceed 70 mph. The RFID transponder in each vehicle is associated with a prepaid debit account; each time the vehicle passes underneath a toll collection site, the account is debited to pay the toll. If a vehicle does not have a transponder, the system uses automatic number plate recognition to take photos of the vehicle and its license plate for processing.

Anybody with a FasTrak transponder can use it to pay tolls on any California toll road or bridge using the system. But people are encouraged to open their accounts with the local agency in charge of the toll facility that they use the most. Different agencies may offer different discounts and incentives, and people may be charged a fee if the majority of their FasTrak use occurs elsewhere.

SunPass is an electronic toll collection system in use by the State of Florida and was originally created by the Florida Department of Transportation's Florida's Turnpike Enterprise. The system uses Amtech active RFID windshield-mounted transponders manufactured by TransCore along with lane equipment designed by several companies including SAIC and TransCore. SunPass is fully interoperable with E-Pass (from the Orlando-Orange County Expressway Authority), O-Pass (from the Osceola Parkway), LeeWay (from Lee County toll bridges) and Miami-Dade Expressway Authority (MDX) toll roads. SunPass may also be used at the Orlando International Airport to pay for parking. There are plans for other major Florida airports to utilize the SunPass system for parking fees.

SunPass-Only toll lanes on most toll roads in Florida allow a vehicle to proceed through the tollbooth at speeds of up to 25 mph (40 km/h). This is a safety guideline, not a technological limitation, and violation may be subject to a speeding ticket and associated fine. Some mainline toll barriers are being constructed with wider SunPass-Only lanes that can handle speeds up to 50 mph (80 km/h). E-Pass-Only lanes system have a speed limit of 35 mph (60 km/h), though the mainline toll barriers will all have dedicated lanes capable of full-speed automatic toll collection at up to 65 mph (105 km/h) by 2009.

I-PASS is the Illinois Tollway's Electronic Toll Collection Program. Users of the Tollway are encouraged to open an account that allows them to travel through the toll plazas faster, in many cases without having to stop, and to avoid having to handle cash toll payments.

Hitachi has developed creative solutions to roadside communications, traffic operation and payment processing to enhance toll collection system performance (Fig. 5). Capable of high-speed operation to enable free traffic flow, the system incorporates a fully integrated payment processing system, comprising facilities to identify and record illegal passage, efficient management of toll-collection data, system auditing and access management for high security and EDI processing to facilitate smooth fund transfers.

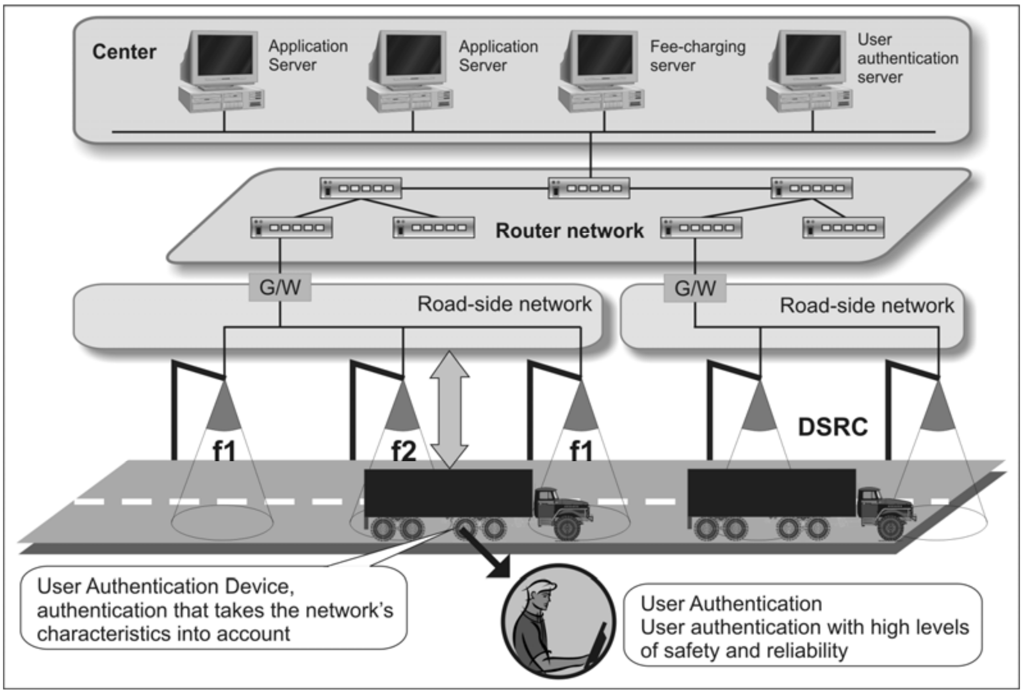

Fig. 5. *The project of electronic toll collection system created by Hitachi and supported by Telecommunications Advancement Organization of Japan*
Based on: http://www.hitachi.co.jp/en/products/its/product/solution/2004613_12384.html

Hitachi covers everything from data collection to information delivery. Hitachi has made advanced system concepts a reality, with a complete information system consisting of data collection, information management, on-board equipment, radio beacons and other facilities.

This system, developed to improve both safety and convenience levels, not only provides accident and other travel-related data to cars driving at high speeds, it also uses the Internet to provide music and image streaming, and to reserve and pay for airline tickets.

Fibre-optic cables buried within the road are capable of detecting road surface temperatures and can issue warnings when freezing conditions exist.

An image recognition system monitors your car as you drive to detect possible danger signs. It offers the driver information on the possible existence of dangerous situations, and provides information on safer driving to avert such dangers.

Microwave-based digital short range communication (DSRC) systems need road-side equipment, typically mounted on a gantry, with electronic tags in the vehicles which may be read-only, read–write or smartcard-based. The majority of systems all over the world have tags reading-only, contain a fixed identification code which, when interrogated by a roadside reading device at the charging point, conveys this identity to the roadside system.

China has got currently ETC systems in Guandong Province, Beijing, and Shanghai [12]. Although several DSRC systems have been developed and used in China, they use different frequency bands and thus are not compatible with each other. To solve this problem, the Chinese Government has determined the domestic standardization of the 5.8 GHz-band (GB/T 20839-2007, GB/T 20851.1, 2, 3, 4, 5. 2007), which indicates that this frequency band will be adopted as the standard for the DSRC systems in China.

Research is underway on a new generation of electronic highway toll collection technology, based on GPS and wireless communication technology to implement such a system in China. For the reason of aforementioned system, China has planned to develop a truly global satellite navigation system, known as Compass or Beidou-2. The current Beidou-1 system (made up of 4 satellites) is experimental and has limited coverage and application. The new system will be a constellation of 35 satellites, which include 5 geo-stationary orbit (GEO) satellites and 30 medium Earth orbit (MEO) satellites that will offer complete coverage of the globe. There will be two levels of service provided; free service for those in China, and licensed service for the military.

The free service will have a 10 meter location-tracking accuracy, will synchronize clocks with an accuracy of 50 ns, and measure speeds within 0.2 m/s.

The licensed service will be more accurate than the free service, can be used for communication, and will supply information about the system status to the users.

Two satellites for Beidou 2 have been launched in early 2007. In the next few years, China plans to continue experimentation and system set-up operations.

By the end of 2020, China will have finished constructing 12 roads and formed the main arteries of state roads with high-grade highways, which will run through capital, cities directly under the jurisdiction of state, the capitals of each provinces and municipalities.

2.2. GPS/GSM Based Tall Collection Systems

Hitachi telematics system was implemented in Japan in 2001 for managing of transport companies [5]. It functions based on GPS, GSM communication and Internet. Each vehicle is equipped with digital tachograph, OBU and telematics terminal, which uses GPS to measure its current position and reports it to an application service provider (ASP) centre at regular intervals (usually every 15 minutes) via a mobile packet transmission network. A PC (personal computer) at the transportation company's office can be connected to the ASP centre via the Internet, and can be used to display the current position and route of each vehicle superimposed on a map of Japan. Hitachi's ASP service can be linked to a toll collect system, allowing the fleet managers to respond precisely to enquiries from consignors about their payment for highways and expressways. In Hitachi's truck fleet management service system, the telematics terminals collect the types of data (speed, time, distance and charge of road), and transmit it to Hitachi's ASP centre via a mobile packet transmission network. The driving data collected in this way can be freely inspected and amended via the Internet, and can be used to print out documents such as daily driving reports and monthly statistical reports, or downloaded into accounting/payroll systems. It is also possible to identify bad driving habits such excessive acceleration or braking, speeding or prolonged idling, and this information can be used to make the drivers safer and more fuel-efficient by providing them with suitable feedback.

The trucks are fitted with telematics equipment, GPS systems, packet cell phone terminals, etc., and thus have the potential to be used as floating cars. First, the truck positional data is superimposed on a map to infer the route on which the truck is travelling, and then the speed of the truck along this route is calculated. Next, this data is statistically processed to calculate the estimated arrival time. To avoid excessive communication costs, the time intervals at which this positional information is uploaded should be made as long as possible. However, this makes it harder to track the routes travelled by the trucks.

Japan has started a new project of Quasi-Zenith Satellite System (QZSS) in FY2003 [11]. QZSS consists of three satellites and will provide a regional satellite positioning service as well as communication and broadcasting services. Each satellite is in three different orbit planes, which are obtained by inclining the geo-stationary orbit (GEO) by about 45 degree. In this system, at least one satellite stays around the zenith for about eight hours and is visible with a higher elevation angle in mid-latitude area (e.g. at least 80 deg. in Tokyo) than in case of using a satellite in GEO. This characteristic is very beneficial in large cities where there are many tall buildings which block the signal from satellites in GEO. Thus, satellite availability for satellite positioning and mobile communication services is expected to be greatly improved.

The QZSS satellite positioning system is planned to be compatible and interoperable with the civil specifications of modernized GPS except its orbit and some experiments, and will compliment and augment the GPS. The aimed accuracy of GPS-QZSS time offset is less than 3 ns rms over any 24-hour period.

Taiwanese telemtaics system (Fig. 6) has the same structure as Hitachi one. It is capable of calculating and collecting road use charges via OBU and GPS. Furthermore it allows Baoruh Digital Tachograph to send vehicle status and position to the backend server via GSM/GPRS, while the server is capable of issuing commands or system parameters simultaneously. To use GIS technology to provide best route-analysis, distance measurement, route management and restrictive access settings, road speed limit. All types of reports can be directly printed out or transformed into other file formats, such PDF, excel, html, CSB, text file [9].

In January 2005 the Toll Collect system was introduced on the 12 000km of German highways for all trucks with a maximum weight of 12t and above. Its technology is based on the GPS, and a web application (GSM). System is capable of calculating and collecting road use charges based on the distance travelled. In addition, the Toll Collect system ensures that the collection of road tolls does not disrupt traffic flow. In contrast to conventional toll systems, Toll Collect does not require vehicles to slow down or stop, or restrict them to a designated lane [7].

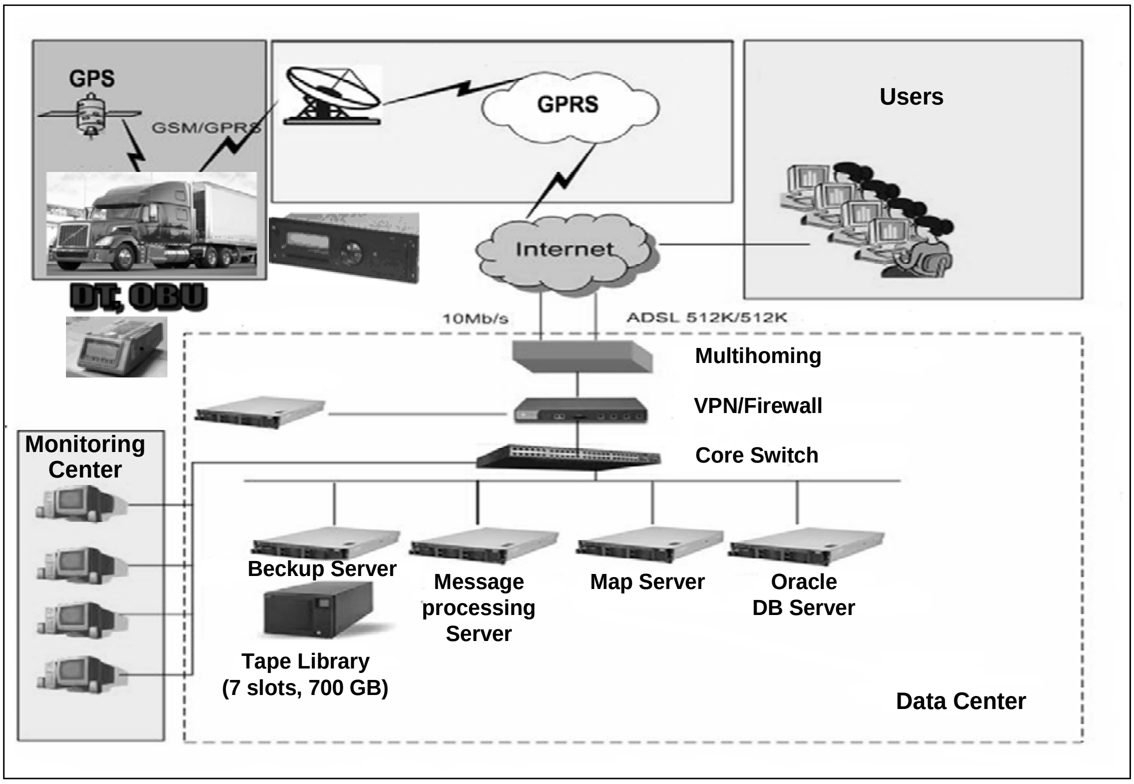

Fig. 6. *The structure of Taiwanese telemtaics system*

The main element of the automatic log-on system is the On-Board Unit (Fig. 7). OBU is used for positioning, monitoring and billing. With the aid of GPS satellite signals and other positioning sensors, the OBU automatically determines how many kilometres have already been driven on the toll route, calculates the toll based on the vehicle and toll rate information that has been entered, and transmits this information to the Toll Collect computer centre for further processing. Additionally the OBUs have infrared interfaces for communicating with stationary control bridges on the motorways. System has 300 gantries equipped with IR detection equipment and high resolution cameras able to pick out trucks via profiling (and record number plates). These send a DSRC signal to a DSRC transponder (which are part of the OBU) in the lorry to check on the accuracy of the GPS as a back-up and also alert BAG officers to toll violations.

Toll Enforcement will also rely on mobile patrols, consisting of a fleet of 300 vehicles with 540 officers of the Federal Office of Freight (BAG). The officers will patrol the autobahns, checking vehicles and drivers to see if they have paid the toll or have the OBU installed (these vehicles will be equipped with an infrared short range DSRC (Dedicated Short Range Communications) system that can be used to scan and monitor trucks in motion). The BAG will have police powers to request trucks to stop for examination at any point during their journey.

The OBU will also be able to work with the new Galileo satellite system for positioning which is being developed in Europe as a more accurate alternative to GPS.

In a field test in Melbourne and the New South Wales region, Siemens ITS, Transurban, the toll solutions market leader in Australia, and the largest Australian mobile radio provider, Telstra, have successfully tested a hybrid OBU from Siemens VDO and a new software application with which both microwave-based and satellite-based toll solutions can be used by one single unit.

The hybrid OBU, into which a DSRC microwave module is integrated, makes it possible to detect existing microwave signals from toll gantries in addition to normal satellite operation. Therefore, Siemens is the first manufacturer of a hybrid OBU which detects microwave signals from gantries and processes GPS signals. This is above all important in view of possible migration from DSRC to GPS solutions.

A GSM/GPS system for road charging has been made a long-term government target in the UK. This technology is the only ETC system that can also potentially support telematics services, including the e-call provision that the EC would like to see introduced for all new cars from around 2010.

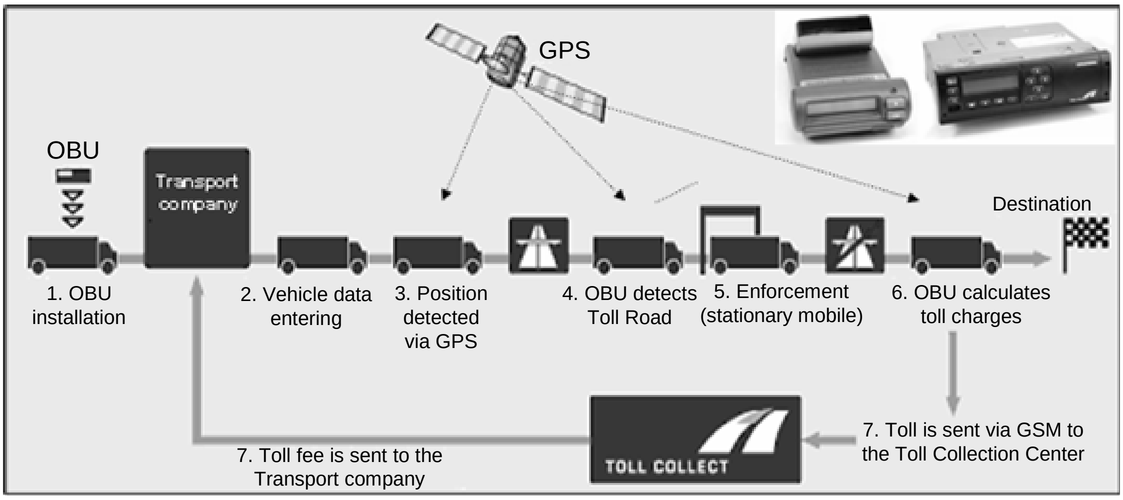

Fig. 7. *Toll Collect System in Germany – automated logging [8]*

The Commission argues that satellite positioning in conjunction with mobile communications is the only solution that allows easy application of 'zone tolls'- within conurbation, for example.

The Commission proposes that the use of satellite positioning technology should be compulsory as from 2008 for newly introduced systems, and as from 2012 for all systems. Systems brought into service before 1 January 2008 will be required to have abandoned the microwave technology by 1 January 2012.

With a view to the possible migration to systems based on satellite and mobile communications technologies from services based on other technologies, the Commission shall submit a report no later than 31 December 2009.

3. Conclusions

These three families of technology for future electronic toll collect systems and all have different attributes, advantages and disadvantages. For many years, microwave-based digital short range communication (DSRC) systems have been preferred, due to their simplicity of operation, potential for supporting additional services for vehicle users and, most importantly, because they are easy for users to understand. These systems need road-side equipment, typically mounted on a gantry, with electronic tags in the vehicles which may be read-only, read–write or smartcard-based. The key limiting factor seems to be the processing speed of the smartcard – each charging point has two gantries – one to start communications with the vehicle and a second one (further down the road) to complete the transaction and perform enforcement measures, if necessary.

A new class of ETC systems is based on a combination of mobile communications technology (GSM) and the satellite-based global positioning system (GPS). An innovative element of the automatic log-on system is the On-Board Unit (OBU), which automatically calculates the amount of charge due and takes into account the emissions class (ecological aspect) and the number of vehicle axles in calculating this charge. The first GPS based system advantage is absence of the need for new road infrastructure (gantries), operators can keep using the existing infrastructure. System works without toll booths, extra lanes, speed restrictions or complex structures along toll roads. The second is much greater flexibility in defining or changing payment by simply redefining the "virtual" toll areas. It means ability to adapt easily and quickly to changes in charge parameters (road classes, vehicle types, emission levels, times slots etc). The third is the systems ability to support other value-added services on the same technology platform. These services might include fleet and vehicle engine management systems, emergency response services, pay-as-you-drive insurance services and navigation capabilities.

These systems were implemented in the Germany and Hong Kong and will be implemented in UK, India, USA, China, and Australia. With regard to future expansion and development, the satellite-based toll collection system will be a better solution, especially with regard to flexibility when it comes to extending toll collection to every road category, every category of vehicle and, what's more, in terms of cost efficiency in implementation and operation.

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DEVELOPMENT OF QUALITY INDICATORS SYSTEM AS ANALYTICAL PART OF INFORMATION SYSTEM FOR RIGA COACH TERMINAL

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The objective of this article is to analyse data about punctuality of bus transportation in Latvia. Regional, intercity and international trips arriving in Riga Coach Terminal are examined. Determination and analysis of punctuality indices for different operators, on the different routes of buses, on day times and days of the week and for terminal as a whole may be a basis for a decision-making on passenger services quality improvement. Analysis of this task solution possibility on the basis of present information in the „Baltic Lines" information system will allow formulating a task for development of analytical part of the system. A solution of this task is an inalienable part of the quality system supported on a Coach Terminal and will serve as a basis for forming the passenger logistic hub on Riga Coach Terminal base.

Keywords: *bus, information system, reliability, punctuality, descriptive characteristics, analysis.*

1. Introduction

Nowadays the process of market regulation principles changing from the direction of the state is going on. Taking into account the EU standards the quality of travel is the important moment in determination for the transport operator or mode of transport.

The role of information system in transport is important from the point of view of the service quality for travellers. The development of the information system is an essential factor for coach terminals as passengers' transport infrastructure objects in their transformation into passengers' logistics centres [1]. The first realization of the coach terminal information system (IS) „Baltic Lines" was implemented in Riga Coach Terminal in 2003. From 2004 the system is being used in other cities of Latvia. Nowadays, plans to introduce it in some EU countries are discussed. The description of information flows, functions, technical decisions of the IS „Baltic Lines" were described in [2] and the possibilities of using this system at the strategic and operative levels were analysed in [3]. The current developing task in this system is the development of the quality indicators system on the base of sampled data from the IS „Baltic Lines".

2. Measure of Reliability as One of Important Measures of Bus and Coach Service Quality

The quality of the rendered service is one of the main characteristics of public transport development, which is the necessary condition of demand for it.

There is the system of measures for the evaluation of city bus service quality in [4]. In this research one of these indices does not make sense, some of them must be calculated on the basis of other algorithms.

Measures of bus intercity, regional and international transportation quality can be classified in 2 groups:

- providing availability (1)
- providing comfort and convenience from the passenger's point of view by this mode of transport (2).

(1) Availability is foremost provided by a network, within the limits of which service is carried out by this mode of transport and time-table (by time and frequency, to the proper queries of users).

(2) Comfort and convenience are connected with reliability of service, first of all, its joining with other modes of transport, passenger seating capacity.

As this mode of transport is in competition with railway (and private cars also) in Latvia the measures that represent comfort and convenience are very important. Railway is the mode of transport, which doesn't feel the influence of congestion or weather conditions, and that's why it is more reliable mode of transport and also is the winner in competition with bus by travel time. On the other hand, it yields to bus transportation by the level of availability (absence of network in some districts, foremost). In this competition, multiplying a comfort and service of bus transportation can play a solution role in the choice of this mode of transport. And if time of moving often differs insignificantly (example), reliability can become the problem for a bus travel. The exact observance of time-table becomes the important property.

In this research the main attention was paid to measure the reliability of coach and bus service. Reliability is a measure determining bus service level from the viewpoint of users as well as operators.

One of the considered in [4] reliability indices is punctuality index. Punctuality of bus operation is a quantitative measure of reliability from the viewpoint of users. This index indicates the magnitude of time gap between actual and scheduled arrival times. Research of this index in combination with different factors influencing on this index and in an ideal development of the model for evaluation of punctuality is a difficult task, possible only at presence of enormous amount of information and its plenitude. The presence of the developed information system of Riga Coach Terminal makes possible the solution of such task in the decision-making designed module.

The task of exposure of different factors influencing this index stronger than others is important for top management first of all. To such factors potentially the following can be referred [4]:

- Traffic conditions,
- Road conditions (weather)
- Road length and number of stops,
- Operation control strategies.

3. Data Collection

The system solution of this task requires fixing of real arrived times at all intermediate stops. It is possible equipping GPS in all busses, that it is planned to carry out by the end of 2009. Information was collected about times of buses arriving on the final bus stop in Riga bus terminal for July 2005 and 2007.

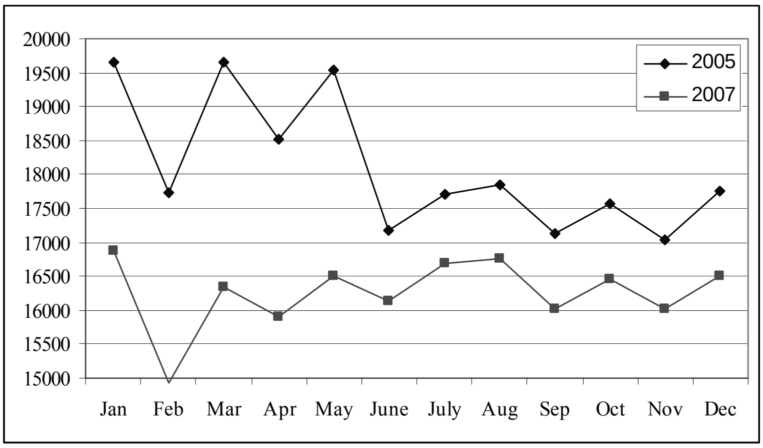


Fig. 1. *Time series of the inbounding trips to Riga Coach Terminal*

In this research the data about delays on the last stop – Riga Coach Terminal in July 2005 and 2007 were analyzed. In 2005, Riga Coach Terminal executed 17703 inbound trips, and in 2007 – 16680 inbound trips and in more than 70 directions (see Figure 1).

Besides, the decision of this task in relation to Riga Terminal is important also because the space of the terminal is limited and for today dissatisfies the tasks of providing comfort and safety to the passengers. Delay of arrival not only violates the plans of passengers but also often complicates the problems of placing for loading and unloading on platforms.

Assumption is accepted – to fix as a delay only delay for a time more than 10 minutes. On every delay a date, time, operator, trip and reason of delay were recorded.

4. Results of Statistical Treatment

4.1. Descriptive characteristics

In Statistica/Win package descriptive characteristics of delays of trips arriving at the Riga Coach Terminal (See Table 1) were obtained.

Table 1. Descriptive statistics for the sample with trip delay in July 2005 and 2007

Year	N	%	Valid N	Mean	Median	Mode	Freq.	Min.	Max.	5%	95%	Variance	Std. Dev
2005	1078	6.09	1078	38.01	19.00	10.00	118.00	10.00	646.00	10.00	122.00	3175.82	56.35
2007	1129	6.77	1129	27.07	16.00	10.00	159.00	10.00	447.00	10.00	80.00	1731.52	41.61

As it is obvious from results of treatment of statistics on delays for July 2007:

- the delay of arrival in Riga is established at 1129 trips, that is 6.77% of the common number of trips;
- the most widespread delay makes 10 minutes;
- 50% delays exceed 16 minutes and 5 % delays make compile 80 minutes;
- the expected value of delay is covered by an interval (24.65;29.50) with the confidence level 0.95 (95% confidence interval – (24.65;29.50));
- a maximal delay in 2007 compiled a bit less than 8 hours (447 minutes), and in 2005 – over 10 and a half of hours;
- deviation of delay – almost 42 minutes.

If to compare these results to the indices for 2005, it is possible to establish a small increase in 2007 of both absolute number of delays and relative (in %) as compared to 2005. As a positive tendency it is possible to mark diminishing in 2007, if compared to 2005, average, maximum of delay and a median, and also characteristics of delay scattering. It is possible to establish a tendency to multiplying the number of small delays. Research of distributing of delays by duration also confirms it. In Fig. 2 distribution of delays by duration is presented. Predominance of delays from 10 to 20 minutes is confirmed in 2007. But at that a part of delays of trips for more than 20 minutes is rather large - more than 30%.

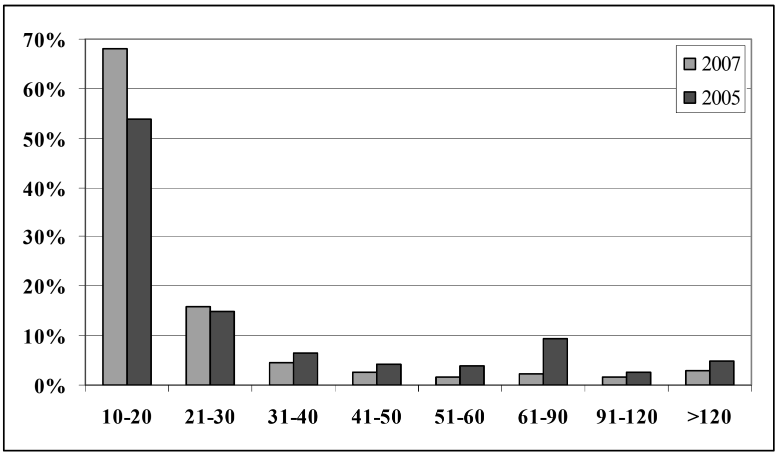
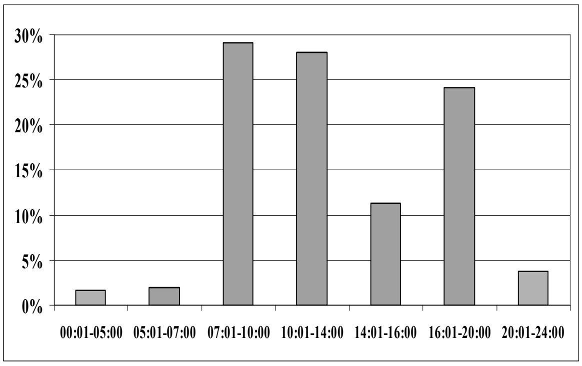
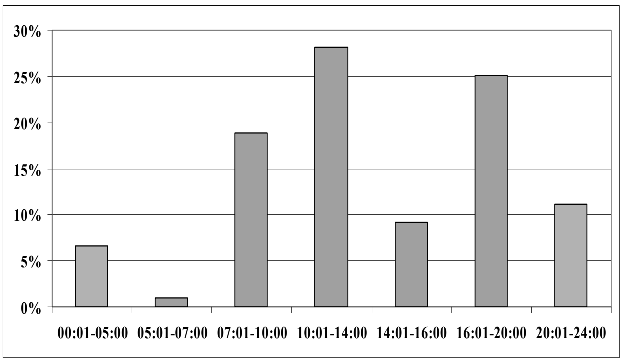


Fig. 2. *Distribution of delays by duration (arriving at the Riga Coach Terminal)*

In Fig. 3 distribution of delays on arriving at the Riga Coach Terminal by the time of the day is presented. As it is obvious from the graph in 2007 most of delays is at 7.00-14.00 and 16.00-20.00, thus this tendency has become stronger if to compare to 2005. It is possible to suppose that one of the factors influencing it, is connected to congestions in the streets of Riga during these hours. Certainly, this supposition requires a separate verification.



a) July, 2007



b) July, 2005

Fig. 3. *Distribution of delays by time of the day*

We can suppose that it the frequency of delays depends on the frequency of trips in these time periods, but it is known [6] that the amount of trips is approximately uniformed distributed between 10.00 and 21.00.

4.2. Analysis of dependence of delay on the day of a week

Distribution of delays by duration for the different days of a week is represented in Fig.4. Evidently, the most prolonged delays are more frequent at weekends.

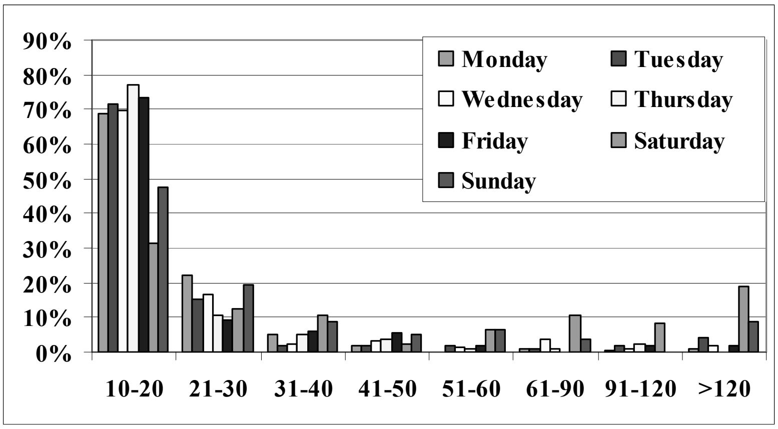


Fig. 4. Distribution of delay by the day of a week (July, 2007)

In Table 2 the descriptive characteristics of delays by the days of a week for the examined time are presented. Evidently there are considerably less delays at weekends in 2007 if to compare with working days, although the amount of trips does not differ so meaningfully (see Fig. 5). However mean value and scattering of delays is considerably greater at weekends.

Table 2. Descriptive statistics for h trip delay in different days of a week in July 2005 and 2007

Day	Delay Time for 2005			Delay Time for 2007		
	Number	Means	Std.Dev	Number	Means	Std.Dev
1	146	28.53	31.46	299	20.70	24.52
2	142	25.28	21.81	193	26.07	35.05
3	140	32.87	35.52	211	25.45	37.36
4	151	38.63	55.77	139	18.74	14.36
5	202	41.88	77.84	161	24.46	36.27
6	168	54.28	67.17	48	80.44	102.77
7	129	40.33	63.04	78	45.71	64.71
Total	1078	38.01	56.35	1129	27.07	41.61

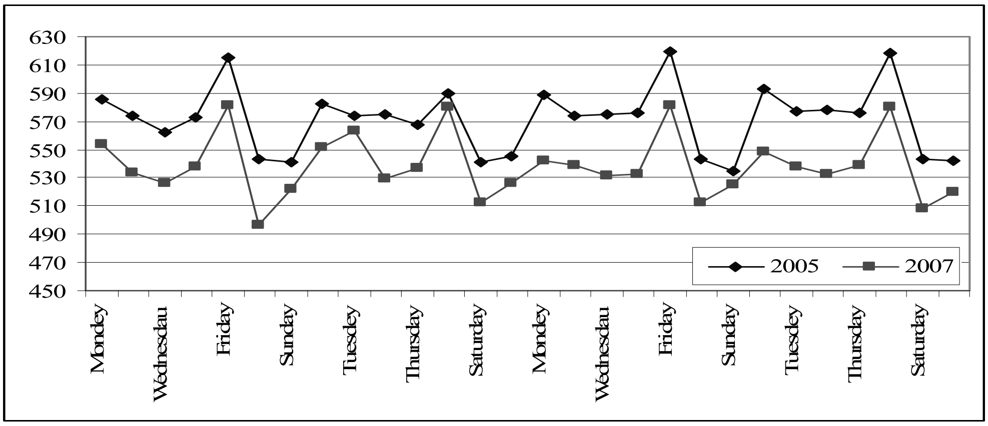


Fig. 5. Distribution of the number of trips by the days of a week (4 weeks, July, 2005 and 2007)

During testing the hypothesis about insignificance of delay value dependence on the day of a week the value of F criterion is significant and, consequently, the hypothesis about insignificance is rejected both for data of 2005 and 2007 (see Table 3). However, the distinction between delays at weekends and working days had been considerably increased to 2007.

Table 3. Descriptive statistics for delays sampling for July 2005 and 2007

	SS	df	MS	SS	df	MS	F	p
2007	187406.2	6	31234.37	1765744	1122	1573.746	19.847	4.00E-22
2005	88095.83	6	14682.64	3332266	1071	3111.360	4.719	0.000094

4.3 Analysis of dependence of delay on direction and trip

The supposition that the number and duration of delays are influenced by congestions in the streets of Riga has been done earlier. All trips have been divided into 4 directions, which determinates the gate of entry to Riga: 1 – Zemgale (Z), 2 – Latgale (L), 3 – Kurzeme (K), 4 – Vidzeme (V) (see Figure 6.).

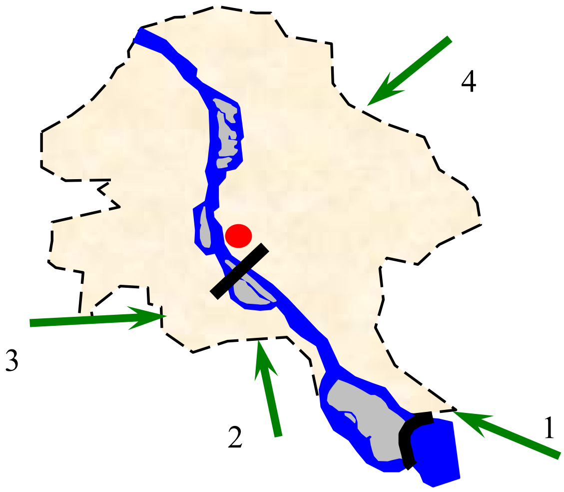
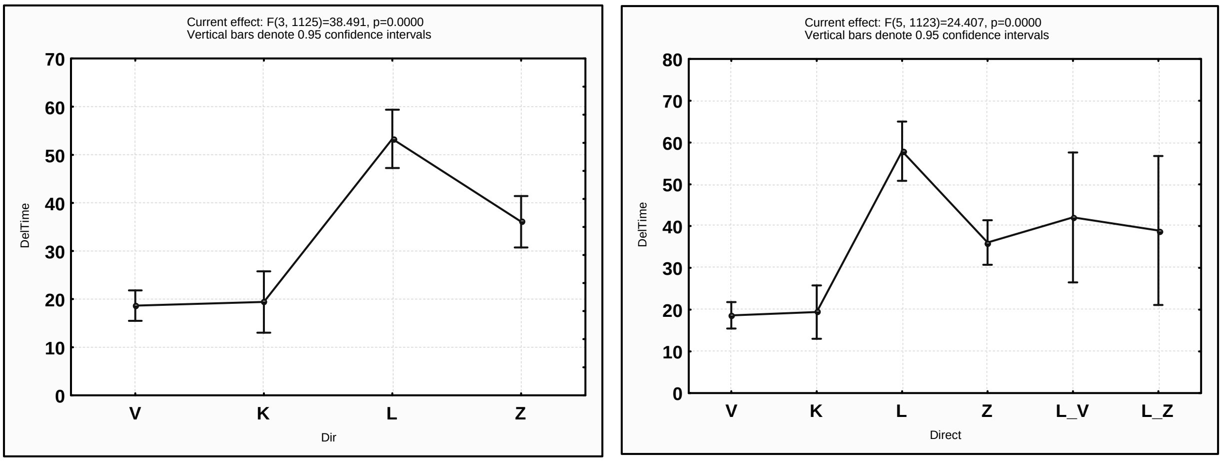


Fig. 6. *Basic directions of buses entry to Riga*



a) 4 gates *b) 6 gates*

Fig. 7. *95% confidence intervals for delay depending on directions (July 2007)*

In Fig. 7a) it is clearly evident that the value of the delay is considerably greater than in case of the Latgalian direction of trips. Changing of entry direction to the city is typical for four international trips. For example, trips from Minsk or Lvov can follow in Riga to the station through Latgalian or Zemgale direction, and trips from Moscow and Saint Petersburg – either through the Latgalian or through Vidzeme direction. In Fig. 7b*)* this case of factor influence analysis is presented at 6 levels – directions of entry – the size of delay. Even in this case the Latgalian direction is meaningfully outstanding by the duration of delay. The F criterion is equal to 24.41 at critical level of F(3,1125)=2.22. In case of 4 directions (without taking into account possible changing of direction) the F criterion is equal to 38.45 at critical level of F(3,1125)=2.61.

Delays for over 2.5 hours in July 2007 have been also analyzed (see Table 4). Among them the first place is occupied by Odessa with maximal value of delay in July – 447 minutes.

Table 4. Distributing of delays of over 2.5 hours for July 2007

>150min	**Odesa**	**Tallina**	**Kijeva**	**Kišiņeva**	**Ķelne**	**Berne**	**Bonna**	**Doņecka**	**Londona**	**Truskaveca**	**Viļņa**	**Krakova**
N	**5**	**4**	**3**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
max	**447**	**367**	**443**	**371**	**340**	**200**	**205**	**212**	**286**	**245**	**207**	**190**

It is clear that considerable delays in Table 4 related to four international trips are also connected to the problems of border crossing.

5. Conclusions

The task of estimating the quality of services from viewpoint of reliability is very important for the area of bus and coach operations. In the presented research delays time of arrival of buses at Riga Coach Terminal for July 2005 and 2007 years were collected and analyzed.

The conducted calculation and analysis of empiric descriptions of delay allows developing algorithms for realization of the proper tasks in analytical part of Information System with the purpose of decision of strategic and tactical tasks of terminal management. In addition, this information can be useful from the standpoint of simulation model construction of bus terminal with the purpose of critical situations analysis during a day. Examining quality of information, one of the major terms of high-quality simulation model, the real information on delay will allow making the model more realistic [5].

One of the important results of this analysis is the discovery of the company being a leader by trip delays with the aim to improve the passenger service quality.

The realization of this task gives the possibility to analyse the reliability of the bus service and to improve the level of quality on the base of these results. Also, the possibility to analyse factors, which influence on reliability of the bus and coach service is very important. The next step of investigation is to analyze the dependence between delay and the following factors: traffic and road conditions; route length and bus occupancy.

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MANAGING AND OPTIMIZATION OF COMPLEX IT-SERVICE PROCESS MODEL BASED ON IT INFRASTRUCTURE LIBRARY-STANDARD AND PROCESS CONTROLLING BY KEY PERFORMANCE INDICATORS

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Business Processes supported by IT Services is one of the mission critical factors of modern companies. Particularly the Business Processes are highly dependent on IT-Services and their process models. On market a trend of further optimization of IT-Processes and Services based on new ISO 20000 Standard is observed.

On the base of service modelling the approach for optimized IT-Services formation in context to ITIL Standard was described. The results of this research were used of further optimization and increasing of productivity of the central IT-Service Desk at Air Traffic Control (ATC) organization. Especially based on IT Services modelling it is possible to increase the customer relationship and efficiency of IT is necessary to standardized IT-Processes in a way that IT-Services are comparable, capable for multilevel benchmarks and shall be purchased on the market. The model has to develop these kinds of internal process interface but in addition also to design the external relationship to the different customers. The modelling of interfaces to the customer is one focus of modelling process because the service desk fulfils the central strategically customer interface between business and IT-provider.

In the paper the mentioned Service Process Modelling for ATC IT-Service Desk was performed as integrated part of process optimization for IT-Service division in the System house as a cost centre for German Federal Administration of Air Navigation Services and to implement an overall Incident Management Process based on ITIL Standard.

Keywords: *Modelling IT-Processes, Process Controlling, Definition of Key Performance Indicators (KPI), Process Optimization, Metric Controlled Models, Practical Examples*

1. Introduction and Problem Description

Based on management decision it was decided to implement a complete IT service management process based on market conform ITIL standard version 2. The main goals of service management implementation was design a customer related service process model including an internal accounting of services between the ATC business units and system house an internal service provider. The requirements for the designed IT Service Process Model were to increase the transparency of service provision and their economically accounting. A main step was in sourcing of a company own ATC service desk. This ATC service desk shall support all users of ATC Company and shall work on the ITIL Incident Management Process. During the implementation phase different services were designed based on simple process description and flow diagrams. With respect to further process optimization in the service desk and generation of new resources by higher level of process automation a special case study was started to perform a real service process modelling. The service process modelling for service desk shall identify lacks of service processes, optimization of process interfaces. A main goal is to implement in the service desk a consistent incident management process over the complete service level support. The modelled service process model shall control and manage by a special developed Key Performance Indicator System (KPI). This KPI-system shall fulfil the requirements for an ATC-specific service desk and shall use for controlling purposes of process quality and service performance.

The paper will discuss proceeding of ATC service desk process modelling and design of parameter to measure the specific service quality. The focus of paper is to describe the modelling process and definition of our specific design criteria. The framework conception and model can be used as a general proceeding and guideline for service process modelling. Based on special performed customer surveys which reflected the success and need of a company own ATC service desk was the motivation to extend the service portfolio, number of business support and ATM- shore applications which shall be supported by the service desk. So it was started a special case study for further optimization of service processes by development of an ATC specific service process model. In addition it was the first adaptation of ITIL standard into an ATC environment and process landscape, starting from an integrated process framework model.

2. Proceeding of ATC IT Service Process Modelling

Based on a case study and process consulting project between the IT-service division of DFS and the consulting company Hisolutions the following goals and general requirements for the IT Service Process Modelling were developed [1].

- A simple goal can be to identify the relevant business processes at first and to identify the business relationship itself. This goal sounds simple, but in some cases it is necessary and very important to identify the processes on different level via process modelling. For example it will be necessary for establishment of new business cases or services or inside of a sourcing project. The experiences show that it is very sophisticated to use business process modelling as a formal proceeding for process identification, their interfaces and needed de-liminitations to other processes.
- Based on an approved high level Business Model it is possible to perform a modelling proceeding on a more detail level and to identify different priority levels of business processes and dependences between different process levels and detailed processes itself. The identification of critical business processes is a very important task for service provider.
- Based on a Business Process Model it will be possible to derivate standardized business processes and to implement these kinds of processes into a specific business portfolio.
- Use of Business Process Modelling to implement IT Services from business and customer view.
- Performance of evaluation and benchmarking of IT process based on Business Process Model and use of process model for further optimization potentials of service quality, services processes itself and their process costs.

Based on these goals a specific new service process framework model was designed. Important for the performed modelling proceeding was the incremental approach, so our IT service desk process model is characterized by a top-down approach of modelling. The real process modelling contains different layer of multi-level details by a given and standardized notation and modelling language. The modelling of business processes is not only a detail description in textual or diagram form but contains also a complete and functioning model of data and process model. Based on business processes models can perform the simulation and evaluation by different views, like by data and event view, controlling and regulation view and functionality view. Figure 1 summarizes the main processing parts of service process modelling.

An important requirement to our optimization of service desk processes are the complete measuring of process quality, service level, and process duration time by a developed KPI-system. This KPI system shall be an integrated part of service process model. The results must be measured by product and process view.

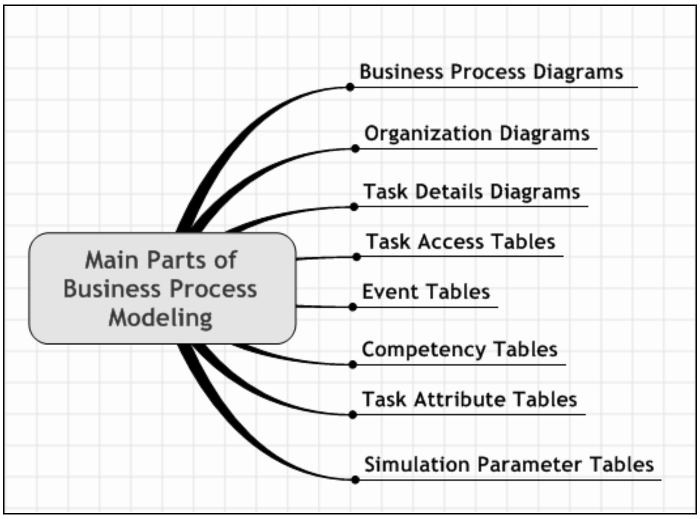

Fig. 1. *Overview of Service Modelling Proceeding*

The product view is the controlling of fulfilled requirement of costumer and the process view evaluates the efficiency of service production for the reviewed business process. To perform the evaluation step it is important to define at first the expected results for the customer and to define the KPIs to measure the process efficiency and performance. For a sophisticated business process model also the measurement methods and measurement point for evaluation shall be defined before.

3. Process Maturity Levels for IT Service Processes

The maturity levels describe the possible reached process quality levels. The maturity level description from the company Hisolutions [2] were used to perform a service process modelling for ATC service desk.

- 1. Level: Infrastructure Orientation of Business Processes
  The lowest Business Provision Level is the focusing on IT Infrastructure Operation. The Provider is

able to operate only IT Computer Centre Infrastructure Processes. Service definitions do not exist; IT-Processes are not controlled and performed only on adhoc- processing level.

- 2. Level: Business Process Orientation
  On this level the provider defines and documented IT-processes. The focus still on IT-Infrastructure. Processes will be controlled but not standardized (ITIL conform), Services are not defined.
- 3. Level: Customer Orientation
  Now real Service will be defined and modelled into the Business Process Models. The Provider realizes the benefit of business processes for customer. SLA will be closed, Service Parameter will be measured. The Provider is trying to satisfy all customer requirements and adapted the related SLA.
- 4. Level: Modelling of Service Business Processes and Products
  The Provider now will design configurable IT-Services and Products. The Service and Processes are standardized, the customer can select between different Service Performance and Quality.
- 5. Level: Market Business Process Orientation
  On the highest Maturity Level the Service Provider has a strong Market Position. Services and Products are completely Market conform and designed for Market Conditions based on a Business Process Model. Services and Products must be selling under Market Condition and in Competition to other Service Provider.

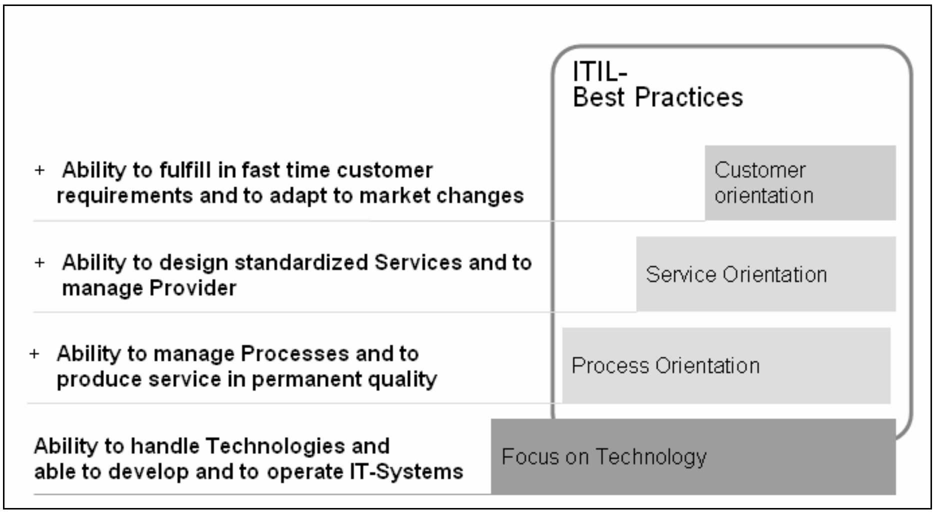

Fig. 2. *General Business Process Maturity Levels [2]*

These different Service Process Maturity levels can be used as a guideline for the requirement design for the Service Process Modelling. The designed Framework Business Process Model shall have general character, but can be adapted to more detailed and different process layers. Figure 3 shows the different steps of Business Process Levels.

4. Design Criteria for IT Service Process Modelling

Inside of the case study to prepare the service optimization by service modelling for the service desk it was noticed that no design criteria for IT service process modelling were available. So it was necessary to develop own design criteria for IT service modelling. An overview of the different design parameters are described in the following Mind Map (Figure 3). The Mind Map reflects a possible bundling of parameters and their different characteristics. This Mind Map has a guideline function, can be adapted to specific modelling purposes and reflects different design parameters to evaluate an IT Service Process Model. These design criteria were especially developed for the in sourcing project of ATC Service desk during project preparation and case study phase. These parameters shall be noted during the preparation of IT Service Process Modelling and specific actions needed to establish.

The main result of the case study is the development of the following proceeding and definition of steps for the modelling proceeding. In summarizing the IT Service Process Modelling can be performed by following steps:

1. Preparation Phase
   - Definition of modelling goals, expectations and conditions
   - Identification of main processes, customer and interfaces
   - Definition of Inputs, Outputs, Results

2. Modelling of Framework Service Process Model
   - Modelling of Service Processes on high level proceeding
   - Allocation of high level service processes to the different categories:
     - Primary Services
     - Support Service
     - Management Processes
     - Controlling Processes
   - Description of Framework Service Process Model
     - Process Sequences Description
     - Definition of required inputs and conditions
     - Description of process results and generated added value
3. Detail Modelling of Service Processes
   - This modelling step can be performed on different and several detailing levels
   - Repeating of modelling steps from (2) but on a more detailed level
   - Definition of KPIs for measuring processes, measuring units, methods and measuring points.

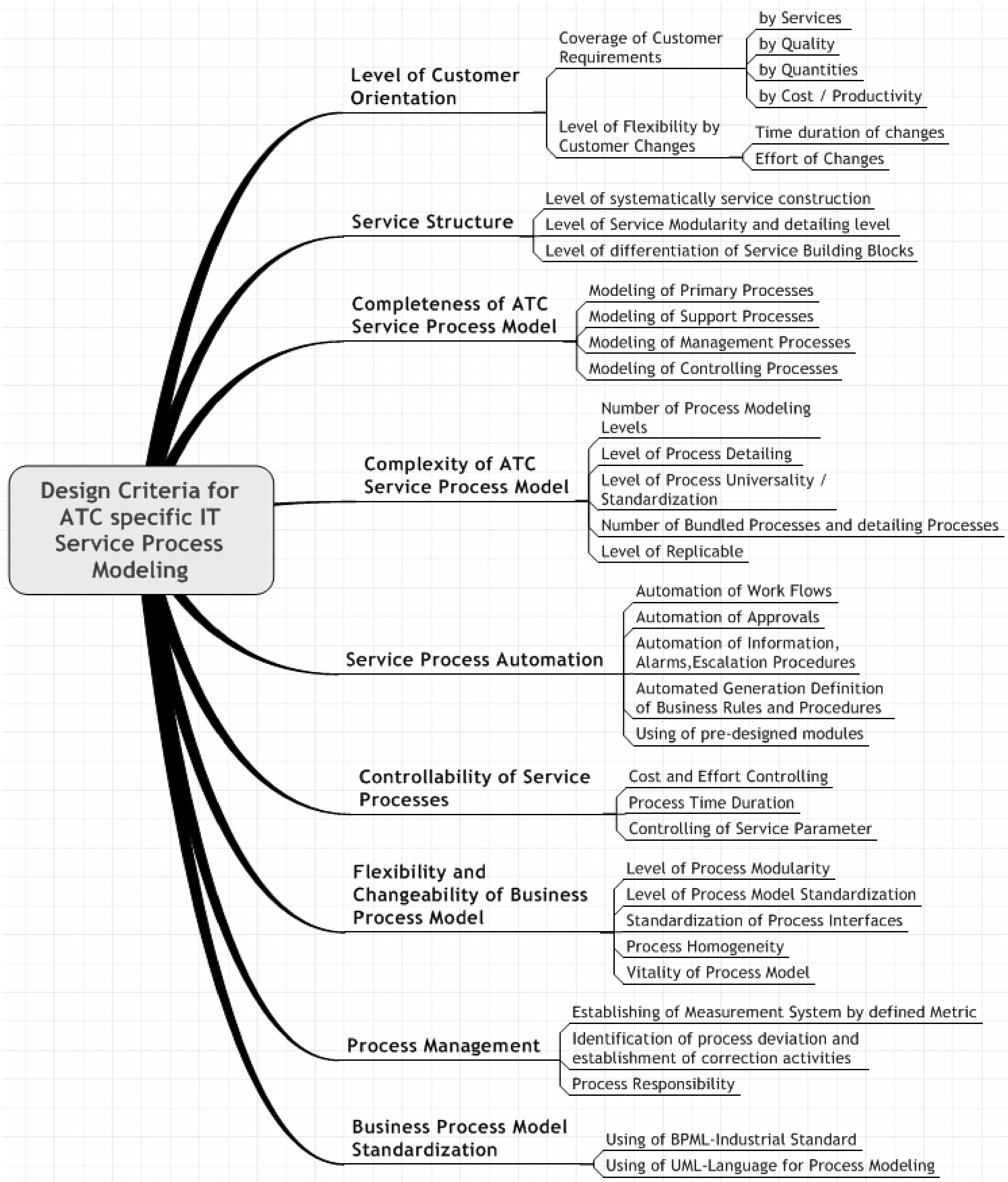

Fig. 3. *Design Criteria for IT Service Process Modelling*

4. - Identification of service resources including human resources and their qualification
   - Implementation of customer requirements into the detailed service processes
5. Analysis and Post-review of Service Process Model
   - Reconsolidation of detailed service processes itself and between the different processes and process detailing levels
   - Definition of process duration time, time periods and needed prerequisites
   - Analysis and Consolidation of interfaces and data objects
   - Analysis of process involved parties and resources
   - performing of service process model simulation
   - Performing of plausibility Checks
   - Establishment of correction activities
   - Performing of efficiency appraisal (effort- profit-analysis)
   - Establishment of KPI reporting system

It shall be mentioned that a sophisticated service process modelling can be performed only with tool support and implementation of automation. Important is to perform the modelling process step by step and to implement an incremental modelling approach. The evolutionary modelling proceeding helps in the practical handling of complex business processes and to decrease the complexity level and so the better control of complex processes.

5. Establishment of KPI System for ATC IT Service Desk

The Service Desk is the central and strategically interfaces to the customer and user of Business Support System on all locations of German ATC organization. Based on the IT Service Process Model will reach a high level of process transparency, implementation of service process management, incremental optimization process to increase the efficiency and performance of Service Desk and to manage the service by KPIs.

The tool GRADE Modeller Version 4.1 [4] was used for modelling the Service Process Model.

Due to the complexity it is necessary to focus to the Framework Service Process Model. Basing on the Framework is very comfortable to go into the more detailing level to each process modelling. The Framework Service Process Modelling for ATC IT Service Desk started from the high level support. It is very important to start by a high level approach. Helpful is to use Process or Service Standards. For the framework modelling level we used the ITIL Standard and the different defined Service Levels as a guideline for a top down modelling proceeding. For a better overview the GRADE Modeller has the possibility to start from a Package View. An example for ATC IT Service Desk is given in figure 4.

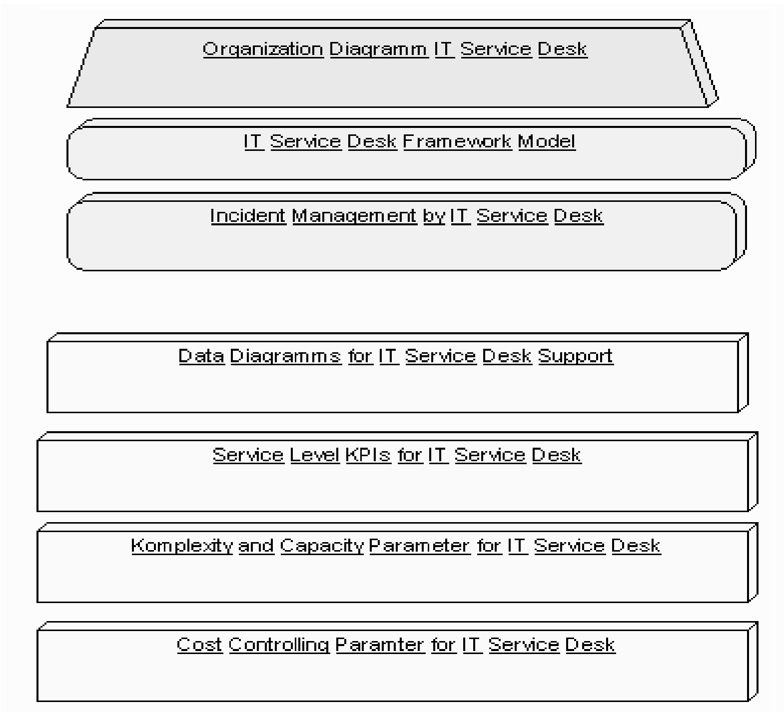

Fig. 4. *Package Business Process Model View*

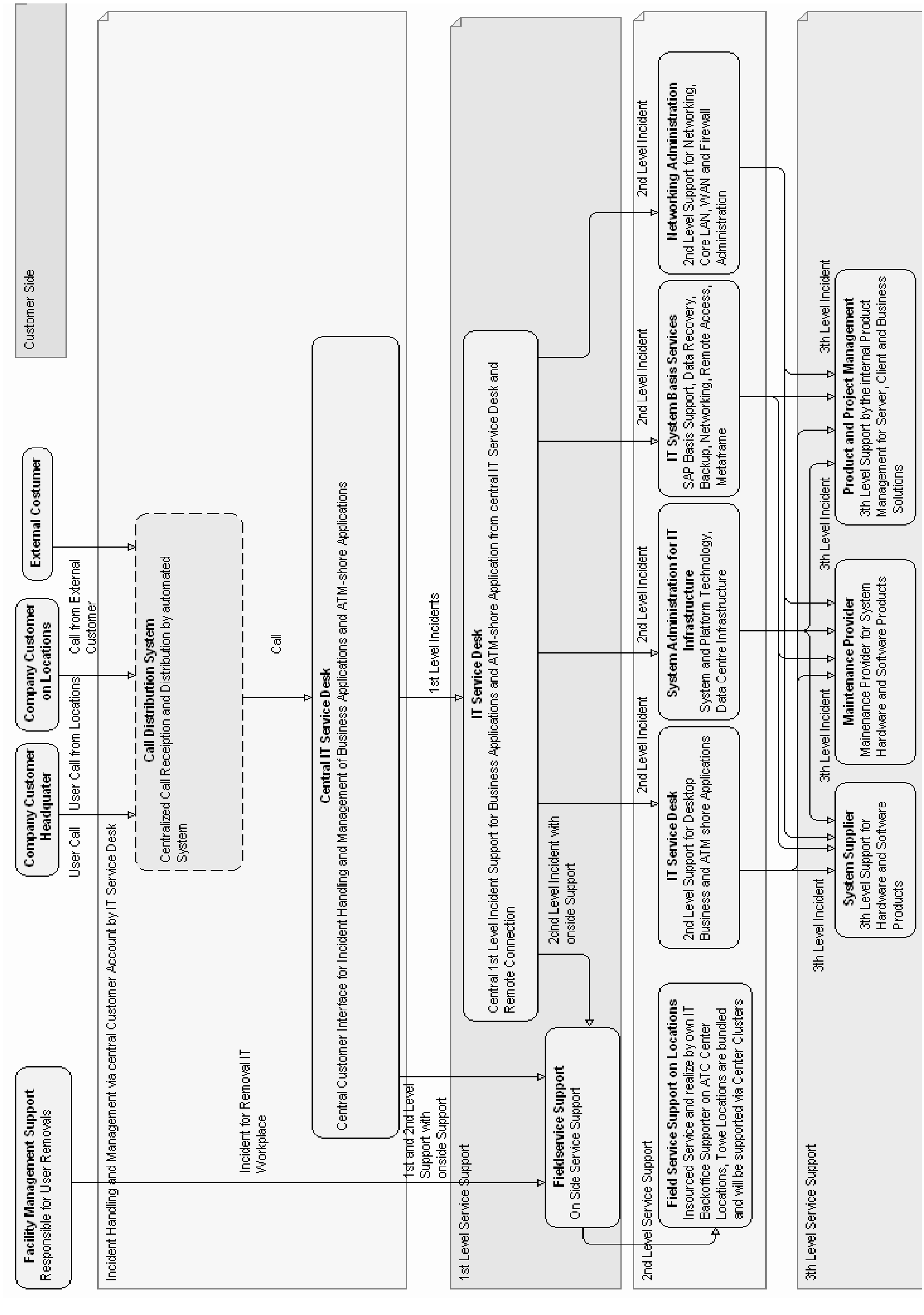

***Fig. 5**. Framework Service Process Model for IT Service Desk*

The Figure 5 shows the framework modelling of ATC IT Service Desk.

Based on this framework service modelling it can be started to design the data diagrams for different purposes. The data diagrams can have the following goals:

- To describe the technical Data Objects including the measuring units, period of measuring and usage of parameter
- To evaluate the ITIL Capacity Management Process and to describe different parameters for description of capacity and complexity of services
- Use indicators for design the required service level for customer
- Identify the right cost parameters

The different kinds of KPIs or parameters are very helpful to perform an external service benchmark. The following data diagrams reflect only some examples of possibility to modelling at the same time with the service process also the related and necessary KPIs.

The design of measuring parameter for the service process model is a significant quality parameter of modelling, because the process modelling can be analysed and evaluated only by predefined specific parameters. So it will be suggested the modelling session and definition on data diagrams at the same time the period should be performed. The following figure presents the data diagrams for service level definition for an IT Service Desk [3].

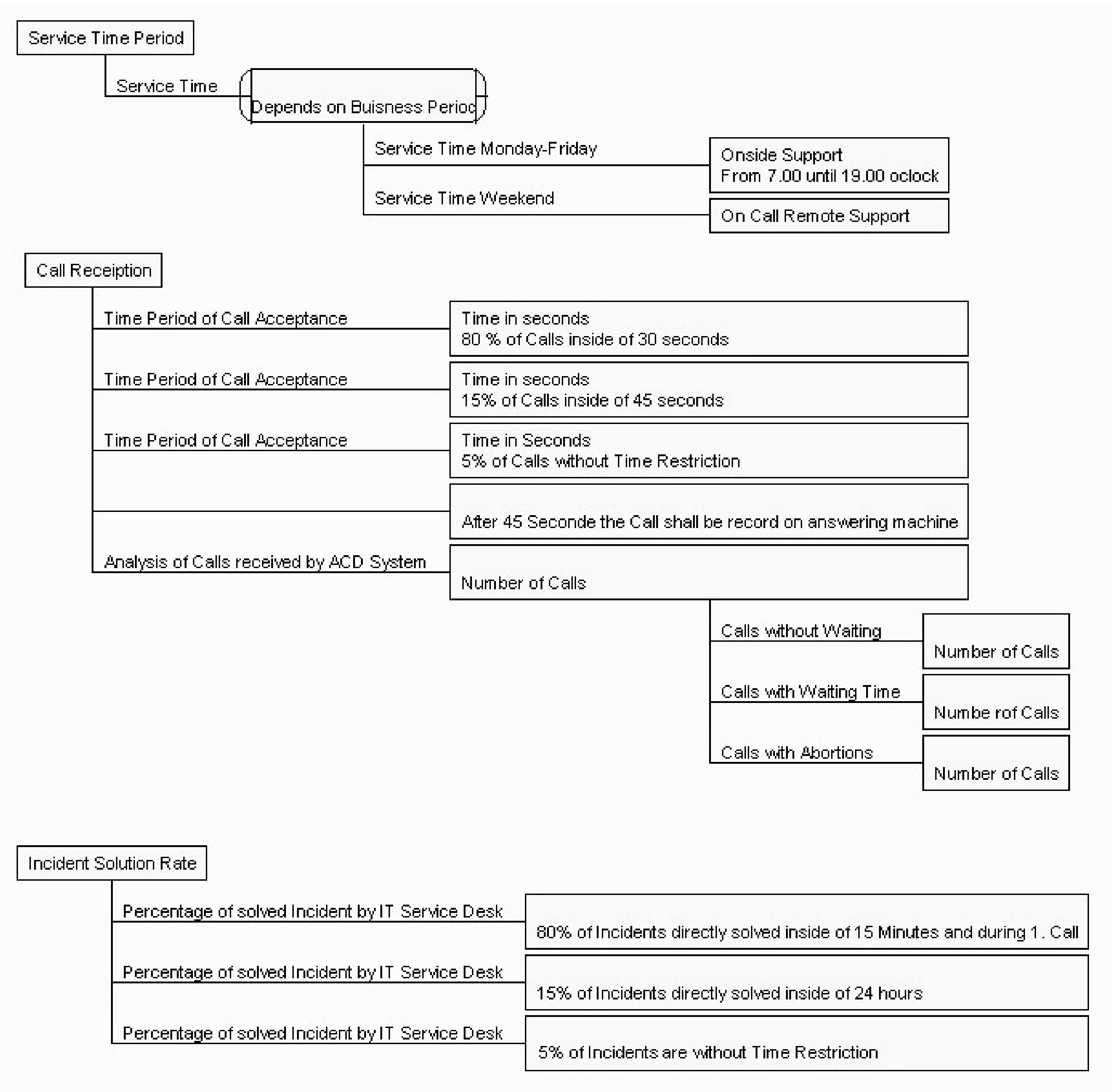

***Fig. 7.** KPIs for IT Service Desk Service Level Definition*

6. Conclusion

The Service Process Modelling gives the scientific approach and approval of following findings:

- Based on international ITIL Standards for IT Service Management it is possible to model and to design IT Services and by using modelling tools to simulate the different detailed service processes before establishment into real practical environment.
- From investigation point of view the modelling process helps to analyse and to check the service processes by a top down approach. It helps to increase the process quality and completeness.
- In addition it will be necessary to define different kinds of parameters, their measuring unit, methods and point for evaluation of service processes.
- Based on service modelling the design of service level can be performed in a sophisticated and approved quality.
- With the help of the framework model and detailing process modelling it is possible to identify possibilities of standardization and harmonisation. For a service provider is sufficient to increase the service standardization level and to be able to generate a standard service portfolio. This is an additionally added result of service modelling.
- The systematical development of IT Service Process Models is a core competence of ATC internal IT-Service Provider, because he has the competence and ATC business view. Professionally designed ATC Service Processes is a main requirement of customer. So the ATC Service Provider will change from individual management to a provider with a specified Service Portfolio based on flexible Business Process Model on different layers and levels.
- The service model and the defined cost controlling parameters will serve to increase operational service cost and to have an independent cost analysis process. The modelling services processes and the complete KPI-system of all kind of parameters is an essential prerequisite to perform external service benchmark.

The presented material reflects the results of investigations executed in frames of PhD study under supervision of Dr.sc.ing., Professor Igor Kabashkin.

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APPLICATION OF INTELLIGENT TECHNOLOGIES FOR IMPROVEMENT OF CUSTOMER SERVICES IN CIVIL AVIATION

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The paper presents an overview of recent trends of application of the newest intelligent technologies in civil aviation aimed at facilitation of passengers' service quality. The need of intelligent technologies is stipulated by the present situation in civil aviation market, i.e. enlarging of passengers and traffic goods traffic at airports. Stricter security procedures and intensive traffic require and call for the need of application of the newest and state-of-the-art technologies as such a tremendous traffic loading becomes too complicated to deal with. There are three intelligent transport technologies analysed in this article – Radio Frequency Identification system; Biometrics technologies and E-ticketing system (including e-check in systems). The current situation of Lithuanian civil aviation market in terms of possibilities to deploy the afore-mentioned technologies is analysed as well.

Keywords: *RFID, ITS, biometrics, e-ticketing, e-check in, e-purchase*

1. Introduction

Passenger traffic at the world's airports accounted for more than 4.4 billion passengers in 2006 (it is 5% more compared with 2005), goods traffic accounted for 85 mill. tons (increase of 4%); 74 million aircraft movements, 38 billion dollars spent by the world's airports on development [1].

Civil aviation market in Europe sees strong growth in the recent years. Restructuring and integration are well advanced, and the market has been broadened with the multiplication of routes served in Europe, the entry of low fares ("cheap flight") companies and the development of regional (many of them – previously not used for civil purposes) airports. Low-fares aviation operators account approx. for 25% of all scheduled intra-EU air traffic and have stimulated the growth of regional airports Traditional aviation companies have reduced costs significantly as well in order to compete with low-fares carriers and keep their passenger's share. This situation in the aviation's internal market of the EU due to increased mobility has brought considerable benefits for customers [2]. On the other hand, more intense traffic requires more effective management and thus fostered implementation of new technologies, the vast majority of them might be considered as IT related.

The IT investment priorities of airports are being shaped by the need to cope with traffic growth and a new breed of technology intensive airlines, but global instability has also refocused attention on security.

In a world of transport, those information and communication technologies that are used in a combination with the vehicles and networks that move people or goods are called intelligent transport systems and services [4]. In terms of civil aviation market, the vast majority of information and communication technologies are highly advanced, this notwithstanding, not all of these might be called or are called intelligent ones. The term "ITS", was born two decades ago, so usually the ones, that were invented and deployed more or less within period of two decades are usually considered as ITS. We have chosen to analyse three ITS systems that were "born" (implemented rather than invented) in the ITS era:

1. Radio Frequency Identification system;
2. Biometrics;
3. E-ticketing system.

Excellent customer service is one of the greatest assets for airports in today's competitive environment of civil aviation. There are many factors that can help airports to build its customer base, and customer service can be a determining factor in the success of an entire operation. Intelligent technologies, undoubtedly, might be treated as the main factor to improve customer service. According to survey on IT trends, almost 60% of airports treat operational solutions as a high priority (mainly due to growing traffic); 57% of airports give the high priority to security related solutions, and approx. half of them perceive passenger and baggage processing systems as the highest priority for IT investment [3]:

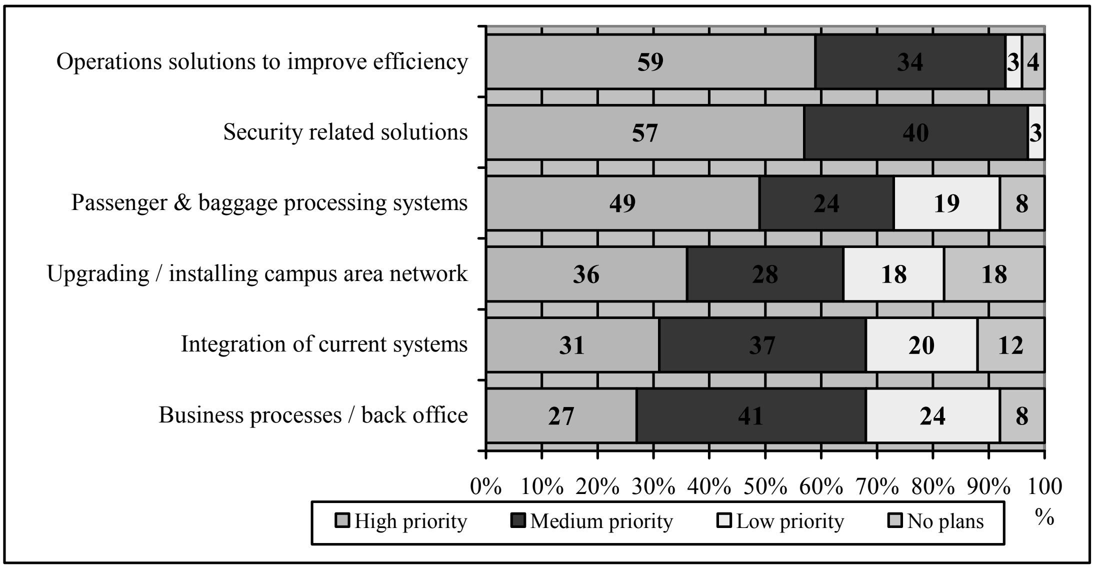

Fig. 1. *IT investment priorities of airlines in 2007*

2. Radio Frequency Identification

Radio Frequency Identification (RFID) – is a technology incorporated into a silicon chip embedded in a tag, which emits a radio signal that can be read at a distance without needing to see the item [1]. Tags can be "talked to" or "written to", allowing the status of an item to be updated as it is processed. It has a great potential to be used in civil aviation, especially for improving baggage handling, which is seen as one of the highest priority for IT investment (see Fig.1). The application of RFID system might significantly improve customer service as, for instance:

1) to reduce mishandling of baggage;
2) to avoid bag tag reading errors;
3) to increase speed of baggage handling operations.

RFID gives many advantages not only to customers (fewer mishandled baggage pieces), but has also many advantages to airport and operating airlines in it as well. These benefits encompass both baggage and in-flight services. A generic example of RFID technological system is shown on Figure 2:

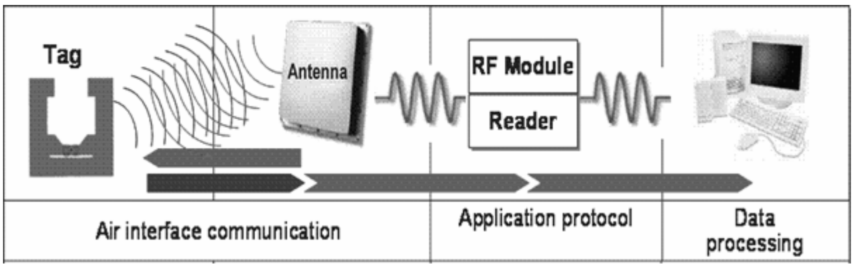

Fig. 2. *Generic principle of RFID System*

The main function of tag (or transponder) is to store data and receive signal. The tag itself might be both active and passive – i.e. is enabled to send a signal or receive it. The antenna launches and receives radio frequency transmission used to allow tag communications and thus enables the tag to transmit the ID information to the reader. Then the reader converts the radio waves returned or received from RFID tag in a form that might be sent to computers. The reader sends data to computer system for logging, processing, archiving and analysing.

The tag can be updated with new information, which is the main difference from other technologies used such as bar code. This means that new information can be updated on an item's tag as it travels around different locations. The technology also allows for tags to be read from a distance, through most substances, and for multiple tags to be read at one time, making it ideal for environments, where items are stored in piles.

RFID readers are very cheap and this is a strong advantage compare to bar code systems. Besides, RFID system allows to read labels without a clear line of sight distinguishes with resistance to damage for both the labels and the readers and a very high read rate for RFID tags. Despite the mentioned advantages, deployment of

RFID technology is not that rapid, as it could be, bearing in mind high demand for facilitation of baggage processing.

3. Application of Biometrics at Airports

Biometrics is a generic term used to refer to a physiological or behavioural characteristic that can be measured to verify the identity of an individual [5]. Physiological biometrics measure a part of an individual's anatomy, e.g. fingerprint, hand, face, and iris; behavioural biometrics measure an action performed by an individual, e.g. voice, signature; in both cases the characteristics have to be identifiable, universal, unique and permanent.

Airports Council International encourages all its members to use standard biometrics in their border control, passenger facilitation and access control implementations, in order to increase security and alleviate congestion, as well as to increase satisfaction of passengers.

Biometrics can be used to verify a specific identity of a person. Biometric systems have a series of key processes that have to be completed in order to allow a person to use the system and to achieve verification or authentication of a user's identity.

These key processes include:

1. Enrolment – the capture of the raw biometric.
2. Template creation – preserving the biometric via the use of an algorithm to extract a template from the image captured that will subsequently allow the image to be compared to others using the same algorithm.
3. Identification – takes new biometric samples and compares them to saved templates of all enrolled users.
4. Verification – takes new biometric samples of a specific user and compares them to old samples taken from the same user.

Figure 3 describes system design of biometric technology. Enrolment process is shown in yellow, the biometric verification – in green light.

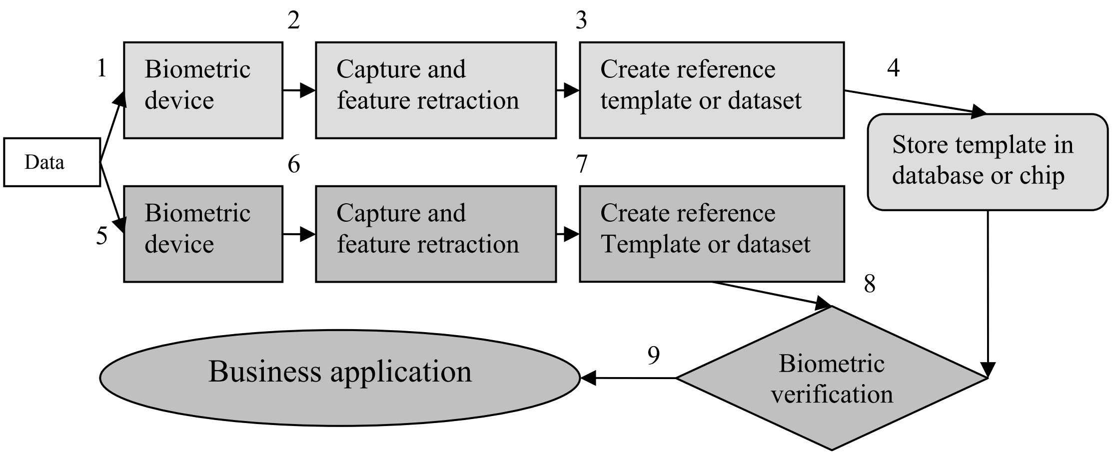

Fig. 3. *Generic principle of biometric processes*

4. E-ticketing Systems

Civil aviation was the first sector that implemented electronic ticketing systems. Opposite to urban transport, where e-ticketing (mobile ticketing) has only been trespassing testing period, e-ticketing in civil aviation has been greatly used and fast developing. E-ticketing was first recognised as a major opportunity by the airline industry in 1995 [1]. E-ticketing is much safer compare with paper ticketing, in a way by introducing e-ticketing, airlines try not only to reduce ticket – related costs (staff, printing, sale points), but also to eliminate fraud, related to paper tickets.

E-ticketing is the most advanced method to document the sale and the best way to track usage of passenger transportation, because details of the ticket are stored in the issuing airline's computer system and made available to enable all transactions, which could be carried out using a paper ticket. In a way, e-ticketing in a broader view might be described a tripartite (see Fig. 4):

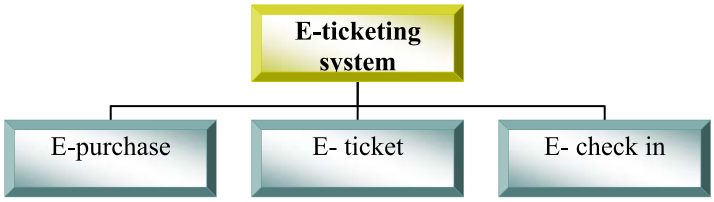

Fig. 4. *E-ticketing system*

The targets of IATA as concerns the implementation of e-ticketing has been successfully achieved: Target of 40 per cent of e-ticketing implementation by end 2005 (achieved November 2005); Target of 70 per cent e-ticketing implementation by end 2006 (achieved October 2006); Target of 100 per cent e-ticketing worldwide by end May 2008.

The main advantages of e-ticketing for passengers encompass easier handling of itinerary changes especially for last minute travel decisions, more effective use of Internet capabilities for booking travel and check-in and eliminations of lost ticket's risk. There are important advantages for travel agents as well – eliminated costs of ticket printers, maintenance, and ticket distribution.

Further step of e-ticket in civil aviation, is to facilitate transfer from aviation network to another mode, i.e. there is a strong need for an integrated e-ticketing system. Based on experience of Lufthansa, this seems quite a viable option: in 2001 Lufthansa concluded an agreement with Deutsche Bahn to offer trips combining a rail journey between Stuttgart and Frankfurt with flight connections in Frankfurt to or from anywhere in the world. Passengers can book a single rail–air ticket in a single transaction. They can check-in their baggage when arriving at the station and in the event of a problem they enjoy the same rights as ordinary air passengers, regardless of whether they are dealing with Deutsche Bahn or Lufthansa. Other options as, for instance, "air-coach (bus)", "air-taxi", "air-car parking" have been introduced in the Netherlands, France, Germany, and are seen as perspective benchmarks.

E-check-in system – is an additional part towards well-functioning and convenient ticket registration service. E-check-in system might be divided into three options that now are available in practice – online, text message (SMS) and self-service kiosk options (see Fig. 5):

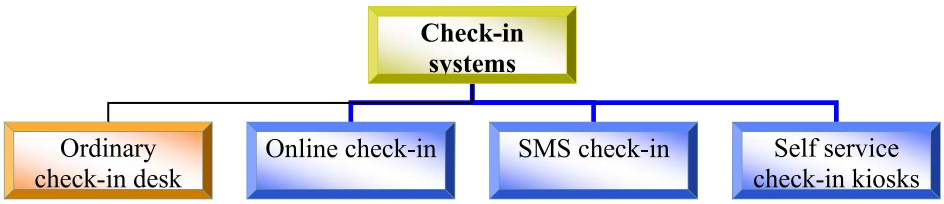

Fig. 5. *Check-in options*

Many companies have made e-check-in self service kiosks available at the busiest airports. Recent trends show self service options very reasonable for domestic flights as well. E-check-in is seen as necessary part of e-ticketing system. The leading airlines where they have frequent flights, install user-friendly touch screen computers at the airports' check-in zone for passengers could choose either to perform self-service check-in, make reservation, or purchase e-ticket and check-in at a one-stop service point. Some companies provide self-check-in services by deploying self service kiosk in other zones as well (hotel lobbies is an option too).

SMS check-in option allows checking-in with a text message in advance. Company sends proposal in advance to passengers for checking-in. Customers only need to reply to a text message before each flight departure. When travelling with carry-on baggage only, passengers may directly proceed to their departure gate. If passenger has a luggage, the latter can be left at the baggage drop desks. The same is true for online check-in and self-service kiosks.

E-check technologies are necessary to handle queues and facilitate inner procedures at airports. Besides, gives more flexibility to passenger (choosing the seat in the aircraft, check-in time depending on ones willingness, and etc.)

5. Implementation of ITS in Lithuanian Aviation Market

The main civil aviation system of Lithuania consists of three international airports: Vilnius, Kaunas and Palanga, and a state enterprise providing air traffic control and air navigation services (SE "Air Navigation"). As passenger flows are rapidly increasing and regulation of aviation safety and flight security has become stricter, further development of the airports is needed and significant investment is foreseen. After Lithuania's accession to the EU, passenger traffic in all international airports has increased significantly (see Fig. 6):

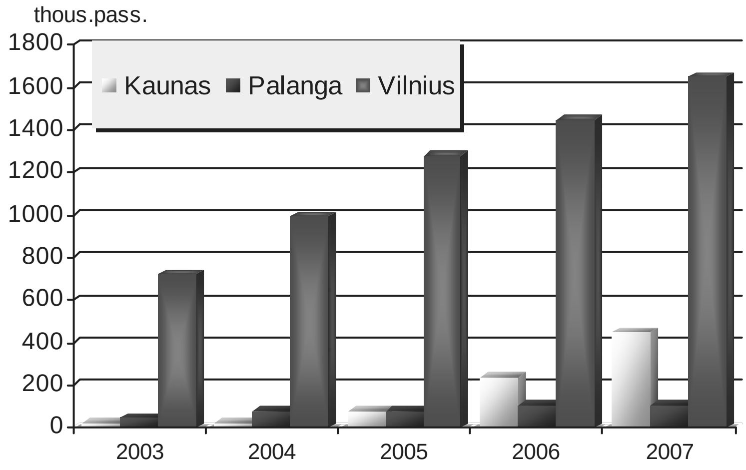

Fig. 6. *Passenger traffic at international Lithuania's airports*

It is expected that in 2007-2013 the average rates of growth in the number of air transport passengers will be 3–4% per annum in most West European countries. More rapid annual growth rates are forecast for Lithuania, i.e. 10–11%. This can be explained by a number of reasons: firstly, further development of the Lithuanian economy will take place and it is expected that during the next 10 years it will be more rapid than in the old EU Member States. Secondly, the common business infrastructure will be developed (including air transport). Thirdly, Lithuania's air transport market is not saturated; the demand is growing, while alternative modes of transport will not be capable of competing with the air transport in providing long-distance carriage services. And finally, low-fare companies, that started operate their business in Lithuania in 2004, successfully augment their share of passengers.

In order to improve passenger and cargo services and to meet the rapidly growing demand for air passengers and cargo carriage, infrastructure of the airports and air traffic services must be improved and its capacity increased; the range of services must be developed, flight security and aviation safety facilities modernised, and competitiveness of airports in the liberalised market increased.

Weaknesses of the Lithuanian civil aviation are related to the lack of technical facilities at the airports. Vilnius international airport as the main airport in the country lacks behind its counterparts in the capitals of the EU Member States due to the lack of conditions for passenger service and underdeveloped infrastructure necessary to service transit flows of passengers and cargoes.

Vilnius airport – the largest in Lithuania, had over 1, 6 mill. passengers' traffic in 2007 (maximum throughput of the airport is 3,5 mill. pass). It is of average size compared to regional airports of the Western Europe. Nevertheless, Vilnius airport sees rapid growth. Although significant investments are being allocated for modernisation during last decade, the airport infrastructure may be not capable of servicing the forecast passenger flows already in the nearest future. Kaunas international airport is the second biggest with runway of 3,250 m and the width of 45 m and had a passenger traffic of over 0,4 mill. in 2007. Rapid development of Kaunas airport is related to the Kaunas free economic area and active operation of low-fares and charter-flight airlines. If passenger flows will increase rapidly, the infrastructure of Kaunas airport can be incapable of providing high-quality services. Palanga international airport focuses on passenger services in order to promote development of resort services and tourism and to meet business needs of port city's Klaipeda region runway.

The underdevelopment of infrastructure oriented investments to the necessary basic development (extension of terminals for Shengen processing, deployment of flight safety and security facilities, replacement of ILS) and thus hindered the bigger projects of ITS for passengers' quality improvements. There are no concrete plans for implementation of RFID of biometrics technologies in any Lithuanian airport. But relatively small size of all airports and extremely fast growing passenger traffic (esp. in Kaunas airport) requires design and deployment of smart technologies to be able to manage arising problems in terms of baggage handling and management of inner logistics. Lithuanian citizens do not have biometrics data in their passports and this is the main obstacle for development of concrete action plans related to this technology.

Any of the main airlines operating in Lithuania, have not deployed self service check-in kiosks. Despite this, such an option might be feasible in a nearest future due to rapid growing passengers' flow and high demand for facilitation of procedures. When passenger traffic reaches its limits, RFID and e-ticketing solutions will be treated as a necessity, while for the time being it is still an option.

6. Conclusions

1. Growing passenger traffic calls for the need to better cope with more and more complicated situation as concerns passenger service, baggage handling, flight safety and security. Therefore intelligent transport systems are needed to improve every section of air transport chain and especially the quality of passenger services.

2. RFID readers are very cheap, allowing the installation of many readers; as a result, the enhanced process visibility allows more control over the operation at a lower cost than with other technologies, such as bar code.

3. Application of biometrics is seen as a progressive means to facilitate passenger at border control, when checking-in and boarding, to ensure security.

4. E-ticketing systems are standardised, well functioning and eliminate fraud related with paper ticketing, when introduced.

5. Relatively small passenger traffic at Lithuania's airports is the main reason for slow ITS deployment process at Lithuanian civil aviation market.

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QUALITY ESTIMATION IN POST-OBJECT TECHNOLOGIES OF SOFTWARE DEVELOPMENT FOR TRANSPORT SYSTEMS

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The quantitative quality estimation problem for modern transport software systems is examined in this paper. Among the most popular post-object development technologies for such systems the aspect-oriented and generative approaches are chosen. The features of these approaches are investigated, and the metrics suite is offered. The metrics suite is oriented to the comprehensive quality estimation in these post-object technologies.

***Keywords**: aspect-oriented approach, generative approach, family of software transport systems, metric, complexity, cohesion, coupling, dependences, aspect, component, crosscutting concerns, quality, estimation*

1. Introduction

Modern software transport systems are the quickly evolutive software families of the 21th century. They cover a wide spectrum of tasks, particularly the tasks of control for complex dynamic objects and whole systems (such as air traffic control systems), forecast, expert estimation and decision-making tasks, transport logistic tasks. All these tasks have defined various requirements to functional and dynamic features of software transport systems.

It is known, that at creation of the modern software for transport systems the object-oriented approach (OOA) is widely applied. However, OOA is not deprived from drawbacks. For example, it extremely unsatisfactorily copes with realization of crosscutting concerns, being a part of practically any modern software system.

Such concerns cannot be accurately enclosed in base program modules — classes that inevitably lead to unjustified increase of software complexity. A promising decision for representation of crosscutting concerns suggests the aspect-oriented approach (AOA), introducing the concept of aspect. An aspect is a structure, realizing crosscutting concern and interacting with system base modules. Introduction of aspects "eliminates" from realization unnecessary complexity and improves programming structure on the whole. AOA expands OOA, reduces coupling between modules and increases their cohesion.

Other perspective line raising software reliability and efficiency is generative approach. Generative approach to development is focused on the automated creation of software products from separate components, it is called to provide transition from decisions meant for single application, to the automated producing of family of various software products, maximally meeting customer's requirements. Such families are presented in terms of library of components.

Unfortunately, quality of both aspect and component decisions can not be estimated, in connection with absence of a proper tooling — metrics suite. Thus, creation of metrics suite will give an opportunity (within the framework of aspect and generative technologies) for correct estimation of quality of project decisions, giving a numerical estimation of quality.

2. Synthesis of Metric Suite for Aspect-Oriented Approach

2.1. Analysis of Problem Domain

As is generally known, at creation of metrics for estimation of program system quality it is necessary to examine the measure of modules complexity, measure of complexity of external relations (between modules) and measure of complexity of internal relations (within modules). Traditionally external relations describe with such characteristics as "coupling", but internal relations — with "cohesion" [5]. Coupling represents a measure of interaction between modules on data, which is desirable for reducing. Module cohesion, in turn, is defined by the measure of dependence between its parts. The higher is module coupling, the better is planning result.

Presently the task of creation of metrics for object-oriented program systems is solved. These metrics form groups in relation to concept "class" — basic building element of such systems.

AOA is a superstructure above the object-oriented approach [1]. This superstructure expands OOA, instead of replaces it. AOA enters into system architecture new building elements (aspects), which cooperate with base elements — objects and classes. Due to this increases power and efficiency of development tools.

As basis for the estimation of structures of aspects it is expedient to use description "coupling", because an aspect, on determination, must be strongly coupled (must intensively co-operate) with the base elements of the system. The higher aspect coupling, the lower coupling system objects and, consequently, the higher quality is of program system.

2.2. Aspect Oriented Metrics Set

2.2.1. Specific Weight of Aspect SWA

The *SWA* metric (Specific Weight of Aspect) estimates the degree of concrete aspect influence on the system base elements (instances of classes) at realization of the certain crosscutting concern. The more is the functionality of aspect, the more is its coupling and the lower is coupling of class instances.

It is clear, that realization of crosscutting concern includes functionality (attributes and operations) of different classes. The more of such functionality lies in aspect, the higher its specific weight.

Let's consider, that some aspect influences on *n* classes. We shall designate the amount of operations and attributes, "withdrawn" by an aspect from *i-th* class, as $f_a(i)$, and the total amount of operations and attributes *of i-th* class as $f_{all}(i)$. In this case SWA metric is calculated as follows:

$$SWA = \frac{\sum_{i=1}^{n} f_a(i)}{\sum_{i=1}^{n} f_{all}(i)}.$$

It is obvious, that SWA metric defines aspect utility degree, it shows how much given aspect "releases" system classes from some crosscutting concern. Value of the metric can range within 0 and 1. The more is aspect specific weight, the higher is design decision quality. If value is close to zero, introduction of aspect does not make sense. SWA values close to unit suggest maximal aspect influence on achieving of AOA ultimate goal – encapsulation of all crosscutting concerns in separate elements.

2.2.2. EFficiency of Aspect EFA

The *EFA* (EFficiency of Aspect) metric is focused on measurement of aspect quality from the point of system view. The basic purpose of aspect is to reduce coupling in program system. In fact the aspect relieves classes from necessity of interaction at realization of crosscutting concern. This metric must show how efficiently this task is solved.

Let's consider still, that some aspect influences on n classes. By other words, these classes "work" on crosscutting concern, realized by aspect. We will name these classes as involved. We shall designate the value of *i-th* involved class coupling before introduction of aspect as C_{ini}, and after introduction of aspect — as $C_{fin}(i)$. Then *EFA* metric pays can be calculated on formula:

$$EFA = \frac{\sum_{i=1}^{n} C_{ini}(i) - \sum_{i=1}^{n} C_{fin}(i)}{\sum_{i=1}^{n} C_{ini}(i)}.$$

For calculation of coupling it is possible to use standard object-oriented metrics, for example, from the Chidamber's and Kemerer's metrics suite.

We see that *EFA* metric can take values in a range from 0 up to 1. The more is the value, the higher is aspect efficiency. If a value is near to the zero, introduction of aspect did not bring desirable result. *EFA* values close to unit, suggest maximal decrease of coupling and, hence, maximal aspect quality.

Use of the offered metrics allows getting of proved reasoned decision during aspect design.

3. Synthesis of Metric Suite for Generative Approach

3.1. Analysis of Problem Domain

As it was already marked, at generative design it is necessary to translate attention from single systems on families of systems [2]. Presently there are a few generative techniques, describing stages of creation of program transport systems families [6, 7, 8, 9, 10]. Each technique describes steps necessary for achievement of the put goal, namely, for development of program system model. Creation of metrics suite will give an opportunity (within the framework of generating approach technologies) for correct and comprehensive estimation of these models quality by assigning a numerical value to quality. The opportunity of estimation of models without their realizations allows in advance to expose the lacks of a future program transport system, and also to make all necessary alterations.

In the generative approach a base element is the component. Thus, it is necessary to create a set of metrics (which presently does not exist), oriented on a component. Certainly, component-oriented metrics, as well as object-oriented metrics, must measure the same base characteristics of any software product (complexity, coupling, cohesion). Considering affinity of "component" and "class" concepts, it is expedient to use in synthesized metrics those ideas which have been put in a basis, for example, in the most popular Chidamber's and Kemerer's object-oriented metrics suite. Certainly, these metrics need to be adapted for orientation to a component (as a base element of the generative approach).

As already it was noted, there are some generative techniques of development of program systems. Techniques by GenVoca and Draco [2, 7, 8, 9], by means of which it is possible to receive different models, are most popular. As it is necessary to have an opportunity of estimation of each model, it is necessary to create two sets of metrics for generating approach. In the given work we shall present metrics for GenVoca's technique.

3.2. A Set of Metrics Focused on the GenVoca's Technique

3.2.1. Weighted Realizations Per Component WRC

The *WRC* (Weighted Realizations Per Component) metric is based on the object-oriented metric *WMC* (Weight Methods Per Class).

Let's admit, that in a component C are defined n realizations with complexity c_1, c_2, … c_n. We suppose that nominal complexity for realization accepts value 1. In this case WRC metric is calculated as follows as follows:

$$WRC = \sum_{i=1}^{n} c_i \ .$$

The amount of realizations and their complexity inside of one component are the indicator of expenses for program realization of this component. With growth of amount of realizations in one component its complexity all more increases, that limits an opportunity of repeated use. On these reasons WRC metric should have reasonably low value. At consideration that all realizations have identical complexity equal to 1, it will be simple amount of realizations in a component.

Unlike object-oriented approach where two opposite variants of account of methods in a class are possible, for the generative approach is characteristic unequivocal way for determining of quantity of realizations in a component. In the object-oriented approach can be taken into account not only current class methods, but also inherited methods. In the generative approach inheritance of components does not exist. Thus, only one variant of the account of realizations is possible.

3.2.2. Depth of Dependence Tree DDT

The *DDT* (Depth of Dependence Tree) metric is based on the object-oriented metric *DIT* (Depth of Inheritance Tree), which measures topology of tree of inheritance of classes. Between components inheritance is not present. Instead of it, it is expedient to use the dependence relation. Hence, our metric should be oriented on topology of a tree of dependences.

Value of metric *DDT* is defined as the maximal path length from the given component to the remote leaf of the dependence tree of components. It is necessary to consider, that the root of dependences tree is below. For example, in presented on a Fig. 1 tree of dependences for component C1the *DDT* value is equal to 3.

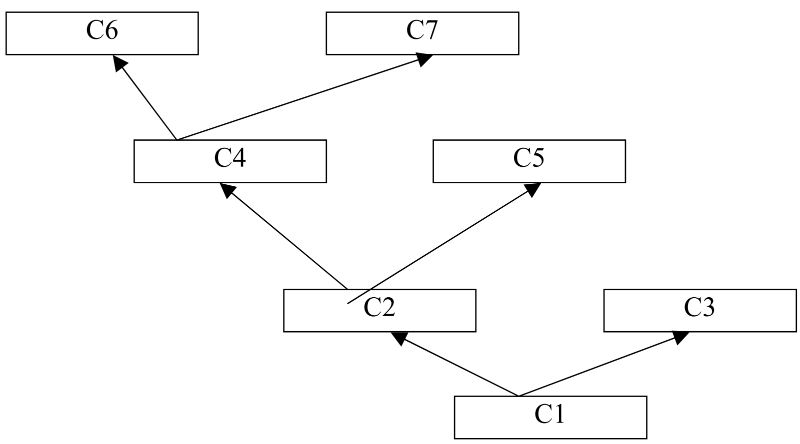

Fig. 1. *Diagram of dependences of components*

Here it is shown, that component C1 depends on C2 and C3, component C2, in turn, depends on C4 and C5, etc. Thus, for separate component *DDT* is a length of the maximal path from the given component to the uppermost component in a tree.

A large DDT value for a concrete component means, that the component is dependent on many other components, and, thus, it leads to restriction of repeated application. Hence, DDT metric should have low value that enables for repeated application of component realizations.

3.2.3. Amount of dependences for a component NOD

NOD (Number of Dependence) metric is based on the object-oriented metric *NOC* (Number of Children).

As inheritance between components in generative programming is absent, hence, *NOD* value is equal to amount of dependences directly for a concrete component on the diagram of dependences of components. Therefore for component C2 (Fig. 1) value of *NOD* metric is equal to 2 as it depends on C4 and C5.

With *NOD* reduction the reuse increases. Large *NOD* value means a plenty of dependences on other components in model.

Like the object-oriented metrics *DIT* and *NOC*, the *DDT* and *NOD* metrics are quantitative characteristics of components structure complexity (form and size). Hence, well structured generative model should be organized as a wood of components, instead of as a ultrahigh tree.

3.2.4. Coupling between components CBC

CBC (Coupling Between Components) metric is based on the object-oriented metric *CBO* (Coupling Between Object classes).

Metric *CBC* is an amount of components, which this component is connected with. Unlike the object-oriented metrics connection here means, that the given component or is either a parameter of the overlying component, or as own parameters has subjacent components. In other words, *CBC* it is equal to quantity of component couplings with other components: those for which it is parameters and those which it uses as parameters. It characterizes the static constituent of component structural realization.

High *CBC* value complicates system as a whole. It is clear, that the more is amount of couplings, the higher is whole project sensitivity to changes in its separate parts.

With growth of *CBC* recurrence of component use diminishes. In fact the more is component independence, the easier it repeatedly to apply. Hence, for each component value of *CBC* metric should have reasonably low value.

3.2.5. Response for component RFCT

The *RFCT* (Response For a ComponenT) metric is based on object-oriented metric *RFC* (Response For a Class). However the sense of the “response” concept changes in our case. In the object-oriented environment response is formed by own methods and called methods of objects, in sum providing service. In the component-based environment response is formed by own realizations and underlying possible realizations of given component.

RFCT metric is an amount of component realizations plus amount of realizations of other components, being in parameters for a current component. RFCT metric is a measure of potential quantity of realizations of the given component in a hierarchy of components. It characterizes a dynamic constituent of structural component realization.

3.2.6. Measurement of cohesion

There can be one or a few realization in a component. These realizations does not depend on each other, therefore measuring of cohesion have no sense in this case.

4. Conclusions

A metrics suite, oriented to the comprehensive quality estimation in such post-object technologies as aspect-oriented approach and generative approach is offered in the given work

The synthesized suite includes such metrics as: Specific Weight of Aspect *SWA*, EFficiency of Aspect *EFA*, Weighted Realizations per Component *WRC,* Depth of Dependence Tree *DDT,* Number Of Dependence for component *NOD,* Coupling Between Components *CBC,* Response For a ComponenT *RFCT.* The metrics received by us allow to estimate all possible base characteristics of program transport systems within the limits of application of the most popular post-objective technologies.

Efficiency and operability of proposed metrics have been verified during practical experiment on development of family of software transport systems. Development was conducted with use of the newest technologies of generative and aspect-oriented approaches, providing raised reliability and efficiency of program decisions.

The results of experiment allow to assert that it is solved an actual problem — arming of the developers, applying technologies of new generation, with a simple and convenient metrics suite, which give an opportunity quantitatively estimate quality of design decisions.

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MANAGEMENT IMPROVEMENT IN AGILE TECHNOLOGIES OF TRANSPORT SOFTWARE DEVELOPMENT

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This paper is devoted to the management of transport software development. Management improvement can be achieved with agile approach to development. The features of agile approach are investigated. The suite of advanced agile management is suggested. This suite oriented on agile approach specificity and gives a clear picture of the development process elaboration. Efficiency and operability of the suite of advanced management have been checked up during practical experiment on agile software development of real transport systems.

Keywords: *agile technologies of development, management, metrics, adaptation, control, program project, requirements changes*

1. Introduction

Nowadays the rapid and effective development of modern transport software is an important problem. One of the perspective directions focused on problem's decision is agile software development. Agile software development easy adapts to customer's frequent requirements changes and provides economical and quality solutions.

The key question of agile software development is management approach. Traditional management focuses on initial software size estimation process. Then effort, schedule and cost are estimated [1]. It is difficult to apply such approach in agile management since requirements are changed frequently and short time intervals are used to build new working version of product [2].

At the same time, necessity of project resource optimisation allowed the set of Throughput Accounting metrics to become the basis of agile management [3]. The undoubted advantage of this set is its principle — let the project team to produce as much functionality as possible for money allocated and time scheduled. Unfortunately the problem of operating control of delivered functionality is still not resolved.

This work offers the solution that takes into account the main specific of agile software development — the ability of the development process to adapt to the customer's requirements. The set of metrics and usage principles oriented on iterative calculation of dynamics of cost and schedule of the project are considered as a solution. The offered suite is simple in use and depicts the project status clearly for the customer and the project team.

1.1. Throughput Accounting

Throughput Accounting is a management accounting process. It can be applied for the management, control and reporting of any system. And one of the advantages of Throughput Accounting is that it can be successfully applied for software development process.

Three financial metrics are used in Throughput Accounting: *Investment* (*I*), *Operating Expense* (*OE*) and *Throughput* (*T*). It's possible to calculate net profit and Return on Investment when *I*, *OE* and *T* are known. Managers must focus attention to three things to make greater profits: increase *T*, decrease *I* and *OE*.

Three production metrics are used for control of software development: *Inventory* (*V*), *Production Rate* (*R*) and *Lead Time* (*LT*). These metrics provide leading and predictive indication of the software development performance. Managers can define which part of client-valued functionality is under development, testing or ready for production at the concrete moment of time.

1.2. Disadvantages of Throughput Accounting metrics

Despite on applicability of Throughput Accounting on software development, it can't resolve one of the major problems in software engineering — estimating. Usually effort and schedule are estimated by analogy and using decomposition in agile projects [2], i.e. estimation is based on expert judgement but not on counting and computation [1]. In case of plan failure or requirement changes it's hard to forecast end date and cost of the project and therefore net profit. That's why there is a demand in additional metrics which might help to calculate project schedule and cost.

2. Advanced Metrics Suite for Agile Management

Before defining new metrics some assumptions must be made. Firstly, one is that project team always works the same number of hours per week without overtime. And, secondly, is that client pays the same amount of money for one working day. By defining these assumptions, we lock client's expenses and simplify further calculations of project cost and schedule.

2.1. Synthesis of metrics

2.1.1. Calculation of project schedule and cost

To calculate the project's schedule and cost accurately, the size of the software that will be built is required. This size can be defined as *Features Total* (*FT*). The size of software that must be implemented in iteration can be defined as *Features Planned* (*FP*). Now *FT* and *FP* can be used to calculate number of iterations that is required to build software — *Iterations Required* (*IR*).

$$IR_i = \frac{FT_i}{FP_i}. \quad (1)$$

FT_1 value (initial size of the software) can be calculated using different techniques [1, 2]. In this paper, we defined that software size is the total number of requirements. This approach may seem incorrect since size of requirements can vary a lot. Therefore each requirement was analysed and broken into smaller requirements when required. Similar process was applied to combine several small requirements into one big requirement. In result, a list of requirements of equal size was prepared.

In order to calculate FT_i, where $i > 1$, more information is required. *FR* — number of released features, *FA* — number of features added and *FM* — number of modified features. Then FT_i can be calculated as

$$FT_i = FT_{i-1} - FR_{i-1} + FM_{i-1} + FA_{i-1}. \quad (2)$$

By omitting various components of (2) it's possible to calculate different *FT* values. For example, omit *FA* and calculate size without added features.

After number of iterations is obtained, *number of Days Required* (*DR*) to built software can be calculated. But before doing this, *Length of Iteration* (*IL*) in days should be defined. Then *DR* value can be calculated as

$$DR_i = IR_i \times IL. \quad (3)$$

Cost of software development can be defined as *Total Cost* (*TC*). It is known that client pays the same amount of money for one working day. Thus, this cost can be defined as *Working Day Cost* (*WDC*). And *TC* value can be calculated as

$$TC_i = WDC \times DR_i. \quad (4)$$

FT value is used in (1). By omitting various components of (2) as stated above, it's possible to observe changes of *TC* value.

2.1.2. Iteration planning

FP should be accurately estimated since it affects *TC*. One of the *FP* calculation methods is to use mean *FR* value:

$$FP_i = \frac{\sum_{j=1}^{i-1} FR_j}{i-1}. \quad (5)$$

It is impossible to calculate FP_1 using (5), because *FR* will be available only after first iteration. Therefore FP_1 should be calculated using different method.

If there are many development iterations in a project then *FP* calculated using (5) will indicate average software size which team can implement per iteration. Sometimes it may not satisfy client, because he always is interested in maximal team's productivity. That's why *FP* also can be calculated on demand, but not after each development iteration.

Further, define the size of the software that was planned but not implemented in iteration as *Features Left* (*FL*)

$$FL_i = FP_i - FR_i. \quad (6)$$

Suppose that some of the planned features have not been implemented, i.e. $FR_i < FP_i$. Let's compare FL_{i-1} to FT_i

$$k_1 = \frac{FL_{i-1}}{FT_i}. \tag{7}$$

If $k_1 \geq x_1$, where $x_1 = 0{,}1$, then *FP* can be calculated.

Suppose that additional features have been implemented, i.e. $FR_i > FP_i$. Let's compare FR_{i-1} to FP_{i-1}

$$k_2 = \frac{FR_{i-1} - FP_{i-1}}{FT_i}. \tag{8}$$

If $k_2 \geq x_2$, where $x_2 = 0{,}1$, then *FP* can be calculated.

Before start using method stated above, x_1 and x_2 values should be agreed. But at the same time, it's possible to modify them during project lifecycle. It is correct to assume that x_1 should be bigger than x_2, because underestimation is more common than overestimation [1].

Further, *FP* value should be calculated. We can suppose that FP value for the next iteration will be the same as was for the previous one, i.e. team can implement the same size of functionality

$$FP_i = FR_{i-1}. \tag{9}$$

Formula (9) can be used both in case of plan failure or successful implementation, even if additional features were implemented. Certainly, we must consider that according to the circumstances, this estimation might be too optimistic or pessimistic.

In (5) and (9) we take into account only *FR* value. But also *FP* value can be used with *FR*. For example, if some additional features were implemented and $k_2 \geq x_2$, then team commits to implement more functionality than was planned, but less than it has implemented in last iteration. In this case, *FP* can be calculated as

$$FP_i = \frac{FR_{i-1} + FP_{i-1}}{2}. \tag{10}$$

Consider (10) also can be used when $k_1 \geq x_1$.

2.1.3. Calculation of iteration planning time and cost

Usually agile teams plan every iteration or working day, like Scrum teams do [4]. Planning time must vary in rational boundaries, because primary team's activity is functionality implementation. Extra planning might reduce *FR*.

Planning Time (PT_i) can be measured in working days or hours. *Planning Cost* (PC_i) can be calculated as

$$PC_i = PT_i \times WDC. \tag{11}$$

Percents Planning Time (*PPT*) can be calculated as

$$PPT = \frac{PT \times 100}{DR}. \tag{12}$$

Percents Planning Cost (*PPC*) can be calculated as

$$PPC = \frac{PC \times 100}{TC}. \tag{13}$$

In case when *WDC* is constant, *PPT* and *PPC* for one project will be equal. Hence, only one of them can be calculated.

2.1.4. Calculation of estimation accuracy of project schedule

In our case *WDC* is constant therefore calculation of estimation accuracy of project cost is not required.

One of the main characteristics of estimate is its accuracy. If estimate is not accurate then it will be useless for controlling project. That's why metrics, which measure estimation accuracy, are required.

Let's define number of iterations, where $FR_i < FP_i$ as *Plan Failure* (*PF*). Number of iterations, where $FR_i < FP_i$ can be defined as *Percents Plan Failure* (*PPF*). *PPF* value can be calculated as

$$PPF_i = 100 \times \frac{PF_i}{IR_i}. \tag{14}$$

PPF value allows control estimation process during project lifecycle. If *PPF* is quite small, then there is no reason to worry about estimation errors. But if this value is increasing then estimates should be revised without delay.

Is it estimation error when $FL_i > 0$? No, since *FP* will change after some iterations.

2.2. Agile management principles based on created metrics

Metrics value should be analysed each iteration to control software development project successfully. Such approach allows managers to make right decisions in time.

Before project start-up, initial *FP* value should be selected or calculated. Since initial *FT*, *IL* and *WDC* values are known, it's easy to calculate *DR*, *IR* and *TC*. And after x_1 and x_2 values definition, project can be started.

FP value should be reviewed after iteration and recalculated if needed. Project team can use more than one calculation method. Further, others metrics are calculated and values analyzed. Required decision should be made to eliminate current problems.

2.2.1. FP, FR and FL metrics analysis

FP, *FR* and *FL* values should be analysed after each iteration. If *FP* and *FR* values are increasing and *FL* value is decreasing then project team successfully achieves project's goals. Corrective actions are not needed in this situation.

If *FP*, *FR* and *FL* values are increasing then overestimation takes place. Team should decrease *FP* manually or by using other calculation methods. If corrective action is done then *FL* value should decrease.

If *FP* and *FR* values are decreasing and *FL* is increasing then problem reason should be found without delay. Perhaps, some technical or organizational problems exist.

If *FP*, *FR* and *FL* values are decreasing then reason should be found. Usually this situation may be observed during last project's development iterations.

2.2.2. PT and PPF metrics analysis

Planning time (and planning cost when *WDC* is not constant) should be also analysed after each iteration. The easiest way to do it is to monitor *PPT* value during project lifecycle.

If *PPT* value is increasing then some problems exist in a project. For example, client changes software requirements too often and team needs more time to perform impact analysis.

If *PPT* value is decreasing then reason should be found. Perhaps, team achieves project's goals without problems. Technical aspects of the project are well known and there is no problem to implement required functionality. Or team is afraid to delay some functionality and doesn't want to spend much time on planning.

Anyway, *PPT* value should be analysed together with other metrics. One of them is *PPF*.

If *PPF* is increasing then team can't deliver planned functionality in time. *FP* value should be reviewed and recalculated if needed. Perhaps, other reasons exist.

PPF value can be used to compare projects after they are finished. Team can monitor accuracy of planning from project to project.

3. Conclusions

The following problems are solved in this paper. Throughput Accounting metrics are analysed and their disadvantages are discovered — they can't be used for project's schedule and cost estimation. Metrics, which allow calculating software size *FT*, number of required iterations *IR*, project cost *TC*, size of software that must be implemented in iteration *FP*, planning time *PT* and cost *PC* are created. Besides, the principles of the agile management based on created metrics are offered.

An experiment is conducted to check efficiency of created metrics suite and advanced management principles. New metrics are used with Throughput Accounting metrics in a software development project of real transport systems. Comparative analysis is conducted in which some of the metrics values are compared with historical data of other projects where Throughput Accounting metrics only are used. Results obtained during experiment show that metrics created allow agile project team to estimate project schedule and cost efficiently comparing to common methods used. Estimation accuracy is improving and planning time is reducing during the experiment.

The results of the experiments confirm that the important problem is solved — arming of the managers, applying agile development technologies, by the simple and convenient metrics suite, providing implementation of agile control principles.

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THE ESTIMATION OF ACCURACY CHARACTERISTICS OF TRANSPORT VEHICLE'S POSITIONING LOCATION COMPLEX IN THE PRESENCE OF INTERMITTENT FAILURES

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The paper deals with precise values of navigation complex for automobiles that consist of one high-precision measurer, that works with persistence (sampling action) and one low-precision measurer, that works without persistence (continuous action) as minimum devices for purposing location of the vehicle.

As well, analytic expressions for precise characteristics estimation in navigation complex with or without taking into account transient processes that happens during operable state recovery of high-precision location measurer of mobile object have been got in this work.

Keywords: *transportation process, efficiency, navigation complex, location of mobile object*

1. Introduction

For efficiency upgrading and improvement of logistic activities for transport enterprises the information about transport vehicle location that provides transportation is used. [1]

It is possible to receive such kind of information if there is navigation complex, installed on transport vehicle.

Also, it is supposed that the usage of navigation complex makes safe transport vehicle's transfer from one point to another for a period of time. Usually, concrete transfer happens with pre-selected speed and route. In the process of movement there are measurements of navigation parameters and elements of movements take place intermittently or continuously. Also a comparison of those parameters with pre-selected ones happens there, as well as generation of control signals takes place for changing or updating the route of transport vehicle. All measurements of navigation parameters are performed by navigation subsystem, other processes are performed by controlling subsystem. Because of random effects to a transport vehicle and because of interferences on detectors of navigation information, the route of transport vehicle will have accidental errors.

For safe and qualitative shipping of goods and passengers for concrete transport vehicle, it is needed to coerce its motion trajectory within some defined region of space. In the general case, assurance of transport vehicle's defined accuracy could be reached at the expense of errors redistribution in control and navigation subsystems. In this work, according to conception of estimation and control separateness [4] has been proposed that control subsystem's errors are pre-selected. Then, due to record keeping and reducing errors in navigation subsystem, it is possible to obtain transport vehicle shipping accuracy in transferring goods and passengers.

A navigation subsystem consists of detectors of navigation information and estimating device of navigation parameters.

The decision of quality for navigation tasks could be estimated as follows:

A) by probability of finding transport vehicle within reliable region of space;

B) by accuracy of estimation for navigation elements of movement, for example, evaluation of variance of transport vehicle's location.

Navigation complex for automobiles consists of one high-precision measurer, that works with persistence (sampling action) and one low-precision measurer, that works without persistence (continuous action) as minimum devices for purposing location of the vehicle.

Such a measurer's selection in a complex is needed to obtain pre-selected probability of finding the vehicle within reliable region of space. As it was shown in [5], [6] high-precision navigation measurers, due to their delayed action according to fundamentals of optimal evaluation, it is possible to keep mobile transport vehicle within reliable region of space. And, its probability will decrease, while driving speed of transport vehicle increases.

It is commonly supposed that complex overall accuracy for transport vehicle location could be defined as cooperative processes of measuring results.

Nevertheless, it is needed to keep in mind that if the vehicle is moving, all measuring devices of navigation complex are working in condition of very sensitive interfering situation. When interference situation changes a multipath propagation mostly takes place. As well as there exists the possibility of base stations blocking with topographic or artificial obstacles. And, as the result, we could have values of location errors of one or more measurers that are greater than permissible rates. So, that could be appraised as a failure of concrete measurer.

Thus, the overall accuracy for transport vehicle location could be defined with the help of automobile navigation complex not only as cooperative processes of measuring results that were received form included measurers, but also the time when measurer/measurers are not available should be taken into account. It is also important to note that when destabilizing factors has finished influencing, an operable state of the measurer self-restores.

The recognition of accuracy figures for automobile navigation complex in case of intermittent failures is really needful to correct evaluation of possible errors in defining location of moving the vehicle.

2. Error Variance Evaluation of Detected Navigation Parameter

The influence of destabilizing factors on measurers in automobile navigation complex could be narrowed down to the following – that operational quality of each navigation device in this complex could be sketched to a discrete semi-markovian process with two possible kinds of state [2, 3]: either available or non-available. For such a model, there are measurement errors of navigation parameter in the given conditions for *i*-kind measurer could be defined:

$$\sigma^2_{av\,i} = \sum_{j \ni M_{av}} \Phi^{(i)}_j \sigma^{2(i)}_j \Big/ \sum_{j \ni M_{av}} \Phi^{(i)}_j \,, \tag{1}$$

$$\sigma^2_{na\,i} = \sum_{j \ni M_{na}} \Phi^{(i)}_j \sigma^{2(i)}_j \Big/ \sum_{j \ni M_{na}} \Phi^{(i)}_j \,, \tag{2}$$

where: $\sigma^2_{av\,i}$ – an error detection variance of navigation parameter, when i-kind measurer is available,

$\sigma^2_{na\,i}$ – an error detection variance of navigation parameter, when i-kind measurer is non-available,

$\sigma^{2(i)}_j$ – an error detection variance of navigation parameter, when i-kind measurer is in j-kind condition of semi-markovian process,

$\Phi^{(i)}_j$ – probability of j-kind condition of semi-markovian process.

Let us suppose that high-precision measurer that works as a part of automobile's navigation complex, assures the estimation of navigation parameter with error variance (σ^2_P – precise) and low-precision measurer will have error variance (σ^2_R – rough). And if statistical characteristics of signals and interferences that can affect on destabilizing factors of automobile navigation complex are known, consequently, it is possible to find out transition rate of each measurer in this complex from available into non-available state and backwards.

Those rates will be defined as uptime and downtime ratio (j). Among other factors, if during the whole interval of system's operating time (T), an i-kind measurer is not available during an average period of time ($\Delta t_{na\ average}$), then the probability of non-available state for i-kind measurer will be the following:

$$P_{na\,i} = \frac{\Delta t_{na\ average}}{T} \,. \tag{3}$$

But in available state the probability of i-kind measurer will be as follows:

$$P_{av\,i} = 1 - \frac{\Delta t_{na\ average}}{T} \,. \tag{4}$$

On the assumption that destabilizing factors could affect high-precision measurer only, taking into account expressions (3) and (4), according to the given formulas (1) and (2), it is possible to define precision values of automobile navigation complex in the presence of intermittent failures:

$$\sigma^2_{av} = \frac{\sigma^2_P P_{av\,P} + \sigma^2_P P_{av\,R}\left(1 - P_{av\,P}\right)}{P_{av\,P} + P_{av\,R}\left(1 - P_{av\,P}\right)} \,, \tag{5}$$

$$\sigma_{na}^{2} \approx \sigma_{R}^{2}. \tag{6}$$

Those given expressions for error variance, when we define navigation parameter in available (5) and non-available (6) states of high-precision measurer in navigation complex, do not take into consideration the possibility of inertial high-precision measurer usage. When there is inertia, then recovery of operation state for the navigation measurer will take place with delayed action during transient phenomena ($\Delta t_{t.ph.}$). That means:

$$\Delta t'_{na\ average} = \Delta t_{na\ average} + \Delta t_{t.ph.}.$$

Due to this the probability of measurer being in available state reduces:

$$P'_{av\ P} = P_{av\ P} - \Delta t_{t.ph.} N_{average}(C),$$

where $N_{average}(C)$ – an average rates number into non-available state for high-precision measurer.

Thus, error variance of navigation parameter detection in navigation complex increases when high-precision measurer is in available states (σ_{av}^{2})

$$\sigma_{av}^{2} = \sigma_{P}^{2} P'_{av\ P} + \sigma_{R}^{2}\left(1 - P'_{av\ P}\right) P_{av\ P}, \tag{7}$$

$$\sigma_{na}^{2} = \sigma_{R}^{2}. \tag{8}$$

3. Conclusions

In such a way, analytical expressions for accuracy characteristics evaluation in navigation complex inclusive and exclusive of transient phenomena are received, when recovery of operable state for high-frequency measurer of moving object takes place.

Received expressions, mentioned above, are approvals of boundary type. By the given permissible errors for transport vehicle location, it is possible to define unique permissible inertia value in precise measurer of automobile navigation complex.

From the expressions that are mentioned above of error variance for navigation parameter estimation in available (7) and non-available (8) states of high-precision measurer of navigation complex, it could be stated as follows – when we have inertia of high-precision measurer, error in estimating object's location by navigation complex increases. That happens because of redistribution of system's operational periods of time in favour of less precise measurer, but inertia less.

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