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REVIEW

Short - term Fiscal Needs vs. Long - term Sustainable Development

WHAT IS, AND WHAT SHOULD BE DONE TO FACILITATE AN OPEN FREIGHT MARKET FREE OF DISTORTED COMPETITIVE CONDITIONS

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ABSTRACT: The following keynote text is to respond to the following fundamental questions: a. What are the existing activities to facilitate an open freight market free of distorted competitive conditions? b. What provisions are governments making for investment in rail infrastructure? c. How do transportation policy makers need to revise their strategies to satisfy EC goals? At the moment, a majority of goods are carried on Europe's roads, even if it brings about grave global problems. This is the main reason for the constant drive to internalize the external costs of road transport pursuing the 'user pays' and 'polluter pays' principles. The recently published Greening Transport Initiatives of the European Commission, especially the amendment of the Eurovignette Directive, are a good step in this direction, even if they evoked a scope of different views aminy stakeholders. Also other initiatives of the Commission, such as the Freight Transport Logistics Action Plan, will lead to a better utilization of transport infrastructure and enhanced support of more sustainable transport modes. The Commission, as well as individual Member States alone or in cooperation with other interested partners, undertakes actions improving the existing rail infrastructure to be utilized by freight transport. New rail transport axes are sometimes at the top of cutting-edge technology and generally designed to host both freight and passenger rail transportation. The text brings some examples of such projects, which are being carried out in the 'new' EU countries, also with the help of European funds. So as to satisfy EC goals, the transportation policy makers need to revise their strategies in a double direction: towards active participation on implementing new Commission initiatives aimed at levelling the playing field between transport modes, and towards improving their domestic rail markets and correcting shortcomings in the implementation of the First Rail Package, so that rail freight should be able to regain and extend its market position also 'by its own force'.

KEYWORDS: Rail freight transport, internalization of external costs, Eurovignette Directive, Freight Transport Logistics Action Plan, rail infrastructure, European funds, First Railway Package, conflicts of interests.

1 EXISTING ACTIVITIES TO FACILITATE AN OPEN FREIGHT MARKET FREE OF DISTORTED COMPETITIVE CONDITIONS

Freight transport has undergone a tremendous growth by more than 30% in the past ten years and is expected to see similar levels of growth over the next decade. At the moment, a majority of goods are carried on Europe's roads. Nevertheless the registered and expected increase in volume causes too many accidents, brings too much congestion, too much noise and too much environmental damage and local pollution, adding to the imminent climate change which belongs to the most grave global problems. As the society bears the costs, there is still little incentive for transport users to change their behaviour and reduce the negative impacts they cause.

This is the main reason for the constant drive to internalize the external costs of road transport, which will open up the possibility for Member States to put the ‘user pays’ and the ‘polluter pays’ principles into practice and help to create a more levelled playing field between transport modes.

The problem remains with growing importance in the scope of transport priorities of both European Commission and Member States as well, which found its expression also in the White Paper "European transport policy for 2010: time to decide", adopted in September 2001. The EU's first attempt at addressing the wide range of negative external effects produced by transport was in 1993, when it put forward a directive enabling EU countries to introduce tolls on motorways, at that point primarily in order to finance the cost of infrastructure deterioration caused by heavy road vehicles[1]. This directive, however, was annulled by a judgment of the Court of Justice of the European Communities in 1995[2], while preserving the effects of that Directive until the Council had adopted a new Directive. Therefore a new Directive 1999/62/EC of the European Parliament and of the Council on the charging of heavy goods vehicles for the use of certain infrastructures was adopted in June 1999[3] and entered into force on l July 2000.

Known as the 'Eurovignette Directive', the Directive was revised by the 2003 Act of Accession, and again in 2006 by the Directive 2006/38/EC[4] with the aim to extend its scope to more roads and vehicles and to making it possible for governments to integrate other costs – such as congestion, accidents, noise and air pollution – into toll prices. This made it possible to improve the efficiency of the road transport system and ensured the use of different tolls or user charges on roads, including roads on the trans-European road network and roads in mountainous regions. From 2012 onwards Directive 2006/38/EC will extend its application also to vehicles weighing between 3.5 and 12 tonnes.

However, due to different views between the Member States and the Parliament, the final text of the Eurovignette Directive de facto excluded this very possibility until a "common methodology for the calculation and internalization of external costs that can be applied to all modes of transport" is agreed. This materialized only in July 2008, when the Commission published its Greening Transport Initiatives, a new package to drive the market towards sustainability[5].

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[1] Council Directive 93/89/EEC of 25 October 1993 on the application by Member States of taxes on certain vehicles used for the carriage of goods by road and tolls and user charges for the use of certain infrastructures, OJ L 279, 12.11.1993, pp. 32.

[2] Judgment of 5 July 1995 in Case C-21/94 European Parliament v. Council of the Court of Justice of the European Communities.

[3] OJ L 187, 20.7.1999, pp. 42.

[4] Directive 2006/38/EC of the European Parliament and of the Council of 17 May 2006 amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures.

[5] see EC 2008a

The proposal to revise the Eurovignette Directive6 constitutes a key part of this strategy. It seeks to establish a framework which would enable Member States to calculate and vary tolls according to the air and noise pollution from traffic emissions and peak-hour congestion levels. This is to encourage freight transport operators to buy cleaner vehicles and improve their logistics and route planning. The tolls are to be collected using electronic systems with the revenue being used in projects to alleviate the negative impacts of transport, such as research and development on cleaner and more energy efficient vehicles. The proposal to revise the Eurovignette Directive[6] constitutes a key part of this strategy. It seeks to establish a framework which would enable Member States to calculate and vary tolls according to the air and noise pollution from traffic emissions and peak-hour congestion levels. This is to encourage freight transport operators to buy cleaner vehicles and improve their logistics and route planning. The tolls are to be collected using electronic systems with any revenue being used in projects to alleviate the negative impacts of transport, such as research and development on cleaner and more energy efficient vehicles. A common method is to be used in toll calculation so that tolls are transparent, proportionate and compatible with the internal market. The package contains besides that the Greening Transport Communication (summarizing the whole package and setting out new initiatives), Greening Transport Inventory (describing EU actions already taken to green transport), Strategy to Internalise the External Costs of Transport (containing a communication and impact assessment texts) and a Communication on rail noise. A methodological tool is also attached to the package[7].

As is usual, the proposals, especially that of the amendment of the Eurovignette Directive, evoked a strong discussion among stakeholders. Railway stakeholders generally welcomed the principles, on which the Greening Transport Initiatives were based, including the suggestion to use earmarking of revenues to promote the development of more sustainable mobility. They noted, however, that CO_2 and also accident costs were not sufficiently integrated. CO_2 costs, in particular, should have also been included with the model, at least as an option, especially with regard to the fact that the link between CO_2 emissions and climate change is possibly the most important political issue of our time. Proposed setting limits on charges in this generally 'enabling' proposed Directive was also subject to criticism[8].

Ecology-oriented NGOs, like European Federation Transport & Environment, point to Switzerland as a successful example for charging road freight operators for the environmental and health impacts of their journeys. The scheme started in 2001 and according to T&E, after seven years, it has led to an increase in the efficiency of road transport, highlighted by a 6.4% decrease in the number of kilometres travelled by heavy goods traffic with a simultaneous 16.4% increase in the volume of goods transported. Emissions of particles have also been cut by 10% and nitrogen oxides by 14%. The effect on consumer prices has been 'negligible'[9].

The other pole of disputation is represented by stakeholders from the road transportation mode. They raised a question whether external costs of each transport mode were correctly defined, assessed and internalized, taking into account internalization through existing taxes and charges. They expressed a belief that the most effective way to pursue was developing

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6 Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures (EC 2008b)

7 Handbook on estimation of external costs in the transport sector, Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT), Version 1.1, Delft, February 2008 (CE Delft 2008)

8 See e.g. Ludewig 2008 or CER, EIM, UNIFE 2008

9 T&E 2008

management initiatives to reduce external costs, instead of penalizing companies with higher taxes. As the road transportation mode has a majority share in the freight transport market, internalization with taxes and charges would produce higher prices of transport services and subsequent higher prices of final products for consumers and an inflationary drive. Higher taxes and charges would drain transport companies profits, thus reducing companies' resources for investment in innovation and vehicles park renewal. The final result would be the continuing loss of competitiveness of European products and reduction of the expected GDP growth rate, which would go against the aim of the Lisbon strategy[10].

Also the positions of individual Member States vis-a-vis the Greening Transport package show a relatively high level of difference. While some Member States, especially those exposed to strong road freight transit flows, are in support of a relatively stringent approach, the others, especially those in a border position, are not too much in favour of the compulsory inclusion of external costs into the toll rates. The 'border' states more frequently note that the recent period is not too auspicious to pursue a stricter road transport taxation, when the economic situation in the road transport sector is relatively depressed, stricken by high prices of oil products and developing economic recession. Other comments concern the network extension of tolling systems and also earmarking of road toll revenue directly into measures reducing adverse effects of road transport. Transport ministers, meeting in La Rochelle on 1-2 September 2008 for an informal session, also showed some reserve towards Commission proposals. French Transport Minister Dominique Bussereau said after the meeting the agreement was that charges "should rather be optional and that revenues should be allocated as European states want them to be"[11]. All in all, it seems that the discussion on the amendment of the Eurovignette Directive will take more time and to draw a compromise solution will not be an easy task.

Another proposal in the Commission's green transport package includes plans to reduce noise emissions from rail, which it says represent "one of the most widespread public health threats in industrialised countries…with about 10% of the population exposed to noise levels above the threshold for 'serious annoyance'."[12] Under the foreseen rules, all wagons with a remaining lifetime of at least five years would have to be equipped with low-noise brakes by 2014. Railways using silent wagons rather than noisy ones would have to pay fewer track access charges. This proposal will, without any doubt, bring a more demanding environment for rail freight operators, in investment into appropriate rolling stock in particular.The Commission's activities comprise of also positive measures aimed at the development of the rail freight sector.

Following the opening of the Community's rail freight market as of 1 January 2007, the discussion concentrates in creating more favourable conditions for the rail freight business. It should be mentioned, inter alia:

- **Communication from the Commission - Freight Transport Logistics Action Plan (EC 2007a)** - an initiative with actions directed towards achieving a better utilization of transport infrastructure, an improved cross-border management of freight flows (e-Freight and utilizing Intelligent Transport Systems), a better integration of transport modes and the reduction of fiction costs affecting intermodal transport, with more emphasis on quality criteria in modal choices and higher competence levels, mobility and attractiveness of the logistics professions.

[10] See e.g. ECG 2008
[11] www.euractiv.com/en/transport/transport-ministers-back-optional-road-tolls/article-175058
[12] http://ec.europa.eu/transport/greening/doc/rail/2008_07_greening_transport_rail_noise_communication_en.pdf

- **Communication from the Commission to the Council and the European Parliament - Towards a rail network giving priority to freight (EC 2007b)** – an initiative aimed at promoting the creation of a strong European rail network which would offer a better quality of service in freight transport than today in terms of journey times, reliability and capacity. The network is derived from the corridors identified as having priority for the deployment of ERTMS or defined in the framework of European research projects (Eufranet, Trend, Reorient and New Opera).
- **Communication from the Commission to the Council and the European Parliament on monitoring development of the rail market (EC 2007c)** – an analytical document focusing on the regulatory and institutional framework created with a view to liberalizing the rail market and strengthening the position of railways as a safe and environmentally friendly mode of transport.

On the other hand, the Commission had to shelve its legislative proposal tabled in 2004 on the duality of rail freight services. The proposal, which had been frozen for the past two years, obliged rail companies to include quality requirements in contracts with customers (e.g. on punctuality) and set financial compensation due in cases of failing to meet the requirements. The text met with hostility from more stakeholders, as it was considered to undermine contractual freedom and imply disproportionate costs.

2 GOVERNMENTS' PROVISIONS FOR INVESTMENT IN RAIL INFRASTRUCTURE

The Commission recently declared the need of freight corridor structures helping to optimize the use of financial resources for the purposes of investment, simplify administrative and technical procedures at borders, ensure better continuity of service by the infrastructure across the Member States, and generally offer an easy-access service to international rail freight operators. Considering this, the Commission intends to propose a legal definition of a freight-oriented corridor structure, in particular setting down the main rules applying to this type of corridor and to encourage Member States and infrastructure managers to create transnational freight-oriented corridors[13].

Simultaneously, individual Member States alone or in cooperation with other interested partners undertake actions improving the existing rail infrastructure.

One of pioneering actions with European importance took place when the transport ministers of Italy, Switzerland, Germany and the Netherlands signed a Memorandum of Understanding in 2003 for the development of a rail corridor between Rotterdam in the Netherlands and Milano in Italy. In 2004, the decision was taken to extend this corridor to Genova, Italy. On the basis of the Memorandum, an action plan has been elaborated to implement measures allowing for an improvement in the quality of rail transport on this corridor[14]. The Rotterdam – Genova line became one of the most important European freight axes with a differentiated structure of both competing and cooperating rail freight operators.

In 1992, the German and Dutch governments signed the Verdrag van Warnemünde, a treaty on enhancing rail traffic, especially on the tracks from Amsterdam and Rotterdam to Duisburg. Work on the Dutch part of the track began in 1998. Widely known as the Betuweroute or Betuwe Line, it was opened in June 2007, connecting Rotterdam 160 kilometres to the German border. The cost of construction was 4.7 billion EUR.

[13] EC 2007b, pp. 9
[14] See IQ-C 2006

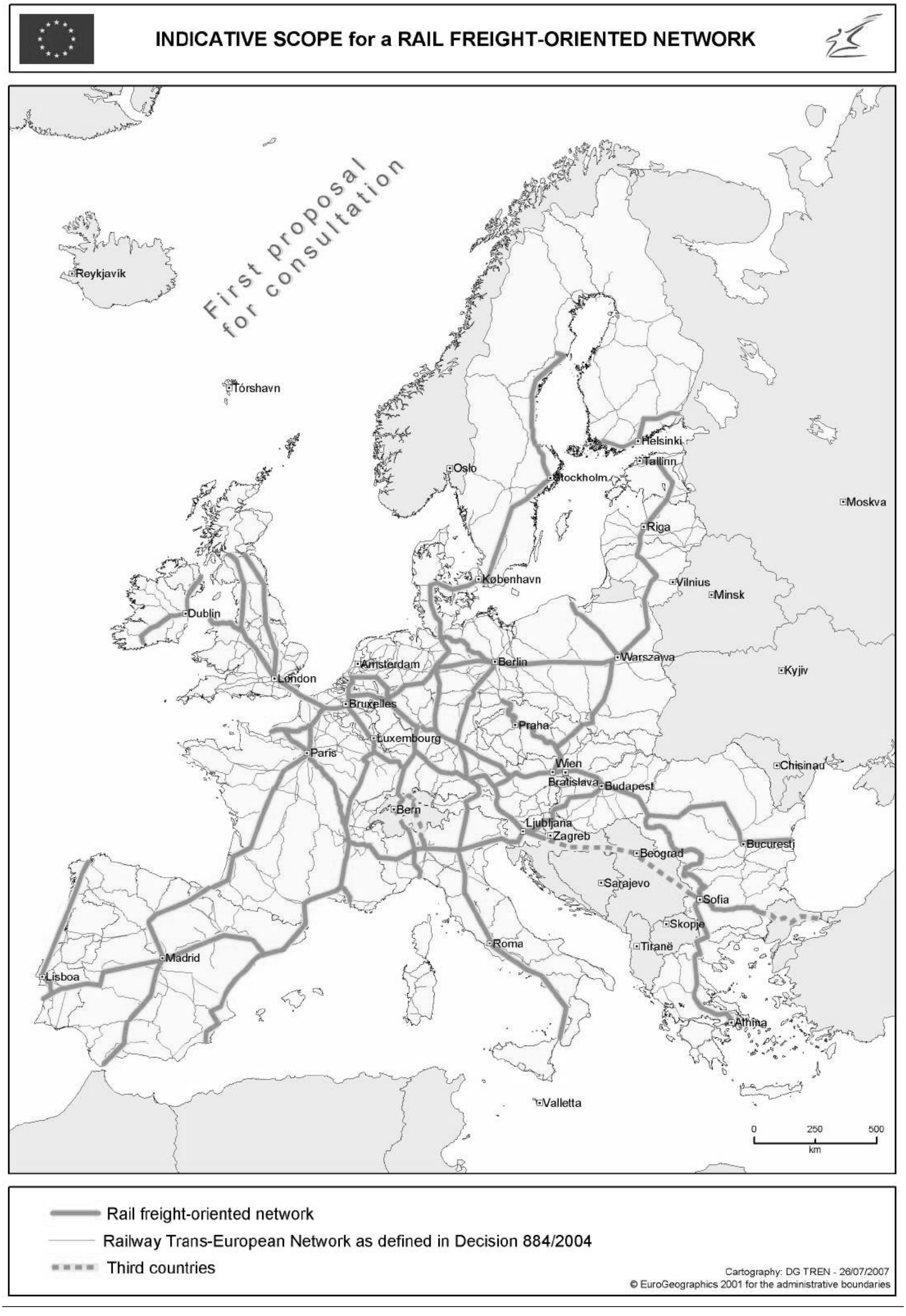

Figure 1: Indication of the rail-freight oriented network/ Source: EC 2007b

Nevertheless, the German part of the link still remains incomplete and the full reconstruction of the section is expected for 2015.

The following infrastructure projects in execution or preparation should serve as only a very selective and incomplete set of examples of governments' efforts to improve conditions for both national and international rail transport network. They are sometimes at the top of cutting-edge technology and generally designed to host both freight and passenger rail transportation (sometimes express freight trains):

Austria: Graz – Klagenfurt (Koralmbahn) – The Koralmbahn is an extension of the former European Corridor VI and a part of internationally important axis Gdańsk – Warszawa – Wien – Trieste – Venezia and Bologna, linking the Baltic and Mediterranean seas. Within Austria, it considerably improves the connection between Bundesländer Carinthia and Styria. A part of its ca. 130 km length 33 km is formed by the new Koralmtunnel. Commenced in 1999, the Koralmbahn should be set into operation in individual parts during 2014 – 2018. The proposed speed of the line is 200 km/h[15].

Germany: Extended and newly constructed Karlsruhe – Basel Line – The extension and new construction of the Karlsruhe – Basel Line is part of an ambitious "programme for the future" ProNetz and at the same time a core part of the already mentioned freight corridor Rotterdam - Genova. The line is projected as quadruple-track and should serve both for international and interregional transport. The project is being accomplished by sections and will be connected to other new investments like the Betuweroute, the already completed Lötschberg-Basistunnel and the prepared Gotthard-Basistunnel in Switzerland. New sections of the line will allow maximum speed of 250 km/h. The total investment amounts to about 4.5 billion EUR[16].

Germany: Berlin – Frankfurt (Oder) – The section in question is part of the European transport axis Paris – Berlin – Warszawa and is to be modernized to the speed of 160 km/h by 2013. The modernization comprises superstructure, substructure, bridges and electronic interlocking and signalling systems. The total investment is about 565 million EUR.

France: Lyon – Torino rail link – The Lyon–Torino project has two key aims: to develop high speed passenger rail services and to provide a freight link capable of transporting tens of millions of tons of merchandise across the Alps under the safest possible conditions and in full respect of the environment. The main portion of the future rail link will be composed of a 52 km long "base" tunel crossing the border between the two countries. The project should enable freight trains to travel with a speed 120 to 140 km/h. The expected term of completion is about 2020[17].

Italy: Torino – Milano – Napoli – Salerno rail axis – The link is part of the Italian "Rete Alta Velocitŕ – Alta Capacitŕ" (High Speed – High Capacity Network) and constitutes a central spine of the entire Italian rail system. With its length of 1,250 km, it is designed to serve both high-speed and capacity freight trains. It is set into operation by sections (finished are e.g. lines Roma - Napoli, Torino - Novara and Napoli-Salerno) and its full completion is expected at the end of 2009[18].

The striking and decade-lasting difference in quality of rail infrastructure between the 'old' and 'new' Member States is being gradually covered by the help of the Cohesion Fund and Structural Funds (European Regional Development Fund, ERDF). One of two items eligible to be supported from the Cohesion Funds with a total sum of 62.99 billion EUR are transport infrastructure projects establishing or developing transport infrastructure

[15] http://www.oebb.at/bau/de/Projekte_Planung_und_Bau/PontebbanaachseSuedbahn/Koralmbahn/index.jsp
[16] http://www.db.de/site/bahn/de/unternehmen/bahnwelt/bauprojekte/ausbau__neubau/ausbau__neubau.html
[17] http://www.rff.fr/pages/projets/fiche_projet.asp?code=654&lg=en ;
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as identified in the Trans-European Transport Network (TEN) guidelines. The ERDF supports rail infrastructure programmes within the Convergence Objective with an allocated total budget of 177.8 billion EUR.
One example of the projects supported by EU funds in the 'new' EU countries is the **Praha – Beroun railway tunnel in Czechia**. According to the existing plans the tunnel is to be 25 km long and is designed both for passenger and freight trains. The tunnel is projected for the speed of 300 km/h. The construction is to begin in 2010 or 2011 and the first trains are to travel through the tunnel in 2016.

The above examples and others are witness to the fact that national governments as well as the European Commission, understand both the existing and future role of rail freight transport within the sustainable transport concept. The extension and reconstruction of the European rail network, however, is a long lasting and never ending process.

3 HOW DO TRANSPORTATION POLICY MAKERS NEED TO REVISE THEIR STRATEGIES TO SATISFY EC GOALS?

This part of the topic could be divided into two separate, but still interdependent parts:

- What is to be done in the relationship between rail and other transport markets, road in particular?
- What is to be done within the railway market itself?

Ad 1. What is to be done in the relationship between rail and other transport markets

The Commission presented a review of the White Paper in June 2006, which stated that the 2001 objectives were still relevant but that, over the last five years, the context of defining Europe's transport policy had changed:

- Enlargement: whereas the EU-15 are suffering from congestion and pollution, accessibility remains the real problem for the EU-10.
- Globalization is accelerating, further challenging Europe's competitiveness and economic growth.
- Oil prices have increased dramatically.
- The Kyoto Protocol came into force, generating emission reduction commitments for Europe.
- Transport networks experienced particularly deadly terrorist attacks.
- In order to adapt to these changes, the Commission proposes a number of new tools to achieve its objective of sustainable transport:

The focus has been shifted towards 'co-modality' - or the optimized use of all modes of transport – rather than 'intermodality'. Co-modality can be achieved by facilitating the passage from one transport mode to another via the harmonization of standards and the integration of the various transport modes into efficient logistics chains. This will be the aim of a Commission logistics action plan to be adopted in 2007.

The proposed Greening Transport Initiatives package, as stated above, is to drive the market towards sustainability. It is in the interest of rail operators to pursue that the utilization of funds collected by the extending toll systems be obligatorily used for developing sustainable transport, even if it is attainable at a European level only in the medium or long term. Nevertheless, individual Member States may, and even should progress in this respect by themselves, creating individual rules enabling that growing toll revenue and sustainable transport and environmental protection expense go hand in hand.

It is necessary that national policy makers give a proper response to the Communication from the Commission Freight Transport Logistics Action Plan, as the freight transport logistics is one of the drivers of European competitiveness and thus a prime contributor to the renewed Lisbon agenda on growth and jobs. More cooperation is needed in aligning insufficient standardization and conflicting national legal requirements hampering the introduction of advanced information and communication technologies (e-Freight). International cooperation is needed in removing freight transport and logistics bottlenecks and in developing and integrating the European network of intermodal terminals and public logistic centres. A key objective is to ease the access to logistic facilities and processes for small and medium enterprises (SME), which can considerably strengthen thein competitiveness, and thus the robustness of the European market as a whole.

Another European concept to be followed is the 'green' transport corridors for freight[19]. They are to complement short sea shipping, rail, inland waterways and road each other to enable the choice of environmentally friendly transport. They are to be equipped with adequate transhipment facilities (seaports, inland ports, marshalling yards, other relevant logistics terminals etc.) and with supply points initially for biofuels and, later, for other forms of green propulsion. A number of initiatives are coming together to promote this objective, including the freight-oriented railway network, motorways of the sea and NAIADES. Account should be taken of the opportunities offered by the TEN-T guidelines on the development and the integration of multimodal transport chains. Open and nondiscriminatory access for operators and customers of these facilities should be ensured in accordance with the rules of the Treaty.

Ad 2. What is to be done within the railway market itself

From many points it is obvious that more speed in opening the European rail freight market is needed to improve the competitive position of rail freight vis-a-vis other transport modes, especially road. Rail freight should be able to regain and extend its market position also 'by its own force'. Even if it can be admitted that rail freight is from the moment of liberalization of its market in a better competition position in relation to road than rail passenger transport, still many shortcomings prevail.

This assessment is supported e.g. by the report of the Rail Freight Group[20], where it is stated that the main problems facing rail freight in much of Europe is the lack of service quality and competitive prices relative to the main competitor, road freight. According to the report, experience in the UK has demonstrated that success and growth can be achieved with competition above rail. This was the intention behind the existing railway packages but, unfortunately, they have not been implemented fairly or comprehensively in all Member States. A very comprehensive description of European rail freight market failures with respective recommendations are also contained in a report jointly issued by EIM, ERFA and ERFCP[21] and in the Railimplement study by Steer Davies Gleave[22].

One of typical problems is the situation with locomotives. The approval of freight locomotives is still a time-consuming process with uneven results among Member States20. New entrants also have problems with obtaining price-accessible used rolling stock, which is monopolized by original owners, often excluded for use in the State of origin by tying contracts with buyers and sometimes wastefully destroyed in incumbent companies, even if it could be able to serve for some time[23]. The result is that a secondary locomotive market in Europe is very limited and cannot meet the existing demand.

Existing obstacles for new entrants to the rail freight market have a very severe impact especially in the 'new' EU countries, as they hinder the access of private investment to the industry, essential in conditions when the governments are lacking funds to improve

[19] EC 2007a, pp. 12
[20] RFG 2004
[21] EIM, ERFA, ERFCP 2006, pp. 7-12
[22] Steer Davies Gleave 2005
[23] ibid., pp. 4, 31-32

the rolling stock of incumbent state rail systems and the share of rail in the respective freight transport markets continuously declines. The absence of an effective European programme to support the renewal of rail rolling stock in the 'new' Member States also feels very detrimental.

The position of rail freight can also be impaired by the existence of holding structures of the incumbent rail undertakings, as there may be more forms of implicit or concealed cross-subsidization in favour of passenger transportation. This cross-subsidization may acquire forms of locomotive[24] or operational facility pooling or merely of specific investment split and operational profit distribution decisions in the headquarters of the holding. In the road freight industry such structures combining freight and passenger transport are very rare, and so this cross-financing effect may also be. Another cross-subsidization may be hidden in national infrastructure price rates for passenger and freight rail transport, and is very hard to prove, as the real separation of accounts for passenger and goods transport in holding structures, which might serve as a proof for the rates, may be for the same reasons subject to doubt.

The European Commission stated in its report on the implementation of the First Railway Package[25] based on the analysis contained in the already mentioned Railimplement study that the directives of the First Rail Package are still having an unequal effect in practice from one Member State to another, and have not led to the arrival of new entrants in all the Member States. Uneven and sometimes doubtful implementation of EU railway packages prompted the Commission to repeatedly open infringement procedures against individual Member States[26]. Recently, the Commission issued a press release calling on Member States to ensure correct implementation of the First Rail Package[27]. Simultaneously, a formal notice was issued on opening new infringement procedures against 24 Member States for the failure to implement the First Railway Package legislation properly. The Commission mainly noted shortcomings such as lack of independence of the infrastructure manager in relation to railway operators, insufficient implementation of the rules of the Directive on track access charging, and the failure to set up an independent Regulatory Body with strong powers to rezedy competition problems in the railway sector.

It is natural that incumbent rail companies, still mostly state-owned undertakings, give more preference to seeking protection from intramodal competition than to pursuing market development of the European rail industry as a whole. More serious are problems embedded in the position of national governments.

The governments are required to act as independent legislators and regulators promoting the development of national rail markets and guarantors of non-discriminatory treatment to the rail operators and their free access to the rail infrastructure, facilities and funds. But they typically find themselves in two relationships with a conflict of interest. In the first of them, they execute an ownership role in incumbent rail holding and company structures and are directly or indirectly responsible for thein financial performance and social stability. Enhanced competition might get the incumbents into economic and social trouble. This situation never occurs in road freight where the governments typically do not have a special attitude to individual operators. In the second conflict of interest, governments are responsible for social stability and employment in the sector of domestic producers of rail equipment, sometimes very extensive and important. The situation sometimes resembles

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[24] ibid., pp. 83
[25] EC 2006, pp. 5
[26] A comprehensive overview of infringement procedures on the First and Second Rail Packages until 2007 see in EC 2007d, pp. 36-44 (Annex 3)
[27]http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1031&format=HTML&aged=0&language=EN&guiLanguage=en

a tacit alliance between the government, incumbent rail operator and domestic producers aimed at suppliesof domestic products. Such an alliance can hardly be found with other rail operators, and is impossible in the road freight sector with its free market of trucks and other equipment. One of main themes for the future is how to ensure that these conflicts of interests can be overcome.

The main recommendations to improve the implementation of the First Railway Package summed up in the report by EIM, ERFA and ERFCP[21] are as follows:

- A strong and independent regulatory body
- A transparent system for the application and delivery of licence
- Necessary setting up of a single point of contact and transparent procedures to get safety certificates
- *De jure* and de facto independence of homologation body
- Further harmonization on the level and structure of charges for freight traffic, as well as on the
- methodologies used for calculating infrastructure cost elements
- Create a public one-stop-shop for new entrants where all information and in particular, those facilitating cross-border traffic can be found
- Better scrutiny of State aid and the potential market distortions that may follow

The cure of existing shortcomings in the rail freight market is not simple and requires a clear strategy in individual Member States, as well as further devoted, legislative initiatives, even when difficult, on the part of European Commission.

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Behavior of Particulate Matter Produced by Cars in a Regional Model of Urban Canopy Layer

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ABSTRACT: This paper introduces the utilization of the CFD technique for the modeling of PM10 (particulate matter 10 μm) behavior in urban areas, focusing on a description of the processes in the ground surface boundary layer. A description of the deposition and re-suspension processes is introduced and applied to the regional numerical model of the city of Brno. The threshold velocity of re-suspension was obtained from the small scale modeling of PM10 dispersion in a street gully located inside the regional model. The predicted concentration fields were compared with theoretical studies and an in-situ measurement.

KEY WORDS: particulate matter, numerical modeling, urban area

1 INTRODUCTION

The increase of the PM (particulate matter) concentration level in cities stimulates an intensive research focused on a better understanding of particles behavior during their lifetime period in urban areas. The highest concentrations of PM are generally present in the inner parts of urban areas, specifically at a close vicinity to major traffic paths. Many parameters influence the formation, transport and deposition of particles at these locations. The particle's behavior is influenced by transportation in moving air, settling due to gravity, interaction with buildings walls, deposition on a ground surface and re-suspension of once deposited particles that are lifted by a local air movement and dispersed into surroundings. Therefore, a particle's behavior is a very complex process difficult for an accurate mathematical description. The numerical models for the prediction of PM concentration fields in urban areas fall into two categories: i) a detailed solution of PM dispersion processes with simplified quantification of PM sources (Fleming, 2003) and ii) a solution of concentration fields for gas species (NO_x) with a known correlation to PM (Kukkonen et al., 2001). The CFD modeling falls into both groups and represents the only tool capable to take into account the detailed geometry of urban areas and the interaction between moving cars and ambient air (Jicha et al., 2000). Numerical models of large areas are necessary for a correct description of long-distance PM10 transport. On the other hand, small scale models are necessary for a detailed prediction of PM concentrations in the close vicinity of traffic paths. The encasing of both types of numerical models enables a correct, complex and effective numerical prediction of PM concentration fields. It is impossible to accurately quantify the production of all real PM sources in urban areas. In this study we focus on the sources directly connected with car movement on traffic paths and the flow conditions of the ground surface boundary layer, namely deposition and re-suspension. Re-suspension represents the most intensive source of PM10 in large urban areas. Particles spend a long time in urban areas and travel over long distances. The deposition is one of the major possible ways of separation of PM10 from the lower part of the atmosphere. In numerical models of urban areas the deposition is considered to be a sink of PM10 (negative source).

2 MATHEMATICAL DESCRIPTION OF PARTICLE BEHAVIOUR

Particle deposition

Deposition occurs on all solid and liquid surfaces located in a polluted atmosphere. The particle's deposition in a boundary layer is described with the inclusion of turbulent transport and particle settling (Csanady, 1973)

$$F = K\frac{dC}{dz} + v_S C\,, \tag{1}$$

where v_s is the settling velocity of the particles, K is the eddy diffusivity for the mass transfer of the species with the concentration C, and F is the downward mass flux.

The eddy diffusivity is correctly solved by the CFD technique in a fully turbulent flow. Wall functions substitute the accurate solution of eddy diffusivity in surface boundary layers. Close to the surface, the eddy diffusivity is nearly zero. The Brownian diffusivity of particles greater than 1 μm is near to zero too. The downdraft mass flux is then controlled by the deposition velocity calculated as (Simpson et al., 2003)

$$v_S = \frac{D_p^2 \rho_p g C_c}{18\mu}\,, \tag{2}$$

where Dp and ρ_p are respectively the particle diameter and density, μ is the air dynamic viscosity, g is the gravitational acceleration. C_c is the slip correction factor expressed as

$$C_C = 1 + \frac{2\lambda}{d_p}\left[1.257 + 0.4\exp\left(-\frac{1.1 d_p}{2\lambda}\right)\right], \tag{3}$$

where λ is the mean free path of gas molecules.

Particle re-suspension

From different studies it follows that the re-suspension of once deposited particles is the most intensive source of urban airborne particles during "dry periods". The re-suspension process of once deposited particles depends on an actual air velocity field above the ground surface, alocal slit load, a surface roughness, particle geometry and other particle parameters. Coarse particles (d > 2.5 μm) are very often able to be re-suspended from dry-surfaces. On the other hand, fine particles and ultra fine particles show only a limited tendency of re-suspension from all surfaces. This results from the significant amount of a liquid fraction forming particles smaller than 2.5 μm and existence of the Van der Waals force between ultra-fine particles and surfaces. Re-suspension of particles is generally impossible from wet and adhesive surfaces. From the above mentioned follows that the re-suspension process is very complex and its mathematical description is generally connected with a high value of uncertainty. The re-suspension of particles settled on surfaces results from the interaction of aerodynamic, electrostatic and mechanical forces, see fig. 1.

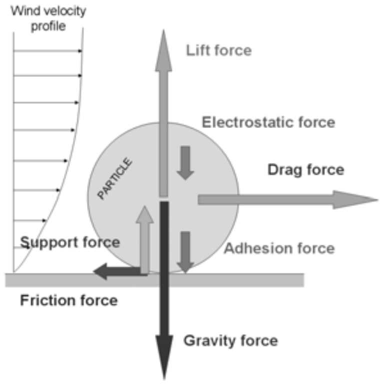


Figure 1: Particle interaction of aerodynamic, electrostatic and mechanical forces

The Saffman lift force due to a velocity gradient near walls is an important aerodynamic interaction. This lift force is oriented perpendicularly to the direction of flow affecting deposited particles in a viscous fluid. An electrostatic force on the charged particles can be calculated only for the known particle charge and the magnitude of the electrical field. This information is not common for dispersion studies and the electrostatic force is commonly excluded from calculations. The Saffman lift force and the fluid turbulence are sufficient to suspend fine and ultra fine particles. Coarse particles are often moved by the drag force along the surface. The turbulent intensity of a stream can also influence the air drag force affecting particles. The drag force affecting particles in a boundary layer was expressed in the form (Punjrath et al., 1972)

$$F_d = \frac{\pi d^2 C_{fx} \rho U^2}{8}, \tag{4}$$

where C_{fx} is the local shear stress coefficient, ρ is the air density, and U is the free-stream air flow velocity. An irregular shape of particles, together with a surface roughness, cause irregular bouncing of the particle against walls. This behavior prepares good conditions for the following up lift of particles in a boundary flow. Various forms of equations can be found in literature for determination of the windblown dust flux. Algorithms solve the dust flux either from the wind velocity and the threshold wind velocity (5) (Tegen and Fung, 1994) or from the friction velocity and the threshold friction velocity (6) (Claiborn et al., 1998)

$$F = C_{TF} u^2 (u - u_t), \tag{5}$$

where F is the dust flux, u is the wind velocity, u_t is the threshold wind velocity and C_{TF} is the constant representing the character of the soil surface (disturbed/undisturbed).

$$F = C u_*^3 a_g \left(u_* - u_{*t}\right), \tag{6}$$

where a_g is the constant expressing the effect of non-instantaneous wind velocity (~ 1.2), $u*$ is the friction velocity, $u*_t$ is the threshold friction velocity and C is an empirical constant.

The friction velocity for a neutrally stable atmosphere can be determined in a couple of ways. From the logarithmic wind velocity profile, the wind velocity is related to the friction velocity as

$$u = \frac{u_*}{k} \ln\left(\frac{z-d}{z_0}\right), \tag{7}$$

where k is the von Karman constant (~ 0.4), z_0 is the aerodynamic roughness length and d is the displacement height.

The wind velocity of re-suspension is the lowest velocity of air at height 10 m above the ground, for which re-suspension represents a significant contribution in an urban air PM10 concentration. The wind threshold velocity of re-suspension is strongly influenced by an actual geometry of an urban area, air density and the geometry of particles. From studies carried out, the corresponding urban threshold velocity of re-suspension is 2.4 m for the studied area. The previous paragraph discussed the wind threshold velocity of re-suspension with the utilization of the driving wind velocity above the "building's roof" level. But numerical models describing processes in a boundary layer require a much more detailed approach to the correct description of re-suspension. For this reason, we focused on a particular street gully in the city of Brno. The numerical model of the studied gully was built up. A series of calculations were carried out with the focus on a detailed description of an air flow above the ground and road surface. We considered spherical particles with a diameter of 10 μm, a density of particles 1200 kg/m^3, a parametrical roughness of surface 0.0003 m and a wind profile displacement 0 m. The street gully threshold velocity of re-suspension was determined as 0.75 m/s (at height 0.35 m). Different studies on determination of the threshold velocity of particle re-suspension were carried out in recent years. The majority of these studies considered particle re-suspension from a flat horizontal surface that fits well to the detailed solution of a bottom part of the studied street gully. We compared the predicted street gully threshold velocity of re-suspension 0.75 m/s with the results derived from formulations published by Cornelis and Gabriels (2004) and Saho & Lu (2003). From the Cornelis and Gabriels (2004) formulation, we derived the threshold velocity of re-suspension 0.724 m/s. From the Saho and Lu (2003) formulation, we derived the threshold velocity of re suspension 0.957 m/s. The predicted street canyon threshold velocity of re-suspension for PM10 particles showed a good agreement with the above mentioned theoretical studies.

3 A SIMPLIFIED DESCRIPTION OF PARTICLES DEPOSITION AND RE-SUSPENSION FLUXES

It is impossible to accurately quantify the production of all real PM sources. Therefore, an appropriate simplification of the particle's production description is convenient for a numerical solution of PM concentration fields.

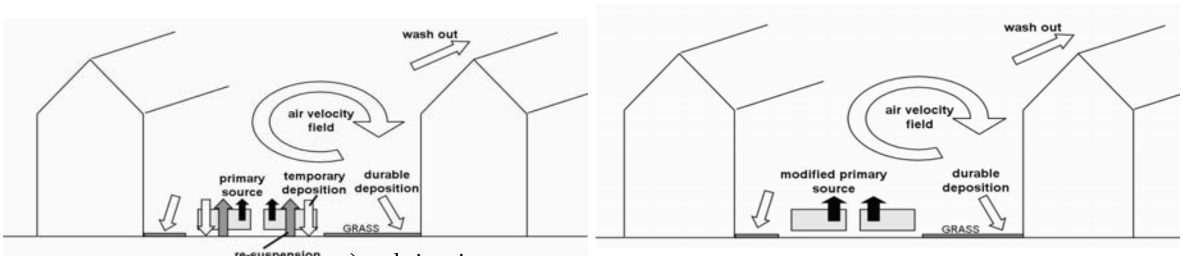
The simplification used in this study assumes the equivalence between the particle's deposition rate on smooth dry surfaces and the particle's re-suspension rate from these surfaces, influenced by wind velocity higher than the threshold velocity of re-suspension. Stable deposition is assumed on grassy surfaces and smooth dry surfaces influenced by wind velocity lower than the threshold velocity of re-suspension. The modified primary source term represents the only particles source term prescribed in the numerical model, see fig. 2. The modified primary source was assigned in the near road surface air layer, where the major amount of airborne particles is generated. From this air layer, particles disperse into the surroundings.

4 PM10 DISPERSION MODELING ON A REGIONAL SCALE MODEL

The above mentioned description of deposition and re-suspension was utilized for PM10 dispersion modeling on a regional model. The regional solution domain involves the city of Brno and nearby surroundings. The solution domain covers an area of 12×12 km. Due to the large modeled area, it is impossible to accurately involve the geometry of all objects. The parametrical roughness is used as a convenient substitution of ground cover geometry. The primary ground surface was built up in accordance with the actual terrain profile. The regional model ground plan was divided into 576 square control regions with a side length of 500 m. A convenient parametrical roughness was assigned within these regions. The ground cover was divided into seven groups that represent the most common ground covers in the studied area. The corresponding parametrical roughness values were derived for all considered ground covers: water surface, meadow, forest, separate buildings up to 3 floors high, continuous buildings in rows up to 3 floors high, separate buildings above 3 floors high, continuous buildings in rows above 3 floors high. The primary ground surface was refined at terminal control volumes size with the top view dimensions 50×50 m. The 900 m high air layer was modeled above the primary ground surface. This air layer was subdivided into 19 sub-layers. The lowest sub-layer height was 2.125 m and the highest sub-layer height was set to 100 m.

Traffic related PM sources

The primary car exhaust emission factor is determined for a considered car fleet composition – diesel engines : petrol engines = 1 : 3. The particular emission factor values were derived from software MEFA v.02 (Mobile Emission Factors) published by the Ministry of Environment of the Czech Republic. The primary car exhaust emission factor value was determined as 0.0179 g/km per car. A non-exhaust particle source related to traffic involves primary particles and the re-suspended particles. Primary non-exhaust particles are released from cars, tires and road surfaces. The emission factors of non-exhaust particles released from cars and tires can be derived from different studies. The amount of the primary road surface particles is a function of a road surface material and an actual road state. Re-suspended particles are silt road particles drawn up from a road surface. The re-suspension process intensity is fully dependant on an actual road silt load. The total PM10 emission factor is a sum of the exhaust particles emission factor and the non-exhaust emission factors. The average total PM emission factor of the regional model domain was derived from a previous study carried out in the studied area as 0.06265 g/km car.



a) real situation b) simplified expression

Figure 2: Particles fluxes in a street canyon

Corresponding traffic activity was derived from the Brno Transport Research Center database. Portions of traffic paths passing through individual control regions (500×500 m) were specified. Traffic activity (car km/day) at traffic paths portions was multiplied by the total emission factor. The average total PM emission factor serves for the determination of the only particles source term prescribed in the numerical model. The source term was assigned at the air layer close to the ground surface, where a major quantity of airborne particles is generated. The inlet/outlet boundary conditions were assigned on the side walls of the regional model. The ground surface utilizes the wall boundary condition with an appropriate parametrical roughness. The top of the domain uses the condition of a wall with no friction. As a model of turbulence, a k-ε RNG model was used.

5 RESULTS AND DISCUSSION

In the calculations, we presume coarse spherical particles with a diameter 10 μm. The density of the particles is set to 1200 kg/m-. Figure 3 shows the predicted PM10 concentration field obtained from the regional model for a wind velocity of 2 m/s and 3 different wind directions. The cuts of concentration fields are led in a height of 3 m above the ground surface. The left column in Fig. 3 contains the concentration fields obtained from calculations without the inclusion of deposition. The right column shows the results with the inclusion of the deposition process. The inclusion of the deposition process decreases the PM10 concentration only by 1-4% in the central parts of the city due to small areas enabling a durable deposition. The decrease of PM10 concentration by 8 – 17 % is observed in the residential areas of the city. The most intensive decrease in PM10 concentration occurs in the outskirts areas richly covered by greens and forests. The PM10 concentration fields show a higher concentration along roads with the highest traffic rate. At the bottom of the concentration fields, the inter-state highway passes around the city. Intensive traffic on this highway causes significantly higher PM10 concentrations along this traffic path. The regional background PM10 concentration of 15μg/m3 was derived from a measurement carried out outside of the urban area. The north part of the city of Brno is without any intensive local sources of particles. This part of the city serves as residential areas without industry. The total predicted PM10 concentration is calculated as the sum of the predicted concentration and the regional background concentration. The result of this calculation is 23.5μg/m^3 at the position of the measurement located in the central part of the city. By our measurements, we obtained the PM10 concentration value 45 μg/m^3.

6 CONCLUSION

The presented study shows the possible inclusion of deposition and re-suspension of PM10 particles in a regional scale dispersion model solved by the CFD technique. The CFD modeling represents a convenient tool for detailed PM dispersion modeling in urban areas. But the accuracy of these predictions is still limited due to the high uncertainty of PM source description and the limited possibilities for a correct description all physical processes. The predicted PM10 concentration field with the inclusion of the deposition and re-suspension process represents 52.2% of the PM10 concentration value obtained from measurements in the central area of the city of Brno. The result shows that the predicted concentration values significantly underestimate the measured concentration values. The difference is probably caused by an intensive re-suspension of soil particles. This process is not taken into account in the numerical models due to difficult description of its source term.

7 ACKNOWLEDGMENT

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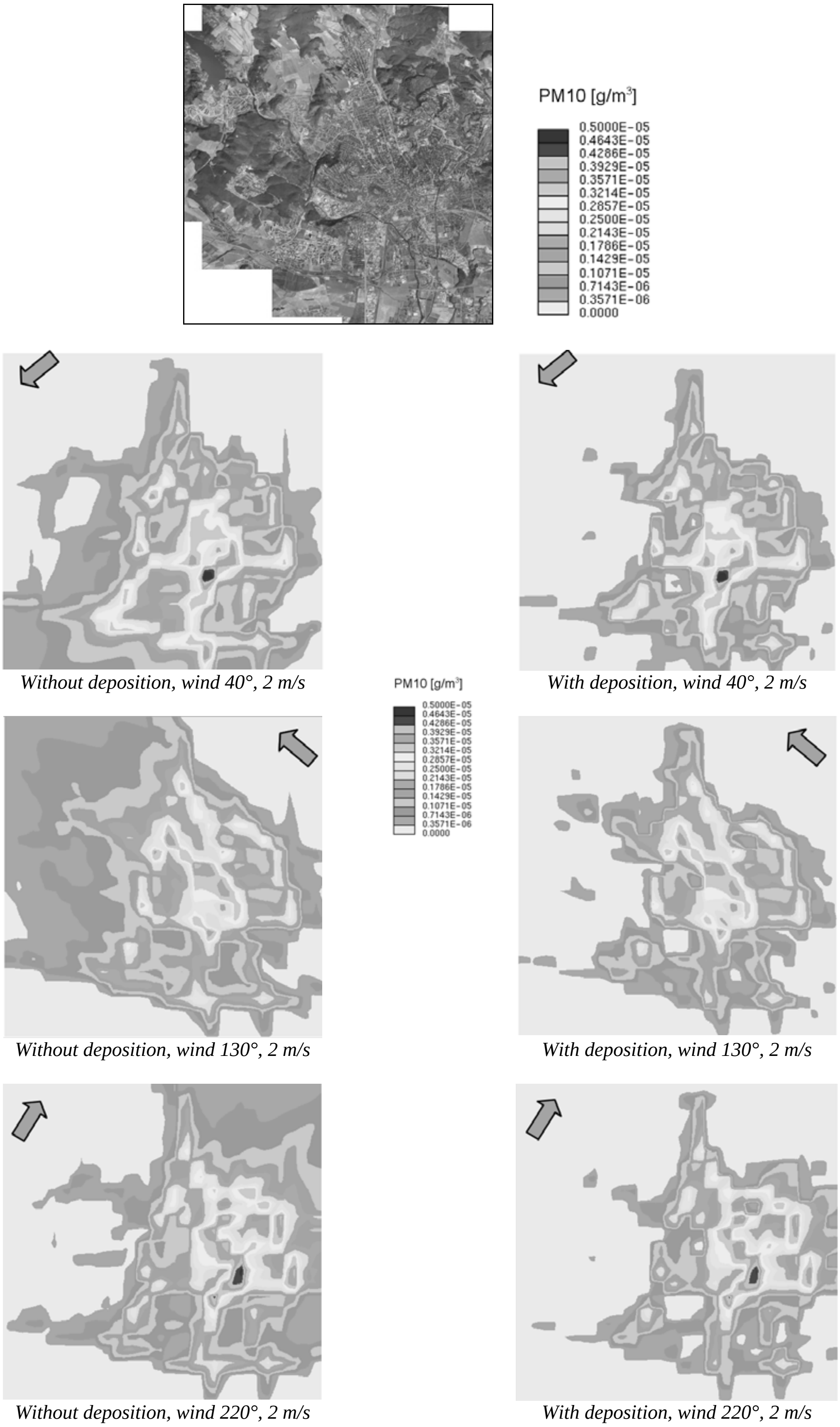

Figure 3: Predicted PM10 concentration fields led 3 m above ground surface

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Hybrid Solution of Interoperable European Toll Service

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ABSTRACT: The paper summarizes the interoperability bottlenecks of EFC (Electronic Fee Collection) on the level of European electronic toll services and provides proposals for a new hybrid architecture that fulfils all European requirements, is compatible with current standards and enables the use of all admissible technologies for toll data collection (GNSS, GSM/GPRS, DSRC) specified in EC Directives. The hybrid solution is discussed with respect to the future development of Czech electronic toll system and also with respect to the interoperability of our neighboring countries.

KEY WORDS: Electronic fee collection, electronic toll systems, electronic toll services, ITS, transport telematics, MISTER, EG9, EETS, RCI, interfaces

1 HISTORY OF EFC REALIZATION IN THE CZECH REPUBLIC AND LESSONS THAT HAVE BEEN LEARNT

From the beginning 2003 a tender for EFC for trucks above 12 tons had been prepared in the Czech Republic by the Ministry of Transport. The whole process was speeded up due to the increasing of volume of foreign trucks using the Czech Republic as an alternative routing when Austria and Germany started their own EFC systems. The tender, published in 2005, called for the building and operation of an EFC system for about 2000 kilometers of highways and selected 1st class roads. All trucks above 12 ton, with some exceptions for the army, security guards and buses, are obliged to pay. The average price for 1 km was specified by the ministry in the amount of 0.13 cents.

A complicated selection procedure had chosen a microwave DSRC system. The EFC system has been successfully in operation from 1st January 2007 and the first results after one year show that revenues are 50% higher than had been expected.

A contemporary consideration suggests to extend the charging system to 6000 km of the 1-st class roads and to about 2000 km of the 2-nd class roads. The price per kilometer had considered:

- Regulation of using alterative roads;
- Economical profitability not only for the state, but also for regions;
- Restriction of possible increasing of commodity stuff due to charging.

The new supplier of satellite technology GNSS will be accepted by a new tender according to European directive 2004/17/EN and according to legislation of the Czech Republic. The strict requirements will be applied to the supplier – both subsystems (DSRC and GNSS/CN) shall be integrated into one system with priority given to GNSS/CN system. The expert group elaborated this concept in March 2007, and it has been named the Hybrid System. The concept comes from the theory of hybrid systems used in automation.

2 FAILURE OF EUROPEAN STANDARDIZATION

After a very long way and tens of hours of discussions between the standardization committee CEN/TC278 "Road Transport and Traffic Telematics", it was possible to say that the set of DSRC standards had been finished in 2004. Quite a different situation is in the field of GNSS/CN.

There are two satellite systems in operation as an EFC system in Europe at present. The german system is a proprietary system covered by a set of patents. Document CEN N1934 "EFC standards and IPR" speaks of about one hundred patents. A very similar situation is according to the Swiss system in view of the fact that it has never published its technical specifications. There is only one possibility for countries aiming to introduce a GNSS based system – to rely on a European standard. The GNSS standard is the only possible way to ensure the necessary interoperability in the European countries.

The first, and, up to now, only one realistic proposal of a GNSS/CN standard was elaborated by WG1 of TC278 at the end of nineties. Standard 17 575 "Application interface definition for electronic fee collection (EFC) based on Global Navigation Satellite Systems and Cellular Network (GNSS/CN)" was formed rather sadly coming from two basic reasons:

- Since there was no common idea how future GNSS/CN were to be built it was decided that the standard should be written as a "toolbox standard";
- The existence of cellular networks based on a standard like GSM led to the conclusion, that the communication stack according to the OSI/ISO 7 Layer Model was well covered.

The standard describes the basic concept of GNSS/CN, scenarios of transactions, description of application layer, etc. in 130 pages. During discussion within the CEN community the standard was remitted due to huge criticism. Just suggestions raised fill more than 80 pages. After a number of meetings in the years 2005-2007 it was decided to stop the work on this standard and split it into a few smaller parts:

- Charging;
- Communication: transactions and connections to lower layers;
- On line updating of toll data and software;
- Roaming.

The expected term of publication of official standards in 2011 evoke thoughts of the same situation, where DSRC was in the nineties. A number of countries designed their charging system following preliminary DSRC standards. The implication of the non existence of valid standard is now solved in a complicated way within the projects as CESARE or RCI, searching for interoperability of different providers of DSRC.

The problem of a non existing GNSS standard is an absolutely crucial problem for the Czech Republic because the tender for charging system for about another 8 000 km roads is under preparation and it will be published shortly. Actually, a worse situation is in the Slovak Republic because the tender for about 2000 kilometers was published at the end of 2007 and they are in a process of evaluation. Hungary also published a tender as a preliminary tender and they are also in the process of starting a charging system.

The worst scenario would be if the Czech Republic would set up its own satellite system, and the same happens in the Slovak Republic and Hungary. The quality and openness of the interface would be only in the hands of the suppliers, and if these would be different, we would have three incompatible EFC systems in this region by 2009. Together with Germany and Switzerland it would make five incompatible systems. To harmonize these systems will cost a great amount of money even if it would be at all possible.

An expert group, having been aware of this situation, proposed to the Ministry of Transport probably the only one possible solution. The solution is to prepare a "de facto" standard describing data exchange only in one cross-section of the complex information chain between On-board-Unit (OBU) and the central system (CS). This proposal, described in the following chapters, comes from ideas from European projects MISTER and RCI, as well as from standard proposal 17 575.

3 ARCHITECTURE OF EUROPEAN ELECTRONIC TOLL SERVICE

The European electronic toll service (EETS) is described in European Directive 2004/52/EC ("the interoperability directive"), in the following way: "Operators shall make available to interested users on-board equipment which is suitable for use with all electronic toll systems in service in the Member States". At the technical level, the EETS therefore comprises the availability of suitable On-Board Equipment (OBE) which will operate in all European EFC systems.

The Minimum Interoperability Specification for Tolling on European Roads (MISTER*) is currently a document which was produced in 2004 by the contract team working for the Commission on the finalization of the draft standard ISO 17575. This draft standard provides for a set of standardized transactions for communication between on-board and central equipment (CE) in an EFC system based on Global Navigation Satellite Systems (GNSS) and Cellular Network (CN) communication. The MISTER was intended as a first draft of the EETS specification, in particular of the EETS OBE. In 2006, MISTER was amended by the Expert Group 9† (EG9) to define the minimum functionality of an On-Board-Unit able to perform the vehicle part of the pan-European EFC service.

All documents have been provided to the Road Charging Interoperability project (RCI) which is expected to modify and extend the current draft. The RCI Architecture shows on Fig.1 the relations between the following actors: EETS User, EETS Provider and the Toll Charger. This architecture agreed in the RCI project allows for both so called "thin client" and "thick client" type of on board units and makes the interfaces between the actors more visible. For the case of interoperability the interfaces and the data exchange through them are of greater importance than the physical units. Some of the interfaces can be regarded as "internal" as they relate to functions belonging to the same actor and are less important for achieving interoperability. The most important interfaces are between the EETS provider (role) and the Toll Charger (role) for exchange of data declaration of road usage and data for enforcement.

* Project supported by EC

† Expert group established by EC

Project supported by EC: www.ertico.com/rci

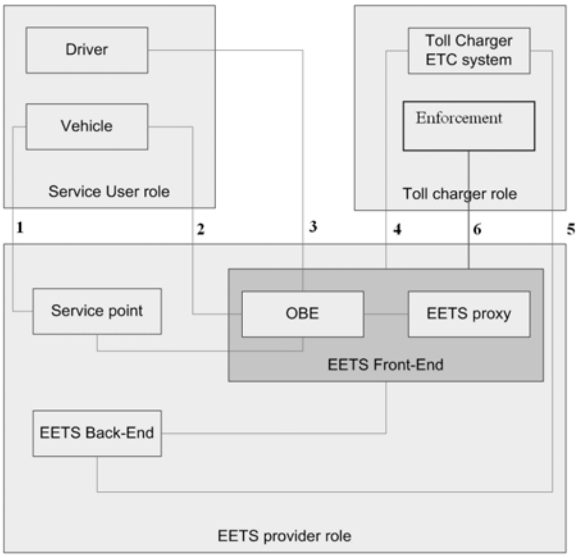

Figure1: The RCI Architecture of EETS with 5 interfaces between EETS provider and Service User/Toll charger roles

The RCI architecture shows the technical interfaces that require standardization for achieving interoperability:

- <u>Interface 1:</u> standardization of vehicle-provided access points for the servicing and maintenance of road charging OBE is not considered critical for interoperability.
- <u>Interface 2:</u> standardization of in-vehicle integration of OBE is not considered critical for interoperability.
- <u>Interface 3:</u> standardization of the Human Machine Interface (HMI) of the OBE is not considered critical for interoperability (functional HMI behavior can be specified through interface 5 as part of the Toll Context Definition).
- <u>Interface 4:</u> the data exchange for sending the 'use data/charge data from the (toll service provider) TSP to the Toll Charger needs to be standardized. For GNSS-enabled road charging: standardization in progress in CEN. For DSRC-road charging: EN 15509 can be used.
- <u>Interface 5:</u> Exchange of the specifications that defines the functionality (charged objects, events and actions) of the Toll Chargers' tolled infrastructure (Interface 5 also hosts the back office transactions/clearing between the toll charger (TC) and the toll service provider (TSP) which is outside the scope of RCI). For GNSS-enabled road charging: standardisation in progress in CEN. RCI validated the concept of the Toll Context Data and RCI will finalize a report that shows how LSVA and Toll Collect can be translated in this RCI Toll Context Data. For DSRC-road charging: no other use than for back office transactions/clearing between the TC and the TSP which is outside the scope of RCI.
- <u>Interface 6:</u> Enforcement interface must allow each Toll Charger to easily check the compliance of the Front End of all TSP sactive on his tolled infrastructure. For GNSS-enabled road charging: standardisation in progress in CEN. For DSRC-road charging: EN 15509 can be used

In 2008 the new approach into CEN 278 and ISO 204 standardization was announced and new project teams (PT) were created and supported by EC. Working groups CEN278/WG and ISO204/WG play only the role of evaluators and reviewers of work done by PT groups.

PT20 starts to divide the draft standard CEN ISO 17 575 into four parts: charging, communication, data elements and definitions of operating more than one EFC regime at the same time. The main principle of PT20 approach is on Fig. 2 where the main process layers described on Fig. 3 are differently allocated within Proxy or OBE based on intelligence distribution on OBE.

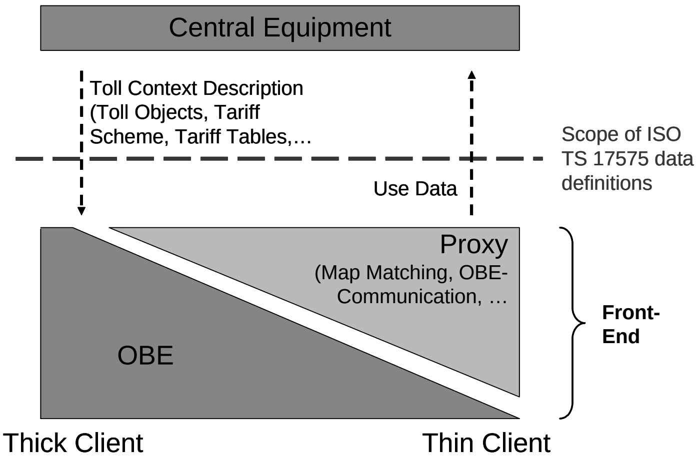

Figure 2: Gradual transition between thin and thick architecture extremesand the interface in cope of this Technical Specification of PT20

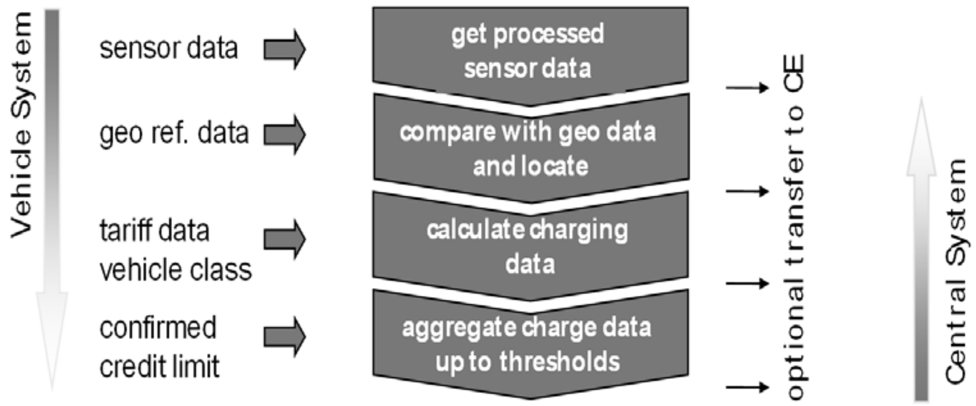

Figure 3: Main process layers between vehicle/central systems created within work of EG9

We can summarize our analysis in that the design of current EFC systems is based more on a series of specifications defining the information exchange between the front-end and the central systems in EFC based on a different kind of on-board equipment (OBE). Due to the enormous versions of OBE and over-estimated role of OBE in the whole system the standardization does not lead to the expected goal. On the other hand, specifications analyzed above did not solve, for example, the combination of all technologies DSRC, GNSS/CN but only solved the combination of a thick/thin satellite variant of OBE. Most of these approaches limit the use of OBE in some specific position in the system design. Finally it leads to a system unusually limited by a standard, to some specific OBE design, not leaving a space in the market for new emergent technologies. Also the business architecture had been widely bound by the standards, when only one globally interoperable unit has to be used.

Our approach overcomes all mentioned problems and provides a new system oriented insight on EETS architecture. Firstly, we identify the three main parts of EETS as: EFC data provider, EFC data processor and EFC data user. Based on this categorization, we can approach definitions of interfaces on a more convenient abstract level than was done within analyzed EU projects. This new approach is independent of the data collection method and all suppliers of EFC data collection service can be incorporated into the design of the system. It facilitates an ability to integrate different EFC data suppliers no matter which technology was used for data collection. In chapter 2 we describe the EFC hybrid approach together with its architecture and business model. In chapter 3 we summarize the benefit of the designed architecture for future EFC for the Czech Republic and also for whole of Europe. Chapter 4 concludes the paper.

4 HYBRID EFC SYSTEM SPECIFICATION

A hybrid system specification could be easily explained on the layered architecture according to Fig. 4. As can be recognized, three basic layers of hybrid EFC system are defined. These layers distinctively clarify three different functionalities of the hybrid EFC system.

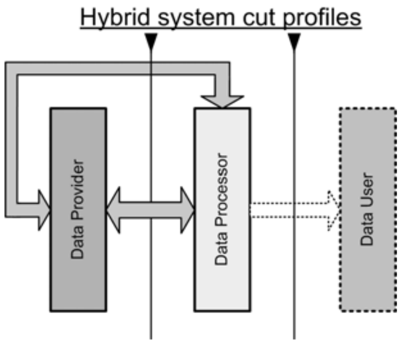

Figure 4: Layered EFC system architecture

The functionality of hybrid EFC system could be seen from the point of its role in data processing as follows:

- Data Provider, the functionality having a major goal in providing trusted data from the data collection environment to the central part of the system for data processing. Data Provider subsystem has to form a trusted system from the point of view of security and in this way provides trusted non-repudiated data to the central system;
- Data Processor, where all the data are processed by applying at least a minimum set of means necessary for toll collection. The central system can provide all basic toll collection functions based on data provided and it is not expected to broaden this functionality beyond some extent*;
- Data User, which is a free collection of functionalities of a different kind, using data from a central system for further calculations and applications, mostly user specific oriented;

* The fact that the central system is used to automatically issue an invoice, which has a form of a legally defined fee based on strict legal rules, leads to the high level of requirements whereas reliability is concerned. In such a case would be better to move out of the central system all functions which do not directly support the major task.

Two cross-sections are important for the hybrid system, specifically the point where these sections are made:

- Data Provider/Data Processor cross-section, which effectively cuts the information flow between;
- Data Provider and Data Processor on the side of data provisioning, where trusted data are transferred into the Data Processor and possibly some amount of information is provided to the Data Provider from the Data Processor, e.g. some specific information known to the Data Processor only;
- Data Provider and Data Processor on the other side of the Data Provider subsystem. This specific cross-section is expected to be used for a unified way of validation of the information obtained from the data Provider subsystem;
- Data Processor/Data User cut, which is not a part of this specification and has to be standardized as an interface for implementation of user specific functionalities, running behind the Data Processor subsystem, insulated by the Data Processor/Data User interface.

These cross-sections above form three distinguished parts of the system and show two important places where standardized interfaces have to be defined.

4.1 Hybrid system architecture

A hybrid system architecture standardization goes behind the simple definition of the functionality of OBE. The hybrid system defines the combined functionality of OBE and so called "Context Server", which is a functional unit dedicated to the interpretation of behavior of the whole data collection system, behind it into a standardized context on the interface between Data Provider and Data Processor*.

The OBE, context server and the communication environment of the subsystem forms complex architecture, which could be seen as a "black box" with two interfaces on its border sides. For further explanation it would be useful to study Fig. 5. The green line shows the scope of the definition of interfaces within the hybrid EFC system.

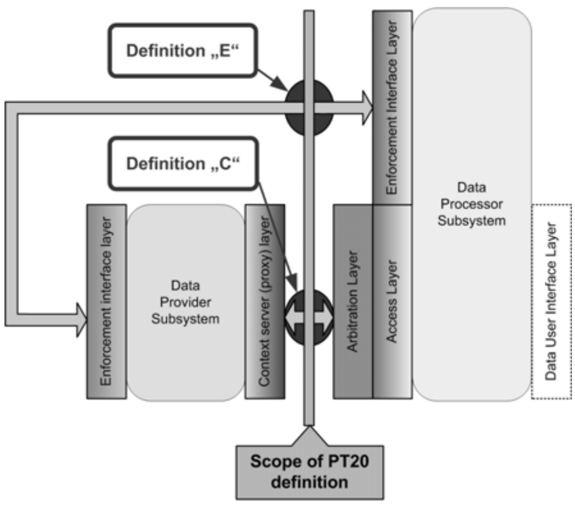

Figure 5: Structure of interfaces in hybrid solution

* In the PT20 terminology the context server could be understand as a "proxy".

Data provider subsystem communicates with Data Processor subsystem via a set of layers defined as follows:

- Context Server Layer on the edge of the Data Provider Subsystem provides an instrument of communication with the Data Processor Subsystems by means of the standardized language of the interface. The partner in this communication on the side of Data Processor Subsystem is the Access and Arbitration Layer*.
- Arbitration Layer is the only place where information from any outer subsystem can enter the Data Processor Subsystem and where the information could be accepted or obtained. A major role of the layer is to arbitrate between information obtained from different sources – Context Servers†.
- Access Layer, is the common input to the Data Processor Subsystem handling all the necessary functionalities belonging to secure access and communication with outer subsystems‡.
- Enforcement Interface Layer on both Data Provider Subsystem and Data Processor Subsystem is dedicated to the verification and validation of the selected information from the Data Provider Subsystem via an enforcement specific channel. The Enforcement Interface Layer on the side of the Data Processor Subsystem is handled by its own access and security means.

To define a standard for the hybrid EFC system we have to describe two major interfaces, which are shown in Fig. 5 as Definition "C" and Definition "E", where

- Definition "C" characterizes the standard interface for the subsystems data exchange. This is done by definition of "languages" on that interface, which has to be common enough to describe the behavior of the interface and data structures transferred. As a part of the standard, the ISO/OSI layers could be defined for that standard interface§.

- Definition "E" specifies the information exchange on the enforcement level. There is also the expectation that as a part of the standard, the ISO/OSI layers could be defined for that standard interface.

As can be easily understood, the basic idea of the hybrid system architecture doesn't limit the Data Provider to any of the predestinated technology of capturing data for electronic toll collection. It only describes the edges of the "black box", which easily could be seen as e.g. a proprietary system. Then, on these edges, the standard behavior of the "black box" is expected, defined by the "standard language" (functionality of the "standard interface") and "standard data structures" (information transferred over the standard interface). This approach simplifies the system design, allowing full interoperability; including roaming among systems involved and, as a matter of fact, creates a new business environment with a precise definition of roles and responsibilities.

* As matter of fact, the order of Access Layer and Arbitration Layer is not important from the point of view of functionality of this part of the system.

† The Context Server is the functional edge of every Data Provider and it would be expected that there could be more than one Data Provider covering the same area of EFC. Based on this expectation we have to be able distinguish between similar information coming from different sources – Data Provider Systems.

‡ It is expected, that the information exchange processes within these layers are based on standard client/server architecture.

§ We believe that most of these ISO/OSI layers could be a part of a standard network interface as e.g. a TCP/IP stack. Only some top layers, as, for example, the application layer, would be different.

4.2 Business specification

According to architecture described above, we should understand “the Toll Charger” as a recipient of the road usage charges, the abstract actor associated with the Toll Charging role. On other hand, we should also understand “the Service Provider” to be an abstract person responsible for operating the data collection environment and in such a way providing trustworthy data to the Tool Charger. The relation between hybrid system architecture and business model can be described in Fig. 6.

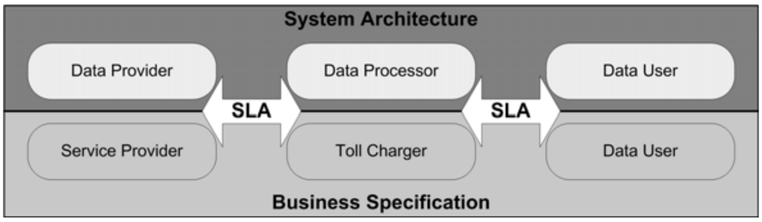

Figure 6: The relationship between models of the business specification and the hybrid system architecture

As can be seen, the business specification and the hybrid system architecture correlate and give an opportunity to define a clear and simple business relationship among entities involved. Clear definition of roles and responsibilities introduces a comfortable environment for the setting up of non overlapping Service Level Agreement contracts based on a well defined architectural model.

4.3 The consequences of hybrid EFC architecture

The original idea of layers elaborated by PT20 is shown in Fig. 2. The new scheme proposed by this solution is very close to the scheme as it is shown in Fig. 7. The main difference is that all suppliers of OBU´s have to also deliver Context Server - Proxy. Connection to the central system will be “symmetrical” for all suppliers and the Proxy server will transfer date on the same way.

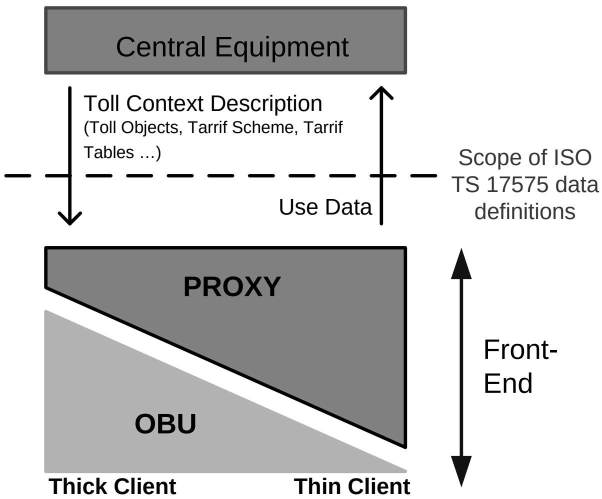

Figure 7: The new scheme is symmetrical for all suppliers OBU´s

5 CONCLUSION

The Hybrid System Architecture for the Electronic Fee Collection System introduces a new view on the standardization process, based on the clear definition of roles and responsibilities inside the system. Also it establishes a new system cross-sectioning, where the original highly important role of the OBE is suppressed and a new role of the Data Provider is introduced. This approach leads to the simplification of the interoperability problem, establishing of a new competitive market for the OBE and Data Provider Services. Also, well bounded model creates a cleaner legal environment for the definition of individual services and the preparation of the SLA's.

6 ACKNOWLEDGEMENT:

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The Modeling Processes Exploitation by Pavement Management System in Slovakia

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ABSTRACT: Road evenness is one of the basic factors of pavement quality. It represents not only the characteristic of the road serviceability, but also road safety and comfort. Longitudinal unevenness causes traffic discomfort and a danger of wheel-pavement interaction decreasing.

Listed aspects were taken into account for an analysis of classification levels in the frame of the Slovak Pavement Management System. The simulations of different boundary conditions during pavement surface diagnostics were oriented above all to the response of unevenness to the vehicle and to the ride comfort consequently. On the other hand, an effect of unevenness to interaction between surface and wheel was the basic criteria of evaluation from a safety point of view. The paper is oriented to the observation and evaluation of described parameters during realized simulations and experimental measurements. For simulations the dynamic characteristics of real vehicles were used.

KEY WORDS: Road serviceability, pavement, evenness, road safety, discomfort

1 INTRODUCTION

The Slovak Pavement Management System (PMS) is a tool for effectively dividing the budget for the management of road rehabilitation. The system includes processes for effective maintenance, repairs and the renewal of road surfaces and structures. The processes are based on the diagnostics of the pavement surface parameters (serviceability level of pavement) and bearing capacity. One of the most important input parameters into PMS is The Longitudinal unevenness - input by the International Roughness Index (IRI), describing the longitudinal unevenness quality in five levels.

In the next part of the paper correlations of internationally established dynamic quantifiers of longitudinal unevenness are presented. Following the ascertained correlations of parameter C and IRI (International Roughness Index) and new legal regulations the classification scale of IRI used in Slovakia has been modified.

2 INTERNATIONAL ROUGHNESS INDEX - IRI

Parameter IRI is obtained using the Reference Quarter Car Simulation (RQCS) according to (Sayers et al 1998) and Fig. 1.

This mathematical model is defined mathematically by two second-order differential equations:

$$\ddot{z}_s \cdot m_s + C_s \cdot (\dot{z}_s - \dot{z}_u) + k_s \cdot (z_s - z_u) = 0 \quad (1)$$

$$\ddot{z}_s \cdot m_s + m_u \cdot \ddot{z}_u + k_t \cdot z_u = k_t \cdot y \quad (2)$$

We can express this system as:

$$\ddot{z}_s + C \cdot (\dot{z}_s - \dot{z}_u) + k_2 \cdot (z_s - z_u) = 0 \quad (3)$$

$$\ddot{z}_s + u \cdot \ddot{z}_u + k_1 \cdot z_u = k_1 \cdot y \quad (4)$$

where:

m_S, m_U – weight of the sprung mass and the unsprung mass [kg]
k_S, k_t – constant of the linear spring and the tire [N.m^{-1}]
C_S – coefficient of linear damper [kN.s.m^{-1}]
z_S, z_U – displacement of the sprung and he unsprung mass [m]
$\dot{z}_s = dz_s/dt$, $\dot{z}_u = dz_u/dt$
- vertical velocity of the sprung/unsprung mass [m.s^{-1}]
$\ddot{z}_s = d^2 z_s/dt^2$, $\ddot{z}_u = d^2 z_u/dt^2$
– vertical acceleration of the sprung/unsprung mass [m.s^{-2}]
y(t) – profile elevation inpu [m]

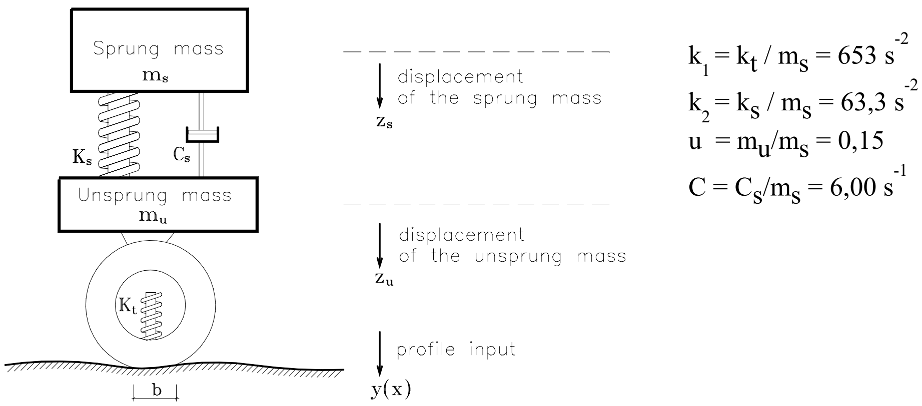


Figure1: The Reference Quarter Car Simulation

Equations (1) - (4) apply for temporal domain. We solve this model in the linear domain, we know the real longitudinal profile per 0.25 m, whereupon we must find a vector of spatial derivations -$Z^T(x)_{(i)} = (z_{1i}, z_{2i}, z_{3i}, z_{4i})$. The values of this vector are calculated as:

$$z'_{s,i} = s_{11} \cdot z'_{s,i-1} + s_{12} \cdot z''_{s,i-1} + s_{13} \cdot z'_{u,i-1} + s_{14} \cdot z''_{u,i-1} + r_1 \cdot y'_i \quad (5)$$

$$z''_{s,i} = s_{21} \cdot z'_{s,i-1} + s_{22} \cdot z''_{s,i-1} + s_{23} \cdot z'_{u,i-1} + s_{24} \cdot z''_{u,i-1} + r_2 \cdot y'_i \quad (6)$$

$$z'_{u,i} = s_{31} \cdot z'_{s,i-1} + s_{32} \cdot z''_{s,i-1} + s_{33} \cdot z'_{u,i-1} + s_{34} \cdot z''_{u,i-1} + r_3 \cdot y'_i \quad (7)$$

$$z''_{u,i} = s_{41} \cdot z'_{s,i-1} + s_{42} \cdot z''_{s,i-1} + s_{43} \cdot z'_{u,i-1} + s_{44} \cdot z''_{u,i-1} + r_4 \cdot y'_i \tag{8}$$

The presented system can be expressed in the following matrix form:

$$Z(x)_{(i)} = \underline{S} \cdot Z(x)_{(i-1)} + R \cdot y'_{(i)} \tag{9}$$

where:

$Z^T(x)_{(i)} = (z_{1,i}; z_{2,i}; z_{3,i}; z_{4,i}) = (z'_{s,i}; z''_{s,i}; z'_{u,i}; z''_{u,i})$
$= (dz_{s,i}/dx; d^2z_{s,i}/dx; dz_{u,i}/dx; d^2z_{u,i}/dx)$ - vector of spatial derivations
S – state transition matrix 4 x 4,
R – partial response matrix 1 ^{x} 4
$y'_{(i)}$ – slope input
i – present step, i-1 – previous time step

The differential equations (7) - (10) can be expressed in the following matrix form

$$Z(t) = \underline{A} \cdot K(t) + B \cdot y(t) \tag{10}$$

where:

$Z^T(t) = (\dot{z}_s, \ddot{z}_s, \dot{z}_u, \ddot{z}_u)$ =(dz_s/dt, d^2z_s/dt, dz_u/dt, d^2z_u/dt)-vector of temporal derivations
$K^T(t) = (z_s, \dot{z}_s, z_u, \dot{z}_u)$ - additive vector of temporal derivations

$$\underline{A} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -K_2 & -C & K_2 & C \\ 0 & 0 & 0 & 1 \\ K_2/u & C/u & -(K_1+K_2)/u & -C/u \end{bmatrix} \tag{11}$$

$$B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ K_1/u \end{bmatrix} \tag{12}$$

For a constant length of the step, on which $y'_{(i)}$ is a constant, the **S̲** and **R** matrices can be computed from the **A̲** and **B** matrices:

$$\underline{S} = e^{\underline{A} \cdot dt} \tag{13}$$

$$R = \underline{A}^{-1} \cdot (\underline{S} - \underline{I}) \cdot B \tag{14}$$

where:

$$dt(s) = \underline{dx}(m)/v(m/s) \qquad (15)$$

$\underline{I}$ – identity matrix 4 x 4

The algorithm for the evaluation of longitudinal unevenness – IRI KCS, according to the original methods (Sayers et al 1998), has been created in Microsoft Excel 97. This program carries out equations (1)-(15) and consists of the following steps:.

Calculation of profile slope input - the profile slope input is computed for every measuring point (we must known elevations of longitudinal profile per 0,25 m):

$$\mathbf{y'_{(i)} = (y_{(i-1)} - y_{(i)}) / dx}, \qquad i = 2,3,.....,N \qquad (16)$$

where:

$\mathbf{y'_{(i)}}$ – smoothed profile slope input
$\mathbf{y_{(i)}}$ - elevation of longitudinal profile [m]
dx – measurement interval dx = b = 0,25 m

Computation of the vector of spatial derivations Z(x)(i) - the computation of vector $Z^T(x)_{(i)} = (z_{1,i}; z_{2,i}; z_{3,i}; z_{4,i}) = (z'_{s,i}; z''_{s,i}; z'_{u,i}; z''_{u,i})$ is realised by the equation (15):

$$Z(x)_{(i)} = \underline{S} \cdot Z(x)_{(i-1)} + R \cdot y'_{(i)}$$

where :

$\underline{\mathbf{S}}$ – state transition matrix 4 x 4,
i – present step,

R – partial response matrix 1 x 4
i-1 – previous time step

Determination of the corrected profile slope

$$T_i = (z_{3i} - z_{1i}), \qquad i=2,3,...,N \qquad (17)$$

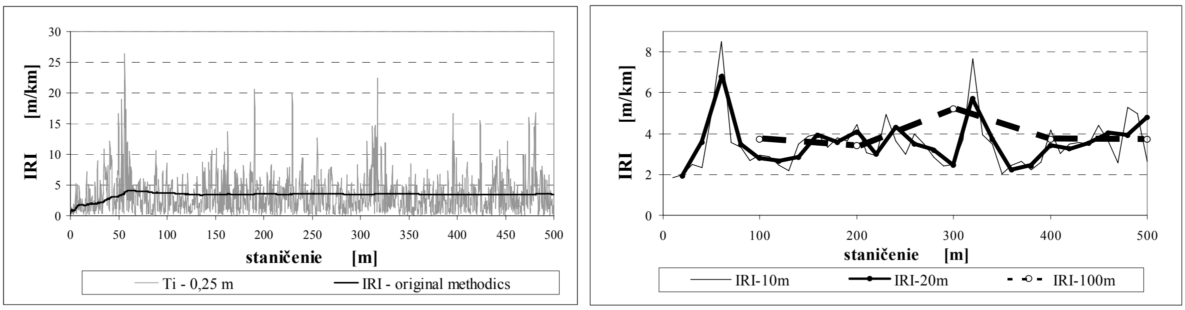


Figure2: Corrected profile slope per 0,25 m and original parameter IRI (left) and IRI appreciated for window 10, 20 and 100m (right)

Calculation of the parameter IRI - IRI represents arithmetic average of the corrected slope. Values of parameter IRI can be appreciated for a window of a discretionary length (conveniently 1, 10, 20, 100 m – Fig.2 right).

$$IRI = \frac{1}{N-1} \cdot \sum_{i=2}^{N} T_i \tag{18}$$

3 POWER SPECTRAL DENSITY OF LONGITUDINAL UNEVENNESS

The discretionary evaluated road sections, which are homogenous from the point of view of construction and degradation conditions, can be evaluated through the medium theory of a stationary random process. This type of random process can be best characterized by a correlation function or power spectral density (PSD). The correlation function $K_h(\lambda)$ for this type of process is expressed in the linear domain with the equation

$$K_h(\lambda) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} [h_1(l) - E_h] \cdot [h_2(l-\lambda) - E_h] \cdot f_2(h_1, h_2) dh_1 \cdot dh_2 \tag{19}$$

where:

λ	-	linear lag [m],
E_h	-	expected value of stochastic unevenness; $E_h = 0$,
$h(l)$	-	stochastic unevenness,
$f_2(h_1,h_2)$		- combination density of expectation.

Stochastic unevenness is computed as the difference between a real and theoretical profile. In our case we must identify elevations of longitudinal profile per 0.25 m and longitudinal unevenness are evaluated through the standardized correlation function $\rho_h(\lambda)$ (left hand side of Fig.3).

$$\rho_h(\lambda) = K_h(\lambda)/D_h$$

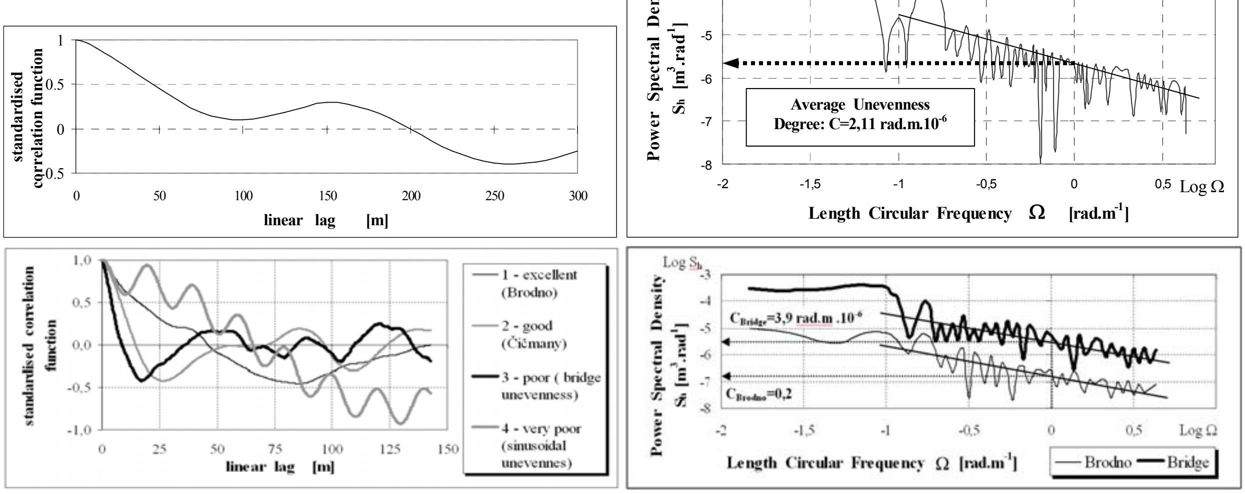


Figure3: Standardized correlation function and PSD of stochastic unevenness

For the purpose of unevenness assessment it is more appropriate to use power spectral density (PSD) $S_h(\Omega)$ (right hand side of Fig.3), which can be expressed from the correlation function by means of Wiener Chinchine equation:

$$S_h(\Omega) = 2/\pi \cdot \int_0^{\infty} K_h(\lambda) \cdot \cos(\Omega\lambda) \cdot d\lambda \qquad (20)$$

where:

D_h	-	dispersion of an stochastic unevenness	[m^2],
Ω	-	angular spatial frequency	[rad.m^{-1}],

$$\Omega = 2 \cdot \pi / L \qquad (21)$$

L	-	unevenness wavelength	[m].

The unevenness degree C [rad.m.10^{-6}] of an evaluated road section is expressed from the basic relation that was modified for our mode of unevenness identification by JP VŠDS.

$$C = \frac{D_y}{I \cdot \frac{1}{N} \sum_{i=1}^{n} v_i} \qquad (22)$$

where:

D_y	-dispersion of sprung mass acceleration - left hand side of Fig.4	[m^2.s^{-4}]
I	-parameter of dynamic transfer	[rad^{-1}.s^{-3}]
C	-unevenness degree – right hand side of Fig.4	[rad.m]
v_i	-digital values of a measured velocity – right hand side of Fig.4	[m.s^{-1}]

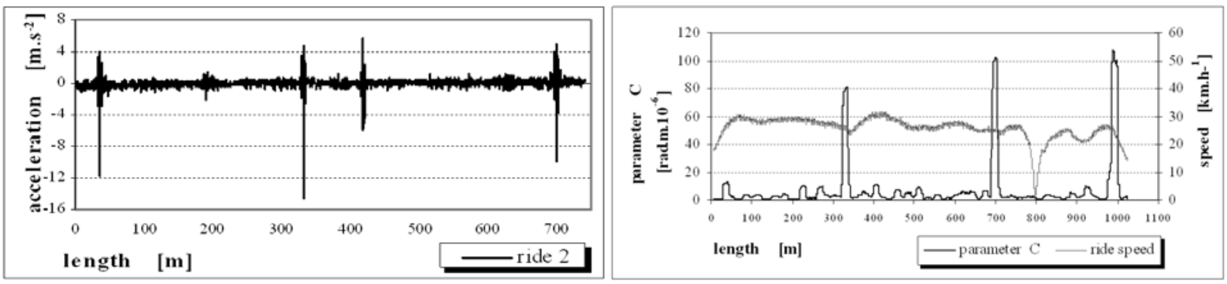


Figure4: Vertical acceleration indicated by speed control bump and ride speed (left hand side of Fig.4) and parameter C evaluated by JP VŠDS

4 THE CRITERIA OF UNEVENNESS EVALUATION BY IRI

The criteria are base on described theoretical principles, and on the request of traffic safety and ride comfort assurance. The ride comfort described by the vertical acceleration of sprung mass of vehicle a_z and the safety described by vertical dynamic strength F_z on the contact of the wheel with pavement surface are described next. The simulation of the crossing of a half car model on generated harmonized unevenness as a random unevenness on real roads, measured by Profilograph GE, were realized for the determination of the relation between longitudinal unevenness and ride comfort (safety, respectively). The values of maximal acceleration of the vehicle body characterizing ride discomfort occasioned by unevenness were compared according to the Slovak standard STN ISO 2631-1.

The calculations and simulations were executed by use of the special software developed in the University of Zilina (Celko et al 2000) and with the CarSim Education program developed in the University of Michigan. The vehicle parameters correspond to the Skoda Felicia car, which is widespread in Slovakia.

The response depended on the amplitude and wavelength of three ride speeds which were detected for harmonized unevenness generated by simulation and described by IRI. Three maximal speeds permitted on the Slovak roads were used. The results for speed 90 kph will be described. From Fig.5 it is definite which wavelength activated the maximal oscillation of the vehicle. These are the wavelengths that are the most unfavourable for passenger comfort. For the declared vehicle and a speed of 90 kph, it is 2.3 m and 18 m. For 60 kph speed, it is 2.1 m and 12 m and for 130 kph speed 3.3 m and 27 m. The model response on the harmonized unevenness is linearly dependant on the amplitude value. The relation between vehicle response and IRI was evaluated next. The relation between acceleration a_z and IRI, correspondingly presented with wavelengths with amplitude A=1 cm and speed 90 kph are shown in Fig.6.

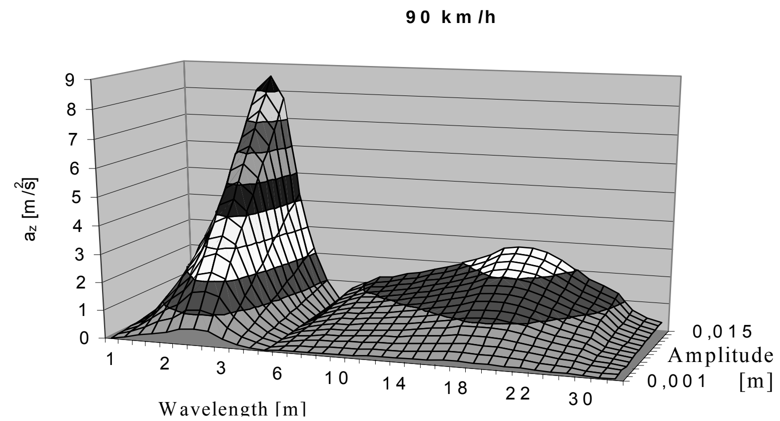


Figure5: The dependency between acceleration, wavelengths and amplitudes for 90 kph speed

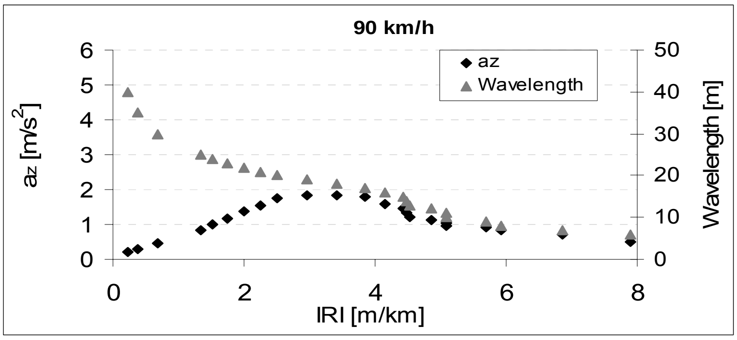


Figure6: The dependency between acceleration, wavelength, and IRI for 90 km/h speed

Following this analysis we can claim the values of the vehicle body acceleration increases with the growing of IRI only to specific point. This point corresponds to specific wavelengths dependant on the speed. A decreasing tendency despite the IRI increasing was observed after this point. On Fig.7 these relations are extensive about the next points, with responsive higher amplitudes.

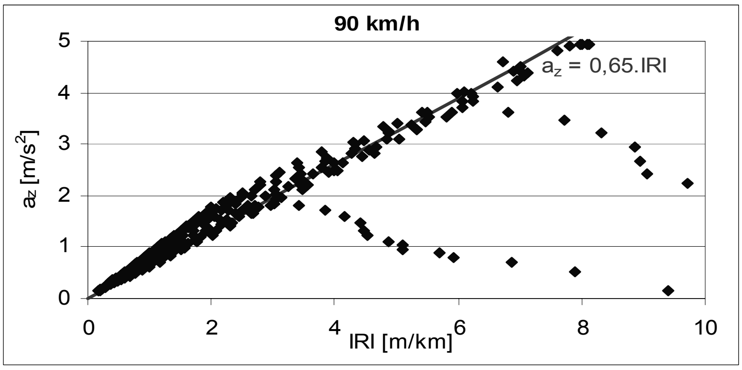
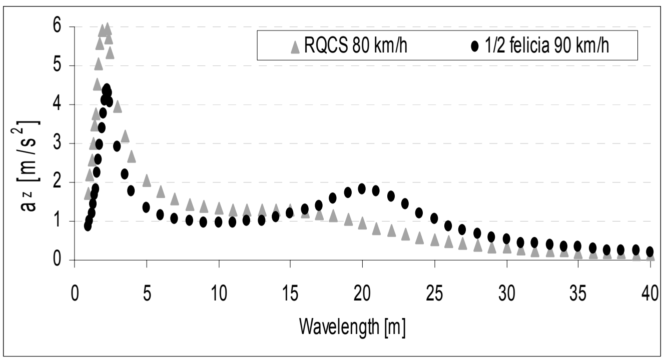


Figure7: The relation of acceleration on IRI for 90 kph

On Fig.7 these relations are extensive about the next points, with responsive higher amplitudes. The relation tendency shows a basic trend of points that delimited an area of maximal discomfort by minimal IRI values. The line by basic points group was interleaved for determination of the relation between IRI and a_Z. The other points lying below the tendency are irrelevant from a comfort evaluation point of view. The upper values of IRI respond to the lower values of the response. The points above this group (of a speed of 60 kph) respond to the great wavelengths (more than 30 m), which do not exist on the roads with a maximal speed of 60 kph. Therefore, we can ignore them. Fig.7 shows a determined relation between IRI and vehicle response characterized by vertical acceleration a_Z, found from a fitted line equation of a basic tendency of the points.

The points outside of the basic tendency confirm that an equal value of IRI can describe more unevenness evocated different response. These points have identical amplitude but different wavelength, which means a lower value of acceleration for a higher IRI. It is also visible that during high speeds a shining oscillation of the vehicle origins for a low IRI value. This fact is determined by an overvaluation of the short wavelengths and undervaluation of the longer wavelengths by reference model of a car quarter. In addition, IRI is calculated for the speed 80 kph, so for higher speeds the differences are greater (Fig.8). However, we must take into consideration that the simulation was realized for the harmonic unevenness that occurs in real conditions in a minimal range.



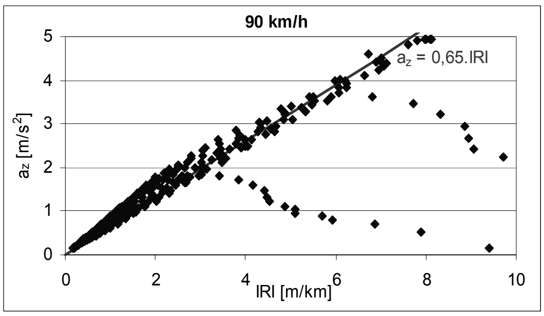


Figure 8: The comparison of response for different speeds of reference and real model

According to the obtained relations, the scale of IRI evaluation depends on the safety and comfort was analyzed. The results show that a critical rank of evaluation of real response to unevenness is wavelengths corresponding with resonant frequency of a car's unsprung mass. The reference model declares lower values of acceleration of the sprung mass as a real car model. The values are two times more for the speed 90 kph and four times more for the speed 130 kph. Depending on the analysis of the harmonic unevenness, the simulations realized on the real road sections were taken into account for design of the IRI classification scale.

The important characteristic of ride safety from the point of view of longitudinal unevenness is the vertical strength F_z on the contact between vehicle and surface. The moment of minimal value was observed. The determined relation is presented on Fig.9.

The strength F_z has a decreasing tendency with an increasing of IRI. The different values of F_z for identical IRI values are possible to achieve alike for acceleration. During simulation of harmonic unevenness and the speed of 60 kph loss of contact does not occur. On the other hand, during speeds of 90 kph and 130 kph F_z achieved the zero value yet for low IRI values. The danger is not only a loss of contact but a low intensity of F_z, too. An intensity of the vertical strength has an influence on the stability of a car in a horizontal curve and on the breaking distance, too. The differences are determined by the characteristics of the reference model. In this case, the generally valid relation is not possible to establish because each vehicle has different weight and so also a different press strength of axle to road surface.

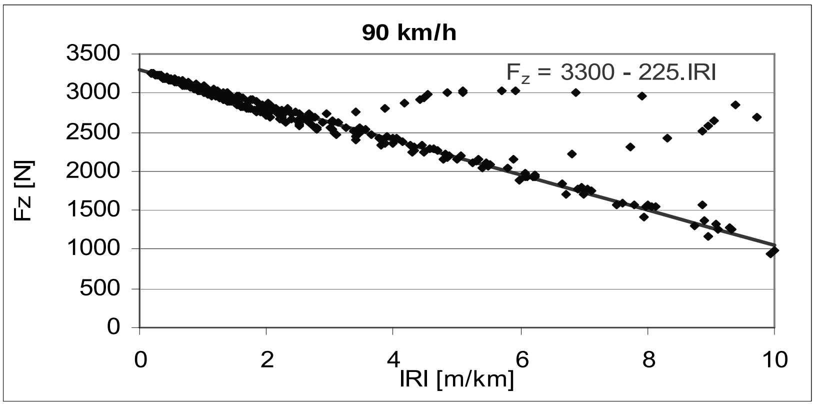


Figure9: The dependency of dynamic strength F_z on IRI for the speed 90 km/h

Dependant on the presented results the new classification scale for IRI evaluation in the frame of Slovak PMS was proposed (Table 1).

Table 1: The proposal of classification scale of IRI

Classification scale	IRI [m/km]		
	Urban roads	Roads	Highways and expressways
1	< 5	< 4	< 3
2	5 - 10	4 - 8	3 – 6
3	> 10	> 8	> 6

5 CONCLUSIONS

The presented results are based on data samples that contain real conditions. The research activity on problems of the interaction between vehicle and surface continues. The analyses of unevenness and skid resistance are in the process of improving results. The verification of the models is verified by next measurements and simulations. The aim of the research is the generalization of the relation between IRI and vehicle response.

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Assessment of Morphology of Wear Particles in Oils for Vehicles

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ABSTRACT: This paper presents the results of a complex analysis of particles isolated from various kinds of oils (automobile engine and transmission oils, hydraulic and compressor oils) and oil filters. Morphological analysis was performed using analytical ferrography in combination with scanning electron microscopy, local electron microanalysis and image analysis. The results are a contribution to the quantitative assessment of processes connected with the wear of parts of vehicles and industrial machinery.

KEY WORDS: wear particles, oils, ferrography, scanning electron microscopy, image analysis

1 INTRODUCTION

Lubricating oil has many functions: to reduce friction between wear surfaces, to prevent deposition of impurities on the lubricated surfaces and conserve them, to conduct friction heat away, to reduce the penetration of foreign particles from the outside, to prevent aggregation of impurities, to take away wear particles. Its properties have a considerable influence on the speed and intensity of the wear of functional surfaces of the parts − therefore also the lifetime of various machinery equipment. Eventually, the selection of the lubrication mode and optimization of the replacement periods influence the level of operation and investment costs; besides the economical context of lubrication conditions, the safety and environmental aspects are additional important factors. Many mechanisms contribute to the wear of surfaces. These unwanted changes, which occur on the surfaces of the parts by separation of particles as a result of a mechanical action and which are connected with the occurrence of abrasion, may also be accompanied by chemical or electrochemical effects. The evaluation of the number, size, shape, colour, character of the surface and other morphological properties of individual wear particles, especially in combination with the knowledge of their chemical composition, will suggest a lot about which part they are from and which mechanism has caused them. This information can contribute to the elimination of the risk of damage or breakdown of the machine, without the need to demount the equipment.

There are many techniques to enable the acquisition of information about the particles. The following basic methods belong to the most important of them:

- Ferrography utilizes the sedimentation of particles at the flow of an oil sample in a strong non-homogeneous magnetic field. The particles sediment in dependence on their size, composition and shape on a suitable pad (glass or plastic), on which it is then possible to evaluate them by means of a microscope ("small" particles of dimensions smaller than 5m correspond to normal adhesive wear, "big" particles larger than 15m is a warning of approaching damage of the parts which are washed by the analyzed oil).

This method is based on the following two basic presumptions:

1. Each friction pair produces wear particles of specific shapes and sizes, characteristic for the particular mode of wear and the materials of the pair.

2. With the increasing intensity of wear the size of the wear particles increases, their shape changes and so does the ratio between the number of "big" and "small" particles (the authors of most publications, e.g. Straka, 1996; Liu et al., 2000; Krethe, 2001, agree that in the normal mode of wear the ratio between the number of "small" and "big" particles is approximately 500:1, while at escalated wear the ratio increases to 50:1).

- Particle analysis utilising particle counters (LaserNet Fines etc.) enables specifying the sizes of particles contained in oil and to sort the sizes; advanced methods utilizing neural networks are applied during the evaluation. The classifier of particles sorts the particles larger than 20m according to their shape and classifies them into 6 groups. When counting the particles, the apparatus is able to distinguish and not to count air bubbles larger than 20m and determine the content of free water in the oil.

- Scanning electron microscopy (SEM) enables the observation of the surface of particles isolated from oil or from oil filters. The resulting images are created by means of secondary electrons. The interaction of accelerated electrons with the mass of the sample X-radiation also generates images, which bring a lot of additional information about the composition of the sample; the energy dispersive analysis enables the determination of the element composition of the particle and also the quantitative content of individual elements by comparison with a suitable standard (with the limitations given by the principle of the method).

- Image analysis is a suitable method for quantification and objectification of evaluation of the morphological characteristics of particles; generally, this method enables us to obtain quantitative information of various statistical and morphological characteristics of a digital image and the objects recognized in it. This method has a wide number of possibilities of application in the fields utilizing microscopic technology.

2 USED EXPERIMENTAL METHOD AND INSTRUMENTATION

The ferrographic workplace is equipped with ferrograph REO 1 (ReoTrade Ostrava) in a set with the bichromatic trinocular microscope H 6000 (Intraco Micro Tachlovice) and the digital camera Micrometrics 122-CU with a connection to a PC. The observation on the scanning electron microscope VEGA TS 5130 (TESCAN Brno) in the electron microscope laboratory

DFJP was, for selected samples, supplemented with the analysis on SEM VEGA TS 5130SB with an energy dispersive analyzer in FSI VUT Brno.

Image processing is done by means of the LUCIA G v. 4.82 system (Laboratory Imaging, Prague). The image analysis was used for the evaluation of particles separated on ferrograms and particles isolated from oil filters; for the latter group of particles EDX-analysis was also done. The selected typical particles were separated from oils and filtration cartridges of oil filters of vehicles and industrial equipment (see chapter 3.2).

3 EXPERIMENTAL WORKS AND THEIR RESULTS

3.1 Image Analysis

The quantitative description of wear particles morphology is an important part of the assessment of relations between the operating conditions and the way, intensity and/or regularity of the wear surfaces.

The basic step in the whole process is always getting a high-quality digitalized image of the microscopic section by means of a USB camera. The image is further modified and analysed by means of the LUCIA program. The key step of the image analysis is segmentation, during which the objects intended for the assessment are marked in the image; then it is possible to perform measuring and determine the required morphological properties of the objects.

Out of the wide range of information that can be obtained by means of image analysis, major attention was paid to the quantification of the shape of individual image objects. Simultaneously additional data were processed, characterizing individual objects, as well as the image as a whole, which can be assessed from the digital images − e.g., the information about the number, area or other size parameters of individual particles, about their global areal content in the analyzed area or in its selected part, etc. The aim of this stage of the works was to algorithmize the quantitative assessment of the selected characteristic parameters of the objects − wear particles, to create and debug the program module of the LUCIA system. The output of the assessment in this stage was the classification of particles according to the type of wear which they can be assigned to. The next prepared stage will focus on defining a practical recommendation to the user of the vehicle/machine.

The processing of the image information on the computer usually starts with elimination of noises and distortion of the image. The basic functions for the image processing used in this stage include the suppression of noise by means of suitable filtration, sharpening of the image, segmentation and recognition of objects (thresholding).

These operations result is a binary image as a data array, containing only the zero (white) or the one (black). Objects are formed by the connection of pixels of one type; the background consists of a set of complements. The connection of pixels is usually defined by means of the nearest neighbours method, i.e., a connection over the edges and over the apexes is acceptable. The smallest structural element contains nine pixels (3 rows and 3 columns around the central pixel).

Typical linear morphological operations are: filtration, erosion (removal of selected pixels from the surface of an object), dilatation (adding of selected pixels to the surface of an object), opening (combination of erosion and dilatation) leading to separation of objects, closing (combination of dilatation and erosion) leading to connection of objects, filling of holes in objects and skeletonization, i.e., replacement of an object with its outline.

The next step of the image analysis is the measuring of characteristic attributes of objects. Both individual characteristics (describing individual objects) and textural characteristics (describing the structure of the entire image) are used.

The information about the shape of the object is, together with the information about the particle size, useful when determining the type and current rate of wear. Professional literature mentions many various shape factors. In this publication we used *circularity* (Kowandy et al. 2006; Xu et al. 2003; Li at al. 2005) defined as

$$circularity = \frac{4\pi \cdot area}{circumference^2}$$

and *elongation*, defined as the ratio between the maximum and minimum Feret diameter

$$elongation = MaxFeret/MinFeret$$

(the maximum/minimum Feret diameter is the largest/smallest distance between two parallel tangents of the object).

In the created program module, after the initial delimiting of objects by means of thresholding, the image can be further processed in the binary view. It is then possible to analyze the entire area or individual particles separately. The results of measuring arrays form a table of values.For individual particles it is possible to measure individual parameters by means of commands, the names of which correspond to their functions: Numbers, Length, Radius, Halfaxes, Area, Angle and many others.

The cycle of separation of objects by means of mathematical morphological methods then follows. After the sorting of particles the measuring frame will be specified, which limits the area of further analysis (this is especially advantageous in the case of imperfect segmentation or in the case of a requirement for selection of analyzed particles from a partial segment of the image). Another possibility is manual modification by means of selection from the menus of commands for binary image processing. All options of the binary image modification lead to the paintbrush tool, which removes or completes (models) particles, which could not be captured precisely by means of the modifications. Displaying is accompanied by the information about the total number of objects selected.

This command starts the calculation part of the program macro. If the image is already calibrated (i.e., the scale was assigned to the image), it is possible to work with it. Otherwise the option for continuing with a non-calibrated image is available.

Then the particles are identified by numbers. If the evaluated area contains more than 100 objects, the function includes the query whether or not to perform numbering in the image (for time or capacity reasons, as well as for the clearness of the image).

The output selection menu includes the text output both in the form of tables and in the form of creation of a report in Word, where important data about the analyzed particles are automatically exported to. This also includes the option of graphical output in the form of histograms of the area, circularity and elongation attributes. Each graph also contains selections of various variants of the numbers of classes and their widths.

The output information includes the draft assessment of the type of wear on the basis of the calculated attributes. This draft has a mainly auxiliary (informative) purpose and cannot be taken unconditionally, without a subjective check based on a deep knowledge of the wear issues. However, for the tribotechnics practice, both the calculated data characterizing individual objects or complete images and the proposed final assessment resulting from the data obtained by means of objective procedures, are an important support.

The above stated functions of the program module were tested on model particles (Figure 1).

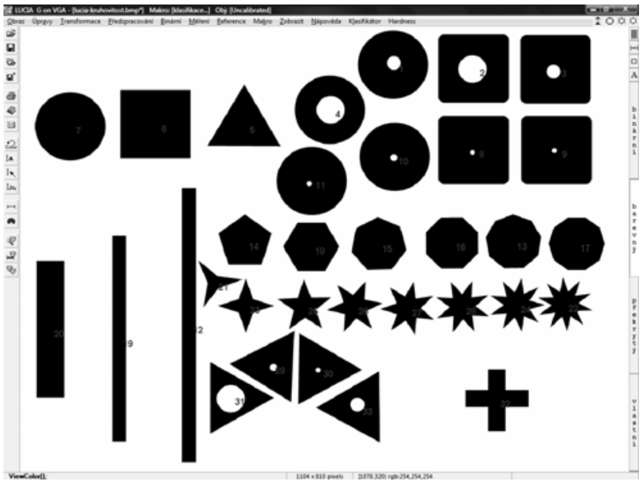
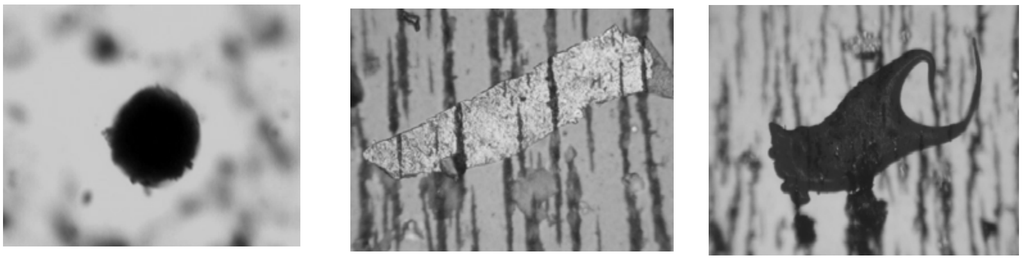


Figure 1: Overview of model shapes of particles

Results of measuring of real particles

The program module was tested on particles typical for individual types of wear − see Figure 2−5 for examples.



a **b** **c**

Figure 2: Typical particles separated ferrographically from oils

a − Fatigue particle of typical spherical shape (diameter approx. 20 µm)

b − Laminar particle with visible signs of abrasive wear (length approx. 150 µm)

c − Indented particle of cutting wear (max. size approx. 100 µm)

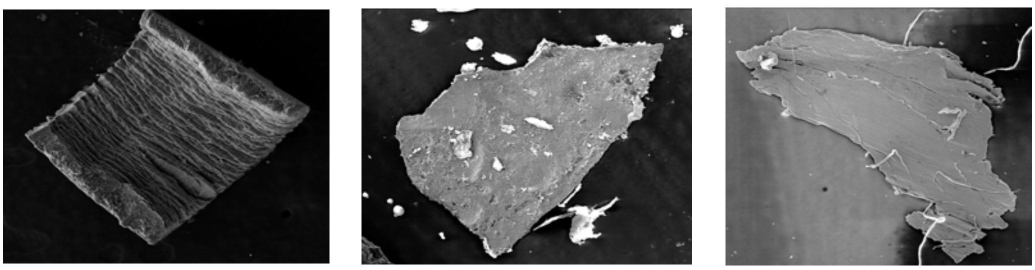


Figure 3: Laminar particle with signs of abrasive wear (max. sizes 200−500 µm)

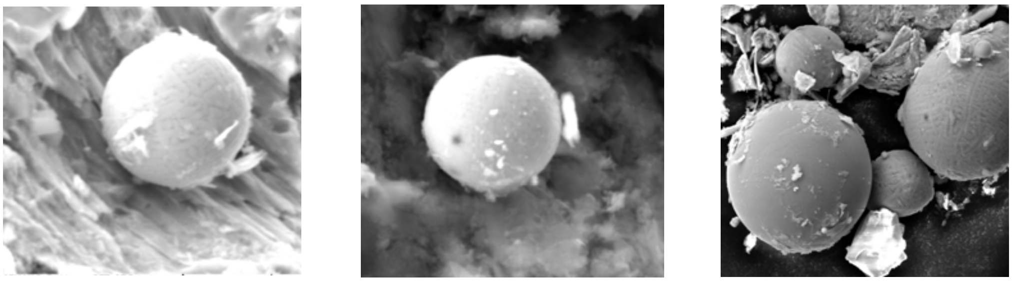


Figure 4: Fatigue particle of typical spherical shape (diameters 10−50 µm)

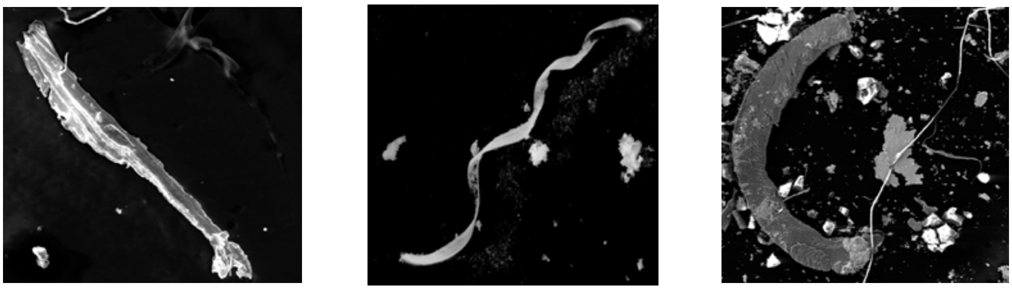


Figure 5: Particles of cutting wear (length 200−600 µm)

Circularity and elongation are the most important attributes, used (together with additional parameters) also for the characterization of the prevailing wearing process

3.2 Local electron microanalysis

The selected typical particles isolated from the filtration cartridges of oil filters from the engines of various vehicles (cars and lorries, trucks, the oil filter of a railway motor car 854222 with an internal combustion engine CAT C15) were analyzed on SEM with an energy-dispersive analyzer. The process of isolation of particles is described in detail in (Machalíková & Schmidová, 2007).

The examined particles can be divided into five groups according to their chemical composition (see Table 1):

Table 1: Composition of typical, most frequent particles

Type	Dominant elements	Elements contained in lower concentrations
1	C (55−85 $\%_{at}$), O (30−40 $\%_{at}$)	Fe (traces) Na, Mg, Al, Si, S, K, Ca,
2	Sn (~80 $\%_{at}$)	Pb, Cu, O, P, Fe (traces)
3	Zn (30−45 $\%_{at}$), O (40−47 $_{at}$), Al (~15 $\%_{at}$)	Fe, Si, S, Cl, Ca, Cr
4	Fe (60−70 $\%_{at}$), O (30−40 $\%_{at}$)	traces of Si, Ca, Cr, Mn, P
5	Si (20−30 $\%_{at}$), O (60−70$\%_{at}$), Al (6.46 $\%_{at}$)	Fe, Na, Mg, K, Ca,

Description of typical particles

Type 1: porous crumbly particles of usually rounded shapes, badly conducting; non-dominant elements may be remnants of additives, impurities from the outside, etc. − *carbon*

Type 2: shiny particles, often with deep grooves, with plastically deformed edges; the main component is stannum − particles from the bearing lining

Type 3: flat thin sharp-edged particles, whose main components are zinc and aluminium; alloys on this basis are used for the increasing of resistance against corrosion and abrasion; particles are released probably from superficial layers of engine parts

Type 4: particles consisting mostly of iron, oxidizing layer on the surface (only Fe and O are present in more significant amounts, Cr and Mn as microelements) − material of the basic structural element

a − spherical particles mostly of a diameter of 10−50 µm; spheroids result from fatigue processes
b − narrow flat, even acicular particles, or spirally twisted, plastically deformed particles of cutting wear
c − large flat particles having cracks and pitting corrosion on the surface − originate by peeling of the Beilby layer

Type 5: non-conductive particle of silicon dioxide or silicate (these could get into the lubricating system from the outside together with the suction of air).

Note: Cl, S and P may be contained in the remnants of EP-additives, stuck to the particles. Finding of sodium may be connected with intrusion of antifreeze into the oil.

3.3 Conclusion

A key part of the work was algorithmization of the process of classification of objects − wear particles. A macro for the LUCIA system was designed and programmed in the C/C++ language, which enables the analysis and statistical processing of the parameters of individual particles and image arrays. The program macro accelerates, objectifies and simplifies the classification process.

A quantitative description of wear particles is an important part of the assessment of relations between the operating conditions and the way, intensity and/or regularity of the wear surfaces. When assessing microscopic images, the use of the image analysis enables one to perform the quantitative determination of parameters of the examined particles quickly and precisely, without any subjective influencing by the person assessing. At the same time this method enables information to be obtained not only about the basic parameters of the particles, but also data which would be very difficult or even impossible to get in the case of the classical way of assessment – especially the information enabling the quantitative assessment of the particles' shapes.

Obviously, the possibility of burdening the results of the image analysis with errors must always be taken into account, e.g., the limitations caused by the digitalization of the image and problem imaging and separation of very small particles in the digital image, elimination of surface defects (scratches, stains, etc.) of the underlying foil, overlapping of the particles on the ferrogram, etc.

This paper verified the possibilities of the use of image analysis as a method suitable for the quantification of data, obtained by means of selected advanced instrumental methods for the classification of the wear of the engine plant. The results of the paper prove that the used combination of methods, i.e., image analysis, analytical ferrography and electron microscopy, may contribute to the extension of possibilities of tribotechnical diagnostics.

In addition, five basic types of particles contained in lubricating oils and oil filters of vehicles and industrial engine plants were defined according to their chemical composition and characteristic morphology.

The examination of wear particles, based on the combination of several methods, creates conditions for obtaining comprehensive information about the process of operating wear of oils, as well as of the mechanisms lubricated by them.

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Information Power in Intelligent Transport Systems

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ABSTRACT: The decision making process in the environment of an Intelligent transport system (ITS) with a high level of uncertainty is strongly dependent on the level of conceptual and contextual knowledge. The effectiveness of the decision making process of ITS relates to the available information power (P) which is considered as a vector in the plane given by the orthogonal system of information flow (Φ) and information content (I). The paper introduces the information power as data, information and knowledge alliance. This approach enables us to measure the ITS effectiveness through information power and yields directly to optimal prognoses given by information power maximization, or, in other words, information resonance.

KEY WORDS: Information power, data, information, alliance, intelligent transport systems

1 DATA, INFORMATION, AND KNOWLEDGE ALLIANCE

Let us suppose that O_i is a set of rated quantities on an object. P_i is a set of states (observers), Φ_i is a set of syntactic strings (data flow), and I_i is a set of information images of state quantities. The Fregge functional concept of information image origin (Vlček, 2003) can be stated in the following graphic form:

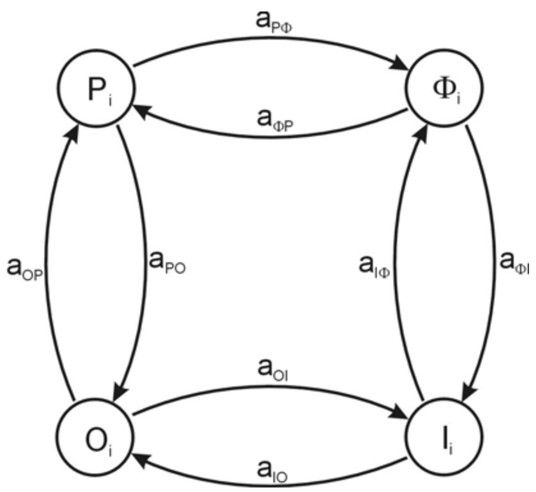

Figure 1: Fregge functional concept of information image origin and action

a_{OP} – identification

a_{PO} – invasivity

$a_{P\Phi}$ – projection in a set of symbols and syntactical strings

$a_{\Phi P}$ – uncertainty correction and identification

$a_{\Phi I}$ – interpretation, information origin

$a_{I\Phi}$ – language constructs reflection

a_{Io} – relation of functions and structural regularity

a_{oI} – integrity verification

If $P\{O_i\ (t_x)\}=O_i$ is a sequence of the object's states O_i, , then the image of the sequence $\{O_i\ (t_1),\ O_i\ (t_2)\ \dots\ O_i\ (t_x)\}$ can be symbolically written as $\{I_i\,(t_1), I_i\,(t_2)\ \dots\ I_i\,(t_x)\}$.

We can also write $P\ \{I_i\ (t_x)\} = I_i$. The difference of state representations $dO_{ix} = O_i\ (t_x) - O_i\ (t_{x-1})$ shall be called an event. The sequence of events $U\{dO_{ix}\} = \{dO_{i1},\ dO_{i2}\ \dots\ dO_{ik}\}$ represents a process recognized on the object. The sequence of events information images $U_I\{dI_{ix}\} = \{dI_{i1},\ dI_{i2}\ \dots\ dI_{ik}\}$ characterizes the process information image.

Let us permit that, for the object framework $O\{O_1,\ O_2\ \dots\ O_k\}$, there is an image assignment $I\{I_1,\ I_2,\ \dots\ I_k\}$ and this assignment system shall be further called the syntactical information system. The sequence of events information images $U_I\{dI_{ix}\}$ creates process information systems. In more complex systems, there are always more objects and more processes in a mutual relation where the mutual share in the arrangement of the system and the share of process parts create an alliance among objects, an alliance among processes.

Syntactical frameworks are characterized by the following relationship:

$$\underbrace{\begin{pmatrix} O_1(t_i) \\ O_2(t_i) \\ \\ O_k(t_i) \end{pmatrix} \rightarrow (A_s) \rightarrow \begin{pmatrix} I_1(t_i) \\ I_2(t_i) \\ \\ I_k(t_i) \end{pmatrix}} \qquad (1)$$

Syntactical systems relation

While the relationship:

$$\{O_k(t_1, t_2 \dots t_x)\ O_e(t_1, t_2 \dots t_x) \dots O_z(t_1, t_2 \dots t_x)\} \xrightarrow{A_p} \\ \longrightarrow \{I_k(t_1, t_2 \dots t_x)\ I_e(t_1, t_2 \dots t_x) \dots I_z(t_1, t_2 \dots t_x)\} \qquad (2)$$

represents a set of processes – a process information system.

The state-of-the-art in information and communication technologies is based upon the convergence of telecommunication and medial data formats. Hence, the terms like the data systems "alliance" in different multiplex standards and sharing transmission, communication, and memory systems are used. It results from the initial model representation that even databases represent sets of non-interpreted data on an object's state. It means that a possibility of different interpretation sources origination can be awaited only within a single shared data set.

The term information is usually pertinent to the process of uncertainty elimination or, optionally, to an increase in a system's ordering. Therefore, information can be expressed by the ordering change rate and the definition can be formulated as follows: Information is "interpreted data, entries, or signals leading to ordering changes in systems of the real world or consciousness".

Quantitative evaluation of information, information flows is impossible without the definition of an information measure and the definition expressing an information flow in a transmission channel. Nevertheless, we will consider a signal as a code carrier enabling expressing data in such a form to be able to transfer and preserve them. In transmission systems and data processing frameworks, we cannot do without the expression of a transmission capacity and without a data storage capacity. To be able to express this capacity we need to find relations by means of which we could express the information amount in a quantitative manner. The properties of a real object or an object in the real world can be described with the help of *n* possible partial reports. Each of those reports consists of the alphabet A (A_1, A_2…A_s) where S is the number of characters in the selected alphabet. If *n* represents the number of elements in a character set then the number of possible reports expressed by the alphabet A is given by the formula:

$$N = S^n \tag{3}$$

where N is the number of possible messages; S is the number of characters in the alphabet A (A_1, A_2…A_s);and *n* is the number of elements in the character set.

It is evident that one message can be expressed by different alphabets consisting of a various number of characters. Therefore, the same number of messages may be transferred by different numbers of elements in a character set using different alphabets. So, in terms of transfer, a message of the same contents may be transferred by a greater or smaller number of characters and may require a larger or lesser channel transfer capacity.

The Hartley tolerance measure of information (Moos *at al.*2008) is defined:

$$I = K \ln N = K\, n \ln S \tag{4}$$

With the help of entropy, information contents in messages are characterized in which symbols are not distributed in a uniform pattern but occur with a *p* probability; the entropy mean value per one symbol may be stated as follows (this formula was derived by C. E. Shanon in 1948):

$$H = -\sum_{i=1}^{S} K\, p_i \ln p_i \tag{5}$$

In the case of a binary symbol system (0;1), the K constant, which is also used in equations (4) and (5), can be expressed under assumption of the same probabilities of the symbols 0, 1 occurrence:

$$K = \frac{1}{\ln 2} \tag{6}$$

Knowledge represents an ability of assignment, classification, and filtration of data, entries, and information images of objects´ probable states and their state transitions and interpretation of causal strings and sensibilities on sets of uncertainties, information images of states and transitions in system links of the real world´s objects.

Inside an application or representative concept, three types of knowledge units may be recognized:

- declarative (standards, classification, etc.);
- procedural (solution, formulas, logical strings, causal strings, relations, etc.);
- inspirative (creative products, new approaches, new phenomenon invention, etc.).
- within the knowledge unit life cycle, the following items are classified:
- creation, finding, synthesis recognition;
- interception, representation, encoding;
- storage, system labels;
- accessing, decoding, protection, distribution;
- system relations identification, application, implementation into decision process, new design;
- implementation, new syntheses, revision, diffusion, knowledge unit consolidation synthesis, life cycle continuance.

The process executed on the system with O_i objects is symbolically characterized in the state space of intensive $P_i(t)$ and extensive $V_e(t)$ quantities:

$$O_i \sim F[P(t),V(t)] \quad (7)$$

Information process images – process information systems may be characterized by graphs assigned to relationships:

$$I_i \sim F[P(t),\Phi(t)] \quad (8)$$

This assignment enables structural interpretations of complex information systems, evaluation of feedback, and the quality of transmission and information processing in partial information systems where an information segment issues from a graphical description displayed in Fig. 2.

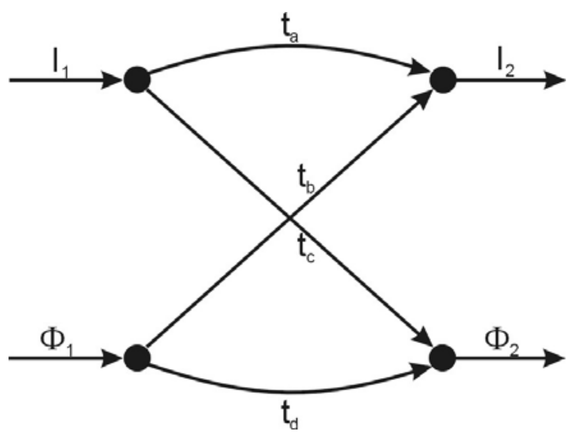

Figure 2: Information segment

The graph issues from matrix representation in the following form:

$$\begin{pmatrix} I_2 \\ \phi_2 \end{pmatrix} \approx \underbrace{\begin{pmatrix} t_a & t_b \\ t_c & t_d \end{pmatrix}}_{[T_i]} \cdot \begin{pmatrix} I_1 \\ \phi_1 \end{pmatrix} \tag{9}$$

The matrix T_i is called the transmission matrix of the i-th information segment, Φi means information flow and I_i information content.

2 INFORMATION POWER

Information performance represents a completely new quantity introduced as a tool for the evaluation of information systems effectiveness related to a probability of proper alternative selection and a probability of a proper decision in a systems control operation, see Fig. 3.,

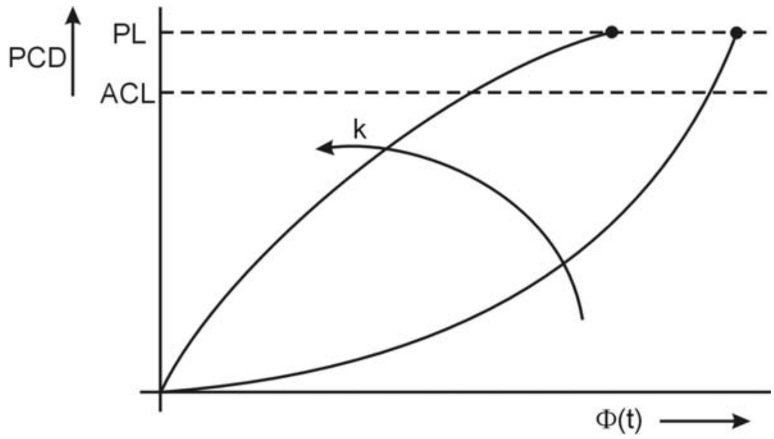

Figure 3: Probability of a proper decision in a systems control operation

where is PCD is the probability of a proper decision; PL is the possible (maximum) PCD probability level; ACL is the acceptable PCD level and *k* is the level of knowledge in the following function:

$$PCD = F[\Phi(t),k] \tag{10}$$

where F is the function representing the ability of interpretation that means the control system with a higher knowledge level makes faster decisions under lesser stress.

The quantity $P_i(t)$ called information power is stated as the product of information content $I_i[t]$ and information flow $\Phi_i(t)$, and it is understood as the value of eliminated uncertainty quantity *E* per time unit. This relationship can be stated as translated-decoded message contents *I* in information flow *Φ* :

$$P = \frac{E}{t} = I.\Phi \tag{11}$$

The definition of information power may also issue from generally known formulas: power is equal to the amount of work per time unit. While applying this definition into the information power field, a crucial problem is encountered. The problem is what methodology to choose for the specification of the amount of (information) work. In simpler information systems, we can do with generally known possibilities. If we consider work as some amount of transferred information through a data network there are no problems with such process of measuring. On an active element, the amount of transferred data is measured, and we are able to simply calculate the power of this data transmission.

3 RESONANCE EFFECT IN THE PROCESS OF CORRECT DECISION

If we consider the magnitude and phase of the vector in the coordination of I and Φ, then the knowledge parameter *k* is acceptable as the ability of prognosis, prepared solution for the certain level of Φ, which can improve the information content, probability of correct decision. The expert knowledge of the prepared solution can compensate the delay between the information content I and information flow *Φ*.

This situation can be described with the help of (10) as:

$$\mathrm{PCD} = \mathrm{F}[\Phi(\mathrm{t} - \varphi_{\mathrm{N1}}) \cdot \hat{\mathrm{k}}(\mathrm{t} - \varphi_{\mathrm{N2}})] \tag{12}$$

where phase φ_{N1} represents the delay in information flow and the phase φ_{N2} the delay in level of knowledge (both in time interval *t*). The synchronization condition means to find the sum of phase parameters ($\varphi_{N1}+\varphi_{N2}$):

$$\mathrm{PCD} = \mathrm{F}[\Phi(\mathrm{t}) \cdot \hat{\mathrm{k}}(\mathrm{t} - \varphi_{\mathrm{N1}} - \varphi_{\mathrm{N2}})] \tag{13}$$

and compensate this phase delay by knowledge prediction. It is evident that the knowledge vector and vector of information flow must have a corresponding angle. For opposite angles we can find and express the decision-making resonance effect. In this case, the information flow is interpreted and used in the opposite way. The detailed theory of complex wave probabilistic functions is presented in (Svítek 2008 a,b).

4 SETTING OF FORMATS FOR KNOWLEDGE MANAGEMENT

Data arrangement in a network is very complex as such and, therefore, it is necessary to avoid the use of incorrect data and uncertified premises. For this reason, it is necessary to build a knowledge management system. This system must be designed as a model over objects and object fields. A common knowledge management system can be described with the help of the following formula:

$$S = F[E(f), C(r), P(e), \gamma(P_s)] \tag{14}$$

where E(f) is set of knowledge elements of a certain function (significance); C(r) is the relation among elements initialized by communication; P(e) is the set of processes running in a knowledge system (each process consists of certain running events considered as changes in knowledge state space); and $\gamma(P_s)$ is the knowledge system's genetic code based on the history, culture, and procedural sequence inside a system.

To find some complex solution for a certain problem set, we must carry out systematic procedures in systematically arranged knowledge units inside relevant knowledge segments relating to a certain knowledge field. For this purpose, a so-called knowledge map represents an appropriate tool. This knowledge map represents a knowledge relations graph in knowledge units volumes arranged in the knowledge segments. The graphical representation of the knowledge map is indicated in Fig. 4.

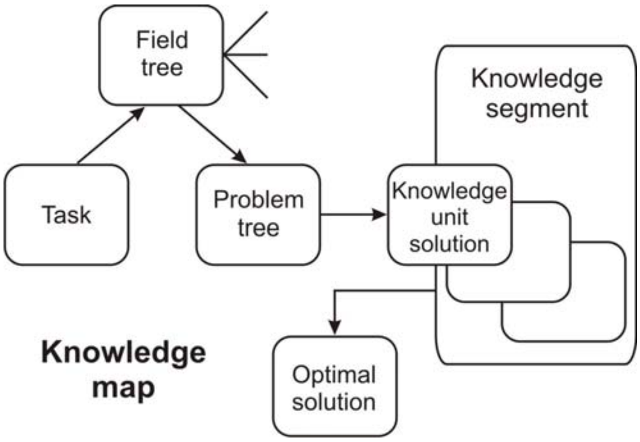

Figure 4: Knowledge map arrangement

Retrieval of the optimum solution from the solution set applying relevant data for input information represents the task. The effectiveness of knowledge management systems particularly depends on the ontology built. In this context, ontology represents a definite accordance in the sense of a shared concept and system in the knowledge set.

There are five ontology types:

- domain oriented;
- task oriented;
- generically oriented;
- application oriented;
- representation oriented.

For a more detailed solute on of certain problems, application oriented ontology may be recommended while, for archiving knowledge units needed for complex teams and project representation, representation oriented ontology is the right choice. It means that it is necessary to achieve accordance within the scope of partial teams and define mandatory document formats, primarily title descriptions as, for example, an object, problem solution, author, etc.

An ideal situation occurs as soon as the respective goals consist of:

- **header + knowledge segment (knowledge units set) + context conclusions**
  (for application oriented ontology)

- **header + authors and teams + knowledge unit**

(for representatively oriented ontology)

In object oriented knowledge management, keywords describing objects are generally used as headers. Documents as, for example, goals descriptions, systematically use HTML labels for reference to sources and quotations.

5 OBJECT ORIENTED “KNOWLEDGE CUBE“

Complex representation of a knowledge unit is based on the three-dimensional interpretation:

$$K_{ij} \rightarrow (L_{ij}, N_{ij}, C_{ij}) \qquad (15)$$

for the application oriented knowledge element, where:

Lij = (Oi, Pj) is the identification of i-th object and j-th process

$N_{ij} = (A_{ij}, D_{ij})$ is knowledge element core part (analytical/projection);

$C_{ij} = (SI_{ij}, SE_{ij})$ is core relation – sensitivity (internal/external).

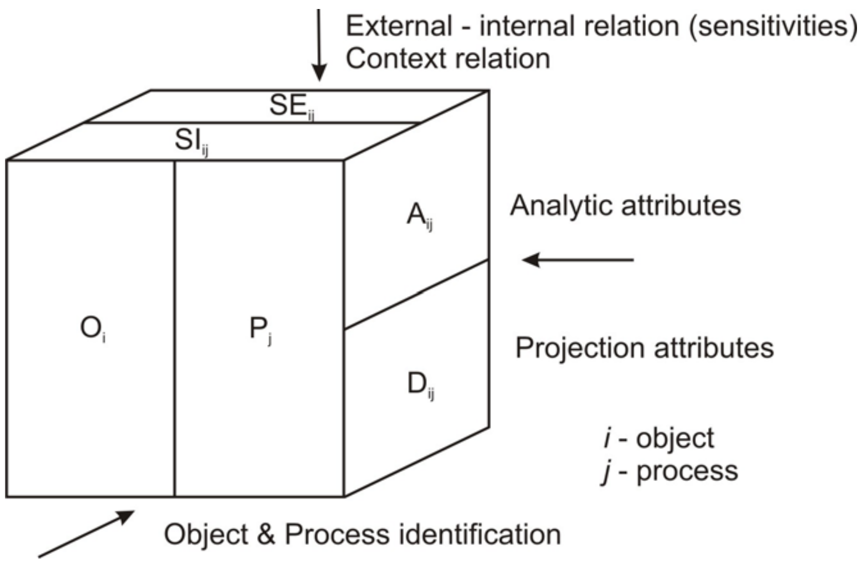

Figure 5: Object oriented “knowledge cube“

In this context, it is very important to point out the fact that a significant knowledge growth can be achieved by means of knowledge synergy among different filed trees and knowledge segments integrated into a meta-knowledge system based on the contextual principle (see Fig. 6).

6 CONCLUSION

This paper could be seen as the basic methodological approach to ITS systems terminology and effectiveness evaluation because every ITS designer tries to build a system that uses the maximum available information. We have shown that information power is the basic measure of used information in decision-making process and we have defined the conditions that must be fulfilled - information flow and information content must have the same phase in the complex domain. Every phase difference yields a worse application of available information. A critical situation can arise if phases are in the opposite direction - this situation can yield into resonance and all energy is spent on idle power.

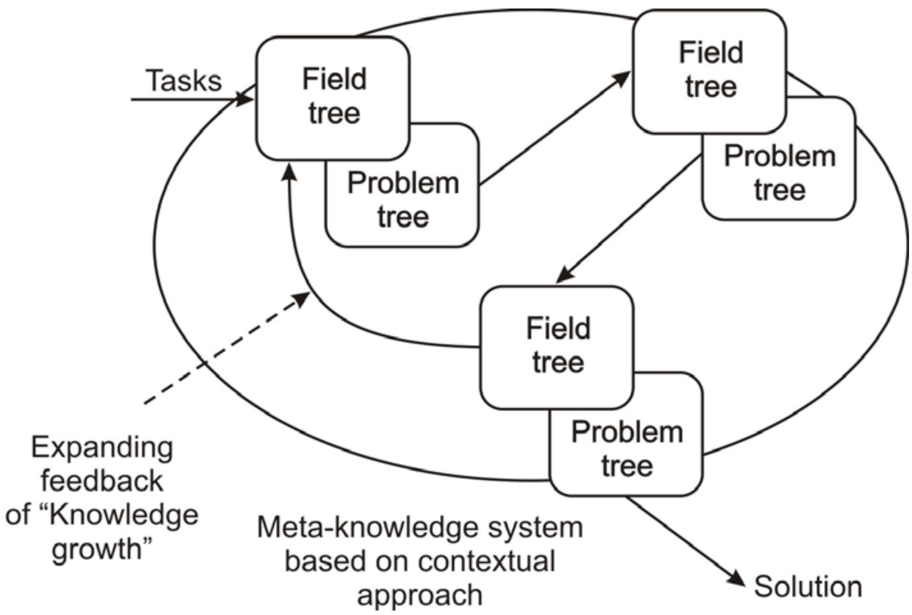

Figure 6: Exchange of corporative knowledge – sharing of best experience

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NDT of Reinforcement Corrosion Using Ultrasonic Spectroscopy

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ABSTRACT: Corrosion of built-in steel reinforcement ranks among the most serious mechanisms of bridge structure degradation. There are many reasons for the corrosion to occur: failures occurring during the bridge construction, consequences of traffic load, or, simple, ageing of the structures. Visual inspection of a bridge provides general information on the bridge condition. However, it cannot provide any information on the internal structure and integrity of the reinforced concrete or pre-loaded elements of the bridge in question.

This is why non-destructive diagnostic methods are acquiring growing importance, helping researchers to properly evaluate the condition of a bridge and decide upon the most convenient methods for maintenance, repair or refurbishment of the bridge in question or its parts and schedule them accordingly.

In this domain, methods employing the non-linear acoustic spectroscopy (NEWS – Nonlinear Elastic Wave Spectroscopy) achieved rush advancement recently. They are based on the fact that a non-linearity, which is due to the presence of a defect, makes an extraordinary indicator of the structure damage. These new, non-destructive methods appear to be promising for application to a wide range of materials featuring relatively heavy non-homogeneities, and for a large span of sites, from micro-chip to bridge structures.

The present paper deals with an experimental study of the application of non-linear ultrasonic spectroscopy methods to the detection of steel reinforcement corrosion and its consequences for reinforced concrete specimens subjected to corrosion induced degradation cycles.

KEY WORDS: Reinforced concrete, reinforcement corrosion, nonlinear ultrasonic spectroscopy, nonlinear effects

1 INTRODUCTION

Bridge structures make up an important element of traffic infrastructure. In most cases they consist of reinforced or preloaded concrete structures originating from the second half of last century. Concrete proved to be a durable construction material in the past. However, concrete structures often experience degradation after years of service. One of the frequent breakdown causes consists in the steel reinforcement corrosion. There are cases where a bridge structure collapsed in consequence of the reinforcement corrosion. Redevelopment technologies have been experiencing a marked growth in foreign countries during last decades. In this country, thanks to the efforts of a number of renowned experts and professional societies a rapid development has come to fruition in this field, too. In this way, our building industry has almost reached the foreign standard. However, the absence of an acceptable, relatively fast and cheap monitoring method, which would be capable of detecting bridge faults at an early stage, thus making a simple and cost-effective maintenance possible, is still persisting. This is why great attention is paid to the design and testing of new non-destructive methods meeting the above mentioned requirements.

2 NONLINEAR ULTRASONIC SPECTROSCOPY

New, promising, non-destructive testing methods are based on the non-linear behaviour of current defects and inhomogeneities regarding the elastic wave propagation processes. There are two groups of methods available for application: resonance and non-resonance. Bodies exhibiting strong resonance effects make it possible to study, above all, the non-linear effect of the resonance frequency shift versus exciting signal intensity. These methods are usually referred to as SIMONRAS (Single Mode Nonlinear Resonance Ultrasound or Acoustic Spectroscopy) (K. Van Den Abeele et. al., 2000, R. G. Litwiller, 2002). The resonance methods are rather labour-intensive and require many readings to be taken (frequency response curves for various signal magnitude levels). Therefore, they are not suited for fast in-process measurements.

Non-resonance methods are used to study suppressed resonance specimens. These methods analyse the effect of non-linearities on acoustic signals propagating through them. These methods can be split into two groups. In the first group, a single ultrasound harmonic signal is employed. The non-linearity gives rise to additional signals featuring different frequencies according to a Fourier expansion. In general, the amplitudes of these additional components decrease with the natural number *n*:

$$f_n = n\, f_1 \qquad \Big|\, n = 0, 1, 2..\infty\ , \tag{1}$$

Nevertheless, among the emerged signals, the third harmonic appears to be most pronounced, see Fig. 1. This is why the third harmonic amplitude is pursued by most researchers, especially in electronics (Hajek et. al., 2003).

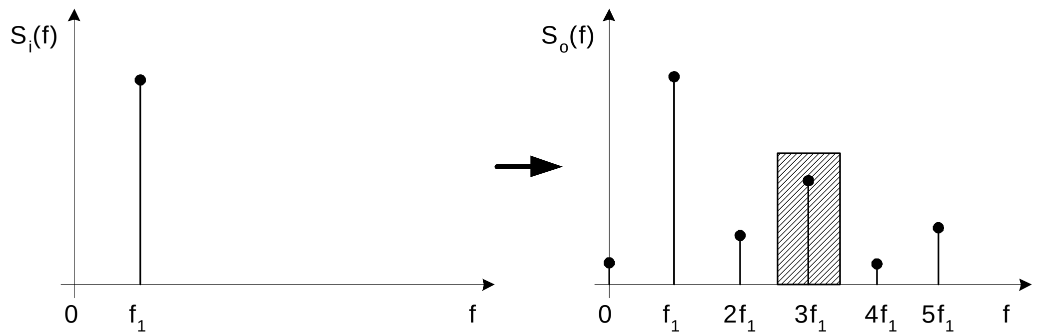


Figure 1: Growth higher harmonic components in frequency spectra at transit pure harmonic signal through nonlinear environment with illustration of selection dominant third harmonic component by the frequency band-pass filter.

In the second case, several (usually two) ultrasound signals are applied to the specimen. The number of additional harmonic components generated is substantially higher.

In addition to both exciting signals' harmonics, one also gets sum and difference frequency components.

$$f_v = \left| \pm m\, f_1 \pm n\, f_2 \right| \qquad \left| m, n = 0, 1, 2..\infty. \right. \qquad (2)$$

Owing to the general harmonic amplitude versus frequency curve downward slope, the first sum and difference components are most pronounced. The application domain of the ultrasound modulation spectroscopy (usually referred to as NWMS – Nonlinear Wave Modulation Spectroscopy) splits into two subgroups, which differ from each other by the exciting frequency ratio. Attention is paid to the second subgroup applied in experimental part. In this case, the frequency mixing principle is used. The signal frequencies are close to each other. The first difference component therefore falls into the low-frequency range, as is shown in Fig. 2.

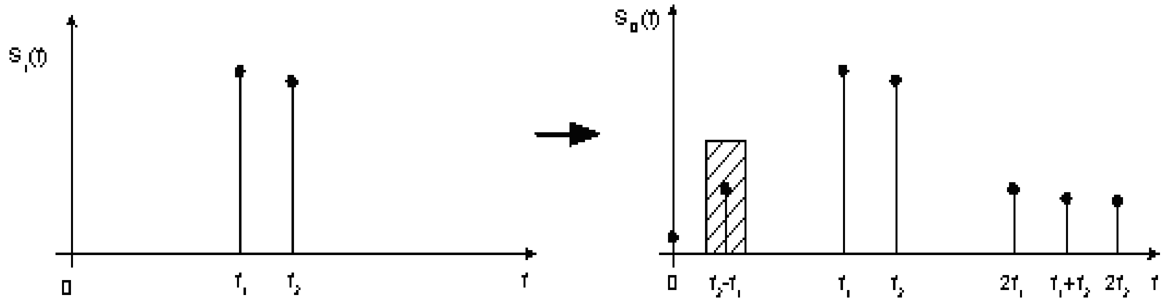


Figure 2: Creation of new harmonic components in frequency spectra at transit two harmonic signal through nonlinear environment with demonstration of selection dominant components by frequency filter - event of mixing (with small rate of f_2/f_1)

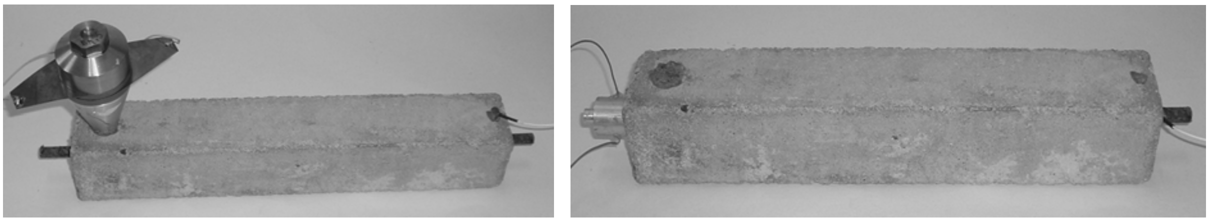
Recently, various papers on both the theoretical and experimental examination of diverse methods and their applicability in some fields have been published. Most published papers, as well as our experience, show these methods to be highly promising for the defectoscopy and the material testing purposes in the near future.

One of the fields in which a wide application range of non-linear acoustic spectroscopy methods may be expected is civil engineering. Poor material homogeneity, and, in some cases, the shape complexity of some units used in the building industry, are heavily restricting the applicability of "classical" ultrasonic methods (Macecek, 2003). Precisely these non-linear acoustic defectoscopy methods are less susceptible to the mentioned restrictions and one may expect them to contribute a great deal to further improvement of the defectoscopy and material testing in civil engineering.

3 TESTED OBJECT AND EXPERIMENTAL ARRANGEMENT

Reinforced concrete joists of atypical dimensions of 50 mm × 50 mm × 360 mm, containing a smooth steel bar of a diameter of 8 mm located in the joist's longitudinal centre line, were studied in this experiment. Two mutual orientations of the ultrasonic transmitter – sensor connecting line with respect to the specimen longitudinal centre line were selected for the measurements, namely, the transversal orientation a), and the longitudinal orientation

b) as is shown in Fig. 3. A set of six specimens in a degradation process stage plus a set of three reference specimens were tested.



a) Transversal orientation b) Longitudinal orientation

Figure 3: Location of the exciter and the sensor on the specimen under testing

In the first measurement stage, a single harmonic ultrasonic signal method was applied. The experimental set-up and testing of its component units have been described in detail previously (Manychova, 2007) and will only be briefly described here, see Fig. 4.

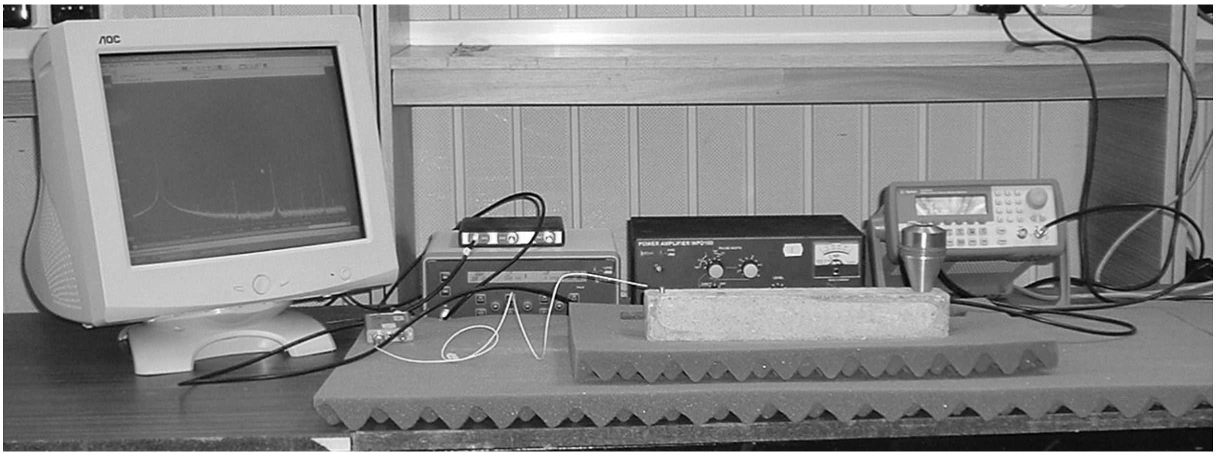


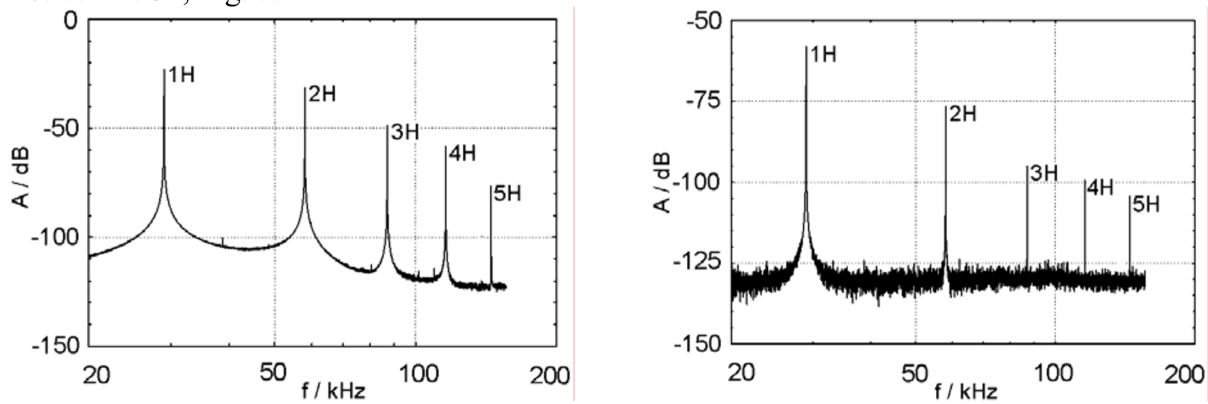
Figure 4: Experimental arrangement, photo of the nonlinear ultrasonic equipment with a test specimen

The measuring apparatus consists of two principal parts, namely, a transmitting section and a receiving and measuring section. The transmitting section consists of four functional blocks: a controlled-output-level harmonic signal generator, a low-distortion 100 W power amplifier, and an output low-pass filter to suppress higher harmonic components and ensure a high purity of the exciting harmonic signal. The main chain of the receiving section includes an input amplifier with filters designed to minimize the receiving chain distortion and a band-pass filter amplifier. Having been amplified, the sensor output signal was fed into a THPS3-25 HandyScope3 measuring instrument to be sampled and analyzed. For the purpose of improving the reliability and accuracy of the nonlinear experiments, and minimizing the error effects, attention was focused on transmission between exciter and sensors. Elements meeting the given requirements were chosen (Korenska et. al., 2006). A program package to control the measuring process, the data processing and evaluation makes an indispensable tool. The measurement results were represented in the form of frequency spectra.

In the second stage of the experiment, a double-signal non-linear ultrasonic spectroscopy was applied, see Fig. 2. In the case of our experiment, the frequency difference fell into a frequency range below 5 kHz. From the relatively high difference between the exciting signal frequencies and the difference component frequency there results a distinctive advantage of directly detecting this difference component, provided that an analog high-dynamic-range (up to over 120 dB) pre-filtering network is used.

4 EXPERIMENT RESULTS

Generation of higher harmonic frequencies for an exciting frequency of f = 29 kHz was studied in the first stage of the experiment. The measurement results can be expressed in the form of frequency spectra, as is shown in the following Figures. Measurement results obtained from reference specimens are represented by frequency spectra of specimen No. 05TP8C0, Fig. 5.

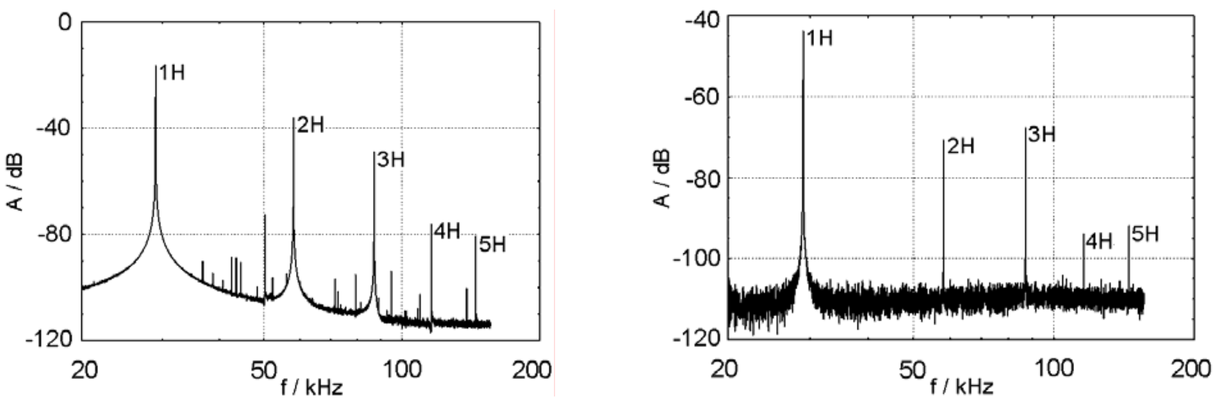


a) Transversal orientation **b) Longitudinal orientation**

Figure 5: 05TP8C0 reference specimen

The spectrum of Fig. 5a) shows the measurement results obtained from this specimen measured under the conditions of transversal orientation. Higher harmonic amplitudes are decreasing with their increasing serial number. The surface area available for fitting the transmitter onto the specimen was restricted by the steel reinforcement in the case of longitudinal excitation. Therefore, a smaller–sized high frequency exciter was used. The longitudinal orientation results are shown in Fig. 5b). This frequency spectrum shows again a drop of higher-frequency amplitudes with an increasing serial number. Lower amplitudes, which were measured in the longitudinal orientation conditions, are due to the lower output of the HF exciter at the exciting frequency 29 kHz.

Measurement results obtained from the specimens which were degraded in 82 corrosion cycles are represented by frequency spectrum of specimen No. 10TP8C82, see Fig. 6.



a) Transversal orientation **b) Longitudinal orientation**

Figure 6: 10TP8C82 specimen - after 82 corrosion cycles

The frequency spectrum of Fig. 6a) corresponding to the transversal orientation contains not only the harmonic frequencies, but also some other frequency components, whose amplitudes are comparable with those of the fourth (4H) and fifth (5H) harmonic frequency. The same effect was observed in concrete and light-concrete joists after they had been stressed in a pressing machine until a visible crack appeared (Matysik et. al., 2007, Korenska et. al. 2008). The longitudinal-orientation transfer function curve differs from that of the intact specimen, see Fig. 6b). In the frequency spectrum the amplitudes of the odd-numbered harmonic frequency components 3H/5H exceed those of the even-numbered ones 2H/4H.

The next Fig. 7 and 8 represented the results of our measurement when two ultrasonic signals f_1 = 32 kHz, f_2 = 29 kHz have been applied to specimens. A difference component of a frequency f_v = 3 kHz was looked for. The chart of Fig. 7 corresponds to reference specimens.

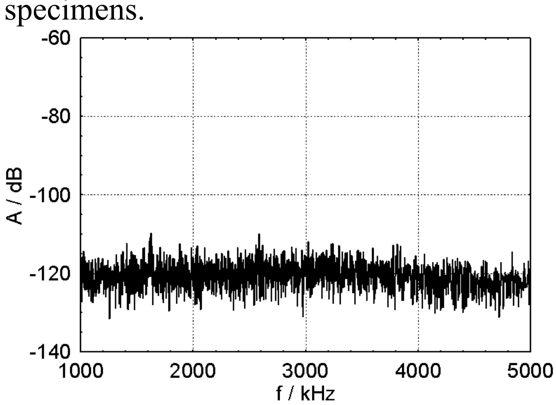


Figure 7: 05TP8C0 reference specimen

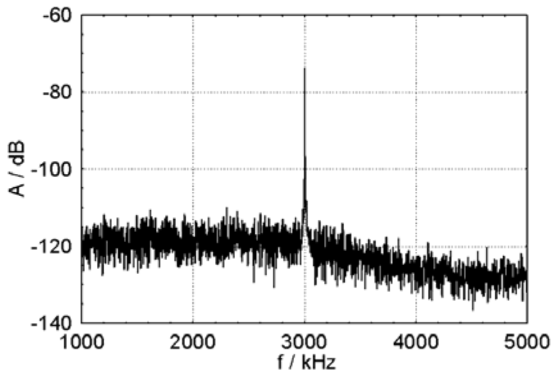


Figure 8: 10TP8C82 specimen - 82 cycles

It is clear from the diagram that no inter-modulation of the two ultrasonic signals takes place, which is evidence of the structure integrity of the specimen under test being intact. Measurement results of a specimen after 82 degradation cycles are represented in Fig. 8. The predominating magnitude of the amplitude occurring at this difference component is due to the presence of a defect in consequence of reinforcement corrosion.

Further to the above mentioned measurements, X-ray photographs of the 05TP8C0 reference specimen and the 10TP8C82 specimen (after 82 corrosion cycle application) were taken, see Fig. 9. The upper photograph, denoted 08 and corresponding to the reference specimen, clearly shows that the reinforcement-to-concrete bond has remained intact. The lower photograph, denoted 8, illustrates the corroded specimen. In consequence of the corrosion, the reinforcement-to-concrete bond has been disturbed at several points along the reinforcement. One of the damaged areas is shown in the photograph.

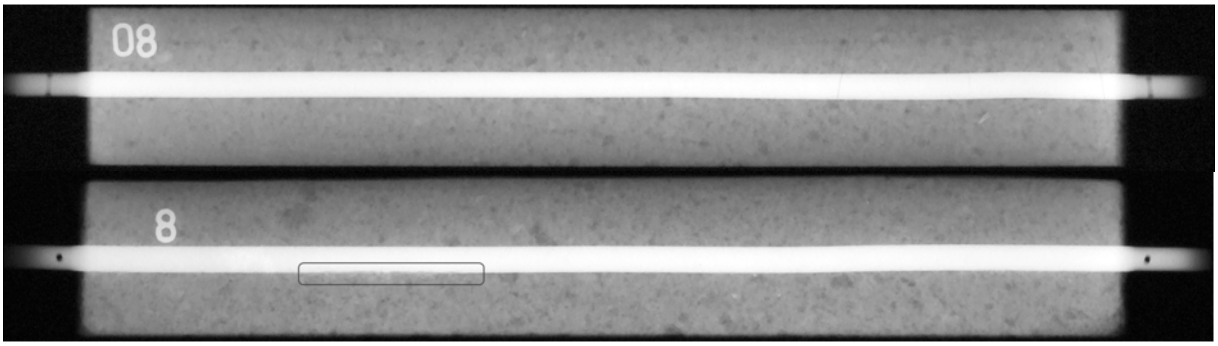


Figure 9: X-ray photographs of 05TP8C0 reference specimen (08) and 10TP8C82 specimen after 82 degradation cycles application (8).

5 CONCLUSION

In the first stage of the experiment, with a single-frequency harmonic exciting signal, it has been proved that the frequency spectra of reference (non-corroded) specimens do not exhibit non-linearities in the signal transmission. On the other hand, transfer characteristics of the specimens measured after the application of 82 corrosion cycles do show non-linear effects, which correlate with the steel armature corrosion consequences.

These non-linear effects are apparent for both transversal and longitudinal excitation arrangements from the relatively high harmonic amplitude behaviour. The respective amplitudes do not show the gradual decrease with the increasing harmonic order number, as is the case of the reference specimens. Moreover, the distorted structure was shown to generate non-harmonic frequency components in the case of transversal excitation.

When a double-frequency exciting signal method was applied, the consequences of the corrosion gave rise to a large-amplitude component whose frequency equalled to the exciting frequency difference.

The following conclusions have been drawn from the application of the above mentioned methods:

The single harmonic signal exciting method provides very sensitive detection and accurate defect localization. It, however, requires – particularly in the case of bulky specimens – a high exciting power, which is rather difficult to generate with the required spectrum purity.

The double harmonic signal modulation method, using an exciting signal whose frequencies near each other, does not require a pure signal spectrum, although it requires a certain degree of the source linearity – to minimize mutual non-linear interaction. A certain drawback of this method consists in the rather low frequency of the exciting signal, which in its turn lowers the localisation potential of this method.

In conclusion, it is to be noted that a mechanical impulse exciting signal carries a much higher power than any pure harmonic signal electric excitation. The measurement sensitivity of such a measuring method is much higher. These methods are especially suitable for pronounced resonance response exhibiting specimens, where the broad-band impulse excitation results virtually in a narrow-band or even harmonic response. A typical example of pulse excitation used in everyday practice is a spectral analysis carried out by a human ear during a hammer-tap test of a railway wagon wheel, or the change in the sound spectrum of a broken bell. Beside the generation of new harmonic components, the defect induced non-linearity also results in a change of the specimen transfer characteristics and both phenomena can be analysed at a time.

6 ACKNOWLEDGMENTS

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Architecturing Future-proof Distribution of Traffic and Travel Information Using TPEG

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ABSTRACT: The article summarizes key recommendations for creating a traffic and travel information distribution architecture, which will function properly and without changes for longer time. Recommendations are based on a work proposing an architecture over a distributing traffic and travel information over digital radio broadcasting and Internet using TPEG formats and protocols. The whole process of architecturing is briefly described starting with the planning scope, expected results and steps to achieve them; and the process of requirement engineering. For the requirements a list of user needs, created for intelligent transportation systems (ITS) by project KAREN, was found to be very useful. Lessons learned from existing traffic information distribution systems are also discussed as they were another source of requirements. Before describing the architecture, unique design concepts of TPEG itself are mentioned, namely the possibility to seamlessly convert a TPEG message from binary format to XML and back; promising location referencing methods incl. AGORA C; and the ability to be backward compatible even after enhancing the TPEG message to the server for new or updated TPEG applications. All those TPEG design concepts allowed the development of very modular and flexible architecture for distribution. The architecture itself is then briefly outlined by means of selected set of use cases, describing core functionality of reception and distribution; and by a sample deployment model, depicting the possible physical structure of a future working system. Finally, based on the created architecture, recommendations are stated. The system must be designed as a pure distribution channel, changes expected in the future are identified, suitable requirement engineering methods are proposed and the need for monitoring and auditing tooling is highlighted. Open issue is practical availability of the dynamic location referencing method which shall be evaluated in the near future.

KEY WORDS: Architecture, TPEG, DAB, Internet, traffic and travel information

1 INTRODUCTION

The architecture of an information distribution system affects many parties: the information provider, distributor and many information consumers. In project ITS 2005 (Svítek, 2006a), the following risk is identified: “ITS architecture does not include all functions needed for supporting current European policy of road transportation and for ITS services (mainly information services), currently being offered by the public, as well as private, sector. Architecture does not include functions necessary for new products and services, which will be developed in the future.” It is highly desirable therefore to create such an architecture, which provides the needed functionality and also works in a long term view.

1.1 Aim, methodology and results

This article aims to summarize key recommendations for creating a traffic information distribution architecture, which will function properly and without changes for a longer time. Recommendations are based on a detailed architecture design for distributing traffic information using the TPEG protocol as described in (Vlčinský 2008a). First the methodology for designing the architecture is mentioned and then the requirements engineering is described. Before describing the resulting architecture, unique features of TPEG are discussed, as they strongly affected and simplified the task. The resulting architecture is then described and finally key findings are summarized.

1.2 What is TPEG and DAB

In our research, pilot testing of distributing traffic and travel information via digital radio, as well as over the Internet, is planned. Before testing and building the system itself, the architecture had to be defined.

TPEG is a new standardized technology for the encoding and distribution of Traffic and Travel Information, providing various modular toolkit solving applications (e.g. Road Traffic Information, Public Transport Information, Parking Information), transmission methods (e.g. Internet or digital broadcasting technologies, like DAB or DMB), location referencing methods (pre-coded like TMC location tables used in existing RDS TMC or "on the fly" like AGORA-C) and devices (vehicle navigation systems, web browsers, mobile devices).

DAB is a digital radio technology for broadcasting radio stations providing primary service (radio stations) and also data service, usable for distribution of traffic information using TPEG technology.

1.3 Architecture – planning the mission

Architecture has long term impact – most of the appreciated functionality, as well as the unwanted problems, originate here. The whole development process should continually narrow uncertainties and with architecture, there was a big portion of that. The following questions had to be clarified:

What is really meant by architecture? It is said that when asking 10 architects for a definition of architecture, one gets 10 different definitions. There was no use to add another one and fortunately, the answer could be found in outputs of project CONVERGE (Jesty, 1998), which clarifies abstraction levels of architecture and offers good guidance for architecturing ITS systems.

What are the requirements for the future system? As described later, an existing dictionary of user needs from project KAREN and known problems in similar systems were a great source of inspiration.

What steps shall be followed to get the task done? After scoping the architecture, Business Process Model (BPM) was created to investigate the context of the system itself (Vlčinský, 2008d). Then, according to Unified Process described in (Arlow 2007), analytical model was built using UML: actors defined behavior of the outer world, use cases described the behavior of the system itself and a class model clarified terms and their relationships. Finally, a deployment model was developed to illustrate a possible physical architecture. Details of used methodology are described in (Vlčinský, 2008b).

2 REQUIREMENTS - NAMING THE OBVIOUS

Neither forgetting someone's needs nor fulfilling wrong ones pleases anyone. Our requirement engineering was based on three sources – user needs for ITS defined in the project KAREN; known problems in similar distribution systems and our will to build an architecture which can last and function for a longer time.

2.1 Shopping list of user needs from KAREN project

Having a list of possible user needs is a big help in requirement engineering, as it concentrates experience and lessons learned from many experts and projects. Project KAREN, defining methodology for ITS architecture in EU, provides such a dictionary (Jesty, 2006). Similarly, project ITS 2005 (Svítek, 2006a), applies the KAREN approach in the Czech Republic, defines methodology and contains many real examples of ITS architecture.

The KAREN dictionary contains about 500 specific needs grouped into more than 40 groups. For the designed architecture 33 of them were selected and are described in (Vlčinský, 2008c).

The general impression is of the dictionary being mature, thorough and promoting an open approach to everyone. To name some examples:

- The Framework Architecture shall not constrain its functionality to be implemented by specific local organizations.
- The Framework Architecture shall support interaction between services provided by private and public bodies.
- The system shall provide emergency, or urgent, information to all road users free of charge.
- The system shall be able to require payment for non-emergency, or non-urgent, information.

2.2 Learning from old and existing problems

Running any distribution system implies involving more different parties who have to perform well to ensure overall performance. Besides a clear definition of responsibilities, some tooling and design concepts might simplify resolving possible problems.

Monitoring shall automatically detect failures and outages and notify responsible persons as it shortens resolution time.

Auditing tools shall provide easy access to information on interfaces between different parties. This is typically achieved by logging data on import/export interfaces; however, providing access to this information via GUI simplifies the task. Digging the information manually from log files is not only cumbersome, but also requires a more privileged and less available resource – a system administrator. The ideal solution is if GUI access is given to all participating parties.

Dependency on one shared map data set, as seen with any pre-coded solution (RDS TMC), but also used in the National Traffic Information Centre (JSDI) in the Czech Republic, can cause some very difficult problems. A scenario whereby all participants update their map data sets in their systems at once is hard to follow and is likely to cause problems with longer resolution times. The biggest problems are if data sets must be exactly the same. A better situation is with TMC location referencing, as it allows at least partial functionality if data sets differ by one version. The best solution would be using some reliable implementation of "on the fly" location referencing. TPEG offers this option using AGORA-C, but implementing is not an easy task. Our architecture defines constraints on functionality with different data sets, however, real implementation has yet to be designed and decided on.

2.3 Trying to anticipate future changes and survive them

Architects are dreaming of architecture, which would last forever, or at least long enough. Reality and bad dreams come with the architecture destroyer – changes. As time goes on the situation around user needs, expectations and technologies changes and the old architecture slowly becomes less and less functional. To fight the changes, the following techniques can be used.

Prohibit any change. As long as architects do not have the power of dictators, this technique does not work much.

Know the changes in advance. The changes which are likely to occur are updating map data sets and implementing new TPEG applications on input and output.

Be transparent and let others deal with the change. The transparency of the transmitting channel is one of the TPEG concepts and we have adopted this approach too. Responsibility for incoming (primary) data is up to the primary data provider. Simply stated, the architected system must prevent trying to take on too much responsibility and do only the minimum necessary. To keep the most of our system untouched by a specific format of processed data, each incoming message gets a generated predesigned metadata, which are then later used to control processing, filtering and distribution. *Metadata* contain information, like TPEG application, source system, message id, time of reception, creation and expiration, urgency, type and subtype (taxonomy), region etc.

Reject wording "Architectural change"; rename it to "System reconfiguration". If the system has to change, it has to change somewhere. The obvious place is a configuration file; plug-ins are also an option as a mean for implementing changed behavior. In the case of our system, plug-ins for converting incoming data to TPEG and for generating metadata for each message are expected.

3 TPEG AS THE UNIVERSAL SOLDIER

Key architectural concepts for TPEG itself are very close to the definition of a universal soldier: they easily change the form appropriate to the situation while not loosing anything of their identity; are expert on knowing where you are; and are able to evolve and grow without harming cooperation with older systems and colleagues.We found these TPEG concepts very handy for architecting our TPEG distribution system.

3.1 Morphing into different forms

TPEG defines two basic formats: binary and XML, which can be converted from one to another. This allows any TPEG message inside of the system to be in a single (XML) format regardless of the format used for final distribution. If the need arises for a new encoding schema (e.g. for other types of digital broadcasting), it is likely that the task will be solved by an additional output filter or converter not affecting the architecture of the whole system.

3.2 Location referencing

Knowing "where" is an essential part of any traffic related message. TPEG is designed from the very beginning with location referencing in mind and has undergone some development over the last years. Methods, using text and simple coordinates, were complemented by other methods using pre-coded referencing as well as dynamic ones.

The distribution architecture expects that consumers could receive messages with location referencing of their choice, if primary information provides enough information for that.

3.3 Adopting future applications

Binary format was developed with backward compatibility in mind so that old devices are able to consume enhanced TPEG messages not known at the date of device production. This goal is achieved by marking each part of the TPEG message in the way, allowing an older device to safely skip unknown sections of data. XML format allows the same.

New TPEG applications, which are likely to be completed in near future, are easy to adopt for distribution. In the case that primary information comes in TPEG format, the distribution system could theoretically distribute it even when not knowing the internal structure of the message.

4 RESULTING ARCHITECTURE

Answering a question "what is a car, daddy?" could be answered by pointing your finger to a picture of a car (physical structure) and explaining "the car goes here and there and does wrrrm, wrrrm" (functionality and behavior).

To describe resulting architecture, functionality will be depicted by means of core use cases and the physical structure will be illustrated by means of a deployment model. A detailed analytical model is described in (Vlčinský 2008e) and a deployment model in (Vlčinský 2008f).

4.1 Use cases describing core functionality

In 0, a key group of use cases participating in reception and distribution is shown. The ovals represent one use case, the rectangle around the ovals shows the border of the modeled system and the line joining the oval with an actor represents the interaction between the system and the world around.

The primary data provider is an actor, which sends source information to the system. The information must be in some agreed format and it is believed to be consolidated (correct and not duplicated).

Use case *Data reception* receives the data, if necessary calls use case *Convert data to TPEG* and hands control over to the use case *Message distribution*. Here, processing starts by generating metadata and if possible, additional location referencing is generated making the message ready for any sort of distribution channel.

Then, processing may fork depending on what distribution channels include the message in their subscription.

Use case *Broadcast TPEG over DAB* encodes the message to binary format, stores it in a collection of messages to be broadcast and keeps them broadcasting.

Use case *Send TPEG over Internet* is actively posting data to url (possibly web service) of the actor *Passive Internet consumer*.

Data can also be published, e.g. placing static XML files or an HTML report on a web server as shown by use case *Publish TPEG on Internet*. The actor *Time* depicts that the publishing is controlled by some scheduler.

Published data can be consumed (downloaded) by the actor *Active Internet consumer requesting data* as shown by use case *Active Internet consumer requesting data*.

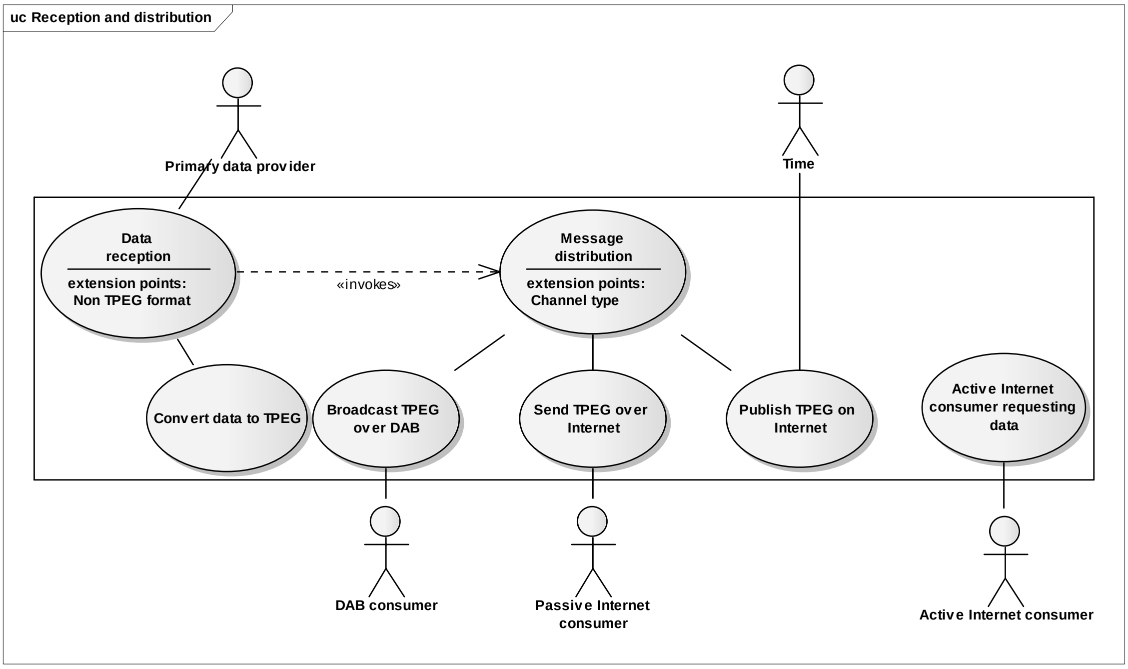

Figure 1:Key use cases participating in reception, processing and distribution

4.2 Deployment model illustrating possible physical structure

0 shows a possible physical architecture reflecting a proposed architecture. Note that, based on the same architecture, different deployments can be built. Take the deployment model as illustrative only.

The 3D box represents a physical device (server, encoder), rectangles inside depict the software component deployed on the device. The crossed arrows symbolize a shared medium (Internet, LAN or Terrestrial broadcasting) interconnecting all devices connected to them by a line. The rectangles around devices are used to show common logical name of that group.

JSDI server (National Traffic Information Center) sends via *DDR* (distribution interface) traffic information to *TPEG distribution* application. Similarly, *IDOS B2B* application provides Travel information (timetables).

TPEG distribution is internally using *Database* and publishes information on a *Web server* or *FTP server.* The w*eb service* on a *TPEG web server* uses data from *TPEG distribution* to respond to a web service request issued from *Application downloading data* placed on *Server of active consumer*. *Application downloading data* can, in the same manner, request data from the *Web server* or *FTP server.*

TPEG distribution can send traffic information to a *Web service – reception* placed on *Server of passive consumer.*

Digital radio broadcasting is via a *DAB encoder* and a *DAB transmitter* “to the air” where the end user with *DAB receiver* can consume the data.

Digital radio broadcasting is also monitored via *Check DAB receiver* and *TPEG checkpoint server*, which closes the loop by providing received data back to the *TPEG distribution* for auditing.

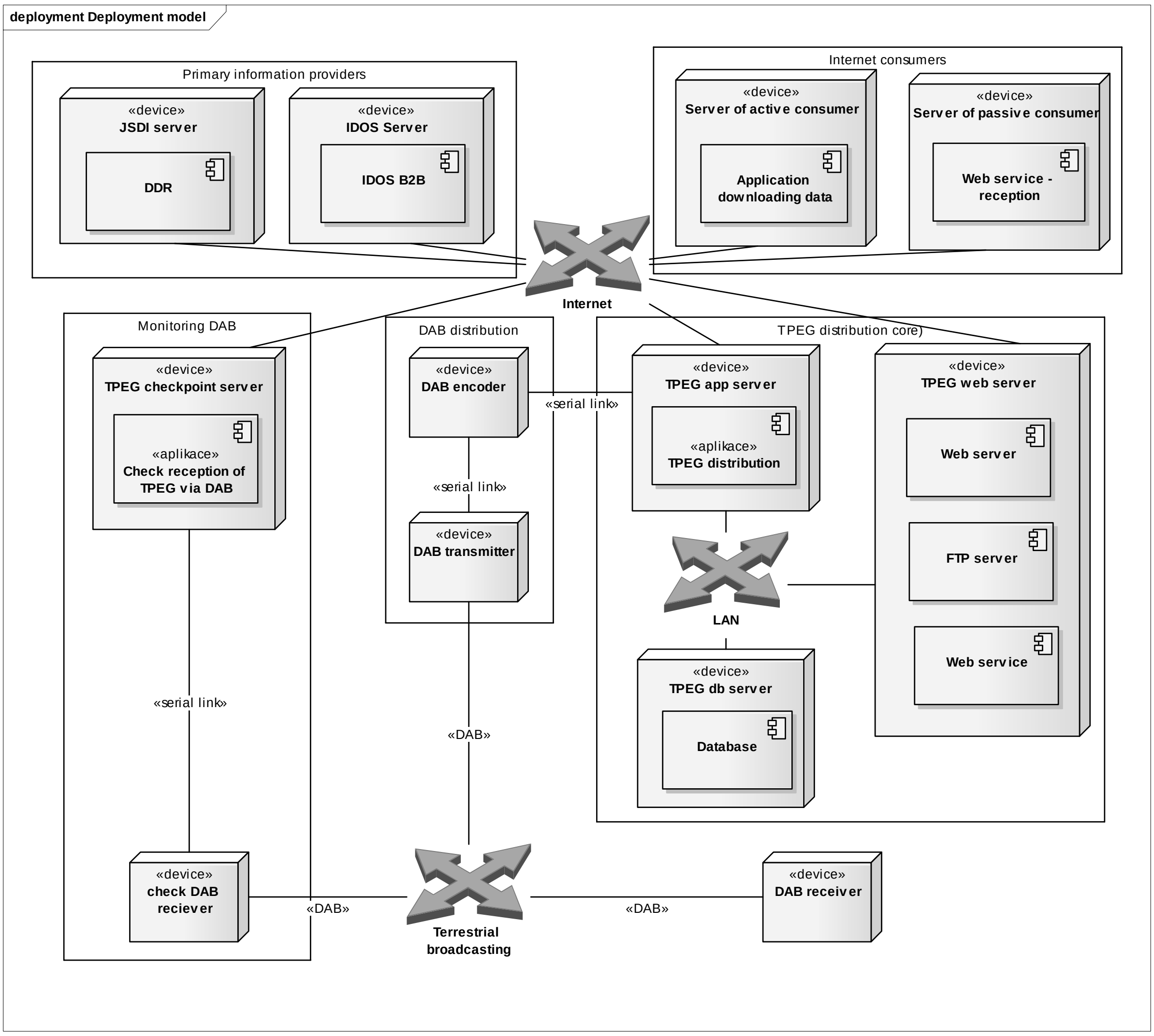

Figure 2: Deployment diagram of possible physical architecture

5 CONCLUSIONS

TPEG design concepts allow designing the architecture of a system for traffic information distribution, which is very likely to last unchanged as new TPEG applications and even distribution channels will appear. To achieve that goal, the distribution system must behave as a pure distribution channel and shall not try to take too much other responsibility.

Changes, which are likely to happen in the future, are in the areas of new and changed input formats, new TPEG applications and new distribution channels. All these changes can be incorporated into the proposed architecture by means of plug-ins solving conversion of incoming data, generating metadata for each message and servicing sending data via a specific distribution channel.

Requirements engineering of the proposed architecture took the advantage of a dictionary of user needs created by the project KAREN and ITS 2005. It is generally highly recommendable to consult these resources for any future work in architecturing, requirements engineering and risk evaluation of ITS systems, as they are very comprehensive and may help prevent some omissions.

Tooling for monitoring and auditing of any information distribution system shall be required, as they shorten problem resolution time and increase the total quality of the provided service.

The currently used distribution systems suffer from using pre-coded location referencing methods like TMC location tables, shared map data sets etc. TPEG seems promising by providing dynamic location referencing called AGORA-C, however, there are still some challenges in the area of technical and commercial availability, which shall be solved, investigated and evaluated in future research.

Assuming dynamic location referencing availability, the proposed architecture has a mechanism for providing location references for consumers in any TPEG standardized location referencing method.

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