KOMUNIKÁCIE
COMMUNICATIONS

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KVALITA DOPRAVY A JEJ MANAŽMENTU V MESTSKÝCH OBLASTIACH

TRAFFIC QUALITY AND ITS MANAGEMENT IN URBAN AREAS

Príspevok poskytuje prehľad o kvalite dopravy v rôznych krajinách na základe dotazníkov a prehľadov uverejnených v literatúre. Základné otázky, na ktoré bolo potrebné odpovedať, boli: Čo je to kvalita dopravy? Aká je úroveň kvality dopravy? Ktorú oblasť kvalita nepokrýva? Ako sa uskutočňuje kvalita dopravy?

Navrhnuté dotazníky mali zhromaždiť údaje o uvedenej problematike. Zodpovední pracovníci výboru PIARC a miestnych sekcií boli s dotazníkmi oboznámení. Zhromaždili sme aj informácie týkajúce sa sledovaných miest. Na dotazník reagovalo 32 miest zo 16 krajín.

The purpose of the paper is to overview the status of traffic quality in various countries, based on a specific questionnaire and some literature survey by trying to give answers to the following questions: What is traffic quality? What is the level of traffic quality? Where is the quality gap? How is traffic quality managed?

To collect information on these issues a questionnaire was established and members of the PIARC Committee on Urban Areas or technical experts indicated by them were approached. Also general information was collected regarding the cities involved. There were 32 cities from 16 countries that replied to the questionnaire.

Quality has become an important issue of traffic management. People complain about traffic quality, while engineers try to improve or at least to manage it better.

In recent decades, the role of and the approach to industrial quality has changed completely. The new ideas appeared in the services with some delay. "While in the industry there are a lot of practical experiences available about quality management, this is certainly not the case in the area of services. Therefore. one has to consider a numbers of aspects, especially for people-related services" [1]. Traffic management, as a rather complex service, can probably use the experiences of other fields.

The purpose of this report is to give an overview of the status of traffic quality in various countries, based on a specific questionnaire and some literature survey, by trying to give answers to the following questions.

- What is traffic quality?
- What is the level of traffic quality?
- Where is the quality gap?
- How is traffic quality managed?

To collect information on these issues a questionnaire was established and members of the PIARC Committee on Urban Areas [9] or technical experts indicated by them were approached. Also, general information was collected regarding the cities involved. There was no preliminary selection of cities; the aim being to obtain the largest amount of data possible. The questionnaire was also designed to be brief, simple and easy to answer.

Accordingly, and with these conditions in mind, we believe we are in a position to provide interesting parameters for those wishing to make a more comprehensive study of this problem.

It should be noted that the data furnished represents the point of view of the Manager of the road system, and that such things are affected by political and cultural choices, and often by financial constraints. The results could outline a non-objective description, since they do not necessarily provide an expression of the needs of the users. At any rate, they give an accurate picture of the state of affairs of the single city.

There were 32 cities that replied to the questionnaire (Table 1.). Six cities only replied to a part of the questionnaire.

It is important to focus on the fact that experts answered for the general public and the answers of the questionnaire were based mostly on estimates rather than on sound data. This method could be questioned, and the interpretation of the results could also be different. However, it is reasonable to analyse the average of the estimates of 32 local experts.

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Countries and cities referred in the questionnaire Table 1

Ref. No.	City	Country
1	Adelaide	Australia
2	Brisbane	Australia
3	Melbourne	Australia
4	Sydney	Australia
5	Vienna	Austria
6	Hull	Canada
7	Montréal	Canada
8	Québec	Canada
9	Hong Kong	China
10	Prague	Czech Republic
11	Helsinki	Finland
12	Lille	France
13	Nantes	France
14	Paris	France
15	Budapest	Hungary
16	Györ	Hungary
17	Bologna	Italy
18	Brescia	Italy
19	Oita	Japan
20	Osaka	Japan
21	Tokyo	Japan
22	Yokohama	Japan
23	Kuala Lumpur	Malaysia
24	Lisbon	Portugal
25	Porto	Portugal
26	Bratislava	Slovakia
27	Basel	Switzerland
28	Bern	Switzerland
29	Zürich	Switzerland
30	Edinburgh	Scotland
31	Southampton	UK
32	Washington DC	USA

1. What is traffic quality?

According to one of the definitions, quality is the adequacy of a product or of a service for a certain purpose. This means that quality is always related to a specific goal.

Complex products or services, e.g. traffic, can be described by a number of quality indicators. "The best description of traffic quality requires the overall coverage of impacts and quality indicators. The most important criteria for road users are the speed, comfort, safety and price (related to the financial situation). It is recommended to use the above factors as the main criteria for the overall evaluation. Travel speed as the most important quality indicator can be used for purposes of a simplified assessment" [2].

Various road transport facilities can have different quality indicators. One of the possible systems is shown in Table 2.

Quality indicators of different road transport facilities [3] Table 2

Type of facility	Quality indicators
Motorway sections between junctions	travel speed
Weaving and merging areas	weaving traffic volumes
Two-lane roads	travel speed
Junctions with traffic signals	delay, number of stops
Junctions without traffic signals	delay
Roundabouts	delay
Urban main streets	travel speed
Mass transit facilities	quality of service
Cycle facilities	density
Pedestrian facilities	density

The evaluation of quality in road traffic shows some specific features as compared to other services:

- not only are the direct clients (road users) interested in the quality of the service (traffic quality), but also other people (e. g. people living in the area under consideration),
- the identity of the service provider (e. g. highway agency) is not evident for the client and there is no formal contract between the service provider and the client (except some special cases such as toll motorways or metered parking facilities).

Traffic quality can be described by a number of indicators / parameters. When speaking about quality, the general public might consider some of these parameters as more important or more relevant. The importance of a parameter and its quality level can be different: e. g. speed can be considered as a very important factor but its level can be both low and high.

In order to collect information about quality management in various cities, a questionnaire survey was undertaken. The survey method was described earlier.

Experts were asked to mark the given indicators of traffic quality, according to their *importance/relevance* in their urban area *for the general public* (1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low).

The average marks of the importance of various quality indicators are shown in Figures 1 and 2.

Both in road traffic and in public transport, the three most important factors are: travel time, delay and safety. In public transport, the service interval was also found to be among the most important factors. The least importance was attributed to those parameters which are only used by professional traffic engineers

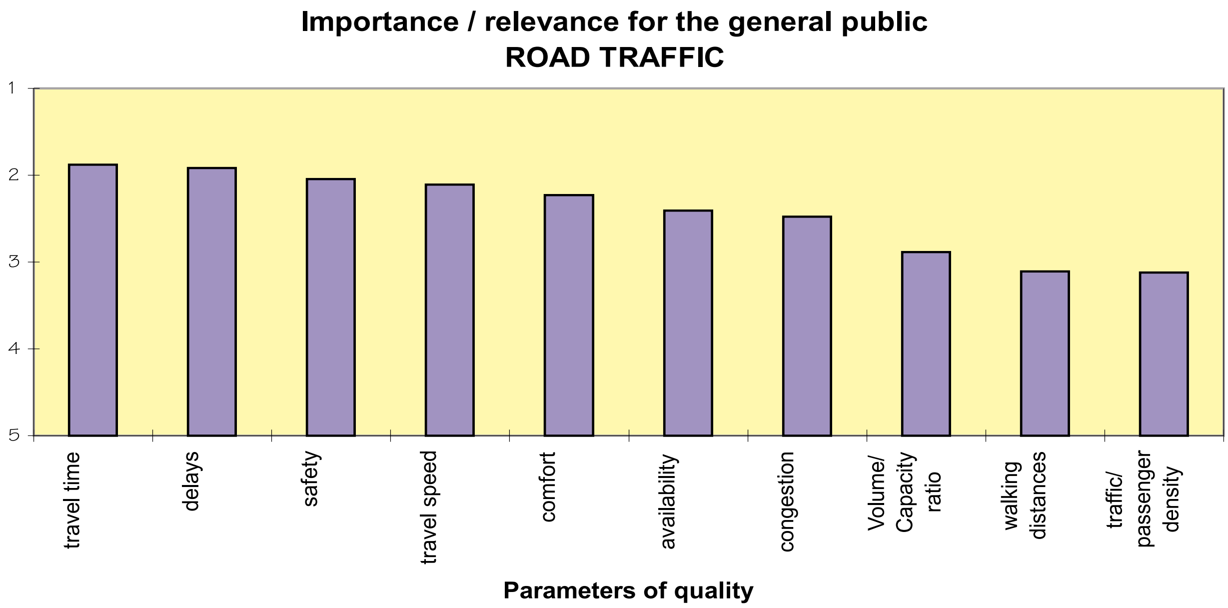

Fig. 1

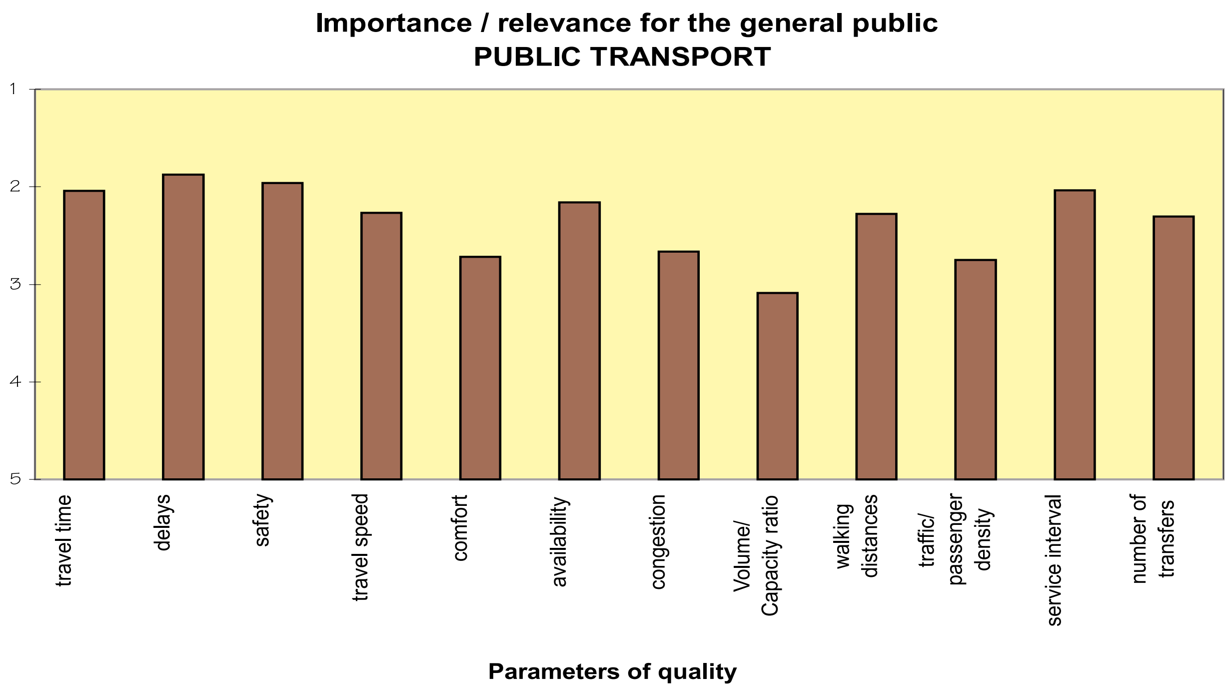

Fig. 2

(e. g. volume/capacity ratio, density) and are not relevant to the general public.

In road traffic, the importance of the parameters was found to be independent from the city size. In public transport, there are some variations according to the city size.

2. What is the level of traffic quality?

In the second part of the questionnaire experts were asked to mark the given indicators of traffic quality, based on their estimate, according to the *general quality level* in the urban area (1 = excellent, 2 = good, 3 = medium, 4 = low, 5 = very low).

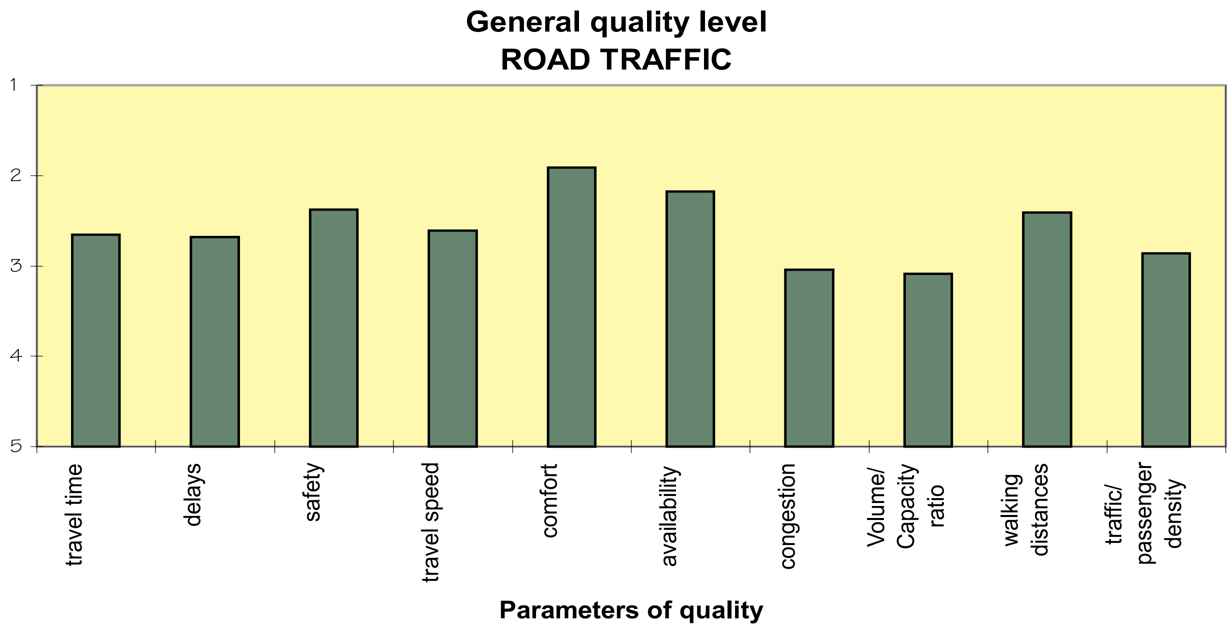

Fig. 3

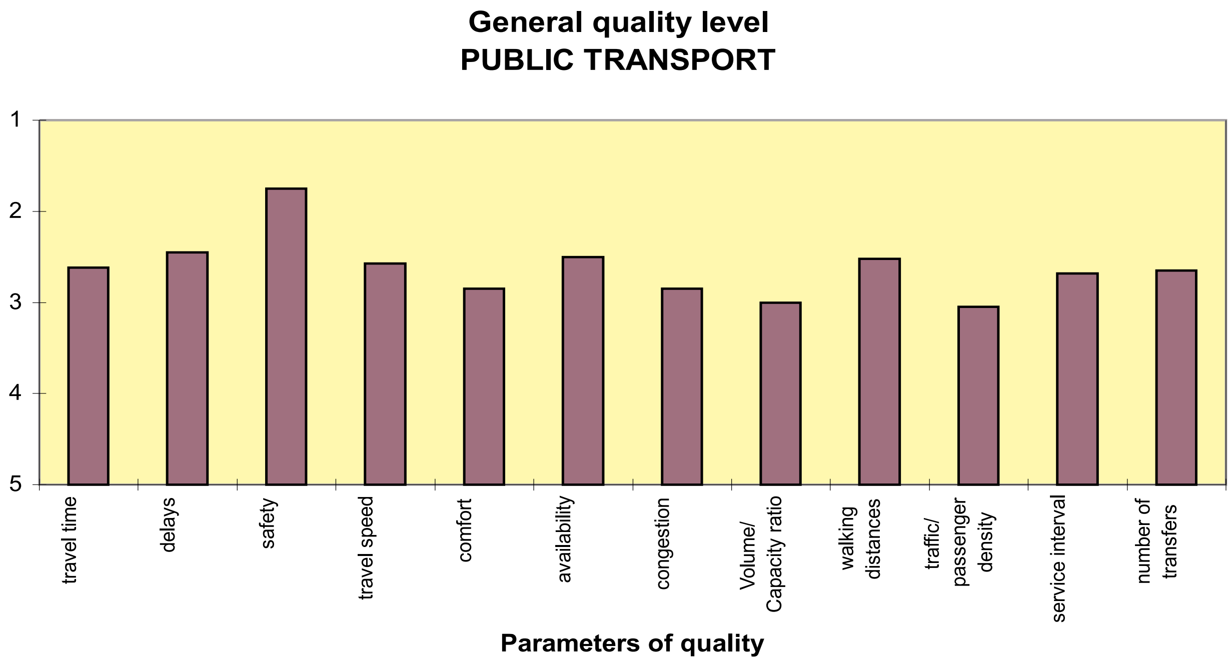

Fig. 4

The average marks of the quality level of various quality indicators are shown in Figures 3 and 4.

Both in road traffic and in public transport the quality level of safety and availability were among the three highest ones. Road traffic comfort was also found to be among the three best parameters, while in public transport the level of delays was found to be good (low).

The three worst parameters were also identical in road traffic and in public transport, namely congestion, volume/capacity ratio and traffic density. This part of the survey is also underlining the importance of congestion problems which are analysed in another part of the report.

When comparing the average marks for smaller and bigger cities, a large difference can be found. The average quality level in cities under 1 million inhabitants is about 2.4, while for cities over 1 million this value is 2.9. This reflects the lower quality level in large cities both in road traffic and in public transport.

3. Where is the quality gap?

Comparing the importance of a parameter and its quality level one can define a quality gap as the difference between them. If on one hand the importance (demand) is high and on the other hand the quality (supply) is low then this parameter shows a quality deficit. In some other cases the actual quality of a parameter can be higher than its importance (this is a surplus situation).

Data are shown in Figures 5 and 6.

Both in road traffic and in public transport, travel time and delay are among the two parameters with the highest quality deficit. In public transport, service interval, while in road traffic congestion also has high negative values.

There are some parameters with quality surplus: in road traffic the walking distances, comfort and availability are much better than their importance. Somewhat surprisingly, in public transport the safety was found to be "too good".

Smaller and larger cities show a significant difference in this respect. The average mark is almost a half mark worse for large

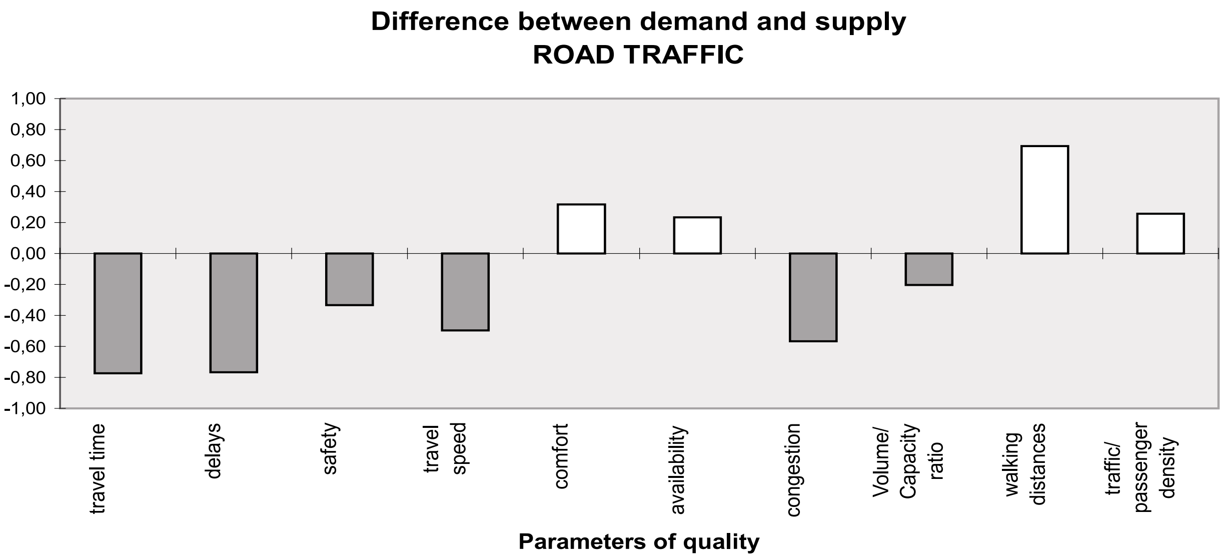

Fig. 5

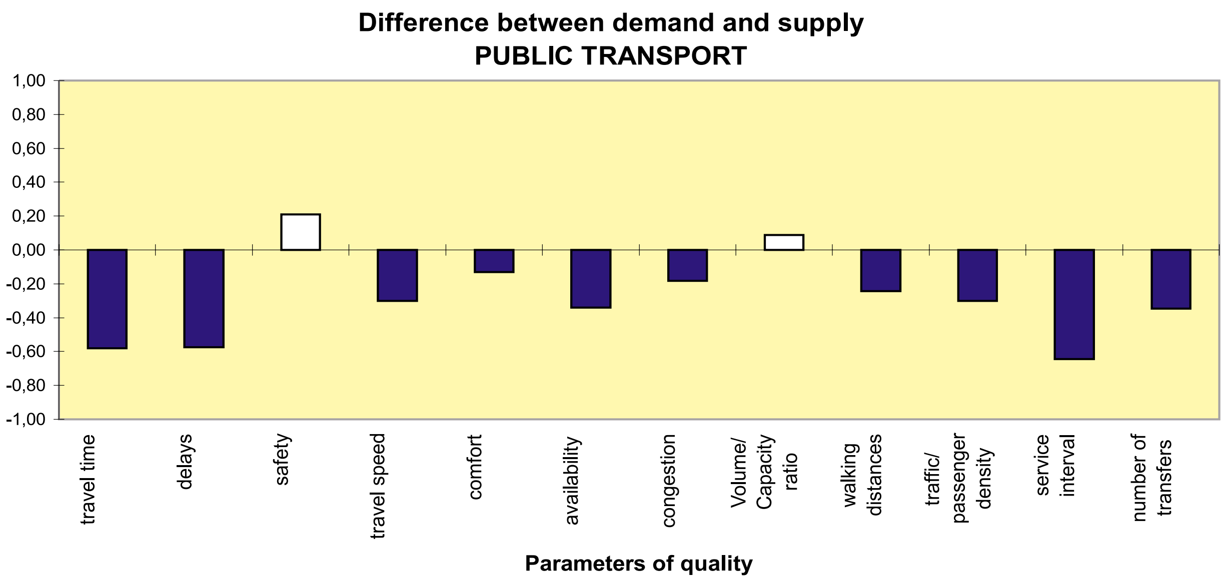

Fig. 6

cities both in road traffic and in public transport. Basically, the same parameters show surplus and deficit in smaller and in larger cities, but the magnitude of the gaps is always higher in larger cities.

This rating can be used by traffic engineers to identify the most important needs in terms of quality improvement and to show some areas where action is not so urgent. However, it can be noticed that most of the indicators are interlinked: when you do interventions regarding congestion, you deal also with delays, travel speeds, and volume-capacity ratios.

4. How is traffic quality managed?

The origin of organised quality control is linked to the beginning of mass production. Mistakes with namely large production series became too expensive. In order to set up a quality management system several components are needed:

- a system of measurements or visual observations (full-scale or sampling) and the comparison of actual values with the standards;
- a system of threshold values (goals, standards, minimal or maximal values, target values, quality classes);
- a set of actions to change quality.

In transport, these systems appeared much later than in the industry.

4.1. Changes in the HCM concept

In the area of car traffic, the concept of traffic quality can be traced back to the 50's. Based on the first edition of the Highway Capacity Manual [4] it was found that "the hourly traffic used in design (DHV) should be the 30th highest hourly volume of the year. Practical or design capacity is predicated on given speeds ... considered as satisfying the condition of operation without unreasonable delay or restriction to the drivers' freedom to manoeuvre" [5].

This means that the design hourly traffic volume should not be higher than the practical capacity of the road. The basis of this approach is that adverse traffic conditions should not be allowed too long on roads. There are only 30 or 50 hours per year with traffic volumes above the practical capacity, the latter being lower than the full capacity based on safety/quality consideration.

This early approach of quality control was also followed later in Europe. In the German version of the HCM [3] the following is mentioned. "Most guidelines [in Germany] are similarly structured. Each traffic facility type has one or more quality indicators and their related minimal requirements. Then three major assessment levels are defined:

- With traffic volumes lower than the practical capacity, the traffic quality is sufficient. The minimal quality requirements are met in this case. However, these minimal requirements are only partially mentioned in the guidelines.
- Between practical capacity and overloading, the capacity can be found. In this range one can speak about an unstable traffic flow.
- Once the traffic volumes exceed the capacity, the facility is overloaded, i.e. the traffic quality is insufficient.

This approach has the disadvantage that only sufficient and insufficient traffic qualities are defined, a more precise assessment of quality is not possible."

In modern production management the approach to quality has changed. It is not enough to define sufficient and insufficient qualities and it is not enough to accept or reject a product at the end of the production line. One speaks about required quality levels and about quality-price relationships. In order to meet the new requirements, nowadays not only is the quality of the products is a subject of control, but also the production process and the system should be designed to avoid possible mistakes and to reach the required quality.

In the field of highway traffic, quality was defined in the Highway Capacity Manual 1965 [6] through the term "level of service".

This is a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists. A level of service definition generally describes these conditions in terms of factors such a speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and safety. Six levels are defined from A to F, with level of service A representing the best operating conditions (free flow) and level of service F the worst (forced or breakdown flow). The appropriate descriptions are well known for traffic engineers.

The speed - flow relationships provide a possibility to estimate the traffic quality from given traffic volumes or to calculate from a given traffic quality the appropriate traffic flow. This way the traffic planners and the decision-makers received a tool for the evaluation of consequences of decisions concerning quality. Once they are able to evaluate consequences of decisions, they can also influence or manage traffic quality.

In later editions of the HCM, this approach has been further developed, quality indicators were defined and their relationships were set up for various facilities: i.e. motorway and road sections, junctions with and without traffic signals, public transport, cyclist and pedestrian facilities [7, 8]. As a result of German studies in 1994, this approach has been adapted to European conditions [3].

The most important advantage of this concept is the uniform evaluation basis for partially loaded facilities. Therefore, the procedure can also be used besides the original design for other purposes, such as traffic assignments, cost-benefit analyses, environmental impact assessments of traffic management schemes.

4.2. Monitoring system

In the *questionnaire* survey experts were asked about the existence of a *monitoring system* of the given indicators/parameters in their country. The answers are summarised in Table 3.

Is there a monitoring system of the quality parameters? Table 3

Number of answers / Parameters of quality	Yes		No		No answer	
	in road traffic	in public transport	*in road traffic*	in public transport	*in road traffic*	in public transport
travel time	*13*	18	*8*	1	*11*	13
delays	*8*	18	*10*	0	*14*	14
safety	*16*	15	*7*	3	*9*	14
travel speed	*13*	17	*7*	2	*12*	13
comfort	*4*	3	*14*	12	*14*	17
availability	*3*	8	*11*	7	*18*	17
congestion	*17*	11	*4*	5	*11*	16
Volume/ Capacity ratio	*16*	12	*6*	6	*10*	14
walking distances	*2*	5	*15*	10	*15*	17
traffic/ passenger density	*11*	12	*6*	4	*15*	16
service interval	*2*	16	*10*	1	*20*	15
number of transfers	*2*	8	*9*	7	*21*	17

In public transport, about half of the cities are monitoring travel speed, travel time, delays, service interval and safety. In general no monitoring system exists for walking distances and comfort.

In road traffic, volume/capacity ratio, congestion and safety are monitored in about half of the cities. Speed and travel time are also among the frequently monitored parameters. Most of the cities are monitoring 5 to 8 parameters (Table 4.)

Number of parameters monitored in cities Table 4

Number of parameters monitored	Number of cities monitoring	
	in road traffic	in public transport
1 to 4	8	2
5 to 8	14	13
9 to 12	1	5
-	23	20

4.3. Threshold values

In the questionnaire survey experts were asked about the existence of quality limits or threshold values of the given indicators/parameters in their country. The number of responses to this question was very low to this question, probably because there are no quality limits in most of the cities. The answers are summarised in Table 5.

4.4. Approaches to quality

In the *questionnaire survey* experts were asked about the existence of *any formal system of quality assessment in urban areas.* The number of positive responses to this question was very low. They are listed below:

Typical quality threshold values Table 5

parameter	in road traffic	in public transport
travel speed	min. 20 km/h	20 km/h
Volume/Capacity ratio	0.9 at intersection 90 % 0.75...0.9 1.0	
walking distances	500 m	500 m, 5 minutes 800 m 200 m 10 minutes 300 m 300...700 m
traffic/passenger density		70 people per bus 0.2 m^2/person 75...55%
service interval		20 minutes 6...60 min
travel time		30 minutes to centre
delays		1 min. before 3 min. after scheduled time
number of transfers		2 1...2

a) for road traffic — Paris, Oita, Tokio
b) for public transport — Paris, Tokio, Edinburgh, Zürich, Helsinki, Hull

A transport company, a traffic authority or a traffic planner deal with traffic quality for various reasons. Even the simple goal to *describe quality* might be not so simple, as there are a number of quality indicators which are inter-related and their measurements need a lot of effort. The previous tables are only very compact compilations of the most important quality indicators.

One can also *evaluate* the *quality* of an existing transport system. The problem in this phase is to find the appropriate quality levels which can only be produced from a broad expert and social consensus following discussion in professional bodies and a certain amount of practical testing.

Companies (also transport companies or highway agencies) usually emphasise that they are *improving* their *quality* for their clients. Traffic *quality* can thus be considered *as a goal* of traffic management. Through various transportation planning and traffic engineering measures, the required quality levels can be reached.

For the traffic planner, traffic *quality* can also be seen *as a tool.* The required goals (e.g. relieving of an area or of certain road sections, improving environmental quality) can be reached through influencing traffic quality. Other, more direct influencing tools (e.g. tolls, full restrictions) can not be used in many cases or they are not acceptable by the public. As the number of captive riders has became smaller and more people have a choice, quality plays a more important role in modal split decisions.

Increasing quality can *pull (attract) traffic* (e.g. the case of a new pedestrian street). Through improving the quality of a link, traffic loads can be *shifted from one link to other links.* Examples are the traffic restructuring impacts of a new motorway section, a new main road or a high quality public transport line.

In other cases, the opposite measure, i.e. the deliberate *decrease in quality* of a link (for specific road users e.g. for through traffic or car traffic) can be the tool leading to a *push (decrease) in traffic* (keyword: traffic calming or parking restrictions). This way quality is created for other purposes, e.g. higher environmental quality for people living in the area. The relation of quality to the goals is emphasised here again.

It is found that traffic quality can be an important goal on one hand. On the other hand, traffic quality can be used to influence many decisions of road management and planning and, thereby, to reach other goals. This is the reason why traffic planners should be more interested in quality management.

A traffic quality management system should consist of the following components:

- a monitoring system of the quality parameters,
- a system of quality goals and objectives,
- a set of possible actions / measures to change / improve quality.

These components should be interlinked with each other, i.e. if a difference between goals and actual values is observed, an appropriate action should be taken, which in turn results in changes of the values of the quality parameters.

In general, cities have not yet reached a complex system dealing with traffic quality. However here are a number of elements which can be integrated later to quality management systems.

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Géza Tarnai *

METÓDA HARMONIZÁCIE HODNOTENIA ZABEZPEČOVACÍCH SYSTÉMOV

HARMONISATION METHOD OF SAFETY VALIDATION SYSTEMS

Článok sa zaoberá metódami ako harmonizovať rôzne validácie preukazov bezpečnosti podľa rôznych predpisov, ktore vznikli v rôznych dobách, navzájom a so súčasne platnými európskymi normami CENELEC v spojitosti s konkrétnym aplikačným príkladom realizácie prvého elektronického zabezpečovacieho zariadenia na MÁV (Maďarskej štátnej železnici).

This paper presents methods to harmonize different safety validations, which were created at different times and by different prescriptions, with each other and with the CENELEC standards, in connection with a concrete application example, the realization of the first electronic interlocking system of the MÁV.

Keywords: Safety validation, railway signalling, CENELEC standards, harmonization

A decision on the modernization of the main line of the Hungarian Railways (MÁV) towards West-Europe was made in the early 90's. The aim of the modernization was to reduce the travel time between Budapest and Vienna. In the frame of this project three railway stations have been equipped with electronic interlocking systems. The first electronic interlocking system of MÁV was installed in 1997 in Tata station, by Siemens Transportation Systems. The Stellwerk Ltd., a Hungarian engineering company took a considerable part in the interfacing tasks and in a number of developing and projecting tasks.

One difficulty of the project was that the most modern electronic interlocking has to work together with the existing relay-based block system. Furthermore, the trackside objects (point machines, signals etc.) are also traditional with a traditional interface. Furthermore, it had to be taken into consideration that the Traffic Rules for the Hungarian Railways are different from the rules of former applications of the Siemens interlocking (DB, SBB etc.). A special requirement was the solution of the control of the 75 Hz track circuits, which is the base of the train protection system. As the original electronic interlocking was not equipped with such a sub-system, it had to be completed with a Siemens safety programmable logical controller, PLC (Fig. 1) [2].

The complexity of the system and the fact that it was the first electronic interlocking system in Hungary, made the preparation of the safety validation and the authority approval process rather difficult. The existing, previously accepted safety validations for

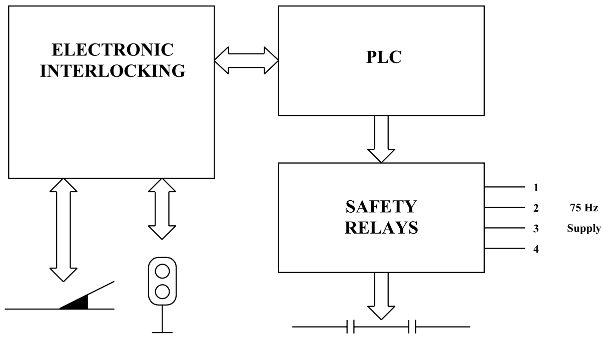

Fig. 1 Control of the 75 Hz supply

those parts, which did not have to be modified for the Hungarian Railways, were accepted by the Hungarian Transportation Authority, too. The modified parts needed a modification or completion of their safety validation, and these had to be approved by the Authority (e.g. signal system). For the brand new parts (e.g. 75 Hz control) a new safety validation had to be created. Of course the interface between the new and old sub-systems (interlocking computer, PLC, block system, relay interface and their communication) also needed a safety validation.

The preparation of the safety cases was not the heaviest task, but rather the harmonization of these different types of documentation. The existing safety validations were prepared before the appearance of the new CENELEC directives, and they followed the directives of additional different standards. Between the new and old safety validation the so called "safety validation interface" had to be created in order to harmonize the different

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safety validations, and the whole package had to be matched with the new CENELEC directives. [15]

In the following section the safety suitability analysis of control PLC of the 75 Hz supply will be outlined.

Proofing the suitability of the 75 Hz control PLC

Railway application of the DIN V 19250 standard

As mentioned in the case of the electronic interlocking system in Tata station, a safety PLC is applied for the control of 75 Hz supply. Of course, it had to be examined previously whether the selected type of PLC is suitable for this application from a safety point of view. To decide this, the given application's requirements from the PLC had to be specified (matching the application and the requirement class) and this had to be compared with the safety requirements that the PLC can fulfill, i.e. from which requirement class does the PLC come.

The classification of the SIMATIC S5 115F PLC that was intended to be used in Tata was carried out in accordance with the DIN V 19250 standard during the type examination [7]. Thus, we classified the safety requirements of the control of the 75 Hz track circuits also in accordance with the mentioned standard.

To match a requirement class with a given application, 4 risk parameters must be taken into consideration:

- degree of the damage (S1...S4)
- staying in the danger zone (A1, A2)
- possibility to avoid the danger (G1, G2)
- probability of the occurrence of the unwanted event (W1...W3).

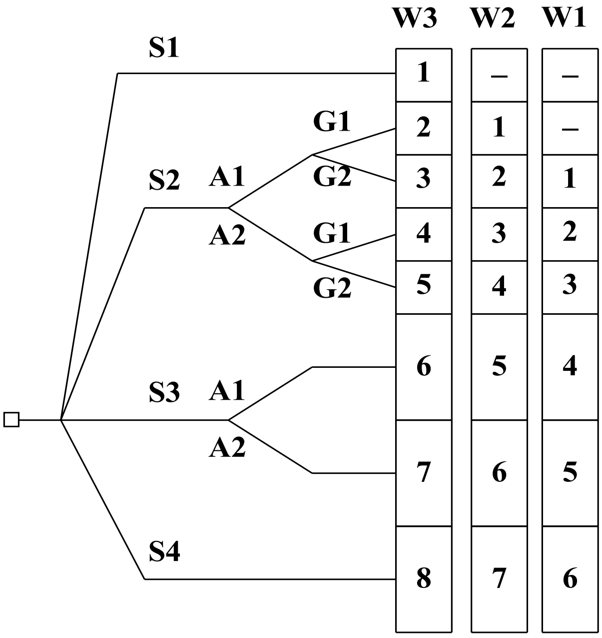

Fig. 2 Risk graph

The connection between the risk parameters and the requirement classes is shown on a risk graph (Fig. 2), where the lowest or mildest requirement class is referred to as 1 and the highest requirement class as 8 [3].

Although the DIN V 19250 is not a railway-specific, but an industrial standard, however with the consideration of some additional definitions for the interpreting of the risk parameters, it can also be applied in the field of the railway operation for the classification of the safety requirements. The required technical and operational arrangements that satisfy the demands of a given requirement class must be carried out in accordance with the DIN V VDE 0801 standard [1, 4, 10].

To match the appropriate requirement class with a given application, the application must be decomposed into sub-functions, and the examinations must be carried out for these sub-functions. To determine the sub-functions the customer requirements must be taken as a basis.

Supply of the 75 Hz track circuits

The 75 Hz track circuits are supplied with coded signal (code '1'...'4'), where code 1 orders the train to stop at the next signal, and code '4' allows to drive at the highest permitted speed. Codes '2' and '3' mean intermediate speeds. The basic safety task of the 75 Hz supply is to stop those trains with an emergency braking that are passing by a red signal at a speed more the 15 km/h [9].

To fulfill this requirement

- the 75 Hz track circuits must be supplied with code '1' (stop!) on a given length before the red signal,
- the track circuit section behind the signal must not be supplied, or only so that the aerial of the train may not receive any 75 Hz signal from the track. The latter is to solve so that the track section behind the signal must be supplied from that side where the train will enter on the track section, i.e. from the signal (Fig. 3).

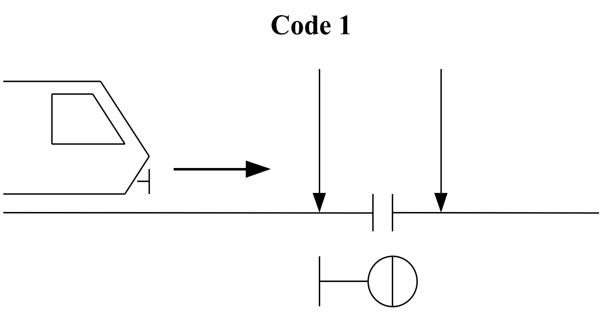

Fig. 3 Supply of the track circuits before and behind the signal

Another task of the 75 Hz supply that must be examined before the classification of the safety requirements is: the onboard repeater signal on the locomotive may not show higher speed than what the real signal beside the track shows. To this the supply code must correspond to the real signal, and in case of a failure it may only be lower. E.g. if the main signal allows 40 km/h speed, the supply may not be code '4' (maximum speed) instead of code '2', not even in case of a failure.

The task of the PLC is to select the required code and to control the safety relays which switch the code (Fig. 1). The code-switching relay circuit is so constructed that in case of a PLC failure or break-down, or in case of a relay failure, the supplied code can only be '1' (stop!).

Result of the Examination

We examined the possible operational cases, and to the mentioned functions we fixed the requirement class 5, with one exception. In one case the requirement class 6 was established. Since for an application always the highest sub-function is significant, for the 75 Hz track circuit control PLC the requirement class 6 can be established.

According to the type examinations of the TÜV Bayern, the S5-115F PLC satisfies the demands of the requirement class 6 of the DIN V 19250 standard [16], thus the selected PLC is suitable for the presented application, i.e. for the control of the 75 Hz supply.

Comparing of the safety prescriptions

Former prescriptions

Different safety directives and safety philosophies have been formed at the railways of the different countries during the development. From the flowing different technical applications have been developed the different safety validation procedures for the railway signalling equipment. A favoured of them in Europe is the "Directives to Technical Authorization of Railway Signalling Equipment" (Mü 8004), elaborated and being regularly updated by the *Central Office of German Federation Railways* (its new name is *Federation Railway Office, EBA*). These directives are not exclusively applied by the German Railway (DB), but many other railways and other railway signalling institutions use this directives' collection during their activity.

In the case of the Siemens's electronic interlocking system in Tata, these directives are also authoritative, since the safety validations for the previous applications of this equipment, e.g. at the DB, were also elaborated in accordance with the Mü 8004. In order to keep the consistency, it seemed to be practical to carry out the safety validation of the for the MÁV application changed or new system parts also on this basis.

The intention to a unified procedure, however, could not be totally successful, because as mentioned before the suitability of the control PLC of the 75 Hz supply could be validated on the basis of the DIN V 19250 standard. A further difficulty was that the Hungarian railway authorities, from the mid-90-s intended to take the new European standards as the basis for future applications in Hungary [13]. It meant for us to examine the compatibility of the former and the new standards or preliminary standards so that the existing safety validations previously elaborated by former prescriptions should not be created again, and only the necessary modifications and additions should be done.

The New Prescriptions

In frame of the elaboration of the new European standards, the DIN V VDE 19250 German standard used as a basis up to now is put into the *IEC 65 A (Sec) 123* international standard [5], and the DIN VDE 0831 which was compulsory for the railway signalling equipment will be transferred to the *EN 50129* European standard [11].

The requirement classes of the DIN V VDE 19250 appear in the IEC 65A (Sec) 123 standard as *Required Risk Reduction* in *8 levels,* signed with letters from 'a' to 'h'. From the Required Risk Reduction levels are deducted the *System Integrity Levels (SIL),* signed with numbers from 0 to 4. These levels form the base of the technical realization by the IEC 65 A (Sec) 123. The connection between requirement classification of the DIN V 19250 and the IEC 65 A (Sec) 123 is shown on table 1. [1]

Table 1

Requirement classes	Required Risk Reduction	System Integrity Level
DIN V 19250	IEC 65 A (Sec) 123	
1	a	0
2	b	1
3	c	1
4	d	2
5	e	3
6	f	3
7	g	4
8	h	4

The main target of the harmonization activities in the frame of the CENELEC is to establish the conditions for cross acceptance of the technical safety procedures in Europe. The elaborated draft standards (prEN 501xx) are based on international preliminary standards (IEC 65 A Sec 122 and Sec 123) and national safety directives e.g. Mü 8004 and RIA 23 (Directives for Software of the British Rail). From these, the basic safety principles were taken over and a well-structured, comprehensive preliminary standard was further developed [6, 8].

The common regulations of the different railways and the general application of former international (e.g. ORE) recommendations eased the euro-norming procedure. However, the differences mainly on the field of servicing and functionality form a considerable obstacle against the general introduction of cross acceptance.

A further purpose of the application of the new standards is to keep the future developments' costs, devoted to the safety only as high as the application really requires. To achieve this aim, 4 Safety Integrity levels have been created concerning the failure probability and the risk class of a system or system-part (table 2).

Table 2

Level	Safety Integrity	Descriptive expressions (alternatives)			
4	Very high	Vital	Critical	Safety critical	Fail-safe
3	High	Vital	Critical	Safety-critical	High-safe
2	Medium	Medium vital	Essential	Safety-related	Medium-safe
1	Low	Medium vital	Essential	Safety-related	Low-safe
0	Not defined	Non-vital	Non-essential	Non-safety-related	Non-safety related

The highest Safety Integrity Level is 4. This level is valid, for example, for railway signalling equipment or a train protection system. The lowest level is 1, which is recommended for simple safety applications. For non-safety applications the level 0 was formed. The required safety class is a function of the frequency and the significance of the hazard possibilities of the controlled process and the expected safety goal.

By the establishing of the hazard, the new preliminary standard has a different basis than the former one. From the risk parameters of the DIN V 19250, it does not contain the "staying in the danger zone" (A) and the "possibility to avoid the danger" (G). It defines the "degree of the damage" (S) and the "probability of the occurrence of the unwanted event" (W) parameters in another way, too. The probability of the unwanted event is shown as probability levels and is classified. The former deterministic and implicit probability approach is exchanged with a stochastic, explicitly on probabilities based approach [14].

The new preliminary standard defines the satisfactory safety as the probability that the technical process or the system suits the determined and proved safety requirements at any time until the uninstallation of the system.

If we include the Mü 8004 standard into the examination, we can state that it does consider neither the probability of the unwanted event, nor the degree of the damage. Furthermore the classification of the system safety requirements can not be found, which is otherwise ordinary in other prescriptions. Thus, according to the Mü 8004 any safety related system should meet the highest requirements (SIL 4 according to the euro-standards). The non-safety systems correspond to the SIL 0 of the euro-standards. The intermediate levels can not be handled by the Mü 8004 standard.

The connection between the requirement classes of the different safety prescriptions is shown on table 3.

Comparing the Mü 8004 and the euro-standards, the difference is obvious in the field of safety process and the approach to safety management [15]. The safety process required by the Mü 8004 is based on a static safety management approach. Practically it focuses on the required safety at the moment of the approval of a new system and does not or hardly contains any prescriptions in connection with the further phases of the system's life cycle. It presumes that the necessary and sufficient examinations to prove the existence of the safety can be carried out. Therefore the examiner's knowledge on the examined system is critical.

In spite of this, the new euro-standards are characterized by dynamic safety management. Obviously the regulation of the approval is similar to the Mü 8004, but the safety process is completed: the whole life cycle is covered by the regulation. Thus, the required level of safety and quality is assured in frame of a properly designed and controlled process. It also means that the approval examination is less emphasized in the process than in the Mü 8004.

According to the new euro-standards it is evident that necessary and sufficient examination of the classical approach can

Table 3

Requirement class	System Integrity Level	Safety Integrity Level	System qualification
DIN V 19250	IEC 65 A (Sec) 123	prEN 50129	Mü 8004
1	0	0	Not safety-relevant
2	1	1	
3	1	1	
4	2	2	
5	3	3	
6	3	3	
7	4	4	Safety relevant, fail-safe
8	4	4	

not be practically carried out. Realization of the additional considerations besides the previously known and unified examination considerations are the responsibility of the developer and the examiner. The realized hazards and the arrangements made for their correction can be followed up. The safety can be connected to and proved at certain levels of the system's hierarchy. The reviser does not need to know the equipment in total; his main task is to control keeping the rules.

Harmonization of the former and newer prescriptions

We can conclude that the two safety validation processes based on different approaches are not to be exchanged, and it is difficult to switch from one to the other. However, the importance of the difference between the above detailed regulations is decreased by several factors: one is that the Mü 8004 recommends to apply an ISO 9000 like quality management in the development and the manufacturing. Thus, the safety as a property of the product can be controlled and followed up with the product itself. Therefore, the result of the two different regulations in the developing and manufacturing phase can be equal.

The results of the examinations of the electronic interlocking system in Tata showed that the data and results gained from the safety validation process according to Mü 8004 can be reordered and completed to reach an end-documentation that meets the requirements of the euro-standards [13]. The differences of the two prescriptions in the safety process can be handled appropriately from the viewpoint of the approval. This allows us to apply previous Mü 8004 safety validations. Furthermore, it makes possible the creation of safety validations by the former directives for changed or new system parts and to integrate them into the safety process in accordance with the euro-standards.

This paper presented the correlation between the safety requirement classes of the different safety directives. The results of the examinations of the control PLC of the 75 Hz supply by the DIN V 19250 standard can be integrated into the safety process, carried out in accordance with euro-standards.

Reviewed by: M. Kunhart, J. Zahradník

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ZABEZPEČENIE ODSTUPU VOZIDIEL - VYUŽITIE SYNERGICKÝCH EFEKTOV MEDZI ŽELEZNIČNOU A CESTNOU DOPRAVOU!

MAINTAINING INTER-VEHICLE SPACING - USING SYNERGETIC EFFECTS BETWEEN RAIL AND ROAD TRAFFIC!

Tak ako doteraz, dopravné služby sú rozhodujúcim kritériom ekonomiky. Toto konštatovanie vytvára predpoklad pre zaoberanie sa rôznym smerovaním a bezpečnostnými zásadami pre dve dôležité základne dopravných systémov, a to: cestnú a železničnú dopravu. Cieľom je určiť, ako dva systémy môžu navzájom prispieť, každý zvlášť vybratými postupmi, k riešeniu a ktoré koncepcie v budúcnosti umožnia túto činnosť.

V železničnej alebo cestnej premávke má dodržanie rozstupu vozidiel priame účinky na viaceré kvalitatívne kritériá dopravného procesu a priepustnosti.

Rôzne teoretické možnosti a praktické aplikované zásady pre dodržanie rozstupu vozidiel sú popísané a odhadnuté so zohľadnením času, bezpečnosti a priepustnosti. Dnes sa používajú rôzne zásady v oboch systémoch, čo je pripisované sčasti historickému rozvíjaniu systému, ale aj jeho pomoci technickou podporou systému. Pretože obidva systémy umožňujú maximálnu dopravnú priepustnosť, je treba zvážiť jej závislosť od dodržiavania odstupu vozidiel.

Synergický potenciál umožní používať a v interdisciplinárnom prístupe zistenie a klasifikovanie dopravného variantu. V budúcnosti bude vozidlová elektronika vyvinutá s rovnakým cieľom a podobným náčrtom podmienok. Železničná doprava potom môže mať zisk zo série efektov cestnej dopravy a tak posilniť svoje trhové postavenie prostredníctvom poskytnutých riešení. Zhodné predstavy v oblasti základnej vozidlovo-traťovej (cestnej) informácie (digitálna mapa) potrebujú priechodné spoločné riešenia. V oblasti dopravného prúdu a automatiky, vodičovej riadiacej činnosti, spoločné štúdium a zdravý rozum prikazujú, že príde k smerovému vedeniu a vozidlovej ochrane.

Now as ever, transportation services are a decisive criterion of an economy. This constitutes the background for dealing with the various routing and protection principles for the two important land-based traffic systems: namely, road and rail transport. The objective is to determine how the two systems could benefit from the respectively chosen approaches to a solution and which future operating concepts this makes possible.

Whether in rail or road traffic, inter-vehicle spacing directly effects several quality criteria of the transport process, and vehicle throughput. The various theoretically possible and practically applied principles for maintaining inter-vehicle spacing will be described and assessed with regard to occupied time, safety, and throughput. Today, various principles are used in both system which is attributable in part to the historical development of the system but also to the possibility of supporting the system through technical assistance systems. For both systems the possible maximum traffic throughput is considered depending on maintaining inter-vehicle spacing.

Synergy potential can be used through an interdisciplinary approach to detection and classification of traffic scenarios. In the future, vehicle electronics will be developed with the same objectives and similar outline conditions. Rail traffic then can profit from the series effect of road traffic and thus reinforce its market position through affordable solutions. Identical concepts in the field of vehicle-based route information (digital map) will permit joint solutions. In the field of convoy formation and automatic, driverless operation, joint studies make sense when it comes to longitudinal guidance and vehicle protection.

1 Routing and Protecting Road and Rail Vehicles - More Than Just a Technical Challenge

1.1 The Social Significance of Transport

Now as ever, transportation services are a decisive criterion of an economy. In the EU 15, passenger traffic increased by more than 10 % during the period 1990-1996. During the same period, cargo transport increased by nearly 10 %. In order to be able to perform these services, investments totalling EURO 70 billion were made in 1996, thereof 65 % for road transport and 25 % for railways. Accordingly, roads and railways together require 90 % of total infrastructure performance. Of the total passenger traffic volume (approx. 35 passenger km per day), approx. 80 % was handled by individual automobile traffic. In 1996, however, there were also approx. 42,000 roadway traffic accident fatalities, which shows an annual decrease of 2-3 %; there were 900 fatalities in rail transport [3]. These figures clearly underscore the grave social

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importance of this issue and make it clear why the subject of safe mobility matters to all social classes, municipalities, and industry. Furthermore, they constitute the background for dealing with the various routing and protection principles for the two important land-based traffic systems: namely, road and rail transport. The objective is to determine how the two systems could benefit from the respectively chosen approaches to a solution and which future operating concepts this makes possible.

1.2 Quality and Performance of Road and Railway Transport

When considered from a "bird's-eye"-view, vehicles operate on traffic routes in traffic flows. These vehicles can be individually powered or coupled vehicle units that lay claim to use the infrastructure for changing location from A to B (routes). Within the meaning of general traffic theory, this claim is a demand (see [3]).

From the standpoint of demand (the infrastructure user), the occupation time or throughput time T it takes to cover route s is a unit of time, cost, and quality[1]. There are other units of cost and quality, for example, the speed $v = ds/dt$, the change in speed dv/dt, pollutant emissions and fuel consumption or intactness of the goods transported, but the subject of spacing has never been touched upon.

Within the meaning of traffic theory, infrastructure is a service facility that accommodates demand and/or provides the slots for meeting the demand (supply of infrastructure).

The supply of infrastructure results in

- Measurements of performance capability ratios, especially throughput (maximum, available, etc.) and
- The reliability and availability of the infrastructure [1]

The combination of supply and demand results in

- Measurements of operational performance, especially capacity utilisation of infrastructure, transitory values of demands (time, cost, quality ratios) as well as congestion figures (waiting time, probability of waiting, production time, etc.) [8].

The objectives of a demand centre for minimal occupation time to cover the route s and of an infrastructure provider for profitable capacity utilisation of the provider's infrastructure are not free of contradictions:

Both individual vehicles and vehicles or trains in traffic that is channelled into lanes have individual wishes with regard to occupation time (travel time, travel speed, speed/acceleration profiles, etc.). This leads to the task of principally organising convoys of heterogeneous vehicles and speeds so that these convoys ensure

- maximum fullfilment of the individual requirements (of the vehicles)
- maximum satisfaction of the requirements of the infrastructure operator (provision of slots, road/line availability...).

In this context, vehicles must be

- able to move quickly and safely in convoys
- able to overtake one another quickly and safely
- able to get into and out of a traffic flow quickly and safely
- able to move quickly and safely in intersecting traffic
- reliably protectable against other oncoming, flanking, and parallel vehicles.

Furthermore, the throughput through the infrastructure (measured in vehicles per time unit on average or by the income from a road/line price system) must be maximised.

The following principles of maintaining inter-vehicle spacing are evaluated on the basis of these demand from the viewpoints of

- *Occupation time of the demand* on the route s
- *Safety of the demand* in the traffic flow
- *Throughput* for an infrastructure cross-section.

The methods used for railways and roadways are compared for the aforementioned outline conditions in order to identify possible synergetic potential. On this basis, the repercussions for automated and driverless operation are considered.

2 Maintaining Inter-Vehicle Spacing - Principles, Possible Solutions and Assessment

2.1 Principles of Maintaining Inter-Vehicle Spacing[2]

Regardless of the type of solution, it is possible to state generally valid basic relationships for maintaining inter-vehicle spacing. The basic equation for maintaining inter-vehicle spacing results from the safety-dependent necessary inter-vehicle spacing l_B, which is the difference in the braking distances of both vehicles (without accounting for reaction time).

$$l_B = \frac{v_2^2}{2b_2} - \frac{v_1^2}{2b_1} \qquad l_B \geq 0 \qquad (1)$$

where l_B Necessary inter-vehicle spacing
b_1 Maximum braking delay of the lead vehicle

[1] The terms occupation time is defined here as they pertain to production technology (compare [9]). In the generally valid definition, these times consist of the components execution of production, extra time-tolerance for manufacturing inaccuracy, synchronisation time and waiting times. In the context that is relevant here, only the production times, i.e., the times for a driving process, are considered with various principles for maintaining inter-vehicle spacing. The theoretical foundations of t he conceptual axioms and the underlying models were set forth in [6].

[2] Compare especially [16] and [18]

b_2 Maximum braking delay, under any circumstances, of the following vehicle
v_1 Momentary speed of the lead vehicle
v_2 Momentary speed of the following vehicle

Safety is assured only if $l_B \geq 0$. A negative spacing would mean that the following vehicle would penetrate the lead vehicle. This does not yet include an additional margin of safety to cover, for example, errors in speed and distance measurement, idle and transition time in the reaction links of a spacing control, and changes in the length of trains due to changes in tensile force or incline. The use of equation (1) as a regulation for maintaining inter-vehicle spacing is called *"operation at relative braking distance".* Thus, the safety concept of maintaining inter-vehicle spacing takes the braking distance of the lead vehicle into account. If the lead vehicle, for example, is forced to halt suddenly by an accident, the following vehicle may drive into it.

To avoid this case, the braking distance of the lead vehicle is not taken into account when calculating l_B.

$$lB = \frac{v^2}{2b} \qquad (2)$$

In this way, provision is also made for an abrupt stop by the lead vehicle (borderline case braking distance of lead vehicle = 0) as far as the safety concept is concerned. This is called *"operation at absolute braking distance".*

If a maximum permissible speed is generally used in equation (2), this results in a regulation for maintaining inter-vehicle spacing that is known as *"operation at constant distance spacing".*

$$l_B = \frac{v_{max}^2}{2b} \qquad (3)$$

In this case, the same and thus constant distance which results from the braking distance at the maximum permissible speed is always prescribed regardless of the momentary speed.

2.2 Possible Solutions and Assessment

In the course of development of traffic control principles, among other things on the basis of the aforementioned theoretical regulations for maintaining inter-vehicle spacing, the methods described below were introduced or used (compare [16]). Furthermore, methods that will become feasible in the future are described.

- *Operation at Visual Range*
  The driver of the following vehicle controls the distance between the lead vehicle and the following vehicle based on his view of the route ahead of him. The driver is responsible for safety; there are no technical assistance systems to support him in this task.

In road traffic, there are various rules of thumb for maintaining spacing relative to the lead vehicle, for example, "spacing relative to lead vehicle equals one-half speedometer distance", in other words: $\Delta s = K1/2v_{Tacho}$. The proportional constant K computes to 1.8 and has the dimension of a time. Thus, the recommendation means operation with a constant time interval of 1.8 sec. regardless of speed (this time also accounts for the motion of the lead vehicle as well as the reaction time of the driver of the follow ing vehicle - compare "operation at relative braking distance"). In practice, vehicles also operate at shorter intervals depending on the operator's willingness to take risks when travelling in a convoy. Theoretical and practical studies have shown that maximum system throughput for convoy trips is attained at a value of $K \approx 1.2$. At $K < 1.2$, the propensity for spontaneous tailbacks (instability) increases. Temporary disturbances are reduced at $K \geq 1.4$ and resolve themselves; in other words, a steady-state traffic flow is attained (for more remarks on this topic, see, among other sources, [11] and [12]).
Because of the longer braking distance, "visual operation" is used in rail traffic only at very low speeds: trams at v_{max} = 70 km/h or trains in emergency operation (v_{max} = 40 km/h) or shunting operations (v_{max} = 25 km/h) [15].

Occupation time
In road traffic, the occupation time depends on the driving behaviour of the participating drivers in the convoys. Because of the strong influence exerted by individual drivers, it is impossible to map the system behaviour deterministically. Theoretically, the minimum occupation time would occur when there is only one vehicle in segment s at a time. As long as multiple vehicles in segment s do not influence one another (so-called free or independent traffic), the minimum occupation time (depending on vehicle speed) would also apply. Inter-vehicle spacing decreases with increasing density. This does not change the occupation time as long as the vehicles do not influence one another. In practice, however, uncoordinated acceleration and braking movements then occur, which diffuse through the convoys in the form of waves. Then speed is reduced and the occupation time increases. At extremely high density, the speed may drop to zero (tailback at $v = 0$), in which case the occupation time increases accordingly. Thus, even without barring accidents, occupation times may become very long in road traffic while they usually remain short where railways are concerned because of the timetable.

Safety
The level of safety attainable in road traffic depends on the driving behaviour of the participating drivers and their willingness to take risks. To begin with, human beings do not pose an increased risk in terms of reliability when piloting vehicles and/or in the special case of maintain inter-vehicle spacing (see also [17]). Rather, the situation becomes critical under special traffic conditions, for example, dense convoy traffic, abrupt braking in the convoy, difficult road conditions, driver fatigue, etc.. "Results of traffic measuring show that especially on motorways, vehicles operate within or even under the zone of minimum safety and the inter-vehicle spacing is influenced only

slightly by the speed. This is apparently attributable to a gross underestimation of the necessary assured clear distance on the part of drivers“ ([18] - S. 87). Road traffic does not attain the same level of safety as rail traffic which is also demonstrated by the accident statistics when averaged over many years.

In rail traffic, “visual operation“ is a special mode of operation. The safety standards inherent in the modes of operation of standard-gauge railways are virtually attained through fixed speed limits and a precise set of regulations for special modes of operation.

Throughput

Depending on traffic density, throughput in road traffic first increases to a maximum, and then, with additional increases in density (increasingly smaller inter-vehicle spacing) reduces erratically (so-called fundamental diagram of road traffic - Fig. 1).

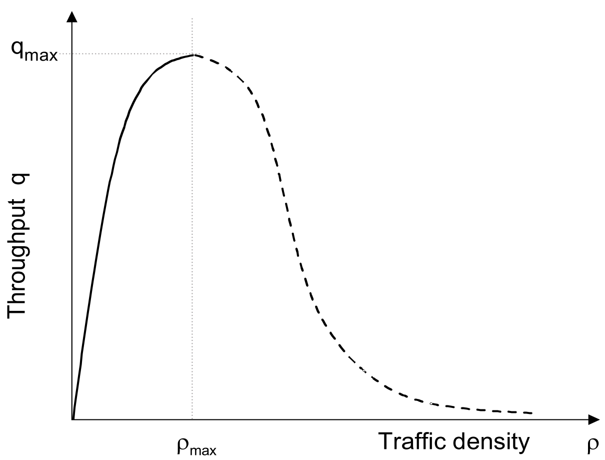

Fig. 1 Fundamental Diagram of Road Traffic

The throughput of rail traffic during “visual operation“ is of course very low, because according timetables do not provide for dense traffic, but rather for free, independent traffic; it is a special mode of operation that is not used in normal operations.

- *Operation at Time Intervals*

In this principle, a vehicle is allocated a fixed time period that it is permitted to use for carrying out its trip (“timeslot“). As a rule, a start time and an end time are each assigned to a fixed position on the route. Within the timeslot, the vehicle is permitted to be between the two positions. The length of the timeslot and the correlating accuracy of location directly influence all assessment values. Operation at time intervals is a longstanding method in railways and was used when routes were not very busy. With the traditional technique, it was only possible to monitor the time interval between trains at departure. Thus, for reasons of safety, large time intervals between trains and low system throughput resulted. Additional auxiliary technical systems for increasing system safety were not used. The timeslot operation method is not used in road traffic. The aforementioned recommendation to drive at “one-half speedometer distance“, however, amounts to a modified form of the principles presented here.

When modern methods (for example, radio-controlled train control) are used, new possibilities may present themselves in rail traffic since precise reporting of train positions and radio-supported cab signals make it possible to shorten the timeslots.

Occupation time

The occupation time in the system depends on the length of the timeslots and this, in turn, depends on the accuracy with which the vehicles can be located. The higher the locational accuracy, the more the timeslots and thus the occupation time can be shortened (threshold: duration for braking from maximum system speed).

Safety

The attainable level of safety depends on the feasibility of observing the assigned timeslots and the route assigned to this time.

Throughput

The system throughput can be optimised through precise methods for determining vehicle locations.

- *Operation at Fixed Distance Spacing*

In operation at fixed distance spacing (compare equation (3)), the route is divided into fixed sections (in rail traffic, this is known as “blocking“). Only one vehicle is permitted in each section. The minimum length of a section depends on the maximum braking distance of all vehicles (within the system of Deutsche Bahn AG, for example, 1000 m at a maximum speed of v_{max} = 160 km/h). Operation at fixed distance spacing is the standard procedure for controlling and protecting trains running one behind the other. Today, it is virtually the only method used in rail traffic. Even current developments draw repeatedly on this principle. This method plays virtually no role whatsoever in road traffic.

Occupation time

The occupation time is influenced by the length of the fixed sections into which the route is divided. The longer the section, the longer the mean occupation time of a vehicle in the system. This effect applies disproportionately at low speeds, because the length of the section is proportional to the maximum system speed. In mixed traffic, slow and fast vehicles obstruct one another, which leads to an additional increase in the occupation time due to the increase in the waiting time (according to timetable) (Fig. 2 - compare [7] and [15]). The figure shows expected value ET_W of the loading of the system in trains per time unit. This waiting time function has a progressively increasing run. It converges with a loading value ρ that is characterised as the maximum operative capability LF_{max}.

Safety

This principle for maintaining inter-vehicle spacing offers the highest standard of safety in rail traffic with the associated train

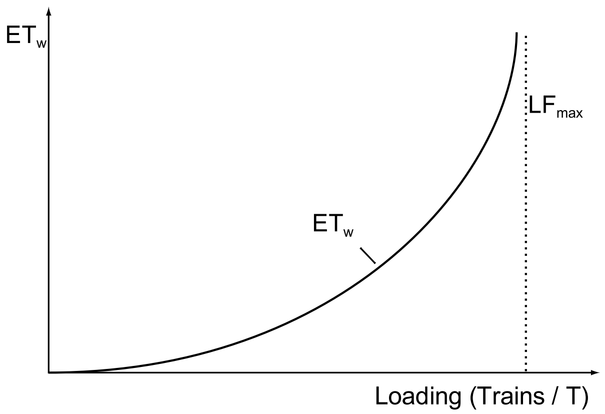

Fig. 2 Waiting Time Function in Rail Traffic

protection systems (signals, axle-counting circuits, track circuits, etc.). Additionally, the driver is supplemented and safeguarded by train running control and protection systems (for example, punctual train running control or linear train running control). Thus, fail-safe behaviour is attained. The system will not leave the secure state in the event of one technical or human error.

Throughput
The throughput of the system depends on the length of the fixed sections of the route ("blocking"). Especially at low speeds, this subdivision leads to low system throughput. In new developments ("high-performance block"), the block length is shortened through additional technical equipment, and thus the system throughput is increased (compare, among others [22]).

The objectives "maximisation of throughput" and "minimisation of occupation time" are not free of contradictions. In road traffic, both objectives are assessed using the so-called "rating" (= traffic performance per hour or the product of traffic intensity and speed) - [18] - S. 80.

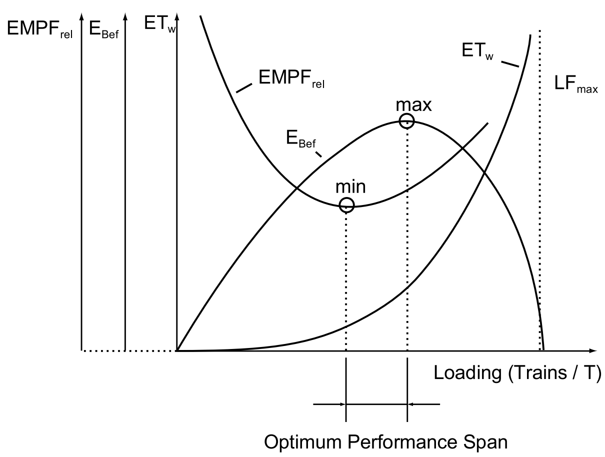

Fig. 3 Optimum Performance Span in Rail Traffic

In rail traffic, [7] an attempt has been made to find an optimum operating range (Fig. 3 - compare also [15]). The lower threshold of this optimum performance span results from the minimum of the relative sensitivity of the system $EMPF_{rel}$. The relative sensitivity is the first partial derivation of the waiting time function (introduced above) to the load ρ, in relation to the value of the waiting time ET_W. The upper threshold of the band of optimum system performance results from the maximum transport energy E_{Bef}. The transport energy is the product of the system load and the mean transport speed which decreases with increasing loading. Operational experience to date has shown that when this theoretical view is applied, the practical loading of the system should rather be set toward the bottom threshold of the optimum performance span.

- *Operation with Variable Distance Spacing (Rail Traffic: Positive Train Separation)*
In this variant, the safety distance spacing is coupled to the following vehicle. A differentiation is made between operation at *maximum braking distance* (equation (3), but with non-stationary distance spacing) and operation at *absolute* (equation (2)), or *relative braking distance* (equation (1)). In the first case, the distance spacing equals the maximum occurring braking distance. When operating at absolute braking distance, the speed and braking characteristics of the following vehicle are taken into account, while the braking distance of the lead vehicle is additionally used for the relative braking distance.

Occupation time
The occupation time in the system is relatively short in comparison to the method of maintaining inter-vehicle spacing described above, because the incidence of mutual interference is minimal with or without a timetable even with mixed traffic (non-uniform vehicle speeds and/or lengths).

Safety
In rail traffic, the level of safety attainable when operating at maximum and absolute braking distance equals the high level of safety of the principle "operation at fixed distance spacing". This likewise requires technical auxiliary systems for vehicle protection and vehicle control, the technical design of which, however, differs from the systems that have been known and introduced to date (for example, vehicle-based location and train integrity monitoring).
In rail traffic today, operation at relative braking distance is considered critical in terms of safety. Fixed obstacles along the route lead to problems, especially with dense traffic. Moreover, use of this principle in rail traffic is prohibited under currently valid regulations.

Throughput
System throughput can be maximised in particular with the approach "operation at relative braking distance". Here it is technically possible to reduce inter-vehicle spacing to "zero" and thus attain maximum throughput.

The aforementioned methods for maintain inter-vehicle spacing are of varying importance for the road and rail traffic segments. The methods must be assessed differently with regard to the attainable levels of safety, as shown above. With regard to the occupation time and/or the throughput or, more generally, with regard to the traffic energy of the system, comparable conclusions can be drawn.

Fig. 4 shows the basically attainable operative capability of the various methods using the example of ICE train trips in rail traffic ([19]). The diagram is normalised to the inter-vehicle spacing maintenance principle "operation at constant distance spacing with station and warning signals" (Q_i/Q_{HV} = 1.0). Various operational cases of ICE train trips are considered. The influence of locational accuracy on the operative capability of the system is apparent. With the principle "operation at relative braking distance", it is possible to increase maximum throughput by a factor of up to 4.36 in comparison to the reference case. Additional increases would be possible through techniques such as convoys or rendezvous techniques. In both traffic systems, these considerations must always be made from the point of view of the required level of safety and the currently valid regulations. Rail traffic is at an advantage in this connection, because the lower number of degrees of independence i n the rail system offers better possibilities for technical support with the objective of a higher level of safety.

3 Technical Solutions

3.1 Rail Traffic[1]

Besides application of the prescribed operating procedures, route- and vehicle-based technical equipment is also used to implement the aforementioned methods of maintaining inter-vehicle spacing. In the process, train protection systems are used which, among other things, are responsible for protecting trains running one after the other - in other words, for maintaining the necessary spacings - without intervening directly in the train control system.

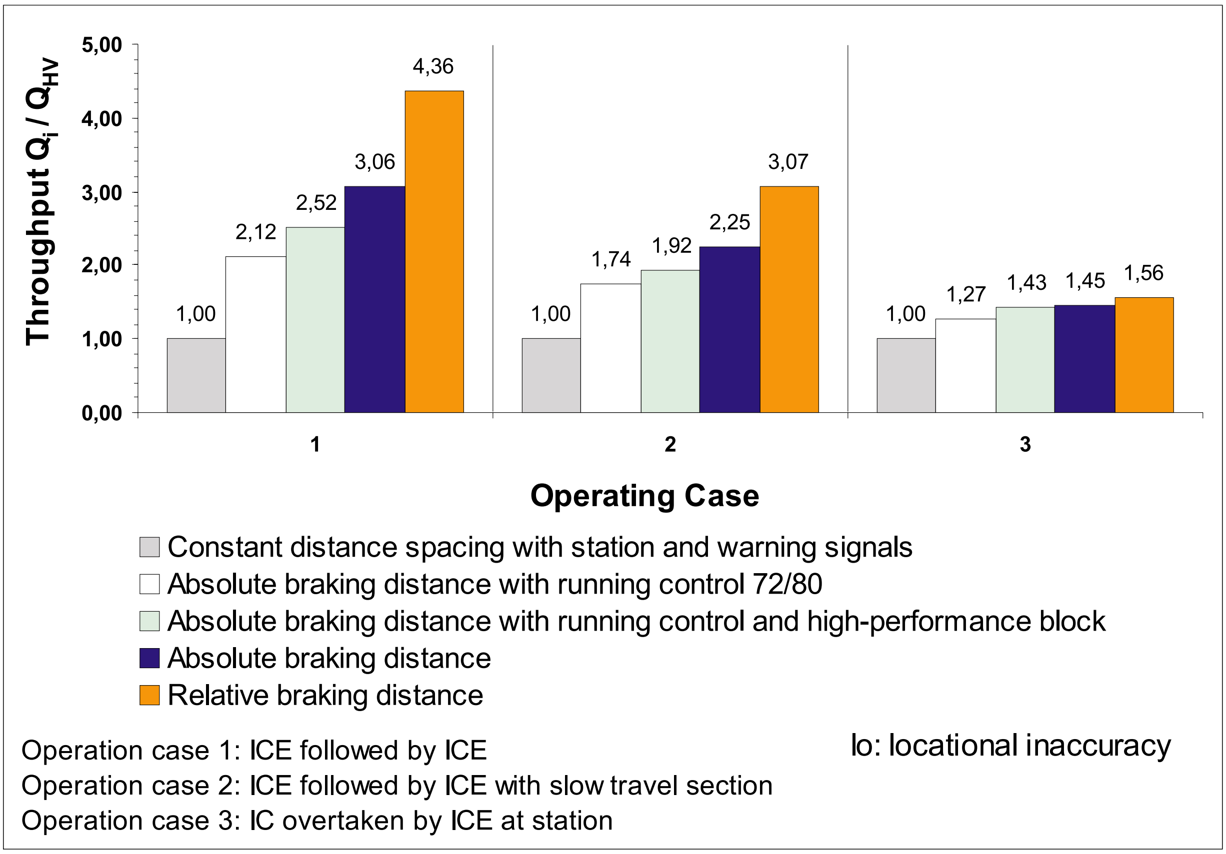

Fig. 4 Normalised maximum throughput Q_i/Q_{HV} of various regulations and systems for maintaining inter-vehicle spacing on newly constructed ICE routes for various operating cases (compare [19])

[1] The technical safety systems and train running control systems have developed in very different directions over many decades. Depending on the high service life of the components, many solutions remain in service even today. A description of this complex family of solutions would far exceed the bounds of the problems under discussion. For this reason, only a few technical implementations are addressed as examples.

One example is a typical facility for operating at fixed distance spacing. In this case, each block of a route is optically protected by an entry signal that is visible to the driver. Due to the long braking distances and limited visibility, at higher speeds, an additional signal (warning signal) that conveys information about the position of station signal is provided at a great distance from the station signal. To monitor the actions of the vehicle driver, facilities can be provided for, at a suit able distance from the signal equipment, which together with equipment aboard the vehicle can detect when the maximum permissible speed is exceeded or the vehicle driver fails to carry out an operating action at this point and, if necessary, trigger the brakes (punctual train running control "PZB").

If one wants to boost system performance (for example, by shortening block distances), then continually active (linear) train running control systems must be used to ensure compliance with the necessary spacings. Moreover, these systems serve to support and monitor the vehicle driver. In the event of driver error, the system will maintain the safe state (fail-safe behaviour).

Safety equipment in rail traffic was originally mechanical or electromechanical in design and is still in use in this form today. As in other fields of technology, today electronic systems are being substituted in place of mechanical solutions for control tasks. Increasingly, modern communications technologies and powerful electronic components are being used in these systems (for example, radio-based technologies in combination with GPS location for indirect determination of spacing). Furthermore, there is a clear trend toward eliminating complex technology from the route and the stationary equipment and putting it inside the vehicles instead. This should reduce the fixed costs and maintenance outlay for the railway operation at the expense of transport-related costs.

3.2 Road Traffic

Today's road traffic is characterised by operating with short spacings, fast-changing scenes, and convoys. There is virtually no route technology to support the maintenance of inter-vehicle distance, aside from the boundary post spaced at 50 m, which can help the driver to estimate distances. Operation is according to the principle "operation at visual range" (see above). Depending on his/her mentality, the driver of the following vehicle follows at absolute braking distance or (if he or she is prone to take risks) at relative braking distance by allowing for the speed of the lead vehicle in his or her braking distance. Maintaining inter-vehicle spacing depends almost entirely on the driver's assessment ability, for example, with regard to the traffic situation, vehicle braking distances, the respective road conditions, etc.. For these cases, vehicle-based technical assistance systems that also assist drivers in taking responsibility for safety (driver assistance systems, for example, ABS, ASR, outside temperature indicator, sleep alarm, proximity warning radar). All systems are, as a rule, vehicle-based; in some cases, they use various items of information from outside the vehicle in data processing and display and control technology. Various methods of determining the distance to the lead vehicle were investigated and, in part, implemented in devices.

- *Radar Technologies - Doppler Radar (Example: Distronic)*
  One example of an application of Doppler radar technology to the problem of maintaining inter-vehicle spacing is Daimler-Chrysler's Distronic proximity-controlled cruise control (Fig. 5-[14]). The system constantly keeps road vehicles at the correct distance from the vehicles in front of them. An electronic processor automatically activates the brakes if the distance to the vehicle ahead is reduced and accelerates automatically to the programmed target speed again as soon as traffic density permits (cruise-control function). The heart of the system is a compact radar antenna mounted behind the radiator grille which incorporates three interrogator-responder units. These units continually send out their signals at an angle of three degrees and cover all three lanes of the motorway at a distance of approx. 80 metres. If the short-wave radar impulses (77 Gigahertz) hit an obstacle, they are reflected and change frequency in the process. A digital signal processor computes the relative speed between the two vehicles on the basis of this frequency change, while the distance is computed based on the transit time of the reflected signal. Normally the system is set for a specific time interval. The speed of the lead vehicle also flows into the computation of the time and distance intervals. One interesting fact is that this does not require any technology along the route.

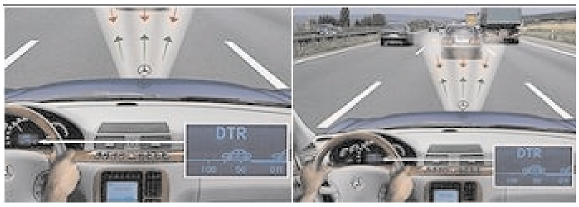

Fig. 5 The Distronic's radar antenna covers all three lanes

- *Optical Methods/Radio-Based Methods (Example: Electronic Drawbar)*

Fig. 6 An electronic drawbar as a prototype implementation for coupling two lorries

3.3 Similarity and Differences in Maintaining Inter-Vehicle Spacing

Principle of Maintaining Inter-Vehicle Spacing	Rail Application	Road Application	Technology Along the Route	Vehicle Technology	Potential for Synergy
Operation at visual range	Only in special modes of operation and emergencies	Standard procedure today	Rail: none Road: roadway markings, roadside borders	Rail: none Road: headlights; Compare operation at relative braking distance	
Operation at time interval	No longer used today. Potential for innovation through new technologies!	Irrelevant (exception: modified form "Distance = half speedometer")	Rail: none Road: irrelevant	Rail: none Road: irrelevant	
Operation at fixed distance spacing	Standard procedure today	Irrelevant and/or is not applied	Rail: signals, switches, INDUSI punctual train running control, track conductor, axle counting circuits Road: irrelevant	Rail: secure vehicle computer, wheel pulse generator, processing equipment, punctual and linear train running control Road: irrelevant	Vehicle control methods, monitoring of dangerous spots, approaching dangerous spots (Rail–> Road)
Operation at maximum braking distance ("moving block")	Selective implementations exist. Will soon be state of the art.		Rail: Balise transmission system Road: irrelevant	Rail: precise location method (balise reader, GPS), train integrity monitoring (train length), secure vehicle computer Road: irrelevant	
Operation at absolute braking distance ("moving block")	Selective implementations exist. Will soon be state of the art.	Used in combination with operation at visual range and driver as control (assistance system).	Rail: Balise transmission system Road: none		
Operation at relative braking distance ("moving block")	Currently the subject of research. Potential for boosting performance. Reservations with regard to safety.	Proximity-controlled cruise controls by various automobile manufacturers (for example, Distronic by Mercedes Benz)		Rail: Obstacle detection sensors Road: Doppler radar with subsequent high-performance processing	Radar sensors with subsequent high-performance processing (Road –> Rail) Obstacle detection (Rail <– –> Road
Convoy operation / rendezvous techniques	Currently the subject of research. Increased potential for boosting performance as well as advantages with regard to energy consumption. Reservations with regard to safety.	Electronic drawbar is currently in the research stage.	Rail: none Road: none	Rail: multiple traction control, train coupling and sharing possibilities Road: optical sensors, high-performance processing, image processing	Optical sensors, image processing, high-performance processing (Road –> Rail)

Under the auspices of the co-operative European research project "Promote Chauffeur", researchers have been working on development of driver assistance systems for utility vehicles since 1996 ([23]). One of the results of this was Daimler-Chrysler's 1 June 1999 presentation of the "Electronic Drawbar" in a research vehicle (Fig. 6). In a coupled lorry unit consisting of two vehicles, the lead vehicle is steered conventionally. The second vehicle follows the first and is steered actively and automatically by a longitudinal and transverse steering system. This process is implemented without any mechanical connection whatsoever between the vehicles.

The heart of this "electronic drawbar" consists of two onboard computers, one in each vehicle, which interconnect all data pertaining to the vehicles and their surroundings. There is a constant 2.4 Gigahertz radio link between the vehicles. Besides the radio link, the vehicles are additionally connected by an optical contact: two video cameras in the rear vehicle continually scan a special code pattern, consisting of infrared lamps, on the back of the lead vehicle. On the basis of the images delivered by the cameras, an image processing system not only calculates the distance between the vehicles, but also detects changes in the direction of the lead vehicle. The second vehicle follows the first and is automatically supplied with all data via the cab of the lead vehicle. The second vehicle steers, brakes, and accelerates just like the first one, in the process maintaining a variable, speed-related distance ranging 6 - 15 metres. Technically, the lorry can travel at speeds of up to 80 km/h. The mini-convoy can handle curves with a radius of up to 50 m.

Thus, this system operates at distances less than the braking distance of the following vehicle, but for now only in the trial stage of operation.

4 Technical Potential for Synergy

4.1 Obstacle and Distance Sensors

If in future maintenance of assured clear distances between vehicles in road and rail traffic is to be supported by vehicle-based systems, then both systems must measure the basic physical quantities speed, position, and distance. Likewise, in the future, detection of obstacles (stationary and moveable) will become increasing important in both systems, for example, for automatic driving processes. A good place to begin with is a joint examination of suitable sensors. The short list could include the sensors listed below:

- GPS- and radio-based location for determining positions at long distances (indirect)
- Radar sensors (Doppler radar) for medium distances
- Optical sensors for short distances
- Radar and optical methods of detecting obstacles and/or registering scenarios

Due to the differences between road and rail traffic at average speeds of travel and the braking distances, however, the outline conditions for such sensor systems may vary considerably. Nevertheless, similar vehicle-based systems can be used as supplements and solutions for special cases, with which for example, through early warning of a crash that is no longer avoidable, the consequences of the accident can be reduced through initiation of appropriate protective measures. These measures include intervention in the brake control system and triggering elements in the vehicle to increase passenger safety.

4.2 Vehicle Electronics

The vehicle-based electronic processing systems in use today in both spheres of application are generally distributed microelectronic computer systems. Due to the spatial separation of the systems, serial communications buses will be used to couple the components. Comparable safety levels must be met for both the control components and the communications buses. Likewise, the requirements for real-time data processing and observation of deterministic time conditions (note the difference: in a maximum time vs. precisely at this time) with both systems. Specifically, potentials for synergy should be reviewed in the areas

- Safe computer system architecture
- Safe time-deterministic communications bus
- High-performance processors
- Operating systems and runtime environments for safe embedded SW processes
- SW solution modules for comparable functionalities (for example, braking curves, algorithms for longitudinal guidance, speed-controlled maintenance of inter-vehicle spacing...)
- Design and development processes for developing safe embedded systems.

For reasons of cost, electronics system vendors in both spheres of application must endeavour to use the cost advantages of a larger series (economy of scale). Thus in any case, the railway industry will carefully consider whether the aforementioned components and solution functions can be carried over from the road vehicle sector with its comparatively large series. Until now, however, this was too often prevented by specific design and licensing regulations, the adaptation of which - even if technically possible - always constitutes a mid- to long-term process.

4.3 Approaching Dangerous Spots

In rail traffic, the principle of operation at visual range, which is predominant in road traffic, has been replaced for reasons of physics by other approaches to maintaining inter-vehicle spacing. Thus, there are limits to the ways in which the assistance systems introduced for supporting the driver can be applied to railways. Refinement of signalling technology infrastructure in road traffic will progress only slowly, in small steps. This means that procedures for approaching dangerous spots will continue to differ significantly from one another in future. Since vehicle-based electronic signalling and monitoring equipment will be available for both types of transportation - even if for different reasons -

synergy can be anticipated when setting up and using electronic map systems. These map systems would not only describe the routes, but also clearly indicate dangerous spots; the information in these systems would be adapted dynamically to changing circumstances. The methods for this dynamic adaptation of the information - if necessary, even automatic learning from specific traffic situations - can be implemented in the same or similar ways.

4.4 Convoy Operations and Rendezvous Techniques

The "electronic drawbar" concept described above is an attempt to introduce the rail traffic concept of "marshalling", with appropriate modifications, to road traffic. In keeping with the pre-requisites of road traffic, the only approach possible here is a vehicle-based one that relies on the aforementioned equipment for maintaining inter-vehicle spacing.

The technical solutions found in road traffic can be reapplied to certain areas of rail traffic. They will be interesting when engineers want to dispense with mechanical coupling mechanisms in order to reduce weight and expense in ultralight vehicles, but without giving up the advantages of marshalling. These advantages are not only flexibility in operation, but also potentially higher capacity utilisation of routes. In implementation, however, varying throughput values will result due to the variou s outline conditions such as masses, locational accuracy, prescribed inter-vehicle spacing, and other factors. Nevertheless, procedural similarities in forming convoys, dissolving convoys, getting into lane (analogous model switching and lane changing), getting out of lane (analogous model switching and lane changing), and convoy speed permit joint consideration of many aspects of this complex of problems. Thus, synergetic effects are anticipated in the area of various methods for partial solutions to the problem.

4.5 Automatic and Driverless Operation

In the field of automatic and driverless operation, rail traffic has consistently taken advantage to date of its systemic advantage of pre-existing tracking. Thus, automatic and driverless operation has been instituted in many places. The following table presents selected sample system solutions.

Besides the systems listed above, there are also many other systems in operation or preparation. All systems run on selected and demarcated travel ways or with a special operating permit. This is generally due to regulations that demand exclusion of danger to human beings and animals that may cross the travel way purposely or inadvertently. Automatic, driverless operation in the standard-gauge railway system requires that the regulations be amended without lowering the established high standard of s afety in rail traffic. Work in this field is pressing ahead in various places around the world.

When it comes to automatic, driverless operation, road traffic has the disadvantage of the lack of transverse vehicle guidance. Moreover, the road system entails an additional degree of independence in comparison to the rail system. The resulting complex traffic scenarios make system automatisation considerably more difficult. Nevertheless, there are various systemic approaches for "seeing and autonomous research-stage vehicles" (compare, among others, [2]).

In this field, synergy will arise primarily in the area of sensor problems (see above), convoy operations (see above), longitudinal guidance, and vehicle protection. With regard to vehicle protection, in this connection, it is primarily interdisciplinary studies of predictive accident detection and initiation of measures to protect people and passengers that will lead to success. It is fairly likely that the strategies for driving processes will be relatively different.

5 Summary, Outlook, and Recommendations for Action

Whether in rail traffic or road traffic, inter-vehicle spacing has an equally direct effect on the occupation time of vehicles in the system, the safety of the transport process, and vehicle throughput. In this context, the parties participating in the transport process, namely system users (users of the infrastructure) and system operators (infrastructure providers) have very different and in part contradictory criteria for optimisation.

The various theoretically possible and practically applied principles for maintaining inter-vehicle spacing have been described and assessed with regard to occupation time, safety, and throughput. Today, various principles are used in both systems,

System	Principle	Characteristics
Docklands Light Railway (London - [21])	Wheel-rail system	Automatic, driverless operation, max. speed 80 km/h, vehicle length 28m, capacity 284 persons/vehicle
People Mover System (various airports world-wide)	Rubber-tired vehicle on elevated travel way	Automatic, driverless operation, max. speed 50 km/h, max. vehicle length 58m, max. capacity 400 persons per unit
U4 System (Frankfurt, Germany subway system - [13])	Wheel-rail system. Subway system converted for automatic operation	Automatic, driverless operation, point-to-point connection as part of an existing subway system, pilot application, max. speed 80 km/h
Automatic signal-controlled traction vehicle (SST - [5])	Wheel-rail system in pilot operation with special operating permit	Fully automated operation on a 13km route, cargo transport as required, individual vehicles

which is attributable in part to the historical development of the system but also to the possibility of supporting the system through technical assistance systems. On the other hand, it is possible to consider for both systems the possible maximum traffic throughput of various principles for maintaining inter-vehicle spacing and this was done in a comparative presentation. In any case, the only way to increase the throughput of the system is to shorten the inter-vehicle spacings. On the other hand, short inter-vehicle spacings with uncoordinated mutual relative movements can lead to longer occupation times. In any case, a new principle for maintaining inter-vehicle spacing must always be introduced without degrading established standards of safety. In this connection, bounds are set by the valid regulations in both systems. A review of regulations in light of modern HW and SW technologies could eventually open up new paths.

The technical solutions being applied in practice today differ widely. Rail traffic is still founded largely on route-based technology. This technical feature is being removed in modern developments. In this connection, rail traffic is moving closer to road traffic, where today, by nature, the technical assistance systems offered are largely vehicle based. Thus, the greatest potential for synergy between the two systems is also in the field of distributed and intelligent vehicle-based solutions for vehicle guidance and protection [10].

In the field of *sensor systems for detection of obstacles and distances,* besides development of sensors on the basis of various physical effects, the main opportunity which presents itself is that of joint studies of signal analysis and processing ("sensotronics"). Synergy potential can also be used through an interdisciplinary approach to detection and classification of traffic scenarios. In the future, *vehicle electronics* will be developed with the same objectives and similar outline conditions. In this connection, rail traffic can profit from the series effect of road traffic and thus reinforce its market position through affordable solutions. Where *approaching dangerous spots* is concerned, identical concepts in the field of vehicle-based route information (digital map) will permit joint solutions. In the field of *convoy formation* and *automatic driverless operation,* joint studies make sense when it comes to longitudinal guidance and vehicle protection. In the field of vehicle protection, it primarily relates to predictive accident detection for the purpose of protecting persons and passengers.

In any case, existing systems cannot be adopted without modification, due to the varying outline conditions. They do, however, constitute a technical basis upon which system solutions can be created without excess outlay in each respective system. Furthermore, when researching future solutions, it imperative to first always follow an interdisciplinary approach, in order to take full advantage of the potential for synergy that undoubtedly exists.

Reviewed by: M. Steiner, J. Majerčák

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Hermann Knoflacher *

NAPRIEK 110 ROKOM LILLOVHO ZÁKONA - 110 ROKOV ZÁKLADNÝCH CHÝB V DOPRAVNEJ VEDE

IN SPITE OF 110 YEARS OF LILL'S LAW - 110 YEARS BASIC MISTAKES IN TRANSPORT SCIENCE

Lillov zákon z roku 1889 implicitne obsahuje tzv. „časovú konštantu" pre mobilitu, ktorá sa v posledných desaťročiach objavuje v mnohých empirických štúdiách na celom svete. Môžeme vidieť, že Lillov zákon sa dá odvodiť zo zákona ľudského správania sa, ktorý objavili Weber a Fechner v 19. storočí. Poznanie tohto zákona nám umoží lepšie pochopiť mechanizmus moderných dopravných systémov a ľudského správania a nájsť riešenia, ktoré spolu navzájom súvisia.

Lills law, published 1889 includes implicitly the so-called "time constancy" for mobility which was found in many empirical studies during the last decades, worldwide. It can be shown that Lills law can be derived from a more basic human behaviour law, discovered by Weber and Fechner in the 19th century. The knowledge of this law helps us to a better understanding of the mechanisms of modern transport systems and to find solutions which are more cause-related.

In 1889 Eduard Lill, a senior Inspector of the k.u.k. Austrian "Nordwestbahn", published the "Basic Law of Person Transport" (1). This law was based on Lill's observation that tickets for shorter railway trips were sold more often than tickets for longer railway trips. Analysing the statistics of his observations, he derived the following fundamental law:

$$M = R \times d \qquad (1)$$

Here M is defined as the so-called "Travel Value". R is the number of trips going out from a village or a city and d is the distance of these trips (Fig. 1). If the number of inhabitants does not change and also the economic conditions remain the same, the "Transport Value" M is constant. Lill proved this law by analysing the Statistical Data of the Austrian "k.u.k. Nordwestbahn" and the "Süd-Nord-Deutsche Verbindungsbahn". Lill's law is well known in Transport Economics and Transport Planning since this time. It has been taught at many Universities - but obviously it has not been understood in a proper way. The fast development of the mechanical transport modes in the last two centuries has not left enough time to study and, therefore, understand the system effects properly. If Lill's law and his ideas would have been used as a basis for further studies, the transport sector and transport planning might have developed in a quite different way.

After the Second World War, the European transport science became dominated by the American view. The Europeans were very impressed by the American Transport System and followed uncritically what the US Transport Science produced and recommended. So the European view of the transport system was narrowed down. It was reduced to motorized cars forgetting all the other modes. The transport science became an ideology, a kind of religion and was taught at the Universities in this way until today. The Highway Capacity Manual became a kind of bible for traffic engineers and transport planners. The reality was not seen anymore and so the ground for unbelievable mistakes was prepared.

Because only parts of the system were seen, the system effects were not understood and not recognized. The outcome of this process is obvious today: Degradation of quality of life and increase of environmental problems. The discipline which promises solutions, transport planners and traffic engineers, can be identified as the ones which produce and maximize transport problems. The greater the transport and environmental problems become, the more attempts are made to solve them. But instead of solving the problems, the mistakes are enlarged. Since social science is already criticizing the technicians, they are acting like a religious society, aggressive and trying to suppress their counterparts. They believe in dogmata without being able to prove them on a scientificly sound basis. The more their arguments became unbearable, the more they react ruthless and aggressive and try to support their untameable basic hypotheses by supporting sub-hypotheses around an empty centre of their discipline.

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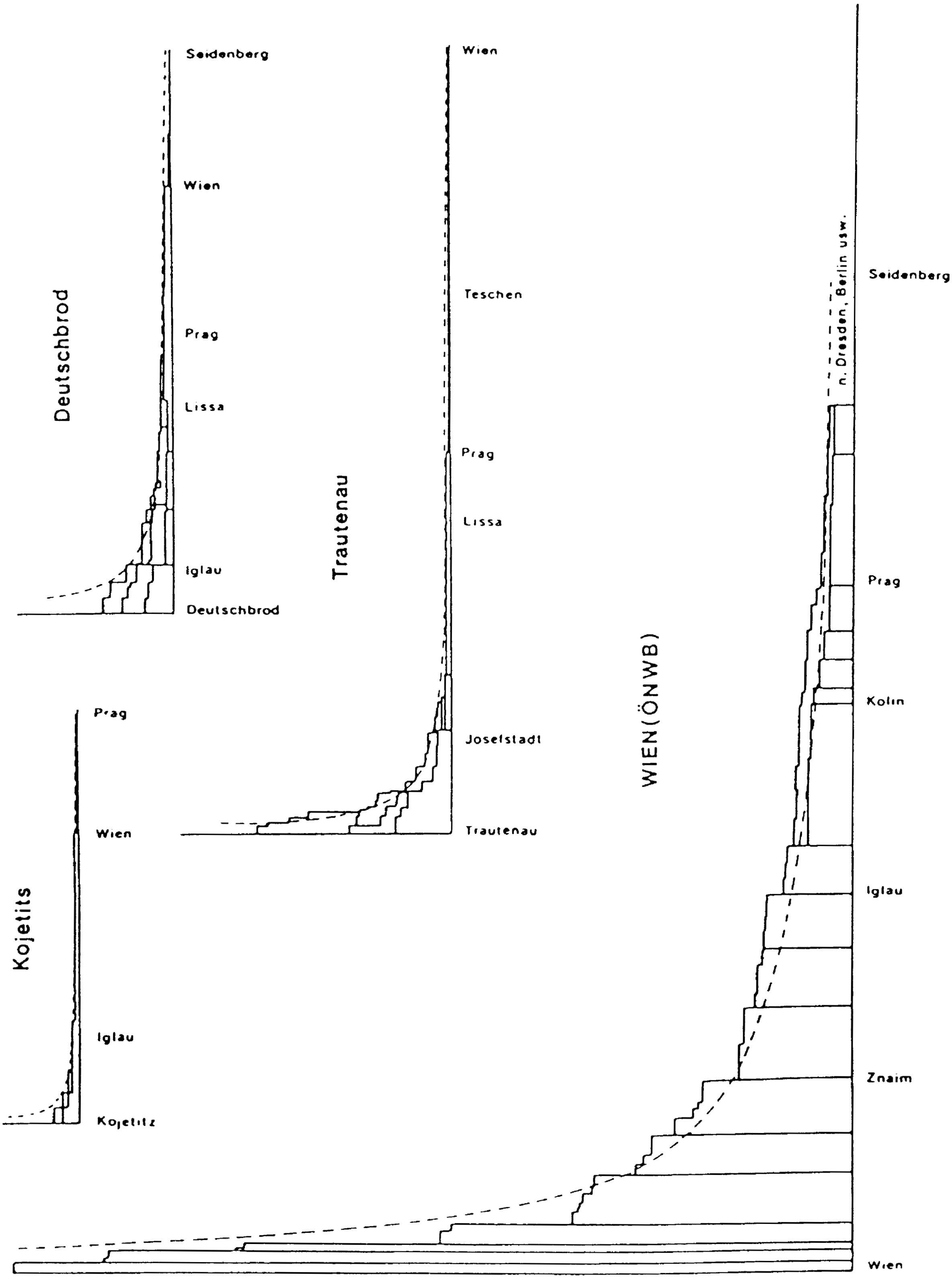
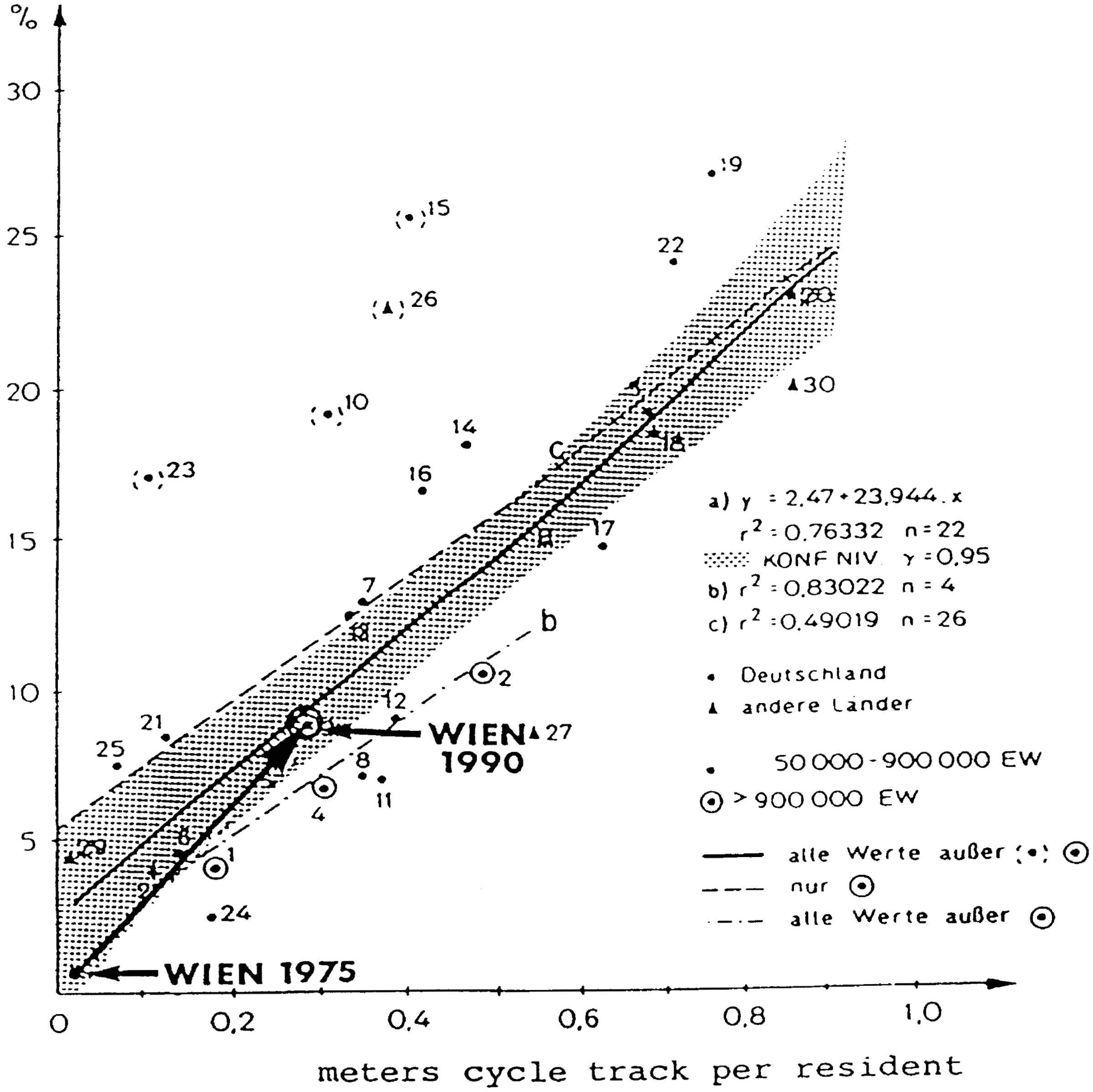


Fig. 1 Number of travellers in the year 1887 on selected railway routes in the Austro-Hungarian monarchy - Vertical axis: R = 425 000 (indication for the first column)



1	Berlin	6	Nürnberg	11	Krefeld	16	Bottrop
2	Hamburg	7	Bielefeld	12	Freiburg/Br.	17	Wilhelmshaven
3	München	8	Mannheim	13	Ludwigshafen	18	Erlangen
4	Köln	9	Karlsruhe	14	Leverkusen	19	Marl
5	Bremen	10	Augsburg	15	Bremerhaven	20	Gütersloh

21	Herford	26	Uppsala
22	Rüsselsheim	27	Stevenage
23	Tübingen	28	Dresden
24	Bayreuth	29	Zürich
25	Troisdorf	30	Wels

Fig. 2 Mutual relationship between the choice of transport mode - cycle - and the meters cycle track per resident
Source: KNOFLACHER, H.; KLOSS, H.P.: "Radverkehrsanlagen: Ergebnisse einer Erhebung". Straßenverkehrstechnik, Heft 4/1979. (Page 115).

The main dogmata in transport science are based on personal experience. They can be proved by personal experience, but they can not be proved for the whole transport system. Most transport engineers believe that their personal experience is the system effect. An example to show that this is absurd: No human being is able to run at a speed of 50 or 130 kilometres in an hour using only his own body energy. But it is possible to drive at this speed on the road. Now they believe that their senses, which are the senses of pedestrians, are able to reproduce the system effects of the nowadays fast transport system. It is interesting that at the Fourth International Road Conference in 1923 the estimation for the maximum future speed on motorways was 45 kilometres per hour (Table 1). In the last 150 years transport engineers have created a transport system operating at high speeds but without understanding the real effects of their activities. The whole system is founded on beliefs and assumptions without any scientific sound basis.

The following main dogmata are the foundation of traditional traffic engineering.

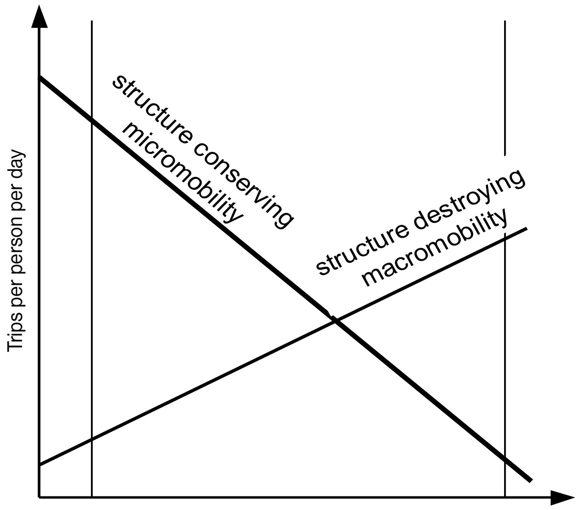


Fig. 3 Micromobility - Macromobility
Source: Knoflacher, H.: Landschaft ohne Autobahnen; Böhlau Verlag, Wien 1997.

Growth of Mobility

The narrow view to consider only motorised car traffic, produced the impression that mobility is growing because the term "mobility" was identical with car driving. The causes for mobility were not understood, although traffic planners are using the gravity law to calculate the number of trips. The cause for mobility is always a potential, a need for something that can not be found in the nearby environment. To compensate the deficits of the surrounding structure, mobility is necessary. So mobility is driven by the basic needs of the society. If the basic needs are not changing, the number of trips is not changing. This is exactly what numerous studies, carried out worldwide, show us today. The number of trips per person and per day is not changing with increasing motorization. What is changing is the kind of mobility. The number of trips and, therefore, mobility is a constant figure (as it can already be seen in Lill's law). If car mobility is increasing, all other kinds of mobility are decreasing. The "mobility" itself remains constant. There is no growth of mobility in one mode without a decline of the same amount in other modes. What was done before using the modes pedestrian, bike or public transport is now done using a car. In 1975, a basic study carried out by Knoflacher/Kloss improved the understanding of this effect (Fig. 2). When cycle tracks are provided or built, cycle trips are "produced". So the kind of mobility can be changed by changing the environment (Fig. 3). The "growth of car mobility" is nothing more than the transformation of public space, which was used by everyone before, to a privileged space for car drivers for parking and driving. So the term "growth" is absolutely wrong. Car mobility is not based on a natural law and, therefore, the growth is not natural. Car mobility is produced. The precise expression is, therefore: "Production of car mobility". This leads to the question: Who is responsible for this production and, therefore, the increase in accidents, air pollution, noise etc? This important question has not been asked until today

Definition of maximum speed at the 4th International Road Conference in 1923 — Table 1

	Maximum speed [km/h]				
		Ordinary roads		Special roads	
Total load [kg]	Iron tyres	Solid rubber tyres	Pneumatic tyres	Solid rubber tyres	Pneumatic tyres
3001-4500	12	25	35	30	45
4500-8000	8	20	30	25	40
8000-11000	5	15	20	20	30
more than 11000	5	5	10	15	20

Conclusion

If Lill's law would have been understood the mistake to believe in the "growth of mobility" would have been avoided.

"Time savings"

If somebody is driving from A to B and uses a faster mode, he recognizes that he needs less time. Transport planners and traffic economists, in principle the whole transport sciences, use this effect for the calculation of benefits from "time savings". All Cost Benefits Analysis are based on this assumption. Investments in fast transport systems must, therefore, produce a lot of benefits for the society. No deficit in the transport system can occur, because the calculations are based on the benefits inside the transport system alone.

The faster the transport system in a society is operating, the more time is saved and more time is available for other things - the society must become very pleasant and relaxing. But this is totally in contradiction to what everybody can observe. In the meantime, it is well known and deeply studied on sound scientific work that increasing the speed of the transport system does not change anything in the overall mobility-time of the whole system. The mistake of traditional transport science is the assumption, that personal experience can reflect system effects. No more than an atom can understand the effects of a molecule, which it is forming together with others into a system, no more personal experience of transport system users can understand the system effects. Today, it can be taken as proved that there are no time savings possible by increasing transport speeds (Bendtsen/Schmidl/Meier/Knoflacher). There is no empirical evidence anywhere that the increase of speed has reduced overall travel times. But there are quite a few other effects. Since travel time is not changing, the distance is changing. This can be found everywhere in the world. Fig. 4 shows one empirical example. The structure is changing while the speed of the transport system is changing. Human tradition is based on the pedestrian and his settlements. If the speed is enhanced in an artificial system, which is not following the laws of our universe due to economic deformation of the physical reality, structural changes are unavoidable. There are two sides of the coin. First, cities spread mainly for housing, because everybody wants to live in the green. On the other side a concentration of activities like trade, work etc. is appearing - but in the new system these activities are no longer connected to the city or the village. The destruction of villages and cities is unavoidable.

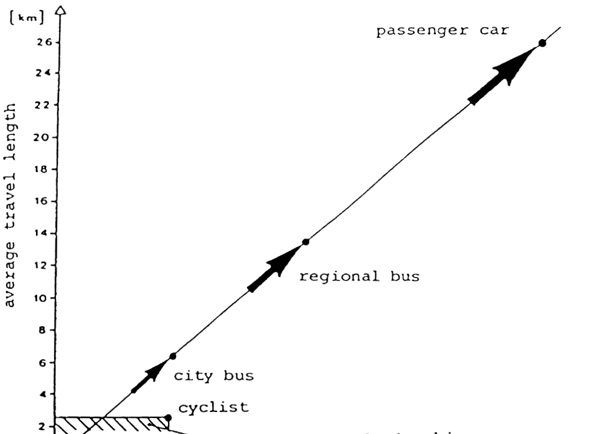


Fig. 4 Relationship: average travel speed - average travel length (empirical results, survey Salzburg 1982)

The constancy of travel time is included in Lill's law. This fact was not seen by the scientific society for more than hundred years. In the belief of doing the best, transport engineers and planners have destroyed traditional high quality settlement structures and degraded them to "machine sheds without roof". The most of the public space is blocked and controlled by machines - namely cars. This is extinguishing all other city activities and, therefore, extinguishing city life.

Understanding Lill's law a little bit better

Transport engineers are trained to believe on physical terms, like distances, time or any indicator as such. They are not educated to understand the human behaviour. So, it is interesting to analyze Lill's law a little bit deeper: Nobody is travelling a certain distance without any reason. The distance in Lill's law can not be seen as the reason for a trip. It must be something else. If we try to calculate the total number of trips for a certain settlement, a village, a certain person etc., we have to integrate the function, shown in equation 1 (h is the number of trips while l is the trip length):

$$h * l = c \qquad \text{(c = constant)} \tag{2}$$

$$h = \frac{c}{l} \tag{3}$$

The total number of trips we derive is as:

$$H = \int h * dl \tag{4}$$

$$H = c * \int \frac{dl}{l} \tag{5}$$

and finally:

$$H = c * \ln l \tag{6}$$

So the total number of trips is nothing else than the logarithm of the "trip length".

In 1843, Weber analyzed human sensation and found the so called Weber's law of human sensation in relation to the intensity of irritation. This law was finally improved in 1880 by G.T. Fechner and has the form:

$$E = h * \ln l \qquad \text{E ... Human Sensation and I ... Intensity of Irritation.} \tag{7}$$

Weber/Fechner's law has the same mathematical expression as Lill's law. What Lill has discovered was nothing more than the relationship between human sensation and the stimulation caused by the environment for the transport system. This describes also the background and cause of Lill's law: It is not the length, it is the stimulation over the length, which makes people moving. The stimulation is always complementary to the stimulation on the spot. Stimulation on the spot or at the origin is called "demand". Stimulation at destination is called desire, "wish" or "demand in a positive sense". Stimulation at the origin is demand in a negative sense. If this would have been understood a hundred years earlier (Knoflacher 1995), we would have a totally different transport system and a totally different kind of engineering.

Traditional education in transport science

Transport engineers believe that problems in car traffic are serious, congestion is seen as negative and a serious problem and the economists calculate time losses from congestion as financial deficits. The reason for this misunderstanding can be found in the factors explained in this paper and in the traditional approach to the transport system, narrowed by the American Highway Capacity Manual and its translation into other languages. Transport planners are educated to use only level of service A - E and to absolutely prevent level F. On the other side, they make their demand oriented transport planning by establishing a certain planning level of service (between A - E). The Capacity C is put into relation to the actual and future traffic flow V and $V + \Delta V$.

$$\frac{V}{C} = los_i \tag{8}$$

If traffic flow is increasing, they try to extend the space for car traffic to keep the same level of service. This basic assumption can be expressed as in Formula 9.

$$\frac{V}{C} = \frac{V + \Delta V}{C + \Delta C} = los_1 \tag{9}$$

The capacity of the existing system is enhanced by ΔC.
If we introduce the changes of traffic volume we get Formula 10.

$$V(t + \Delta t) = V(t) + \frac{dV}{dt}\Delta t \tag{10}$$

If you put Formula 10 into 9 we get 11 and finally 14.

$$l + \frac{dV \,.\, \Delta t}{v \,.\, dt} = 1 + \frac{\Delta C}{C} \tag{11}$$

$$\frac{dV}{V} = \frac{\Delta C}{\Delta t \,.\, C} \cdot dt \;\Big|\int \tag{12}$$

$$\ln V = \frac{\Delta C}{\Delta t \,.\, C} \cdot t + k \tag{13}$$

$$V = ke^{\frac{\Delta C}{C} * \frac{t}{\Delta t}} \tag{14}$$

The traffic volume V is increased as the effect of traffic engineering activities always putting more capacity into the existing system and, therefore, creating exponential growth.

Traditional traffic planning is, therefore, the cause of exponential growth of car traffic. But there is also another way to explain the totally wrong education of transport engineers in traditional transport science. The intensity of stimulation for the traditional educated transport engineer is car traffic "growth". The information comes from traffic counts, which means counting car traffic, and the reaction is to provide more infrastructure for car traffic. So the behaviour of the transport engineer is influenced by his own sensation in a clearly specified way. If the stimulation from car traffic is increasing, he has learned to react with adding some capacity to the existing system. If we describe this behaviour of transport engineers or the traditional transport science (traditional worldview) we get Formula 15.

$$E = \ln I \tag{15}$$

E ↑ *Sensation of Administration Engineers Politicians, Public*; $\ln I$ ↑ *Car Traffic*

If we introduce the terms the way administration, engineers etc. react, we get Formula 16.

$$\pm \frac{\Delta C}{C} = \ln V \tag{16}$$

It is easy to recognize that Formula 16 is nothing more than a version of Formula 14. So, traditional transport teaching, transport science and transport engineering is the cause for the exponential growth of traffic problems and not the solution.

Solution:

A solution can only be successful if we prevent basic mistakes:

1. No "growth of mobility".
   Only the kind of mobility can be changed from sustainable to unsustainable or in the opposite direction.
2. Changes in Parking Organisation:
   Since human behaviour was not understood, traditional transport engineers were taught to solve the problem where there is no solution possible - at the flowing part of the transport system. Problems in transport flows are not the causes. They are only the effects of underlying causes. As it was discovered by Knoflacher in 1981, the organisation of parking is the cause of most of our transport problems. As long as cars can be parked close to the human activities, there is no solution possible (Fig. 5). The first step of a real solution of the transport problems is, therefore, to introduce a parking regime which makes transport regulations meaningful and effective. So, at least the distance to the parked car for each of the activities must be as long or longer as the distance to the next public transport stop (Fig. 6). The structure has to be changed in parking. If we change this structure, the city structure will become stable and many transport problems will disappear. Parking is the key to the

solution of the transport problems. Attempts to solve problems in transport flow, including telematics are a kind of symptom treatment. A completely wrong organized transport system can not be improved by introducing a sophisticated information system on a totally wrong point of the system structure. Lot of research is going in the absolute wrong direction due to the lack of understanding of the system by all professions dealing with the transport system. We are losing time, we are losing money and we are losing understanding.

3. There is no "growth of mobility" if we count mobility in the number of trips, there is only a shift of mobility between different modes. There is also no "time saving" in the system, by increasing speed.

The solution is the change of parking regulations, a solution at the source.

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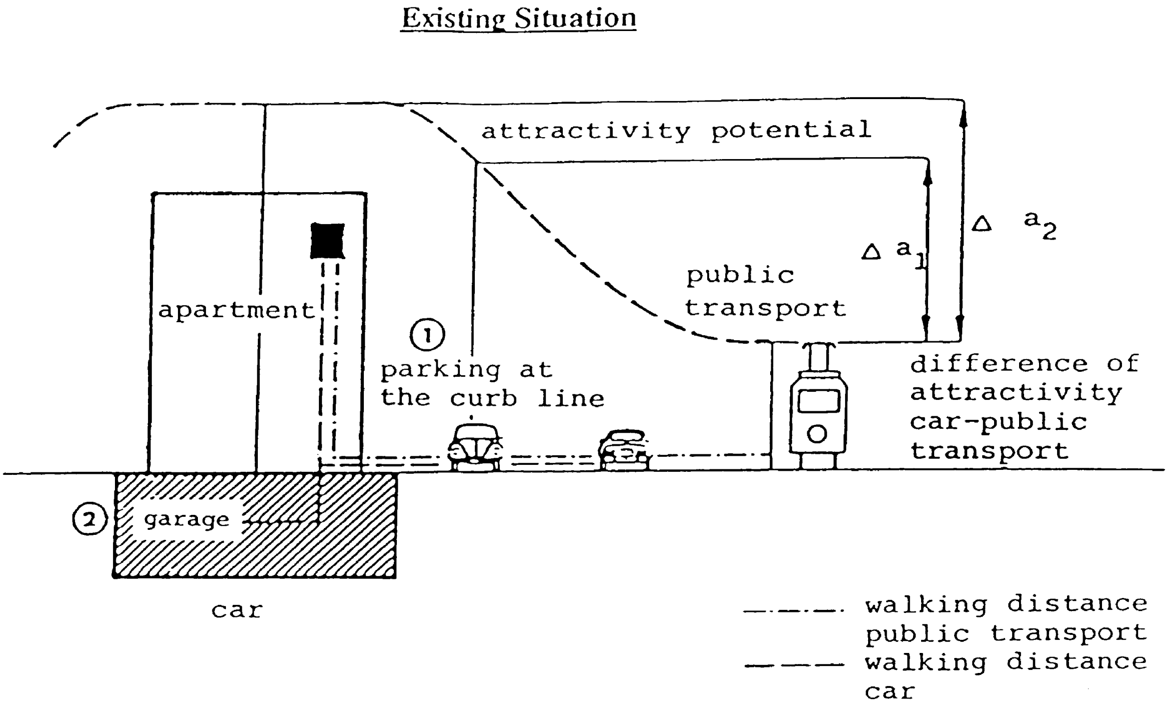

Fig. 5

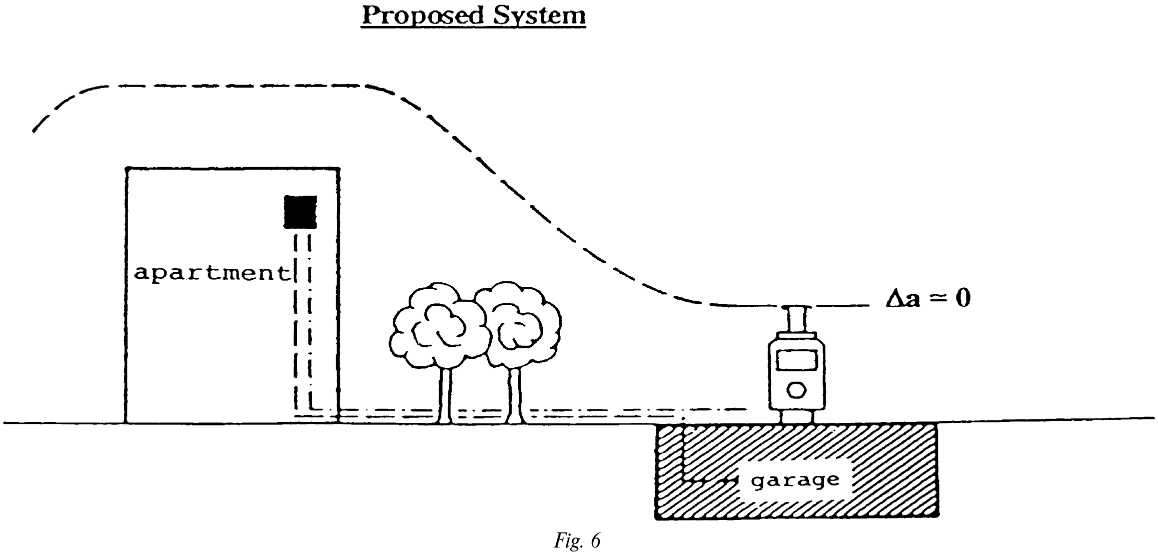

Fig. 6

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MATEMATICKÉ MODELOVANIE TVORBY OXIDOV DUSÍKA V ZÁŽIHOVOM MOTORE NA CNG

A MATHEMATICAL MODELLING OF NITROGEN OXIDE FORMATION IN A CNG SPARK IGNITION ENGINE

Medzi plynnými škodlivinami emitovanými výfukovými plynmi spaľovacích motorov majú oxidy dusíka zvláštne postavenie, ktoré sa navonok prejavuje ako súvislosť medzi energetickými a ekologickými vlastnosťami motora. Príspevok hovorí o 3D modelovaní tvorby oxidov dusíka v zážihovom motore na CNG s využitím programu FLUENT.

Úvod

Spaľovacie motory svojou prevádzkou zaťažujú životné prostredie. Niektoré emisie sú legislatívou limitované, iné nie. Požiadavka znižovania emisií CO_2 pri súčasnom znižovaní produkcie ostatných toxických emisií vedie v konečnom dôsledku k eliminácii spaľovania palív na báze uhlíka. Táto skutočnosť v súčasnosti smeruje k používaniu palív alternatívnych, napr. rekonštrukciou spaľovacích motorov na stlačený zemný plyn (Compressed Natural Gas) - zníženie produkcie CO_2 až o 25 %. Kritériom ekologického spaľovania prestáva byť len kvantita emisií, ale stáva sa aj kvalita spaľovania. Vo všeobecnosti je v povedomí menšie zaťaženie životného prostredia prevádzkou spaľovacích motorov na plynné palivá. Pri spaľovaní CNG sa javí ako problematická produkcia uhľovodíkov, ktoré spolu s oxidmi dusíka - NO_x (pojem oxidy dusíka zahŕňa skupinu emisií obsahujúcich predovšetkým oxid dusnatý NO a oxid dusičitý NO_2) sa okrem iného podieľajú na tvorbe smogu. Doterajšie skúsenosti s používaním plynných palív možno zhrnúť do nasledovných bodov:

- zníženie produkcie oxidu uhličitého,
- podstatné zníženie emisie pevných častíc a dymivosti motora,
- zníženie hluku vyžarovaného motorom,
- čiastočne zvyšovanie produkcie nespálených uhľovodíkov v suchých spalinách so zvyšovaním súčiniteľa prebytku vzduchu.

Nitrogen oxides occupy a specific position among gaseous harmful emissions produced by combustion engines. This position may externally appear as a coherence between energetic and ecological properties of the engine. The paper deals with a 3-D modelling of nitrogen oxides formation in a CNG ignition engine when the FLUENT programme is applied.

Introduction

Operation of combustion engines impairs the environment. Some emissions are limited by law, others are not. The requirement of lower CO_2 emission limits while simultaneously lowering production of other toxic emissions has finally led to the elimination of combustibles based on carbon. This fact has at present aimed at the use of alternative fuels, e.g. by a reconstruction of combustion engines to engines using compressed natural gas (CNG). Such a reconstruction can bring about a decrease in CO_2 production by as much as 25%. The criterion of ecologic combustion is no longer the emission quantity but at present also the quality of emission. Generally, it is believed that operation of gas combustion engines impairs the environment less. When CNG is used as a combustible, some problems arise due to the production of hydrocarbons which together with nitrogen oxides - NO_x (the term nitrogen oxides includes a group of emissions containing mainly nitrogen oxide NO and nitrogen dioxide NO_2) forms among other things, smog. The experience with gaseous fuels used up to this time can be summarised to the following points:

- decrease in production of carbon dioxide,
- substantial reduction of solid particle emission and engine smoking,
- reduction of engine-emitted noise,
- and a partial rise in production of unburnt hydrocarbons in dry combustion gases together with an increase in the excess coefficient.

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Oxidy dusíka ako súčasť plynných emisií a vplyv vybraných parametrov na ich tvorbu

Medzi plynnými škodlivinami emitovanými výfukovými plynmi spaľovacích motorov majú oxidy dusíka zvláštne postavenie, ktoré sa navonok prejavuje ako súvislosť medzi energetickými a ekologickými vlastnosťami motora. Spaľovací motor s vysokým merným výkonom a vysokou účinnosťou obyčajne vykazuje nízky obsah produktov nedokonalej oxidácie v spalinách, zatiaľ čo produkcia oxidov dusíka zlepšovaním energetických parametrov motora rastie. Vnútornou príčinou tejto skutočnosti je fakt, že vplyvy zlepšujúce akosť premeny chemickej energie paliva na mechanickú prácu motora, t. j. dostatok prípadne prebytok okysličovadla (pre dobrú chemickú účinnosť) a vysoká maximálna teplota pracovného obehu (pre dobrú termickú účinnosť) súčasne podporujú oxidáciu dusíka.

Zníženie kompresného pomeru znižuje maximálne teploty spaľovania vo valci motora, a preto má pozitívny vplyv na redukciu oxidov dusíka. Toto zníženie kompresného pomeru, podobne ako zníženie uhla predstihu zážihu, má za následok ale pokles termickej účinnosti, zníženie výkonu, vzrast mernej spotreby paliva a merných emisií ostatných škodlivín. Tieto nedostatky je možné čiastočne kompenzovať u motorov na CNG preplňovaním, vzhľadom na dobré antidetonačné vlastnosti metánu, ktorý je obsiahnutý v palive. U preplňovaných motorov je obmedzenie dané parametrami použitého turbodúchadla, prípadne teplotou výfukových plynov. Ak je potrebné znížiť koncentráciu oxidov dusíka pod určitú hranicu, najjednoduchšou a najúčinnejšou úpravou je zníženie uhla predstihu zážihu, i keď za cenu čiastočného poklesu výkonu a vzrastu mernej spotreby paliva. Efekt zníženia koncentrácie oxidov dusíka a mernej spotreby paliva zvyšovaním kompresného pomeru pri súčasnom znížení uhla predstihu zážihu (konštantná hladina maximálneho tlaku) je výraznejší pri nižších kompresných pomeroch. Pokles mernej spotreby paliva zvýšením kompresného pomeru a znížením uhla predstihu zážihu je výraznejší u bohatších zmesí (max. o 5 %), zatiaľ čo pokles oxidov dusíka je výraznejší u chudobnejších zmesí (cca 3,6-krát). Motory so zvýšeným kompresným pomerom a zníženým uhlom predstihu zážihu si vyžadujú kvalitnú a výkonnú elektrickú zapaľovaciu sústavu, aby sa zaručilo spoľahlivé zapálenie zmesi a tým aj rovnomerný chod motora.

Ochudobňovaním zmesi za inak rovnakých podmienok sa dosiahne nižšia koncentrácia oxidov dusíka a vyššia merná spotreba. Tento jav je spôsobený poklesom maximálnych teplôt náplne valca v dôsledku nižšej energetickej hustoty obsahu náplne valca. Zvýšenie mernej spotreby paliva nie je podstatné, ale pokles produkcie oxidov dusíka ochudobňovaním zmesi je výrazný. Problémom použitia chudobnej zmesi je pokles výkonu a nerovnomernosť chodu motora. Pokles výkonu je možné kompenzovať preplňovaním.

Vplyv teploty stien valca je možné posúdiť na základe vplyvu veľkosti tepelného odporu vloženého valca.. Pri nízkych hodnotách tepelného odporu vložky dochádza k väčšiemu odvodu tepla z pracovného priestoru do chladiaceho média. Tento odvod tepla

Nitrogen oxides as part of gaseous emissions and the influence of chosen parameters on their formation

Nitrogen oxides occupy a specific position among gaseous harmful emissions produced by combustion engines. This position may externally appear as a coherence between energetic and ecological properties of the engine. The combustion engine featuring a high specific output and high efficiency usually shows a poor content of products of insufficient oxidation in combustion gases, while the production of nitrogen oxides increases due to the improvement of energetic parameters of the engine. The internal cause leading to the mentioned reality is the fact that the influences that improve the quality of change of fuel chemical energy to mechanical work of the engine, i. e. sufficiency or excess of oxidizer (for a good chemical efficiency) and high maximum temperature of the working cycle (for a good thermal efficiency) simultaneously support oxidation of nitrogen.

A decrease in the compression ratio lowers maximum temperatures of combustion in the engine cylinder and has, therefore, a positive influence on the reduction of nitrogen oxides. This lowering of the compression ratio similarly as a decrease in an advanced ignition angle lead, however, to a fall of thermal efficiency, lower output, increase of the specific fuel consumption and specific emissions of other harmful substances. These shortcomings may be partly compensated in CNG engines by supercharging owing to good antidetonant properties of methane contained in fuel. In supercharged engines the limitation is given by parameters of the used turbocharger or by temperature of exhaust gases. If the concentration of nitrogen oxides is to be lowered under a certain limit, the easiest and most efficient arrangement is to lower the advanced ignition angle, even though the output partially decreases and specific fuel consumption increases. The effect of decrease of a nitrogen oxide concentration and specific fuel consumption by increasing the compression ratio at a simultaneous lowering of the advanced ignition angle is more marked with richer mixtures (max. by 5%), while the decrease in nitrogen oxides is more remarkable with leaner mixtures (approx. 3.6-times). Engines with a higher compression ratio and lower advanced ignition angle need an efficient electric ignition system of high quality in order to provide reliable ignition of mixture and, consequently, a regular engine running.

Making the mixture leaner, under otherwise similar conditions, leads to a lower concentration of nitrogen oxides and to a higher specific fuel consumption. This phenomenon is caused by a fall of maximum temperatures of the cylinder charge due to a lower energetic density of the cylinder charge content. An increase in the specific fuel consumption is not substantial but a decrease in production of nitrogen oxides due to making the mixture leaner is marked. A disadvantage of the use of lean mixture is a decrease in the output and irregularities in the engine run. The decrease in the output can be compensated by supercharging.

The influence of the cylinder wall temperature can be judged on the basis of the influence of a thermal resistance magnitude of the cylinder liner. Low values of the liner thermal resistance bring about higher heat abstraction from the working area to the cooling medium. This heat abstraction causes a decrease in temperatures má za následok pokles teplôt pracovného obehu motora samozrejme s dôsledkom na tvorbu oxidov dusíka.

V zážihových motoroch na CNG sa predpokladá kinetické spaľovanie homogénnej chudobnej zmesi. Pri kinetickom spaľovaní je zóna pred plamenným frontom vyplnená rovnorodou zmesou paliva so vzduchom. V okamihu prechodu plameňa dochádza ku takmer skokovej zmene koncentrácií. Základná predstava pre porovnanie kinetického a difúzneho spaľovania z hľadiska produkcie NO_x je skutočnosť, že pri kinetickom spaľovaní chudobnej zmesi je aj vzduch, ktorý sa nezúčastňuje chemickej reakcie prítomný priamo v oblasti plameňa a svojou tepelnou kapacitou prispieva k zníženiu teploty horiacej vrstvy. Pri kinetickom spaľovaní stechiometrickej zmesi je priamo v plameni prítomné len práve potrebné množstvo vzduchu k uskutočneniu chemickej reakcie. Spaľovanie prebieha v tomto prípade pri vysokej teplote, čo je nevýhodné vzhľadom na tvorbu oxidov dusíka. Ochudobňovaním zmesi sa teda znižuje úroveň teplôt pracovnej látky vplyvom poklesu výhrevnosti zmesi ako aj vplyvom posunu výrazného podielu fázy prívodu tepla do pokročilého štádia expanzného pohybu piesta pri pomalom horení chudobnej zmesi [2].

Tvorba oxidov dusíka

Z pohľadu škodlivosti oxidov dusíka je rozhodujúcou zložkou NO_2. Hlavnou emitovanou zložkou spaľovacím motorom je však NO. Legislatíva limitov emisií vychádza z predpokladu, že celé emitované množstvo oxidov dusíka v atmosfére oxiduje na NO_2. V niektorých prípadoch sa z praktických dôvodov používa prepočet emisií oxidov dusíka vo výfukových plynoch na množstvo oxidu dusnatého.

Oxid dusnatý vzniká z väčšej časti pomalou reťazovou reakciou - Zeldovičov mechanizmus [3]:

$$O_2 + N \leftrightarrow NO + O$$

$$N_2 + O \leftrightarrow NO + N$$

Nosným procesom z hľadiska prítomnosti oxidov dusíka vo výfukových plynoch je výskyt pomerne vysokej rovnovážnej koncentrácie NO vo fáze s vysokou teplotou nasledovaný dramatickým znížením reakčnej rýchlosti dekompozície NO po poklese teploty náplne valca v priebehu expanzného zdvihu piesta. Spomalenie reakcie rozpadu oxidu dusnatého je tak náhle, že sa pre jeho popis používa termín zmrazenie koncentrácie NO [4]. Pri znížení spaľovacích teplôt klesá hodnota maxima rovnovážnej koncentrácie NO, znižuje sa rýchlosť tvorby NO, čím sa znižuje aj celková koncentrácia NO v spalinách. Veľkosť maximálnych spaľovacích tlakov nevplýva priamo na chemické reakcie, ale ovplyvňuje teploty reakcií. Najvyššie teploty sa dosahujú pri mierne bohatých zmesiach. Ako je zrejmé z vyššie uvedených reakcií, nedostatok kyslíka brzdí produkciu NO_x. Maximum produkcie je posunuté do oblasti mierne chudobných zmesí so súčiniteľom prebytku vzduchu okolo 1,15. Poloha maxima rovnovážnej koncentrácie emisií NO sa teoreticky zhoduje s polohou maxima

of the engine working cycle and, of course, has an impact on the formation of nitrogen oxides.

In CNG spark ignition engines kinetic combustion of homogenous lean mixture is suggested. At kinetic combustion the area in front of the flame front is filled in with a homogenous air-fuel mixture. In the moment of flame transition almost a jump change in the concentration occurs. A basic idea for comparison of kinetic and diffusion combustion from the point of view of NO_x production is the fact that at kinetic combustion of lean mixture there also is air that does not take part in a chemical reaction present directly in the area of flame and contributes with its thermal capacity to a decrease in temperature of a burning layer. In the case of kinetic combustion of stoichiometric mixture there is exactly such an amount of air present directly in the flame that is needed to carry out a chemical reaction. The combustion in this case takes place at a high temperature which is disadvantageous from the point of view of formation of nitrogen oxides. Thus, making the mixture leaner decreases a temperature level of the working medium due to a decrease in a calorific value of the mixture as well as due to a marked part of a phase of heat induction in an advanced stage of an expansion piston movement at a low combustion of lean mixture [2].

Formation of nitrogen oxides

From the point of view of nitrogen oxides harmful effect, a decisive component is NO_2, although the main component emitted by the combustion engine is NO. Legislation of emission limits is based on a suggestion that the whole emitted amount of nitrogen oxides in the atmosphere oxides to NO_2. In some cases, from practical reasons a conversion of emissions of nitrogen oxides in exhaust gases to the amount of nitrogen oxide NO is used.

Nitrogen oxide is formed, from a greater part, during a slow chain reaction - Zeldovic mechanism [3]:

$$O_2 + N \leftrightarrow NO + O$$

$$N_2 + O \leftrightarrow NO + N$$

From the point of view of presence of nitrogen oxides in exhaust gases, the main process is an occurrence of a relatively high equilibrium NO concentration in a phase with a high temperature followed by a dramatic fall of a reaction velocity of NO decomposition after a decrease in temperature of the cylinder charge during the expansion piston movement. Deceleration of a reaction of nitrogen oxide NO decomposition is so sudden that to describe it the term NO concentration freezing [4] is used. At a decrease in combustion temperatures the value of maximum of NO equilibrium concentration decreases, the velocity of NO formation decreases and, consequently, the overall NO concentration in combustion gases also decreases. A magnitude of maximum combustion pressures does not directly influence chemical reactions, but it influences temperatures of the reactions. The highest temperatures are reached with slightly rich mixtures. As it can be seen from the above mentioned reactions, lack of oxygen slows down NO_x production. The production maximum is shifted to an area of slightly teploty v spaľovacom priestore. V skutočnosti je však maximum tvorby posunuté ďalej. Čím vyššie sú teploty, tým viac sa blíži skutočná koncentrácia NO ku koncentrácii stanovenej podľa rovnovážnych stavov [3].

Z vytvoreného oxidu dusnatého sa sekundárne tvorí oxid dusičitý. Podľa [3] možno približný mechanizmus vzniku NO_2 popísať nasledujúcim postupom:

- oxid dusnatý nachádzajúci sa v zóne plameňa môže byť rýchlo premenený na NO_2 reakciou:

$$NO + HO_2 \rightarrow NO_2 + OH$$

- ďalej nastupuje premena NO_2 na NO

$$NO_2 + O \rightarrow NO + O_2$$

Reakcia prebieha dovtedy, kým NO_2 vytvorený v zóne plameňa sa neochladí zmiešaním sa s relatívne studenými plynmi.

Matematický model

Pre výpočet spaľovania bol využitý program FLUENT. Je ním možné riešiť problémy z oblasti prúdenia buď plošne alebo priestorove. Po zostavení geometrického modelu je potrebné zvoliť model fyzikálny. Po zadaní všetkých okrajových a začiatočných podmienok i správnej voľbe podrelaxačných a disipačných faktorov možno uskutočniť výpočet. Model popisujúci chemickú kinetiku v podmienkach kinetického alebo difúzneho plameňa je vytvorený pomocou programu pre výpočet chemickej kinetiky a termodynamiky. Plameň možno modelovať buď ako kinetický s voľbou kinetických rovníc, alebo ako difúzny s výpočtom rovnovážnych koncentrácií zložiek v laminárnom alebo turbulentnom režime. Je výhodné použitie malých reakčných schém na presný popis rozhodujúcich vlastností plameňa. Tieto schémy majú význam najmä z praktického hľadiska pre problémy v oblasti spaľovania, pretože obsahujú všetky aplikácie zahrňujúce akékoľvek palivo. Jedna z najdôležitejších aplikácií je aplikácia turbulentného spaľovania, kde fluktujúci charakter prúdenia a s tým spojené chemické deje popisujúce turbulenciu spôsobujú niektoré ťažkosti pri modelovaní.

Schémy globálnych reakcií pre spaľovanie alkánových uhľovodíkov (až po bután) v zmesiach so vzduchom v kinetických a difúznych plameňoch obsahujú dve vedľajšie reakcie rozkladu paliva. Reakčný mechanizmus je popísaný následovnými rovnicami [5]:

$$C_nH_{2n+2} + \frac{n}{2} O_2 \rightarrow nCO + (n+1)H_2 ,$$

$$C_nH_{2n+2}\, nH_2O \rightarrow nCO + (2n+1)H_2 ,$$

$$H_2 + \frac{1}{2} O_2 \leftrightarrow H_2O ,$$

lean mixtures with an excess coefficient around 1.15. The position of maximum of NO emissions equilibrium concentration is theoretically identical with the position of the temperature maximum in the combustion chamber. Though in reality, the formation maximum is shifted further. The higher the temperatures, the more a real NO concentration approaches the one determined in compliance with equilibrium states [3].

From the formed nitrogen oxide secondary nitrogen dioxide is formed. According to [3] the approximate mechanism of NO_2 formation can be described with the following procedure:

- nitrogen oxide present in the flame area can be quickly changed to NO_2 by the reaction:

$$NO + HO_2 \rightarrow NO_2 + OH$$

- then a change of NO_2 to NO takes place

$$NO_2 + O \rightarrow NO + O_2$$

The reaction takes place until NO_2 formed in the flame area is cooled down mixing with relative cold gases.

Mathematical model

The program FLUENT was applied for calculation of combustion. It enables the solving of problems from a field of flow either in an areal or spatial way. After a geometric model is constructed, a physical model is to be chosen. After all boundary and initial conditions are set and subrelaxation and dissipation factors are correctly selected, the calculation can be carried out. The model describing chemical kinetics under conditions of a kinetic or diffusion flame is created with the help of a program for calculation of chemical kinetics and thermodynamics. The flame can be modelled either as kinetic with a choice of kinetic equations or as diffusive with a calculation of equilibrium concentration of components in a laminar or turbulent regime. It is good to use small reaction schemes for a precise description of the flame decisive properties. These schemes are especially significant for problems from a practical point of view in the field of combustion as they contain all applications covering any fuel. One of the most important applications is the one of turbulent combustion where a fluctuating character of flow and related chemical processes describing turbulence cause some difficulties during modelling.

The schemes of global reactions for combustion of alkane hydrocarbons (up to butane) in mixtures with air in kinetic and diffusion flame contain two subsidiary reactions of fuel decomposition. The reaction mechanism is described with the following equations [5]:

$$C_nH_{2n+2} + \frac{n}{2} O_2 \rightarrow nCO + (n+1)H_2 ,$$

$$C_nH_{2n+2}\, nH_2O \rightarrow nCO + (2n+1)H_2 ,$$

$$H_2 + \frac{1}{2} O_2 \leftrightarrow H_2O ,$$

$CO + H_2O \leftrightarrow CO_2 + H_2$.

Priestorový model spaľovacieho priestoru (zložený zo 16 tisíc elementov tvaru šesťstena) je vytvorený na základe súradníc bodov popisujúcich tvar spaľovacieho priestoru. Tak bola vytvorená povrchová a fyzikálna sieť. Zážih palivovej zmesi v uzatvorenom spaľovacom priestore bol simulovaný zadaním plôšky so zápalnou teplotou. Okrem toho na začiatku bola zadaná veľkosť tangenciálnej rýchlosti pre turbulentné prúdenie.

Výpočet bol realizovaný v dvoch častiach. V prvej časti bolo zvolených päť reakčných zložiek: CH_4, O_2, N_2, CO_2, H_2O a rovnica popisujúca oxidáciu metánu. Štyri zložky sa priamo zúčastňujú chemickej reakcie (CH_4, O_2, CO_2 a H_2O) a piata zložka, dusík, bola volená z dôvodu jej najväčšieho podielu v atmosférickom vzduchu. Priebeh koncentrácie tejto zložky je výhradne numerickou záležitosťou (dopočet do čísla 1, ktoré predstavuje súčet mólových zlomkov zadávaných zložiek, t. j. metánu, dusíka a kyslíka). V druhej časti bolo zvolených deväť reakčných zložiek: CH_4, O_2, N_2, CO_2, H_2O, NO, N, O, Ar a okrem rovnice popisujúcej oxidáciu metánu aj chemické rovnice popisujúce tvorbu NO, rozklad kyslíka a rozklad dusíka. Tak napr. reakcie v prvej časti výpočtu prebehnú takto:

$CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O;$

$O_2 \rightarrow O + O;\ N_2 \rightarrow N + N;\ O_2 + N \rightarrow NO + O;$

$N_2 + O \rightarrow NO + N.$

Pohyb reakčnej zmesi je popísaný rovnicami [6]:

- kontinuity

$$\frac{\partial p}{\partial t} + \frac{1}{r}\frac{\partial \rho v r}{\partial r} + \frac{\partial \rho u}{\partial z} = 0,$$

- Navier - Stokesovými

$$\frac{\partial \rho v}{\partial t} + \frac{1}{r}\frac{\partial \rho v^2 r}{\partial r} + \frac{\partial \rho u v}{\partial z} = -\frac{\partial p}{\partial r} + \frac{1}{r}\frac{\partial \rho_{rr} r}{\partial r} + \frac{\partial \sigma_{rz}}{\partial z} - \frac{\partial \sigma_{\phi\phi}}{\partial r},$$

$$\frac{\partial \rho u}{\partial t} + \frac{1}{r}\frac{\partial \rho u v r}{\partial r} + \frac{\partial \rho u^2}{\partial z} = -\frac{\partial \rho}{\partial z} + \frac{1}{r}\frac{\partial \sigma_{rz} r}{\partial r} + \frac{\partial \sigma_{zz}}{\partial z}$$

- energetickej bilancie toku

$$\frac{\partial \rho E}{\partial t} + \frac{1}{r}\frac{\partial \rho E v r}{\partial r} + \frac{\partial \rho E u}{\partial z} = -\frac{1}{r}\frac{\partial \rho v r}{\partial r} - \frac{\partial p u}{\partial z} +$$

$$+\frac{1}{r}\frac{\partial(\sigma_{rr} v r + \sigma_{rz} u r)}{\partial r} + \frac{\partial(\sigma_{rz} v + \sigma_{zz} u)}{\partial z} - \frac{1}{r}\frac{\partial r q_r}{\partial r} -$$

$$-\frac{\partial q_z}{\partial z} + qc$$

V uvedených rovniciach je:

ρ	hustota,
u, v	zložky vektoru rýchlosti v smere r a z,

$CO + H_2O \leftrightarrow CO_2 + H_2$.

The spatial model of the combustion chamber (composed of 16 thousand elements of a six-wall shape) is created on the basis of co-ordinates of points describing a shape of the combustion chamber. Thus, the surface and physical network was created. The ignition of air-fuel mixture in a closed combustion chamber was simulated by setting a small surface with an ignition temperature. Apart from this, the magnitude of tangential velocity for turbulent flow was given in the beginning.

The calculation was done in two stages. In the first stage five reaction components: CH_4, O_2, N_2, CO_2, H_2O and the equation describing oxidation of methane were selected. Four components take part in the chemical reaction directly (CH_4, O_2, CO_2, H_2O) and the fifth component, nitrogen, was selected because of its largest portion in the atmospheric air. The course of concentration of this component is an exclusively numerical matter (additional calculation up to number 1 representing the sum of molecular fractions of the given components, i. e. methane, nitrogen and oxygen). In the second stage, nine reaction components: CH_4, O_2, N_2, CO_2, H_2O, NO, N, O, Ar were selected apart from the equation describing oxidation of methane also chemical equations describing NO formation, oxygen and nitrogen decomposition. So, e.g. the reactions in the first stage of calculation have the following course:

$CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O;$

$O_2 \rightarrow O + O;\ N_2 \rightarrow N + N;\ O_2 + N \rightarrow NO + O;$

$N_2 + O \rightarrow NO + N.$

The motion of reaction mixture is described with the equations [6]:

- of continuity

$$\frac{\partial p}{\partial t} + \frac{1}{r}\frac{\partial \rho v r}{\partial r} + \frac{\partial \rho u}{\partial z} = 0,$$

- Navier-Stoke

$$\frac{\partial \rho v}{\partial t} + \frac{1}{r}\frac{\partial \rho v^2 r}{\partial r} + \frac{\partial \rho u v}{\partial z} = -\frac{\partial p}{\partial r} + \frac{1}{r}\frac{\partial \rho_{rr} r}{\partial r} + \frac{\partial \sigma_{rz}}{\partial z} - \frac{\partial \sigma_{\phi\phi}}{\partial r},$$

$$\frac{\partial \rho u}{\partial t} + \frac{1}{r}\frac{\partial \rho u v r}{\partial r} + \frac{\partial \rho u^2}{\partial z} = -\frac{\partial \rho}{\partial z} + \frac{1}{r}\frac{\partial \sigma_{rz} r}{\partial r} + \frac{\partial \sigma_{zz}}{\partial z}$$

- of energetic balance of flow

$$\frac{\partial \rho E}{\partial t} + \frac{1}{r}\frac{\partial \rho E v r}{\partial r} + \frac{\partial \rho E u}{\partial z} = -\frac{1}{r}\frac{\partial \rho v r}{\partial r} - \frac{\partial p u}{\partial z} +$$

$$+\frac{1}{r}\frac{\partial(\sigma_{rr} v r + \sigma_{rz} u r)}{\partial r} + \frac{\partial(\sigma_{rz} v + \sigma_{zz} u)}{\partial z} - \frac{1}{r}\frac{\partial r q_r}{\partial r} -$$

$$-\frac{\partial q_z}{\partial z} + qc$$

The symbols in the above equations are as follows:

ρ	density,
u, v	components of velocity vector in the directions r and z,

p	tlak,
ρ_{rr}, ρ_{rz}, $\rho_{\phi\phi}$, ρ_{zz}	zložky tenzoru viskózneho napätia,
E	celková energia pre ktorú platí $E = [2(u + v) + I]^{-1}$, I je merná vnútorná energia,
q_r, q_z	tok energie v smere r a z, spôsobený tepelnou vodivosťou a difúziou,
q_c	rýchlosť uvoľňovania tepla vplyvom chemických reakcií.

Výpočet bol umelou difúziou stabilizovaný. Rovnice hybnosti pre zmes boli stabilizované prostredníctvom viskozitného koeficienta. Rovnica celkovej energie je stabilizovaná pridaním difúznej časti cez pomer koeficientu tepelnej vodivosti a merného tepla pri konštantnom objeme. Stabilita riešenia rovníc transportu zložiek je kontrolovaná rovnicou zákona zachovania hmoty. Výpočet bol realizovaný pre tieto parametre:

- otáčky motora 2000 min^{-1},
- točivý moment 726 Nm,
- predstih zážihu 24,1 ° pred HÚ,
- súčiniteľ prebytku vzduchu 1,41,
- veľkosť časového kroku $1{,}6.10^{-3}$ s,
- teplota steny 500 K,
- referenčná teplota 707 K,
- referenčný tlak 1,872 MPa,
- tangenciálna rýchlosť 5 ms^{-1},
- model turbulencie k - ε

Výsledky výpočtu

Proces oxidácie metánu je zobrazený na obrázku 1. Miesta zobrazené tmavšími odtieňmi predstavujú zóny s menšou koncentráciou metánu, t. j. tie, kde proces spaľovania už prebehol. Spaľovanie začína od stredu spaľovacieho priestoru, teda od miesta polohy zapaľovacej sviečky a postupuje do rozšírenej časti spaľovacieho priestoru. No v niektorých úsekoch cyklu proces spaľovania samovoľne začína aj v okrajových miestach spaľovacieho priestoru. Tento jav je možné vysvetliť lokálne zvýšenou teplotou v zúženej časti spaľovacieho priestoru počas spaľovania, obrázok 2. Na obrázku 3 vidieť vplyv nestacionárneho prúdenia v systéme, pretože rozloženie koncentrácie metánu nie je rovnaké na symetrických rezoch spaľovacieho priestoru. Z výpočtu vyplýva, že proces dohorievania prebieha v rozšírenej časti spaľovacieho priestoru a končí v jeho dolnej časti, kde zostávajú aj zvyšky metánu po skončení procesu spaľovania, obrázok 4. Ich koncentrácia je však pomerne nízka 0,0313. Rozloženie koncentrácie všetkých zložiek je ovplyvnené teplotou. Vypočítané priebehy koncentrácií oxidov dusíka v určitých časových krokoch sú zobrazené na obrázkoch 5, 6, 7 a 8.

Výpočet umožňuje sledovať aj šírenie sa tlakových vĺn v spaľovacom priestore počas horenia palivovej zmesi, obrázok 9. Tlak nie je kritériom konvergencie tohto výpočtu. Zmena tlaku nemá podstatný vplyv na priebeh koncentrácií jednotlivých zložiek.

Z priebehov rýchlostí počas spaľovania vyplýva, že počas procesu spaľovania dochádza k nestacionárnemu šíreniu sa tlako-

p	pressure,
ρ_{rr}, ρ_{rz}, $\rho_{\phi\phi}$, ρ_{zz}	components of viscose stress of tensor,
E	total energy for which holds $E = [2(u + v) + I]^{-1}$, I is specific internal energy,
q_r, q_z	flow of energy in the directions r and z caused by thermal conductivity and diffusion,
q_c	velocity of heat release due to chemical reactions.

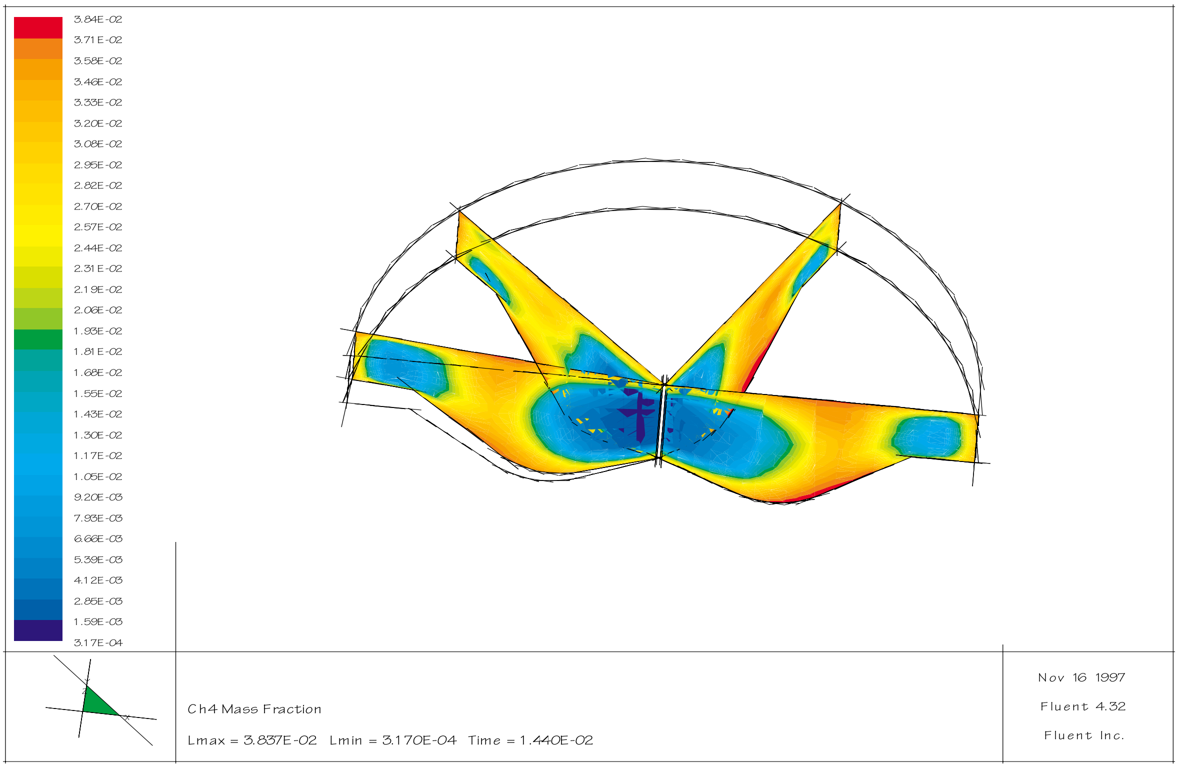
The calculation was stabilised by an artificial diffusion. The equations of motion for mixture were stabilised via the viscosity coefficient. The equation of total energy is stabilised by adding the diffusion part via a ratio of the coefficient of thermal conductivity and specific heat at a constant volume. The stability of solution of equation of the component transport is controlled by the equation of the law of mass conservation. The calculation was done for the following parameters:

- engine revolutions 2000 min^{-1},
- torque 726 Nm,
- advanced ignition 24,1 ° in front of TDC,
- excess coefficient 1,41,
- magnitude of time interval 1,6.10-3 s,
- temperature of wall 500 K,
- reference temperature 707 K,
- reference pressure 1,872 MPa,
- tangential velocity 5 ms^{-1},
- turbulence model k - ε

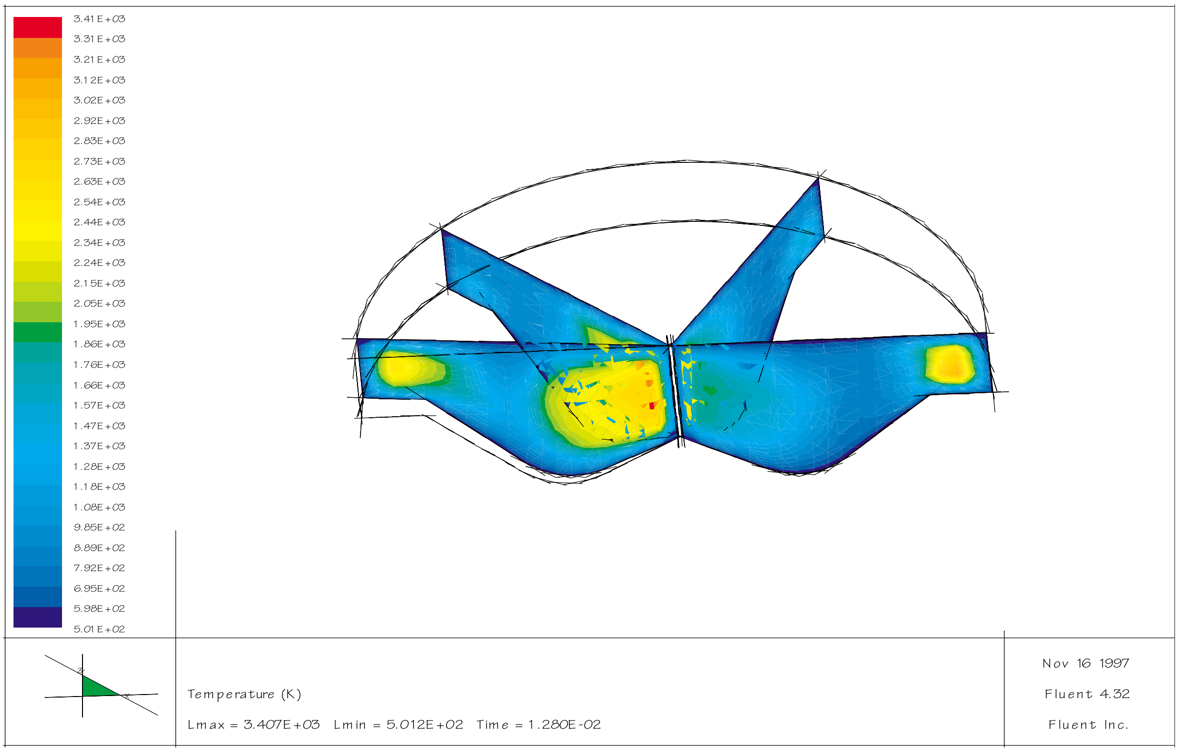
Results of the calculation

The process of methane oxidation is shown in Fig. 1. The darker places represent the areas of a lower methane concentration, i. e. those where the combustion process is already over. The combustion starts from the centre of the combustion chamber, that is, from the place where an ignition plug is located, and proceeds to an extended part of the combustion chamber. But in some intervals of the cycle, the process of burning starts automatically also in boundary places of the combustion chamber. This phenomenon can be explained by a locally increased temperature in a tapered part of the combustion chamber during burning, Fig. 2. Fig. 3 shows the influence of non-stationary flow in the system as the distribution of methane concentration is not the same on symmetric cuts of the combustion chamber. From the calculation it follows that the process of burning low takes place in an extended part of the combustion chamber and ends in its bottom part where methane residues also remain after the combust ion process is over, Fig. 4 But their concentration is relatively low - 0.0313. The distribution of concentration of all components is influenced by temperature. The calculated courses of nitrogen oxides concentration in certain time intervals are shown in Figs 5, 6, 7, and 8.

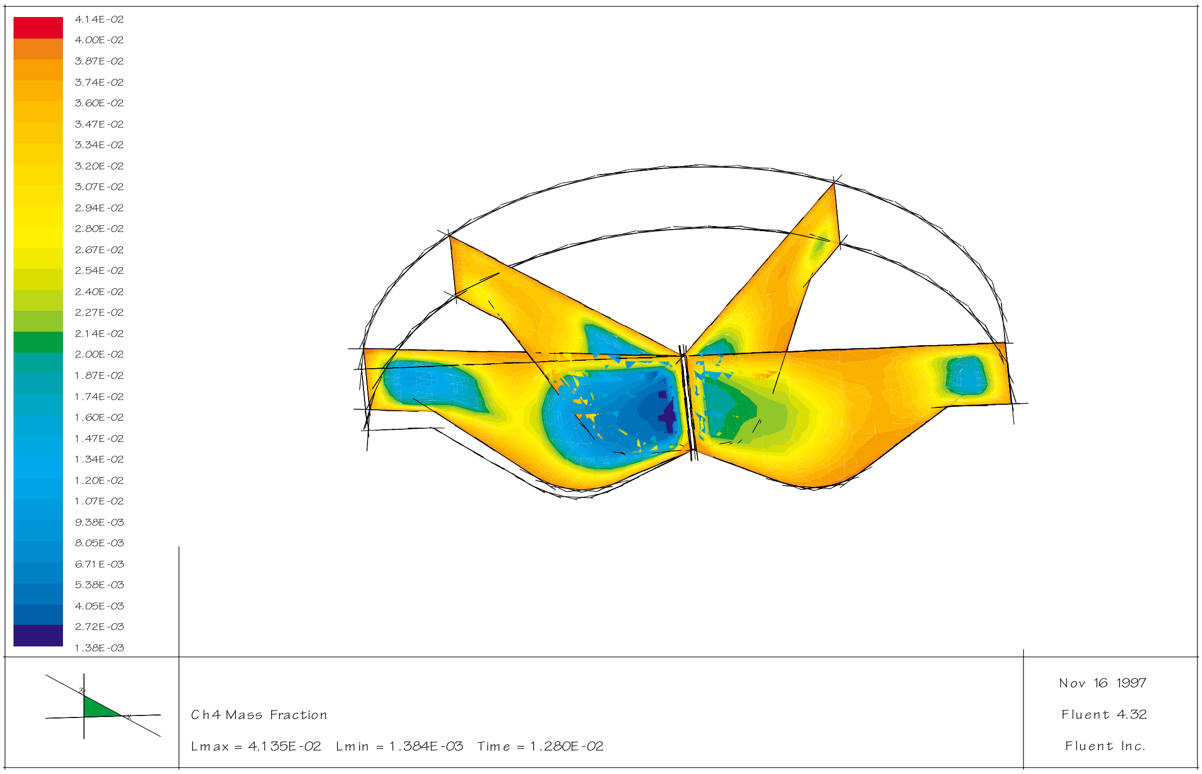
The calculation also allows to follow propagation of pressure waves in the combustion chamber during burning of air-fuel mixture - Fig. 9. Pressure is not a convergence criterion of this calculation. A change in pressure does not have any substantial influence on the concentration of individual components.



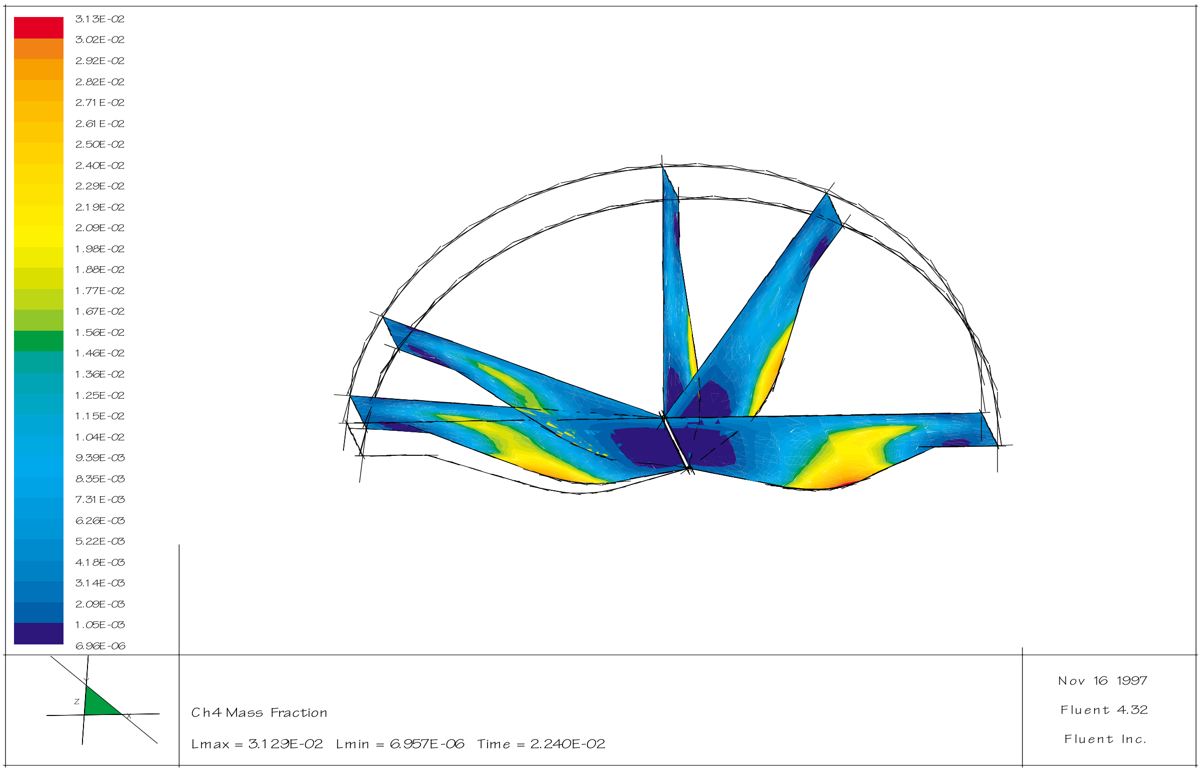
Obr. 1 Oxidácia metánu
Fig. 1 Oxidation of methane



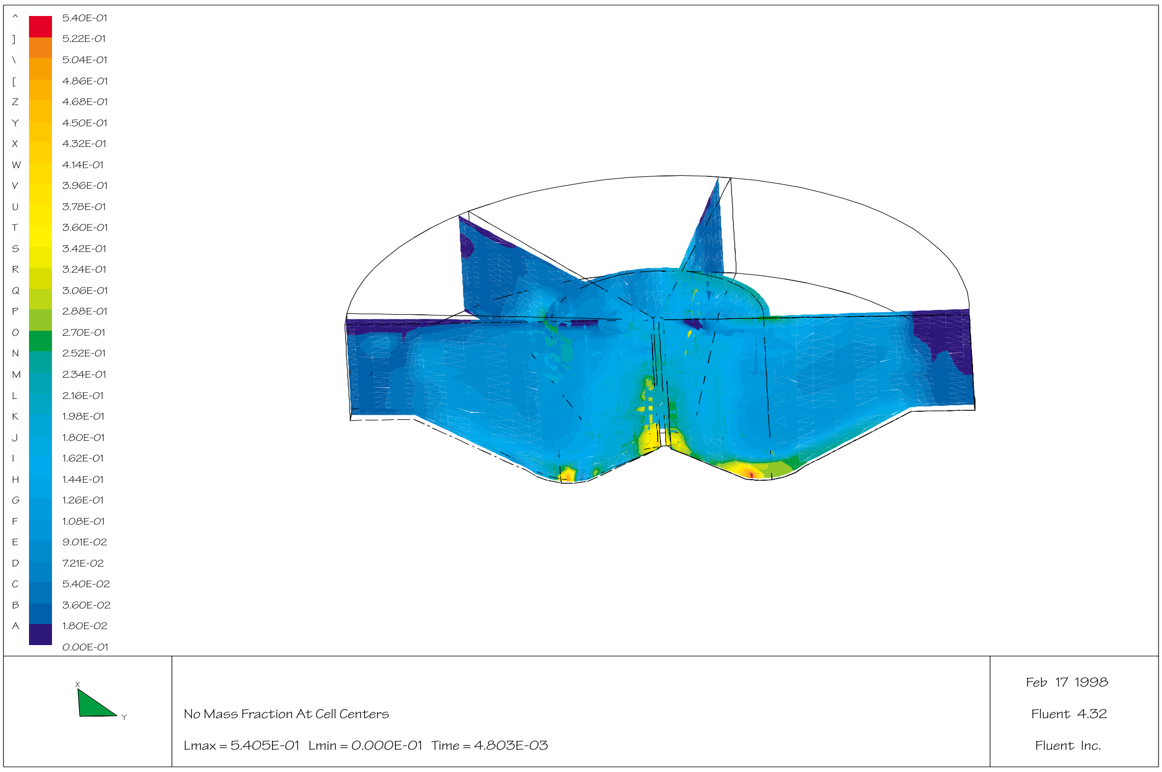
Obr. 2 Rozloženie teploty
Fig. 2 Distribution of temperature



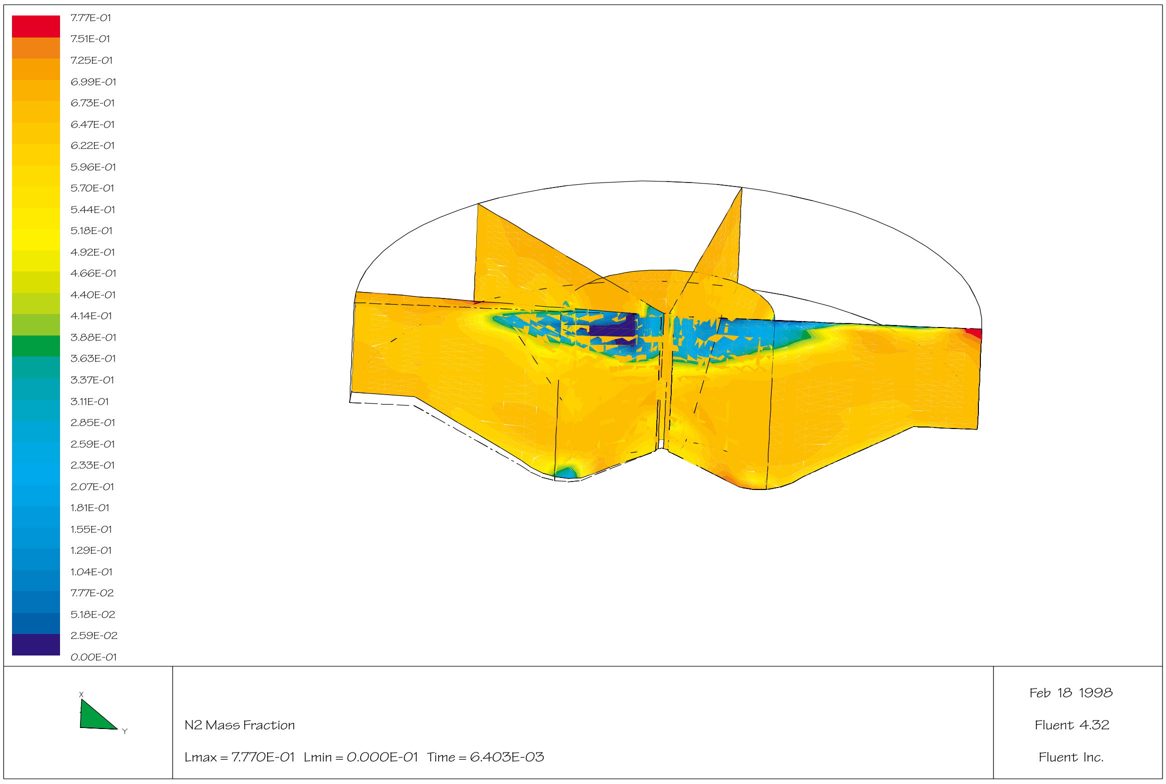
Obr. 3 Vplyv nestacionárneho prúdenia na koncentráciu metánu
Fig. 3 Influence of nonstationary flow on concentration of methane



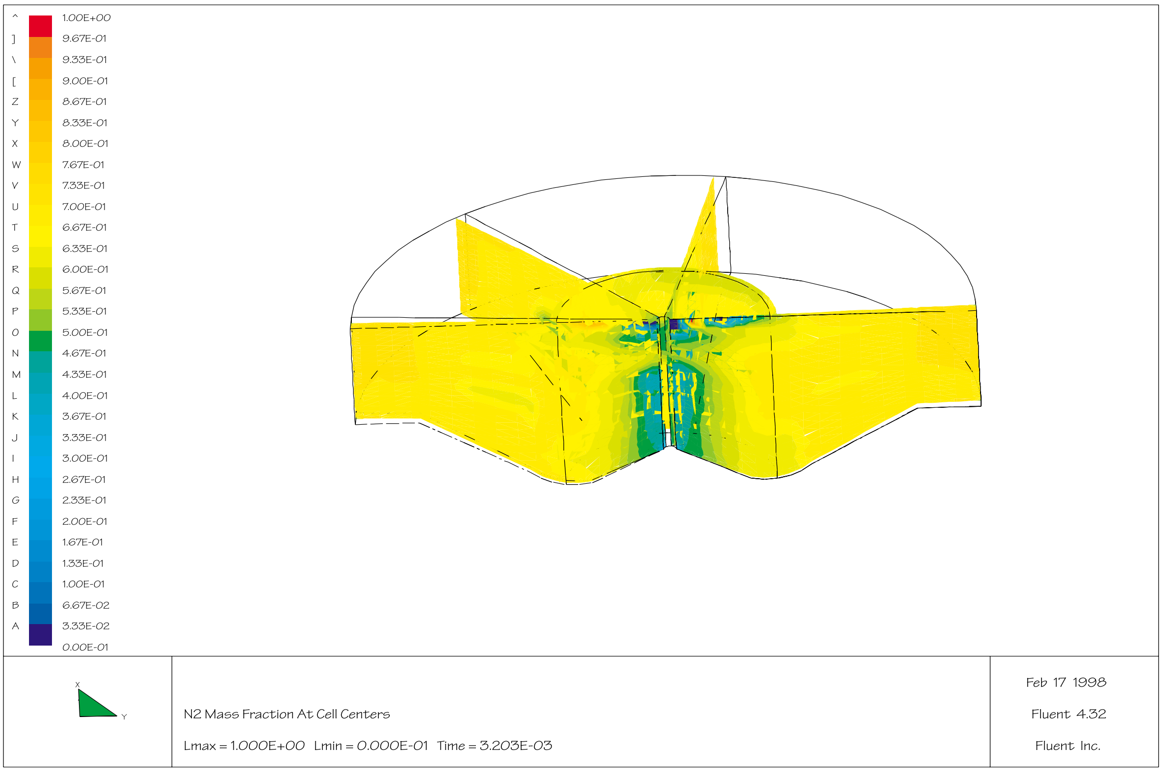
Obr. 4 Zvyšky metánu po skončení spaľovania
Fig. 4 Residues of methane after combustion is over



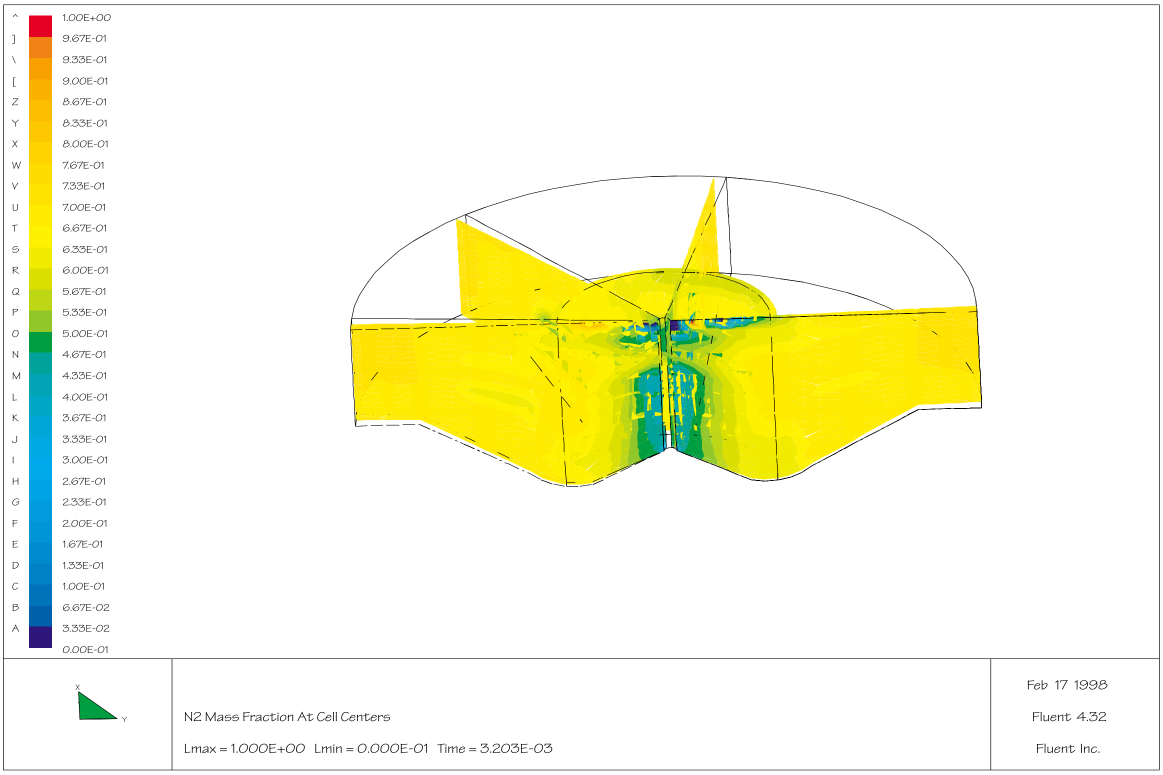
Obr. 5 Koncentrácie NO
Fig. 5 NO concentrations



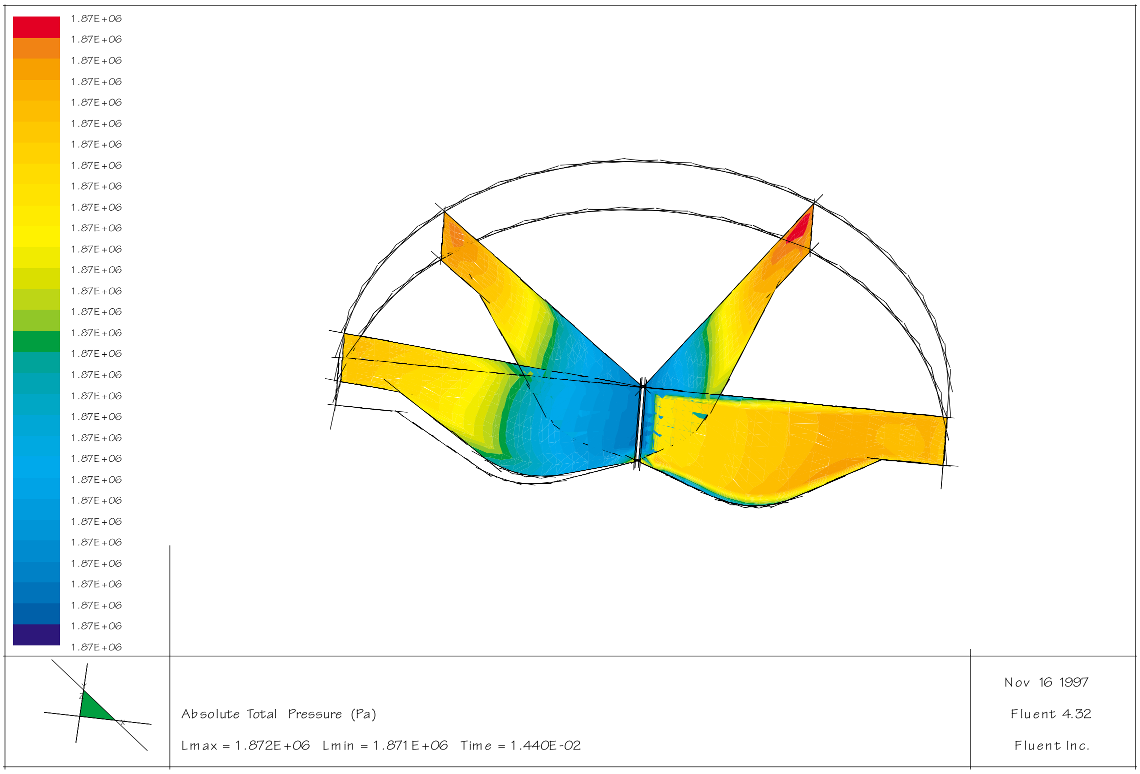
Obr. 6 Koncentrácie NO
Fig. 6 NO concentrations



Obr. 7 Koncentrácie N_2
Fig. 7 NO_2 concentrations



Obr. 8 Koncentrácie N_2
Fig. 8 NO_2 concentrations



Obr. 9 Rozloženie tlakov
Fig. 9 Distribution of pressures

vých vĺn v priestore. Priebeh rýchlostí je časovo nespojitý, premenlivý, striedajú sa zóny s najnižšou a najvyššou rýchlosťou. Zmena rýchlostí nenastáva len vzhľadom na osovú symetriu, ale sa aj po obvode. Vplyv počiatočnej tangenciálnej rýchlosti sa prejavuje aj počas horenia zmesi a horením generovaná rýchlosť častíc sa superponuje na stacionárne počiatočné rýchlostné pole za de finovanej počiatočnej podmienky rýchlosti. S horením sa prejavuje vplyv trecích síl o stenu valca, čo spôsobuje postupné znižovanie rýchlosti s časom.

Záver

Ako z výpočtu vyplýva, skutočný okamžitý obsah každej zložky reagujúcej zmesi v priebehu reakcie leží medzi východiskovým obsahom tejto zložky vo vstupných produktoch reakcie a jej rovnovážnym obsahom pre okamžité stavové a koncentračné podmienky. Proces tvorby a zániku príslušnej zložky je možné chápať ako posun hodnoty okamžitej koncentrácie medzi týmito krajnými hodnotami v smere k ustanoveniu rovnováhy, ktorý je určený integrálom reakčnej rýchlosti za dobu trvania reakcie. Vo valci spaľovacieho motora sa však navyše mení s časom tlak a teplota, pričom teplota má v rôznych miestach spaľovacieho priestoru rôzny časový priebeh, najmä je do veľkej miery ovplyvnená prechodom plamenného frontu daným miestom.

From the courses of velocities during combustion it follows that during the combustion process nonstationary propagation of pressure waves occurs. The course of velocities is time-discontinuous, variable, areas with the lowest and highest velocity interchange. The change in velocities does not occur only due to an axial symmetry, but it is also on the periphery. The influence of initial tangential velocity is felt also during burning of the mixture and the speed of particles generated by burning is superposed to a stationary initial velocity field at a defined initial condition of velocity. The influence of friction forces against the cylinder wall is observed with burning. It causes a gradual decrease in velocity with time.

Conclusions

As it results from the calculation, the real instantaneous content of each component of the reaction mixture during the course of reaction lies between the initial content of this element in the input products of the reaction and its equilibrium content for instantaneous state and concentration conditions. The process of formation and extinction of a particular component can be understood as a shift of a value of the instantaneous concentration between these boundary values in the direction to the equilibrium stabilization that is determined by the integral of reaction velocity during the reaction duration. Pressure and temperature change most with time in the cylinder of a combustion engine. Temperature

Na priebeh koncentrácie reakčných zložiek má významný vplyv chemická reakcia s najväčšou rýchlosťou. V porovnaní s prvou časťou výpočtu boli v druhej časti problémy s numerickou stabilitou systému, pretože program počíta s veľmi malými hodnotami koncentrácií jednotlivých zložiek. Použitá metóda konečných diferencií je optimálna vtedy, keď pomer diferencií počítaných veličín (rýchlosť, tlak, teplota, koncentrácie jednotlivých reakčných zložiek) je hodnota blízka číslu 1. V prípade počítania s veľmi malými hodnotami koncentrácií (rádovo stotiny až tisíciny) dochádza k chybám výpočtu. Pre dosiahnutie korektnejšieho výpočtu by bolo preto vhodnejšie pracovať s časovo premenlivou sieťou, t. j. každý výpočtový krok počítať s novou sieťou. Takúto možnosť má napríklad výpočtový program RAMPANT, ktorý je určený len pre výpočty v oblasti prúdenia. Pre zabezpečenie konvergencie výpočtu by bolo vhodnejšie použiť rozdielnu voľbu časového kroku pre prúdenie a pre chemické reakcie, ktorú umožňuje verzia programu FLUENT UNS.

Recenzenti: M. Steiner, Š. Liščák

has a different time course in different places of the combustion chamber and it is influenced, to a great extent, by a transition of the flame front across the given place.

The course of reaction component concentration is greatly influenced by the chemical reaction of the highest velocity. When compared with the first stage of the calculation, in the second stage there were problems with a numerical stability of the system as the program considers very small values of concentrations of individual components. The applied method of finite differences is optimal when a difference ratio of the calculated magnitudes (velocity, pressure, temperature, concentration of individual reaction components) is a value near number 1. When the calculation is done with very small values of concentrations (hundredths or thousandths) some errors in calculation occur. In order to achieve a more correct calculation it would be suitable to work with a time-variable network, i. e. to calculate each calculation step with a new network. This possibility is provided e. g. by the program RAMPANT which is designed for calculation from the field of flow only. To provide a convergence of calculation it would be better to use a different option of a time interval for flow and for chemical reactions which is enabled by a version of the program FLUENT UNS.

Reviewed by: M. Steiner, Š. Liščák

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Ida Ercsey *

PREDPISY Č. 1 A 2 TÝKAJÚCE SA BALÍKOVÝCH ZÁSIELOK V ZMYSLE PODMIENOK UPLATŇOVANÝCH V EÚ

INSPECTION NO. 1 AND NO. 2 OF POSTAL OBLIGATIONS CONCERNING MAIL PARCELS UNDER EU-REGULATED UNIVERSAL SERVICES

Skúmanie možností dodávania poštových balíkov do hmotnosti 10 kg. Porovnanie súčasnej a predpokladanej úrovne. Predstavenie novej zásielkovej služby a podmienok pre jej zavedenie. Vyčíslenie finančných nákladov v distribučných uzloch a prepravných úloh v podmienkach nového systému rozvozu zásielok. Kalkulácia nákladov na služby v zmysle predpisov EÚ.

The examination of the possibility of the nation-wide delivery of postal packets no larger than 10 kg. The comparison of the present and expected packet service level. The presentation of the new packet forwarding service and the conditions for its introduction. The putting into figures of the extra turnover at the distribution points and of the transportation tasks in the new packet delivery system. Cost calculation for the service according to the EU regulations.

1. Introduction

Uniform universal scope of services shall be defined in member states pursuant to planned EU regulations by taking into consideration the interests of consumers and the improvement of service quality.

The scope of universal services comprises addressed mail items below 2 kg in weight, addressed books, catalogs, papers and magazines. Moreover, addressed mail parcels below 10 kg in weight, as well as registered and insured services are included. The above-mentioned items shall be collected at collection points at least once on a minimum of 5 working days each week and delivered to natural and legal entity persons at the address location.

2. Establishment of new parcel service for national door-to-door delivery of mail parcels below 10 kg in weight

Comparing the current level of services with expected levels

The inspection of conditions and a survey of the logistics system showed that in some areas in Hungary mail parcel services fulfill more and in some other areas less than what is expected under EU regulations.

Parcel services' level of compliance with EU requirements in Hungary:

- 100 % for availability of acceptance,
- 100 % for delivery and processing of items,
- in the field of delivery,
  - 5 % of settlements,
  - 71.5 % concerning the ratio of door-to-door delivery items.

It can be seen from the above that major changes are needed in the current system, specifically to increase the number of settlements involved in the door-to-door delivery of parcels. From another point of view problems are accumulating in the delivery service in close connection to the task to be solved at the present. Changes in the economic and social structure have caused a deep-down transformation in the structure of postal items (distribution, and dispersion as per type of posters, place of posting and destination, weight and size parameters, special services, local and re-forwardable, etc.). This causes some tension in demands for services and the slowly changing service structure.

This requires - among other things - repeated surveying of the overall delivery system and its transformation in accordance with current and expectable requirements.

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Description of conditions for introduction of the new system

The most typical feature of the forwarding system of postal items is that it is a uniform whole. This means that - almost completely regardless of item type - the system has the same input (source) points, primary (local) collection (and processing), secondary (interurban) collection (and processing), exchange forwarding, primary (interurban) distribution (and processing), and secondary distribution (delivery) and is performed on the same routes and with the same means of transport.

The objective is not to develop a completely new system but to transform an operating systems with respect to the item forwarding network's transformation.

changes, elements that require changes, and what transformation is needed. Moreover, I will determine what qualitative, quantitative and cost parameters can be used to describe the transformations (innovations). You can see in Fig. 1 the elements of the mail parcel forwarding system.

The current system is concentrated in the centre with Budapest.

- Basically, the current elements of local collection and acceptance are available for utilization. However, it is undoubtable that the establishment of regional coverage door-to-door delivery of parcels also has an effect on the collection system.

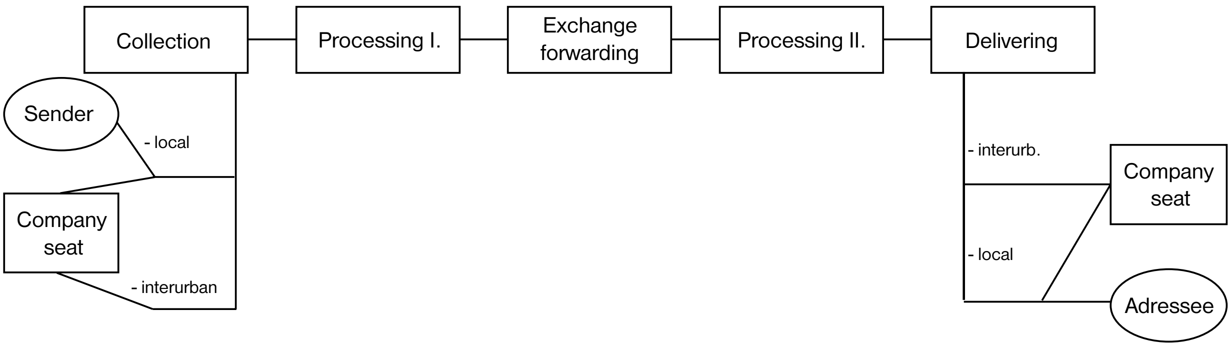


Fig. 1 Elements of the mail parcel forwarding system

It will be necessary to take into consideration traffic peculiarities of elements (fixed points), the size of traffic on such points, as well as their role in prevailing innovation plans. Outline maps are used to describe the key elements of the current parcel forwarding system and the one to be established. (Inset 1, 2, 3.) Twenty four % of the current parcel delivery post offices are processing post offices, 34 % of them are route starting post offices and 60 % of them regional post offices. Ninety % of the proposed regional centers are regional post offices and 83 % of them are planned in IPN.

Important standpoints concerning innovation include dispersion of parcel items, flow data and any possible alternative solution for flowing.

It is necessary to maintain the system's theoretical central management. It is also necessary to establish and, if needed, further develop the information system required for the same. One must make use of information gaining and forwarding facilities offered (to be offered) by the Integrated Postal Network. I think it is natural that the IPN innovation plans contain more points than the parcel forwarding network, but I believe that some points of the latter should be included for the IPN if these are taken into consideration as regional centers.

In the course of the audit I will determine the elements of the current system which can be utilized in the new system without

- Interurban collection demands no special tasks. At the same time the modification and expansion of the distribution system to be detailed hereunder will require changes in the processing system and in turn this will result in a transformation of interurban collection to a certain degree.

- The processing of parcels for interurban distribution will change to the extent that post offices involved in delivery and interurban distribution undergo changes. Both will change to some extent, because the national expansion of delivery requires designation of new post offices involved in delivery tasks. However, the number of parcels to be processed will not change, only the place of their processing and to a certain degree the content of dispatches, in other words the order of their management.

- Efforts should be made for exchange forwarding to avoid Budapest, or at least the Processing Center, and be made directly between processing points where quantity levels and the network allow for the same in an efficient manner. It is necessary to make possible direct exchange forwarding in an ad hoc manner between processing centers. The transportation of some items (e.g. newspapers) might become uncertain or even abolished. Thus, there is a great probability for moving exchange forwarding and interurban distribution of parcels to road routes. The parcel forwarding system as per EU requirements does not make the above transformation obligatory because requirements can be fulfilled without it. However, it is evident that it would improve the parcel service, its flexibility and throughput times, and work conditions as well. The change would demand large one-time expenditures (automobiles) and some surplus operating costs on a temporary basis.

- Major changes will be needed in the item forwarding system in the second phase processing of parcels. In part, post offices participating in the door-to-door delivery of parcels will require transformations and in part, new ones will have to be developed. Important factors include the lowest possible number of transloading and low transportation distances. Efforts should also be made for such post offices to be accepting from the point of view of other postal requirements. These post offices processing (regional) centers as well. Presently, there are a total of 128 settlements in Hungary designated for overall door-to-door delivery of parcels. In the future, 115 of these will be kept in business, 13 will be abolished (and their function transferred) and 28 new units will be created. Thus, a total of 143 post offices (not including Budapest) will be engaged in the door-to-door delivery of parcels. Demand for new tools differs at every location. At post offices to be transformed and expanded, the surplus requirements are expected for tools and sources, because of the function and traffic growing. With respect to delivery, I differentiate between local and interurban parcels.

Fig. 2 presents input and output of the regional centers.

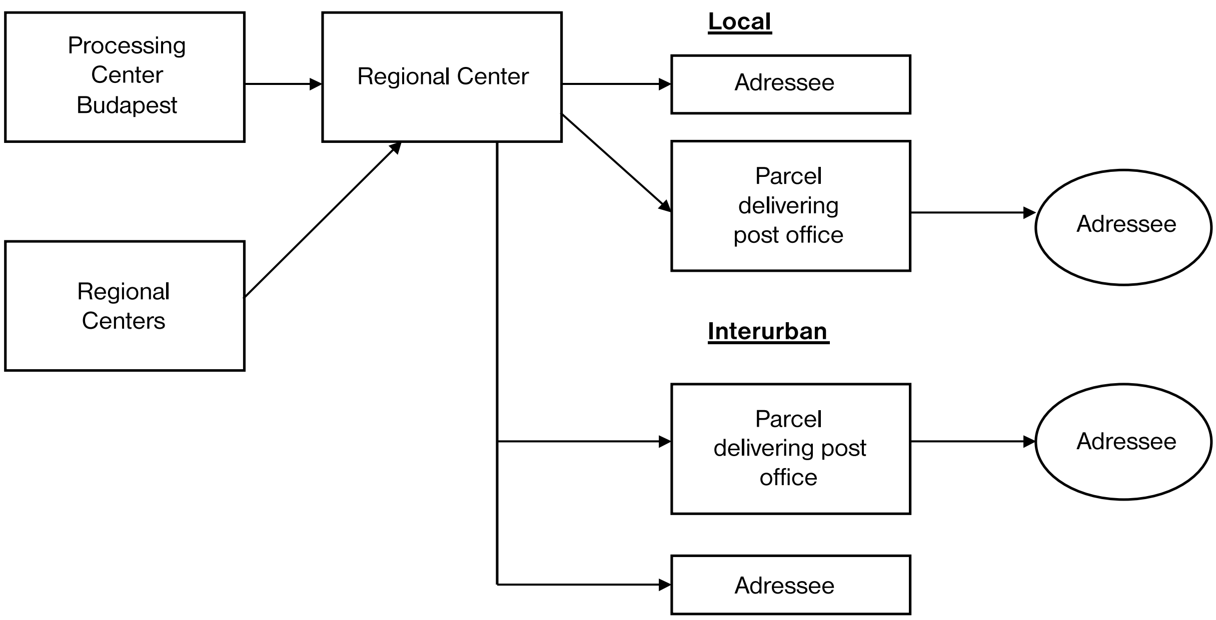


Fig. 2

become the "general" regional centers of the territory. In addition to the innovation of the parcel forwarding service, and ensuring its compliance with the requirements of the EU, these centers will play a key role in the postal network's operation from other points of view as well. The number of post offices engaged in the delivery of parcels was calculated on the basis of parcel traffic data. I suppose that the workforce will be recruitable locally, processing will be operative and forwarding management decentralized. Thus, I suppose that it will be possible to establish "mixed" function (forwarding and delivering) routes, flexible use of assets and other sources, and to form local and central reserves. In determining the location of processing post offices and regional post offices connected to them, I put emphasis on their harmonious integration into the current system of the post.

- Parcels are delivered from selected post offices via automobile routes. The vast majority of post offices engaged in delivery are

3. Cost calculation for services pursuant to EU regulations

In this chapter I will determine the size of the one-time investment necessary for the planned innovation of the current delivery system and I will prepare calculations on the increase in operating costs caused by the new centralized delivery method. On the basis of delivery traffic data supplied for working out this topic I will first determine the traffic of regional centers and post offices involved in delivery, and then the increase in traffic in the new parcel service system. I will examine the size of the ground area required by the local and interurban parcel traffic increase of centralized delivery at distribution points.

I will determine the number of routes and vehicle needs for performing new delivery tasks.

I will estimate the increment in material movement tools and the volume of sources needed for innovation of the information system.

Finally, I will present the one-time expenditures necessary for services required under EU regulations and growth in operating costs.

Determination of traffic increase at regional centers and parcel delivering post offices

Calculations were prepared in local and distance breakdown for post office, directorate and overall post levels.

The calculations were performed on the basis of delivery traffic data broken down to each distribution point available.

Although parcel traffic has dropped back from the levels taken into consideration, it is expected to reach those levels again soon.

Delivery traffic of post offices proposed for regional centers can be local (within the settlement designated for delivery) and distance (outside the settlement designated for delivery). Twenty-one of the post offices engaged in post site delivery will be assigned with parcel door-to-door delivery function in the centralized distribution system.

The increment in items to be delivered is around 20,000 pcs/day.

The comparison of local and interurban delivery traffic of regional centers shows major differences at various centers. At large settlements (Tatabánya, Szolnok) local traffic is more than two-times higher than distance traffic. However, the opposite is true for small settlements (Encs, Vásárosnamény).

At the level of directorates door-to-door delivered traffic at present is generally higher than distance delivery traffic (with the exception of BUVI).

Determination of delivery routes

First of all I specified three types of routes for determination of the number of routes required for national door-to-door delivery of parcels having a maximum weight of 10 kg and calculation of miscellaneous costs related to these.

The first group contains routes located in a large city environment, the second routes outside the above at the headquarters of the delivering post office, and the third group contains routes which deliver regionally or fall outside the territory of the delivering post office (distance).

For local routes I calculated with 60 parcels and 30 km of route length per route and per day. I calculated with shorter parcel handover times for routes in the second group pursuant to delivery distance.

The following data was used for determination of the delivery route necessity of distance parcels: parcel item number, number of delivering post offices, number of settlements, average route length, average running speed, parcel handing in time, preparation and counting time. On the basis of the above, door-to-door delivery of parcels below 10 kg in weight (as per EU regulations) demands a total of 17 new local and 310 new distance that is, a total of 327 delivery routes.

Determination of vehicle requirements at regional centers and post offices engaged in delivery

Substantial increases will be needed in the vehicle fleet for the centralized delivery system required for the expansion of door-to-door delivery. I calculated using 8-hour delivery routes for both local and distance door-to-door delivery, and the increase in routes number was used to calculate vehicle needs and the sum of the investment needed.

Ground area requirements of the parcel distribution system

The expansion of door-to-door delivery of parcels requires investments and expansions in the ground area at regional centers and a new post office engaged in the delivery of parcels.

I used the new ground area needs (for storing, placing in a row and processing) and calculated using 50,000 HUF/m^2 construction costs.

Innovations in material movement machines

The innovation involves material movement tasks at places and/or to the extent which has not had to be faced in the past. For this purpose I calculated using a durable hand-cart for each delivery route. Necessary volumes will be determined according to the increase in traffic; in other words, the increase in the number of parcel delivery routes.

Innovation of the information system

The expansion of door-to-door delivery of parcel items requires among other things operation of an information system higher in quality than the current one.

From this point of view I rank post offices engaged in delivery into four groups, and I am using identical sums for post offices in the same group.Table 1 presents the structure of the investment sum.

The structure of the investment sum — Table 1

The name of the innovation	Percent weight (%)
Vehicle	83.6
Grund area	14.1
Material movement machines	1.8
Information system	0.5
Total:	100.0

Determination of operating costs in the centralized delivery system

I also performed calculations to determine surplus fuel, payroll and vehicle amortization expenditures per year - required by higher delivery traffic and route number.

Calculations involved the “norms“ of local and distance routes, as well as the average of the monthly mean base sum of post directorates.

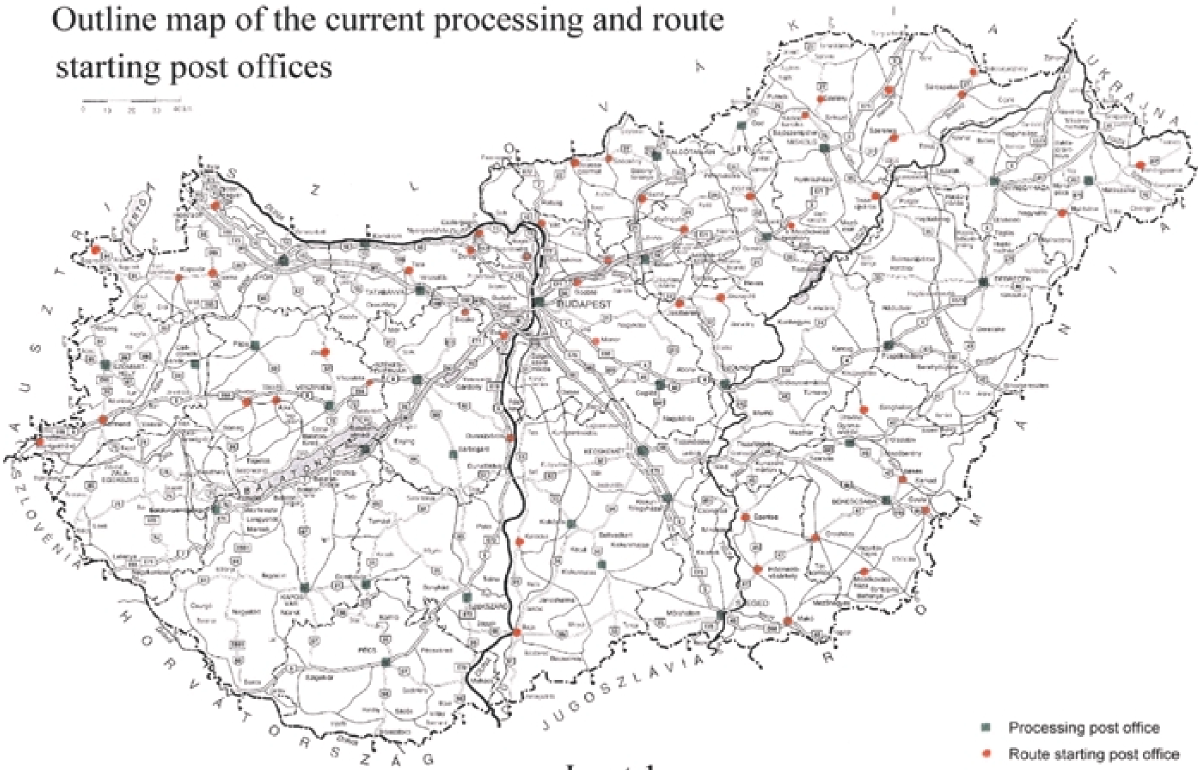
Surplus costs originating from expansion in material movement tools

Twenty % annual amortization was used in calculations of the increment in operating costs.

Surplus costs originating from expansion of the information system

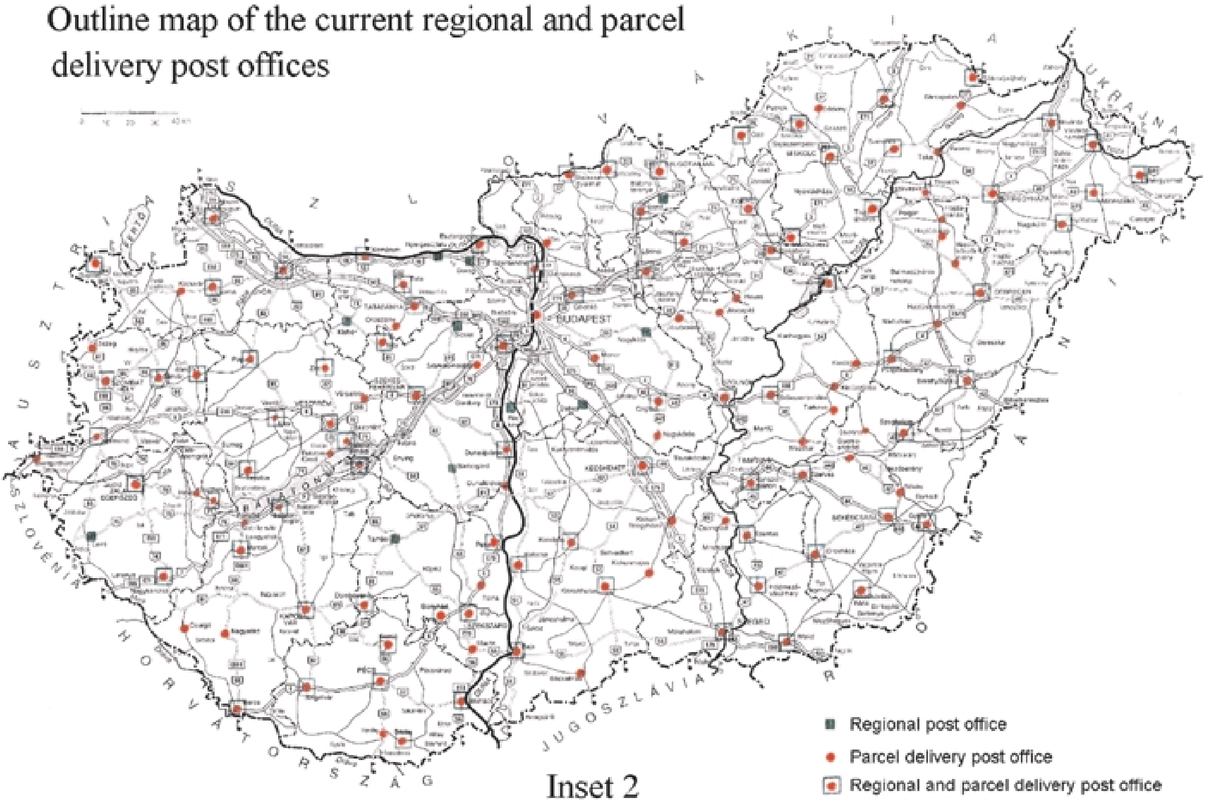
Thirty-three % annual amortization was used in calculations of the increment in operating costs.

Outline map of the current processing and route starting post offices



Inset 1

Outline map of the current regional and parcel delivery post offices



Inset 2

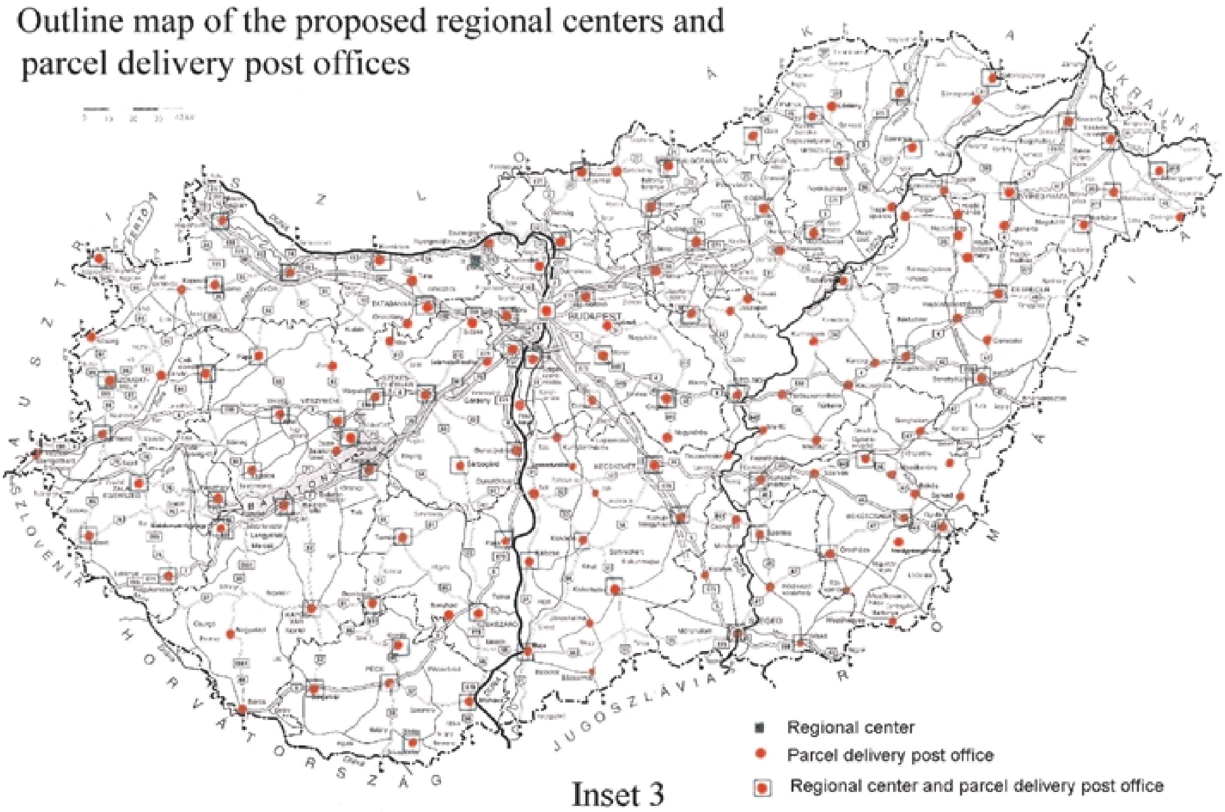


Table 2 presents the structure of the annual operating surplus costs.

The structure of the annual operating surplus costs Table 2

The name of the costs		Percent weight (%)
Fuel:	local	0.50
	interurban	16.60
Payroll:	local	2.30
	interurban	41.20
Vehicle amortization:	local	2.00
	interurban	36.20
Material movement tools:	local	0.04
	interurban	0.76
Information system		0.40
Total:		100.00

Conclusions

The implementation of national door-to-door delivery of postal parcels below 10 kg in weight demands substantial developments in the current system of distribution. Trouble-free operation makes it necessary to coordinate the previous system's transformation - under the innovation project under way at the Post - with the Integrated Postal Network. Regional centers will have a special role in the centralized delivery system in the field of tasks, responsibility, scope of authority and as a communications center. The centers will have key importance in the operation of the postal network for other factors as well. The time schedule of the new system's implementation should be coordinated on the one hand with other elements of the system, and on the other hand the time requirement of the task to be solved and expenditures to be made. Expansion of door-to-door delivery of parcel to nation-wide service will have an effect on parcel fees as well.

Reviewed by: M. Chytil, T. Čorejová

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Istvan Standeisky *

AM STEREOFÓNNY SYSTÉM S PRENOSOM DOPLNKOVÝCH ÚDAJOV

AN AM STEREO SYSTEM WITH ADDITIONAL DATA TRANSMISSION

Skôr vyvinuté AM stereofónne systémy už boli popísané. V príspevku je popísaný nový kompatibilný AM stereofónny systém. Nový systém umožňuje zavedenie stereofónneho vysielania so šírkou pásma zvukových kanálov od 50 Hz do 4,5 KHz (alebo viac) a prenos dát s prenosovou rýchlosťou 25 bit/s.

Previously proposed systems for AM stereo are discussed. The new compatible AM stereo system is described. The new system makes it possible to implement a stereo transmission with a bandwidth in the sound channels from 50 Hz to 4.5 (or more) kHz and a data transmission with a modulation rate of 25 bit/sec.

Introduction

Due to increasing interest in stereophonic music reproduction in the 1950s, techniques for stereo transmission on AM stations were investigated. Work on the AM stereo system has been in progress ever since. Several solutions have been developed.

All the proposed systems transmit a sum signal, usually L + R, and a difference signal, usually L - R. The modulation of the carrier with the L - R signal is generally phase or frequency modulation. The main purpose is to ensure that satisfactory reception of stereo can be obtained without unduly impairing the reception of the sum (monophonic) signal on conventional AM receivers. The spectrum of the composite radiated signal must be contained within the normal passband and the difference signal components must be chosen with care if they are not to cause envelope distortion. Thus, the specification must be somewhat of a compromise. Some proposals use quadrature amplitude modulation of the carrier to carry the stereo difference components.

Table I. gives a summary of the main characteristics of five systems under consideration (in 1984) by the American FCC.

The phase deviations of the proposed quadrature systems are much smaller than those of the PM and FM systems. Thus, the monophonic receivers with envelope detectors can work with little distortion, but the coverage area of the stereo reception is significantly smaller than that of the monophonic reception.

The PM and FM systems do not have this shortcoming. They work without any distortion if all bandpass filters in the transmitter, antenna system and receiver have a flat amplitude and linear phase response. (A distortion-free monophonic reception with envelope demodulation requires the same conditions.) The coverage area can approach that of the monophonic reception.

During the development work on AM stereo, successful experiments on systems with additional data transmission were also carried out on long wave and medium wave AM transmitters.

The author of this article has worked with AM stereo and the admittional data transmission for several years. The experimental works in the laboratories of the Szechenyi Istvan College have confirmed the idea that it is possible to combine the AM stereo with a low rate data transmission.

System considerations

Both methods, the AM stereo and the LF radio data, need similar techniques in the transmission of the necessary additional signals. If the additional signals are transmitted by phase modulation of the carrier, we can regain them from the phase demodulator of the receiver. It is easy to separate the two signals if their bands do not overlap one another. That means that the spectrum of the data signal must be limited. The limit is the lowest frequency in the sound transmission which is about 30 ... 40 Hz.

The signalling for the stereo transmission can be solved by means of the data signal as well. A signalling system alerts the listener that a stereo broadcast is being received and can automatically switch the receiver between its mono and stereo modes.

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Table I.

Company		Harris	Haseltine/Kahn	Motorola	Magnavox	Belar
System		PM	ISB	C-QUAM	AM/PM	AM/FM
(L + R) signal modulation		AM	AM	AM	AM	AM
(L - R) signal	modulation	Quadrature AM	Quadrature MA	Quadrature MA	PM	FM
	frequency or phase deviation	± 15°	-	± 45°	± 1 radian	± 1.25 kHz
	additional features	-	(L - R) predistortion to compensate for subsequent envelope distortion 90° phase shift between sum and difference	(L - R) predistortion to compensate for subsequent envelope distortion	-	-
Additional signals (stereo)		20 - 25 Hz added to (L - R)	15 Hz	25 Hz 4 % added to (L - R)	5 Hz 4 radians added to (L - R)	-
Preffered method of stereo detection		L and R synchronous detectors each operating at 90° to the unwanted signal, with phase locked loops	Modulation with (L + R) to remove distortion, then synchronous (L - R) detection, 90° before sum/ difference	Envelope distortion introduced prior to L and R syn- chronous detector	Limiter and phase detector provides (L - R)	Limiter and frequency demo- dulation provides (L - R)

If it is a requirement that the stereo transmission has to achieve the coverage area of the monophonic transmission, S/N in the L - R channel must equal S/N in the L + R channel which can be fulfilled only by use of FM or PM. The latter is more advantageous because of its implementation simplicity. The S/N of the L + R channel equals that of the L - R channel if the demodulation gains are the same. At an AM - PM system it means:

$$m_p^2 = \frac{2m_a^2}{2 + m_a^2}$$

where mp and ma are the modulation indices.

Channel noise can be particulary perceived if the modulation indices are small. In this case

$$m_p \approx m_a$$

and the channel noise is merely 3 dB higher in the L and R channel than that in the L + R channel. (The S/N depends also on the signal distribution between the L and R channel. The extreme values are 3 dB higher or 3 dB lower than S/N is in the L + R (monophonic) channel.)

Thus, at the maximum modulation

$$m_p = m_a = 1,$$

That is the maximum phase deviation must be at least 1 radian. But at the final specification of the phase deviation, the properties of the demodulator, the value of the synchronous PM modulation of an AM transmitter and the bandwidth of the modulated carrier must be taken into consideration. The synchronous PM modulation and the phase noise of transmitters are very different. It is a very good value if the phase deviation of the synchronous PM modulation is smaller than 6° (at 1000 Hz and $m_a = 1$). The phase deviation from the L - R signal must be at least 10 times larger, that is 60°, so that we can achieve a good separation of the channels and a low distortion. (The synchronous PM modulation is in general largely distorted.) But too large phase deviations cannot be processed by certain PM demodulators. If the joint phase deviation coming from the data signal and the L - R signal are limited at 90°, most PM demodulators can be used in AM stereo receivers.

The bandwidth of a PM signal depends on the frequency of the modulating-signal and the phase deviation. At the phase deviation of 60° there are 2 ... 3 significant side frequencies in the spectrum. Fortunately the high-frequency components of the sound signal are of a small level. Thus, the phase deviation is small as well, and the spectrum can be kept within the specified bandwidth.

We can see that the phase deviation of 60° is an appropriate compromise. It makes possible a good S/N and channel separation with a low distortion. The spectrum spread of the transmitter is negligible. The lab experiments have proved that the stereo transmission is not disturbed by the data signal if the phase deviation for the data transmission is smaller than 22.5° at a modulation rate of 25 Bd. (The highpass filters at the input of the L - R and L + R channel in the receiver were first-order with a cut-off frequency of 50 Hz.) The data-shapping filter in the transmitter had an amplitude response:

$$H_T(f) = \begin{cases} \cos \dfrac{\Pi f t_d}{4} & ; 0 < f < 2/t_d \\ 0 & ; f > t_d \end{cases}$$

and here $t_d = 1/12.5$ second. (The logic 1 at the filter input was $\delta(t)$, the logic 0 was 0.)

If the sound transmission is monophonic, the phase deviation for the data channel can be enlarged up to 45° or even more. The receiver can automatically switch on its stereo mode if the phase deviation for the data transmission is between 22.5° and 45°.

The coverage is monophonic at a phase deviation higher than 45° or smaller than 22.5°. The 22.5° phase deviation is satisfactory for a secure data transmission.

Thus, the time function of the stereo signal is:

$$U(t) = [1 + (L + R)] \cos[\omega_c t + 1.047(L - R) + 0.393d(t)]$$

$d(t)$ is the data signal, for example, a shaped and biphase coded data waveform. All signals L + R, L - R and $d(t)$ have relative values and vary between -1 and l.

Implementation

The AM demodulator of the AM - PM stereo system is the envelope detector. It is absolutely insensitive to the phase noise and synchronous PM modulation of the transmitter, which is very useful for the system. This type of the demodulator is traditional for the AM broadcasting and most receiver ICs incorporate it.

An effective AGC is an indispensable part of AM - PM stereo systems. The ICs designed for AM stereo reception contain this stage, and the level of the L + R signal is practically independent of the level of the input RF signal.

The receiver has to be exactly tuned in to ensure an excellent stereo reception. This is why electronically tuned receivers are advantageous for AM stereo.

After having reviewed the most important aspects we shall now see what the extra functions required for AM stereo are.

1. Removing the amplitude modulation from the phase - modulated carrier.
2. Demodulating the stereo difference signal (L - R).
3. Matrixing the L - R and the L + R signal.
4. Detecting and indicating the stereo identification (signalling system).
5. Soft blending of AM -stereo depending on receiving conditions.

For demodulating the phase modulated signal containing the L - R stereo information and the data signal, the so called quadrature demodulator of FM receivers can be used especially in an extended AM stereo - FM stereo receiver. In this case the demodulated L - R signal has to be corrected to transform the FM demodulation response with an integrator into a corresponding phase demodulation response.

If the receiver has a data stage, the filtered data signal can be used for the stereo identification (or signalling). After rectification and filtering of the received data signal we have a DC level depending on the phase deviation of the data transmission. By means of an appropriate comparator the signalling can be solved.

Measured system characteristics

The following data was achieved in a receiver incorporating an IF stage with two parallel resonant circuits. In stereo mode the L - R signal was regained by means of a quadrature FM demodulator.

Channel separation (40 Hz.....4.5 kHz)	(cross talk)	30 dB
Distortion (m_a = 0.8, f = 1000 Hz)	stereo mode	2 %
	monophonic mode	1 %

The channel noise in the L and R channels is at stereo reception 4 dB higher than that at monophonic reception.

If the transmission of the AM transmitter was switched in stereo mode the cross talk in the adjacent mono channel inereased by 2 ... 4 dB depending on the modulation depth of the stereo transmitter and the field strength of the received mono signal. The channel distance was 9 kHz at this measurement.

Conclusion

The measurements on the experimental system have proved that the AM stereo and AM radio data can be combined advantageously. The two systems do not disturb each other if the data rate is low, moreover the signalling of the stereo transmission can be fulfilled by means of the data signal.

With a phase deviation of 22.5° in the data channel and of 60° in the L - R channel both, the data and the sound transmission have a good quality.

The implementation simplicity is an important feature of this system as well. The data signal and the L - R signal can be demodulated by the same phase demodulator.

Reviewed by: S. Marchevsky, J. Dúha

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Karel Kovářík *

NOVÉ NUMERICKÉ METÓDY PRE MATEMATICKÉ MODELOVANIE PRENOSU ZNEČISTENIA

THE NEW NUMERICAL METHODS FOR MATHEMATICAL MODELLING OF POLLUTANT TRANSPORT

Článok sa zaoberá riešením riadiacej rovnice prenosu v nasýtenej zóne pomocou metódy náhodnej prechádzky a metódy DR v spojení s metódou hraničných prvkov. Metóda hraničných prvkov dáva spojité pole rýchlostí ktoré sa používa pre riešenie rovnice prenosu v obidvoch metódach. Takéto modely môžu účinne simulovať problémy znečistenia podzemnej vody.

This paper deals with a solution of the transport governing equation in the saturated zone by the random-walk and DR method connected with the boundary element method. The boundary element's solution produces a continuous velocity field which is used to solve the transport equation by both methods. These models can be effectively used to simulate groundwater contamination problems.

Úvod

Modely prenosu sa začali používať ako účinný nástroj pre predpoveď prenosu znečistenia v podzemej vode. Napriek tomu, že dodnes bol vyvinutý a publikovaný v literatúre celý rad numerických modelov, ani jeden nie je celkom bezchybný. Modely, ktoré priamo riešia rovnicu prenosu znečistenia, podliehajú numerickej disperzii alebo osciláciám, predovšetkým vtedy, keď je konvekčná zložka prenosu dominantná, t. j. pre vysoké Pecletove čísla. Tento problém sa môže riešiť pomocou časticových metód (Kinzelbach, 1988). Tieto časticové metódy sú síce veľmi užitočné, ale tiež majú niekoľko nevýhod, spojených hlavne s niektorými okrajovými podmienkami. Niektoré nové metódy pre priame riešenie tiež vyzerajú sľubne. Je to metóda dvojnej reciprocity (DR metóda) v spojení s metódou hraničných prvkov. Základná myšlienka metódy je detailne opísaná v (Partridge et al, 1992). Pôvodne bola táto metóda odvodená pre riešenie prenosu tepla v strojárstve, ale môže sa po niektorých úpravách veľmi jednoducho použiť aj pre prenos znečistenia.

Základné rovnice

Riadiaca rovnica prenosu látky je rovnica hydrodynamickej disperzie (pozrite tiež Bear, 1972)

$$\frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial C}{\partial x_j} - v_j C\right) = R\,\frac{\partial C}{\partial t} \qquad (1)$$

Introduction

Transport models have been adopted as tools for the prediction of pollutant transport in groundwater. Although a number of numerical models have in recent years been developed and reported in the literature, none of them are flawless. Models that directly solved the equation of pollutant transport are subject to numerical dispersion or oscillations, particularly when the advective part of mass transport is dominant, i.e. for high Peclet's numbers. This problem can be solved using the particle-tracking methods (Kinzelbach, 1988). The particle tracking methods are very useful but they also have some disadvantages connected mainly with the specific boundary conditions. A new method of direct solution appeared and it shows promise. It is the dual-reciprocity method (DRM) connected with the boundary element method. The basic idea of this method has been described in detail (Partridge et al, 1992). This method has been developed to solve the thermal convection in mechanical engineering but it can al so be very easily applied to the solution of the pollution transport.

Basic equations

The governing equation of pollutant transport is the equation of hydrodynamic dispersion (see e.g.Bear, 1972)

$$\frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial C}{\partial x_j} - v_j C\right) = R\,\frac{\partial C}{\partial t} \qquad (1)$$

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kde D_{ij} sú koeficienty hydrodynamickej dispersie, C je koncentrácia látky, v je pórová rýchlosť prúdenia a R je retardačný faktor (v prípade lineárnej sorpcie).

Pole rýchlostí sa môže vypočítať pomocou hydraulického modelu. Pre riešenie riadiacej diferenciálnej rovnice ustáleného prúdenia podzemnej vody v rovine (rov. 2) sa použila metóda hraničných prvkov.

Rovnica má tvar

$$T_x \frac{\partial^2 \Phi}{\partial x^2} + T_y \frac{\partial^2 \Phi}{\partial y^2} + \sum_{k=1}^{N} Q_k = 0 \quad (2)$$

kde Φ je tlaková výška (potenciál prúdenia) a T_x, T_y sú koeficienty prietočnosti v smere x, y a Q je výdatnosť zdrojov v oblasti. Okrajové podmienky môžu byť

- Dirichletova podmienka $\Phi = \Phi_B$ na časti Γ_1 hranice,
- Neumanova podmienka $\partial\Phi/\partial \upsilon = q_B$ na časti Γ_2 hranice, kde υ je jednotkový vektor vonkajšej normály,
- Cauchyho podmienka $\partial\Phi/\partial \upsilon = f(\Phi)$ na časti Γ_3 hranice.

Riešenie rov. (2) metódou hraničných prvkov dáva Φ a $\partial\Phi/\partial \upsilon$ v prvkoch na hranici oblasti. Hodnoty pórovej rýchlosti v ľubovoľnom bode vo vnútri oblasti sa môžu vypočítať pomocou vzťahu

where D_{ij} are the coefficients of hydrodynamical dispersion, C is the concentration of pollutant, v is the pore velocity and R is the retardation factor (in case of linear adsorption).

The velocity field of groundwater can be computed by a hydraulical model. The boundary element method has been used to solve the governing differential equation of two dimensional horizontal steady groundwater flow

$$T_x \frac{\partial^2 \Phi}{\partial x^2} + T_y \frac{\partial^2 \Phi}{\partial y^2} + \sum_{k=1}^{N} Q_k = 0 \quad (2)$$

where Φ is the pressure head and T_x, T_y are the coefficients of transmissivity in the direction x, y and Q is discharge of wells inside the domain. The boundary conditions to this problems are of the following types

- the Dirichlet's condition $\Phi = \Phi_B$ on the Γ_1 part,
- the Neumann's condition $\partial\Phi/\partial \upsilon = q_B$ on the Γ_2 part of boundary, where ν is the normal outward unit vector,
- the Cauchy's condition $\partial\Phi/\partial \upsilon = f(\Phi)$ on the Γ_3 part of boundary.

Solution of the eq. (2) by the BEM gives the values of Φ and $\partial\Phi/\partial \upsilon$ along the boundary. Now the pore-water velocities distribution inside the domain can be computed as

$$V_x = -\frac{K_x}{n_{ef}} \left[\sum_{j=1}^{N} q_j \int_{\Gamma j} \frac{\partial \Phi^*}{\partial x} d\Gamma_j - \sum_{j=1}^{N} h_j \int_{\Gamma j} \frac{\partial}{\partial x} \left(\frac{\partial \Phi^*}{\partial \upsilon} \right) d\Gamma_j + \sum_{k=1}^{N_Q} \frac{Q_k}{T_x} \frac{\partial \Phi^*}{\partial x} \right] \quad (3)$$

kde K_x je súčiniteľ filtrácie, Φ^* je fundamentálne riešenie, n_{ef} je účinná pórovitosť a N je počet okrajových uzlov. Obdobná rovnica platí aj pre rýchlosť v smere osi y. Fundamentálne riešenie pre Laplaceovu rovnicu pre rovinnú úlohu môžeme písať v tvare

$$\Phi^* = \frac{1}{2\pi} \ln\left(\frac{1}{r}\right) \quad (4)$$

where K_x is the coefficient of hydraulic conductivity, Φ^* is the fundamental solution, n_{ef} is the effective porosity and N is the number of boundary nodes. A similar equation is obtained for the velocities in the y-direction. The fundamental solution for the 2D steady flow can be written as

$$\Phi^* = \frac{1}{2\pi} \ln\left(\frac{1}{r}\right) \quad (4)$$

Metóda náhodnej prechádzky

Pre riešenie rov. (1) použijeme teraz metódu náhodnej prechádzky. Základný predpoklad metódy spočíva v tom, že rozdelenie koncentrácie látky môže byť nahradené rozdelením konečného počtu častíc. Každá táto častica je nositeľkou určitého množstva látky, ktoré sa môže v čase meniť (napr. pôsobením rozpadu). Počet častíc musí byť dostatočne vysoký, aby metóda konvergovala k presnému riešením rov. (1). Mechanizmus prenosu pozostáva z dvoch častí, a to z konvektívnej a disperznej zložky.

Random-walk method

Now we use the random-walk method to solve eq.(1). The basic assumption of the random-walk model is that the distribution of the concentration of pollutants may be represented by a distribution of finite number of particles. A certain mass is assigned to each of these particles which may vary with time (e.g. decay). The number of particles must be sufficiently high to approximate the exact solution of the eq.(1). The mechanism of mass transport consists of two parts, the advective transport and

Konvektívny prenos sa simuluje pohybom častice v smere prúdenia podzemnej vody v danom bode, disperzná zložka je založená na posunutí podľa pravdepodobnostnej funkcie. Výsledkom tohto prístupu je normálne rozdelenie častíc. Štandardná odchýlka rozdelenia je

$$\sigma_L = \sqrt{2.D_L.t} \qquad \sigma_T = \sqrt{2.D_T.t} \tag{5}$$

kde D_L, D_T sú koeficienty pozdĺžnej a priečnej disperzie. Nová poloha častíc sa potom môže určiť zo vzťahu (Kinzelbach, 1988)

$$x = x_0 + \Delta t.V_x + \frac{V_x}{V}.\lambda_1.\sigma_L + \frac{V_y}{V}.\lambda_2.\sigma_T$$
$$y = y_0 + \Delta t.V_y + \frac{V_y}{V}.\lambda_1.\sigma_L + \frac{V_x}{V}.\lambda_2.\sigma_T \tag{6}$$

kde V je veľkosť vektoru pórovej rýchlosti, λ_1, λ_2 sú náhodné čísla podľa normálneho rozdelenia s priemerom nula a štandardnou odchýlkou jedna a Δt je časový krok.
Pre výpočet rýchlosti pre každú časticu môžeme použiť rov. (3). Pomocou rov. (6) potom stanovíme novú polohu každej častice. Častice sú potom unášené prúdením podzemnej vody a celá skupina sa rozptyľuje disperzným pôsobením. Ak potrebujeme kvantifikovať výsledky modelu, môžeme vyniesť izolínie koncentrácie. Musíme použiť pomocnú sieť a spočítať množstvo častíc v jednotlivých blokoch siete. Pri tejto konštrukcii vzniká problém optimálnej veľkosti bloku siete. Ak je blok príliš veľký, zavádza sa v tomto okamihu do výsledkov určitá numerická disperzia, na druhej strane príliš malý rozmer bloku spôsobuje zvýraznenie štatistických odchýlok.

Pri použití tejto metódy vzniká tiež problém s okrajovou podmienkou 1. rádu (Dirichletova p.). Táto podmienka vyžaduje, aby sa do siete dostávali stále ďalšie a ďalšie častice v každom časovom kroku. Tak by táto podmienka viedla k veľmi vysokým počtom častíc. Preto sa často robí predpoklad, že sa nové častice vytvoria presne v mieste starých a pohybujú sa teda po rovnakej dráhe. Ak urobíme tento predpoklad, môžeme sčítať počet častíc v každom časovom kroku a simulovať tak túto okrajovú podmienku.

Metóda duálnej reciprocity

Pre riešenie rov. (1) môžeme teraz použiť aj metódu duálnej reciprocity (DRM). Najskôr použijeme transformáciu súradníc v tvare

$$\tilde{x} = x \qquad \tilde{y} = y\,.\sqrt{\Lambda} \qquad \Lambda = \frac{D_x}{D_y} \tag{7}$$

Potom riadiaca rov. (1) sa môže písať v tvare

$$\frac{\partial^2 C}{\partial \tilde{x}^2} + \frac{\partial^2 C}{\partial \tilde{y}^2} = \frac{v_x}{D_x}\cdot\frac{\partial C}{\partial \tilde{x}} + \frac{v_y}{D_x}\cdot\frac{\partial C}{\partial \tilde{y}} + \frac{R}{D_x}\cdot\frac{\partial C}{\partial t} \tag{8}$$

the dispersion. The advective transport is simulated by moving the particles according to the velocity vector in given point. The dispersive transport is based on the probability distribution of displacements. The result of this estimation is a normal distribution. Standard deviations of the distribution are

$$\sigma_L = \sqrt{2.D_L.t} \qquad \sigma_T = \sqrt{2.D_T.t} \tag{5}$$

where D_L, D_T are the coefficients of longitudinal and transverse dispersion, respectively. The new location of the particle is then given by (Kinzelbach, 1988)

$$x = x_0 + \Delta t.V_x + \frac{V_x}{V}.\lambda_1.\sigma_L + \frac{V_y}{V}.\lambda_2.\sigma_T$$
$$y = y_0 + \Delta t.V_y + \frac{V_y}{V}.\lambda_1.\sigma_L + \frac{V_x}{V}.\lambda_2.\sigma_T \tag{6}$$

where V is the average pore-water velocity, λ_1, λ_2 are normally distributed random variables with mean 0 and a standard deviation 1, and Δt is the time step.
The eq. (3) can be used to compute the velocity for each particle. This velocity may be used at each time step to calculate a new position of the particle. The cloud of particles is then moved according to groundwater flow and spread by the dispersion. If we need to quantify the results we could create the contours of concentration. Then the temporary net must be created and the number of particles in each cell of this net must be counted. There is a problem with the optimal size of these cells. If the cell's size is large numerical dispersion arises, on the other hand, the statistical errors occur if the size is too small.

There is also a problem with the boundary condition of the first kind (Dirichlet). This condition requires generating the new set of particles at each time step and it leads to a very large number of particles. Therefore, we suppose the new particles should create in the same place as the old ones. If we make this assumption, we can sum the number of particles at each time step and so we can simulate this boundary condition.

Dual reciprocity method

For the solution of eq.(1) we can now use the DRM. At first we use the following transformation of coordinates

$$\tilde{x} = x \qquad \tilde{y} = y\,.\sqrt{\Lambda} \qquad \Lambda = \frac{D_x}{D_y} \tag{7}$$

Then the governing transport equation (1) can be written as

$$\frac{\partial^2 C}{\partial \tilde{x}^2} + \frac{\partial^2 C}{\partial \tilde{y}^2} = \frac{v_x}{D_x}\cdot\frac{\partial C}{\partial \tilde{x}} + \frac{v_y}{D_x}\cdot\frac{\partial C}{\partial \tilde{y}} + \frac{R}{D_x}\cdot\frac{\partial C}{\partial t} \tag{8}$$

Metóda duálnej reciprocity bola odvodená pre riešenie Poissonovej rovnice iba pomocou okrajových prvkov. Uvažujme rovnicu v tvare

$$\Delta C = b \tag{9}$$

Pravú stranu rov. (9) môžeme aproximovať v tvare

$$b = \sum_{i=1}^{N+L} \alpha_i \, . f_i \tag{10}$$

kde N je počet uzlov na okraji oblasti a L je počet vnútorných bodov v riešenej oblasti. α_i je množina neznámych koeficientov a f_i sú aproximačné funkcie. Základná myšlienka DRM je použiť pre riešenie superpozíciu partikulárnych riešení riadiacej rovnice. Počet týchto riešení sa rovná celkovému počtu uzlov v oblasti. Môžeme písať

$$\Delta \hat{C}_i = f_i \tag{11}$$

kde $\hat{C}_i$ je množina partikulárnych riešení rov. (9). Ak dosadíme rov. (11) do (10) a (9), dostaneme

$$\Delta C = \sum_{i=1}^{N+L} \alpha_i (\Delta \hat{C}_i) \tag{12}$$

Teraz môžeme použiť opäť riešenie obdobné metóde hraničných prvkov na rov. (12) (Patridge, 1992) a dostaneme

The double reciprocity method has been used to derive a boundary-only solution of the Poisson's equation

$$\Delta C = b \tag{9}$$

The right side of eq.(9) can be approximated as

$$b = \sum_{i=1}^{N+L} \alpha_i \, . f_i \tag{10}$$

where N is the number of boundary nodes and L is the number of internal nodes in the area of interest. The α_i are a set of initially unknown coefficients and the f_i are approximating functions. The basic idea of the DRM is a superposition of localized particular solutions of the governing equation. The number of these solutions are equal to the total number of nodes in the problem and we can write

$$\Delta \hat{C}_i = f_i \tag{11}$$

where $\hat{C}_i$ is the set of particular solutions of eq. (9). If we substitute eq. (11) to (10) and (9) we get

$$\Delta C = \sum_{i=1}^{N+L} \alpha_i (\Delta \hat{C}_i) \tag{12}$$

Now we can apply the BEM solution of the eq.(12) (see Patridge, 1992) and we can write

$$e_i \, . \, C_i + \int_\Gamma \frac{\partial \Phi^*}{\partial v} C d\Gamma - \int_\Gamma \Phi^* \frac{\partial C}{\partial v} d\Gamma = \sum_{j=1}^{N+L} \alpha_j \left(e_i \, . \, \hat{C}_{ij} + \int_\Gamma \frac{\partial \Phi^*}{\partial v} \hat{C}_j d\Gamma - \int_\Gamma \Phi^* \frac{\partial \hat{C}_j}{\partial v} d\Gamma \right) \tag{13}$$

Množinu aproximačných funkcií f_i môžeme zvoliť napr. v tvare konečného radu

$$f_i = 1 + r_i + r_i^2 + r_i^3 + \ldots + r_i^m \tag{14}$$

Potom množina partikulárnych riešení má tvar

$$\hat{C}_i = \sum_{k=0}^{m} \frac{r_i^{k+2}}{(k+2)^2} \tag{15}$$

a ich derivácia podľa vonkajšej normály sa môže vyjadriť ako

$$\frac{\partial \hat{C}_i}{\partial v} = \frac{\partial r_i}{\partial v} \cdot \sum_{k=0}^{m} \frac{r_i^k}{k+2} \tag{16}$$

Ak máme dané hodnoty b v rov.(10) v $N+L$ bodoch, môžeme stanoviť neznáme koeficienty α_j v rov. (13) ako

$$\alpha = \boldsymbol{F}^{-1} \, . \, \boldsymbol{b} \tag{17}$$

The set of approximating functions f_i can be chosen e.g. as the series

$$f_i = 1 + r_i + r_i^2 + r_i^3 + \ldots + r_i^m \tag{14}$$

Then the set of particular solutions has the following form

$$\hat{C}_i = \sum_{k=0}^{m} \frac{r_i^{k+2}}{(k+2)^2} \tag{15}$$

and the normal derivative can be written as

$$\frac{\partial \hat{C}_i}{\partial v} = \frac{\partial r_i}{\partial v} \cdot \sum_{k=0}^{m} \frac{r_i^k}{k+2} \tag{16}$$

If we have defined the values of b in eq.(10) in $N+L$ points, we can determine the unknown coefficients α_j in the eq. (13) as

$$\alpha = \boldsymbol{F}^{-1} \, . \, \boldsymbol{b} \tag{17}$$

kde sme označili F^{-1} inverznú maticu k matici aproximačných funkcií f_{ij}. Ak použijeme maticové označenie, môžeme rov. (13) písať v tvare

$$\boldsymbol{H}\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\,.\,\boldsymbol{F}^{-1}.\,\boldsymbol{b} \tag{18}$$

Pravá strana rov. (8) je súčet troch rôznych členov b_1, b_2 a b_3, kde

$$b_1 = \frac{V_x}{D_x}\frac{\partial C}{\partial \tilde{x}} \qquad b_2 = \frac{V_y}{D_x}\frac{\partial C}{\partial \tilde{y}} \qquad b_3 = \frac{R}{D_x}\frac{\partial C}{\partial t} \tag{19}$$

Teraz môžeme použiť rovnaký postup na konvektívne členy b_1 a b_2. Rov. (17) môžeme teraz písať ako

$$\alpha_i = \frac{V_x}{D_x}\sum_{j=1}^{N+L} F_{ij}^{-1}\frac{\partial C}{\partial \tilde{x}} \tag{20}$$

a rov. (18) má tvar

$$\boldsymbol{H}\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = \frac{V_x}{D_x}(\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\,.\,\boldsymbol{F}^{-1}\cdot\frac{\partial C}{\partial \tilde{x}} \tag{21}$$

Ak vyjadríme deriváciu C ako funkciu hodnôt C v uzloch (see Partridge, 1992) v tvare

$$\frac{\partial \boldsymbol{C}}{\partial \tilde{x}} = \frac{\partial \boldsymbol{F}}{\partial \tilde{x}}\boldsymbol{F}^{-1}.\,\boldsymbol{C} \tag{22}$$

potom rov. (21) môžeme písať ako

$$(\boldsymbol{H} - \boldsymbol{A})\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = 0$$

kde sme označili

$$\boldsymbol{A} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1}\cdot\frac{V_x}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{x}}\cdot\boldsymbol{F}^{-1} \tag{23}$$

Rovnaký postup použijeme na člen b_2. Potom matica A sa môže vyjadriť ako

$$\boldsymbol{A} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1}\left(\frac{V_x}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{x}} + \frac{V_y}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{y}}\right)\cdot\boldsymbol{F}^{-1} \tag{24}$$

Keď aplikujeme DRM na posledný člen b_3, rov. (23) bude mať nasledujúci tvar

$$(\boldsymbol{H} - \boldsymbol{A})\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = \boldsymbol{B}\cdot\frac{\partial \boldsymbol{C}}{\partial t} \tag{25}$$

kde matica $\boldsymbol{B}$ je

$$\boldsymbol{B} = \frac{R}{D_x}(\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1} \tag{26}$$

where we denoted F^{-1} the inverse matrix to the matrix of the set of approximating functions f_{ij}. If we now use the matrix notation we can express the eq. (13) in the form

$$\boldsymbol{H}\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\,.\,\boldsymbol{F}^{-1}.\,\boldsymbol{b} \tag{18}$$

The right side of eq. (8) is the sum of three different terms b_1, b_2 and b_3, where

$$b_1 = \frac{V_x}{D_x}\frac{\partial C}{\partial \tilde{x}} \qquad b_2 = \frac{V_y}{D_x}\frac{\partial C}{\partial \tilde{y}} \qquad b_3 = \frac{R}{D_x}\frac{\partial C}{\partial t} \tag{19}$$

Now we can apply the same procedure to the advective terms b_1 and b_2. We can write eq.(17) as

$$\alpha_i = \frac{V_x}{D_x}\sum_{j=1}^{N+L} F_{ij}^{-1}\frac{\partial C}{\partial \tilde{x}} \tag{20}$$

and eq. (18) has the form

$$\boldsymbol{H}\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = \frac{V_x}{D_x}(\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\,.\,\boldsymbol{F}^{-1}\cdot\frac{\partial C}{\partial \tilde{x}} \tag{21}$$

If we express the derivative of C as a function of values C at nodes (see Partridge, 1992) in the form

$$\frac{\partial \boldsymbol{C}}{\partial \tilde{x}} = \frac{\partial \boldsymbol{F}}{\partial \tilde{x}}\boldsymbol{F}^{-1}.\,\boldsymbol{C} \tag{22}$$

then the eq.(21) can be written as

$$(\boldsymbol{H} - \boldsymbol{A})\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = 0$$

where matrix A is

$$\boldsymbol{A} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1}\cdot\frac{V_x}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{x}}\cdot\boldsymbol{F}^{-1} \tag{23}$$

The same procedure will now be used in case of the term b_2. Then the matrix A can be expressed as the sum of two terms b_1 and b_2

$$\boldsymbol{A} = (\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1}\left(\frac{V_x}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{x}} + \frac{V_y}{D_x}\cdot\frac{\partial \boldsymbol{F}}{\partial \tilde{y}}\right)\cdot\boldsymbol{F}^{-1} \tag{24}$$

When we apply the DRM procedure to the last term b3, eq.(23) will have the following form

$$(\boldsymbol{H} - \boldsymbol{A})\,.\,\boldsymbol{C} - \boldsymbol{G}\,.\,\boldsymbol{Q} = \boldsymbol{B}\cdot\frac{\partial \boldsymbol{C}}{\partial t} \tag{25}$$

where matrix $\boldsymbol{B}$ is

$$\boldsymbol{B} = \frac{R}{D_x}(\boldsymbol{H}\,.\,\hat{\boldsymbol{C}} - \boldsymbol{G}\,.\,\hat{\boldsymbol{Q}})\cdot\boldsymbol{F}^{-1} \tag{26}$$

Rov. (25) je sústava lineárnych diferenciálnych rovníc, ktorú môžeme riešiť pomocou niektorej štandardnej schémy priamej integrácie. Najjednoduchšia je schéma dvoch po sebe nasledujúcich časových krokov. Zmenu $\boldsymbol{C}$ a $\boldsymbol{Q}$ v rozsahu každého časového kroku môžeme vyjadriť v tvare

$$\boldsymbol{C} = (1 - \Theta_c) \,.\, \boldsymbol{C}^i + \Theta_c \,.\, \boldsymbol{C}^{i+1}$$
$$\boldsymbol{Q} = (1 - \Theta_Q) \,.\, \boldsymbol{Q}^i + \Theta_Q \,.\, \boldsymbol{Q}^{i+1} \qquad (27)$$

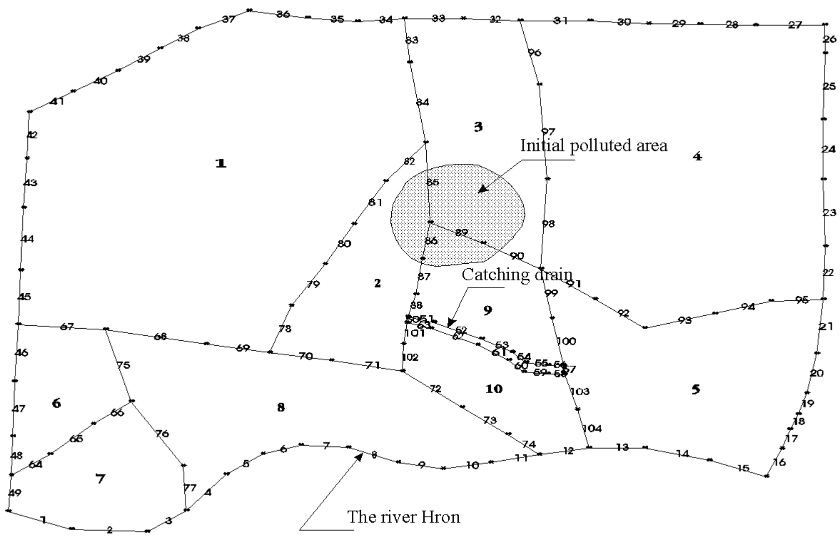
kde Θ_c a Θ_Q sú parametre, ktoré určujú polohu hodnôt $\boldsymbol{C}$ a $\boldsymbol{Q}$ medzi dvoma časovými krokmi i a $i+1$. Po dosadení rov.(27) do rov. (25) dostaneme

The eq. (25) is the set of linear differential equations which can be solved by any standard direct time-integration scheme. The simplest one is the two-level time integration scheme. The variation of $\boldsymbol{C}$ and $\boldsymbol{Q}$ within each time step can be expressed in the form

$$\boldsymbol{C} = (1 - \Theta_c) \,.\, \boldsymbol{C}^i + \Theta_c \,.\, \boldsymbol{C}^{i+1}$$
$$\boldsymbol{Q} = (1 - \Theta_Q) \,.\, \boldsymbol{Q}^i + \Theta_Q \,.\, \boldsymbol{Q}^{i+1} \qquad (27)$$

where Θ_c and Θ_Q are parameters which position the values $\boldsymbol{C}$ and $\boldsymbol{Q}$ between time intervals i and $i+1$. Substituting eq.(27) to eq.(25) yields

$$\left(\frac{1}{\Delta t}\boldsymbol{B} + \Theta_c \,.\, (\boldsymbol{H} - \boldsymbol{A})\right) \,.\, \boldsymbol{C}^{i+1} - \Theta_Q \,.\, \boldsymbol{G} \,.\, \boldsymbol{Q}^{i+1} = \left(\frac{1}{\Delta t}\boldsymbol{B} - (1 - \Theta_c) \,.\, (\boldsymbol{H} - \boldsymbol{A})\right) \,.\, \boldsymbol{C}^i + (1 + \Theta_Q) \,.\, \boldsymbol{G} \,.\, \boldsymbol{Q}^i \qquad (28)$$



Obr. 1 Sieť hraničných prvkov
Fig. 1 The Boundary Element Net

Pravú strana rov. (28) v okamihu i+1 poznáme a potom je rov. (28) sústava lineárnych rovníc, ktorú môžeme v každom časovom okamihu riešiť.

The right side of eq.(28) is known at time i+1 and the eq.(28) is the set of linear equations which can be solved at each time step.

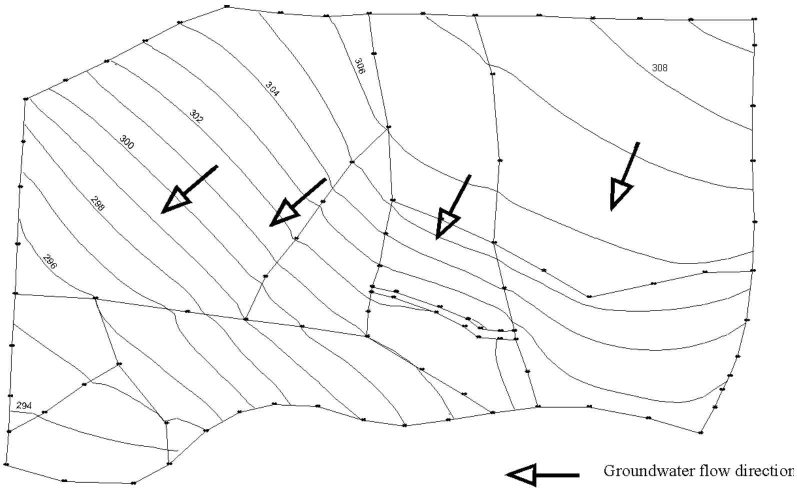
Príklad riešenia pomocou metódy náhodnej prechádzky

Príkladom je model sanácie podzemnej vody na lokalite bývalej vojenskej leteckej základne na strednom Slovensku. Na tejto lokalite je rozsiahle znečistenie, spôsobené rôznymi zdrojmi. Prevážne sa jedná o ropné látky, čiastočne plávajúce vo forme fázy na hladine podzemnej vody a čiastočne rozpustené. Pre ich zachy-

Example of random-walk solution

As an example it is possible to present the model of a groundwater remediation of the former military airbase in central Slovakia. There is large pollution caused from different sources. There are mainly oil hydrocarbons, partly flowing on the groundwater level, partly soluted in the groundwater. Groups of tenie a zároveň pre zabránenie priesaku do rieky Hron sa navrhla sústava infiltračných a záchytných drénov.

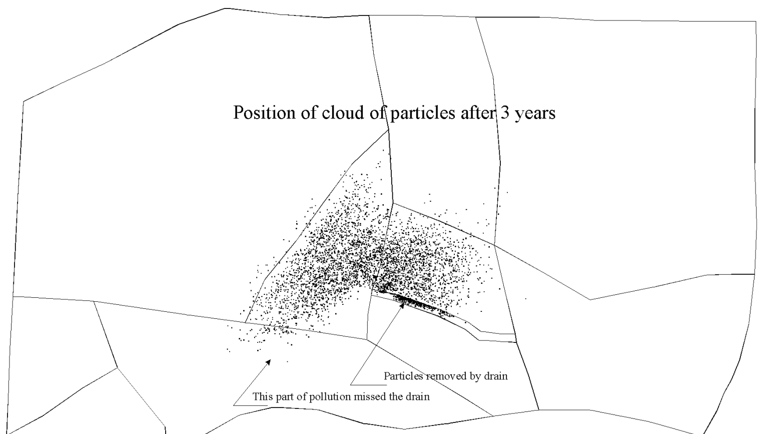
infiltration and catch drains have been suggested to protect the groundwater and also to prevent infiltration into the river Hron.



Obr. 2 Izolínie hladín podzemnej vody
Fig. 2 Contours of groundwater level

Cieľom modelovania bolo posúdenie správnosti funkcie navrhnutých drénov. Obr. 1 ukazuje sieť hraničných prvkov v prvej časti skúmanej oblasti, obr. 2 potom ukazuje izolínie vypočítanej úrovne hladiny. Znečistenie je prenášané podzemnou vodou z počiatočnej znečistenej oblasti (obr.1) do blízkosti záchytného drénu. Výsledky modelu ukazujú, že v tomto prípade sa znečistenie rozdelilo na dve hlavné časti. Prvá bola zachytená drénom, ale druhá pokračovala v prúdení smerom do rieky Hron (obr. 3). Tento výsledok modelu potom bol premietnutý do zmeny projektu a umiestnenie drénov bolo zmenené tak, aby bolo zachytené celé znečistenie.

The aim of modeling has been to asses the right placement of these drains. Fig.1 shows the net of boundary elements in the first part of surveyed area, Fig.2 then shows contours of the computed groundwater level. The pollutant is transported by the groundwater from the initial area (see Fig.1) to the catch drain. Results of this mathematical model show that the pollution is divided into two main parts. The first part is caught by the drain, the other one flows toward the river Hron (see Fig.3). This result of the mathematical model has caused the change of the project and the placement of drains has been corrected to catch the whole pollution.



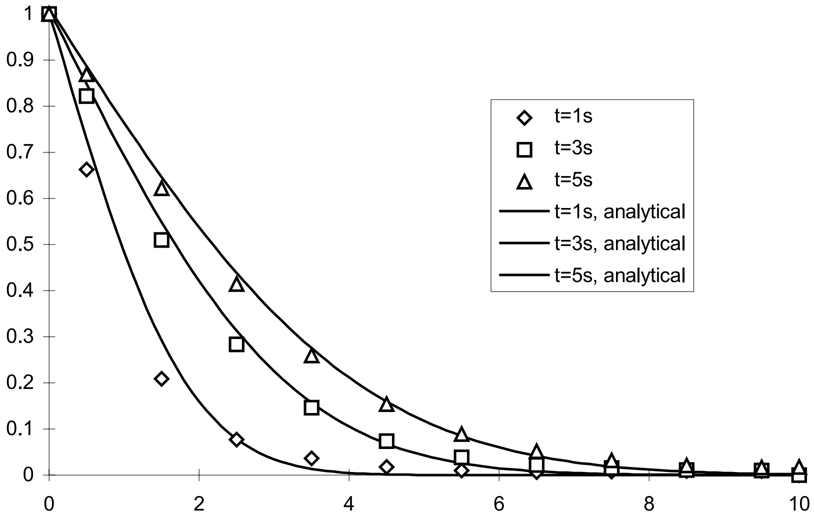
Obr. 3 Častice po 3 rokoch
Fig. 3 Cloud of particles after 3 years

Príklady DRM riešenia

Počítačový program DISDRM bol zostavený na základe už uvedených rovníc a pomocou tohto programu bolo vyriešených niekoľko príkladov. Tak ako všetky nové metódy, bola aj DRM najskôr testovaná na súbore jednoduchých vyriešených príkladov. Jedným z nich je jednorozmerný prípad hydrodynamickej disperzie, riešený bežne v literatúre (Bear, 1972). Tento problém bol riešený v oblasti v tvare obdĺžnika o rozmeroch 10 x 1 meter, ktorý bol rozdelený na 22 okrajových prvkov a mal 3 vnútorné body. Pre riešenie sa použilo 5 časových krokov o dĺžke $\Delta t = 1$ s. Výsledné hodnoty a ich porovnanie s analytickým riešením je na obr. 4.

Examples of DRM solution

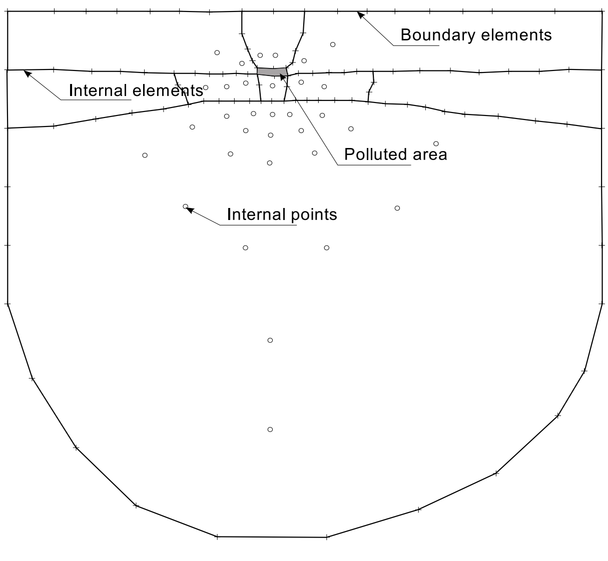
The computer program DISDRM has been prepared according the aforementioned equations and some examples have been solved. Like any other new developed method the DRM is first tested on the set of well-known examples. One of them is the one-dimensional case of hydrodynamic dispersion (see e.g. Bear, 1972,). The problem has been solved on the strip area 10x1m, which has been divided to 22 boundary elements and 3 internal nodes. Only five time steps with $\Delta t = 1$ s has been used. The results and the comparison with analytical solution can be seen on Fig. 4.



Obr. 4 Priebeh koncentrácie v jednorozmernom modeli
Fig. 4 Variation of C along x-axis

Ďalší príklad je model prenosu znečistenia v podzemnej vode z čerpacej stanice pohonných hmôt na južnom Slovensku. Ide o šírenie sa rozpusteného znečistenia z jedného zdroja. Tento príklad je veľmi vhodný pre testovanie, pretože hydrogeologické pomery sú veľmi jednoduché. Obr. 5 ukazuje sieť prvkov, použitú pre riešenie tohto problému. Znečistená oblasť je vytvorená vnútornými prvkami a celá oblasť je rozdelená do niekoľkých zón.

Rýchlosť prúdenia podzemnej vody je $5{,}2 \cdot 10^{-8}$ m.s^{-1}, koeficienty disperzivity sú $a_L = 5$ m, $a_T = 1$m, sorpcia bola v tomto riešení zanedbaná. Výsledky šírenia znečistenej vody sú na obr. 6 a 7 pre čas 10 a 20 rokov.



Obr. 5 DRM sieť
Fig. 5 DRM discretization

The other test example is a model of the groundwater pollution from the gas-filling station in south Slovakia. There is concentrated dissolved oil pollution from one source. It is a good test example because the hydrogeological properties are very simple. Fig. 5 shows the mesh used to solve this transport problem. The polluted area is created by internal elements and the whole area is divided into several zones.

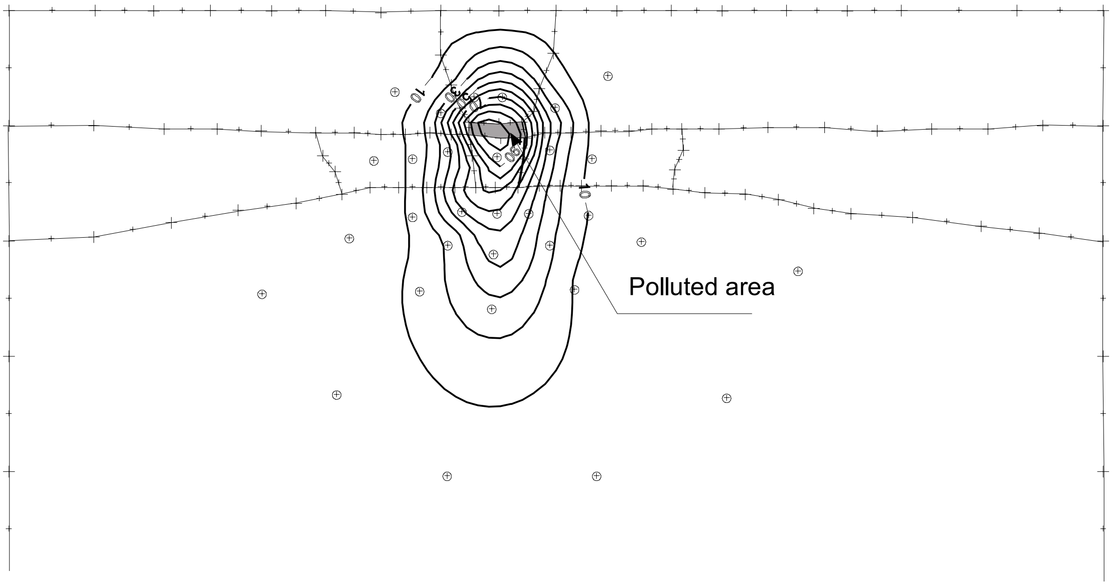
The velocity of the groundwater flow is $5.2 \cdot 10^{-8}$ m.s^{-1}, the dispersivity coefficients $a_L = 5$ m, $a_T = 1$ m, adsorption has been neglected. The results of spreading of the polluted water is on the Fig. 6 and Fig. 7 for the time 10 and 20 years respectively.

Závery

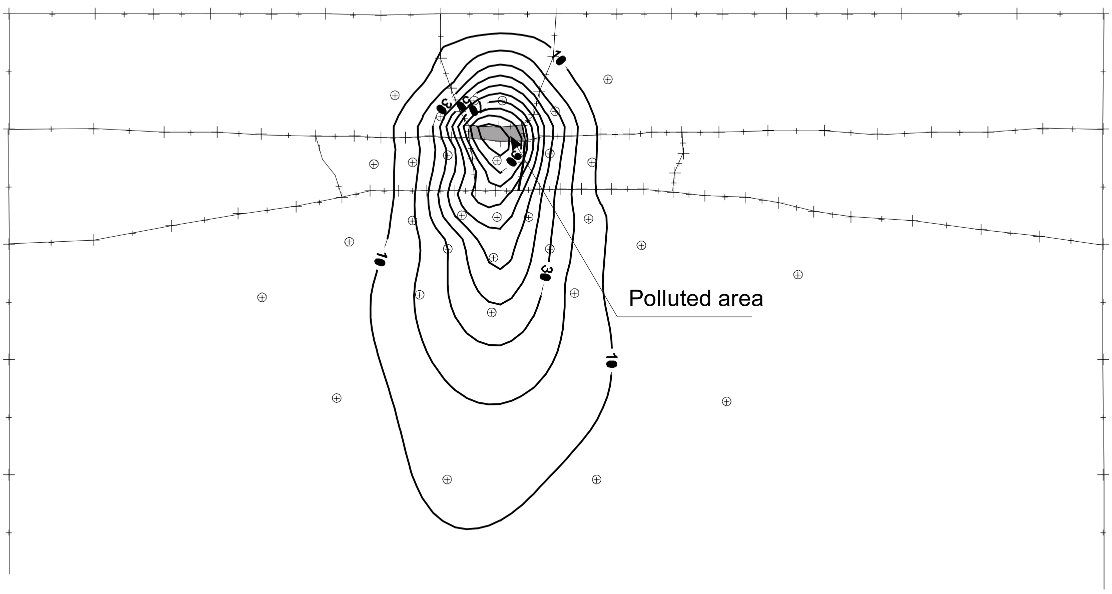
Časticové metódy pre riešenie transportu by mali byť vždy spojené s matematickým modelom prúdenia. Metóda hraničných prvkov je pre tento účel velmi vhodná, pretože umožňuje výpočet rýchlosti prúdenia v ľubovoľnom bode oblasti. Iný spôsob vytvorenia numerického modelu transportného javu je spojenie metódy hraničných prvkov s DRM. Tento spôsob sa tiež ukazuje byť veľmi účinný pre riešenie disperznej rovnice. Metóda sa ukazuje byť veľmi stabilná a použité časové kroky môžu byť veľké a pritom

Conclusions

The particle tracking method should always be connected with the numerical model of the groundwater flow. The boundary elements method seems to be very feasible because the velocity of flow can be computed in an arbitrary point of the domain. The other way to prepare a numerical model of transport phenomena is the connection of the boundary elements and dual reciprocity method. It seems to be also very useful to solve the dispersion equation. This method seems to be very stable and the used time



Obr. 6 Izolínie pomernej koncentrácie po 10 rokoch
Fig. 6 Contours of concentration after 10 years



Obr. 7 Izolínie pomernej koncentrácie po 20 rokoch
Fig. 7 Contours of concentration after 20 years

nevznikajú žiadne oscilácie, zvyčajné u ostatných metód. Táto metóda môže byť v budúcnosti jednoducho doplnená aj o riešenie rádioaktívneho alebo chemického rozpadu spolu s niektorými druhmi sorpcie látky.

Recenzenti: I. Kazda, M. Slivovský

ste ps could be very large and no oscillations are reported. This method will also be developed in the future to solve problems of radioactive or chemical decay with some kinds of adsorption.

Reviewed by: I. Kazda, M. Slivovský

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Jaroslav Broul *

NIEKTORÉ PRVKY OPTIMALIZÁCIE PODZEMNÝCH TESNIACICH STIEN ŽIVICAMI

SOME OPTIMIZATION ASPECTS OF UNDERGROUND GROUTING WALLS BY RESINS

Predmetom príspevku je predloženie niektorých aspektov prvkov optimalizácie (dôležitých pre projekčnú činnosť) pri budovaní podzemných tesniacich stien (PTIS) pomocou injektáže na báze živíc. Autor uvádza niektoré skúsenosti s budovaním PTIS na skládke RSTO Duslo, a.s. Šaľa, vo fáze experimentálnej. Súčasťou je tiež otázka aplikácie možných kontrolných metód počas výstavby PTIS.

Matter of this contribution is presentation of some optimization aspects by constructing of UGW's, on the base of injection by resins. The author presents some experience of UGW construction in experimental stage on waste dump RSTO Duslo, a.s. Šaľa (SR). Simultaneously, is also important to develop methods quality checking during UGW construction and during next monitoring, when UGW will be fully in action. In this contribution some methods could be found.

Foreword

At present, we will observe construction of underground grouting walls (UGW) for deep foundation of objects, reclamation of waste dumps, etc. Their significance is mainly in the fortification of fundaments, or build up of isolating bar against underground water flow, alt. dispraise these a.m.

From a technical and economical point of view, the UGW constructed by building chemistry agents application has a number of facilities on the contrary to the classical UGW (e.g. hollowed mud - cement UGW, etc.); namely, higher corrosion resistance, lower expense, non-challenge of working area, quantity of excavated and highly contaminated soils, etc. This trend is comparable to both our experience and foreign experience. At present, the CSN and STN standards don't define their carrying out and quality control. Newly prepared European Standard CEN WG 8 (according to issued standards for anchorage, micropiles, etc.) is fully filling up this legislative gap. From our experience, we can define some elements which have to be an accepted phase of the advance project stage for high quality of UGW's. Definition of the ways for checking and controlling IGW's quality is also important from time point of view. We must account that the properties of UGW's (esp. for resin) will arrive the full sealing effects in underground geological conditions in longer time (one year or more).

Procedure for UGW project

As a first stage of UGW project is geological prospection works and laboratory analyses, to obtain the basical physical and mechanical properties of soils (background), to check underlay, chemical properties of ground water, velocity and direction of flow incl. changes in horizontal and vertical directions. The second stage contains the laboratory tests for study of isolating properties of applied mass, incl. temperature and viscosity. As a third stage is necessary to carry out the model tests in triaxial cell, for modelling of injection technology in bigger scale than in lab (pumping pressure, radius of injected area, etc.). The all results have to be verified at worksite (workplace), on small experimental UGW section. The size of this experimental UGW section is not limited (the size depends on the total number of injected holes and distance between them, e.g. 1 %). The experimental UGW section is closed, in circle or square form. The section contains observing holes and observating wells for pumping tests. This system allows the pumping tests between inner and outer wells, for determination of filtration coeff., before and after injection works. The mode of pumping tests must to be proportional to the flow of ground water, according to given geological conditions.

The project of works contains the technological procedure in details (e.g. quantity of materials for injection, pressure of injection at maximum, radius of injection around the hole, etc.).

The radius of injection is possible to calculate by addapted Maag's formula:

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$$R = \left[\frac{2}{\frac{L}{(L^2 - 4r_o^2)^{0.5}} \cdot \ln \cdot \frac{L + (L^2 - 4r_o^2)^{0.5}}{2r_o}} \cdot \frac{K_m \cdot t \cdot H}{n_{ef}} + r_o^2 \right]^{0.5} \quad (1)$$

where: R radius of injected area (m),
L length of hole (m),
r_o halfdiameter of hole (m),
k_m soil filtration coeff. for resin (m.sec^{-1}),
t time of injection (sec),
H pressure height (pressure of inj. in m),
n_{ef} effectiveness porosity.

For k_m coeff. calculation is formula:

$$K_m = k_f \cdot \frac{\eta_v}{\eta_p} \cdot \frac{\chi_p}{\chi_v} \quad (2)$$

where: η_v water dynamic viscosity (mPa.sec),
χ_v water density (g.cm^{-3}),
η_p resin dynamic viscosity (mPa.sec),
χ_p resin density (g.cm-3; pract. 1.10(1.80 gcm^{-3})
k_f filtration coeff.of soils in situ (m.sec^{-1}).

The consumption of resin by injection according to CSN Std. (see [5], [8]) formula is calculated:

$$Q = a_1 \,.\, a_2 \,.\, a_3 \,.\, n \,.\, V \quad (3)$$

where: Q resin quantity (m^3),
a_1 resin enlarge coeff. (practically 1.1 - 1.4)
a_2 pressure displacement coeff. (water by resin, 1.2 - 1.4),
a_3 porous filling coeff. (0.4 - 0.7),
n soil porosity,
V theoretical soil volume for injection (m^3).

The theoretical results and practical results (testing section of UGW) have to be continuously compared.

Some experience of UGW construction.

As a specimen of UGW construction, it is possible to show the situation in the waste dump RSTO Duslo, a. s. Šaľa (south Slovakia). At this time, the waste dump is under reconstruction. The waste dump near the river Váh was in action by chemical works for a long time. The waste dump is squared large, app. 30 ha.

The geological conditions are very complicated. Continuous jointing layer is at the depth 13 – 15 m, jointing interlayer is at depth 7 m on some places only. The soils are watery sands and gravels, quarter and neogen periods. The flow of underground water is from north to south, the average flow velocity is 5 cm/day. In observation wells around the waste dump, there are higher concentrations of salts, hard metals, etc. Previously the 3 m thickness of clay as an upperlayer of waste dump has been partly removed. In these places, the oil substances can be indicated. Filtration coeff. are $X \,.\, 10^{-4} - X \,.\, 10^{-5}$ m . sec^{-1}.

The UGW as a continuous vertical wall around the waste dump is projected. For higher safety, 10 – 12 pumping wells in inner side will be drilled and cased. The project calculates with vibrating and casing of holes (depth 13 – 15 m, 0.5 m fastly to the clay bottom) by steel tubes O. D. 48 mm/4 mm, perforated á 20 cm (the total length of perforation is 10 m), distance between holes is 1 m. Injection of hole from bottom to the top (2 stages) by polyuretan (PUR) type 3P of Hungarian provenience, or Bevedan - Bevedol WF of German provenience.

Injection works are carry out through packers ANKRA (Czech construction) up 3 MPa pressure at maximum. In given geological conditions, this value of pressure sinks the danger of "clacage" (see Fig. 3 - down). The injection radius is 55 cm, acc. calculation by Maag's formula (see (5)).

The quantity of PUR is 70 – 80 kg/hole, calculated by formula (2). Foaming in situ is 7 – 8 x (increasing of material volume). Before injection works, the hole has to be clean up to the total depth, as the same as both neighbouring ones.

The filtration coeff. in range $X \,.\, 10^{-8} - X \,.\, 10^{-9}$ m. sec^{-1}, from laboratory tests on samples has been determined.

There is a situation (lay down) of the experimental UGW section where holes No. 11 - 16 are parts of UGW waste dump on Fig. 1.

On Fig. 2 there is a situation (cross section) after injection works of one half experimental UGW section.

The pumping test shows filtration coeff. in range $X \,.\, 10^{-5} - X \,.\, 10^{-6}$ m.sec^{-1}.

After total injection of experimental UGW section is executed, we obtain a filtration coeff. in the range $X \,.\, 10^{-6} - X \,.\, 10^{-7}$ m.sec^{-1}.This value is sufficient for tightness of UGW in situ. In the future when UGW will be in full action, tightness embodies higher values. This is proportional to the foreign experience (see [5]).

Conclusion

For the high UGW's quality, we can define the principles as following.

1. In details, to evaluate the results of geological and hydrological prospection acc. stages (see [1]).
2. In details, to evaluate the results of laboratory and model tests (triaxial cell) and start put down starting he technological procedures for experimental UGW section. The calculation of material quantity, injection radius, etc., alt. exploitation of inertial materials - muds (see [5], [6], [10]) is possible.
3. To define precisely the number of injection stages and pressures at maximum.

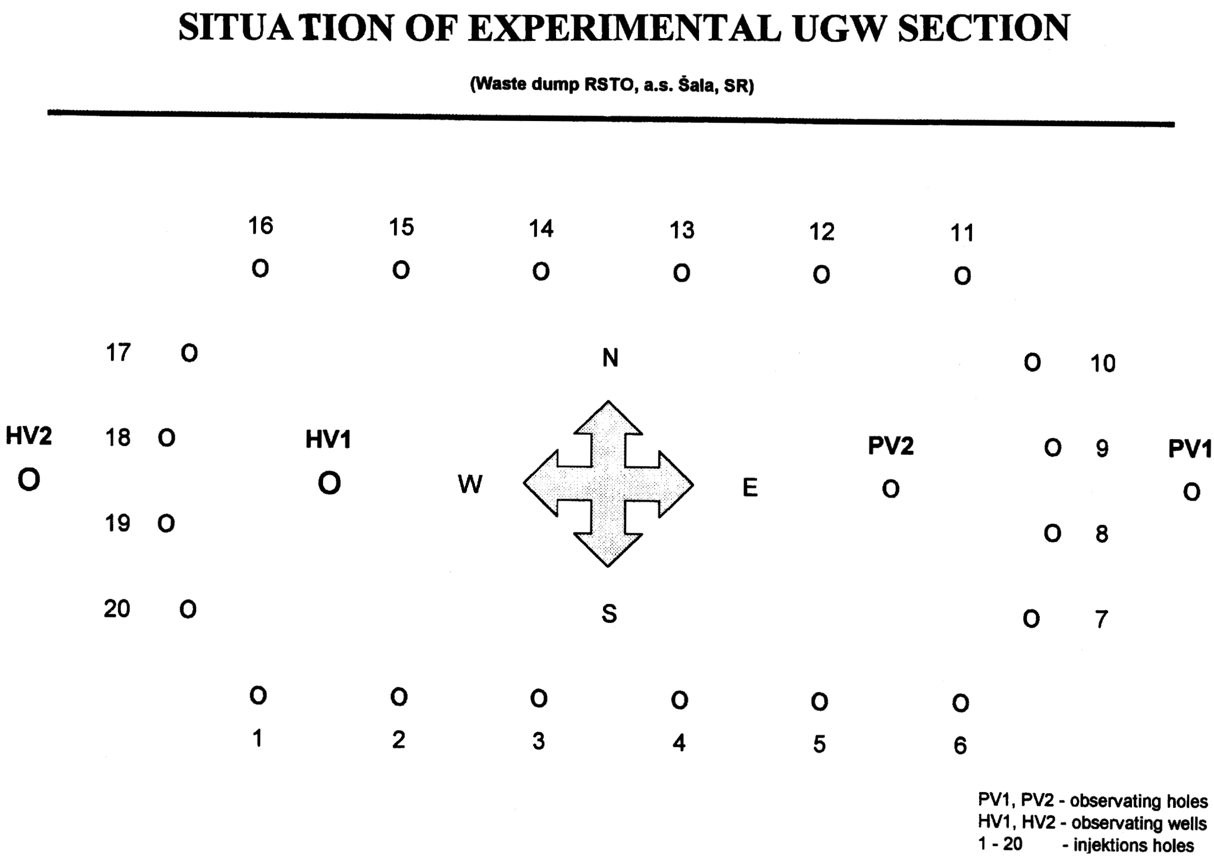

SITUATION OF EXPERIMENTAL UGW SECTION
(Waste dump RSTO, a.s. Šala, SR)
HV2
HV1
PV2
PV1
N
S
W
E
PV1, PV2 - observating holes
HV1, HV2 - observating wells
1 - 20 - injektions holes

Fig. 1

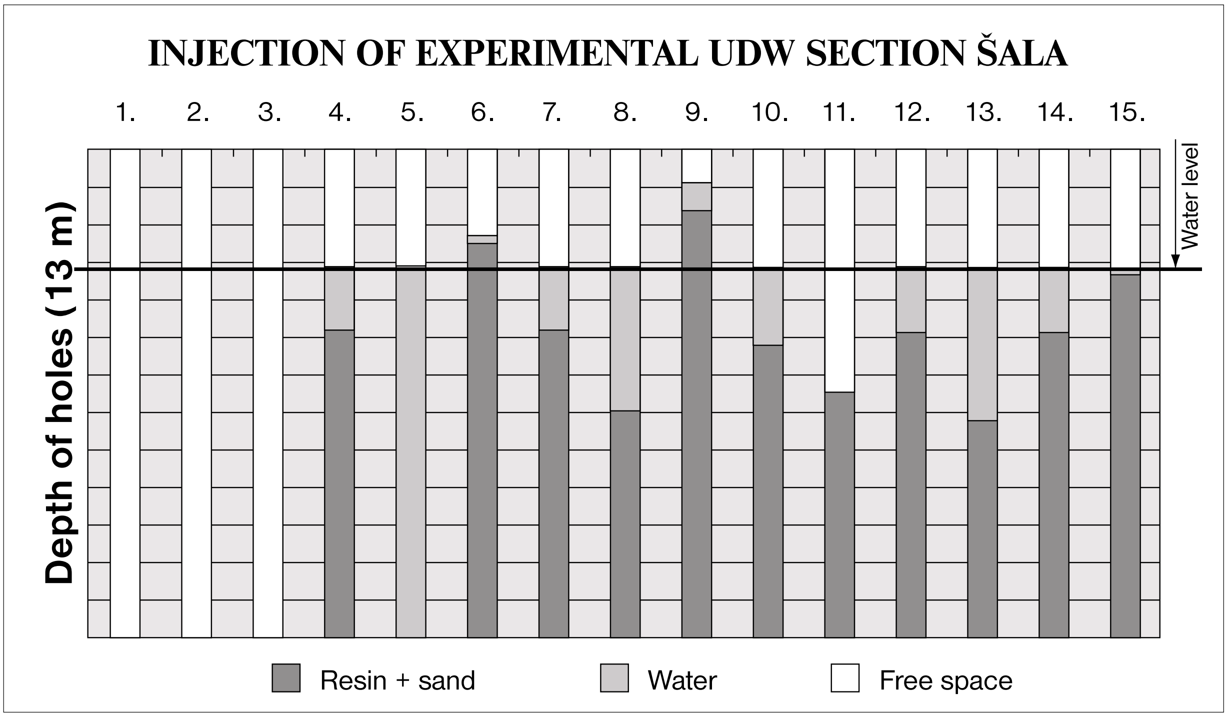
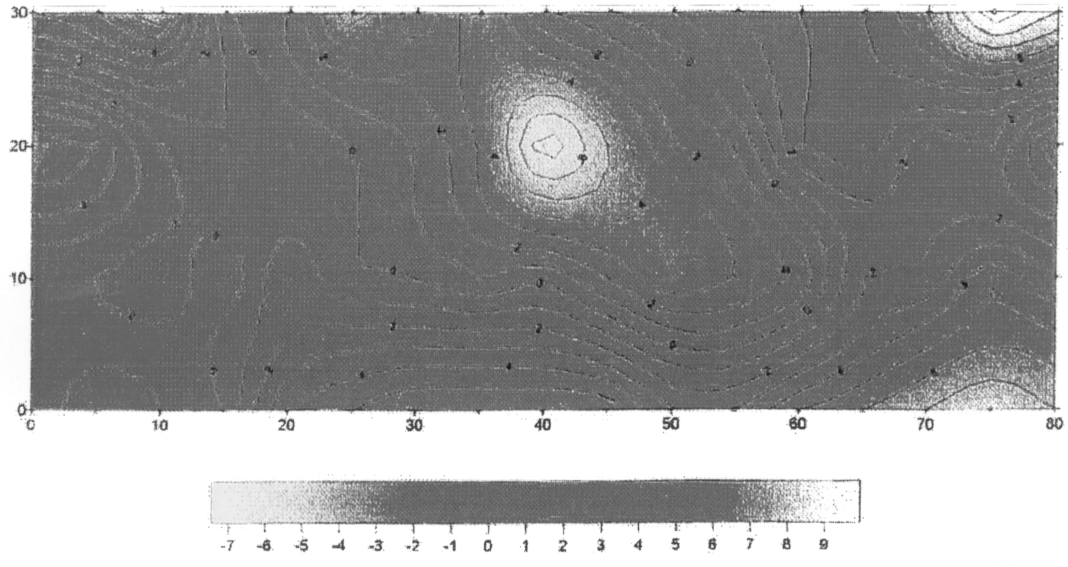

INJECTION OF EXPERIMENTAL UDW SECTION ŠALA
Depth of holes (13 m)
Water level
Resin + sand
Water
Free space

Fig. 2

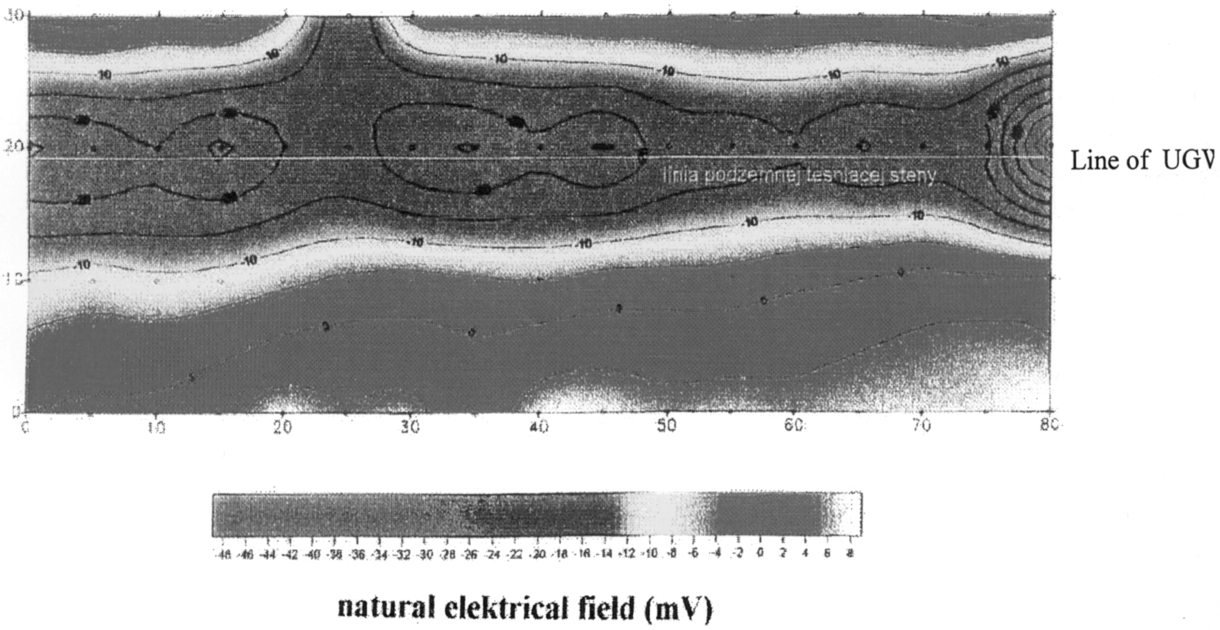
THE FLAT LAY – DOWN OF NATURAL ELECTRICAL FIELD OF UGW SURROUDING AREA

Situation before building up of UGW



filtration potencials (mV)

Situation after building up of UGW



natural elektrical field (mV)

Fig. 3

With this connection it is very favourable to apply retrievable packers (repair works in hole).
4. To document each hole (work sheet) for vibrating, casing, injection pressure, material consumption (flowmeter, accurate balance, etc.).
This working sheet has to be verified by a supervisor daily.
5. For checking of experimental UGW section tightness quality and to carry out the pumping tests (the mode has to be proportional to geological conditions in a given area),
6. To apply geophysical methods (VES, SP and MEPNI) in the course of UGW realisation (see Fig. 3, [3], [7], [9]). The methods in controversial cases by dynamic penetration test could be added.

These principles are in brief form, however, they are valid for the whole number of UGW injections.

Reviewed by: I. Kazda, N. Giang

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KLASICKÉ A NOVÉ METÓDY DIAGNOSTIKOVANIA PODNIKU

CLASSICAL AND RECENT METHODS OF ENTERPRISE DIAGNOSTICS

Článok sa zaoberá klasickými ako aj modernými metódami diagnostikovania, ktoré môžu byť použité pri diagnostikovaní podniku. Okrem základných pojmov sú tu definované tiež vzťahy diagnostiky k analýze, controllingu a konečne aj ku informačným systémom. Aplikácia metód a techník diagnostikovania je analyzovaná vo vzťahu k vonkajšiemu ako aj vnútornému prostrediu.

This article deals with both classical and more recent methods of diagnostics which may be used when making diagnostics of enterprise. Besides the basic terms there is defined also the relation of the diagnostics toward the analysis, controlling and finally to the information systems. The application of methods and techniques of diagnostics is analysed in relation to the evaluation of both external as well as internal factors.

Základné pojmy

Úvodom je potrebné vymedziť základné pojmy, ktoré sa vzťahujú k diagnostike. V podstate termín diagnóza - z gréckeho základu *„dia“ = skrz* a *„gnosis“ = poznanie* - predstavuje poznanie skrz naskrz, čo teda môže byť v prenesenom význame rozpoznanie *javov a procesov,* prípadne zistenie či určenie stavov *javov a procesov.*

Ďalší kľúčový pojem je *diagnostika,* ktorá je všeobecne definovaná ako náuka o poznávaní *javov a procesov,* ktorá využíva svoje metódy a techniky k naplneniu cieľov poznávania.

Od týchto základných pojmov sú odvodené pojmy, ako je *diagnostikovať,* t. j. poznávať, prípadne určiť (stanoviť, zistiť) diagnózu a pojem *diagnostikovanie,* ako proces poznávania. Z týchto všeobecne platných definícií sa odvodzujú pojmy diagnostiky podľa účelu, ku ktorému diagnóza slúži. Najčastejšie sa uplatňujú tieto pojmy v medicíne. V ostatnom období majú však stále širšie uplatnenie aj v iných odboroch, kde sa ich obsah prispôsobuje odvetvovému zameraniu, napr. *podniková diagnostika* v konkrétnych odvetviach a odboroch, prípadne podľa konkrétneho zamerania, ako je to pri *technickej* či *technologickej* a *ekonomickej diagnostike.* Týmto však pojmová oblasť nie je uzatvorená. Ide o oblasť celého radu ďalších pojmov, ktoré sú viac-menej v predchádzajúcej skupine konkrétnych diagnostík štruktúrované na základe konkrétneho zamerania diagnostiky. Napr. *diagnostika marketingu, diagnostika stratégie, diagnostika bonity podniku, diagnostika finančného zdravia podniku, diagnostika podnikovej logistiky, diagnostika akosti a diagnostika ľudských zdrojov.*

Basic Terms

In the introduction it is necessary to define the basic terms related to the diagnostics .Basically the term *diagnosis* originates from the Greek basis *"dia" = through* and *"gnosis" = knowledge* denoting the thorough knowledge which might metaphorically mean the distinguishing of the phenomena and processes, respectively the determination and defining of the state of the *phenomena and processes.*

The next key term is *diagnostics,* which might be generally defined as a science of recognising *phenomena and processes* using its methods and techniques to fulfil the objectives of the process of recognition.

From these basic terms further terms are derived, such as *to diagnose,* i.e. to recognise, respectively to determine (designate) the diagnosis and the term *determination of diagnosis* as the process of recognition. From these generally valid definitions the more exact terms of diagnostics are derived according to the final purpose of each diagnosis. These terms are most often applied in medicine. However, recently these terms are applied more widely in other fields of study as well, where their content is adapted to the branch orientation, as e.g. *enterprise diagnostics* in specific branches and fields of study or, if need be, in harmony with the concrete orientation as it may be in *technical* or *technological* and *economic diagnostics.* However, this does not mean closing the area of this term. The question of a whole range of further terms which are more or less in the previous group of concrete diagnoses structured on the basis of the concrete orientation of the diagnostics. Thus, it is the matter of *marketing diagnostics, strategy diagnostics, diagnostics of the enterprise financial standing, diagnostics of the financial stability of the enterprise, diagnostics of the logistics of the enterprise, diagnostics of quality, diagnostics of human sources.*

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Vzťah diagnostiky k „rozborom“ a ku controllingu

Ako prvé je potrebné spomenúť vzťah diagnostiky k *rozboru.* Často sa nesprávne uvádza, že rozbor je totožný s *analýzou,* čo však nie je úplne správne, pretože *analýza* je prvá časť rozboru, na ktorú nadväzuje *syntéza,* presnejšie súhrn navrhovaných opatrení a krokov, ktoré majú analýzou zistené *javy a procesy* usmerniť pre dosiahnutie cieľov vytýčených stratégiou, plánmi či programami. Následne na *rozbor* nadväzuje činnosť *controllingu,* ktorého základné úlohy spočívajú v:

- identifikácií možných rizík a príležitosti,
- definovaní alternatív a v nich možných variantov riešení,
- informovaní o dosiahnutých výsledkoch.

Z predchádzajúceho vyplýva, že *rozbor* by mal byť uskutočňovaný prostredníctvom útvarov *controllingu,* ktorého základnou úlohou je *pomáhať podnikovému manažmentu pri riadení.*

Vzťah diagnostiky k rozborom a ku controllingu je definovaný tak, že metódy diagnostiky sú súčasťou metód rozborov s presným vymedzením a cieľom, pričom diagnostiku môže uskutočňovať nielen útvar controllingu, ale aj iný nezávislý orgán, napr. diagnostický ústav. Z tohto ponímania vyplýva, že controlling môže používať diagnostické metódy tak, aby neustále podával informácie, návrhy riešení pre proces rozhodovania, ktoré uskutočňuje manažment a naopak, nezávislé orgány napr. diagnostického ústavu viac-menej napomáhajú rozhodovaniu na základe diagnostického poznania *„od prípadu k prípadu“,* to znamená napomáhanie k diskrétnemu riadeniu *javov a procesov.*

Metódy a techniky diagnostikovania

Metódy, ktoré je možné použiť pri diagnostikovaní, sa delia v podstate na:

- *klasické:*
  - metódy porovnávania
  - metódy hodnotenia dynamiky ukazovateľov pomocou sústavy nerovnosti (napr. normálové nerovnosti, vymedzenie normality javov a procesov)
  - metódy faktorového rozboru
  - metódy kauzálneho rozboru
  - metódy časového rozboru
  - metódy optimalizačné a racionalizačné
  - metódy matematické a štatistické
  - metódy modelového rozboru
- *nové pre hodnotenie vonkajšieho prostredia,* ako sú:
  - metóda STEP pre ohodnotenie vonkajšieho prostredia
  - porterov model analýzy konkurencie v odvetví
  - analýza ekonomických charakteristík odvetví
  - analýza hybných síl v odvetví
  - tvorba strategickej mapy
  - analýza konkurencie

Relation of Diagnostics to “Investigations“ and Controlling

First, it is necessary to specify the relation of the *diagnostics* to the *investigation.* It is not correct, though often introduced, to identify the investigation with the *analysis* as the *analysis* is the first part of an investigation followed by the *synthesis,* which is more exactly expressed as a complex of proposed measurements and steps which are supposed to regulate the *phenomena and processes* ascertained by the analysis for the reaching of objectives laid out by the strategy, plans or programmes. Next, the *investigation* is being followed by the *controlling* activity. Its basic assessments include:

- identification of possible risks and opportunities,
- definition of alternatives and possible variants of solutions,
- information of the achieved results.

The previous objectives result in the fact that the investigation should be put in force by means of the departments of *controlling,* the basic assignment of which should be *to help the enterprise management to control.*

The relation of the diagnostics to the investigation and to the controlling is defined so that the methods of diagnostics may be at the same time components of the methods of investigation with an exact specification and objective taking into account the fact that the diagnosis might be performed not only by the department of controlling but also by other independent body, e. g. an institute for diagnostics. This will result in such an application of diagnostic methods by the controlling that it may continuously supply information and proposals of solutions for the decision process performed by the management and vice versa the independent body of the institute for diagnostics might contribute more or less in making decisions on the basis of the diagnostic knowledge *“as the case may be“,* which means a contribution to a discrete management of *phenomena and processes.*

Methods and Techniques of Diagnosing

The methods which may be applied for the diagnosing can be basically divided into:

- *classical:*
  - comparative method
  - method of evaluation of dynamics of the indicators by means of the system of disparity (e.g. normal disparity, surveying of normality of the phenomena and processes)
  - factor investigation method
  - causality investigation method
  - time investigation method
  - optimisation and rationalisation method
  - mathematical and statistical method
  - model analysis method.
- *new methods for the evaluation of external factors,* such as:
  - method STEP for the evaluation of external factors
  - porter’s model of the analysis of branch competition
  - investigation of the branch economic characteristics
  - investigation of the branch development stimuli
  - development of strategic map
  - competition analysis

- *nové pre hodnotenie vnútorného prostredia,* ako sú:
  - evaluácia doterajšej stratégie
  - analýza jednotlivých oblasti stratégie (výroby, financovania, marketingu, personalistiky a pod.)
  - analýza exponovanosti (posúdenie silných a slabých stránok)
  - tvorba portfólia analýz
  - analýza konkurencie-schopnosti
  - SWOT - analýza - prehľad vzťahov medzi vnútornou silou a slabosťou ku príležitostiam a ohrozeniam.

Existuje aj celý rad metód, ktoré nie je možné priamo priradiť k metódam hodnotenia vonkajšieho či vnútorného prostredia. Takouto skupinou metód sú metódy diagnostickej misie, najmä:

- metódy EKOS-EDAROČ, t. j. expertná diagnostická analýza odborov a činnosti
- diagnostické BM tabuľky s označením PD-EKOS-DBMT, prípadne
- diagnostické DM diagramy s označením PD-EKOS-DDMD, napr. hviezdicový diagram (grafický záznam informácií v diagnostických tabuľkách)
- diagnóza filozofie podnikania, identity a integrity firmy s označením PD-EKOS-DFII
- test vízie (invencie) podnikania firmy
- rýchly test filozofie firmy - predbežná diagnóza strategického potenciálu (PD-ZMILL-PO)

V tomto období *uplatnenie* tých - ktorých *metód závisí aj od faktorov: software, hardware, bookware, peopleware a orgware.* Použitie jednotlivých metód je teda determinované nielen technickým zabezpečením počítačovou technikou, ale aj programovým vybavením, užívateľskými príručkami (bookware), použitím podnikateľských modelov v procese riadenia podnikateľských aktivít (peopleware), či nakoniec využívaním takých spôsobov riadenia, aby sa robili dobré veci dobrým spôsobom (t. j. orgware). V rámci tejto skupiny je známy celý rad metód, ktoré sú prispôsobené konkrétnemu cieľu v určitých oblastiach, podnikoch, rezortoch i špecifikám jednotlivých krajín. Tieto metódy nenesú označenie prevažne podľa podniku, podľa cieľa, ale podľa modelu (napr. simulačné metódy).

Okrem uvedeného triedenia metód existujú aj iné skupiny metód, ktoré sú uplatňované aj v oblasti diagnostiky. Skôr ide o metódy, ktoré sa odlišujú spôsobom použitia. Tieto metódy môžu byť nielen klasické, ale aj novšie. Ide napr. o:

- metódy grafické,
- metódy dedukcie a indukcie,
- metódy analógie,
- prípadne - rôzne druhy metód prognostiky.

Metódy grafické majú teraz široké uplatnenie v kombinácii už so spomínanými metódami diagnostickej misie, či metódami modelového rozboru a majú svoj význam v sprehľadnení rôznych foriem zameraní rozborov. Ide teda o zameranie predovšetkým klasifikačných, vzťahových, kauzálnych, prípadne dialektických

- *new methods for the evaluation of internal factors,* such as:
  - evaluation of present strategy
  - analysis of different parts of the strategy (production, financing, marketing, human sources etc.)
  - assessment analysis (evaluation of week and strong sides)
  - development of portfolio of investigations
  - investigation of competition possibilities of the enterprise
  - SWOT - investigation of the survey of internal strengths and weaknesses in relation to the opportunities and threats.

There do exist further methods which cannot be directly related to the methods of internal or external factors. Let us introduce the following methods of the *diagnostic mission,* especially:

- method EKOS-EDAROČ, i.e. Expert Diagnostic Analysis of Branches and Activities
- diagnostic BM tables marked PD-EKOS-DBMT, or if need be
- diagnostic DM diagrams, marked PD-EKOS-DDMD, e.g. the star diagram (graphical representation of information in diagnostic tables)
- diagnosis of the entrepreneur philosophy, identity and integrity of an enterprise marked PD-EKOSD-DFII
- test of vision (invention) of the enterprise entrepreneur activities
- quick test of the enterprise philosophy - anticipatory diagnosis of the strategic potential (PD-ZMILL-PO)

Nowadays the *application of concrete methods depends also on software, hardware, bookware, peopleware and orgware.* The application of individual methods is thus determined not only by the technical computer equipment but depends also on the programme equipment, access to the users' manual handbooks (bookware), the application of entrepreneur models in the process of management of entrepreneur activities (peopleware), or the application of different ways of management in an optimal way (orgware). In this group there are many well known methods which will be adapted to reach concrete objectives in specific areas, factories, branches of industry as well as to the specifications of different countries. These methods usually do not bear the denominations according to the factory or objectives but according to the model applied (thus e.g. simulation methods).

Next to the above introduced classification of methods there exists further methods which might also be applied in the sphere of diagnostics. It concerns more methods with a different way of application. Both classical as well as recent methods belong here. Let us mention the following:

- graphical methods
- deduction and induction methods
- methods of analogy
- and if need be - different prognostic methods.

Graphical Methods have nowadays a wide range of application in combination with the already above mentioned methods of diagnostic mission or with methods of the model analysis. Their importance lies in clear surveying of different ways of different investigation orientations. Above all, they serve to the investigation of classification, relation, causality, respectively of dialectic rozborov, ktoré môžu byť súčasťou retrospektívneho (ex post) hodnotenia, ale aj perspektívneho (ex ante) hodnotenia.

Metódy dedukcie a indukcie sú významné pri hľadaní príčinnosti a závislosti, prípadne pri stanovovaní nadväznosti javov a procesov v budúcnosti. Dedukcie ako aj následné indukcie sa môžu uskutočňovať:

- exaktne, t. j. v prípadoch, kedy nemáme dostatok vhodných informácií, alebo pôsobenie faktorov na sledované javy a procesy nie je možné významnejšie vymedziť,
- logicky, t. j. keď pôsobenie je významne ovplyvňované konkrétnymi faktormi s možnosťou zistenia miery pôsobenia jednotlivých faktorov,
- prípadne iným spôsobom, ako je napr. kvalifikovaný odhad, či niektoré iné metódy (napr. metódy brainstormingu).

Dedukcia je dynamickou formou prechodu myšlienkových procesov od všeobecného k osobitnému a nakoniec k jednotlivému hodnoteniu *javov a procesov.* Uplatňujú sa dva spôsoby deduktívnych systémov, a to prirodzený a axiomatický. U indukcie ide o metódy, ktoré uplatňujú poznatky dedukcie a sú používané skôr pre predpoklady vývoja či chovania sa *javov a procesov.*

Metódy analógie sú obdobné ako predchádzajúce metódy dedukcie a indukcie. V podstate hodnotenie sa predpokladá na základe určitej podobnosti správania sa niekedy nesúrodých javov a procesov.

Metódy prognostické majú význam pre diagnostické hodnotenie do budúcnosti (per ex ante). V tejto skupine je celý rád metód, ktoré sú odvodené z matematickej či ekonomickej štatistiky (časová, korelačná a regresná analýza), ale aj novšie metódy analytickej či syntetickej aproximácie.

Záver

Záverom článku je potrebné konštatovať, že v každej skupine je celý rad metód. Preto sú v tomto článku uvedené iba najzákladnešie. Stupeň poznania (diagnózy) závisí nielen od teoretického poznania diagnostických metód, ale predovšetkým od ich optimálnej voľby vzhľadom na dostupnosť zdrojov pre naplnenie konkrétnych metód. Mnohokrát zložité a prácne metódy nemusia priniesť očakávané výsledky, ba niekedy ich použitie pohľad na *javy a procesy* a ich tendencie len komplikuje.

Recenzent: T. Čorejová

investigations which might be components of retrospective (ex post) as well as perspective (ex ante) evaluation.

Deduction and Induction Methods are important when looking for the cause and dependence respectively when stating the linking up of phenomena and processes in future. Deduction as well as the following induction may be performed:

- in an exact way - i.e. in cases with the absence of applicable information or by only vague determination of phenomena and processes in question
- in a logical way - i.e. in cases when there is a big influence of concrete factors with the possibility to find out the level of influence of individual factors
- in some other way - respectively - e.g. by qualified guessing or by other methods (e.g. brainstorming).

Deduction is a dynamic form of transition of mental processes from the general to the specific and finally to the individual evaluation of *phenomena and processes.* There are two deductive systems: natural and axiomatic. The induction uses methods implementing the knowledge of deduction, being used more for the suppositions of development or behaviour of *phenomena and processes.*

Methods of Analogy are similar to previous methods of deduction and induction. Basically, the evaluation is supposed to be based on a certain similarity in behaviour of sometimes incongruous phenomena and processes.

Prognostic Methods are of big importance for the diagnostic evaluation in the future (per ex ante). In this group there is a whole number of methods derived from mathematical or economic statistics (time, correlation and regression analysis), but also more recent methods of analytic or synthetic approximation.

Conclusion

Concluding, it is necessary to state that there is a wide number of different methods in each group. Therefore, this article has introduced only the most important basic ones. The level of knowledge (diagnosis) depends not only on theoretical knowledge of the diagnostic methods but above all on their right choice in relation to the accessibility of sources necessary for the application of a concrete method. However, very often even complicated and laborious methods do not bring about the expected results and, moreover, sometimes their application makes the view of *phenomena and processes* and their tendencies even more complicated.

Reviewed by: T. Čorejová

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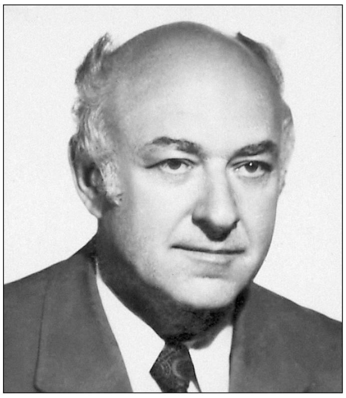


Prof. Ing. Miroslav Steiner, DrSc. 70 ročný - 70 years old

Prof. Ing. Miroslav Steiner, DrSc. zasvätil celý svoj život automobilizmu. Po vyučení absolvoval priemyselnú školu strojnícku a v r. 1953 ukončil pražskú techniku v odbore stavba automobilov a traktorov.

Po ukončení vysokoškolského štúdia nastúpil do Výskumného ústavu dopravného v Prahe, kde v r. 1958 obhájil kandidátsku dizertačnú prácu v odbore konštrukcia spaľovacích motorov a mechaniky jazdy automobilov. Postupne sa zaoberal koncepčnými úlohami, ktoré vyplynuli z rozvoja dopravy a automobilového priemyslu a kde využil svoje poznatky zo študijného pobytu vo Francúzsku. Založil a riadil celoštátne výskumné programy bezpečnosti cestnej premávky a v tejto súvislosti sa zaslúžil o výstavbu prvej medzinárodnej skúšobne zadržovacích systémov v bývalých východoeurópskych krajinách. Bol taktiež iniciátorom založenia odboru „využitia matematických metód v cestnej doprave“. Je spoluzakladateľom spoločného výskumného pracoviska ČSAV a FMD pre základný výskum zameraného na bezpečnosť a spoľahlivosť dopravných systémov.

V r. 1984 obhájil doktorskú dizertačnú prácu na tému „Vzťah úžitkového automobilu a vozovky z hľadiska ich vzá-

Prof. Steiner dedicated all his life to the automobile transport. After taking his studies at the engineering high school, Mr. Steiner graduated in the year 1953 the Prague technical university, the specialisation of motor-cars and tractors construction. After finishing his academic studies Prof Steiner began his career in the Research transport institute in Prague where he reached in the year 1958 the PhD degree on the basis of the dissertation work dedicated to the construction of combustion en gine and the mechanics of motor-car driving. In successive steps he dealt with conceptual tasks that resulted from the development of transport and automobile industry and where he utilised his knowledge gained from the educational stay in France. He founded and conducted state-wide research programs of road traffic safety and in this coherence he deserved the building-up of the first international laboratory of retentive systems in the former eastern European countries.

Prof. Steiner was also a floater of the establishment of the specialisation „the utilisation of mathematical methods in the road transport“. He was co-founder of the common research working place Of the Czecho-Slovak Academy of Sciences and the Federal Ministry of Transport for the basic research on safety and reliability of transportation systems.

Mr.Steiner reached in the year 1984 the scientific degree Doctor of sciences and the dissertation he concentrated on the problem of the relationship of the utility motor-car with road from the viewpoint of their mutual functions. In 1987 he was appointed as professor for the specialisation of transport technique and technology. In the problem of interaction between the transport means and the roads, he elaborated the theory of jomného pôsobenia“. V r. 1987 bol menovaný profesorom pre odbor dopravná technika a technológia. V problematike interakcie dopravného prostriedku a dopravnej cesty rozpracoval teóriu ich vzájomného pôsobenia z hľadiska zvislých dynamických síl, metódy merania a hodnotenia vplyvov, navrhol metódy určenia dynamických rázových činiteľov a navrhol a overil metódy a prístroje pre hodnotenie kvality povrchu vozoviek.

Svoje znalosti a skúsenosti z konštrukcie a prevádzky automobilov odovzdával ako pedagóg na Českom vysokom učení technickom - Dopravnej fakulte, na Žilinskej univerzite a na Pardubickej univerzite, kde pôsobí dodnes. Prednášal tiež na univerzitách v De Kalb v USA, Tokiu, Viedni, Hamburgu, Drážďanoch, Budapešti, Viedni. Pôsobil tiež ako predseda i ako člen odborných komisií pre obhajobu kandidátskych a doktorských prác.

Veľmi rozsiahla je i jeho publikačná činnosť, napísal rad výskumných správ, publikácií a recenzií.

Prajeme Prof. Ing. Miroslavovi Steinerovi, DrSc. pevné zdravie a životný optimizmus do ďalších rokov.

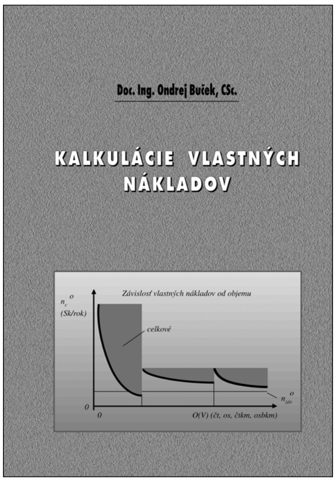
their mutual impact from the point of view of vertical dynamic forces, the methods of measurement and influence valuation. He designed the methods of dynamic impulse factors destination and drafted and attested the methods and instruments for roadway surface quality valuation.

Prof. Steiner transferred his knowledge and experience from the construction and operation of motorcars to the next engineers as a professor on the Czech technical university - Faculty of transport, on the University of Zilina and on the University of Pardubice, where he works up to these days. He take lectures at the universities in De Kalb (USA), Tokyo, Vienna, Hamburg, Dresden, Budapest, Vienna, too. He reacted as chairman and as member of scientific committees for advocacy of dissertation wo rks for PhD and for Doctor of sciences.

Very large is his publication activity, he wrote a lot of research reports and notices.

Best wishes to Prof. Miroslav Steiner. Firm health and living optimism to the future years.

Prof. Ing. Ján Mikolaj, DrSc.



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Predložená monografia spracováva problematiku, ktorá v hospodárstve každého štátu patrí medzi najviac sledované ekonomické problematiky. Riadiaci pracovníci na rôznych úrovniach podnikovej hierarchie požadujú výrazne kvalitnejšie informácie o nákladoch a výnosoch. Tieto informácie patria k základným finančným informáciám, ktoré sú potrebné pre komplexné riadenie podniku.

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Tretia kapitola v podstate znázorňuje technologický proces železničnej dopravy pre potreby analytického spracovania problematiky vlastných nákladov. Toto znázornenie je vykonané pomocou ukazovateľov dopravných výkonov, naturálne prepravných ukazovateľov, ukazovateľov úrovne výkonov a práce ako aj hodnotových ukazovateľov. Spracovaná problematika je doplnená názornými obrázkami a tabuľkami. Záver kapitoly tvorí pojednanie o transformácii druhovo členených nákladov na členenie kalkulačné. Túto časť monografie považujem za významnú, pretože práve tejto problematike sa niekedy nevenuje dostatočná pozornosť, čo má za následok nepresnosť vykonávaných kalkulácií.

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Šiesta kapitola je venovaná problematike výpočtu ukazovateľov dopravnej práce v železničnej doprave. Ide v podstate o rozšírenie tretej kapitoly, ale s novým analytickejším pohľadom na oblasť osobnej a nákladnej železničnej dopravy.

Predložená monografia je spracovaná na veľmi dobrej úrovni. Autor monografie už využil časť rukopisu pri spracovaní problematiky analýzy nákladových modelov v železničnej doprave ako člen kolektívu pracovníkov Fakulty PEDaS, Žilinskej univerzity, ktorý spracoval pre MDPT SR štúdiu „Analýza nákladových modelov v jednotlivých druhoch dopráv“. Monografia môže poslúžiť ako analytická pomôcka pre všetkých záujemcov o danú problematiku. Je použiteľná pre študentov, ale aj pre odborníkov z oblasti teórie a praxe.

Doc. Ing. Štefan Cisko, CSc.

Dizertačná práca:	**Návrh systému controllingu k hospodárnosti vnútropodnikovej jednotky ŽSR**
Autor:	**Ing. Buková Bibiána**
Študijný odbor:	**62-03-9 Odvetvové a prierezové ekonomiky**
Školiace stredisko:	**Žilinská univerzita v Žiline Fakulta prevádzky a ekonomiky dopravy a spojov Katedra železničnej dopravy**
Školiteľ:	**Doc. Ing. M. Sroslík, CSc.**

Resumé:

Dizertačná práca navrhuje zavedenie nového obchodného systému ŽSR. Daný systém je budovaný od zákazníka, jeho potrieb. Návrh obchodného systému ŽSR podrobne rozoberá jednotlivé fázy predaja prepravných služieb, spôsoby organizácie obchodného personálu, počet obchodného personálu, jeho riadenie, kontrolu, odmeňovanie i motiváciu. Kontrola v tomto systéme má rozhodujúcu funkciu, umožňuje jednoduchú, pružnú komunikáciu so zákazníkom, prostredníctvom obchodného personálu ŽSR.

Práca je členená do 5 kapitol, obsahuje 101 strán textu , 22 strán príloh.

ŽILINSKÁ UNIVERZITA V ŽILINE

Fakulta prevádzky a ekonomiky dopravy a spojov

Katedra železničnej dopravy

NÁVRH SYSTÉMU CONTROLLINGU K HOSPODÁRNOSTI VNÚTROPODNIKOVEJ JEDNOTKY ŽSR

Dizertačná práca

Autor: Ing. Bibiána BUKOVÁ

Školiteľ: Doc. Ing. M. SROSLÍK, CSc.

Žilina 1999

Dizertačná práca:	**Nový prístup k navrhovaniu výrobnej dispozície**
Autor:	**Ing. Róbert Debnár**
Študijný odbor:	**23-07-9 Strojárske technológie a materiály**
Pracovisko:	**Žilinská univerzita v Žiline, Strojnícka fakulta Katedra priemyslového inžinierstva**
Školiteľ:	**Prof. Ing. Ján Košturiak, PhD.**
Obhajoba:	**7. 6. 1999 na ŽU SjF**

Resumé:

Doktorandská dizertačná práca Nový prístup k navrhovaniu výrobnej dispozície sa zaoberá problematikou navrhovania výrobnej dispozície s využitím metód skupinovej technológie a simulácie. Je motivovaná potrebami zameranými na zvládnutie vysokej variantnosti a pružnosti výroby pri nízkych výrobných dávkach a pri súčasnom zachovaní prehľadnosti vo výrobe, nízkych nákladoch a vysokej produktivite. Ťažiskom riešenia je navrhnutie komplexnej metodológie pre segmentáciu výroby, ktorá pozostáva z nasledovných krokov:

- *vstupná analýza, príprava údajov,*
- *segmentácia výroby - triedenie súčiastkovej základne, vytváranie skupín súčiastok a strojov,*
- *formovanie jednotlivých výrobných buniek,*
- *kapacitný výpočet,*
- *návrh výrobnej dispozície,*
- *dynamické prehodnotenie výrobnej dispozície - modelovanie a simulácia.*

V rámci tejto práce bol vytvorený modul pre segmentáciu výroby. Ide o integrované riešenie, ktoré je implementované do simulačného systému SiMPLE++.

ŽILINSKÁ UNIVERZITA

Strojnícka fakulta

Katedra priemyslového inžinierstva

NOVÝ PRÍSTUP K NAVRHOVANIU VÝROBNEJ DISPOZÍCIE

Dizertačná práca

Autor: Ing. Róbert DEBNÁR

Školiteľ: prof. Ing. Ján KOŠTURIAK, PhD.

Žilina 1999

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