VOLUME 5 NUMBER 2 2012

TRANSACTIONS ON TRANSPORT SCIENCES

Ministry of Transport

TRANSPORT RESEARCH CENTRE

CZECH TECHNICAL UNIVERSITY

TRANSACTIONS ON TRANSPORT SCIENCES

Publisher: *Ministry of Transport*, nábř. L. Svobody 1222/12, 110 15 Praha 1, Czech Republic
E-mail: *info@transportsciences.org*
URL: *www.transportsciences.org*

Editorial Office: Olga Krištofíková
Hedvika Kovandová
Jana Zelinková
Petr Polanský
Petr Šenk
Irena Zedková

Periodicity: Quarterly
Language: English
Scope: International scientific journal for transport sciences
Print version: ISSN 1802-971X
On-line version: ISSN 1802-9876
Registration Number: MK EČ E 18012

Each paper in the journal is evaluated by two reviewers under the supervision of the International Editorial Board.

The Research and Development Council of the Government of the Czech Republic indexed this journal in the Title List of Peer-Reviewed Journals.

Responsibility for the contents of all the published papers and technical notes is upon the authors. Abstracting is permitted with credit to the source. For all other copying, re-print or re-publication permission write to the Ministry of Transport of the Czech Republic.

Distributor: CDV – Transport Research Centre, Líšeňká 33a, 636 00 Brno, Czech Republic, journal@cdv.cz.

Stochastic Analysis of a Queue Length Model Using a Graphics Processing Unit

J. Přikryl*
Faculty of Transportation Sciences, Czech University of Technology, Prague, Czech Republic
Institute of Information Theory and Automation, Czech Academy of Sciences, Prague, Czech Republic
** Corresponding author: prikryl@utia.cas.cz*

J. Kocijan
Jožef Stefan Institute, Ljubljana, Slovenia
Centre for Systems and Information Technologies, University of Nova Gorica, Slovenia

DOI: 10.2478/v10158-012-0007-2

ABSTRACT: Mathematical modeling is an inevitable part of system analysis and design in science and engineering. When a parametric mathematical description is used, the issue of the parameter estimation accuracy arises. Models with uncertain parameter values can be evaluated using various methods and computer simulation is among the most popular in the engineering community. Nevertheless, an exhaustive numerical analysis of models with numerous uncertain parameters requires a substantial computational effort. The purpose of this paper is to show how the computation can be accelerated using a parallel configuration of graphics processing units (GPU). The assessment of the computational speedup is illustrated with a case study. The case study is a simulation of Highway Capacity Manual 2000 Queue Model with selected uncertain parameters. The computational results show that the parallel computation solution is efficient for a larger amount of samples when the initial and communication overhead of parallel computation becomes a sufficiently small part of the whole process.

KEY WORDS: Graphics processing unit, GPU, Monte Carlo simulation, computer simulation, modeling.

1 INTRODUCTION

Computer simulation is recognized as one of the most frequently used tools in system analysis and design in science and engineering. Technology development enables increasingly sophisticated mathematical models to be simulated in less and less time. On the other hand it is also true that the increasing capability of hardware and software does not prevent scientists and engineers to reach the computational limits of the hardware.

The purpose of this paper is to show how computation with a personal computer can be accelerated using a parallel configuration of graphics processing units (GPU). This is done from the user's point-of-view to test the usability of the compared computational platforms for simulation.

The change of computational configuration is validated and illustrated with the case of a Monte Carlo simulation of a dynamic system model from the field of transportation science. Other such applications are increasingly popular, e.g., Raina et al. (2009), Catanzaro et al. (2008).

Mathematical models are inevitable in science and engineering. When parametric mathematical description is used, the issue of parameter estimation accuracy arises. Models with uncertain parameter values can be evaluated with various methods and computer simulation is among the most popular in the engineering community. Nevertheless, an exhaustive numerical analysis of models with numerous uncertain parameters requires a substantial computational effort. An example of such an exhaustive numerical analysis is the Monte Carlo simulation of dynamic systems with uncertain parameters, see e.g., Ray and Stengel (1993), Calafiore and Dabbene (2006).

The structure of the paper is as follows: the next section describes the hardware used and the implementation of simulation software for graphics processing units. Section 3 describes the selected case study and the comparison of computational time for selected hardware configurations. Conclusions are stated at the end.

2 COMPUTATIONAL ACCELERATION WITH GPU

While “standard” CPUs continue to provide users with more and more computing power nowadays (Shen and Lipasti, 2005), many computer scientists migrate towards general-processing GPU (GPGPU) applications (Kirk and Hwu, 2010), using graphics card processors as parallel accelerators for memory-dense, floating-point intensive applications. GPGPU accelerators are becoming the tool of choice in many computationally-bound research tasks such as bioinformatics or numerical modeling and simulation, and also in traffic simulation (Strippgen and Nagel, 2009).

The concept of a GPGPU processor evolved from the needs of 3D-graphics-intensive applications. This need dictated the design of the processor in such a way that more transistors were dedicated to the data processing rather than to control and data caching, as in a regular CPU. Subsequently, the processor was designed to be able to execute a data-parallel algorithm on a stream of data; consequently, the GPGPU processors are sometimes called “stream processors”. The currently dominant architectures for GPGPU computing are the nVidia CUDA (nVidia, 2011) and the AMD APP (formerly ATI Stream) (AMD, 2011). Graphics processing units are currently a low-cost, high performance computing alternative. With their intrinsic parallel structure they allow for significant computational increase in speed in comparison to the single processor architecture.

In order to show how the computation problem of Monte Carlo numerical analysis of a traffic model using the Matlab package for numerical computation (MathWorks, 2010) can benefit from the use of currently available GPGPU hardware, we describe the computing architectures that were used in our tests. The basic characteristic of the tested hardware configurations is given in Table 1.

For demonstration purposes, two different hardware configurations and two different software configurations will be used:

- Multiple-core CPU (CPU). A standard PC was used, equipped with a four-core Intel i5/750 processor with 4MB of cache memory (1MB per core). The Matlab interpreter will use its built-in multiple-core capabilities, resulting in most of the elementary matrix operations being computed in parallel on all four processor cores.

- Multiple-core GPU (GPU). The same PC platform as in the tests above will be used, but the most computationally intensive parts of the code, namely the Monte-Carlo simulation of the HCM model, will be offloaded to the GPU. We will use the NVIDIA

GeForce GTX 275 GPU, which includes 30 streaming multiprocessors with 8 cores each (in total 240 processor cores). Every processor may use up to 16 kB of fast shared memory similar to the cache memory of a traditional CPU.

- The first software configuration will use the GPU-accelerated Jacket library for Matlab (AccelerEyes, 2011). The library allows for almost seamless conversion of an existing Matlab code into a code that runs on a GPU.

- In order to assess the efficiency of the Jacket library, we will also use manually programmed GPU code in the form of a MEX file (an external routine, directly callable from the Matlab code).

We have written a small benchmark program based on Matlab, which tests the execution times of a typical HCM simulation cycle. The program gathers computation times in relation to the number of samples used in the simulation. This approach provides us with a view on the impact that different architectures have on the computation time from the user's perspective.

Table 1: Parameters of our hardware configurations: the used GPU is the first-generation GPU with double precision support and, as such, its double precision performance is 8 times lower than that of a single precision computation.

	Multiple-core CPU	*Multiple-core GPU*
Type	i5/750	GTX275
Cores	4	30×8 (240)
Cache memory	8MB	240×16kB (~4MB)
Total memory	4096MB	896MB
Memory bandwidth	17 GB/s	127 GB/s
GFLOPS (float)	42.56	1010
GFLOPS (double)	42.56	124

The NVIDIA GPGPUs come with the CUDA API (Garland et al., 2008), which is used to directly program the GPU hardware. While Jacket makes the use of CUDA (and other third party libraries) internally, for the assessment of Jacket efficiency we had to implement two custom GPU programs (kernels).

Although it is relatively easy to manually setup and perform basic mathematical operations on a GPU, it quickly becomes more complex when dealing with more demanding numerical problems. Additionally, due to the GPGPU architecture, special care must be taken when performing memory operations:

- due to relatively slow memory transfer, data transfers between the host system and the GPU device shall be as few as possible, and shall be asynchronous if possible,

- improper kernel code design, with respect to the operation on different memory types (main GPU memory, shared memory, constant memory, texture memory) and ignoring memory access coalescing on the GPU device, can cause a significant performance loss,

- shared memory in a block is organized into banks and accessing elements not consecutively will cause a bank conflict,

- shared memory and processor register space is scarce, and care should be taken to limit the number of kernel variables to as low as possible; this issue is critical, even more with double precision arithmetic, as a double precision number occupies two register units.

3 CASE STUDY

As an example of a mathematical model that will be used for Monte Carlo analysis the Highway Capacity Manual 2000 Queue Model for back of queue presented in the Highway Capacity Manual (2000) will be considered. The model is composed of two queue components,

$$Q_{k+1} = Q_{1,k+1} + Q_{2,k+1}, \tag{1}$$

where $Q_{1,k+1}$ represents an average back of queue for uniform arrival distribution that is corrected by a multiplicative correction factor accounting for queue progression, and $Q_{2,k+1}$ is an additive correction term accounting for randomness and uncertainty in the queue development process.

Under the assumption that the cycle length C is equal to the period of data collection T_Δ, the original model can be reformulated as

$$Q_{1,k+1} = \mathrm{PF}_{2,k} \frac{\frac{v_{\mathrm{L},k} C}{3600}(1 - z_k)}{1 - \min(1.0, X_{\mathrm{L},k}) \cdot z_k}, \tag{2}$$

where $\mathrm{PF}_{2,k}$ is an multiplicative correction factor adjusting the queue length for the effects of progression, $z_k = g_k/C$ is the relative green signal length in the k-th cycle corresponding to the absolute green length g_k, and $X_{\mathrm{L},k} = v_{\mathrm{L},k}/c_{\mathrm{L},k}$ is the lane saturation ratio computed from the current traffic volume $v_{\mathrm{L},k}$ and the lane capacity $c_{\mathrm{L},k}$. The correction factor is given by

$$\mathrm{PF}_{2,k} = \frac{(1 - R_{\mathrm{P},k} \cdot z_k)(1 - y_k)}{(1 - z_k)(1 - R_{\mathrm{P},k} \cdot y_k)},$$

where

$$y_k = \frac{v_{\mathrm{L},k}}{s_{\mathrm{L},k}}$$

is a flow ratio of the approach expressing its degree of total saturation for the current saturation flow $s_{\mathrm{L},k}$ and

$$R_{\mathrm{P},k} = \frac{P}{z_k}$$

is the platoon ratio of the approach concerned. Here, the variable P specifies the proportion of vehicles arriving during the green signal.

The second term of (1) attempts to correct possible errors in (2), caused by uncertain and random factors, such as the previous queue length, or a non-uniform arrival distribution. Assuming approximately constant flows during the data collection period T_Δ it is defined as

$$Q_{2,k+1} = \frac{c_{\mathrm{L},k} \cdot T_\Delta}{4} \left(X_{\mathrm{L},k} - 1 + \sqrt{(X_{\mathrm{L},k} - 1)^2 + \frac{8 k_{\mathrm{B},k}\, x_k}{c_{\mathrm{L},k} \cdot T_\Delta} + \frac{16 k_{\mathrm{B},k}\, Q_k}{(c_{\mathrm{L},k} \cdot T_\Delta)^2}} \right). \tag{3}$$

The second-term adjustment factor $k_{\mathrm{B},k}$ accounts for early arrivals and for actuated signals and is defined as

$$k_{\mathrm{B},k} = 0.01 I_k \left(\frac{s_{\mathrm{L},k} \cdot g_k}{3600} \right)^{0.6}. \tag{4}$$

The upstream filtering factor I_k in this equation expresses the influence of saturation ratio $X_{\mathrm{u},k}$ at the upstream intersection on platoon arrivals at the modeled intersection. In our case it is computed using formula given by the Highway Capacity Manual (2000) as

$$I_k = 1 - X_{\mathrm{u},k}^{2.68}. \tag{5}$$

After obtaining the average back of queue by evaluating (1), a percentile back of queue factor has to be applied to the predicted value to get a more conservative prediction of the queue length. The percentile correction factor $f_{\mathrm{B\%}}$ is defined as

$$f_{\mathrm{B\%}}(Q) = p_1 + p_2 \cdot e^{-\frac{Q}{p_3}} \tag{6}$$

where parameters p_1, p_2 and p_3 are usually determined by the desired percentile (Highway Capacity Manual, 2000). The final queue length $Q_\%$ incorporating the percentile correction is then

$$Q_{\%,k+1} = Q_{k+1} \cdot f_{\mathrm{B\%}}(Q_{k+1}). \tag{7}$$

In our case parameters p_1, p_2 and p_3 are uncertain parameters for which we have only interval values. These values are $p_1 \in [1.1, 1.5]$, $p_2 \in [0.2, 0.4]$, $p_3 \in [25, 35]$.

The Monte Carlo simulation with 10^6 simulation runs where parameter values were uniformly distributed within their intervals was run within Matlab on both previously mentioned configurations. Simulation results are depicted in Figure 1.

3.1 User effort

As we would like to compare the results not only in terms of acceleration, but also in the context of user effort that went into particular variants of the tested software, we will now summarize the latter.

- Multiple-core computer (CPU). In the case of a recent Matlab version, the Matlab computing kernel automatically uses a multithreaded version of certain functions and operations in case that the size of operands exceeds a certain limit.

- Personal computer with GPU using Jacket (Jacket). The transition from pure Matlab to "Jacketized" code has been very swift. The original Matlab function that represents the model had to undergo just minor changes and has been compiled by Jacket as a kernel code. The other change was changing the model simulation to run element-by-element (rather than vectorized) in a loop using a special GPU optimized loop construct provided by Jacket. The total effort was a few hours for a person fairly familiar with the Matlab environment.

- Personal computer with manually programmed GPU (GPU). The simulation procedure has been rewritten as a MEX file, manually implementing the model as a GPU kernel. In addition, as Jacket provides accelerated implementations of functions for finding mean value, maxima and minima of a data vector, these three operations have been implemented as custom kernels too. The current code snapshot represents a few days of programming and debugging effort for an experienced programmer. Most of the effort probably went into debugging the model code due to its high register space requirements.

3.2 Computational effort

The comparison of computational times is illustrated with a case study of a Monte Carlo simulation using from 100000 to 6400000 samples of a HCM model with changing parameters p_1, p_2 and p_3. The computational effort assessment is given in Figure 2.

We can see that for a low number of samples the overhead of GPU computation severely affects the computation – the time needed to set up the GPU hardware and to transfer the data from the host computer to the GPU severely affects the performance of the GPU-accelerated code.

Once reaching above approximately a hundred thousand samples, the full advantage of the GPU capabilities starts to be visible: The "Jacketized" code, despite the minimum effort necessary for the changes of the original HCM model, reaches a speedup of a factor of more then 15, and the manually programmed version of the HCM model outperforms the CPU version by factor of more than 25.

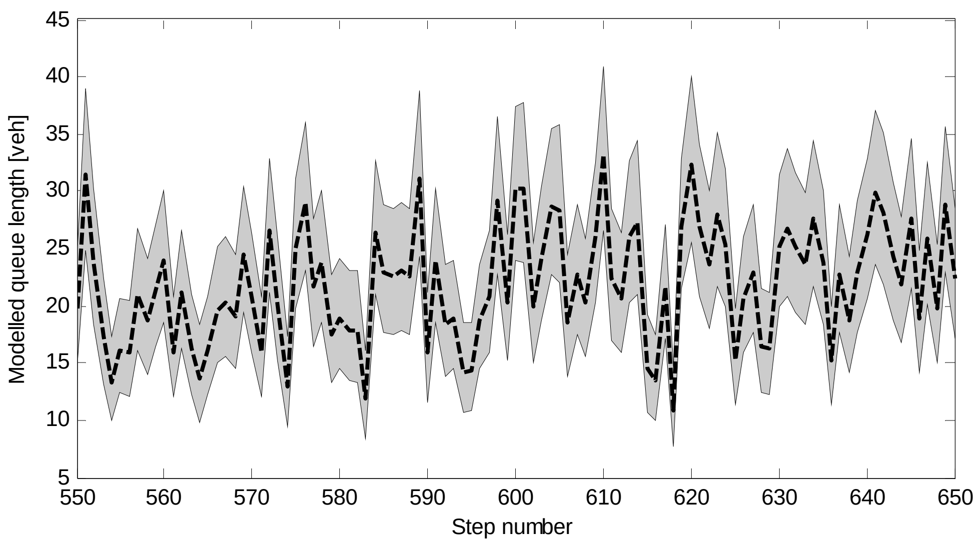

Figure 1: Response of the queue-length model with stochastic parameters p_1, p_2 and p_3.

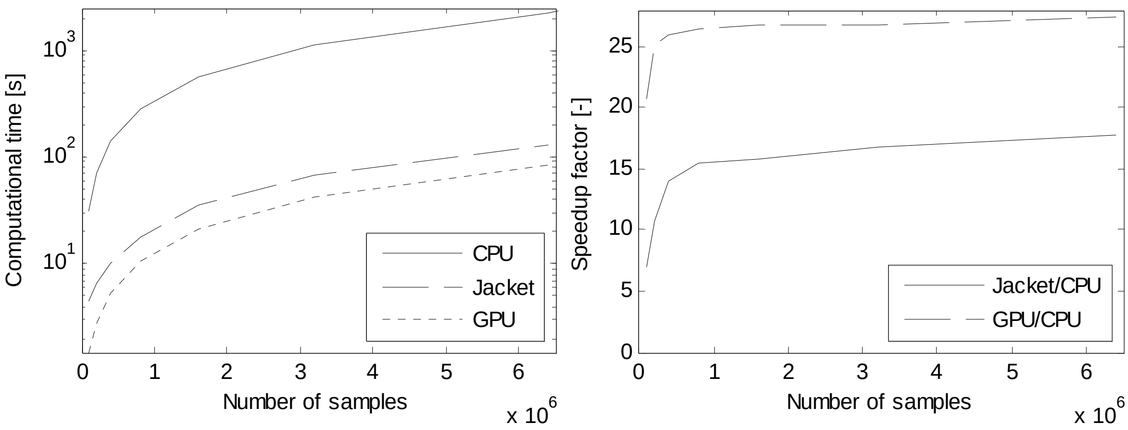

Figure 2: Computation times of the model Monte Carlo simulation versus the number of simulation runs for different hardware configurations (left). Relative speedups of a simulation run on a personal computer utilizing graphics processors, with respect to the multi-core computation (right).

4 CONCLUSIONS

Computer simulation is a flexible and frequent tool that can be used for analysis and design in science and engineering. When the amount of simulation runs is increased – as it is the case of the Monte Carlo simulation – and the models are complex, the drawback is an increasing computational time. This paper provides a description of the implementation of the Monte Carlo simulation on graphics processor units and a comparison of computational-time with a standard multi-core personal computer on a dynamic system simulation case-study. The assessment was performed from the user's point-of-view to test the usability of the compared computational platforms for simulation.

The assessment of the simulation algorithm implementation on nVidia GTX275 graphics processing unit for the Highway Capacity Manual 2000 Queue Model revealed that even a straightforward acceleration using a third party library for GPU computation (Jacket) can increase the simulation speed by a factor of more than 15 and that a speedup of more than 25 can be reached by manually programming the GPU hardware. It has to be noted that the GPU used is currently a middle-class device and that its computing capabilities in double precision floating point arithmetic are inferior to state-of-the-art devices.

As hardware capabilities are improving constantly and research on efficient algorithms is on-going the presented assessment might not be of long-term value. However, it offers a state-of-the-art comparison of an affordable hardware configuration that might help to circumvent the computational issue in intermediate time before more efficient algorithms or better technologies arise. With this it fulfills the purpose for which it was intended.

ACKNOWLEDGMENTS

This work has been supported by the Slovenian Research Agency, grants Nos. P2-0001 and J2-2099, and by a bilateral project between Slovenia and Czech Republic 'System Identification Based on Gaussian Process Model for Traffic Control Applications' (MEB091015).

REFERENCES

AccelerEyes, 2011. *Jacket User Guide* Version 1.8.1. Atlanta, GA (USA): AccelerEyes.

AMD, 2011. *AMD Accelerated Parallel Processing OpenCL Programming Guide.* Sunnyvale, CA (USA): Advanced Micro Devices, Inc.

Calafiore, G., Dabbene, F. (Eds.), 2006. *Probabilistic and Randomized Methods for Design under Uncertainty*. London: Springer. ISBN 978-1846280948.

Catanzaro, B., Sundaram, N., Keutzer, K., 2008. Fast support vector machine training and classification on graphics processors. In *Proceedings of 25th Annual International conference on Machine Learning*. New York: Omnipress, pp. 104 – 111.

Garland, M., Grand, S. L., Nickolls, J., Anderson, J., Hardwick, J., Morton, S., Phillips, E., Zhang, Y., Volkov, V., 2008. Parallel computing experiences with CUDA. *Micro, IEEE*, vol. 28, no. 4, pp. 13 – 27. ISSN 0272-1732.

Highway Capacity Manual 2000. Washington (USA): Transportation Research Board, Federal Highway Administration.

Matlab 2010b, 2010. Natick, MA (USA): MathWorks Ltd.

NVIDIA, 2011. *CUDA Programming Guide* Version 4.0. Santa Clara, CA: NVIDIA Corporation.

Kirk, D. B., Hwu, W. W., 2010. *Programming Massively Parallel Processors – A Hands-on Approach.* 1st edition. Burlington, MA: Morgan Kaufmann (USA). 280 p. ISBN 978-0123814722.

Raina, R., Madhavan, A., Ng, A. Y., 2009. Largescale deep unsupervised learning using graphics processors. In *Proceedings of International Conference on Machine Learning*.

Ray, L. R., Stengel, R. F., 1993. A Monte Carlo approach to the analysis of control system robustness. *Automatica*, vol. 29, no. 1, pp. 229–236. ISSN 0005-1098.

Shen, J. P., Lipasti, M. H., 2005. *Modern Processor Design: Fundamentals of Superscalar Processors*. McGraw-Hill Series in Electrical and Computer Engineering. New York (USA): McGraw-Hill. 640 p.

Strippgen, D., Nagel, K., 2009. Multi-agent traffic simulation with CUDA. In *Proceedings High Performance Computing & Simulation (HPCS '09)*, pp.106 – 114.

Volkov, V., Demmel, J., May 2008. *LU, QR and Cholesky factorizations using vector capabilities of GPUs.* Technical Report No. UCB/EECS-2008-49 [online]. Berkeley: EECS Department, University of California. Retrieved from: http://www.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-49.html.

A New Impact Simulation Device for Testing Passive Safety Equipment

J. Hampl
Passive Safety Department of DEKRA Automobil a.s., Prague, Czech Republic

DOI: 10.2478/v10158-012-0008-1

ABSTRACT: The described device presents a cheap improved system for routine impact tests. The impacts are simulated by cart accelerations. The necessary energy is accumulated in rubber ropes. The required shape of acceleration curve is achieved with replaceable cams. The reactive acceleration force moves the drive system in the opposite direction on the base, which is shaped as an inverted box. Its walls are sealed in contact with the floor. The inner space of the "box" is empty. Therefore, the total "weight" increases. The recoil is limited by springs and hydraulic shock absorbers. For easy replacement of the device in the test room area the lifting function of the exhauster and several small wheels with level adjustment can be used.

KEY WORDS: Passive safety of vehicles; replacing impact deceleration by acceleration; energy accumulation in elastic ropes.

1 INTRODUCTION

Within the state-aided project "Passive Safety of Children in Cars" a great dispersion of the shapes of deceleration curves was observed (these decelerations simulate vehicle crashes). This hindered finding an optimal method of routine testing side impacts of child restraint systems, for example. To solve this problem we have designed the device described below.

2 EXISTING DEVICES FOR SIMULATING VEHICLE IMPACTS

A usual method of how to simulate impact deceleration, i.e. a steep slowing down of the tested object, is the sharp stopping of a sled or trolley carrying the tested object, such as a dummy with fastened seat belt. Using this method child restraint systems, competition car seats, partition walls separating passengers from the cargo space, and so on, can also be tested. The required deceleration rates attain values corresponding to up to ten times the acceleration of gravity and the tested object's speed is expressed in tens of kilometers, and the braking distance in decimeters.

2.1 Current State of Simulating Impacts

The most conventional breaking system uses a resilient bush made of plastics with reversible deformation properties, inserted in a steel tube and furnished with a hole the diameter of which is smaller than the diameter of a pin. The pin is connected to the tested object and is protruding into the bush during the impacting process. The kinetic energy of the moved object is thus absorbed by the friction between the surface of the pin and the internal surface of the bush hole. The required rate and diagram of deceleration during intrusion of the pin into the bush is achieved by providing variable diameters of the bush hole. Such a breaking device is presumed to be used, for example, pursuant to UNECE Regulations No. 16 and 44 (although other methods with the same effect are not excluded).

Nevertheless, it may be understood that even upon the maintenance of the prescribed bush temperature, the actual pin deceleration value will fluctuate due to the age and history of the bush when exposed to tens of repeated tests. Therefore, the above-mentioned standards allow for relatively broad limits, in which the diagram of deceleration is defined. For example, with UNECE Regulation No. 44, the limit for the maximum deceleration is 20 - 28 g. This may lead to disputable statements as to the compliance with the prescribed standards.

Concerning the physical effects, the impact deceleration may be substituted by impact acceleration exhibiting the same time behavior. To this effect, various devices, also called catapults, have been used. For example, UNECE Regulation No. 44, Series of Amendments No. 04 (§ 8.1.3.12.1.3.2 and Annex 7, Appendices 1 a 2) states the use of a catapulting device.

Hydraulic driven catapults simulating the course of impacter acceleration through the precise and prompt control of the flow rate of the fluid moving at a high speed through the hydraulic system are also known. Such systems are able to simulate various rates and diagrams of acceleration, which, due to a feedback system, may be maintained within relatively close limits. Such highly flexible and sophisticated systems are, however, very expensive and therefore more suitable for research and development purposes than for the routine practice of testing laboratories and shops.

3 PRINCIPLE OF THE NEW IMPACT SIMULATOR (catapult with elastic ropes)

The tested object is placed on a trolley whose movement is guided by a slide bar during the impact simulation. The trolley receives the acceleration impulse from the actuator-bumper which has a cylindrical roller bearing on the opposite end. The bearing is in contact with a cam which is shaped in such a way so that the required acceleration course is attained. The cam is fixed on a common shaft with a winch for a steel cable attached to the elastic ropes bundle. During the impact the energy accumulated in it passes to the accelerating trolley. After having reached the required velocity the trolley equipped with wheels leaves the guiding bars defining the section measured. Immediately, intensive deceleration is initiated using guy ropes being unreeled from intensely braked winches. The stopping distance is short (ca 2 m). After unhitching the guy ropes the trolley can be pushed away and another one with a further object installed for testing can be attached.

For stopping the movement of the actuator a spring and a hydraulic shock absorber are used. Similarly, the rotation of the winch and cam is stopped. To elongate the elastic ropes an electromotor is used.

That catapult is not fixed to the test room floor; it stands freely on it. But it is not the impact simulator itself which is in contact with the floor; a separated base shaped like an empty inverted box stands under it. The base is sealed on its edges so that the underpressure generated by an exhauster heightens the force pressing the catapult to the floor. During the impact the simulator moves by reaction along the base in the opposite direction to the trolley (similar to that of the cannon recoil). The recoil length is limited by springs and shock absorbers.

The device is made up of a minimum number of components, which may guarantee maximum reliability and the minimum of trouble-causing incidents. Its operation is simple and enables the selection and performance of the desired or required course of acceleration consistent with the requirements of the standards by selecting a suitable shape of the cam. As compared with a hydraulic controlled catapult, the production cost of the device is considerably lower, which in turn may result in low operating costs.

3.1 DESCRIPTION OF THE NEW IMPACT SIMULATOR

The text and the mechanical scheme of the catapult itself (without the base and without the recoil system) is taken from the patent application PCT/EP/2008/064326. Note: In the previous paragraph (2) the tested object is situated on a trolley, while in the following description (used for the patent application) the tested object is mounted on a sled sliding on rails. Such a difference is immaterial.

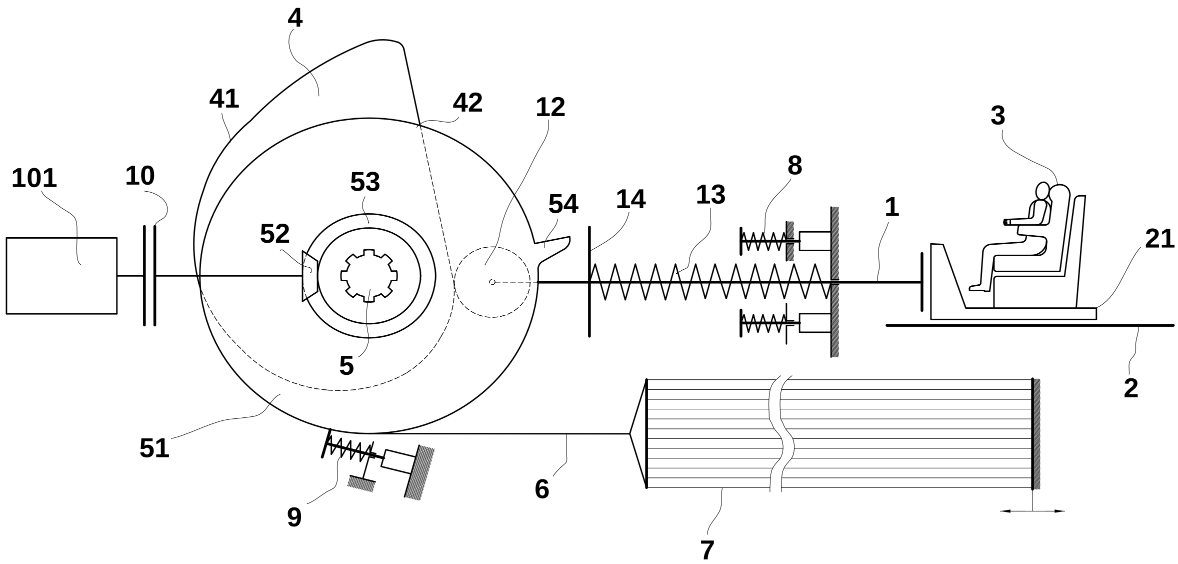

Figure 1: Mechanical schema of the catapult.

As an example of a testing device for dynamic tests simulating impact into the front part of a vehicle a catapult was selected with which a child restraint system with a dummy was installed. The tested object was situated in a forward direction. This arrangement is consistent with Paragraph 7.1.4.4.1.1. of ECE Regulation No. 44-04. The basic calculation was made in order to verify the feasibility of the device. More specifically, the calculation was made in order to determine the shape of the cam used for a simulation of this type of impact.

In the figure above, the child restraint system 3 with a child dummy is placed on a sled 21. The sled 21 can move on rails 2 and can be equipped with wheels for moving in the testing area in order to reduce friction. This part of the device, i.e. the sled system, is shown only to understand better the purpose of the invention. It is demonstrated on a smaller scale.

To simulate a crash deceleration the impacter 1 pushes the sled 21 with the tested object. The impacter is fitted at its other end with a roller 12 with antifriction bearings. The roller 12 of the impacter 1 is pushed to the cam 4 by a spring 13 over a spring disc 14. The cam 4 is mounted on a fluted shaft 5 and its outer periphery is composed of an active surface portion 41 and a transitory surface portion 42. The active surface portion 41 is formed in such a shape that upon rotation of the cam 4 the required and predetermined course of acceleration of the impacter 1 derived from rolling the roller 12 along the active surface 41 of the cam 4 is achieved.

For various types of acceleration diagrams a number of cams 4 with appropriately shaped active surfaces corresponding to desired acceleration diagram types may be mounted on the fluted shaft 4 and then adjusted into a position in contact with the roller 12. The shaft 5 further bears a rope winch 51 to which a pull rope 6 is firmly attached. The opposite end of the pull rope 6 is attached to an energy source - in this case to a linear engine in the form of an elastic ropes bundle 7.

To stop the impacter 1 at the end of its movement before the roller 12 reaches the transitory surface portion 42 of the cam 4 the first shock absorber assembly 8 is mounted on the immovable part of the testing device structure. To stop the delayed rotation of the rope winch 51 and that of the cam 4 before the roller 12 engages the opposite end of the transitory surface portion 42, the rope winch 51 is provided with a side stop 54 for engagement with the second shock absorber assembly 9 also mounted on the immovable part of the testing device structure.

The shaft 5 bearing the rope winch 51 is driven through a clutch 10, pinion 52, and crown gear 53 assembly by an external motor 101. By winding up the pull rope 6 on the rope winch 51, the elastic rope bundle 7 is stretched and linear motor loaded with energy. The anchored end of the elastic ropes bundle 7 is mounted for longitudinal motion on the immobile testing device structure in the direction of the pull rope 6, more specifically in the direction of the force exerted by the elastic ropes bundle 7. This arrangement enables the setting of the maximum extension of the elastic ropes bundle 7 by election of the corresponding position of the anchored end of the bundle, and thus to adjust the energy capacity of the linear motor and finally the speed of the sled 21.

4 INFORMATION ABOUT THE PRELIMINARY COMPUTATION METHOD FOR THE CAM OF THE IMPACT SIMULATOR

The dynamics of the system are described by balancing the actuating force with the inertial force of the sled:
Actuating force minus inertial force of the cam, winch and ropes minus transmission ratio multiplied by inertial force of the sled and actuator equals 0

$$F_{elastic\ ropes} - m_{cam+winch+ropes} * a_{elastic\ ropes} - i * (m * a)_{sled+actuator} = 0 \quad (1)$$

where $m_{cam+winch+ropes}$ incorporates inertia torque of the cam and winch

For reasons of simpler computation a linear dependence of the elastic force on the elongation of the ropes is supposed:

$$F = F_{max} - Z * k \quad (2)$$

z is replacement of the moving end of the elastic ropes [m]

k is rigidity modulus of the elastic ropes bundle [N/m]

When (2) is substituted into (1), then:

$$F_{max} - Z * k - m_{cam+winch+ropes} * a_{elastic\ ropes} - i * m_{sled+actuator} * a_{sled+actuator} = 0 \quad (3)$$

so the notation of transmission course:

$$i = F_{max} - Z * k - m_{cam+winch+ropes} * a_{elastic\ ropes} / m_{sled+actuator} * a_{sled+actuator} \quad (4)$$

($Z = \Sigma z$, where $z = i * [s_n - s_{n-1}]$; s the relevant distance of the trolley)

The computation is not trivial, not only due to the relevant length of the necessary releasing of the elastic ropes Z, but also the deceleration of the moving end of the elastic ropes bundle depends on the transmission ratio. This means that the input value is influenced by the computation result, and cyclic dependence (feedback) occurs. Therefore the iterative computation is necessary.

Owing to reduced cam steepness at the initial impact it is useful to defer starting deceleration of the trolley (therefore the elastic energy is first used for accelerating the cam and the winch, and only later for the trolley acceleration).

The preliminary computation includes neither the friction, nor the non-linear course of the elastic ropes force (see the following diagram relating to the rope diameter 20 mm; the producer Sandow Technic recommends using it in an elongation range of 20 – 80 %). Additionally the contact kinematics between the cam and bearing of the actuator were not taken into account (the cylindrical roller bearing was replaced with an edge).

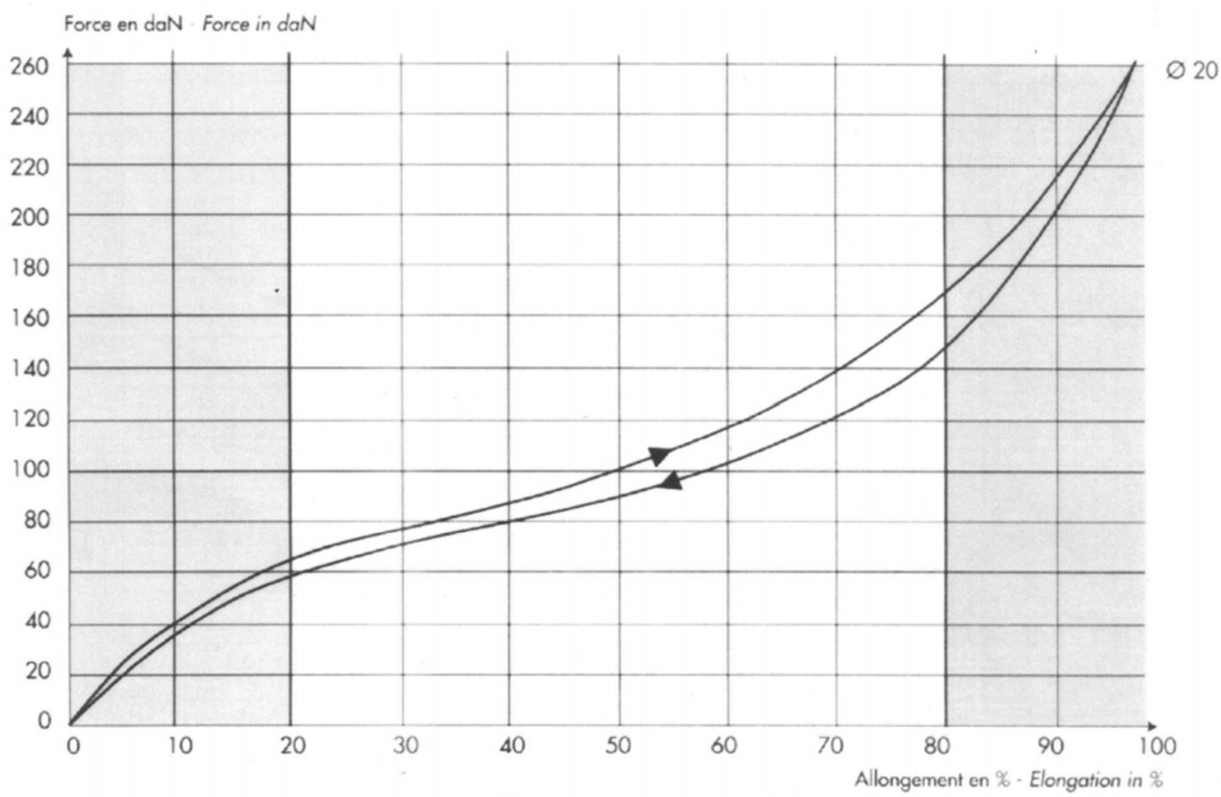

Figure 2: Relation between the force and the elongation of the rubber rope Ø 20 mm.

The calculation of the cam shape was used for impact simulation according to UNECE Regulation No. 44, § 8.1.3.1.1.3.2, which specifies the dynamic testing of the child restraint system by frontal impact. In the next diagram the trolley acceleration is limited from above by the red broken line and from below by the blue broken line. Moreover, the acceleration curve has to lie above the green straight line segment. According to ISO 17373 Standard the beginning of the impact is defined by an acceleration value of 0.5 g. The final speed is 52 km/h +0 -2 km/h. The accelerating distance is 650 ± 50 mm.

To find an approximate cam shape the acceleration course was designed using two slightly different sinusoidal curves joined in their peaks (see the violet curve in the next diagram).

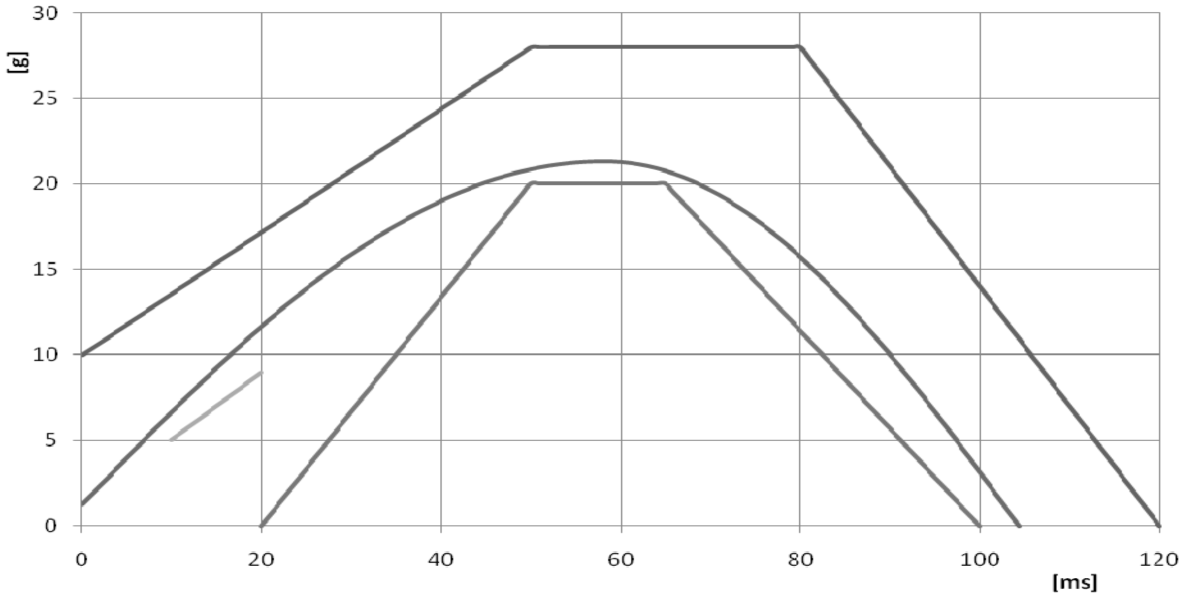

Figure 3: The designed acceleration curve within the limits of § 8.1.3.1.1.3.2 R44-04 UNECE.

In the following diagram the speed course (red curve) was gained by integrating the acceleration from the previous diagram. The integration of the speed course resulted in the blue curve (track dependence on time). Time [ms] is on the horizontal axis. The scale on the vertical axis applies to acceleration [g] (black curve), speed [km/h] and accelerating distance [cm]. The designed acceleration course more or less met the above mentioned requirements. It will be upgraded within the detailed computation taking into account all the influences which were ignored during the preliminary calculation.

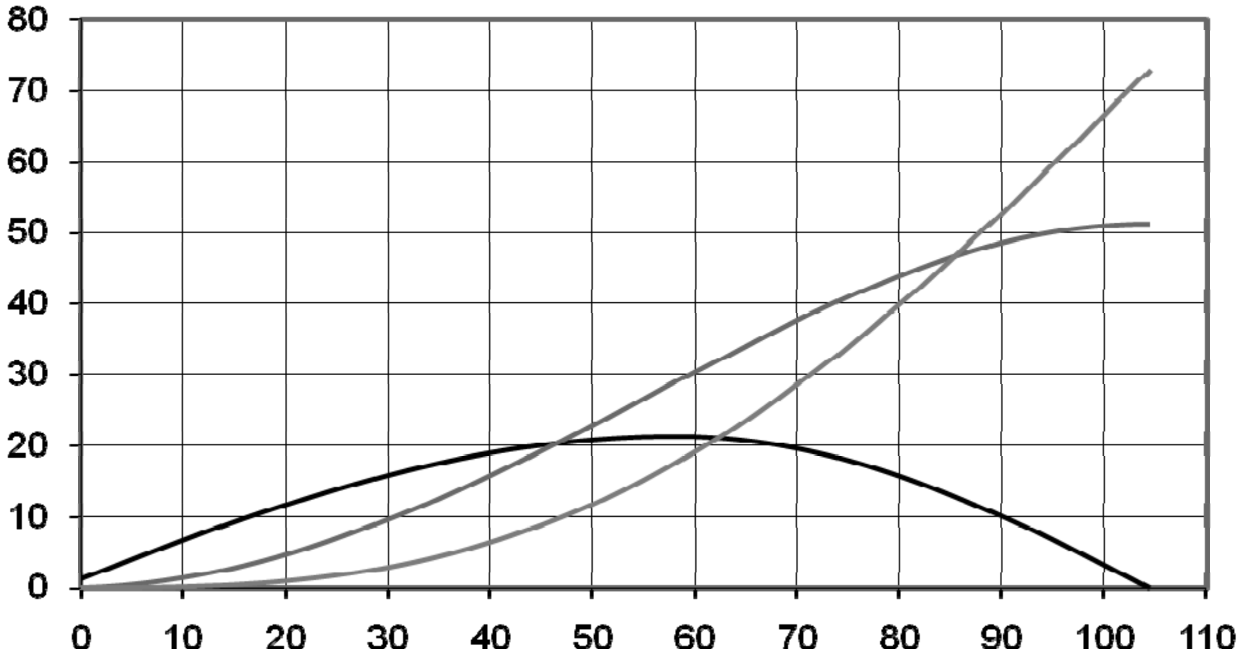

Figure 4: Courses of speed and accelerating distance for the designed acceleration course.

The informative shape of the active part of the cam (next fig.) was formed on the basis of preliminary calculation of the transmission ratio between the motions of the trolley and elastic ropes bundle. The cam's eccentricity depends on its rotation (after transfer into polar coordinates).

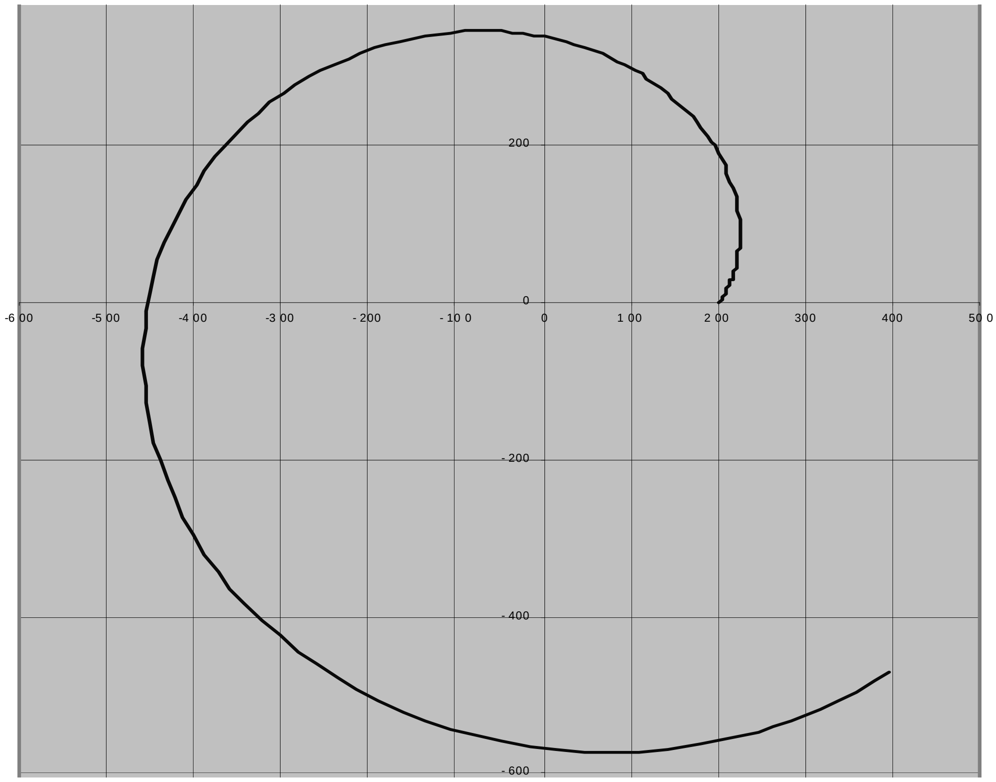

Figure 5: Shape of active part of the cam.

5 EXPECTED ADVANTAGES OF THE NEW IMPACT SIMULATOR

- Simulation of the required deceleration curve shape of the impact is more accurate than at the device using braking polyurethane tubes.
- The relatively expensive braking polyurethane tubes are not needed.
- When the impact starts, the tested object (e.g. dummy in a restraint system) is in the specified position, and not in a position somehow moved by the acceleration force during the trolley's initial acceleration.
- If the safety belt ruptures in the present testing device, the dummy will continue moving and can be damaged; while in the accelerating simulator the dummy remains in place.
- The trolley of the present devices is substituted by a simple sled gliding on the track without generating parasitic oscillation (unlike the restless rolling wheels of the trolley).
- The stopping distance after impact can be considerably shorter than the moving-off distance of the decelerating simulator as the change of the dummy's position through intensive braking after impact is irrelevant. Therefore the necessary space in the test room can be significantly smaller. For transporting the complete device a platform semitrailer can be used.
- The braking part of the sled track can be bifurcated so that more sleds can be used. Productivity will thereby increase.

- Due to a low acquisition price smaller manufacturers of restraint systems will also be able to acquire these simulators for internal production checking. Therefore, batch production will further decrease the price.

6 INDUSTRIAL APPLICABILITY

The device can be used by testing shops performing dynamic tests of safety systems to satisfy the standard requirements of regulatory authorities. Additionally, it may be used by the testing laboratories of manufacturers producing safety systems to control their current production and, subject to minor modification to the device, even for research and development purposes.

ACKNOWLEDGEMENTS

The article was prepared under the terms of the project ”Passive Safety of Children in Cars” (No. CG711-040-160) which has been supported by the Ministry of Transport of the Czech Republic.

REFERENCES

Gehre, C. et al., 2008. Restrained Children in Side Impacts – Crash Tests and Simulation. In *1st Conference Protection of Children in Cars, Cologne, 2003*.

Gallegos, D. et al., 2008. Frontal Absorbed Energy Systems Applied to a CRS. In *Protection of Children in Cars. International Conference Proceedings*, Munich.

Hampl, J. et al., 2008. *Pasivní bezpečnost dětí v motorových vozidlech.* DEKRA Automobil Report of the project CG711-040-160 for the Czech Transport Ministry, pp. 48 – 52. (inCzech).

Instron® Structural Testing Systems (IST) [online]. © 2010 Illinois Tool Works Inc. Retrieved from: www.instron.com/ist.

Messring [online]. © 2011 MESSRING Systembau MSG GmbH. Retrieved from: www.messring.de/wp-content/uploads/MESSRING_Accelerator-Sled-Systems.pdf

UNEC E: Paragraph 8.1.3.1.1.3.2, Regulation No. 44 - 04.

Methods for Solving Discrete Optimization Problems

D. Mocková*
Department of Logistic and Transportation Processes, Czech Technical University of Prague, Czech Republic
** Corresponding author: mockova@fd.cvut.cz*

DOI: 10.2478/v10158-012-0009-0

ABSTRACT: The article specifies a group of discrete optimization problems, such as location problems and tour problems, from the aspect of individual approaches (exact, heuristic, and metaheuristic) and seeks to explain all the approaches on specific problems.

KEYWORDS: Discrete optimization problems, heuristics, metaheuristics, P-median problem, P-hub median problem, genetic algorithms.

1 INTRODUCTION

In transportation and logistics systems (network problems) we distinguish two basic types of combinatorial problems. The first group consists of problems whose solution is a well-defined set of items, such as the spatial distribution of facilities (service centres), terminals, warehouses, etc.

The solution to the second group of combinatorial problems is defined as a sequence of visited nodes, or a sequence of customers served. A typical instance of the second group of problems is a VRP (vehicle routing problem). A travelling salesman is the simplest example of vehicle routing.

1. Exact approach

This approach allows an optimal solution to be found, if one exists, unless one can prove that there is no admissible solution to the problem. A great price is paid for precision – especially in computation time - where an extensive problem is concerned. Moreover, it is difficult to estimate the time required for computation purely from the size of the problem. The approach can, for example, prove that it is not possible to construct a Hamiltonian circle.

2. Simple heuristics

This is used to find a good and admissible solution to a problem, or improve existing solutions. The heuristic approach, though, does not guarantee that an optimal solution will be found. Nevertheless, heuristics are very useful for practitioners who need to solve in real time problems of great sizes in order for their solutions to be used quickly (in real time).

- Primal heuristic

A primal heuristic works from an admissible solution to a problem, and tries to improve the solution through permitted operations that transform the current solution to another admissible solution with a lower objective function value. The new solution then becomes the current solution for the next step in the improvement process. The primal heuristic ends once no further improvement can be achieved by way of the permitted operations.

- Dual heuristic

A dual heuristic works from an inadmissible solution and seeks to reduce the degree of inadmissibility by using permitted operations. Individual steps of the algorithm are performed with a view to minimising growth in the objective function value. The process continues until an admissible solution is found or until it is no longer possible to reduce the inadmissibility of the solution by means of permitted operations.

Primal and dual heuristics can be combined (e.g., a primal heuristic provides the initial admissible solution for a dual heuristic).

3. Metaheuristics

This removes certain shortcomings of simple heuristics in that it does not become trapped in a local optimum. It jumps in the set of all admissible solutions and, at one moment, it explores several places in the set of admissible solutions (producing a sequential series of solutions), the objective function jumps; its gradient does not decrease, as in the case of simple heuristics. It is able to escape from a local optimum and find the global optimum.

Approaches – methods for creating a sequence of solutions

- approach based on exploring surroundings – Simulated Annealing, Tabu Search
- approach based on the evolutionary process – Genetic Algorithms, Ant Colony

We will look at individual approaches to solutions to specific problems.

2 SOLUTION APPROACHES

2.1 Solving a P-median problem exactly

P-median problem (maximum distance problem)

We have a given set of customers and some facilities (service centres). The customer is satisfied if its distance from any facility is less than or equal to the constant D_{MAX}. This formulation of the problem corresponds to the real problem of decision-making, such as in the case of the placement of alarm sirens, public (municipal) loudspeakers, or location of healthcare centres. The optimality criterion is to cover all customers through a minimum number of localised facilities, depots, etc. A classic instance is for a set of customers $j \in J$ and a set of facilities $i \in I$, where we define the sets:

$$N_j = \{i \in I : d_{ij} \leq D_{Max}\} \quad (1)$$

these are sets of possible locations of facilities from which it is possible to satisfy the need of a *j*-th customer.

The problem can easily be transformed into the known problem of covering the vertices of a graph (customers) using the minimum number of subsets from the given system of subsets. Note: a vertex is covered when its distance from a facility is $\leq D_{MAX}$. Individual subsets contain customers whose distance from the given facility does not exceed D_{MAX}.

Instance of a specific problem:

Given facts: D_{MAX}, location of customers, set of candidates for the placement of facilities. We are looking for the minimum number of facilities that will cover the customers' requirements.

We compile the sets $N_j = \{i \in I : d_{ij} \le D_{MAX}\}$ for $j \in J, J = \{v_1, v_2, v_3, v_4, v_5\}$. The sets are expressed in a table where the rows are customers and the columns are facilities. The *j-th* row of the table corresponds to the *j-th* set N_j, a one in the *i-th* row indicates that the facility S_i belongs to the set.

Table 1: N_j Initial admissible solution to the problem.

	S_1	S_2	S_3
v_1	1		
v_2	1	1	
v_3	1		1
v_4	1	1	
v_5			1

Formulation of the LP general problem:

We denote the elements of the table as a matrix $A = (a_{ij})_{i,j=1}^{3,5}$ (2)

Then we can formulate the model of the coverage problem: to minimize: $\sum_{i \in I} y_i$ (3)

Under the conditions: $\sum a_{ij} y_i \ge 1$ for $j \in J$, $y_i \in \{0,1\}$ for $i \in I$ (4)

We fill the model with data from the example: minimise the function: $y_1 + y_2 + y_3$ (5)

Under the conditions:

$$y_1 \ge 1, \quad y_1 + y_2 \ge 1, \quad y_1 + y_3 \ge 1, \quad y_1 + y_2 \ge 1, \quad y_3 \ge 1, \quad y_i \in \{0,1\} \qquad (6 – 10)$$

We will examine the entire set of solutions, and then choose the one which is admissible and has the smallest objective function value.

An admissible solution to the problem (5) – (10) is each triplet consisting of ones and zeros that satisfies the inequalities (6) – (10). It is obvious that the vector $y = (1,1,1)$ meets all the conditions and therefore belongs to the set of admissible solutions. Conversely, the triplets *(0,1,1)* and *(1,1,0)* fail to meet the conditions (6) and (10), and are therefore inadmissible solutions.

The number of admissible solutions to the illustrative example (5) – (10) is small and contains only two solutions, so it is easy to determine the optimal solution that minimizes the function (5). The first solution gives us a criterion value equal to 3, the second solution then gives us the value 2. Therefore, the second solution, with an objective function value equal to 2, is the optimal solution to our problem.

While this example is simple and easily solvable, we should not be misled into believing that for every problem it is easy to determine the admissibility of the solution and optimality. Quite the contrary, most real problems must be described by hundreds or thousands of variables and conditions, and the number of admissible solutions exceeds the number 10^{12}. In such circumstances the use of the brute-force method, i.e., an examination of all admissible solutions, is unrealistic and unmanageable in a reasonable space of time necessary for practical use.

The above points lead us to the use of various computer-oriented methods, allowing the calculation of the solution to be completed within a reasonable time.

2.2 Solving a P-median problem through a simple heuristic

P-median problem (maximum distance problem)

To illustrate a heuristic method we will use the example of a heuristic approach to solving the maximum distance problem already formulated above.

The solution to the maximum distance problem is determined by the set of located facilities. A solution is considered admissible if each customer has at least one facility available within the distance D_{MAX}. The default admissible solution can be obtained by placing a facility in all possible locations (the set of candidates for the depot, facility). Each solution can be represented by a list of located facilities. If we were to denote *n* number of facilities in the list, the following algorithm can describe the *primal heuristic*.

STEP 0: We put $k = 1$.

STEP 1: Examine, check each facility from the list of facilities currently valid. If removing a facility does not disturb admissibility, then remove that facility from the list.

STEP 2: If $k < n$, put $k = k + 1$ and go to STEP 1., else end the calculation 3.

STEP 3: End.

If we were to apply this heuristic to our example with the default list $\{S_1, S_2, S_3\}$ of facilities, $n = 3$, $k = 1$, we can easily determine that the facility S_1 cannot be removed because the customer v_1 cannot be satisfied by either facility S_2 or S_3. The facility S_2 is examined and we find that its removal does not violate the solution's admissibility (all customers have least one facility available at a distance of $d_{ij} \le D_{MAX}$). The new solution is expressed by the set $\{S_1, S_3\}$, $k = 2$, $k < n$. By examining the facilities S_1 and S_3 we find that neither S_1 nor S_3 can be removed due to the requirement of v_5. The algorithm ends with the resulting solution $\{S_1, S_3\}$.

Even though in our simple demonstration example the heuristic enabled us to find the optimal solution, in general this does not hold true, since, particularly in the case of complex and extensive problems, heuristics do not guarantee optimal solutions. A primal heuristic, based on an admissible solution, can end the search process far from the optimum. Each primary heuristic merely ensures that one admissible solution is replaced by another, better solution.

2.3 Solving the P-hub median problem through metaheuristics by using genetic algorithms

Hub and Spoke principle in general

- consolidation of small consignments at terminals (hubs)
- transportation between terminals over long distances
- distribution of consignments and delivery

Advantage: transportation between terminals (hubs) is cheaper and more frequent, drawback: extension of the route

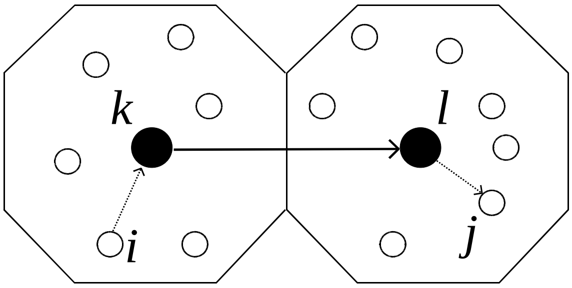

Figure 1: Hub and Spoke Principle.

Calculation of transportation costs – transportation costs between vertices *i*, *j*:

$$C_{ijkl} = c_{ik} + \alpha c_{kl} + c_{lj} \qquad (11)$$

c_{ik} – cost of pick-up part
α – coefficient of savings in transportation between hubs $(0 < \alpha < 1)$
c_{kl} – cost of transportation between the nodes *k*, *l*
c_{lj} – cost of the delivery part

Variants of the problem:

- capacity limited / unlimited hubs
- known / unknown number of terminals
- same / different transportation costs in individual directions
- same / different α for individual routes between hubs
- same / different amounts of transportation flows between nodes
- simple / multiple allocation

Simple location – served objects are firmly assigned to a specific hub

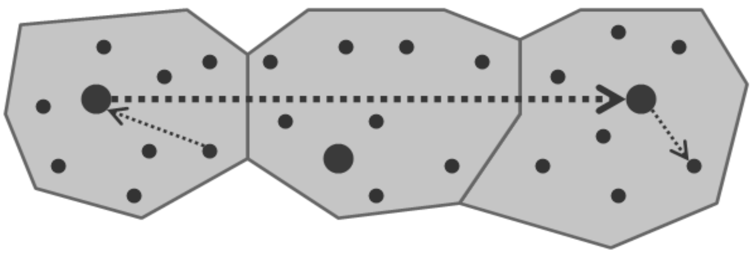

Figure 2: Simple location.

Fitness function:

$$\min \sum_i \sum_j b_{ij} \left(\sum_k c_{ik} h_{ik} + \sum_k \sum_l \alpha c_{kl} h_{ik} h_{jl} + \sum_k c_{il} h_{jl} \right) + \sum_k h_{kk} f_k \tag{12}$$

$$\sum_k h_{kk} = p \, , \; \sum_k h_{ik} \qquad \forall_i \in V$$

$$h_{ik} \le h_{kk} \quad \forall_i, k \in V \quad h_{ik} \in \{0,1\}$$

b_{ij} – transportation volume

c_{ik} – pick-up costs

αc_{kl} – transportation costs between hubs

c_{lj} – delivery costs

$\sum h_{kk} f_k$ - costs of building depots

Multiple location – objects can be assigned to attraction zones of several hubs

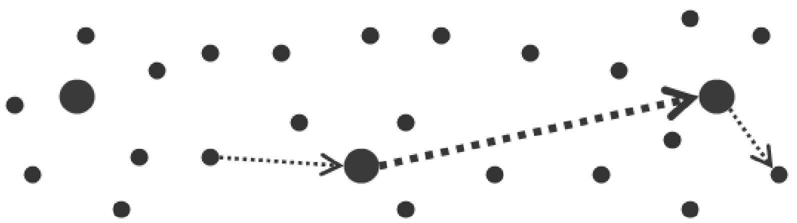

Figure 3: Multiple location.

- partial elimination of shipments in opposite directions
- pick-up (delivery) for a given point is not always performed by the same hub, the choice of the two hubs depends on the specific relation *i, j*

Fitness function:

$$\min \sum_i \sum_j \sum_k \sum_l b_{ij} (c_{ik} + \alpha c_{kl} + c_{lj}) X_{ijkl} + \sum_k h_{kk} f_k \tag{13}$$

b_{ij} – transportation volume

c_{ik} – pick-up costs

αc_{kl} – transportation costs between hubs

c_{lj} – delivery costs

$\sum h_{kk} f_k$ - costs of building depots

Solution using genetic algorithm

- encoding the problem's solution – chromosome
- creating the initial population
- selecting individuals for reproduction (selection)
- reproduction – crossing, mutation => new generation
- repeating iterations according to the requirements of the problem

Instance of a specific problem:

Find the optimal distribution of hubs on the network, where the number of a network's vertices is $n = 4$, the number of located hubs is $k = 2$, $\alpha=0.6$, C is the matrix of costs for unit shipments and B is the matrix of the quantities transported between individual vertices. This is a simple location, where the objects served are firmly assigned to one of the hubs.

$$B = \begin{pmatrix} 0 & 1 & 2 & 2 \\ 1 & 0 & 4 & 5 \\ 6 & 1 & 0 & 3 \\ 3 & 2 & 1 & 0 \end{pmatrix} \qquad C = \begin{pmatrix} 0 & 5 & 2 & 3 \\ 5 & 0 & 3 & 2 \\ 2 & 3 & 0 & 1 \\ 3 & 2 & 1 & 0 \end{pmatrix}$$

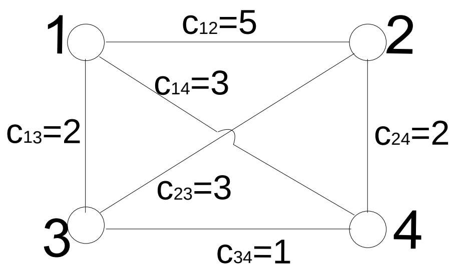

Figure 4: Graphical representation of the situation.

Options of encoding the problem's solution – chromosome

1) *n* parts each having 2 segments:
- is the given node a hub? (1-yes, 0-no)
- is the node assigned to its nearest hub? (0-yes, 1-no)

for example: (00|10|01|10) – hubs at vertices 2, 4; 1st in the attraction zone of the nearest hub, 4th in the attraction zone of the farthest hub.
(the specific network must be known)

2) n-component vector divided into 2 parts
- hubs – the length *k*, directly written numbers of hubs
- assignment of other vertices to hubs

for example: (24|21) – hubs at the vertices 2, 4; vertex 1 assigned to the 2nd hub in the order listed (i.e. to hub 4); vertex 3 assigned to the 1st hub in the order listed (i.e. to hub 2).

Encoding of the solution according to 1)

- Example encoding of one solution:
  k = 1, 2; A (1)={1,3}; A (2)={2,4}
- Solution: (10|10|00|00), hubs at the vertices 1, 2
  d(3,1)<d(3,2)   d(4,2)<d(4,1)

Calculation of the fitness function

- according to the equation: (12) without costs for building the depot

example: (10|10|00|00), A (1) = {1,3}, A (2) = {2,4}, the sum of all shipments between *i* and *j*; $i, j \in \{1,2,3,4\}$

1. pick-up – non-zero for *i = 3, 4* => shipments 3-1; 3-2; 3-4; 4-1; 4-2; 4-3

2. shipment – non-zero: 1-2; 1-4; 2-1; 2-3; 3-2; 3-4; 4-1; 4-3

3. delivery – non-zero for *j = 3, 4* => shipments 1-3; 1-4; 2-3; 2-4; 3-2; 3-4

Table 2: Calculation of the fitness function of an individual.

hubs	**1**	**2**				
ass. vert's	1, 3	2, 4				
i, j	pick-up	shipment	delivery	total	b_{ij}	value
1 – 2	0	3	0	3	1	3
1 – 3	0	0	2	2	2	4
1 – 4	0	3	2	5	2	10
2 – 1	0	3	0	3	1	3
2 – 3	0	3	2	5	4	20
2 – 4	0	0	2	2	5	10
3 – 1	2	0	0	2	6	12
3 – 2	2	3	0	5	1	5
3 – 4	2	3	2	7	3	21
4 – 1	2	3	0	5	3	15
4 – 2	2	0	0	2	2	4
4 – 3	2	3	2	7	1	7
Total						**114**

The value of the fitness function of an individual is 114.

Initial population – 8 randomly selected individuals.

Table 3: Initial population.

number	configuration of the individual	fitness value
1	(10|10|00|00)	114,0
2	(00|10|10|01)	90,8
3	(01|01|10|10)	99,6
4	(10|00|00|10)	72,0
5	(10|10|01|01)	146,0
6	(00|10|00|10)	78,8
7	(10|00|10|00)	78,0
8	(10|01|00|10)	132,0

Selection – selection of individuals for reproduction using weighted roulette.

- the problem of genetic algorithms is that they work with a utility maximisation function, therefore we convert the utility fci is according to the equation

$$f_i = 1 + \frac{F_i - avg}{best - worst} \qquad (14)$$

F_i – the value of fitness function for the given solution
avg – average fitness value fce in the generation
best – the best fitness value fce in the generation
worst – the worst fitness value fce in the generation

- probability of the individual passing into the next generation according to the equation

$$P_i = \frac{f_i}{\sum_{i=1}^{n} f_i} \qquad (15)$$

Table 4: Selection.

number	configuration of the individual	fitness value F_i	converted fitness f_i	probability of passing P_i
1	(10|10|00|00)	114.0	0.830	10.4 %
2	(00|10|10|01)	90.8	1.143	14.3 %
3	(01|01|10|10)	99.6	1.024	12.8 %
4	(10|00|00|10)	72.0	1.397	17.5 %
5	(10|10|01|01)	146.0	0.397	5.0 %
6	(00|10|00|10)	78.8	1.305	16.3 %
7	(10|00|10|00)	78.0	1.316	16.5 %
8	(10|01|00|10)	132.0	0.586	7.3 %
Φ		101.4	1.000	

Using weighted roulette, the following pass into the next generation : f_4, f_2, f_6, f_3, f_7, f_1, f_4, f_8

Reproduction – Crossing

- creation of a combination of the genetic material of 2 individuals with the hope of gaining a better individual
- algorithm:

  1. browse the genetic code of individuals from right to left and look for the position *i* at which the 1st individual in the 1st gene segment has 1 and the second has 0. If found, replace the entire genes of both individuals at the position
  2. concurrently browse the genetic code of individuals from left to right and search for the position *j*, at which the 1st individual in the 1st gene segment has 0 and the other has 1. If you find it, replace the entire genes of both individuals at the position.
- both processes run until achieving $j \geq i$

Probability of crossing: $p_c = 0{,}75$, genes *f3´* and *f4´* proceed without crossing

Table 5: Crossing.

	original	**result of the crossing**
f1´=f4	(10|00|00|01)	(10|10|00|01)
f2´=f2	(00|10|10|01)	(00|00|10|10)
f3´=f6	(00|10|00|10)	(00|10|00|10)
f4´=f3	(01|01|10|10)	(01|01|10|10)
f5´=f7	(10|00|10|00)	(10|10|00|00)
f6´=f1	(10|10|00|00)	(10|00|10|00)
f7´=f4	(10|00|00|10)	(10|00|00|10)
f8´=f8	(10|01|00|10)	(10|01|00|10)

Reproduction – mutation

- operator's purpose: to produce as yet unexplored or lost genetic material
- prevents premature convergence to a local optimum
- alteration of both segments with low probability
  - 1st segment: 2 substitutions in the generation (pm1 = 2/(8*4) = 6.3%)
  - 2nd segment: 1 change in the generation (pm2 = 1/16= 6.3%)
- in the case of the mutation of the 1st segment it is necessary to keep in mind the given number *k*, and, in the case of the 2nd segment, the occurrence of the nonsense positions of the type (…|11|…)
- mutation of the 1st segment
  - 6th individual – substitution of the 1st position for the 2nd
  - (10|00|10|00) → (**0**0|**1**0|10|00)
  - 5th individual – substitution of the 1st position for the 4th
  - (10|10|00|00) → (**0**0|10|00|**1**0)

- mutation of the 2nd segment
  - 3rd individual – substitution at the 3rd position
  - (00|10|00|10) → (00|10|0**1**|10)

The minimum of the function utility value after the first iteration is **67.6**; this corresponds to the minimum of the 2nd and 3rd iteration and also to the result of the exact solution.

Optimal solution: hubs at vertices 3 and 4. Vertex 1 is served from hub 3, and vertex 2 from hub 4.

Table 6: Mutation, result of the first iteration.

	genetic code	**fitness value**
f1	(10|10|00|01)	118.0
f2	(00|00|10|10)	67.6
f3	(00|10|01|10)	121.2
f4	(01|01|10|10)	99.6
f5	(00|10|00|10)	78.8
f6	(00|10|10|00)	71.2
f7	(10|00|00|10)	72.0
f8	(10|01|00|10)	132.0

3 CONCLUSION

Discrete optimization problems can generally be solved in different ways, ranging from exact, through simple heuristic methods, to metaheuristics. Simple heuristic methods, however, do not provide any guarantee of achieving an optimal solution, nor even an admissible solution. In general they are characterized by passing from one admissible or inadmissible solution to the next one, and by a local criterion with the help of which the resulting solution is selected from a set of possible subsequent solutions. Metaheuristics are heuristic approaches that under certain circumstances make it possible to depart from a local minimum, and, through a sequence of iterative steps, move into other parts of the set of admissible solutions where there is hope of finding a solution with a better objective function value than that of the local minimum. As with other heuristic methods, metaheuristics do not guarantee finding an optimal solution to the problem. The metaheuristic shown above using genetic algorithms does not create a sequence of solutions, but works concurrently with an entire set of solutions called a population. The work of a genetic algorithm begins with the creation of an initial population, the genes are then paired and crossed on the basis of benefit coefficients, and the newly-created individuals are mutated. Selection is made in the newly-created population, the best solution yet found is updated, and the whole process is repeated until either of the conditions for ending the optimization process is satisfied.

ACKNOWLEDGEMENT

This contribution is supported by MSM6840770043. The research was supported by the Czech Technical University, Faculty of Transport Science, Department of Logistic and Transportation Processes and by the EU - project FOCUS.

REFERENCES

Janáček, J., 2002. *Optimalizace na dopravních sítích*. Žilina: Žilinská universita v Žilině. ISBN 80-8070-031-1. (in Czech)

Janoš, V., Baudyš, K., Vichta, F., 2006. Financing the Public Transport in the Sphere of Regulated Competion. In *Proceedings Conference Euro Traffic 2006*. Praha (Czech Republic): ABF, a.s. ISBN 80-86905-15-2.

Lánská, M., 2006. Costs in Bus Transportation. In *Aktuálně problem v podnikání v cestnej doprave*. Žilina: Technical University of Žilina. ISBN 80-8070-610-7.

Campbell, A. M., Lowe, T. J., Zhang, L., 2005. The p-hub center allocation problem. *European Journal of Operational Research*. ISSN 0377-2217.

Distraction of Drivers: Causes, Effects, Prevention

J. Šmolíková *
Faculty of Transportation, Czech Technical University, Prague, Czech Republic
**Corresponding author: smolikova@fd.cvut.cz*

J. Hoskovec & J. Štikar
Department of Psychology, Charles University, Prague, Czech Republic

DOI: 10.148/v10158-012-0010-7

ABSTRACT: This paper concerns definitions, theory, causes, effects, and prevention of driver distraction. Internal and external stimulation on driver attention are analyzed. The simulation of driving is compared with driving under real conditions. The characteristics of older, as well as younger, drivers are given. The perspectives of preventive measures are presented from a technical, cognitive, and behavioural point of view.

KEY WORDS: distraction of drivers, preventive measures for accidents.

At present demands on a driver's attention are growing significantly, which is what brought us to selectively process new information regarding the causes and effects of so-called driver distraction, and to provide a theoretical, or possibly a model basis, for research along with its application (Štikar, Hoskovec & Šmolíková, 2010). For a long time, attention has stood at the forefront of the characteristics of drivers' mental activity during driving (Bena, Hoskovec & Štikar, 1962 and 1968, 2nd ed.).

Traditionally when we speak about distraction, we realize that often this refers to an unsuitable distribution of attention, or attention that is unsuitably focused. From a certain point of view, distraction in traffic can be understood as drawing attention away from activities that are important for safe driving (Regan, Lee & Young, 2009).

Attention can be distracted as a result of the driver's subjective condition, due to external stimuli, by other activities, such as telephoning, communication with passengers, and by thoughts that do not concern driving, as well as others. We call these secondary activities. During an analysis of 100 accidents or near-accidents in relation to secondary activities during driving, Dingus et al. (2006) determined the order in which individual activities are distracting among 241 drivers. The most distracting was found to be information from various devices and manipulation with other passengers, distraction caused by external stimuli outside of the vehicle, talking to oneself or singing, personal hygiene, daydreaming, and smoking. Attention must be related especially to perceptual processes (central and peripheral). Attention can fail during central vision, when the object can be visually perceived, but the brain is not aware of it. Attention can fail during peripheral vision due to insufficient or inflexible searching.

1 THEORETICAL APPROACH

Driver distraction causes many accidents; the concept of selective attention is essential for important theoretical constructs of cognitive ergonomics, including situational awareness and workload. It is necessary to provide a framework for uniting expert approaches, which will show the direction for future research and implications for interventions proposed for lowering the number of accidents. Fundamental features and findings are summarized, which illustrate the key principles. Enns and Trick (2006) divide the topic into three parts: the first one presents two global dimensions that serve as the basis for this framework; the second describes the framework and summarizes four ways of choosing information; the third part deals with practical effects for accident prevention.

Selective attention is considered to be indispensable, because our surroundings consist of too many objects to be perceived in one moment and to which we can react. At present, however, basic research lacks a general theory on selective attention. Instead, there are closely focused theories related to specific activities, for example visual searching, filtering, carrying out several activities at once (dual tasking), and watching several objects. Varying performance during these activities reflects the presence of two elementary dimensions of selection on the basis of focusing attention.

The first dimension deals with awareness and includes the differentiation between automatic and controlled processes. Specifically there are two ways in which the selective process can function. First mode: stimuli and reactions can be selected without awareness. Selection without awareness has been described by various authors as pre-attentive, subconscious, and unintentional. Regardless of these terms, this type of selection is automatic. Automatic selection is quick, it does not require any effort, it is subconscious, and as soon as the process begins, it is difficult to stop it or alter it. These processes are triggered by the presence of certain stimuli in our surroundings and they run till the end without interrupting any other processes. Second mode: Stimuli and reactions can be selected on purpose, with awareness. Selection with awareness (variously called attentive, conscious, or deliberate) includes controlled processing, which indicates that this form of selection is rather demanding and slow. However, it is possible to start it wilfully, or to stop it or alter it, which is a feature that makes this type of processing flexible. Controlled processes can cause changes in long-term memory through learning, and with proper practice some types of controlled processes can even become automatic. The fundamental problem of controlled processing lies in the fact that it is demanding to perform several controlled processes at once. Distinguishing between automatic and controlled processing is often discussed as if there were a strict dichotomy. Enns and Trick (2006) think that it is probably more useful to consider them as a continuum. Some processes are more automatic than others in the sense that they commence more quickly, they require less effort, they are more likely evoked unintentionally in the given situation, and therefore it is more difficult to get them under intentional control.

The second dimension deals with the origin of the attention process, whether it is given at birth and thus common to all people (exogenous), or whether it was created due to the specific aims of an individual (endogenous). Exogenous selection arises from human biological nature. The nervous system is structured in a way that allows it to react preferentially to some stimuli; hence there exists an innate continuum of significance of stimuli, with some types of stimuli becoming the object of exogenous selection with a greater possibility than others. On the other hand, endogenous selection arises from our knowledge of our surroundings and from what people wish to achieve. It is specific to each situation. People actively seek out information in their surroundings that is relevant for their specific goals or intentions, and they perform these acts in ways that are in compliance with their expectations and previous learning. These expectations may function as a kind of "perceptual set", which causes people to search for specific objects in specific places. Lim et al. (2004) describe a model of driver's visual attention which gathers information on the basis of selective processes so that it would be possible to model effects such as distraction. This model includes the ability to gather visual information, and the mechanisms of visual attention, on the basis of subjective and objective factors. Due to the fact that the research was focused on its practical application, the model was designed so that it could be integrated as a component processor within a computer traffic simulation. The model determines visual attention with the help of two mechanisms: internal and external focusing. The mechanism for internal focusing is a proactive attention regulator. This subjectively founded mechanism moves the head and eyes in a general direction so that relevant information for the given task is actively sought out on the basis of the driver's expectations. Mechanism of external focusing is a reactive attention regulator founded on the basis of the characteristics of objects in the driver's field of vision. External control allows for the modelling of distraction, because irrelevant information may objectively require more attention than relevant information. These two controlling mechanisms determine the attention demand value (ADV) of each visible object. Therefore, we receive visual information from the object with the highest ADV. ADV also plays its role in determining the time needed for processing information and the amount of attention that is reserved for driving. By using this model and the possibility of various internal and external input variables, it is possible to simulate various types of drivers with different visual abilities (for example, in relation to age or intoxication) in an environment full of detailed visual information.

2 A REVIEW OF ATTENTION DISTRACTION IN DRIVERS

Young, Regan, and Hammer (2003) provide a complex review of research results concerning the distraction of driver's attention coming from the vehicle's interior. They examine the effect of technology (e.g., mobile telephones and navigation systems) and nontechnical distractions (e.g., food consumption, smoking, and talking to other passengers) on driving performance, and they deal with the relative effect that these distracting elements have on driving. It is estimated that about one quarter of car accidents in the United States are caused by drivers' inattention or distraction. Results from research (Ho & Spence, 2008) lead to an overview concerning mobile telephones, navigation systems, e-mail and internet devices, entertainment devices, and nontechnical distraction. In brief, there is consistent evidence that attention distraction caused by technology and other stimuli may have a negative influence on a driver's performance. The degree to which distraction threatens safety is, nonetheless, dependent on the frequency with which the driver is subjected to the given distraction, and on specific driving conditions.

Electronic systems are even used in the form of external billboards. In their report, Farbry et al. (2001) present a summary of research findings regarding the possible safety consequences of electronic billboards during driving. The review covers the period between the publishing of a similar text in 1980 up to the year 2000. Gaps in our knowledge were identified on the basis of literature research, and sets of research questions and related research findings were put together on their basis. Research questions are categorised into road characteristics, e.g., turns, crossings, and work zones; billboard features, such as the length of time that a picture is displayed, movement, and the readability of the advertisement; characteristics of drivers, e.g., knowledge of the area and age. It also includes related findings from research carried out on the readability of information boards regarding various types of traffic information.

3 RESEARCH IN REAL AND SIMULATED CONDITIONS

Apart from the review of research results regarding driver distraction caused by technology or other stimuli coming from the interior of the vehicle, Young, Regan, and Hammer (2003) examined various methods used to measure the distraction of drivers and to measure driving performance (e.g., keeping to one's traffic lane), which seems to be easily influenced by various types of distractions. The following scientific methods for measuring attention distraction were identified: research studies on roads and test routes, research studies carried out on driving simulators, studies on dual tasks, studies monitoring where eyes are focused, visual method for verifying when eyes are taken off the road, and the detection of peripheral impulses.

The outcome of this review shows that rather than using just one method, it is suitable to use a set of methods for measuring attention distraction when evaluating the proposed concepts of devices in relation to human machine interface (HMI) and prototypes of vehicles. The technology applied or the selected sets of methods will depend on the specific aspects of HMI, which are to be evaluated, and especially as regards the form of distraction that distracts the driver's attention within the given interface. Conducting research on roads is more dangerous and it is less experimentally controlled than studies conducted on simulators.

Studies carried out in real conditions allowed experts to create a model of drivers' behaviour during rear-end crashes, which was based on attention (Brown, Lee & McGehee, 2000).

The research of Reimer et al. (2007) is an example of a study conducted on a simulator. They examined the participation of adult drivers with Attention Deficit Hyperactivity Disorder (ADHD) in traffic accidents and of control group drivers in a simulated experiment, which was designed to increase the effects of tiredness. Due to the fact that symptoms of ADHD include problems with maintaining attention, it was assumed that drivers with ADHD would be more prone to the effects of tiredness during driving. The data was received from a validated study of driving simulation, and its parts were focused on the increased effect of fatigue. The data received from the simulator were supplemented by written data received from questionnaires. Drivers with ADHD were compared with the control group. Results indicate that drivers with ADHD get tired more quickly than drivers from the control group. These drivers then face a higher risk of car accidents on highways or on roads with an open view, where the visual monotonousness of the environment and routine tasks contribute to the greater tiredness of drivers.

Another example of attention research carried out on simulators is a study by Benoit et al. (2008). They propose developing a driving simulator that would take into consideration information regarding the user's state of mind (concentration of attention, states of tiredness or stress). The analysis of the user's state of mind is based on data from a video and on physiological parameters.

Nakayasu et al. (2007) researched how drivers perceive information regarding danger in selected traffic situations. The relationship between visual attention and the extent of the useful visual field was examined by measuring eye movement during simulated driving.

4 CATEGORIES OF CLASSIFICATION

Diverse schemes of classification are created in different countries (Gordon, 2005). When we speak about distraction, experts have a tendency to describe the character of distraction according to four types, which include various sources and modes of sensory perception (e.g., Young, Regan & Hammer, 2003). These four types are:
Visual distraction: source of distraction and/or the form of attention are related to sight;
Auditory distraction: source of distraction and/or the form of attention are related hearing;

Physical distraction: the driver performs physical movements, which typically means taking one or both hands off the steering wheel, the manipulation of something.
Cognitive distraction or mental diversion of attention: source of distraction and/or form of attention are related to cognitive processes, e.g., being "absorbed" by something or by some mental activity.

Let us add *emotional distraction* to these four as the fifth type. Behaviour connected with distraction usually includes several sources and ways of distraction. Picking up a mobile phone for example (reaction to an auditory signal, picking up and manipulating the phone, conversing or reading, and consequently hanging up and returning the telephone to its place) can include all types during the whole process. However, it is important to note that distraction is not only about information overload and opposing requirements, but it also includes the limits of human perception and the failure of controlling processes, such as feedback, planning, and predicting "events" (Lee, 2005).

An important difference between a source of cognitive distraction and other sources of distraction seems to be the amount of time that the given behaviour lasts. For example, various types of behaviour that distract attention, such as moving an object from one place to another, changing a CD/ radio station, are very isolated activities and are limited by time and also by the given task. Other distracting behaviours, such as conversing with a fellow passenger or smoking, may last a long time and take up a large part of the journey. If someone gets into a car after an argument or is stressed and is thinking about the day that has passed, it is possible to say that this person is cognitively inattentive and distracted, and it is better to describe attention distraction as a "state" we can find ourselves during our journey. The definition of distraction by Regan (2005) is apparently able to include cognitive distraction as, for example, being preoccupied by a certain thought, since such distractions can be considered to be secondary activities which can last throughout the whole journey; these are focused on the driver and certainly can disrupt performance of the primary task, which is driving.

5 DRIVERS´ AGE

Tuttle et al. (2009) compared the attention of older and younger drivers. Groups of younger drivers (N = 49, average age = 21.7 years) and older drivers (N = 52, average age = 73.0 years) performed cognitive tests and driving simulation. Results from cognitive tests were subjected to Principal Component Analysis (PCA), out of which 6 components arose: speed, divided attention, sustained attention, executive attention, selective attention, and visual search. Scores for individual components were used for anticipating performance during simulated driving. Results showed that speed and divided attention explain the differences in driving performance with a greater probability.

Mourant et al. (2001) used a task, during which it was necessary to distribute attention, in order to measure younger and older drivers' ability to obtain information from a display placed in a vehicle. Performance when using a display in the vehicle was compared with performance when information was transferred onto a driving scene image on simulator. Older drivers were less exact when receiving information from the display inside the vehicle, the average position error in a driving lane was higher among older drivers and older drivers spent more time driving outside of their lane. These results indicate that using displays inside cars in their current configuration is not suitable for older drivers. When following information transferred onto a driving scene, older drivers were much more exact and had better control of their cars. This fact shows that the low performance of older drivers when using displays inside cars is caused more by changes in vision, e.g., a longer period is needed for the eye to adapt, than by cognitive processes.

Visual attention and behaviour during driving among older people was monitored by Richardson and Marottoli (2003). Their research study was designed with the aim to specify those cognitive variables that are connected to the specific behaviour of drivers on roads in a sample of active drivers older than 72 years. The driving score significantly correlated with the performance tests of visual attention and visual memory. Visual attention, which is a cognitive function that includes searching, selection, and switching, plays an important role in the risk related to older drivers. Visual attention is mostly connected to key driving manoeuvres, which include interaction with other vehicles/pedestrians, e.g., giving right of way and safely making a turn in the traffic. Specification of cognitive risk factors, as well as their effect on problematic driving manoeuvres, may give us a lead for the development of targeted interventions to lower the risk in older adults.

6 PREVENTION

Due to the fact that the factors supporting the occurrence of distraction are, for example, tiredness or the consumption of alcohol, research focused on the development of tools that would detect these factors as well. Regan, Lee and Young (2009) give a whole set of techniques to proceed against distraction. Many proposals are engineering-psychological, that is the adaptation of interior and exterior devices that provide information. These authors even focus on alerting drivers when they do not realize their state of distraction. Some automobile producers especially, such as Saab (Nabo, 2009), are trying to develop and apply this kind of technology.

Loss of control occurs when the driver diverts his/her attention from driving, if only for a couple of seconds. In order to drive safely, it is necessary to continuously pay attention to driving. At the same time, it is well known that people easily divert their attention or even become sleepy when driving.

Other intelligent transportation systems are also being developed which should help drivers and which should secure a safe environment on the roads. One approach to designing ergonomic automobile systems is to incorporate our understanding of human systems for processing information into the process of designing. It is necessary to support the designing of ergonomic interfaces that include several senses by using research from the fast-growing field of cognitive neuroscience. These focus mainly on two aspects of information processing among drivers: interaction that includes several senses and the special distribution of attention during driving (Ho & Spence, 2008).

A review of international standards and the design of devices for vehicles that can influence attention is given in the 7th part of the Regan, Lee and Young (2009) publication. Data received from the European Union are compared with data from the USA and Japan.

Research conducted in the form of group discussions gives certain indications of how drivers consider questions concerning driver distractions and other strategies which they think could be used to lower possible risks. In connection with the research on the effect of distraction on driving and on the limits of human attention this research indicates that drivers can realize only some of the problems comprised in this topic. It is necessary to conduct further research focused on the monitoring of drivers' behaviour inside the vehicle.

Research conducted in the form of group discussions indicates that the public partially understand how distraction influences driving, and people presume that they are capable of performing a lot of these activities as a regular part of driving. Taking into account the aforesaid, providing information about how distraction works and about the risks of various distracting behaviour could at least increase awareness, and it would be possible to give advice and instructions for applicable behavioural solutions, e.g., in programmes for driver training. For example, some types of distraction could be prevented by better planning, i.e., by securing objects on seats before driving. With other distractions, it is possible to use a behavioural strategy in which people should be encouraged to change their habits and behaviour, which can include a combination of practice, training, and programmes for raising awareness, and/or stimuli coming from the surrounding environment (e.g., legislation or enforcement).

When training drivers, it is important to repeatedly emphasize that many distractions are related to events/objects outside the vehicle, such as landscape and other people, and that there are many distractions coming from inside the vehicle, such as objects brought by the driver with him/her into the car, that have nothing to do with technology. Moreover, we bring technical devices into the vehicle, e.g., telecommunication devices, portable computers, or entertainment devices, which were not developed with the intention of being used during driving. If we add other tasks to our elementary driving task, the complexity increases and this may sometimes catch us off guard. The less secondary tasks there are, the better.

A significant factor that influences distraction is so-called self-regulation. We recognize strategic self-regulation, e.g., not using a mobile phone when driving, or operational self-regulation (lowering our speed).

Training and educational programmes exist that support attentive driving. As part of these programmes, it is also possible to make use of results from experimental research (Metz, 2009) on improving attention performance in more demanding situations, e.g., when driving through complex intersections.

Mills (2010) promotes an approach called disciplined attention. This approach has one goal – to lower the number of car accidents. The course develops safe driving styles. Disciplined attention is a new term used in training drivers. It starts with visual and cognitive demands placed on drivers at all levels of experience, from beginners to experienced professionals. The course of disciplined attention draws information from modern science, as well as from top driving school instructors.

REFERENCES

Bena, E., Hoskovec, J., Štikar, J., 1962, 1968, 2. vyd. *Psychologie a fyziologie řidiče*. Praha: Nadas. (in Czech)

Benoit, A. et al., 2008. *Multimodal focus attention detection in an augmented driver simulator, Personal and Ubiquitous Computing* [online]. Retrieved from: www.enterface.net

Brown, T. L., Lee, J. D., McGehee, D.V., 2000. *Attention-based model of driver performance in rear-end collisions: Annual Meeting of the Transportation Research Board No. 79.* Washington, D.C.: INIST-CNRS.

Dingus, T. et al., 2006. *The 100 – car naturalistic driving study, Phase II: Results of the 100 – car field experiment*, Report DOT HS 810-593. Washington, D.C.: National Highway Traffic Safety Administration.

Enns, J. T., Trick, L. M., 2006. Driving and selective attention: Four modes of selection. In Bialystok, E., Craik, I. M. (Eds.). *Lifespan cognition: mechanisms of change, Chap. 4*, Oxford: Oxford University Press.

Farbry, J., et al., 2001. *Research review of potential safety effects of electronic billboards on driver attention and distraction: Final Report*, September 11. Washington, D.C.: Office of Safety Research and Development, Federal Highway Administration.

Gordon, C., 2005. *Driver distraction: An initial examination of the „attention diverted by“ contributory factor codes from cash reports and focus group research on perceived risks.* Paper presented at the September 2005 IPENZ Conference in New Zealand.

Ho, C., Spence, Ch., 2008. *The Multisensory Driver*: *Implications for Ergonomic Car Interface Design*. London: Ashgate. 158 p. ISBN 978-0-7546-7068-1.

Lee, J. D., 2005. *Driver distraction: Breakdown of a multi-level control process*. Paper presented at the Driver distraction conference, 2-3 June, Sydney.

Lim, C., et al., 2004. A driver visual attention model, Part 1. Conceptual framework. *Canadian Journal of Civil Engineering*, vol. 31, no. 3, pp. 463-472.

Metz, B., 2009. *Worauf achtet der Fahrer? Steuerung der Aufmerksamkeit beim Fahren mit visuellen Nebenaufgaben, Dissertation*, Würzburg, J.- M.- Universität.

Mills, K. C., 2010. *The disciplined attention driver education program* [online]. Chapel Hill, NC (USA): Profile Press. Retrieved from: http://alertdriver.com

Mourant, R. R. et al., 2001. *Measuring divided-attention capability of young and older drivers, Transportation Research Record No. 1779*. Washington, D.C.: Transportation Research Board.

Nabo, A., 2009. *Driver attention – dealing with drowsiness and distraction*, Saab Automobile AB report.

Nakayashu, H. et al., 2007. Measurement of visual attention and useful field of view during driving tasks using a driving simulator. In *Proceedings of the 2007 Mid-Continent Transportation Research Symposium*. Ames (USA): Iowa State University.

Pradhan, A. et al., 2009. Attention maintenance in novice drivers: Assessment and training. In *Proceedings of the fifth international driving symposium on Human factors in driver assessment, training and vehicle design*. Iowa City, IA (USA): University of Iowa.

Regan, M., 2005. *Driver distraction: Reflections on the past, present and future*. Paper presented at the Driver distraction conference, 2-3 June, Sydney.

Regan, M. A., Lee, J. D., Young, K. L., 2009. *Driver distraction. Theory, effects and mitigation.* Boca Raton, FL (USA): CRC Press.

Reimer, B. et al., 2007. Task-induced fatigue and collisions in adult drivers with attention deficit hyperactivity disorder. *Traffic Injury Prevention*, vol. 8, no. 3, pp. 290-299.

Richardson, E. D., Marottoli, R. A., 2003. Visual attention and driving behaviors among community- living older persons. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, vol. 58, no. 9, pp. 832-836.

Štikar, J., Hoskovec, J., Šmolíková, J., 2010. Nepozornost řidiče. In *Zborník Transport Psychology – Trends, Medzinárodná vedecká konferencia z dopravnej psychológie*. Bratislava: CZU, pp. 114 – 124. (in Czech)

Tuttle, S. et al., 2009. Attention function structure of older and younger adult drivers. In *Proceedings of the fifth international driving symposium on Human factors in driver assessment, training and vehicle design*. Iowa City, IA (ISA): University of Iowa.

Young, K., Regan, M., Hammer, M., 2003. *Driver distraction: A review of the literature, Report 206*. Melbourne (Australia): Monash University Accident Research Centre.

Experimental Research on the Parameters of Electric Vehicles

R. Čech*, P. Tomčík, J. Kulhánek, R. Trojan
Department of Vehicle Materials and Technologies, Faculty of Metallurgy and Material Engineering, VŠB -TU of Ostrava, Czech republic
** Corresponding author: radim.cech@vsb.cz*

DOI: 10.2478/v10158-012-0011-6

ABSTRACT: This paper describes the methodology and measured results obtained by monitoring the drive and electric vehicle management. It describes an application for recording functional values during the operation of The StudentCar Electric developed by the Department of Vehicle Materials and Technologies. The end of the article is devoted to the comparison of measured and generally available data.

KEY WORDS: electromobility, electric vehicle, BMS.

1 INTRODUCTION

Electrical power has become one of the most important parts of our everyday life. Most people take it for granted, but they do not associate it with their personal vehicles. They travel by trams, underground, trolley buses, and trains, while their cars are diesel or gasoline powered. The reason for this is twofold. Firstly, diesel fuel was cheaper and more accessible than electrical power at the turn of the 19th and 20th centuries. Secondly, the battery capacity was low at that time. The trend has continued for over 100 years, up to the present time. The tendency to reduce gas emissions from fossil fuels started in the 80s. This manifested itself as an increase in indirect expenses for making combustion more efficient. Even so, the efficiency of today's internal combustion engines does not exceed 35% (Macur, 2011).

We dare say that we have reached a time when the mass use of electromobility is starting to be introduced into transportation. We are unsure why the development in electromobility is escalating so rapidly at the moment. There are clearly more factors influencing this development, for example the pervasive requirement to be eco-friendly, the decreasing supply of fossil fuels, the lobbying of the automotive industry and power engineering, the progressive development of battery technology or mass media pressure. The present time clearly favours electromobility development. The aim is to convince as many people as possible that we are going in the right direction.

2 DVMT ACTIVITIES OF SCIENCE & RESEARCH

Thanks to this new trend, the Department of Vehicle Materials and Technologies at the Technical University of Ostrava (hereinafter “DVMT”) has engaged in activities aimed at increasing its qualification in the area of electromobility research and development.

2.1 EkoCar Project

UPTAT initiated its electromobility technology development with the pilot project EkoCar CZ.1.07/1.1.07/11.0109. As part of this project, the electric automobile StudentCar Electric was created (Figure 1). This electric car features several different approaches to electromobility.

Figure 1: StudentCar Electric.

StudentCar Electric was designed as a two-seater roadster with acceleration to 100 km/h in 8 seconds, and a top speed electronically limited to 150 km/h. The range of the vehicle is 180 – 260 km, depending on the driving style. The car includes batteries with a total capacity of 27 kWh and a nominal voltage of 270 V. The water-cooled asynchronous motor (Figure 2) has a maximum power output of 77 kW, torque of 190 Nm, and a frequency of rotation 12,000 r/min.

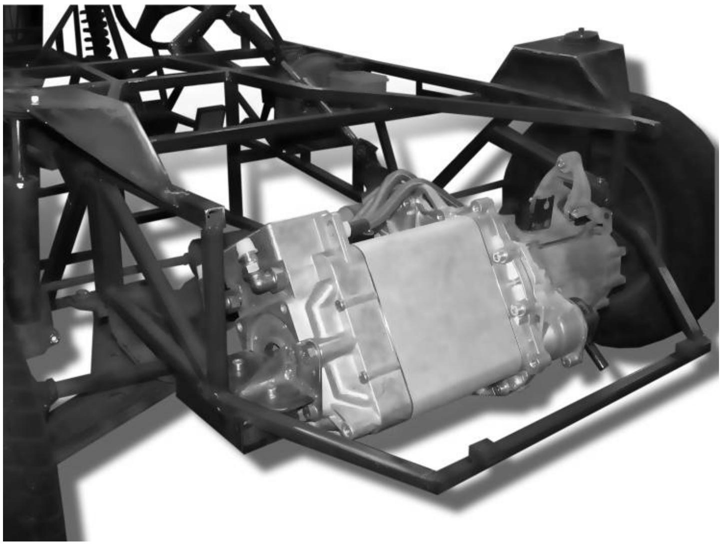

Figure 2: Asynchronous water-cooled 3f motor Siemens.

Through StudentCar Electric we wanted to demonstrate that even an electric car can meet the ambitions of a sports car. The possibility of placing individual components arbitrarily on the chassis allowed us to deliver an optimal balance of the axle and lower the vehicle's centre of gravity as low as possible to the road (Figure 3). This would be more difficult with a common car converted to an electric one.

Figure 3: Illustration of how components are balanced on StudentCar Electric.

We managed to keep the vehicle's weight under 850 kg even with a battery weight of 300 kg. The total weight of the vehicle is a very important factor in designing electric cars. It positively effects both consumption and range, but also vehicle characteristics, such as acceleration, top speed, and braking distance. Making the vehicle lighter is undeniably the right step, which leads to reducing the environmental burden of transport. The vehicle's weight is directly dependent on its comfort and safety. Today's modern cars must meet strict standards in both passive and active safety. Safety features increase the weight of a car by an average of 200 kg, and comfort features, such as damping and servomotor, a further 300 kg. This is evident, for example, in the weight difference of 405 kg between the first and fifth generations of VW Golf, the most common car in the EU (Plichta, 2008). It is important to develop alternative materials and seek ways to reduce the weight of car components.

2.2 Research of Materials for Electric Vehicles

DVMT studied alternative materials for the manufacture of functional and electrical insulation parts of the electric car. The materials were tested for breakdown field strength. Based on the newly acquired information, we are now able to choose better construction materials from the perspective of balancing electrical and mechanical properties (Čech, Buřval & Klaus, 2011).

2.3 Use in Education

StudentCar Electric was designed also to be used in teaching to demonstrate individual design groups and functions of the electric car (Figure 4).

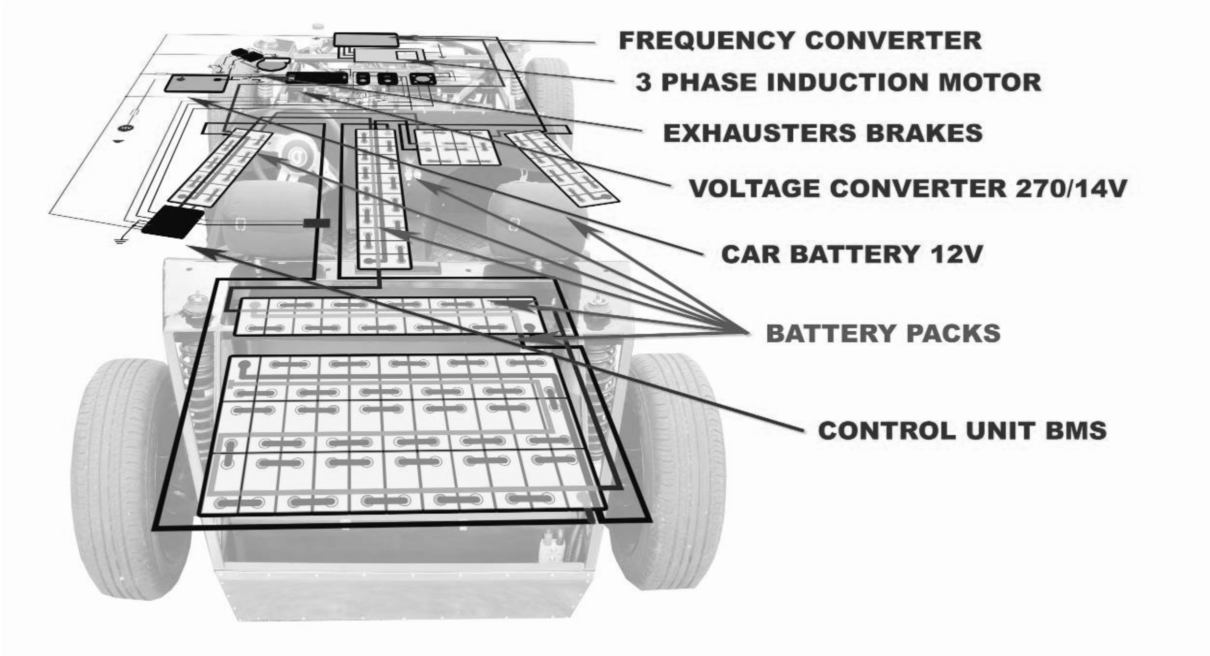

Figure 4: Components placement - StudentCar Electric.

To store energy, LiFeYPo4 traction batteries (Figure 5) were used, which are characterised particularly by a high current density. Among the advantages of these batteries are compact design, low weight, high capacity, high current values, and very low self-discharge. The downside of the batteries is the need for the use of electronic protection for the individual cells when charging and discharging. Values specified by the manufacturer must not be exceeded, else cells could be damaged. Such damage is usually irreversible, therefore when charging the batteries, parameters must be checked in real time.

Figure 5: Battery cell LiFeYPo4 ThunderSky.

The project instigated teaching platforms to map the individual systems of the electric car. One of the platforms deals with the electronic control of the cells and the control and management of the modern traction batteries. This system is called BMS (Battery Management System). Figure 6 shows a block diagram of this system.

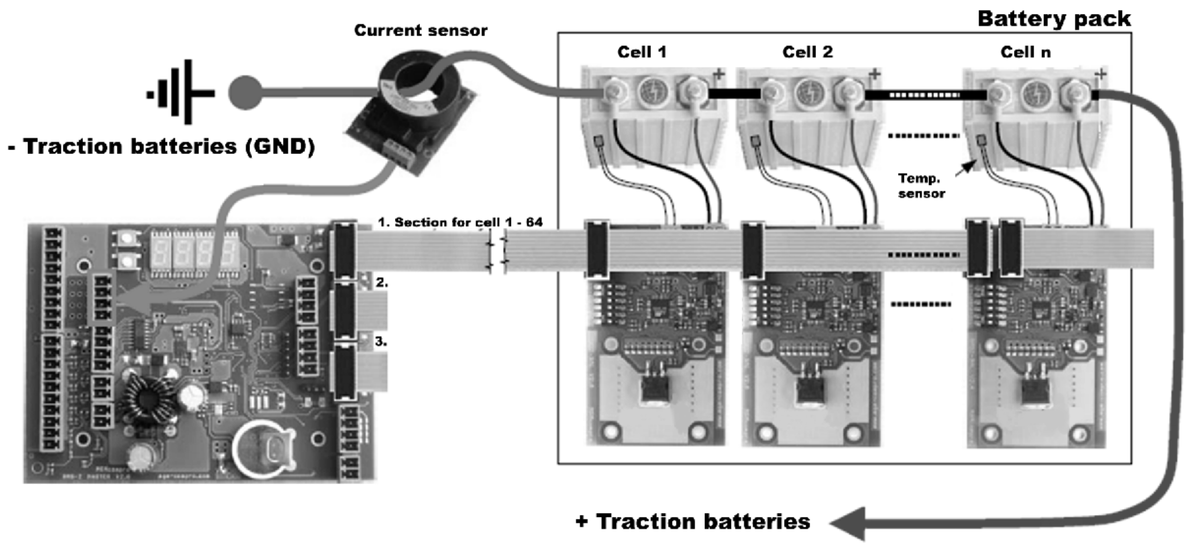

Figure 6: Battery management system.

Another training block deals with monitoring the recovery and discharge using software developed at DVMT. The software is called Controller Monitor (Figure 7) and processes the main parameters of the electric car's operation. This allows the creation of a time map of discharge, charging, and position of the accelerator, as well as the temperature of the components (e.g., traction motor) in normal operation.

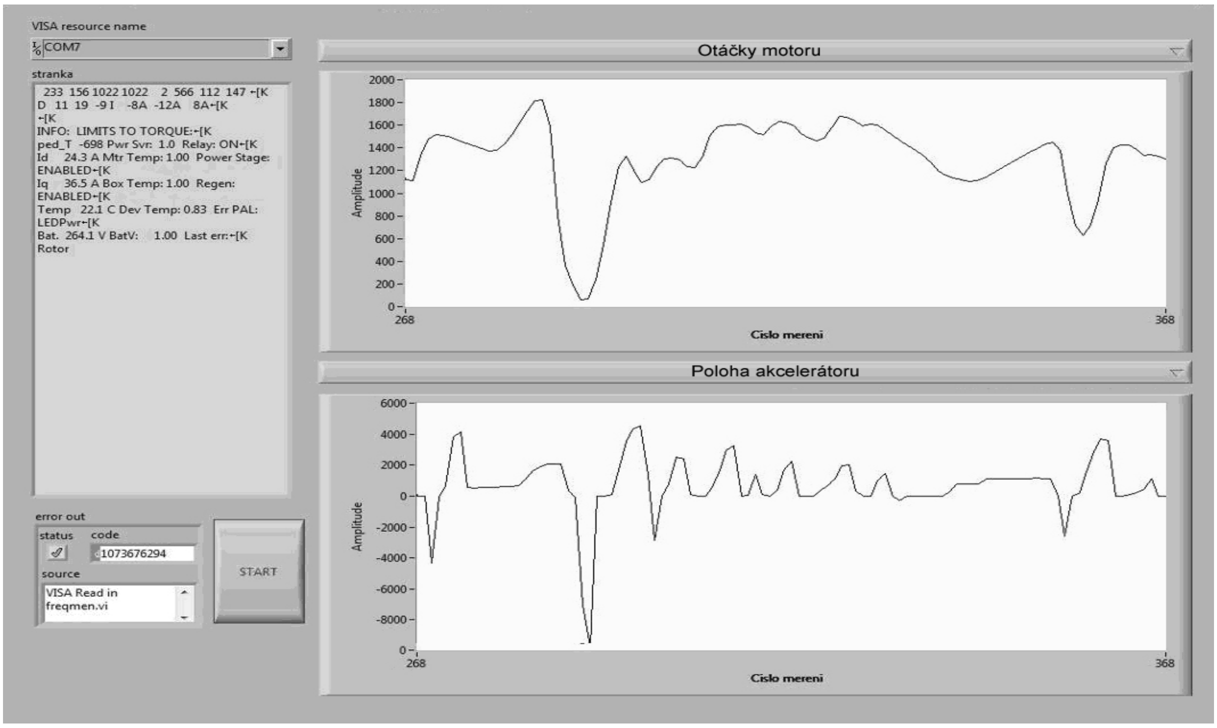

Figure 7: Controller Monitor Software.

Through a comparison of data measured by the software, we verified the mutual relations of the measured quantities. Figures 8 and 9 illustrate how the accelerator's position depends on the current, speed, voltage, and time. These values are measured in real time in the StudentCar Electric using Controller Monitor. In the first graph (Figure 8), we can see that the position of the accelerator (thin line) is directly dependent on the current waveform (thick line). In addition, we notice an immediate response of the current to the accelerator's instruction. The current then creates proportional torque in the motor. The response of the accelerator to torque in the motor is virtually instantaneous. This is positively reflected in the operational flexibility of the car. With modern cars, the fast response of the throttle is, by contrast, partially suppressed. The start of the torque is deliberately slowed down to avoid an increase in emissions due to the rapid acceleration of the combustion engine.

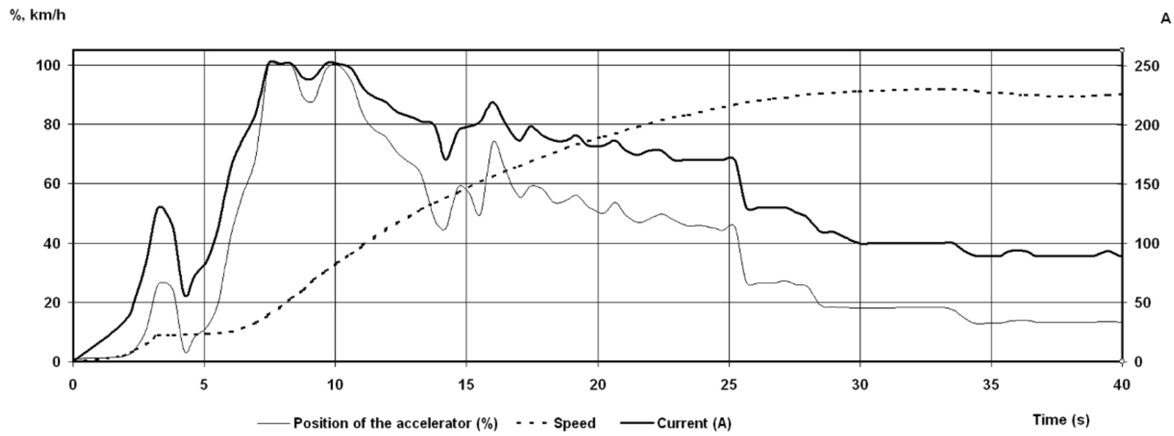

Figure 8: Electric operating values.

The second graph (Figure 9) shows the mutual relationship between the current (thick line) and voltage (thin line). At the beginning, in the range of 0-5 seconds, it is obvious that the battery acts as a hard source. Short-term stress is followed by a sharp drop in voltage, which corresponds to the discharge characteristics of these battery types.

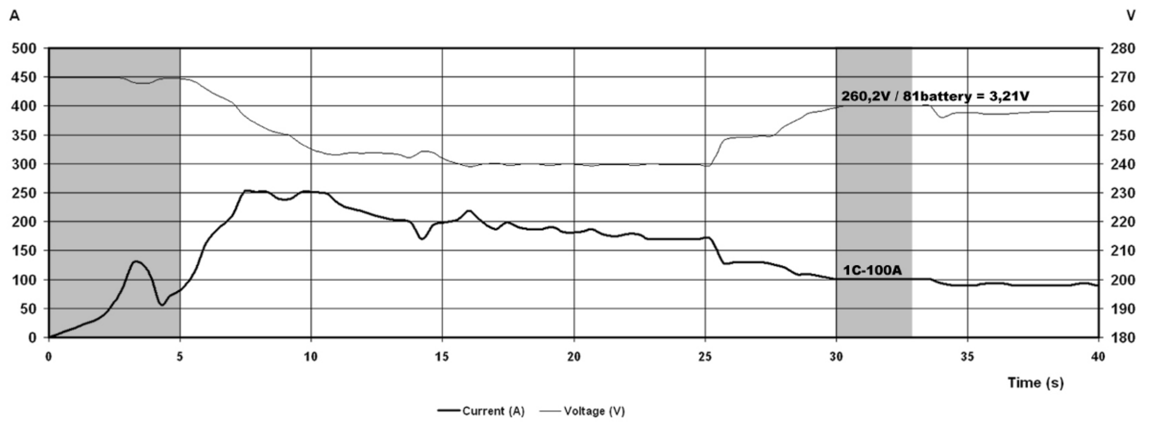

Figure 9: Comparison of voltage and current.

If we focus on the specific voltage decrease with the current of 1C (100A), which is visible on the graph (over 30 seconds), the value is 260.2 V. If we calculate the total pack voltage for a single cell, i.e. 260.2 / 81 = 3.21 V, we obtain a value which corresponds to the discharge characteristics shown in Figure 10 (manufacturer's parameters) (ThunderSky, 2007). The cell‘s voltage, with Discharge Capacity ranging from 0 to 60 % in this graph, is at about the same level. Through this analysis, we verified the correct function and behaviour of the battery under load, as well as the accuracy of the measurement through Controller Monitor. The manufacturer’s graph shows a sharp drop in voltage with a Discharge Capacity of 100 %. The battery is not used anymore at this level. Voltage below the allowed limit of 2.8 V leads to irreversible changes, which have a negative effect on the subsequent capacity and current load of the cell.

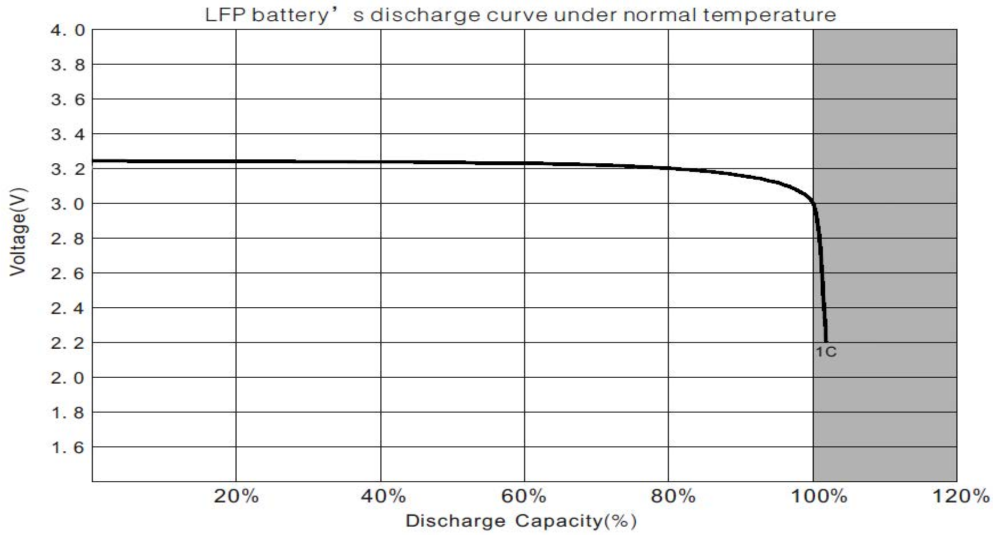

Figure 10: ThunderSky LFP battery discharge curve (ThunderSky, 2007).

Another measuring device developed by DVMT as part of the ExperimentalCar CZ.1.07/2.2.00/07.0060 project measures the dynamic and static acceleration in three mutually perpendicular axes. Figure 11. shows a scan of the program analysing vibration on the vehicle. The program measures acceleration in real time and enables signal filtering, as well as the frequency analysis of the measured values. At the same time, it is able to save the measured data for further processing.

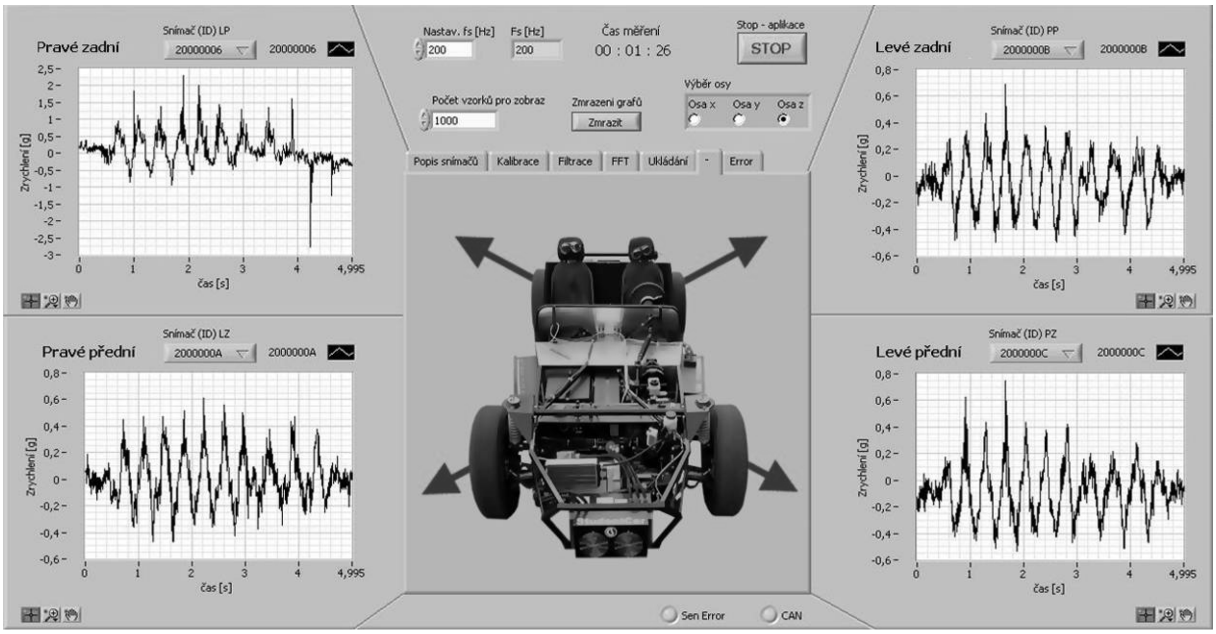

Figure 11: Vibration analyser.

3 RESULTS AND DISCUSSION

The above mentioned measurement possibilities and achievements enabled a complex mapping of the electric car‘s operating conditions. As a result, we can better develop scientific and developmental activities in the area of the functional units’ optimisation. Diverse measurement options also significantly speed up the development of electromobility and vehicle construction.

Based on the measurements, we obtained the data and parameters necessary for a detailed simulation of the boundary conditions of a partial construction point. The data mainly concerns the acceleration of the wheels (axle) and the load on the respective frame parts. We use this information as input data, and, based on this information, we derive boundary conditions for the given type of construction. The subsequent simulation is carried out in the SIMPACK and ANSYS programs. This significantly enhances the quality, as well as the faster and cheaper development, of each new prototype created at DVMT.

The results of the operating quantities measurement using the Controller Monitor program influenced the subsequent dimensioning of batteries with regard to the range and performance of the electric car. Information about the electric car’s consumption at different loads was particularly useful.

These advanced activities created conditions for a new project, under which DVMT is developing a totally unique type of an electric car.

The above mentioned activities of DVMT constitute only a small part of the institute‘s portfolio. They map the institute‘s rapid development over the past two years.

The results were achieved thanks to the financial support provided for the project CZ.1.07/1.1.07/11.0109.

REFERENCES

Čech, R., Buřval, L., Klaus, P., 2011. Measuring the Electric Strength of Board Composite Materials and Insulators. *Transactions on transport science,* vol. 4, no. 1, pp. 19-24. ISSN 1802-971X.

Macur, J., 2011. *Alternativní pohony v dopravě: Technická, ekologická a sociální analýza* [online]. Asociace elektromobilového průmyslu. [cit. 2011-11-03]. Retrieved from: www.elektromobily.org/w/images/6/66/AltPohVDopr.ppt (in Czech)

Plichta, V., 2008. Bohatší vybavení automobilů působí proti redukci jejich hmotnosti. *Technik* [online]. [cit. 2011-11-03]. Retrieved from: http://technik.ihned.cz/c1-28859510-bohatsi-vybaveni-automobilu-pusobi-proti-redukci-jejich-hmotnosti (in Czech)

ThunderSky, 2007. ThunderSky: Lithium Battery [online]. [cit. 2011-11-11]. Retrieved from: http://www.everspring.net/TS-LFP100AHA.pdf

A Strategic Approach to the Transformation of Czech Highway Administration

K. Pospíšil*, D. Mečiarová
CDV – Transport Research Centre
**Corresponding author: karel.pospisil@cdv.cz*

A. Hanzelková, M. Keřkovský
B.I.B.S., a.s. (Brno International Business School)

DOI: 10.2478/v10158-012-0012-5

ABSTRACT: Studies of the current condition of management in the Czech Republic show, that strategic management is one of the greatest weaknesses in the management of Czech businesses when compared with their western competitors. The intended transformation of the Czech highway administration from the existing state allowance organisation to a company with a new legal status is an excellent opportunity to design a strategically oriented and well-organised body which will be capable to be effective in strategic development, investment, maintenance, and operation of the managed highway network. At the Brno International Business School considerable attention has been paid to studying strategic business management over the last ten years. It supports the effort of the CDV – Transport Research Centre to achieve a holistic approach to the strategic development of the transportation sector. The paper describes a possible way for drafting a strategy concept for transforming the highway administration.

1 INTRODUCTION

The existing situation concerning the management and funding of the transport infrastructure is currently unsatisfactory. The major task in this area is carried out by the Road and Motorway Directorate of the Czech Republic (ŘSD) – the highway administration, which still has the legal status of a state allowance organization. It is a body responsible for investment, construction, modernisation, maintenance, and reconstruction of the motorways and primary rural roads in the Czech Republic.

The legal status of a state allowance organization is currently considered unfavourable particularly in the following areas:

a) insufficient flexibility,
b) labour legislation limitations,
c) impossibility to deduct VAT,
d) financial limits.

Ad a) Insufficient flexibility is given by the existing legal status of the allowance organization. At the moment, the highway administration is managed by a general director directly appointed by the minister of transport. The activities of the organization are funded by an allowance provided by the State Fund for Transport Infrastructure (SFDI) on a contractual basis from the state budget of the Czech Republic, international institutions' funds, and other financial sources.

Ad b) At the moment, the remuneration system is based on a governmental grades system which is not able to be motivating enough. A change in legal status from the existing state organization will allow it to adopt its own tailored remuneration motivating system.
Furthermore, the legal status change could lead to depoliticization and a release from the relationships with the Ministry of Transport, which is based upon the fact that the organizational structure of a joint stock company is, according to Commercial Code, far better in reflecting the needs for these types of activities.

Ad c) In the case of the highway administration becoming a full VAT payee, all construction costs would be reduced by the current VAT rate, which the highway administration may claim.

Ad d) This area includes the much simpler possibility to issue bonds to provide funds for individual projects lacking public funds, project loans, and co-operation with the private sector, and the possibility to be more flexible in the support of individual projects.
Due to the above mentioned problems, which are currently having a negative impact on ŘSD, the currently considered transition of ŘSD as a state allowance organization to an entity with a different legal status will definitely be a positive step towards the new funding of the transport infrastructure in the Czech Republic.

2 SENSE OF STRATEGY

There are several models for designing the strategy of a company. These models use the notion "strategy" either as a way of achieving the intended target, e.g. Kotler (1984), Johnson and Scholes (1993) etc., or as a long-time plan, as described by Dobson and Starkey (1993).

A wider understanding of strategy is presented by Nickols (2000). He states that there are at least three basic forms of strategy in the business world, such as: (1) strategy or "strategy in general," (2) corporate strategy and (3) competitive strategy. The relationship between the above-mentioned forms of strategy is shown in Figure 1.

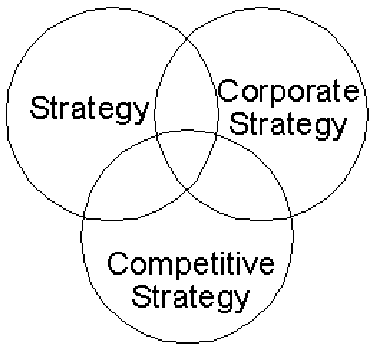

Figure 1: Three Forms of Strategy (Nickols, 2000).

Nickols (2000) highlights that there are many definitions of strategy found in management literature which fall into one of four categories: plan, pattern, position, and perspective.

According to these views, strategy is:

- A plan, "how" means of getting from here to there;
- A pattern in actions over time; for example, a company that regularly markets very expensive products is using a "high end" strategy;

- A position, i.e., it reflects the decisions to offer particular products or services in particular markets; and
- A perspective, i.e., a vision and direction, a view of what the company or organization is to become.

Nickols summarises accordingly with of Porter (1996) that strategy in general is concerned with the how, with the courses of action intended to achieve particular objectives. Corporate strategy is concerned with the choices and commitments regarding markets, business, and the very nature of the company itself. Competitive strategy is concerned with competitors and the basis of competition. These basic points are illustrated in Figure 2.

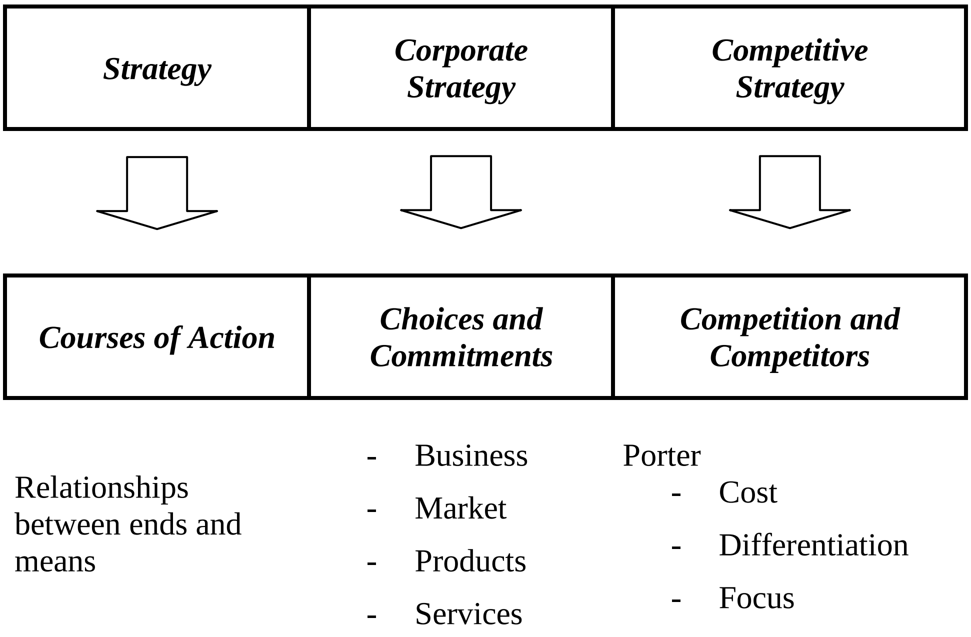

Figure 2: Focal Points of Strategy (Nickols, 2000).

The introduced approach to strategy formulation uses the Keřkovský and Vykypěl (2006) concept of stratifying strategy into three-level-model of strategies:

- corporate strategy,
- business strategy,
- functional strategy.

3 USED METHODS

3.1 Hierarchy of Company Strategies

As shown at the end of the introductory part, the model selected operates with three levels of strategies in a company. The structure and main characteristics of these are visible in Figure 3.

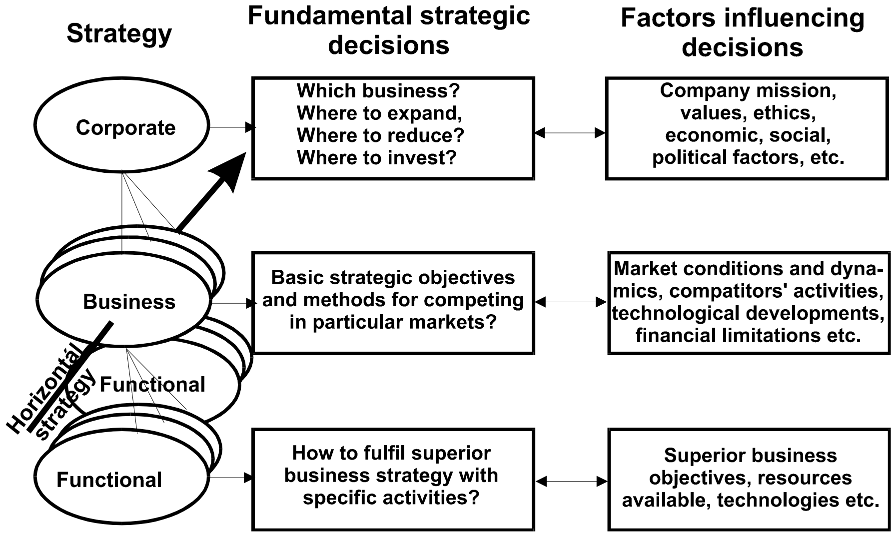

Figure 3: Strategy hierarchy – the concept applied in the research described in this paper Keřkovský and Vykypěl (2006).

3.1.1 Corporate strategy

Corporate strategy transforms the mission and vision of the company into basic business decisions and goals, such as in which country and industry to start or continue a business, how to allocate disposable resources, what should be the basic ideas for business management or which of the existing business plans should be preferred. Using Keřkovský and Vykypěl (2006) the corporate strategy can be taken into account as an elaboration of the company's vision and mission in the following three steps:

1. Strategic Business Units [1)] definition;
2. Designation of the basic strategic targets to the particular SBUs; and
3. Achievement ways specification of designated targets of particular SBUs.

3.1.2 Business strategy

Business strategy expresses basic strategic objectives and ways of realising them for a particular SBU. An SBU can be basically defined on the basis of:

1. Organisational approach: Definition of an SBU fits with the existing or proposed organisational structure of the company.
2. Strategic and market approach: In this case one organisational unit can have more than one SBU, i.e., more than one business strategy, or one SBU and its strategy affects more than one organisational unit. The first option can be applied, for example, if the specific type of production or service has specific types of customers with specific needs. The second option can be applied, for example, in the production or service delivery which is a task of the follow-up organisational units.
3. Project oriented: A more flexible variation of the previous approach having a temporary validity due to a limited project duration.
4. Combination of described approaches.

---

[1]) Strategic Business Unit - SBU - is defined by specifying a group of customers and their needs the company or sector intends to satisfy, together with the production technologies used to this end, Kotler (1984) – discussed at the specific chapter.

There are several indicators if an SBU has been defined properly:

- Are there specific customers or competitors for a specific area of operation?
- Can specific, different, non-overlapping, and non-competing goals and objectives be defined for designated SBUs?
- Can a specific SBU be cancelled without the necessity of specification changing of others?

3.1.3 Functional strategy

For each business strategy or for several business strategies commonly, functional strategies for specific areas should be defined to support and specify it in each field of strategic management. Functional strategy should follow business strategy at a lower level of the hierarchy and set out strategic goals for specific areas in the company in R&D, quality management system, marketing, HRM, IS/IT, production, and so on. The basic function of this strategy is to ensure the development of strategically important parts of the business in accordance with the company's overall strategic development.

3.2 Employed methods of analyses

Corporate, business, and functional strategies should be formulated on the basis of in-depth analyses; the structure of these is displayed in table 1.

Table 1: Table of kinds of employed analyse in the dissertation.

Analysis		***Selected Kind of Analyse***	***Output***	***Overall Output***
External Factors	***General***	SLEPT / MAP	ETOP	SWOT
	Branch	Porter's Five Forces model		
Internal Factors		7 S or 7 P	SAP	
Stakeholders		Analyse of stakeholders	SWOT	

3.2.1 General external factors SLEPT

Acronym SLEPT means analysis of Social, Legal, Economy, Politics, Technology factors, see diagram in Figure 4.

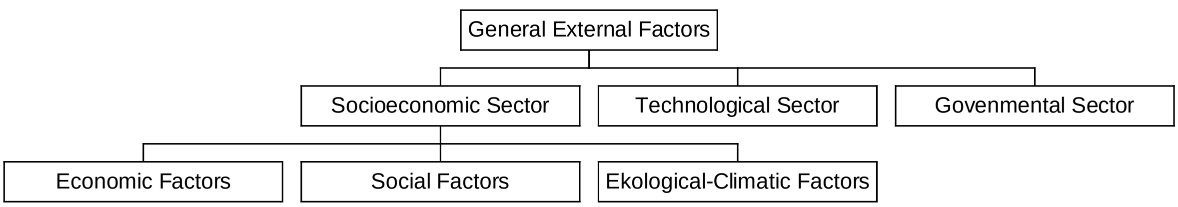

Figure 4: External General Factors (Keřkovský and Vykypěl, 2006).

3.2.2 Branch external factors analysis using Porter's Five Forces model

Porter's Five Forces model, Porter (1985), concentrates analysis of the branch external factors into five groups of forces influencing the behaviour of a company operating in a specific area, i.e.:

- Threat of new competition
- Threat of substitute products or services
- Bargaining power of customers (buyers, users)
- Bargaining power of suppliers
- Intensity of competitive rivalry

As can be seen, only two of Porter's forces are relevant in the case of the highway administration, due to it not having any competitor, substitute, and competitive rivalry. Customer force is employed through stakeholders because customers, i.e., road users can be very powerful stakeholders. The remaining powers, i.e., Suppliers' power, should be deeply analysed.

3.2.3 ETOP as an output of analyses of external factors

ETOP (Environmental Threat and Opportunity Profile) is understood as a method for summarising external environment analyses. The results of SLEPT and Porter's analysis are expressed through Opportunities and Threats.

3.2.4 Analysis of internal factors

As an ETOP summarizes external environment analyses, SAP (Strategic Advantages Profile) can serve as a summarisation of internal factors analyses. SAP closely relates with the method used for the analyses.

McKinsey's 7 S method of analyse, e.g., according to Rasiel and Friga (2001); The 7 S framework of McKinsey is a Value Based Management (VBM) model that describes how one can holistically and effectively organize a company. The model consists of the following elements:

- Shared Values – the interconnecting centre of McKinsey's model; what does the organisation stands for and what does it believe in. Central beliefs and attitudes;
- Strategy; Plans for the allocation of the firm's scarce resources, over time, to reach the identified goals. Environment, competition, customers;
- Structure; The way the organization's units relate to each other: centralized, functional divisions (top-down); decentralized (the trend in larger organizations); matrix, network, holding, etc.;
- Systems; The procedures, processes and routines that characterize how important work is to be done: financial systems; hiring, promotion, and performance appraisal systems; information systems;
- Staff; Numbers and types of personnel within the organization;
- Style; Cultural style of the organization and how key managers behave in achieving the organization's goals. Management Styles; and
- Skills; Distinctive capabilities of personnel or of the organization as a whole. Core Competences. Well-known.

Besides the 7 S McKinsey model the Marketing Mix Model (MMM) in its extended version can be used as analytic tool for an SAP drafting. The extended MMM, as with the 7 S model, consists of seven components summarising an internal environment, i.e.:

1P – Product
2P – Price
3P – Place
4P – Promotion
5P – People
6P – Process
7P – Planning

Figure 5: 7P Marketing Mix Model (Keřkovský and Vykypěl, 2006).

If MMM is used as a tool for SAP creation, i.e., for the analysis of a company's internal environment, it results in a company Strengths and Weaknesses definition.

3.2.5 Analysis of stakeholders

Analysis of key stakeholders can be done through interviews, meetings, and negotiations with them. It is very sensitive in the case of the highway administration transformation, as the administration works with large amounts of public money, and its operation is subject of public concern, including politicians.

3.2.6 Summary of analyses as a starting point of strategy formulation

A summary of analyses carried out can be expressed using a SWOT table, where the analyses of stakeholders, and internal and external factors should be evaluated by their importance. For a strategy formulation it should be known that "each" Strength could be employed, Weaknesses eliminated, Opportunities drawn on, and for Threats remedial measures could be adopted. In a defined case the strategy should be balanced and fit the real environment of the company.

4 POSSIBLE APPLICATION OF THE DESCRIBED MODEL

4.1 Vision and mission

The vision and mission of the transformed highway administration should be seen as being wider than that of the case of a private company. They have to give answers to crucial and highly important questions and should be drafted after an in-depth discussion with all powerful stakeholders and analyses of their impact. Questions should include the following:

- Which legal status will the transformed organisation have, i.e., state public enterprise or joint stock company?
- Will the transformation be carried out using a special act – *lex specialis*, which can define the specific parameters and behaviour of the transformed organisation?

- Will the transformed highway administration include motorways only or first-class roads as well?
- Will lands, pavements, and structures be the property of the transformed organisation or will it have rights for only the management of them?
- Will it be possible to pawn lands, pavements, and structures?

All answers on the above drafted questions are “input parameters” to the corporate strategy and their subordinated business and functional strategies. The input parameters create a foundation for the operation of the future highway administration and have to consulted and verified by all core stakeholders, mainly the representatives of all relevant political parties.

Figure 6 displays the hierarchies of the three-level understanding of strategies and necessary analyses for their formulation.

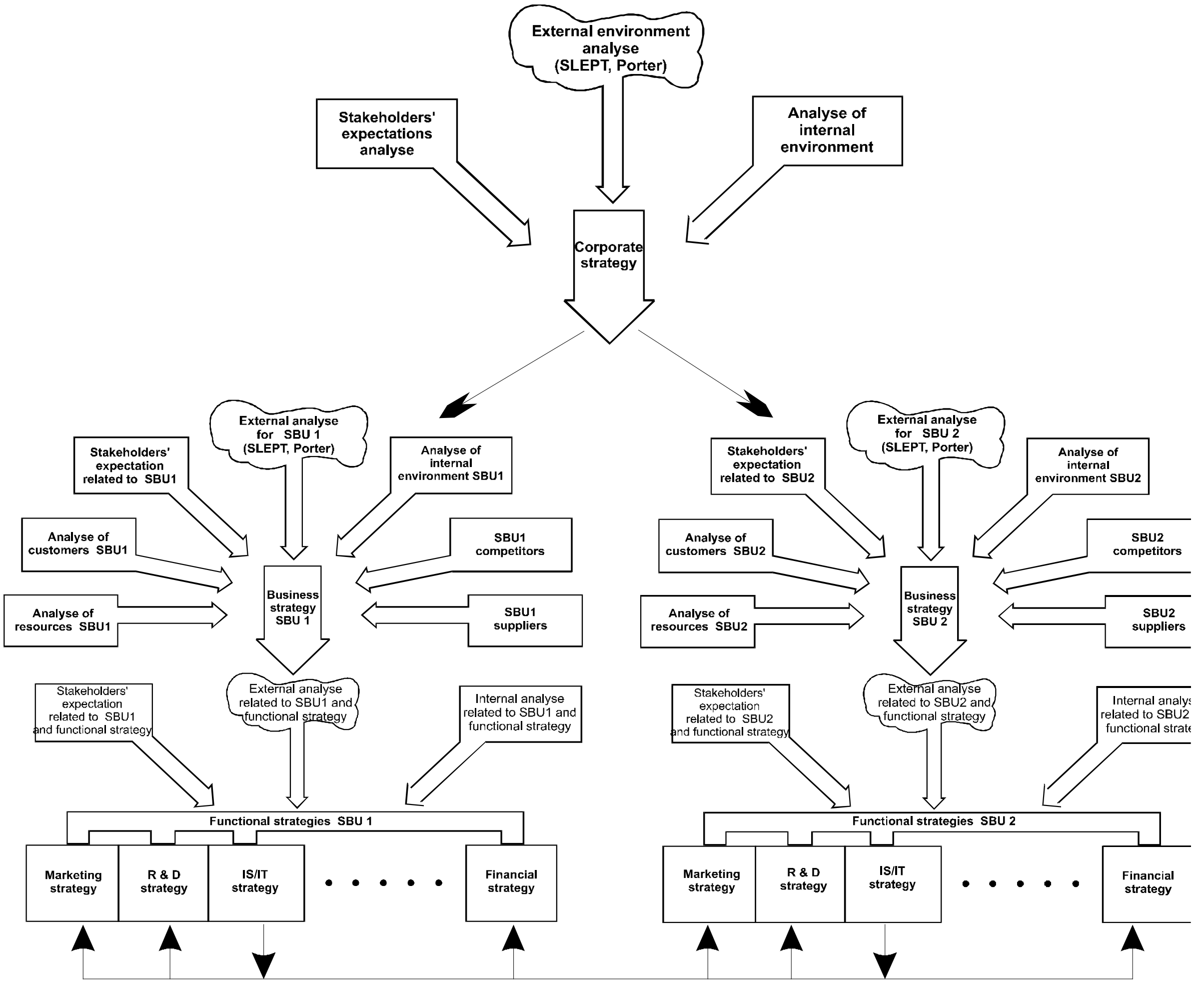

Figure 6: Strategy hierarchies and analyses needed for their formulation (Keřkovský and Vykypěl, 2006).

4.2 Corporate strategy

When the above-mentioned input parameters have been stated, the analyses necessary for the corporate strategy can start. As explained in 3.1.1, the corporate strategy should consist of three components:

- A Strategic Business Units definition which can fit e.g.:
    - either types of operation of the highway administration, i.e.:
        - SBU 1: Construction
        - SBU 2: Maintenance
        - SBU 3: Winter maintenance
        - SBU 4: Financing (toll collection, bonds...)

      Note: If the transformed highway administration covers both motorways and first-class roads, the above drafted structure should be doubled.
    - or methods of operation of the highway administration, i.e.:
        - SBU 1: Preparation of construction
        - SBU 2: Contracting (selection procedures, agreements...)
        - SBU 3: Supervision (construction works, completion certificates, evaluation in warranty period)
        - SBU 4: Maintenance planning (based on Pavement and Bridge Management Systems)
        - SBU 5: Maintenance performing– in-house
        - SBU 6: Maintenance performing– outsourcing (contracting and supervision)
        - SBU 7: Winter maintenance performing– in-house
        - SBU 8: Winter Maintenance performing– outsourcing (contracting and supervision)
        - SBU 9: Toll collection
        - SBU 10: Other financial sources (bonds, loans, subsidies)
        - etc.
- Designation of the basic strategic targets to the particular SBUs, e.g.:
    - Number of kilometres of new motorways...
    - Level of maintained network quality expressed exactly in...
    - Costs of construction works…

  Note: Each of the designated targets has to be defined through SMART[2].
- Achievement methods specification of designated targets of particular SBUs; in the case of the highway administration this could be:
    - definition of financing sources,
    - definition of limits,
    - etc.

[2] SMART is an acronym of Specific, Measurable, Ambitious, Realistic and Time-fixed

4.3 Business Strategy

Each SBU has to have its own business strategy. For its formulation analyses can be carried out as described in part 3.2 of this paper. These analyses mostly cannot be elaborated without the support of experts in specific areas, i.e., civil engineers, ITS experts, economic experts, lawyers, etc.

4.4 Functional strategy

In effect a functional strategy describes the "how to do it" area. As a corporate strategy states how, for example, toll collection will be carried out, a functional strategy should state, on the basis of in-depth analyses, how much money will be added to the budget of the highway administration or, for example, R&D will be performed through external bodies, a functional strategy should state how R&D programs or projects will be formulated, financed, evaluated and their results utilized.

Modern concepts of traffic management are widely supported with intelligent transport systems (ITS). The goal is especially to optimize the movement of vehicles to be smooth and "wring out" hidden highway capacity. The development of ITS is strongly influenced by highway structural parameters, driver behavioural patterns, budget possibilities, and technological development, (for example, in sensors, ways of data collection and its interpretation and delivering to users etc.). All the above-mentioned should be taken into account in the formulation of ITS and relating strategies.

An ITS strategy can be formulated as either a business strategy or functional strategy. This depends on the sense of importance and understanding. The following text assumes the ITS strategy to be a functional strategy supporting the majority of business strategies of a highway administration.

Due to the above-mentioned, an ITS strategy could be seen as a paradigmatic strategy concerning its significance. ITS have a potential of being an opportunity for the transportation sector – a strategic asset, a tool for collecting strategic information regarding highway network development, a tool for raising its effectiveness, quality, flexibility and environmentally friendly impact (Pípa and Plíhal, 2009). Paradoxically, due to the extremely rapid technological progress, the traditional weaknesses of management, where the use of ITS is concerned, are becoming more and more evident. These are especially:

- Improper use of ITS, lack of long-term approach to making decisions about ITS development in the full context of strategic management;
- Poor communication with experts;
- Failure to involve users, failure to exploit the opportunities/potential to the full;
- Insufficient attention to "human factors".

It is also important that ITS are managed effectively at all levels of management – the strategic, the tactical, and the operational. There are research and implementation documents targeting the ITS architecture, i.e., Jesty et al. (1998) composed guidelines for the development and assessment of ITS architectures, Ferro et al. (2004), Ortgiese and Escher (2004), Angebaudand and Escher (2005) and Escher and Grammling (2005) published their contributions to specific components of telematic system.

There are several key research documents in the Czech Republic aimed towards ITS in the Czech Republic, i.e., Svítek et al. (2005), which describe the achievements of the R&D project awarded by the Czech Ministry of Transportation, and Moos and Přibyl (2008) elaborated on comprehensive guidelines for a systematic approach for the application of transport-telematic projects. The guidelines describe the best-practice in the design of the above-mentioned systems architecture and tools for architecture creation and are very useful tools for any ITS project elaboration. Pípa et al. (2009) dealt with the relationship between highway design and ITS in an R&D project of the Ministry of Transport.

The above cited documents take the ITS challenges from both systemic and technical points of view. Strategic management can affect them either positively or negatively, as well as tactical and operational management.

5 CONCLUSION

The introduced concept of strategic management discussed in the paper is the result of research based on a confrontation of the study of fundamental literature on strategic management and an experience of the practice of strategic management and the functionality of the Czech transport sector. The transformation of ŘSD, the highway administration, is a fundamental act which could have a very promising impact on the functionality and effectiveness of the highway administration. A presumption of a positive opportunity of the highway administration’s legal status change is its substantial preparation supported by in-depth analyses and high-quality design of strategies at all three described levels. If the legal status change is only a formal change, the “new” organisation will assume the defects and flaws of the “old” one.

6 REFERENCES

Angebaud, D. and Escher, A., 2005. *Global System for Telematics: DEL_EFCD_3_1 Architecture and Interface Specifications*. PTV AG, ERTICO.

Dobson, P. and Starkey, K., 1993. *The Strategic Management Blueprint*. Oxford: Blackwell Business. 161 p. ISBN 9780631186243.

Escher, A. and Grammling, M., 2005. *Global System for Telematics. DEL_EFCD_3_2 Reference Implementation*. PTV AG, ERTICO.

Ferro, F. et al., 2004. *Global System for Telematics. IP High Level Architecture*. Motorola, ERTICO.

Jesty, P. H. et al., 1998. *CONVERGE - TR 1101 - Guidelines for the Development and Assessment of Intelligent Transport System Architectures. Report of Work-Package SA2&3* [online]. Retrieved from: ftp://ftp.cordis.europa.eu/pub/telematics/docs/tap_transport/converge_dsa2.3.pdf

Johnson, G. and Scholes, K., 1993. *Exploring Corporate Strategy: Text and Cases, 3rd edition.* New York: Prentice Hall. ISBN 987-0132974417.

Keřkovský, M. and Vykypěl, O., 2006. *Strategické řízení: teorie pro praxi*. Praha: C.H. Beck. 206 p. ISBN 80-7179-453-8. (in Czech)

Kotler, P., 1984. *Marketing Management*. New York: Prentice Hall (Engelwood Cliffs, N. J.). ISBN 0135579279.

Moos, P. and Přibyl, P., 2008. *Tvorba systémového projektu dopravně-telematických aplikací: Metodický pokyn* [*Creation of Traffic-Telematic Application System Project: Guidelines*]. Praha: Czech Technical University. (in Czech)

Nickols, F., 2000. *Three Forms of Strategy Corporate, Competitive and Strategy in General* [online]. Retrieved from: http://home.att.net/~nickols/strategy_forms.htm

Ortgiese, M. and Escher, A., 2004. *Global System for Telematics. DEL_EFCD_2_1 Use Cases and System Requirements*. PTV AG, Ertico.

Pípa, M. et al., 2009. *Projektování silnic a dálnic s ohledem na ITS systémy, projekt MD*. [Roads and highways design reflecting ITS, R&D Project of the Czech Ministry of Transport, Research report]. Brno: Centrum dopravního výzkumu, v.v.i. (in Czech)

Pípa, M. and Plíhal, J., 2009. Novou výzvou je komunikace mezi vozidly a infrastrukturou. [Vehicle infrastructure integration is a new challenge]. *Dopravní noviny*, vol. 18, no. 30, p. 3. ISSN 1210-1141. (in Czech)

Porter, M. E., 1985. *Competitive Strategy*. New York: Macmillan.

Porter, M., 1996. What is Strategy? *Harvard Business Review*, November-December 1996, pp. 61 – 78.

Rasiel, E. M. and Friga, P. N., 2001. *The McKinsey Mind: Understanding and Implementing the Problem-Solving Tools and Management Techniques of the World's Top Strategic Consulting Firm*. New York: McGraw-Hill. 272 p. ISBN 978-0071374293.

Svítek, M. et al., 2006. *ITS v podmínkách dopravně-telematického konceptu České republiky, projekt MD [ITS in condition of the traffic-telematic concept of the Czech Republic, R&D Project of the Czech Ministry of Transport, Research report]*. (in Czech)

The article was produced under the support of the project

Transport R&D Centre (CZ.1.05/2.1.00/03.0064).

Instructions to the authors

1 GENERAL GUIDELINES

Papers based on accepted abstracts and prepared in accordance to these guidelines are to be submitted through the journal's web site www.transportsciences.org. All papers, using Microsoft Word2000 (or newer) are limited to a size of at least 4 and no more than 8 single-spaced pages on A4 paper size (297 mm X 210 mm), including figures, tables, and references and should have an even number of pages. The paper's top, bottom, right and left margins must be 2.5 cm. No headers, footers and page numbers should be inserted.

2 TITLE, AUTHORS, AFFILIATIONS

The title of the paper must be in title letters, Times New Roman, font size 16, and aligned left. Use more than one line if necessary, but always use single-line spacing (without blank lines). Then, after one blank line, aligned left, type the First Author's name (first the initial of the first name, then the last name). If any of the co-authors have the same affiliation as the first author, add his/her name after an & (or a comma if more names follow). In the following line type the institution details (Name of the institution, City, State/Province, Country and e-mail address of a corresponding author). If there are authors linked to other institutions, after a blank line, repeat this procedure. The authors name must be in Times New Roman, regular, and font size 12. The institution details
must be in Times New Roman, italic, and font size 10.

3 ABSTRACT

The abstract should start after leaving eight blank lines. Type the text of the abstract in one paragraph, after a space behind the word abstract and colon, with a maximum of 250 words in Times New Roman, regular, font size 12, single-spaced, and justified. After leaving one blank line, type KEY WORDS: (capital letters, Times New Roman, font size 12), followed by a maximum of five (5) key words separated by commas. Only the first letter of the first key word should be capitalized.

4 THE TEXT

The main body of the paper follows the key words, after two blank lines (i.e., two blank lines between the first heading and the key words). The body text should be typed in Times New Roman, font size 12 and justified. The first line of the paragraphs should be indented 5 mm except the paragraphs that follow heading or subheading (i.e., the first line of the paragraphs that follow heading or subheading should not be indented). Never use bold and never underline any body text.

4.1 HEADINGS AND SUBHEADINGS

The headings are in capital letters, Times New Roman, font size 12. Subheadings are in title letters Times New Roman, font size 12. The headings and subheadings must be aligned left and should not be indented. Leave two blank lines before and one after the heading. There should be one (1) blank line before and after the subheadings. All headings and subheadings must be numbered. If a heading or subheading falls at the bottom of a page it should be transferred to the top of the next page.

4.2 FIGURES AND TABLES

Figures, line drawings, photographs, tables should be placed in the appropriate location, aligned centre, and positioned close to the citation in the document. They should have a caption, Times New Roman font size 12, with a colon dividing the figure number and the title (Figure 1: Material properties) and should be numbered consecutively, e.g. Figure 1, Figure 2, Table 1, and Table 2.

4.3 REFERENCES

At the end of the paper, list all references with the last name of the first author in alphabetical order, underneath the heading REFERENCES, as in the example. The title of the referred publication should be in italic while the rest of the reference description should be in regular letters. References should be typed in Times New Roman font size 12. citation standard ISO 690.

More details can be found at www.transportsciences.org.

TRANSACTIONS ON TRANSPORT SCIENCES

Volume 5 | 2012 | Number 2

CONTENTS