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The Risk Estimation of Dangerous Liquid Transport

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ABSTRACT: Transportation of liquid substances by tank vehicles on the road is an integral part of our economy. It is the petroleum products, especially fuel, that are transported in the vast majority of cases. Transportation of these hazardous liquid substances must comply with strict rules to ensure maximum transport safety. Nevertheless, there are situations where the liquid outflows outside of the car tank. The most common causes are the traffic accidents, various technical failures or human failure. Immediately following this outflow surface water and soil are threatened.

Our department develops software that is able to estimate the risks of hazardous liquids escaping into the vicinity of roads. It is a complex task involving several different disciplines. The software processes geographic data for the creation of digital terrain models. These terrain models are entered into the numerical model to calculate the spreading of a liquid. An integral part of the software is the processing of uncertainties in the environmental description which may significantly affect the calculation. Due to uncertainties the stochastic approach of evaluation was chosen. Results are expressed by statistical parameters. Software provides both qualitative and quantitative results for the liquid captured on the surface, the surface infiltration, evaporation or affecting surface waters. For example, we obtain probability maps of affected areas around transport routes, mean liquid volume leaked into a stream or the confidence interval of liquid volume infiltrating into soils.

This text describes the basic logic of software function. Specific features have been described in detail, for example in Balatka & Havlíček (2012).

KEY WORDS: Terrain digital model, simulations of natural processes, liquid, uncertainty, spill spreading.

1 INTRODUCTION

Transportation of liquids by road is an integral element of the current economy. Fuel occupies the largest share of liquids transported by road. Various types of acids, hydrocarbons, including their derivatives, food preparations, etc. are transported as well. This kind of transport is provided by road tankers of many types that differ in their design, tank volume, number of chambers, additional equipment, etc.

Shippers who run a business in the field of liquids transport in our country must follow rules set out by an international agreement on the transport of dangerous goods ADR. However, road transport of fluids still means some risk. In this case we mean a leak outside of the tank volume. The most common cause of leakage may be a technical fault or accident resulting in damage of the shipping tanks. The vast majority of transported liquid substances are industrial products which, in the transported quantities and concentrations, can bring negative results for people and all aspects of the environment. The seriousness of leakage depends on many factors, such as the quantity of liquids, hazardousness of liquid for objects nearby the leakage, climatic conditions, etc. The most threatened receptors in the first moments of leakage are the components of the environment, such as soil or surface water. This is the main difference between the leakage of a liquid substance and a gas leak. In the case of a gas leak people are the first to be threatened. The outlined risks can be currently assessed using a numerical computer model that is being developed at the Technical University of Liberec.

2 SPREAD OF A THIN LAYER OF LIQUID

The leakage of a liquid substance from a tank may occur if there is a failure of valves designed for filling, draining and other purposes, or if a tank shell is disrupted. The most common cause of this adverse event is a traffic accident.

Once the liquid substance begins to flow to the surface, it creates a spill, which further spreads on the surface. Temporal evolution of the behavior of a spill depends on many factors, such as terrain morphology, the physico-chemical properties of the surface and of the liquid, climatic conditions, and the course of leakage of the liquid from the tank. The level of the spill, depending on the above-mentioned factors, frequently reaches a height ranging from a few millimeters to several centimeters.

The driving force of the fluid flow is the Earth's gravity. This acts on each particle of fluid in the direction of the surface gradient. With a very low level of a spill the dominant direction of propagation is influenced by even the smallest surface details, such as tracks, furrows in the field of agricultural machinery, rutted tracks in the meadow, etc.

Between the surface and the liquid adhesion forces also act that cause the fluid to be captured on the surface. Another reason for the capture of liquid on the surface is its roughness. An important process in the spread of a spill on a permeable surface is its infiltration. Infiltration depends on the properties of the liquid, on the properties of the surface and on the climatic conditions. For example, if grassland is frozen or saturated by rainwater, infiltration is much slower than in the opposite case where infiltration is much faster. When infiltration is slower, propagation of the spill on a surface is much greater. In addition to soil and related vegetation the liquid may also affect surface water.

3 METHODOLOGIES FOR ESTIMATING THE EXTENT OF CONTAMINATION

The process of the spread of a thin layer of liquid substance can be predicted using different methods. The motivation for this step may be an estimation of the extent of damage to the vicinity of the accident caused by the leakage. Some methods are described in Farrar et al. (2005), Zhiming (2006) or Yellow Book (2005). There is a wide range of methods ranging from simple screening practices to sophisticated solutions of partial differential equations. However, these methods require sufficient density and accuracy of data that describe the surface of the site concerned for producing adequate results. Such data are in practice available only in a very limited form. It should be noted that the fine surface details, such as depth of ruts in the dirt road or the density of grassland is rapidly changing. Similarly, the saturation of soil by water depends on the current weather conditions. These above-mentioned examples represent a fraction of the characteristics influenced by uncertainties that can significantly affect the spillage spreading.

Additionally our department at the Technical University of Liberec is developing its own methodology implemented by software. It is a software package composed of several computational modules and graphic applications, which was named SPILLSIM. The main emphasis is given to processing input data uncertainties. The task is divided into two stages.

- Estimate of the extent of contamination from a point source;
- Risk assessment for a part of the transport route.

Part of the route can be seen as a line object which is composed of sufficiently small segments. Each such segment represents a potential risk of fluid leakage. In the first stage, we estimate the extent of leakage for each separate small segment of road network that can be considered to be a point source of leakage. In the next stage, we assess the risks for the road network part as a whole.

To estimate the extent of contamination from a point source is a very complicated complex problem which is divided into several mutually interpenetrating parts. These are:

- Input data describing the environment, liquid substance properties and type of leakage;
- Solving of mathematical-physical models of the liquid spread;
- Processing of uncertainties.

Risk assessment for the part of the route then constitutes the final processing of data obtained from the calculations of the point source.

4 ENVIRONMENT DESCRIPTION

The first necessary step in the solution of the problem is to obtain suitable data describing the environment in which we want to simulate the fluid's propagation. Input data divides into altimetry, planimetry and physico-chemical properties of the surface and the liquid substance.

Altimetry is a group of data that describe the morphology or shape of the terrain. This is the most important type of data that determines the dominant direction of liquid spread. These data are normally organized either in the form of contour lines or point grids. The SPILLSIM is able to use any resource altimetry saved as a file format for geographic information systems Esri Shapefile or any text tables stored in an ASCII text file. Sufficient density and accuracy of the data is a very important feature for the purpose of simulation.

Planimetry contains data with the occurrence of surface objects. These objects are geometrically expressed by points, lines or polygons. Points represent objects with negligible areal extent, such as solitary boulders or trees, small buildings, memorials, etc. The lines represent the linear nature of the objects. Among the most common are roads, railways, waterways, and many others. The last type of surface expression are polygon objects. Polygons describe areal formations, such as buildings, vegetation cover (e.g. forest, meadow, field), water areas, etc. The software retrieves planimetry formatted in Esri Shapefile.

For the existing calculations the ZABAGED database (ZABAGED database, 2010) was used, which falls under the administration of the Czech Office for Surveying, Mapping and Cadastre. ZABAGED is a Czech acronym for the basic basis of geographic data. It is a vector model of the territory of the Czech Republic which contains altimetry and planimetry. Altimetry can be obtained in the form of contour lines and point field with grid size 10x10 m. Accuracy of heights ranges from 1.5 m in flat terrain to 5 meters in very rugged wooded terrain. Topography contains more than 100 types of objects organized into layers.

After loading of the planimetry and altimetry the data are further processed into a raster surface model. The threatened area of interest is the rectangular cutout, which is divided into equal square elements. The length of the element's side is usually chosen from 0.5 to 1 meter. Each element gets its parameters that are entered directly into the simulation calculations of liquid spread.

The first parameter assigned to the element is the identifier of the surface object occurring in the position of an element. This information is obtained directly from the planimetry. Additional data of the element is altitude. This is in addition to the altimetry also determined by planimetry. Based on the elevation a digital raster elevation model is first interpolated. The altitudes are assigned to the elements. In practice the altimetry in most cases does not cover details such as terrain morphology, such as the aforementioned rutted tracks in a dirt road, saddles and ditches formed by roads or a land surface topography in the forest. These details can be predicted just by using objects, which form small changes in the surface. Based on the planimetry it is possible to edit the altitude of elements derived from altimetry. These small properties have a major impact on the direction of the spread of a thin layer of liquid substance.

With the knowledge of the types of objects that are located in the areas of elements, we can also determine the physico-chemical properties of their surfaces, which are necessary for the simulation calculations. Besides the planimetry and altimetry in the calculation a table of values assigned to individual types of surfaces is also entered. These are parameters characterizing the interaction between the surface and the respective liquid, infiltration and evaporation. The contents of the table with these properties depend both on the type of surface and the liquid, and the particular climate state. A specific liquid substance is described by density, viscosity, and other parameters. The climate state is described by parameters such as temperature or humidity.

Altimetry, planimetry and tables of physico-chemical properties together form the input data structure, which we call vector surface model.

5 MATHEMATICAL-PHYSICAL MODEL SOLUTION

A mathematical-physical model is used for calculations of the time evolution behavior of a spill of leaking liquid substances. The calculation is directly based on the form of a raster model of the environment. The results of the simulation calculation are the values describing how the volume of the liquid substance develops in the individual elements over time. To each element of the raster environment model are also allocated four state variables. These values represent an immediate volume of liquid per unit area of the element. The meanings of the state variables are as follows:

- The volume of liquid trapped on the surface due to roughness and adhesion;
- The volume of fluid infiltrated from the beginning of the simulation (leak);
- The volume of liquid evaporated from the beginning of the simulation (leak);
- The volume of fluid contaminating surface water from the beginning of the simulation (leak).

In addition to the raster surface model a scenario enters into the calculation which contains the following groups of parameters:

- Determination of the locality;
- The initial and boundary conditions;
- Properties of the numerical calculation;
- Types of the desired results.

The parameters for the determination of the locality are the material for creating a raster surface model. The initial and boundary conditions describe the position and course of leakage on the plane of the raster surface model. Leakage is modeled in such a way that on the surface of defined elements the defined volume of fluid increases in each time step. These elements form a circle with a specified radius of several units of meters. This is due to the point source nature. Features of the numerical calculation include a range of the moving calculation time step, precision limit and the simulated time of spread.

Using these scenarios we can set up six different types of results. Each result is stored in a file with a special raster format, where each element is assigned a numeric value. The meanings of the first four types of result correspond to the four aforementioned state variables. These outputs can be stored for different time moments, which are selected in a script via the step notation. As the two remaining types of result it is also possible to save the grid with altitudes and raster with object identifiers.

6 PROCESSING UNCERTAINITIES

The vector model of the surface is a data structure that is usually affected by the uncertainties of the input data. These uncertainties arise for various reasons.

Inaccuracies of contour lines or elevation points of altimetry can generally range from a few centimeters to several meters. The character of a thin layer spill movement is already very sensitive to the terrain asperity in order of centimeters. Uncertainties in altimetry depend primarily on how the data are obtained. The most accurate method of determining the elevation is remote sensing performed by using satellites or aerial photography based on various laser measuring methods. These methods in some cases may achieve accuracies of a few centimeters. The surface in these scales is however dynamically changing both by natural processes and human activity.

Planimetry is also affected by uncertainties. The positions and shapes of buildings, roads, waterways and vegetation cover types in the data compared to the actual state may vary from a few centimeters to tens of meters. Physico-chemical characteristics are directly dependent on the current season and weather. This affects infiltrated volume and leakage distance.

An uncertainties solution means a generalization of the described deterministic problem to a stochastic approach. All values contained in the vector surface model are not understood as strict numerical values. The stochastic approach considers these values as the most probable. In terms of probability theory, each such value describes the modus of the random variable distribution. Variances of these distributions are given by the maximum possible expected deviations. These deviations are entered common to the whole group of contours lines and object types. From the expected values and deviations densities of probability distributions are constructed. We can either set the Gaussian distribution, triangular distribution or uniform distribution, which we use when we have no idea of the expected value.

With the help of a random number generator, we can create a large number of raster surface models from the probability distribution of random variables, from which we obtain the raster results of the described state variables. In this way we get a large number of spill spread variants, which are entered into the statistical processing. This method is generally called Monte Carlo.

7 STATISTICAL EVALUATION

Using the Monte Carlo calculations we obtain a set of values for each state property and an arbitrary time step for each element. These values represent the selection of some probability distribution of random variables. By statistical calculations we mean estimates of the statistical parameters of this distribution. Among the statistics that the software calculates are values of distribution and quantile functions, the mean, variance, etc. Statistical calculations are divided into two types:

- Statistical calculations for individual elements;
- Statistical calculations for whole objects.

The results of the evaluation for individual elements are the estimates of liquid relative volume statistics per unit area for the individual elements. These type of results can be graphically interpreted as the spatial distribution of the threat in the vicinity of a leak. An example is on figure 1, which shows the probability distribution of the effect on particular areas in a locality after a leakage on the road.

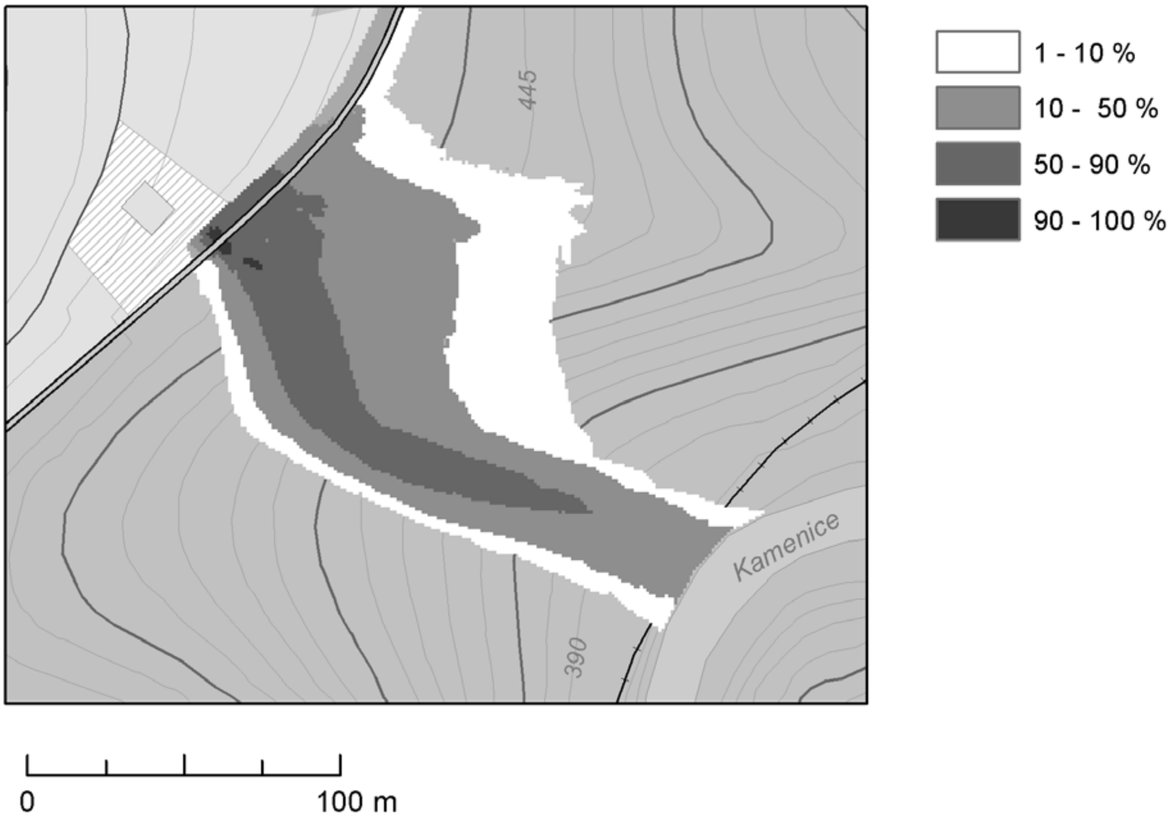

Figure 1: Probability of affection for various places of locality from a point source.

In the same way we can make estimates, for example, of mean values of infiltrated volume or the probability of exceeding the limit volume of infiltration.

The results of statistical calculations for whole objects are statistical estimates of volumes and surface extent of fluid that hit the object. A typical example is the contamination of water flows. For example, it is possible to estimate the mean values or confidence interval of fluid volume that affects a water flow in the vicinity of the road. These types of statistics can be estimated also, for example, for the area of affected grassland.

8 ESTIMATES OF TRANSPORT ROUTE RISKS

Remember that the transport route can be visualized as a line consisting of sufficiently small segments, which we can consider as point sources of potential leaks. For each segment we can obtain any of the statistical parameters of one of the state variables as was mentioned before. The risk for the transport route comes from the post-processing of those results and from data on the accidents on the relevant route segment.

The data on accident rates for different road segments can be obtained from the statistics held by various institutions such as the Ministry of Transport, Police, etc. The quality of these data can be variable. Generally, it is not easy to pick out the data from only those accidents which accounted for the leak of hazardous fluids during its transport. Accident rate is described as accident frequency (unit 1/km/year). Threat on every position around the road is described by the frequency of affection (unit 1/year).

After evaluation we obtain a spatial distribution of frequency of affected positions around the investigated road part, as shown in the example in figure 2.

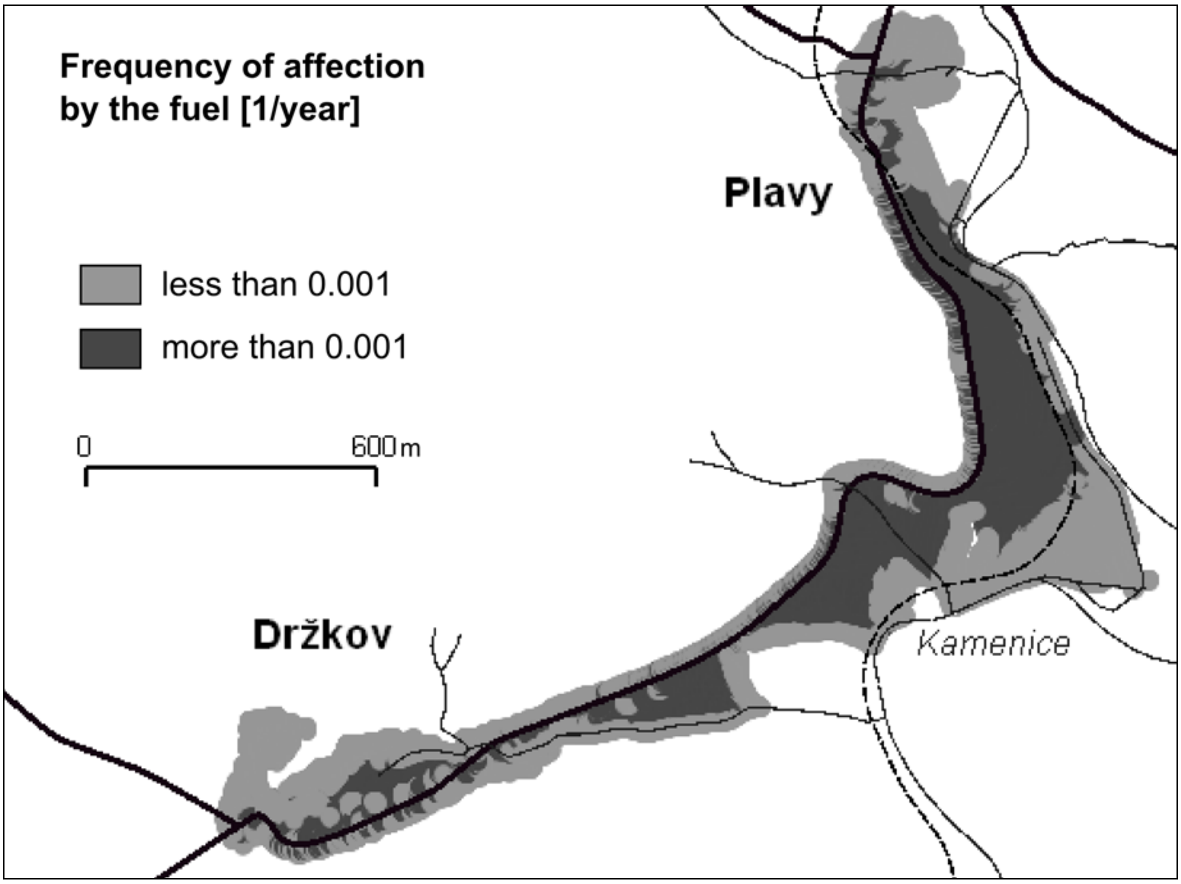

Figure 2: Example of the affected surface extent in the vicinity of the road.

CONCLUSIONS

The aim of this paper was to explain the principle function of the SIMSPILL software system, which is designed to predict the extent of the potential damage caused by the leakage of fluid transported by road. A detailed description of the model function was presented e.g. in Balatka & Havlíček (2012).

The current version of the system has already been successfully applied to solve two scientific research projects. The first was project no. SPII1A0/45/07 – “Complex interaction between natural processes and industry with regards to major accident prevention,” supported by the Ministry of the Environment of the Czech Republic. The second was project No. 2B08011 – “Guidelines for the assessment of transport ways on biodiversity and environment components” supported by the Ministry of Education, Youth and Sports of the Czech Republic. Currently the system is used to support the project of the Technology Agency of the Czech Republic No. TA01030833 – “Integrated information system for road transportation of dangerous chemicals.”

System development is still in progress and it is intended to be deployed in other areas of risk assessment.

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Quay Cranes in Container Terminals

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ABSTRACT: Container's transport over the world plays a major logistics role in the contemporary global economy. Seaports and their container terminals represent an important function in the logistics chain. The transshipment speed of containers in the container terminal is the significant factor participating in the overall transport time. Quay cranes served as one of the essential elements of the trans-hipment containers in the container terminal. This paper deals with quay cranes, comparing particular specific crane´s components. Furthermore, the paper carries out an analysis of the optimal quay crane productivity, with regard to contemporary requirements. At the end of the article requirements for the future development of the quay cranes are submitted.

KEY WORDS: Container, quay crane, trolley, hoist, spreader.

1 INTRODUCTION

Loading and unloading operations with containers from/to container vessels are performed in the quayside area by quay cranes (QCs). These cranes are found at container terminals, a place where containers are handled from one of the transports (container vessel, feeder vessel etc.) to the other (chassis, automated guided vehicle), and vice versa. QCs are also known as ship-to-shore cranes and they are moved by rail tracks. The first QC (called Portainer) dates back to 1959 and was built by Paceco Corporation. It was first used in a marine terminal in Alameda. Since then, the size of QCs have more than doubled. The first QC was designed to lift 23 t boxes 16 m over the rails with an outreach of 24 m. The newest gigantic QCs are taller and heavier than any before, which means a height of up to 75 m and a weight of up to 1,800 t (Super Post-Panamax). It also means that these quay cranes, such as the ones shown in Figure 1 (Super Post-Panamax with Dual hoist tandem 40´, single trolley); lift 65 t boxes 42 m above the rails with an outreach of 65 m. Current typical size characteristics QCs are shown in Table 1.

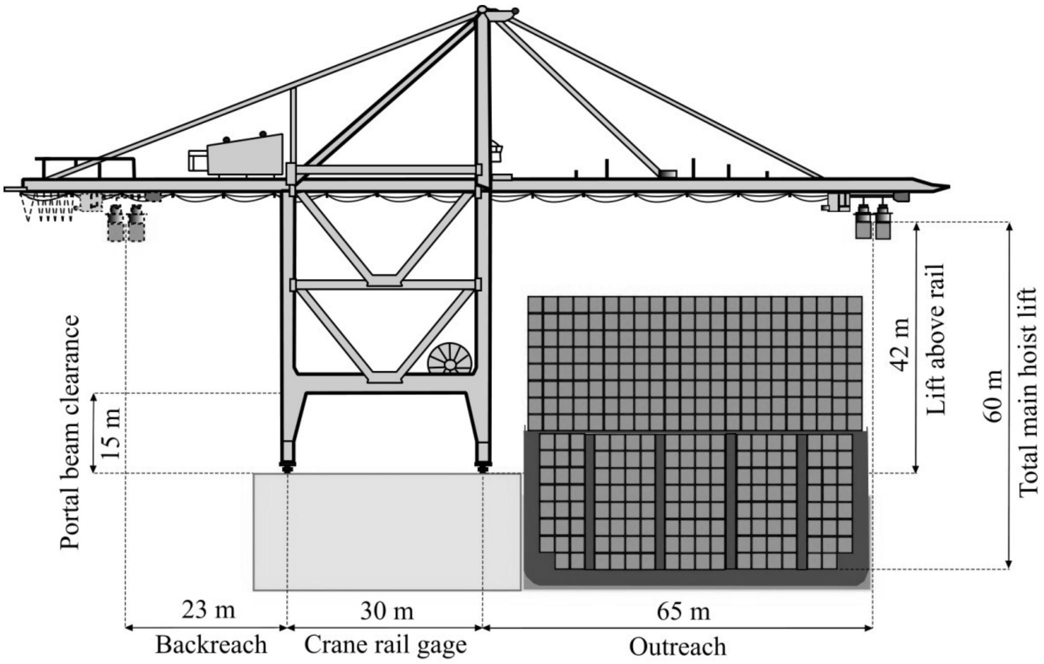


Figure 1: Typical dimensions for the current quay crane.

Table 1: Quay cranes particulars* (Liebher, 2011).

Port	Boom type	Girder type	Machinery (MT) or rope trolley (RT)	Rated load under spreader (t)	Lifted load under cargo beams (t)	Crane weight (t)	Waterside outreach (m)	Main hoist - load (m/min)	Trolley speed (m/min)
Hamburg	A-frame	Single box	MT	61	84	1,410	64	90	210
Los Angeles	Low profile	Single box	RT	61	100	1,723	62	75	240
Savannah	A-frame	Twin box	RT	65	100	1,369	61	90	180
Dubai	A-frame	Twin box	RT	80	100	1,280	68	90	240

** The values in this table are approximate.*

2 QUAY CRANES CLASSIFICATION

QCs are divided into the several categories. The first possible category is a classification according to the size of container vessel, which is able to serve QC:

- Panamax QC - able to transship vessels with 11-13 containers wide (rows) or more and with an outreach 30-40 m. These container vessels are capable of passing through the Panama Canal;
- Post-Panamax QC - able to transship vessels with 17-19 containers wide or more and with an outreach 45-55 m;
- Super Post-Panamax QC - able to transship vessels with 21-23 containers wide and with an outreach 60-70 m.

These QCs are further classified by the boom mechanization (see Figure 2):

- High profile (so called A-Frame) with tip-up boom above the water surface and prove of vessel anchor (port of Rotterdam). This profile exhibits the lowest cost and the lowest wheel loads;
- Low profile where the boom is able either to push forwards or to push in above vessel deck (port of Boston). These QCs are suitable especially for their minimum height near airports and for reduced visual impact. This profile exhibits higher costs and higher wheel loads.

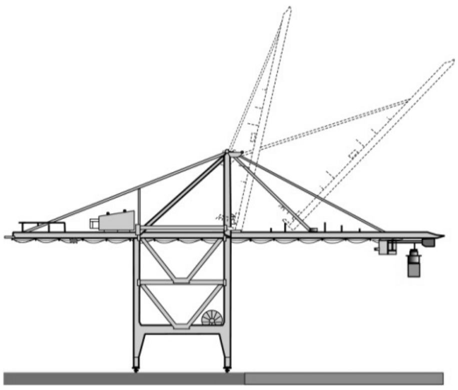
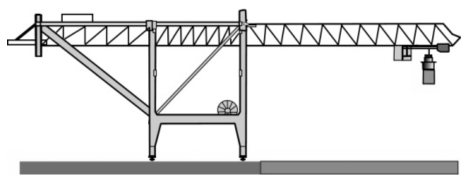
High profile QC (A-Frame)	Low profile QC
	

Figure 2: High profile and low profile quay crane.

QCs can be powered by two types of power supplies:

- Alternating current (AC) - AC hoist motors have dedicated inverters where each motor is controlled separately. QC equipped with an AC must be continuously hooked up to an AC power supply or generator;
- Direct current (DC) - DC hoist motors are wired in a series where only one DC serves to control the motors. QCs equipped with DC can be moved to any location and can operate off a battery supply.

There are, of course, QCs equipped with both power supplies. For example, in the Buchardkai container terminal (Hamburg) where the hoist and trolley have DC and gantry has AC (Marek & Bartošek, 2011).

3 CRANE COMPONENTS

The loading and unloading operation of a container is described as a move. The QC spreader is placed on the container, fixed by twistlocks, than lifted by a hoist, to unload it. The crane's trolley moves the container to the quay where the spreader is lowered and the container is either put on the ground (wharf) or transport vehicle. The container is released by unlocking the twistlocks and the spreader is hoisted again. The loading of a container uses the same crane operations and vice versa (Meisel, 2009). Vessels can be equipped with cell guides for easier positioning of containers within the hold.

Since the end of the 80s, hoist and trolley speeds have nearly doubled. Of course, everything is affected by the development of motor dimensioning and drive systems. QCs currently have normal hoisting speeds of 180 m/min (empty spreader) and 90 m/min (rated load). Main trolley speed typically varies between 50m/min (Panamax) and 240 m/min (Super Post-Panamax). Gantry speed is 70 m/min with an acceleration ramp time of four to eight seconds (Kocks, 2011).

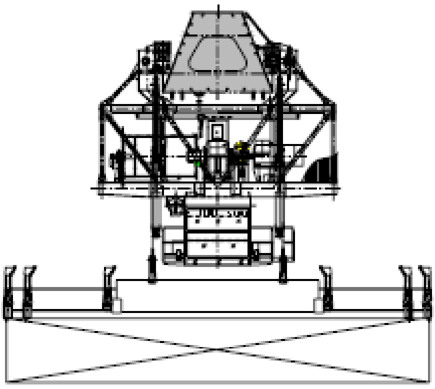
The QC trolley selection has to be based on the needs of a particular location, as well as the crane structure and the wheel loads. The QC trolley can be rope towed or machinery type. From the point of the structural design, weight is the main difference between these two types of trolleys, as shown in Table 2. The rope towed trolley system has the trolley drive and main hoist.

Table 2: Trolley comparison matrix (ZPMC, 2011).

Trolley type	Trolley weight (t)	Moving load (t)	Average crane weight (t)	Wheel loads (operating) - waterside (t)	Wheel loads (operating) - landside (t)	Trolley motors	Main hoist rope life (h)	Total rope length (m)	Trolley acceleration
MT*	85	175	1,500	220	150	2-4	3,500	500	High
RT*	30	110	1,350	200	120	1-4	1,500	3,600	Average

** MT = Machinery trolley, RT = Rope trolley.*

Boom hoist drums and machinery are placed in the machinery house, attached to the crane frame. Trolley and main hoist ropes run from the machinery house to the end of the trolley girder, through the trolley, and to the tip of the boom. This layout permits the trolley to be shallow and lightweight, allowing a taller lift and smaller loads on the QC structure and wharf. The rope trolley is common, rope driven is the lightest; if self driven, it is a little heavier. It requires long ropes, catenary trolleys or continuous supports. A machinery trolley has the trolley and main hoist machinery on board. Most of the machinery on the trolley have machinery housings on the frame much smaller, containing only the boom hoist. There are no necessary trolley drive ropes and the main hoist ropes are shorter than for a rope towed trolley (see Figure 3).



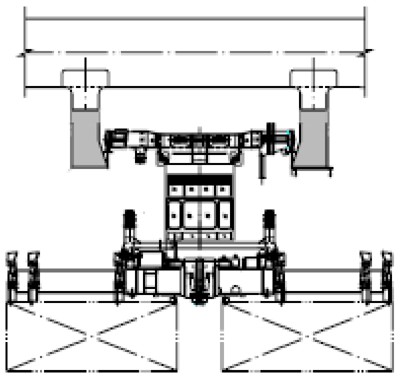


Figure 3: Machinery trolley/monogirder and rope trolley/twin girder (Kalmar, 2011).

Another current typical specification of QC is the so-called portal trolley. A single portal trolley transships the containers between the vessel and the loading/unloading place on the quay. On the other hand, QCs equipped with a double portal trolley are more common in recent years. This QC type features a second trolley that runs on the portal beams. The main trolley (waterside) is controlled by the operator. QCs are sometimes operated in a semi-automatic mode, operated by staff only during the actual set-down or pick-up on the vessel.

The rest of the move is fully automatic (landside). It means transship container from lashing (coning) platform to set-down or put on a transport vehicle (horizontal). The lashing platform (buffer position) serves for two 40′ or 20′ containers. QCs equipped with a double trolley can be used for a reduced dwell time. These QCs are used, for example, in Hamburg Altenwerder terminal (Marek & Bartošek, 2011).

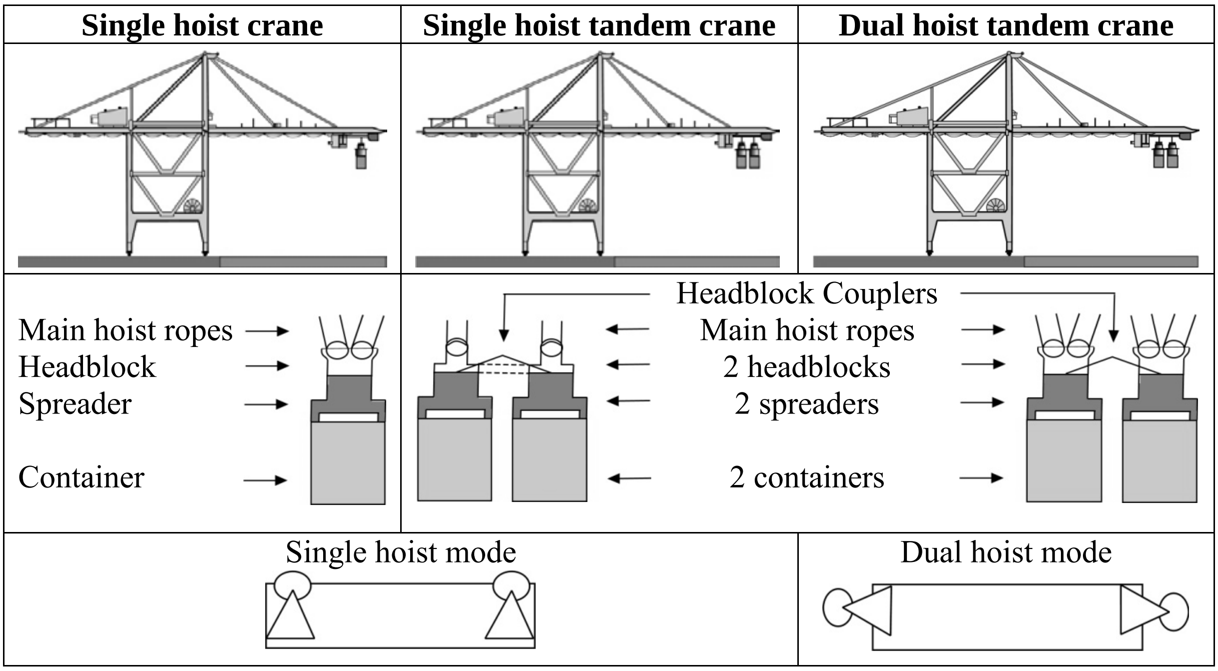


Figure 4: Single hoist and dual hoist (Konecranes, 2012).

QCs can also feature a single or dual hoist, as shown Figure 4. Conventional QCs have a single hoist with a single spreader for a rated load of up to 65 t. QC with a single hoist picks up either a single 20′, 40′, 45′ or two 20′ (twin 20s), under a single spreader. To the contrary dual hoist QC includes two hoisting systems on the main trolley and can handle either two 40′ or four 20′ for each lift (see Figure 5). There are also QCs equipped with a hoist with a tandem. This could double productivity against the conventional single hoist. Tandem means side by side, as opposed to end-to-end twin lifts. These dual hoist tandem QCs are used currently, for example, in the port of Pusan.

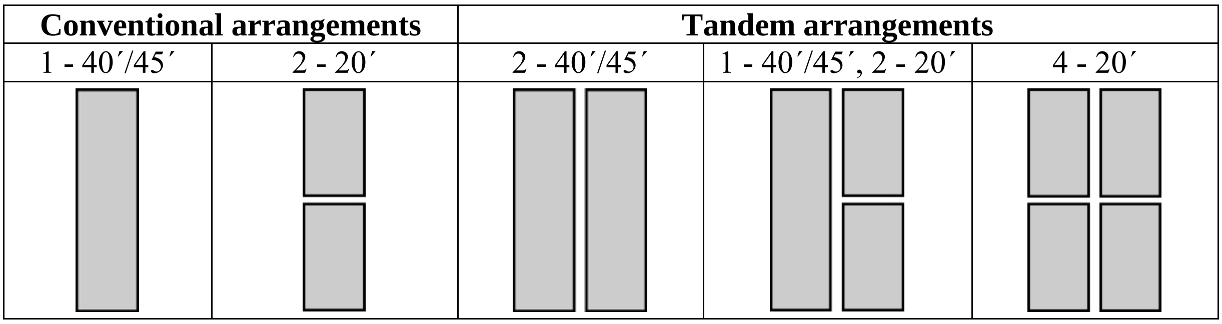


Figure 5: Container arrangements under spreader.

The most significant differences between the dual hoist QCs and conventional single hoist QCs are:

- Dual hoist QCs are heavier and have bigger wheel loads,
- Dual hoist QCs have larger trolleys, twice as many sheaves, and headblock stowage accommodations,
- Dual hoist QCs have two main hoist systems, two headblocks and conventional spreaders and sets of falls,
- Dual hoist QCs are equipped with ancillary devices to help the operator.

4 QUAY CRANE PRODUCTIVITY

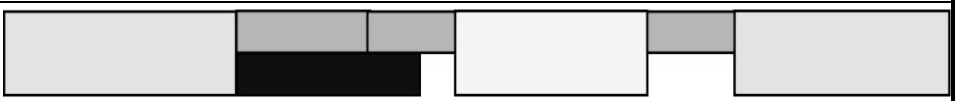
Quay crane productivity is a key indicator and one of the critical parts of overall terminal productivity at the same time. The productivity of a QC is measured by the number of moves per hour. One move equals a transship of containers between vessel and transport vehicle in the quay (wharf). QCs are currently able to realize about 30-50 moves per hour in practice, see Table 3 (Post-Panamax, 1.75 TEU per lift). Almost all terminals are able to achieve maximum productivity as low as 70 % and as high as 80 % of the computed number. QCs do not achieve the technically possible productivity due to productivity losses caused by operational disturbances. Nevertheless, technological improvements are increasing QC productivity. The overall time load/unload of vessel is generated from the total sum of loading/unloading containers. This sum is known in practise shortly before the vessel's arrival. The transhipment is determined by the stowage plan. For example, it will take nearly three days to tranship 12,000 TEU vessel and exchange 75 % of its containers, using 6 cranes producing 40 lifts an hour. The effective work means a practical limit up to 6-8 QCs servicing one ship on one quay. While a feeder vessel can be served by 1-2 QCs, big container vessel can be served by up to 8 QCs (Marek & Bartošek, 2011). The bays of the ship will be partitioned into several areas. Each area will be served by one QC, which is called crane split.

Table 3: Comparison quay crane productivity (Böse, 2011).

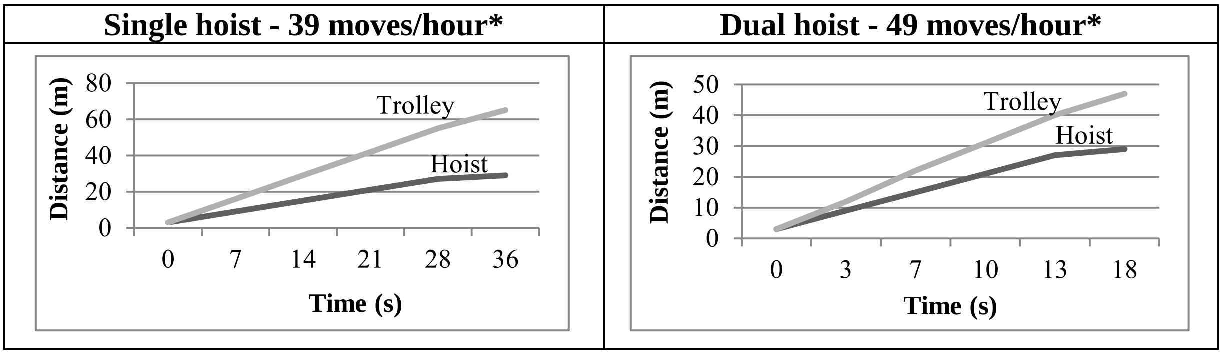
Vessel Size (TEU)	**Lifts per hour**			**Cranes**
	30	40	50	
	Vessel turnaround time (hours)			
8,000	69	51	41	5
10,000	71	54	43	6
12,000	86	64	51	6

The move (travel time) is the simple cycle time from the wharf to the inside ship´s hold, shown in Table 4 (single hoist and rope trolley). The hoist and trolley times are parallel and the dwell times are in series. The longer parallel time dominates, the travel time can vary. Depending on the location of the container the hoist or trolley time will dominate.

Table 4: An Example of cycle timeline (Post-Panamax).

		Pick from wharf Raise Lower Find guides Lower Set in hold
Travel time	Hoist	
	Trolley	
Time (s)		0 13 25 35 39 52

QC equipment variations, such as rope trolley or machinery trolley and single hoist or dual hoist, can make a significant difference in moves per hour, see Figure 6.



*maximal values

Figure 6: Productivity of single and dual hoist (Rudolf, 2009).

QC productivity (one move) can be computed as a technical output. QC productivity QC_p (TEU) per hour is computed by using this simplified following formula:

$$QC_p = 3{,}600\ \frac{n_c}{t_t} \cdot t_p \cdot c_t \cdot f_t,$$

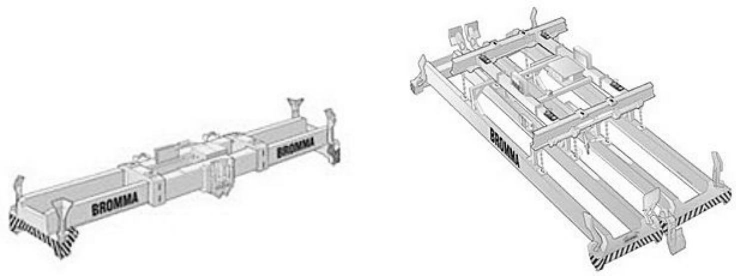
where n_c is the number of tranship containers in one move [TEU], t_t is a theoretical time for one move [s], which is composed of the sum of all time necessary for the transhipment of the container (see chapter 3 and 4). This time is only theoretical, operation productivity (number of moves) can achieve in practise 70 % of theoretical productivity. Therefore, this fact has to be modified by the coefficient of utilization of theoretical productivity t_p, the value is 0.7. Furthermore, inefficient down time must be included. Waiting time for loading/unloading of containers and other dwell time are expressed by the coefficient of transhipment c_t. It is also necessary to compute QC failure time, which is expressed by the coefficient f_t. The aim is to maximize the value of all coefficients up to the value one or totally eliminate them (Dávid, 2009).

5 REQUIREMENTS FOR THE FUTURE

QCs should be operational for 25 years, but the effective life will not be more than 20 years. Vessels are currently bigger and bigger and will continue to grow (class Triple-E from Maersk with length 400 m, width 59 m and capacity up to 18,000 TEU). QCs operated and ordered today have to be capable of serving these new big ships and production has to increase to maintain reasonable turnaround times at the same time. The future-proofs of QCs are shown in Table 5 and illustrate some of the issues that need to be considered.

Table 5: Future-proofs of quay cranes.

Capacity	*Operating load*	Total maximal weight of containers will not increase with the regard to the valid regulations for the size of containers and their maximal beam load. Sporadically a much heavier cargo beam load is admitted. Super Post-Panamax QC has currently a maximum capacity of between 50-70 t. For some container terminals 100 t cargo beam capacity is economical. It is obvious that many more will operate

		tandem spreaders, which are according to numerous papers economically and capacitively more profitable (for example Široký, 2011). Hereafter, will more boost triple spreader, which are able to lift even three 20′. These spreaders are equipped with Twin-lift technology (2 - 40′), see Figure 7. It is also possible to take advantage of elevating girder QCs that enable raising or lowering the height of QC before vessel service operations begin. Quay crane productivity can achieved 50 moves per hour.  **Figure 7: Twin-lift spreader for 2 – 20′, 40′ and tandem twin lift spreader for a 2 - 40′ (Bromma, 2012).**
Dimension	*Crane rail gage*	The wide crane rail gage is simpler and more stable, which means no more than 35 m, although there are some good arguments for increasing the crane rail gage to as much as 45 m. The cost of transship will be much greater because the larger crane rail gage cannot be shipped through vessels.
	Lift above rail	The current height should be kept as an optimal, which means 42 m. It suits present needs for vessels with 8 containers on deck. When trolley is higher above the wharf then it is more difficult to control the load. Lift above rails for future QCs may be increased maximal up to 50 m.
	Outreach	Current cranes are able to serve for vessels with 22-24 containers on deck (i.e. 60-65 m). The limits for future growth are represented by the parameters of the Suez Canal (400 m length, 50 m width) and the Malacca Strait (470 m length, 60 m width). Furthermore, there are limitations for the maximal vessel draft, which means that the current range will in the future be optimal with an economical 22-24 rows of containers on the deck. Outreach will be increased later.
	Backreach	Contemporary backreach length (22 m) is optimal for future QCs. Shorter or longer backreach may be reasonable, but the cost reduction is low.
	Portal beam clearance	Portal beam clearance is 15 m nowadays. This height is recommended to provide for future transport vehicles, such as straddle carriers. If the landside operations will be fully automated then a second hoist may be a rational addition. The higher portal beam clearance demands an increased

		structure to maintain a reasonably solid crane in the trolley travel direction.
Trolley	*Type and speed*	Currently the maximum speed of hoist is at 90 m/min for loading and at 180 m/min for unloading. The speed will not increase so much due to the vessel size and capacity. The trolley type will be either machinery trolley or a rope trolley, both have pros and cons (see Table 2). The machinery trolley seems to be better (rope towed option), but if a rope trolley is used, the ropes should be coherently supported by the boom and girder, so the load can be regularly supervised when the landside operation is fully automated. Among the disadvantages of the machinery trolley on the wharf belong the increased QC weight and wheel loads.

6 CONCLUSION

Present-day vessel's size and capacity demands lead to bigger and faster QCs. These QCs have to be capable to serve 22 wide's vessel and to lift 65 t of load under spreader and 100 t under hook rapidly. Fast developing improvements in QC structure, electronical, automatic and optical equipment will reduce dwell times and improve increasing QC productivity. Releasing automation is one of the ways how to increase QC productivity; one of others is to use either a double trolley system or a double hoist system on QCs. These QCs cranes offer high potential capacity, but also require a well-integrated terminal process. From the point of view of the container terminal operator these improvements are perspectived and improving the vessel transshipment time.

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Converting Recorded RDS-TMC Services into XML to Simplify Following Quality Assessment

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ABSTRACT: RDS-TMC is a technology for distributing traffic information over the air. Despite its age, its popularity is still growing and is in many countries being freshly implemented. Because the way the information is encoded into RDS data is complex, it is quite difficult to objectively test and evaluate any RDS-TMC service; many times the evaluation simply states "it works" or "it does not work" on some particular device. This paper describes our approach to the conversion of raw RDS data into XML, which is much easier to understand and evaluate. We describe the format of XML and also mention possible technologies and tools which could help evaluating the information stored in these files, like XQuery, BaseX, etc. The described solution was used in real-life tests of three services: country-wide service in Czech Republic, regional service in Prague and pilot testing in Poland.

KEY WORDS: RDS-TMC, XML, traffic information, monitoring, quality.

1 INTRODUCTION

RDS-TMC is a relatively old technology with limited over the air capacity which is not totally suitable for new navigation devices (Bureš, 2009). It is, however, proven technology and many navigation devices depend on it. Even today RDS-TMC services are being introduced in many countries and it is very likely the number of those countries will grow and the services will last for some years. Therefore it is still meaningful to monitor the end to end quality of RDS-TMC (Bureš & Vlčinský, 2011; Langebaek & Friis, 2008).

The main purpose of this paper is to present the conversion of raw RDS-TMC data into XML and to point out that any further service evaluation is much easier, as well as more flexible. Public traffic information services shall conform to a quality standard; the paper tries to approach the problem in a complex way by setting up the whole recording, processing and presentation chain of a future quality observation service.

1.1 Why to Convert the RDS-TMC Service into XML Form?

RDS-TMC technology is quite complex and it is not easy to extract readable information from data conveyed over the service. To understand the content, one must record raw RDS data from the air, stored as RDS groups, decode the TMC related content and finally interpret and evaluate traffic messages. Working with raw RDS data is not easy, as one TMC message can span multiple RDS groups and there are many other types of RDS groups, which are not relevant to TMC.

By converting the raw RDS data into XML, the situation gets much better, even plain XML files can be read by a human reader and primary understanding of the content is thus very quick. There are also many tools which allow the processing and evaluating of XML so getting aggregated information is also possible. Simply stated, translating the content from the exotic and cryptic language (raw RDS) into a very common one (XML) makes evaluation easier.

2 WHAT IS RDS-TMC?

RDS-TMC is the current system for getting traffic information into navigation systems, where RDS stands for the delivery system and TMC stands for structure of traffic messages.

2.1 Radio Data System (RDS)

RDS allows the transmission of digital information over analog (VHF FM) channels. It provides a number of facilities that are of use to all radio listeners, such as providing radio station name to be displayed on the radio display, declaring the current type of programme, indicating traffic news, providing alternative frequencies where is the service available, etc. RDS data are transmitted in the form of a continuous stream of 11.4 RDS groups per second. The standard defines 32 possible group types, where each group type can be used for different purposes. The TMC service uses groups 3A (TMC service information) and 8A (actual traffic messages).

2.2 Traffic Message Channel (TMC)

TMC allows the continuous delivery of traffic information suitable for reproduction or display in the language chosen by the user and without interrupting normal audio broadcast services. Received data are typically processed by a navigation system, which then offers the driver a proposal for alternative routes to avoid traffic incidents (Wikipedia, 2011).

TMC defines how to fit traffic information into a standardized container. It introduces set of rules and tables that are together used to encode and to decode traffic information at traffic centers and navigation devices. Each traffic incident is binary-encoded and sent as a TMC message. Each message consists of an event code and a location code in addition to expected incident duration, affected extent and other details.

Event codes and location codes references table items containing more information. These tables, which allow real interpretation of TMC message, are never broadcast over RDS. It is always delivered to the device by other means. Event codes are given by a European standard CEN 14917-2, location tables are country / region specific and are developed and distributed by the information provider concerned according to the European standard CEN 14917-1.

Table 1: TMC message structure and its reconstruction according to location table.

Event	Location	Direction	Extent	Duration
105 = “stationary traffic for 6 km”	LC=1267	0 = Positive	3	2 = “30 minutes”
message: D1 between exit 11and exit 29 in direction to Brno, congestion for 12 km				

The description of a problem location in table 1 is derived from the location table using location, direction and extent codes. Real messages can be as simple as those shown in Table 1, but could get much more complex, using multiple event codes; quantifiers, making the information more specific; defining explicit start and stop time; proposing directions for avoiding the reported problem, etc.

2.3 RDS-TMC Transmission

Since RDS data are in reality easily affected by external noise, each 8A RDS group (group containing traffic information) must be received at least twice with the same content to be accepted as correct, so to prevent the reception of mistaken data.

Also, to allow tuners to scan other frequencies and services, so called gaps are introduced. The service declares how many non-8A RDS groups are inserted in between two consecutive 8A groups. The tuner can then safely use the time of the gap to scan other frequencies without being in risk of losing an 8A RDS group.

3 LOGICAL CONTENTS OF RDS AND ITS MAPPING TO XML

3.1 Requirements to the Logical Structure of RDS-TMC

We deal with the problem of how to efficiently evaluate the quality of RDS-TMC. To understand the content, we process raw RDS data and store the results in XML files. The information in XML shall be organized in such a way that it is easily accessible and does not require too much processing. The following list shows the necessary information we have to store in order to understand and to be able to evaluate the quality of RDS-TMC service.

- General information (regardless TMC content);
  - Station name (i.e. Regina);
  - Frequency of the station (i.e. 96,2 MHz);
  - Duration of recording period in seconds (i.e. 60 seconds);
  - Start and stop time of recording period (in UTC, i.e. 2011-01-03T14:23:25Z);
- Message information (for each TMC message);
  - Message identifier, version and number of reception (i.e. uuid="{46fb4867-8104-47d4-9d30-dca80e0105ea}", count="3891" version="1");
  - Number of 8A RDS groups forming the message (i.e. groups="3");
  - Time of first and last reception (i.e. <T1ST>2012-09-23T01:19:10Z</T1ST>);
  - Message start and stop time (i.e. <TSTO>2012-09-27T22:00:00Z</TSTO>);
- RDS quality information (related to errors in the reception of a signal);
  - Number of valid, corrected and invalid RDS groups (some bad groups can be repaired (labeled as corrected) which is worth knowing);
  - Statistics of RDS group types detected and the number of groups received (to find out if the channel is used at its optimal capacity);
  - Gaps between groups 8A detected and their counts (shall be same as indicated in TMC information groups);
  - 8A groups immediate repetition (for rejection of erroneous TMC messages).

The time period of testing can be sometimes be quite long and it is practical to split the XML data into some reasonable time slots, such as 1, 5 or 15 minute long. To make the processing easier, it is practical to include at the beginning of each XML file all messages which are valid at a given time. In this way, each file is self contained and there is no need to search for valid messages in the preceding files.

The RDS-TMC standard defines a so called virtual terminal as a logical model of a virtual device receiving RDS-TMC information. There are rules on how long the terminal shall keep each received message as valid. XML shall contain a container, called a snapshot, which is able to hold all the valid messages which are in the virtual terminal at the beginning of a given time slot. A snapshot (one record per unique message) contains messages in the same structure as messages received during the time slot (all - not only unique - messages are in this tag, so if one exact message was received 100 times it will be presented that many times). In order to evaluate the service RDS parameters have to be stored somewhere in the XML file, parameters such as received RDS groups (valid/invalid/corrected), percentage of RDS group types, etc.

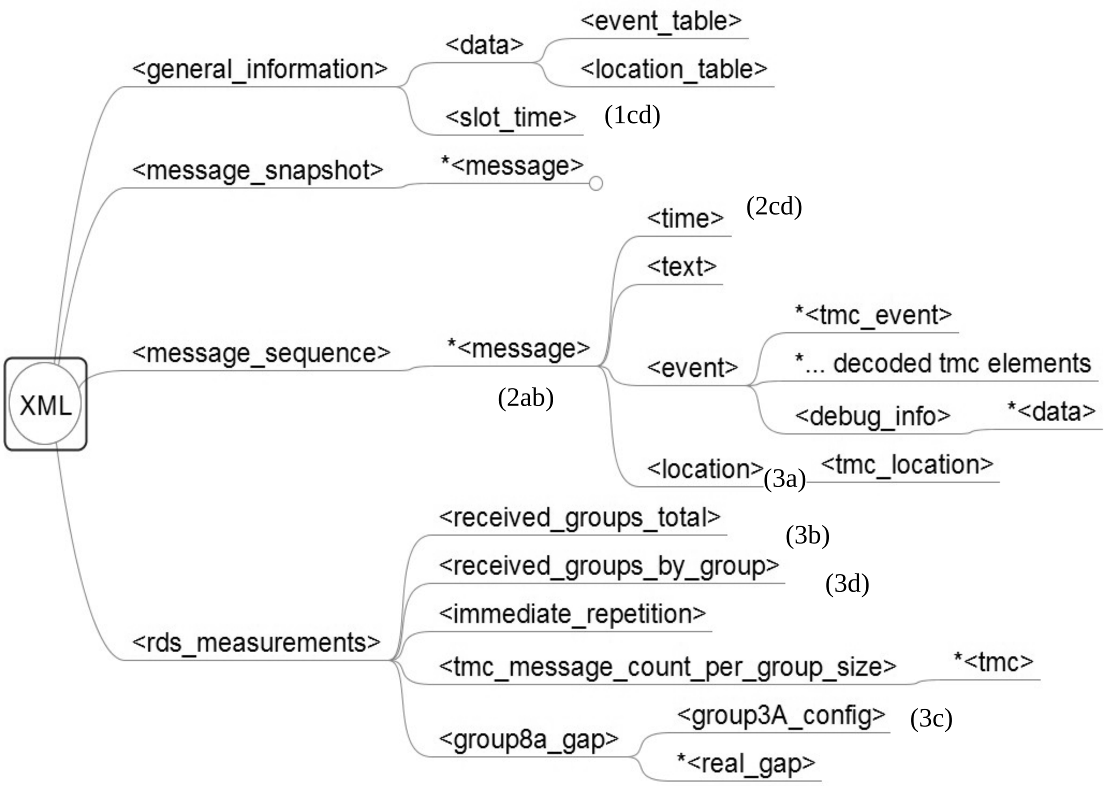


Figure 1: Example mapping of logical structure of RDS-TMC into XML[1].

3.2 Mapping of RDS-TMC Information to XML

Each logical element defined in section 3.1 has to be transformed into a structural element as a part of an XML structured message. RDS standards and TMC standards were formally analyzed for all possible information elements. These elements have then been translated into XML elements and nested in a proper structure. Some of the items in figure 1 are mapped to list items in section 3.1 through sequence numbers of the list items, i.e. (2a) refers to a message identifier, version or number of reception. Some elements in the figure are not mentioned in previous list; an explanation of these is provided (even though it is not necessary, since the figure is in the paper just to prove the necessity of a transposition of a “list of items” to a machine readable code). The resulting XML document has been

[1] Asterisk in the image means possibility of repetition of the element in the structure (multiplicity)

viewed from the perspective of the user and processing software, this led to a changed structure (Figure 1) and added elements for faster computer processing like element debug_info. Each xml file holds a snapshot of a virtual terminal in the tag <message_snapshot> and a sequence of received TMC messages in the interval of recording (for an explanation see section 3.1) so it can be said that the general container “message information” was split into 2 more concrete ones that allow the recovery of all information from just one xml file, rather than from a collection of successive xml files if a snapshot element was missing. Other elements in the figure are just to give a more detailed view of other self-explanatory necessary elements, like a lite version of a location table.

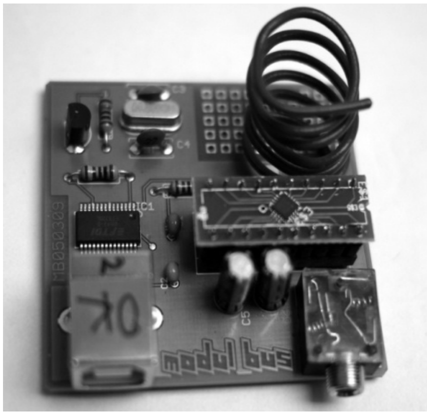
4 SETTING UP AN RDS-TMC SERVICE EVALUATION CHAIN

RDS data shall be received, recorded, then converted into XML documents and finally evaluated and possibly presented. These steps may be connected in real-time, or could be evaluated off-line.

4.1 RDS-TMC Data Recording – ModulBusRds

We were looking for a device which allows the receiving and providing of RDS data to a PC connected over USB; to allow the PC tune the frequency; and is small and easy to use. Even though RDS is quite an old technology, we had a real problem with finding a suitable solution.

We considered 5 devices and after several trials we decided to use the PC-Radio SI4735 Set even though we had to write our own drivers for I2C communication with the embedded radio chip.



```
>modulbusrds.exe –f 96.5 –g –w MB2
# Opening radio [MB2 - ModulBus v2]...
# Tuning [96.5 MHz FM]
321C814811910023;00;60;96.5 MHz;27.12.11 11:05:28
321C21534C61676F;00;60;96.5 MHz;27.12.11 11:05:28
321C0148E0CD2020;00;60;96.5 MHz;27.12.11 11:05:28
321C0149E0CD504C;00;60;96.5 MHz;27.12.11 11:05:29
321C8143C9910026;00;60;96.5 MHz;27.12.11 11:05:29
321C014AE0CD5553;00;60;96.5 MHz;27.12.11 11:05:29
321C014FE0CD2020;00;60;96.5 MHz;27.12.11 11:05:29
321C2154646E6520;00;60;96.5 MHz;27.12.11 11:05:29
321C8143C9910026;00;60;96.5 MHz;27.12.11 11:05:29
```

Figure 2: RDS receiver PC-Radio SI4735 Set and the resulting stream of RDS data.

Our program, called ModulBusRds, controls the PC-Radio SI4735 Set and provides output complying with the format (see Figure 2) used by TIC Radio from the company GEWI, even though we are planning small modifications showing time in ISO format and with fractions of seconds. The output of the program can either be stored on PC in files or pipelined to an application for processing TMC information or both.

4.2 Converting Raw RDS Data to XML Files – TmcCruncher

Output from ModulBusRds can be fed to an application, called TmcCruncher, which is actually creating the XML files described in this paper. All TMC message test than could be handled internally using the XML message as the source document.

The next figure is a print screen of an XML file containing example messages with real values. In this example the following setup was used. Message content presented in message_snapshot element is zero, because the reception has just started. Element message_sequence contains just one multi group message (Figure 3, lines 12-29), which means only two 8A (x2 repetition) groups were received during the whole 60 s measurement period. This is also reflected in the element rds_measurement (Figure 3, line 32).


```xml
1  <?xml version="1.0"?>
2  <doc>
3      <general_information station="  PLUS   96.50 MHz" transmission="FM" period="60">
4          <data>
5              <event_table version="2.01" language="en"/>
6              <location_table version="2.41" number="6" country="3"/>
7          </data>
8          <slot_time start="2011-12-27T13:04:24Z" stop="2011-12-27T13:05:25Z"/>
9      </general_information>
10     <message_snapshot unique_messages="0" received_messages="0"/>
11     <message_sequence unique_messages="1" received_messages="1">
12         <message uuid="{4b68ab24-9318-41e8-81a8-52d4c82e238c}" received_count="1"
13         version_type="update" groups="2" alertc-id="38-5">
14             <time first_reception="2011-12-27T10:05:29Z" last_reception="2011-12-27T13:03:35Z"
15             start="2011-12-27T13:03:35Z" stop="2011-12-27T14:03:35Z"/>
16             <text/>
17             <event urgency="U" directionality="1" duration_type="L" duration="0" diversion="false">
18                 <tmc_event eventcode="401" updateclass="5">closed</tmc_event>
19                 <separator/>
20                 <tmc_event eventcode="641" updateclass="5" eventorder="2">one lane closed</tmc_event>
21                 <debug_info>
22                     <data label="14" data="0"/>
23                     <data label="9" data="641"/>
24                 </debug_info>
25             </event>
26             <location>
27             <tmc_location primary_code="38" extent="1" direction="-"/>
28             </location>
29         </message>
30     </message_sequence>
31     <rds_measurements>
32         <received_groups_total valid="684" corrected="1" invalid="0"/>
33         <received_groups_by_group grp0A="400" grp2A="157" grp3A="24" grp4A="1" grp8A="2"/>
34         <immediate_repetition repetition="2"/>
35         <tmc_message_count_per_group_size>
36             <tmc type="single" size="1" valid="0" invalid="0"/>
37             <tmc type="tuning" size="1" valid="0" invalid="0"/>
38             <tmc type="multi" size="2" valid="1" invalid="0"/>
39         </tmc_message_count_per_group_size>
40         <group8a_gap>
41             <group3A_config gap="3" m="basic" sid="7" ltn="6"/>
42             <real_gap gap="3" count="171"/>
43             <real_gap gap="4" count="1"/>
44             <real_gap gap="5" count="1"/>
45         </group8a_gap>
46     </rds_measurements>
47 </doc>
```


Figure 3: Example of XML message generated from RDS-TMC data.

Such an XML file can be used for information about current valid messages (snapshot) and message flow during the measurement period (sequence). The message sequence is vital, because if, for example, some message starts and ceased to exist during one measurement period it will be reflected only in the element message_sequence, since the element message_snapshot contains only a list of messages valid at the start of the measurement period.

4.3 Evaluating TMC Content in XML files

Evaluation of a couple of days of raw RDS data, converted into XML files with a time slot of 1, 5 or 15 minutes is a challenge, involving a large quantity of XML files. We use XQuery language that allows such processing in a very effective way. For the processing itself we use an Open Source XML database tool called BaseX (BaseX, 2011), that provides the latest XQuery specification and offers a very comfortable GUI.

For the standard tests a set of XQueries has been developed which can be run after all the XML data are imported into the BaseX database. Therefore, almost a complete evaluation can be performed automatically within a few minutes.

The following table shows the results of such a query performed on a larger volume of XML files with the task to obtain an overview of the evolution of TMC characteristics of received messages, such as locations and events. A description is added to each element after the symbol %.

Table 2: Sample (shortened) result of quick data evaluation created using XQuery.

Sample INF element code
<result groups="1 2" *% TMC messages were formed from 1 or 2 RDS groups* event_code="1622 1602 701 401 505 ... 1627" *% event codes in all messages* update_class="20 11 5 2" *% classes of the above event codes* primary_code="82 140 156 .. 8517 63" *% location codes (pointers to) from location table* direction="+ -" *% directionality of all messages* extent="1 4 3 2 8 5 6 7" *% extent used in all messages (span over x locations)* urgency=" U" duration_type="D L" *% urgency and duration used in all messages* currently_valid_msgs="0 52 92 122 122 122 116 118 ... 125" *% snapshot messages* unique_msgs_count="2160" *% number of unique messages received* received_messages="1 2 3 ... 2604 2605" *% unique messages repetition* max_received_count="2605" *% maximum repetition of a single message* diversion_recommended="false" *% diversion recommendation from all messages* msg_directionality="1" /> *% directionality from all messages*

4.4 Presenting Results on-line on the Public Website – SIMILE Gadgets and Exhibit

Using BaseX, Python and SIMILE Gadgets technology (MIT. SIMILE, 2011), we have a prototype public website where any user with a common web browser can evaluate current data in time and location context with the possibility to do many kinds of data filtering on-line. This is currently a work in progress and can be seen at http://live.rds-tmc.cz.

5 CONCLUSIONS

The solution for a user friendly presentation of the RDS-TMC service has been developed; the solution consists of the reception of raw RDS data, conversion into XML files, evaluation of almost any aspects using XQuery and XML database BaseX and finally the presentation of results on the web using SIMILE Exhibit. The conversion is the most significant achievement, as it makes the RDS TMC content really tangible, and, at the same time, was the most difficult part of the project.

From the start of the project we have recorded more than a year of continuous reception of two of the most prominent Czech RDS-TMC services (NDIC at 105.00 MHz and TIC Prague at 92.6 MHz). The stored XML files are already being used for a detailed service analysis to uncover the sometimes faulty settings of services and to report this to their providers.

In the near future we plan to fine tune the format of raw RDS data (time in ISO format showing fractions of seconds i.e. 2011-01-03T14:23:25,99Z) and enhance the XML format to also show some subtleties, such as RDS TMC service related changes during the analyzed period.

ACKNOWLEDGEMENTS

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Concept of the Mechanically Powered Gyrobus

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ABSTRACT: The new gyrodrive concept is an innovation of the mechanical gyrobus transmission by Hampl & Vítek (2006). The legitimate aim of substituting urban buses with zero emission vehicles is actually very difficult to achieve. First of all, no existing non-rail vehicle for urban mass transport can compete with urban buses in terms of cost. Even trolleybuses on the busiest lines are less economically efficient. In addition, they lack the flexibility of buses. Electrobuses with their heavy and slow to charge accumulators are almost as expensive as fuel-cell buses whose specific problem is refueling with compressed or liquefied hydrogen. A gyrodrive does not face such problems and it is also reasonably safe. But even a modern electric system for power transmission from the flywheel to the driving axle is neither light nor cheap. A mechanical solution with CVT (Continuously Variable Transmission) can be more advantageous. Such a system has been used for the recuperation of braking energy. The mechanical system described in this article uses an IVT system (Infinitely Variable Transmission) for the vehicle drive. If that system is used for flywheel charging at the terminal, it will be connected as a CVT (by using an external three-phase 50 Hz electromotor). The higher-than-average requirement for transmitted power should be met by the suggested special CVT solution with rigid friction members. Thanks to its planetary configuration it has acceptable dimensions and mass. The slip minimization and the fact that the pressure forces do not load the bearings should ensure good efficiency.

KEY WORDS: Gyrobus, mechanical power transmission, CVT, IVT, planetary differential.

1 INTRODUCTION AND MOTIVATION

1.1 History

The first electrically driven road vehicles independent of a trolley wire were made in Europe and in the USA as early as the late 19th century. These included mainly vehicles with electrochemical current sources. Such sources have prevailed in electrocars and electrobuses up to now. But despite long and concentrated research on electrochemical sources, the relationship between their price and lifetime is still almost unacceptable for use as a vehicle drive. They also have other undesirable attributes: in the case of fuel cells, used now in many experimental vehicles, in particular electrobuses, the main problems concern the distribution and refuelling of expensive hydrogen, whether in compressed or liquefied form (Ingvarsson et al., 2011). Problematic attributes of electrochemical accumulators are as follows: relatively slow charging (particularly towards the end), insufficient reliability, energy capacity reduction during their lifetime, power and exploitable energy capacity linked to temperature and the destructive influence of a deep discharging on the battery lifetime.

Such disadvantages are not associated with kinetic energy accumulation. However, flywheels have another serious drawback: fast self-discharging, which makes their use in electrocars almost impossible. However, this is not relevant for urban mass transportation vehicles. They have regular and short routes with breaks at terminals where there is enough time for charging the flywheel fully (but not for fully charging any electrochemical accumulator). This is how the idea of gyrobus came about.

The first regular gyrobus transport started in Switzerland in October 1953, on a 4.5 km-route between Yverdon-les-Bains and Grandson. The most extensive use of those gyrobuses was in Leopoldville (today's Kinshasa in the Democratic Republic Congo, Africa) where they operated until 1969.

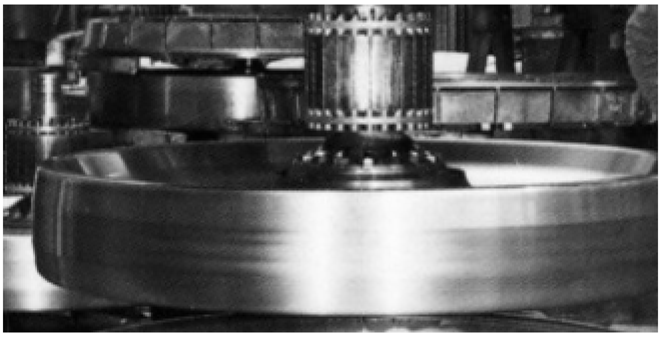


Figure 1: Rotor of the asynchronous motor-generator and steel flywheel of the FMO gyrobus.

Their gyrobus drive was developed by the Swiss company Oerlikon. Its flywheel of compact steel had a vertical rotation axis and an external diameter of *1.6 m*. Its mass was *1500 kg*. It was coaxially connected to an asynchronous motor-generator. During the "refuelling" (about 4 minutes, *150 kW*) the motor-generator was powered from the common three-phase *50 Hz* network by using bar collectors on the vehicle roof. The maximum motor speed was *2900 rpm* and its minimum operation speed was *2300 rpm*. Therefore *63 %* of the accumulated energy was non-utilizable. When the vehicle was running this asynchronous generator supplied the current to the three-phase asynchronous traction motor. The main control was performed in steps by switching over of the poles.

1.2 Present Solutions

Current technology allows a step-less and entirely smooth control of flywheel propulsion over a wide running speed range, and also minimizes the consequences of unlikely material destruction. That is to say that in the area of inertial energy accumulation a lot of theoretical and experimental work has been performed with positive results, particularly in the USA. The new "super-flywheels" make use of light materials such as glass type E, aramid or carbon. In the form of a filament they are extremely strong. A wound flywheel can also accumulate more energy due to the permitted low safety coefficient (a ruptured filament will be disarmed by the flywheel box without endangering passengers or pedestrians).

In order to eliminate ventilation losses such a flywheel runs in a vacuum and it is directly connected to a synchronous motor-generator whose rotor has permanent magnets, e.g. made of Fe-B-Nb alloy (electromagnets would need cooling which is difficult in a vacuum).

One of the first similar solutions was an inertial accumulator developed by NASA for supplying electric energy to satellites when they pass through the Earth's shadow, where the photocells do not work (an electrochemical accumulator would work there for only a few months). Chrysler used 15 of these sources for the powering of an experimental electrocar.

More significant in this context were additional flywheel units for urban buses or trolleybuses used together with main energy sources to cover the peaks in consumption and for regenerative braking (possibly also for a short independent drive). Such units were installed by the Magnet Motor GmbH in two urban buses in Munich in 1988, and in twelve trolleybuses in Basle in 1992. Their carbon filament flywheels had a maximum speed of *12,000 rpm*. Their relatively high extra mass was also unfavorable for use in road vehicles.

The Kinetic Energy Recovery Systems (KERS), with a mechanical transmission of power using CVT, are lighter. For example, the company Hybrid Automotive Limited has developed the Flywheel Hybrid System for Premium Vehicles (FHSPV for Jaguar XF prototype). Another of their sets designed to meet the FIA regulations for Formula One is shown in Fig. 2. Its accumulated energy is *400 kJ* (*60,000 rpm*), its additional power *60 kW* (limited by its toroidal CVT). Its total weight is *25 kg* and volume *13 litres*.

Figure 2: Flywheel unit combined with the TOROTRAK CVT as auxiliary drive for F1 racers.

Concerning rail vehicles, the increased price due to the installed flywheel unit is not dramatic and the mass increase is hardly relevant. Therefore, an auxiliary flywheel unit made by the rosseta Technik GmbH was installed into the LIREX articulated train produced by Alsthom LHB. Its carbon fibre flywheel had a net mass of *160 kg*, a maximum speed of *25,000 rpm,* a maximum accumulated energy of *6 kWh* and a maximum output of *350 kW*. Its specific energy of *135 kJ/kg* was comparable to that of CD-Ni accumulators. (The new lithium batteries, e.g. $LiFePO_4$, have a higher specific energy but such a flywheel can outperform them in terms of power. Its lifetime, measured in cycles, is more than 1,000 times longer.)

The flywheel together with the rotor of the motor-generator runs in its box on ball-bearings lightened by permanent magnets. The bearing losses do not exceed *200 W* but the losses in the motor-generator during its idle run were *3.5 kW* (causing fast self-discharging). Therefore, the producer recommended its use only for applications where charging or discharging lasts only about ten minutes. Our intention is to significantly extend that time by a radical restriction of self-discharging so that the flywheel could be used as the only energy source for the gyrobus drive. Furthermore, we want to increase the total efficiency (Dede et al., 2012) and reduce the mass of the entire gyrobus propulsion unit to the level of a standard bus engine-gearbox assembly. We also aspire to cut the price of the unit.

2 PRINCIPLE OF THE NEW GYROBUS DRIVE

We expect to use a nearly identical design for the composite flywheel as noted above but we will replace the electric power transmission from the flywheel to driving wheels with a fully mechanical one. An Infinitely Variable Transmission (IVT) will be used for this purpose. This should result in a substantially decreased self-discharging, increased total efficiency and a smaller mass. The price is also expected to decrease.

A disadvantage of the mechanical transmission is the leeway loss due the dislocation of drive components in the vehicle. Concerning the placement of the flywheel, a parallel orientation of its rotation axis to the vehicle's transverse axis would be favorable because if the flywheel rotation is reverse to the vehicle wheels rotation the gyroscopic moment counteracts the tilting torque of the centrifugal force during vehicle turning (Shaobo & Shuyun, 2012). The rpm has a linear influence on the gyroscopic moment but a quadratic influence on the accumulated energy. So, if a high speed flywheel and a low speed one have the same accumulated energy, the high speed flywheel will have a lower gyroscopic moment. Therefore, its axis orientation is not very important (for example, in the case of our gyrobus the maximal lateral force on the axles generated by both flywheels during very rapid turning of the vehicle can reach approx. 1 kN).

Due to the low-floor concept the drafted gyrobus has an individual drive for each rear wheel. Therefore, two flywheels are used. They are placed tplajerogether with the IVT systems under fours of passenger seats (2 + 2, dos à dos on the elevated floor). Similarly, under the next four seats the driving wheels are situated, see figure 3:

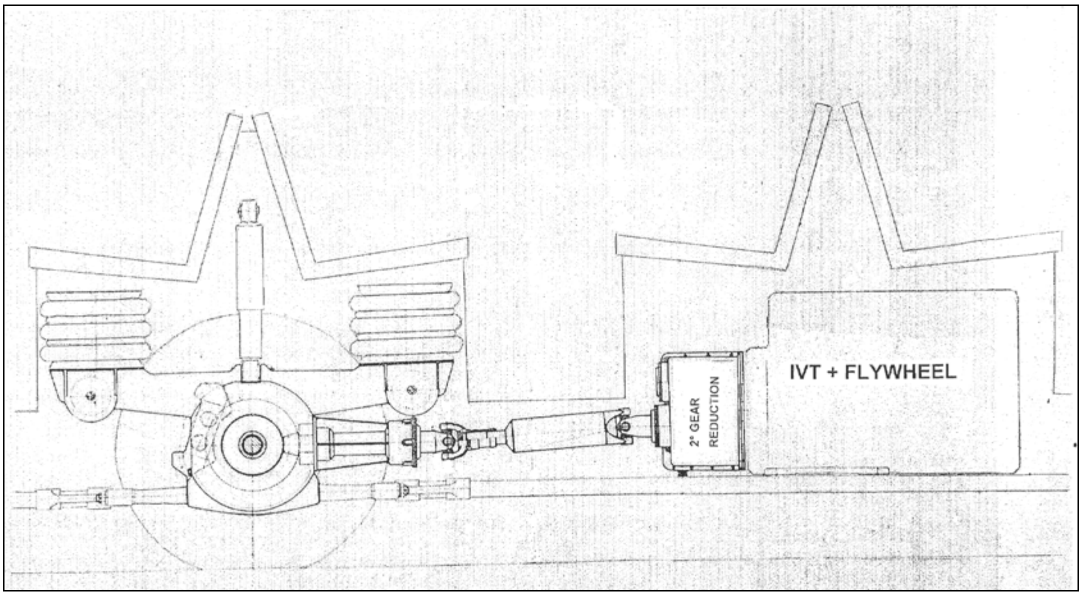


Figure 3: Scheme of individual drive for each of both rear wheels of the low floor gyrobus.

The flywheel rotational axes are parallel with the longitudinal axis of the vehicle. The special drive of the rear wheel is illustrated in figure 4.

In order to minimize ventilation losses there will be a vacuum in the flywheel box and rarefied hydrogen in the IVT box. Compared to air, hydrogen has half the kinematic viscosity, 14 times lower specific mass and better conducts away the heat produced. The vacuum in the flywheel box must be renewed by an on-board exhauster (at terminals only). The hydrogen infiltrates into the flywheel box from the IVT box along the shaft sealing, and into the IVT box from the bearing inter-space where it is replenished from a small container. The filling pressure must be slightly higher than the atmospheric one so that no explosive mixture can result due to air penetrating from the outside.

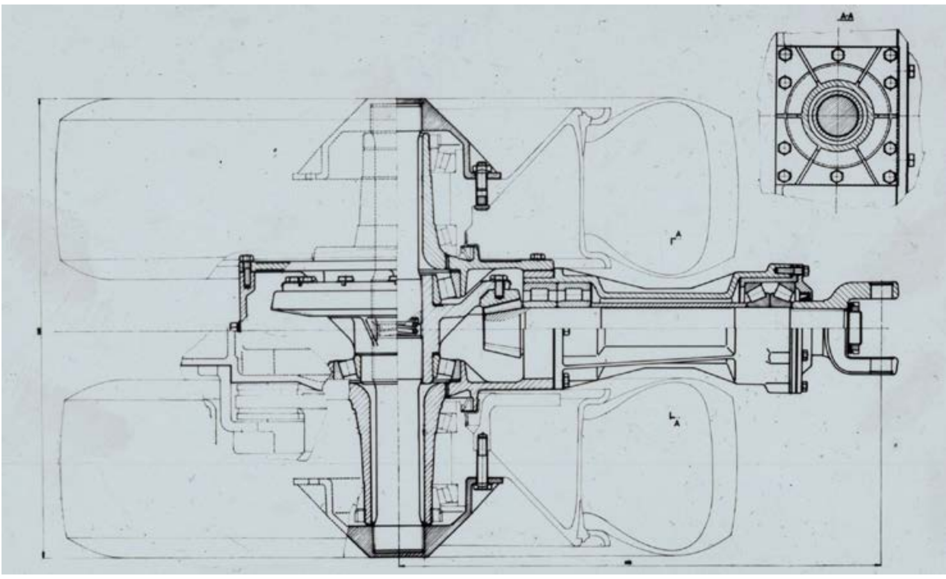


Figure 4: Special drive of the rear wheel (inner tyres are mountable from the vehicle interior).

3 THE NEW CVT AND ITS OPERATION AS IVT

Currently produced CVTs are installed into cars with a considerable output surplus available so that the CVTs mostly transmit only a small part of the presented maximum torque. Also, the number of service hours is far lower for cars than for urban buses. Therefore, such CVTs would not work well for a gyrobus. However, this is not the only reason - they are not high-speed enough either.

Therefore, our draft considers an IVT that is based on the planetary CVT presented in figure 5 (next page). This planetary CVT outdoes existing CVTs with rigid friction members by:

- small dimensions, mass and moment of inertia in relation to the transmitted torque;
- allowing transmission of big tangential forces due to a high number of contact facets between the friction elements (48 co-operating facets between disks and double-cones);
- a total absence of the “spin” slip type;
- using the mechanical transmission ratio control (energy savings due to the absence of a hydraulic pump);
- a small slip forced by geometry (“creep” type) due to the differential linkage of the parallel friction elements as are illustrated in figure 6;
- axial pressure forces (figure 7) avoiding the bearings; it ensures, together with the small slip, good efficiency;
- a low value of Hertzian pressure between (see figure 8); the maximum Hertzian pressure (*1.35 GPa* - TOROTRAK admits *4 GPa*) is achieved in sporadic cases only: when a big output at the minimum operating r.p.m. is required during the maximum or minimum transmission ratio; this ensures the long life of friction elements without requiring any extremely high quality material for them.

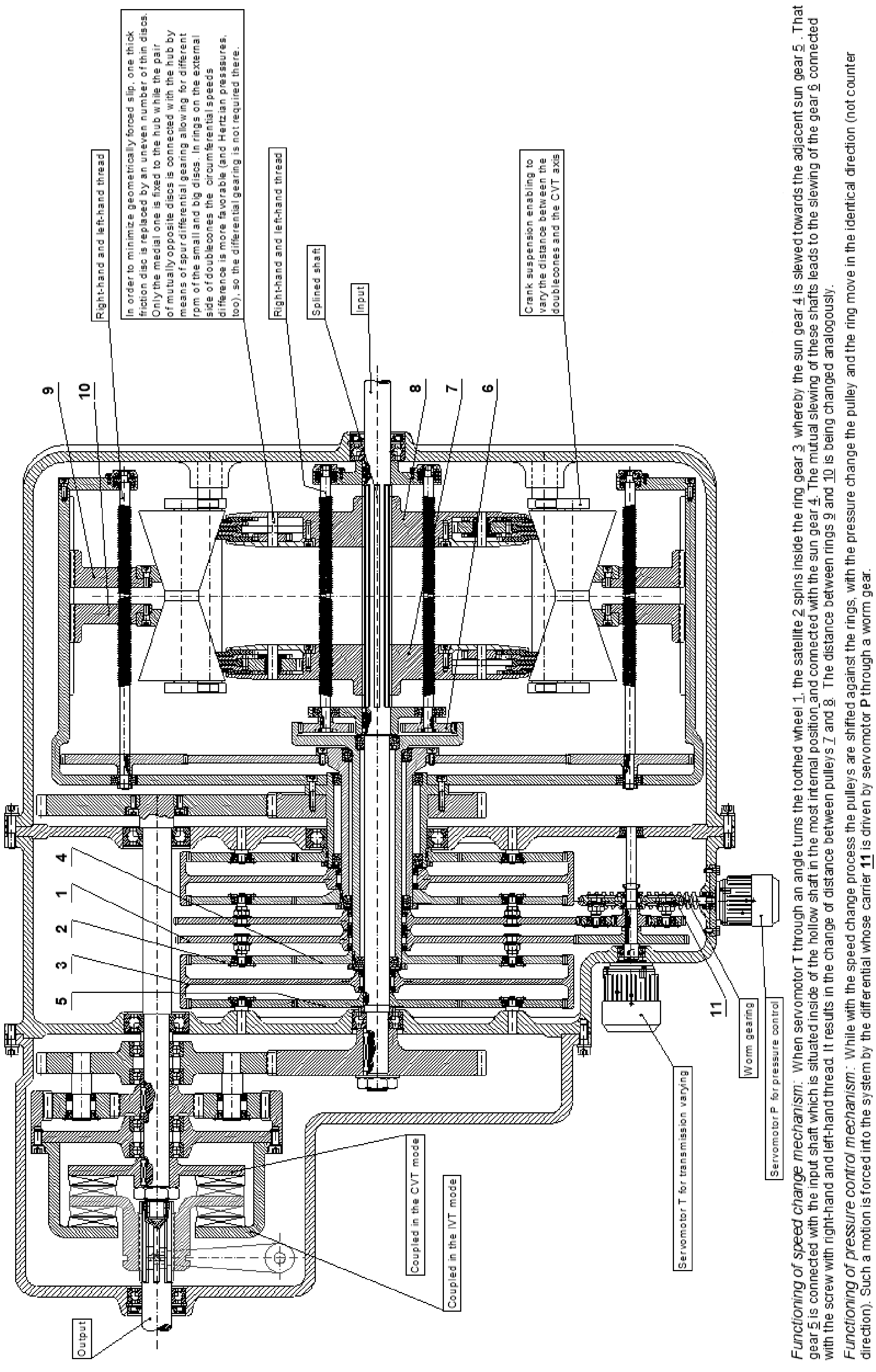


Figure 5: Hypothetic scheme of mechanically controlled IVT (both pressure and gear ratio are actuated).

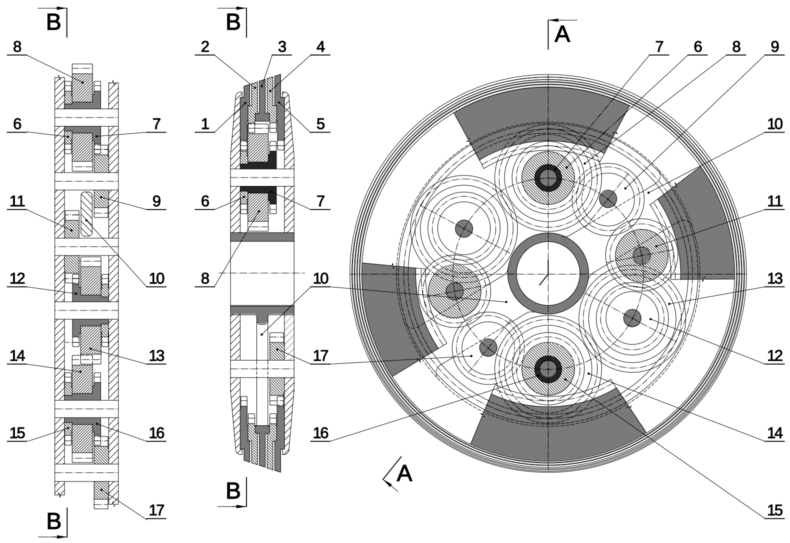
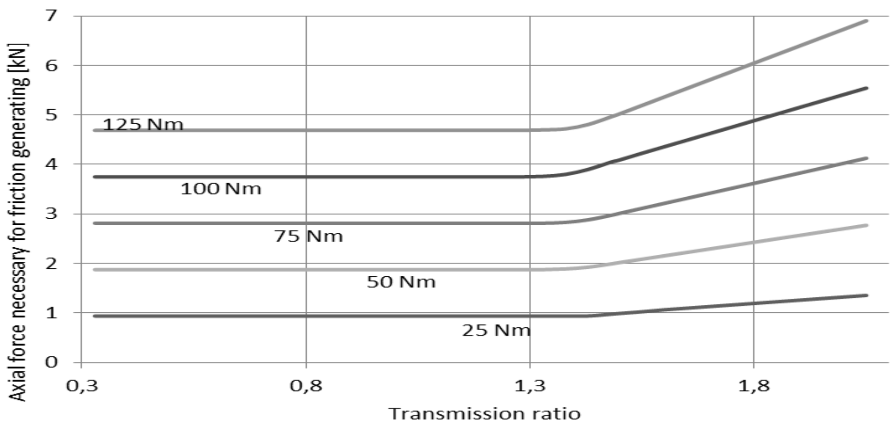


Figure 6: The conic pulley composed of discs forced to rotate with uneven rpm when rolling.



During the rotation and at a steady transmission ratio the axial forces between rings and double-cones are equal as between pulleys and double-cones (the rotation “nullifies” the friction in direction of the cone surface straight line). In the horizontal parts of curves the input torque requires bigger axial force than the output torque and vice versa in the inclined parts.

Figure 7: Axial forces between friction members depending on torque and transmission ratio.

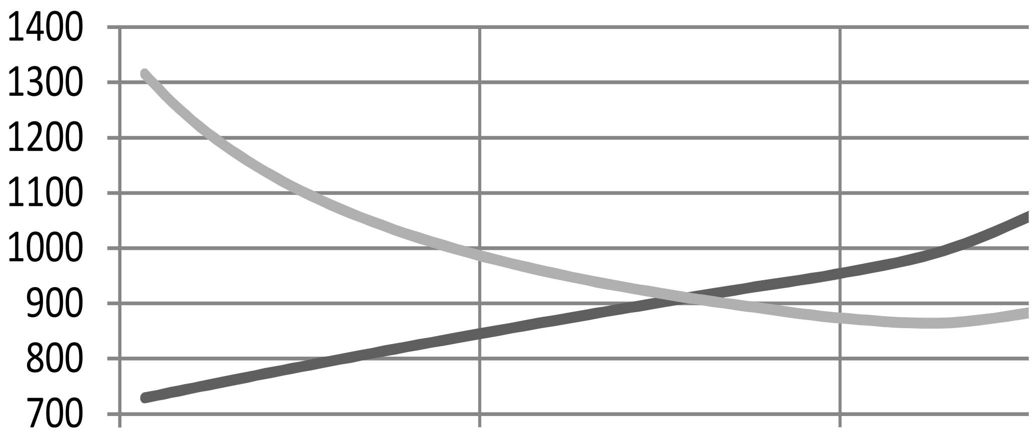


Figure 8: Hertzian pressures [MPa] at maximum input torque (125 Nm).

The mechanical control of the transmission ratio change is implemented by a mutually opposite shift of friction disks (and rings) by means of screws with right-hand and left-hand threads (Fig. 5). This ensures a permanent perpendicularity of pulleys and rings to the rotational axis during their shift. The mechanism concerned is driven by an energy saving electric servomotor. Mechanical actuation is also used for the mutual thrust of friction members by using a worm gearing for the second servomotor. This type of self-locking gear makes it possible to nullify its incoming power when the thrust maintains a steady value.

3.1 Modes of Transmission System

It is not possible to control the speed of a gyrobus (unlike bus and trolleybus) by varying the power source rpm. There is only one method for doing this: continuous varying of the transmission ratio. The variability range must be considerable, also owing to counteractive changes (when the vehicle speed increases the flywheel rpm goes down and vice versa).

For our purposes current mechanical CVTs have insufficient transmission ratio. We can extend the ratio if the CVT collaborates with a differential, changing the transmission into an IVT (Infinitely Variable Transmission). Then the vehicle can move without using a clutch and it will be possible to decelerate and stop without using friction brakes. In the IVT mode the flywheel will be connected to the differential in two ways: both directly (e.g. with the planet carrier) and by means of CVT (e.g. with the sun wheel). Then three different modes can be identified at the output (ring gear):

- Pseudo-locking mode. Although the connection of the flywheel with the vehicle driving wheels is not interrupted the vehicle is stopped as if the parking brake had been used. In this mode the sun wheel (driven by the CVT) turns round faster than the planet carrier in order for satellites to roll in the stopped ring gear. Such a situation occurs when the CVT transmission ratio is nearly the quickest one.
- Reverse. The absolutely quickest CVT transmission ratio is used (the return motion does not require any gear shifting).
- Driving forwards. When the CVT transmission ratio starts getting slower (from the pseudo-locking mode) the sun wheel rpm decreases; however, without any rpm change of the planet carrier connected to the flywheel. Therefore, the ring gear starts rotating in the same direction as the planet carrier and the sun wheel. The vehicle starts moving forwards.

During the pseudo-locking mode the output taken from the flywheel circulates inside the IVT and the energy is being dissipated by its internal resistances. Nevertheless, the IVT output torque $M_{out\ IVT}$ is several times bigger than the CVT output torque $M_{out\ CVT}$ (in a situation where the differential operation is disconnected and when only the CVT is working). The corresponding multiplication factor depends on the efficiency η of the circuit in which the energy circulates.

$$M_{out\ IVT} = M_{out\ CVT} * \eta / (1 - \eta)$$

The multiplication factor of the torque decreases by moving away from the zero transmission ratio, and the energetic efficiency increases. However, it remains significantly worse than without differential linkage.

Therefore, we disconnect the differential linkage after the transmission range depletion towards the slow output rpm. The IVT will, therefore, change into the CVT, which has better efficiency. Before disconnection the ring gear rpm increase to the level of the planet carrier rpm due to the deceleration of the sun wheel rotation (the rpm of the sun wheel and ring wheel equalize) and so the planetary gear set start to revolve as a whole. Consequently, the changeover of the output withdrawal from the sun wheel to the ring wheel runs totally without shock. After the shifting, the CVT transmission ratio starts to return from the slowest value to quicker values causing the vehicle to accelerate.

Automatic stepped gearboxes present the problem of undesirable alternating up- and downshift at the boundary between adjacent speed gears. Vehicles with combustion engines have solved the problem by shifting up at a higher vehicle speed than for downshift. This is not possible for a gyrobus with mechanical transmission because a shock-free shifting between IVT and CVT is possible only during the slowest CVT transmission ratio. The alternating gearshift mode cannot be totally excluded but the probability of its occurrence is very low. It can only arise when the change of flywheel rpm is exactly identical to the change of the vehicle speed during the slowest CVT transmission ratio. Furthermore, such an alternating gearshift represents no danger for the driving system. Only the driver would notice it and he can easily stop it (a tiny change of power would be enough).

The driver sets the required value of the output torque using the accelerator. The difference between the required and the actual value determines the velocity of the transmission ratio change and, consequently, the flywheel deceleration. The same applies to the brake pedal in the recuperative braking mode when the flywheel accelerates.

Both the driving force and recuperative braking force will be limited by the control system:

- if the maximum value of the CVT torque is achieved,
- if the maximum vehicle speed is achieved,
- if the set maximum output is achieved (so that the vehicle dynamics are not influenced by the level of the flywheel charge).

3.2 Energy Recharging

The most important part of the charging station at the terminal are two common three-phase two-poles electromotors with a short-circuit armature, *50/60 Hz, 6 kV,* approx. *150 kW*, connected to the gyrobus by sheathed articulated shafts. During charging their non-variable rpm are changed into ascending rpm of the flywheel by the same CVTs used to drive the vehicle after moving off (during charging the differential linkage changing CVT into IVT will not be used). Unlike an electrochemical accumulator, the charging accelerates with the increased accumulated energy. Full charging takes 4-5 minutes.

If, exceptionally, it is necessary to start running the flywheel from a total standstill, the external electromotor will also start running from standstill (with Y-connection).

At the terminals, the on-board *24 V* (or *42 V*) $LiFePO_4$ battery will be charged from an on-board quick-charger connected to the external *220/380 V* network together with a quick-charging heat reservoir (approx. *75 kW*, *5 kWh*) and with the exhauster and air-compressor electromotor.

4 SAFETY OF GYRODRIVE

4.1 Reduction of Damage Caused by Flywheel Collapse

With regard to the high circumferential speed of the flywheel (up to 2800 km/h) it is necessary to protect the flywheel box from ruptured fibres (Wisnom et al., 2010). The moment of friction could even release the flywheel box from its attachment. In order to protect the box we use a thin ring of carbon laminate which has a little smaller diameter then the flywheel box inside. The pressure of the ruptured fibres extends the ring diameter, so the ring presses on the box and the flywheel decelerates intensively. Graphite coating on the outer surface of the ring reduces the friction coefficient and improves the heat removal. The kinetic energy of 39 MJ of the fully charged flywheel would change 15 liters of 20 °C water into 100 °C steam. Therefore the flywheel box will be surrounded by a housing and through the so-created interlayer a coolant will flow. Definitely, the emergency flywheel deceleration will be more intensive if air is let in Ribeiro et al. (2012).

4.2 Flywheel Safety in Case of a Vehicle Accident

The obligatory most severe destructive test of a bus (which applies to a gyrobus) is the overturning test according to Regulation No. 36 ECE. Such an accident represents no danger for the flywheel if situated outside the deformation zone. This Regulation does not require barrier crash tests. With respect to a bus impact into a non-deformable barrier (*50 km/h*), the specialists' opinion is that the deceleration of the vehicle frame should not exceed $400\ m.s^{-2}$ during approx. *50 ms* (stopping distance approx. *½ m*).

Such a deceleration represents no problem with respect to the flywheel, its box and the attachment to the vehicle frame, but the choice of bearings is not straightforward. The energy losses of robust bearings are definitely not negligible. Therefore, relatively small ball-bearings are used, supported by permanent magnets. When a vehicle impact occurs, the floppy part of the flywheel box which houses the outer bearing rings will experience an elastic deformation. Thus, the rotating shaft bears on a robust friction bearing which had not operated before due to large clearance. The calculated shock force of *0.2 MN* will require about $150\ cm^2$ of sliding surface.

5 ASSUMED MAIN PARAMETERS OF THE GYROBUS DRIVE

The preliminary calculations considered a haul length of *12 km* (Mazloumi et al., 2012) and the energy taken away from two flywheels of a two-axled gyrobus of *78 MJ*. At present, composite flywheels achieve a specific energy of *150 kJ/kg* (theoretically 673 kJ/kg). So the net mass of two flywheels will be *520 kg* (estimated mass of the whole driving system will be about *1200 kg*). The power losses of freely rotating flywheels will probably not exceed *0.5 kW* and so self-discharging would only present a problem if the drive interruption lasts more than one or two hours. The friction coefficient between the friction members lubricated by a special oil was estimated to be f = 0.05 (following the experience of the TOROTRAK company). That reduces the friction losses under the theoretical values shown in figure 9:

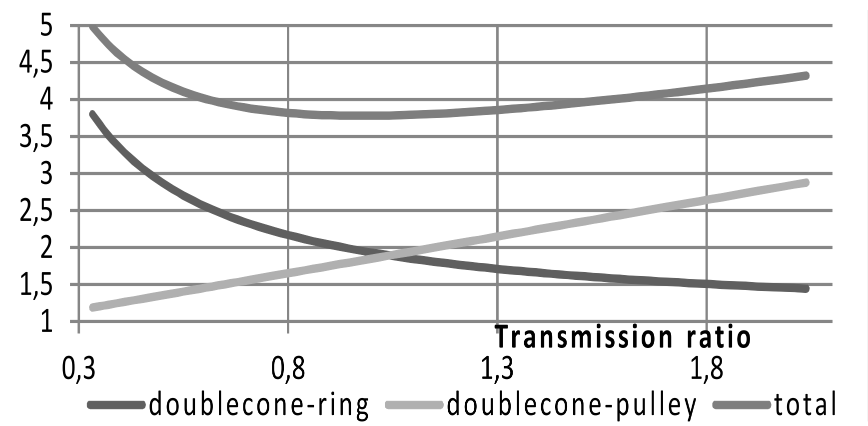


Figure 9: Slip [%] caused by the geometry of friction members rolling.

The selected value of the maximum output from the shaft of each flywheel is *110 kW*. If it is supposed to be available also at a minimum operating speed of *8400/min* (maximum *25000/min*) then the input torque of the CVT will be *125 N.m* (in all other modes it will be lower). With the rpm decreasing to *8400/min* each flywheel still holds *4.4 MJ* of energy (*11.3 %*), which may be used for a short emergency. Taking the torque *125 N.m* into account, the diameter of the IVT box will be about *300 mm*.

Even at minimum operating rpm the required maximum vehicle speed is *70 km/h*. The corresponding minimum vehicle speed in the CVT mode will be *12.9 km/h* (the transmission ratio range according to the drawing is *5.43*). With fully charged flywheels it will be *38.4 km/h*. In that case, or if only a little energy is depleted, a slower drive will have to use the IVT mode, consequently with a lower efficiency (Meulen, 2012).

That is why the drive of each rear wheel is equipped with an additional two-speed gearbox. If its low gear ($i \approx 5.5$) is used and the flywheel energy is maximal, already at approx. *7 km/h* the less economical mode IVT will be changed to the more economical mode CVT. When the speed exceeds *39 km/h*, the high gear ($i = 1$) will be used.

Gear shifting is not simultaneous for both drives of rear wheels. The transmission ratio of one drive is changed at a lower speed than for the other. If shifted, the driving force is interrupted and therefore the torque for the driven other wheel is boosted (controlled by ASR).

The planetary gear set turning a CVT into an IVT (in the differential mode) has wheels with a number of teeth in the ratio of $t_{sun\ gear} : t_{carrier} : t_{ring\ gear} = 14 : 24 : 62$.

Our draft has used rough calculations only. The following problems have not been solved at all:

- Providing for a pressure balance of parallel disks on the double-cones;
- A concept of a comprehensive control system, including a sensor for load torque;
- Transmission scheme for charging;
- Heat removal.

6 EXPECTED ADVANTAGES

- A cost-saving when substituting city buses with equally flexible zero emission vehicles;
- Reduced operating costs for routes where the substitution has been implemented;
- A more economical use of non-renewable sources (Shepherd, 2008); for example, in the Czech Republic almost 30,000 tonnes of diesel fuel could be saved annually;
- Reduced GHG emissions (Andress et al., 2011) – yearly about 60,000 tons of CO_2, 2,000 tons of NO_x;
- The possibility of utilizing the developed IVT also in other areas (e.g. ground machines, military vehicles, trucks etc.

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Health Benefits of the Low Emission Zone Introduction in Prague City Centre

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ABSTRACT: This paper presents an assessment of the economic benefits of the possible introduction of a low emission zone in central Prague restricting the access of vehicles that do not meet specified emission limits. Two variants were considered: in the first scenario entry is banned for vehicles that do not meet the EURO 2 emission limit, and in the second scenario access restriction applies to vehicles that do not meet the EURO 3 emission limit. The spatial extent of the zone is designed to cover the wider city centre, while allowing unrestricted access on the boundary roads of the zone. Using the impact pathway approach based ExternE methodology, an estimation is made of the benefits from reduced emissions of air pollutants based on dispersion modelling of primary pollutants. The scope of assessment is limited to impacts on human health only; other effects caused by air pollution (as well as other externalities) are not covered. The results suggest that the introduction of a low emission zone would likely lead to a tiny reduction in negative impacts by 1% and 2.3%, respectively, for a looser and stricter variant of the low emission zone. A policy lesson from this exercise is that if the introduction of a low emission zone in Prague is to be adopted, then thorough preparation and evaluation of alternative variants for the efficient fulfilment of the objective(s) sought should precede it.

KEY WORDS: Air pollution, low-emission zone, impact pathway approach, health benefit valuation.

1 INTRODUCTION

Prague, the capital of the Czech Republic, saw a massive growth in transport of about 300 percent (measured by vehicle-kilometres driven) between 1990 and 2011 (TSK-ÚDI, 2012). This traffic volume seriously compromises the quality of the environment for the inhabitants despite a significant improvement in vehicle emission performance and fuel quality, as well as the continuous development of the traffic network and traffic management. According to the latest report on air pollution, the 24-hour air quality limit for particulate matters (fraction PM_{10}) was exceeded more than 35 times per year at 10 out of 17 air quality monitoring stations in the Prague agglomeration, with the majority of them categorized as relevant to traffic (Ostatnická et al., 2011).

This paper deals with a stylized assessment of the health benefits from the possible implementation of a low emission zone, i.e. designing areas with a ban on the entry of vehicles that do not meet specified emission limits. Only recently has the new Air Protection Act enabled local authorities to design low emission zones, *inter alia*, when air quality limits have been exceeded (see Art. 14 of Act no. 201/2012 Coll.). Recently, two studies from Germany explored the reduction of air pollution induced by low emission zones using time-series analysis. Wolff & Perry (2011) find that the introduction of low emission zones leads to a reduction in PM_{10} levels by 7 to 9% in urban traffic areas, and Malina & Fischer (2012) suggest that more stringent emission zones can reduce PM_{10} level even further.

Two variants of a low emission zone are considered in our study; in the first variant, the entry restriction applies to vehicles that do not meet the EURO 2 (“Variant 1”) emission limit, and in the second variant the ban applies to vehicles that do not meet the EURO 3 (“Variant 2”) emission limit. The spatial extent of the zone was designed to cover a wider area of the city centre that at the same time would allow for detoured traffic on the roads on the edge of the zone.

2 METHODS

The damage function approach is a generally recognized analytical approach to the valuation of environmental and transport externalities such as impacts on the environment, human health, buildings and infrastructure (Maibach et al., 2008). This approach, also called the impact-pathway approach (IPA) in the assessment of atmospheric emission impacts, has been developed since the 1990’s in a number of projects supported by the European Commission, collectively called ExternE (Externalities of Energy). The impact-pathway approach was initially developed for the assessment of energy production (Bickel & Friedrich, 2005), but in the late 1990’s it was expanded to include the assessment of transportation (Friedrich & Bickel, 2001).

IPA tracks individual pathways from pressure to state and impact, or more specifically pathways of pollutants from emission sources (i.e. change in traffic flow and/or its composition), to receptors (population, buildings, etc.) that bear the ensuing negative effects. The physical impacts on human health (mortality and morbidity), on crops, building materials and ecosystems are then translated into monetary terms. Goods and services are traded in the market using market prices, while non-market valuation methods are used for non-market goods. Such effects are “externalities” in economic terms, i.e. the unintended impacts on the utility (or production function) of the recipient of externality (e.g. an individual afflicted by respiratory problems induced by irritating pollutants). A corresponding measure of change in benefits (welfare) is the individual’s willingness to pay (WTP), or willingness to accept compensation (WTA). The size of the changes in social welfare is usually understood as the sum of (changes of) individual benefits.

The approach taken in this paper is based on a detailed modelling of the atmospheric dispersion of primary pollutants (particulate matter, nitrogen oxides, sulphur dioxide, benzene, benzo(a)pyrene, and formaldehyde). A drawback of the Gaussian (plum) dispersion model used is that it does not allow for the accounting of secondary pollutants (such as tropospheric ozone), which would need to incorporate the chemical transformations taking place in the atmosphere into the model.

The input to the model is detailed data on individual emission sources, meteorological conditions, and data on reference points (coordinates, altitude, height above ground, character of the traffic flow). The data vary according to the type of emission sources that conventionally distinguish between area (e.g. intersections, parking lots) and line (roads) sources. The output of the model is pollutant concentration in reference points (short-term maximum concentrations and annual average concentrations). Depending on the density of the reference point network and the terrain complexity, an extrapolation to isolines and expression of impacts for concentration bands using geographic information systems is used. A formalized calculation of the physical impacts for each concentration band derived from the dispersion modelling then is

*physical impact = concentration band * population* at risk * *risk group * CR function*

where the *concentration band* is the annual (daily) concentration of the respective pollutant, *population at risk* is the age-determined proportion of the population relevant to the specific health impact, *risk group* is the proportion of the population (usually) with a higher sensitivity to a specific impact (e.g. asthmatics), *CR function* is the estimated relationship between exposure to a certain concentration band and the response in the form of a health impact (e.g. a new case of chronic bronchitis) or an increased risk of premature death. Physical impacts are then converted into monetary terms (external costs) using unit values which were determined by using valuation techniques for each impact type.

The concentration-response functions from the most recent update of the ExternE methodology (Bickel & Friedrich, 2005) are used in the impact assessment. In the case of health impacts for population sub-groups at risk, the latest Czech Statistical Office data on the age structure of the overall Prague population were used. For valuation of the impacts (effects), default monetary values contained in the ExternE methodology are used.

3 DATA

Data on traffic flows, emissions and atmospheric dispersion were elaborated in a separate study reported in detail in Karel et al. (2011). The low emission zone was designed to include the wider city centre to the maximum extent bordering the completed parts of the inner ring road (cf. Figure 1). The acreage of the low emission zone is approximately 41 sq. km.

The traffic volumes for 2009 were used in the calculations and the estimated changes in traffic after the introduction of the zone were determined by an expert estimate, not based on the traffic model (which would be the optimal approach) due to the limited scope of the study. The following assumptions (other than the known proportion of vehicles that do not meet a permitted emission class) were made:

- 20% of drivers will switch to a compliant vehicle within a short time – i.e. they will keep driving into the zone, but the vehicle will meet the applicable emission limit;
- 30% of vehicles will no longer enter the zone – their drivers will use public transport or other means to address their needs in the city centre (internet, telephone, taxi, etc.);
- 50% of vehicles will bypass the zone – their destinations are outside the zone.

The respective zone entry restrictions reduce the traffic flows by the following amounts (per vehicle categories passenger cars / light duty vehicles / heavy duty vehicles / buses) – 36%, 26%, 33% and 43% in variant 1 and 57%, 47%, 61% and 69% in variant 2. Based on the assumption that a part of automobile traffic will move to alternate routes, the increase in emissions on the zone’s borders was also taken into account.

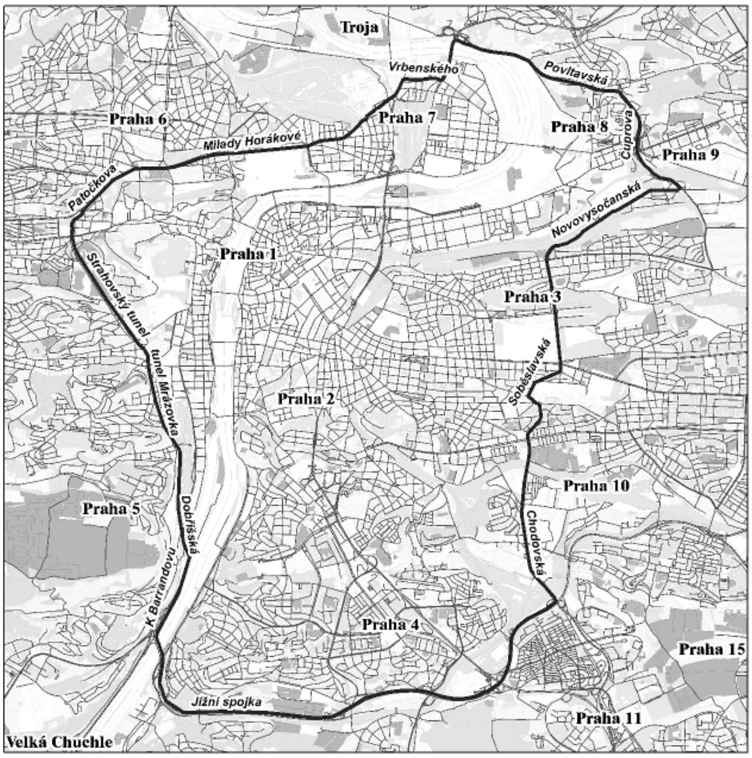

Figure 1: Map of designed low emission zone.

The emission inventory of PM_{10} and $PM_{2.5}$ and other pollutants evaluated is summarized in the following table.

Table 1: Emissions of polluting substances inside and outside the zone ($t.yr^{-1}$).

	Absolute values			**Difference**	
	var0	*var1*	*var2*	*var1 - var0*	*var2 - var0*
PM_{10}	**843.2**	**906**	**781.9**	**62.8**	**-61.3**
inside the zone	843.2	609.1	434.2	-234.1	-409
zone border	-	296.9	347.7	296.9	347.7
$PM_{2.5}$	**256.6**	**265.6**	**233.2**	**9**	**-23.4**
inside the zone	256.6	163.4	114.4	-93.2	-142.2
zone border	-	102.2	118.8	102.2	118.8
NO_2	**1536.5**	**1411.3**	**1337.6**	**-125.2**	**-198.9**
inside the zone	1536.5	392.8	209.4	-1143.7	-1327.1
zone border	-	1018.5	1128.2	1018.5	1128.2
SO_2	**9**	**8.3**	**7.7**	**-0.7**	**-1.3**
inside the zone	9	5.7	3.6	-3.3	-5.4
zone border	-	2.6	4.1	2.6	4.1
benzene	**87.2**	**55.9**	**49.8**	**-31.3**	**-37.5**
inside the zone	87.2	17	9.2	-70.3	-78
zone border	-	39	40.6	39	40.6
benzo(a)pyrene ($kg.yr^{-1}$)	**8907.8**	**8847.5**	**8795.5**	**-60.3**	**-112.3**
inside the zone	8907.8	5521.4	3645	-3386.4	-5262.8
zone border	-	3326.1	5150.5	3326.1	5150.5
formaldehyde	**76.4**	**46.5**	**41**	**-29.9**	**-35.4**
inside the zone	76.4	16.5	8.8	-59.9	-67.6
zone border	-	30	32.2	30	32.2

Emissions of both fractions of particulate matters increase at the border zone; in Variant 1 they increase even more than the overall reduction inside the zone, while Variant 2 leads to an overall decrease in emissions of both fractions (the PM_{10} fraction decreases by about 7% and the $PM_{2.5}$ fraction by approximately 9%). NO_2 emissions decrease in both variants, by about 8% in Variant 1 and by 13% in Variant 2. With respect to the emissions of other pollutants, a decrement occurs in both variants, and almost by a half in the case of benzene and formaldehyde in Variant 2.

4 RESULTS

4.1 Baseline Impacts (Current Situation)

The following table shows the quantified impacts on human health from exposure to emissions of particulates ($PM_{2.5}$ and PM_{10}), SO_2, NO_2, benzene, benzo(a)pyrene and formaldehyde inside the zone and at the zone's boundary (baseline scenario). The last two columns of the table show the impacts (external costs) estimated for the lower and upper limit of annual average concentrations of each respective pollutant.

Table 2: External costs of traffic-related air pollution in the baseline scenario (tsd. $EUR_{2000}.yr^{-1}$).

Pollutant	Impact	Lower estim.	Upper estim.
$PM_{2.5}$	Life expectancy reduction	228 165	260 989
$PM_{2.5}$	Minor restricted activity days	12 296	14 064
$PM_{2.5}$	Work loss days	35 956	41 128
$PM_{2.5}$	Restricted activity days	17 452	19 721
PM_{10}	bronchodilator use (adults)	48	59
PM_{10}	bronchodilator use (children)	4	5
PM_{10}	Cardiac hospital admissions	128	155
PM_{10}	Increased mortality risk (infants)	3 015	3 666
PM_{10}	New cases of chronic bronchitis	54 505	66 287
PM_{10}	Lower respiratory symptoms (adults)	18 071	21 978
PM_{10}	Lower respiratory symptoms (children)	11 630	14 144
PM_{10}	Respiratory hospital admissions	207	251
SO_2	Increased mortality risk	1 030	1 272
SO_2	Respiratory hospital admissions	13	16
NO_2	Increased mortality risk	2 552	3 063
NO_2	Respiratory hospital admissions	47	57
Benzene	Cancer	94	165
Benzo(a)pyrene	Cancer	63	133
Formaldehyde	Cancer	54	101
Total		**385 328**	**447 256**

Human health impacts from the current level of traffic-related emissions inside and around the zone are estimated in the range of EUR 385-447 million per year. Approximately ¾ of this sum is attributable to the effects associated with exposure to fine dust particles (2.5 μm fraction); most of the remaining damage is associated with the impacts of coarse particulates (10 μm fraction), while the share of impacts associated with the other pollutants (SO_2, NO_2, benzene, benzo(a)pyrene and formaldehyde) does not exceed 1 % of the total sum.

4.2 Change in Impacts from the Introduction of a Low Emission Zone

Table 3 shows quantified potential benefits (negative values) and additional damage (positive values), respectively, from the introduction of a low emission zone according to the variant under consideration. In economic terms, for Variant 1 the total effects range from benefits of about EUR 11.5 million to additional damage of about EUR 6.2 million or, in percentage terms, from a 3% reduction to a 1.4% increase in the external costs vis-à-vis the baseline situation. In Variant 2, the estimated effects range from benefits of EUR 18.8 million to additional damage of about EUR 2.2 million or, in percentage terms, from a 5% reduction to a 0.5% increase compared to the baseline situation.

Table 3: Change in external effects from the introduction of a low emission zone (tsd. $EUR_{2000}.yr^{-1}$).

Pollutant	Impact	var1 - var0		var2 - var0	
		Lower estim.	*Upper estim.*	*Lower estim.*	*Upper estim.*
$PM_{2.5}$	Life expectancy reduction	-6 017	3 753	-10 778	2 275
$PM_{2.5}$	Minor restricted activity days	-505	315	-581	123
$PM_{2.5}$	Work loss days	-1 460	911	-1 699	359
$PM_{2.5}$	Restricted activity days	-730	495	-793	238
PM_{10}	bronchodilator use (adults)	-2	0	-3	0
PM_{10}	bronchodilator use (children)	0	0	0	0
PM_{10}	Cardiac hospital admissions	-4	1	-7	-1
PM_{10}	Increased mortality risk (infants)	-98	25	-171	-28
PM_{10}	New cases of chronic bronchitis	-1 767	458	-3 088	-502
PM_{10}	Lower respiratory symptoms (adults)	-586	152	-1 024	-167
PM_{10}	Lower respiratory symptoms (children)	-377	98	-659	-107
PM_{10}	Respiratory hospital admissions	-7	2	-12	-2
SO_2	Increased mortality risk	-5	3	-6	2
SO_2	Respiratory hospital admissions	0	0	0	0
NO_2	Increased mortality risk	-254	-7	-298	-26
NO_2	Respiratory hospital admissions	-5	0	-6	0
Benzen	Cancer	-49	1	-55	-2
Benzo(a)pyren	Cancer	-38	14	-40	13
Formaldehyd	Cancer	-53	3	-57	1
Total		**-11 956**	**6 224**	**-19 277**	**2 174**
Percentage change from baseline situation		***-3.1%***	***1.4%***	***-5.0%***	***0.5%***

Notes: negative values represent a potential benefit from the zone compared to the baseline.

Besides the simple summing of the impacts of changes, one can further explore what the distribution of benefits and additional burden in the population of the territory under consideration are. The following figure illustrates the distribution of benefits and additional damage from the implementation of low-emission zones in Variant 1. The population for whom there is a change in the concentration of particulates from the introduction of a low emission zone is plotted on the horizontal axis, while the impact change in monetary term is plotted on the vertical axis. Positive benefits, i.e. a reduction of PM_{10}, will benefit about 247,000 residents in the territory, while the additional burden will be borne by approximately 116 thousand residents. For $PM_{2.5,}$ the benefits will be enjoyed by some 127,000 citizens, while about 40 thousand citizens will bear the additional burden from a concentration increase. Both graphs show that the distribution of the benefits is relatively steep in comparison with the additional damage.

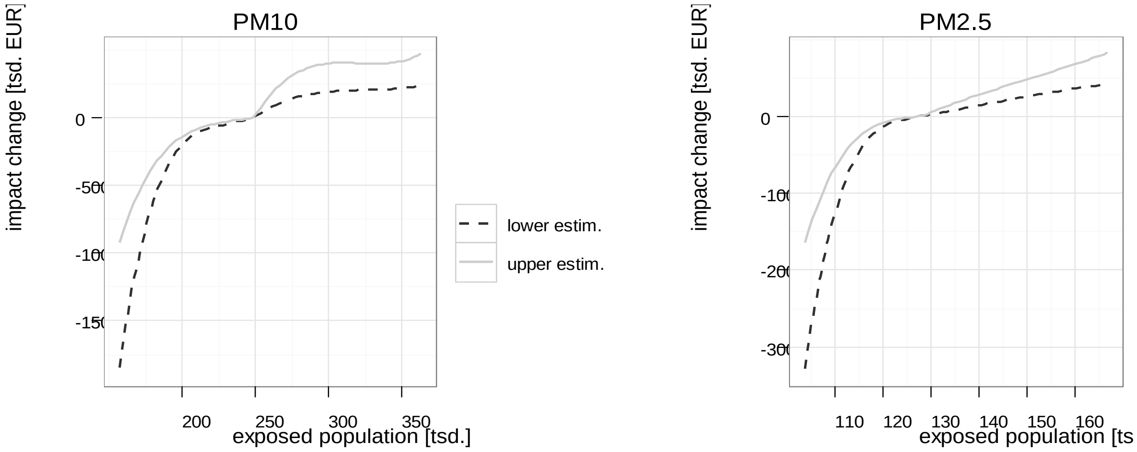

Figure 2: Distribution of benefits or additional damage in the affected population in Variant 1.

The cumulative distribution of effects, benefits or additional damage in Variant 2 for PM_{10} and $PM_{2.5}$ is shown in the next figure. Reduced concentrations of PM_{10} will benefit about 274,000 residents in the territory in this variant; the additional burden will be borne by approximately 107,000 citizens. Similarly, the positive benefits of a $PM_{2.5}$ concentration reduction will be enjoyed by 222,000 citizens, while in contrast some 44,000 citizens will suffer from increased air pollution. The distribution of benefits and additional damage from the other pollutants under consideration could be expressed in the same way, but the overall effect is negligible compared to the impact of particulates.

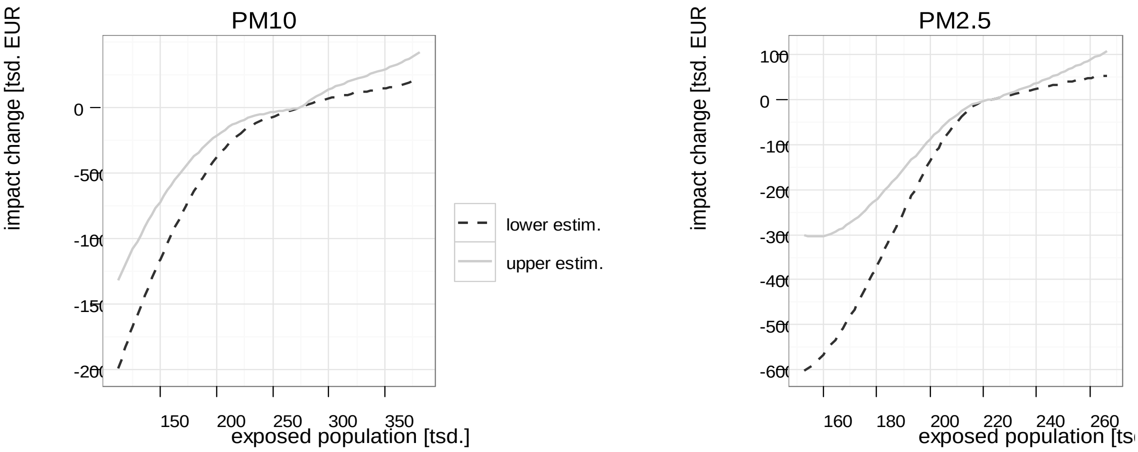

Figure 3: Distribution of benefits or additional damage in the affected population in Variant 2.

5 CONCLUSIONS

The assessment of the benefits from the introduction of a low emission zone in the Prague city centre presented here shows a relatively marginal reduction in external costs from traffic-related air pollution. The overall benefit amounts to a several per cent reduction, albeit with a relatively differentiated distribution in the population. While there is a modest pollution reduction inside the zone, the opposite situation occurs on the zone's boundary, where an increase in air pollution concentration is caused by increased traffic bypassing the zone.

Although it is a rather approximate model calculation, our assessment clearly shows the need for thorough preparation prior to any planned introduction of a low emission zone in Prague and in-depth evaluation of the alternatives – meaning not only a focus on entry bans on vehicle emission classes, but also on how to design zone borders because a substantial improvement in air quality for residents will only be achieved when an alternative route – used in increasing numbers by vehicles failing to comply with emission zone entry limits – is located outside densely populated residential areas.

Although the primary goal of low emission zones is to improve local air quality it is also necessary to take into account other induced effects. While a decrease in the number of vehicles in the city centre is a welcome effect, the impacts in terms of accessibility might be ambiguous – while less cars means reduced congestion inside the zone it may on the other hand hamper access to locations inside the zone (but this will depend on the changes in public transport and modal choice options). Some related effects including noise and crowded parking reduction can be expected inside the zone but these will likely worsen on its boundary. In addition, more indirect effects such as an increased demand for new (or compliant) vehicles may be expected in the short term with a possible reduction in demand in the longer term.

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Phenomena Disturbing European Security and Tasks for Future Research

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ABSTRACT: Based on the concept that Europe and its parts are represented by the model "System of Systems", denoted as a human system, the in-depth study of disasters and disasters' management reveals the tasks for future security research. The formulation of tasks for research is based on the philosophy that each responsible government should protect their inhabitants daily and especially during critical situations. The outputs show that European citizens are very threatened by organisational accidents, the causes of which are human behaviour defects and, mainly, human management defects on all levels of government.

KEY WORDS: Safety, security, disaster, disaster management, future research tasks.

1 INTRODUCTION

The security situation in Europe, the world and in each territory continuously changes with time, and therefore, it is necessary to form a new safety culture especially taking into account the actual knowledge and experiences with interdependences among the public assets leading to extreme social crises (in history, e.g., great famines). Due to the historical development there are: a lot of preventive and mitigating measures that have been applied in practice by legal rules, technical standards and norms, and public instructions; response systems; and renovation methods. However, it is true that their effectiveness decreases with time, because new risks emerge and territory and human vulnerabilities increase in all domains.

The performed research comes from the systematic concept of reality and its aim is systematically to create Europe as a safe community that has a highly sustainable potential. Europe stands as a significant world power if it ensures the security of itself and of its vicinity, which, in the globalization era of the world, is only possible by using a human system management based on a strategic, systemic, and proactive system of systems management (Procházková, 2012a; Procházková et al., 2012). To enable the solution to most present problems the concept used is complex. The paper summarizes the results of disaster research and disasters' management research in Europe. On their basis, it identifies the shortages in disaster management, forms the tasks for the removal of serious shortages and also proposes the directions in which the following research should head, so that Europe would systematically create a safe community and build a background for sustainable development.

2 PRIMARY FINDINGS AND PRINCIPLES OF RESEARCH OF DISASTERS AND DISASTERs' MANAGEMENT

The present goal of humans is to live within a safe space, and therefore the UN formulated the aim of a "safe human system" in 1994 (United Nations, 1994) and the EU "safe community" in 2004 (EU, 2004). In agreement with the EU and UN proclamations and the professional knowledge it is necessary for the conservation and sustainable development of a human society to create a safe territory. With regard to present knowledge we should consider that we want to build a safe, open, and dynamically variable system that is a complex system, the model of which is a system of systems (SoS), i.e., several overlapping systems (Procházková, 2012b).

The security and development of both humans and the human system are troubled by disasters, i.e., internal or external phenomena that lead or from a certain size can lead to damage, harm, and the loss of humans and human system assets. This means that human system safety (i.e., a set of measures and activities ensuring the security and development of the above-mentioned objects) must consider both the processes, actions, and phenomena that are under way in human society, environment, the planetary system, galaxy and other higher systems, and also human management acts. Therefore, for safety reasons, we must negotiate with risks of a different origin and kind. The research performed under the FOCUS project (Procházková et al., 2012) deals with the principles of negotiation with risk at all stages of its mitigating and managing in selected sections of human system management, and it gives tools in favour of the public administration for public affairs´ governance because it is responsible for territory governance and conditions; especially, it concentrates on EU governance.

On the basis of current knowledge it is not possible to solve significant problems of a complex system, which is every area including also the EU and Europe, by reducing complex problems to a set of simple problems, because, in this way, we neglect the non-linearities and various interdependencies that create the specific couplings which are the causes of risks across systems, among partial systems, between the systems and their vicinities, etc.

Current knowledge shows that it is necessary to deal with the problems on the basis of the systemic concept of reality, which is based on systemic (holistic) thinking, the typical feature of which is focusing on the whole view of a system and on research on the relationships among their individual parts. The characteristics of systemic thinking are: to see both the whole and the details at the same time; to focus on the dynamics of processes; to pay attention to relations, associations and interactions; to take into account the roles of feedback; to consider the relativity of possible situations; and to think in a long-term way. A system according to its core means more than only a sum of its parts, and, therefore, stress is put on: the study of the interactions and associations; non-linear thinking; interactions; inductions; feedback; and experiments or realistic simulations. For example, feedback causes non-linearities in the system's behaviour that is not predictable, and, therefore, it is not possible to use the common prognostic methods for the identification of the possible states of a system.

In engineering practice there are used for the characteristic and management of: simply organized units the results of analytic solutions; composite systems (in practice the term construction is used) that are understood as a representation of elements that are organized and connected in a certain way and because of a proper structure they fulfil certain functions, the results of statistical solutions based on analytic functions, the parameters of which are variable in a certain interval, which is a reflection of various possible states / variants of the system behaviour; complex systems, the results of simulations and their optimization. The reason for the last mentioned approach is in reality that the complex systems are aggregates with many components (often systems too) that interact together and are organized in several levels, which results in us observing: suddenly emerged behaviour features that are not possible to obtain from the knowledge of the components' behaviour (so-called emergent behaviour); hierarchy; self-organization; and various management structures, which all together seem to be chaos. Present knowledge shows that in such cases it is necessary to take a multidisciplinary and interdisciplinary approach. For their management it is then necessary to use the multi-criteria approaches, i.e., to use several criteria, and to also consider the cross-sectional risks (Procházková, 2012b; Procházková et al., 2012). For the solution of their problems the tools based on the theory of chaos (Ott, 2012), theory of fuzzy sets (Zadeh, 1975), complexity theory (Gleick, 1996; Lucas, 2006; Mayers, 2009), theory of possibilities (Demster, 1967; Shafer, 1976) exist. Since Europe belongs to the developed parts of the world and the EU has ambitions to be a world power, it is necessary for it to build its politics on the current knowledge.

The systematic research of disasters, the summary of which is based on more than 5000 professional works, historical catalogues, databases, archives is in works (Procházková, 2011, 2012c, 2012d) revealed that we must consider the following disaster types as being the results of processes:

- In and out of the Earth: natural disasters – avalanches, earthquake, floods, drought, strong wind, volcanic activity, land slide, rock slide etc., land erosion, desertification, fundament liquefaction, sea floor spreading, etc.;
- In the environment including humans, animals and plants – illnesses;
- In the human society separated to:
  - Unintentional: involuntary human errors –in operations and in management;
  - Intentional: mutual improper behaviour of an individual or groups of individuals: wrongful appropriation of property; killing a human; bullying; religious and other intolerance; criminal acts such as: vandalism and illegal business, robbery and attacking, illegal entry, unauthorized use of property or services, theft and fraud, intimidation and blackmail, sabotage and destruction, terror against individuals, terrorist attacks; local and other armed conflicts; intentional disuse of technologies, such as: improper application of CBRNE substances; data mining from social networks and other cyber networks used for psychological pressure on a human individual; incorrect governance of public affairs: corruption; abuse of authority; and the disintegration of human society into intolerant communities.
- Which are connected with human activities: incidents; near miss; accidents; infrastructure failures; technology failures; loss of utilities, etc.;
- That are reactions of the Planet or the environment to human activities: man-made earthquakes; disruption of the ozone level / layer; greenhouse effect; fast climate variations; contaminations of air, water, soil and rock; desertification caused by human bad river regulation; drop of the diversity of flora and fauna (animal and vegetal) variety; fast human population explosion; migration of large human groups; fast drawing off of renewable sources; erosion of soil and rock; land uniformity, etc.;
- Connected with inside dependences in the human system and its surroundings separated into:
  - Natural: stress and movements of territorial plates; water circulation in environment; substance circulation in the environment; the human food chain; planet processes; interactions of solar and galactic processes;
  - Human established: human society management; flows of raw materials and products; flows of energies; flows of information; flows of finances, etc.

In the social domain for reasons of internal relations the monitored adverse effects are put together into the following groups:

- Subsequent crime and other offences. The group includes: vandalism and illegal risk behaviour, robbery raids and attacks, property crime, killing and rioting;
- Tax fraud and fraud. The group includes: tax fraud, fraud;
- Damage to the customs laws, including: customs fraud, smuggling of prohibited goods;
- Illegal access to information systems. The group includes: data theft or data changes, espionage, partial fraud - forgery of documents, partial terrorist attacks, data mining from social networks leading to psychological pressure on people, bullying;
- Corruption and serious economic crime, including money laundering, extortion and humiliation. The group includes: corruption, abuse of authority;
- Society disintegration into intolerant groups. The group includes: religious and other intolerances.

Due to lack of data there are not considered: child labour, sabotage, infringement of law by government agencies, maritime piracy, severe negligence with criminal responsibility, misuse of postal services, an anonymous notice of alarming information, environmental crimes including pollution, and violations of security regulations.

3 DATA AND METHODS OF SPECIALISED RESEARCH

For the investigation of disasters and level of disasters' management original data and results of special projects were used, e.g. Switzerland - the PLANAT project, US – FEMA projects, Canada, the Netherlands, EMA (Australia), OCHA, the Czech Republic, IAEA, OECD, UN etc. – real references are in Procházková (2011) and in materials quoted in. For obtaining the original results there were also used:

- Historical catalogues, databases, archives and original papers on phenomena that caused harm and losses to public assets within the time period from historical times up to now (floods, earthquakes, chemical accidents, epizootic, epidemic, electro-energy net failure) that obtained very detailed results;
- Different methods, from very simple ones to scientific ones.

The outputs described in the next paragraphs are created through pure scientific methods (analysis and synthesis of directly obtained or published results on disasters; specific investigation of disasters by analytical and heuristic methods with step in which the heuristic methods were at first tested on real data to see if they are suitable for security tasks solutions; specific investigation of the level of disaster management with regard to human survival, security and development with the help of special logical tools tailored for FOCUS project targets (Procházková, 2012d). Detail descriptions of data and methods used for the original results derivation, with references, are in publications quoted in the appropriate places.

4 SUMMARY OF OUTPUTS OF INDIVIDUAL STUDIES OF DISASTERS AND DISASTERS´ MANAGEMENT

The detailed study on disasters and disasters' management in the EU (Procházková et al., 2012) was concentrated into ten domains, the outputs of which are concisely summarized in papers (Procházková et al., 2012; Binková et al., 2012; Procházková, Mozga, Richter, Procházka, Z. & Procházka, J., 2012; Procházková, Richter, Procházka, Z. & Procházka, J., 2012; Procházková & Kopecký, 2012; Procházková & Pešková, 2012; Procházková & Říha, 2012a,b,c; Procházková, Šenovský & Mozga, 2012; Procházková, Bartlová & Šenovský, 2011; Procházka, J., Procházka, Z., Říha & Procházková, 2012; Procházková, Šenovský & Bartlová, 2012). The work (Procházková et al., 2012) also obtains the results of a theoretical study from which it follows that the advanced EU security concept: is based on the systemic (holistic) thinking, the typical feature of which is the focusing on the whole views at systems and on research of relations among their individual parts; uses the proactive approach; apples all hazard approach (FEMA, 1996); and respects the co-existence of overlapping systems (Procházková, 2012b). At its realisation it is necessary to sophistically manage the disasters that damage the security of communities and their assets, i.e., to apply measures and activities of prevention, preparedness, response and renovation. For practical purposes good technical solutions based on recent findings and experiences and correctly aimed governance of public affairs supported by legislation with sufficient legal force, finances, qualified human personnel and material base are necessary.

5 LIST OF SECURITY CHALLENGES

Synthesis of results obtained by detailed studies of disasters and disasters' management described in (Procházková et al., 2012; Binková, Horáková & Procházková, 2012; Procházková, Mozga, Richter, Procházka, Z. & Procházka, J., 2012; Procházková, Richter, Procházka, Z. & Prochazka, J., 2012; Procházková & Kopecký, 2012; Procházková & Pešková, 2012; Procházková & Říha, 2012a,b,c; Procházková, Šenovský & Mozga, 2012; Procházková, Bartlová & Šenovský, 2011; Procházka, J., Procházka, Z., Říha & Procházková, 2012; Procházková, Šenovský & Bartlová, 2012) is summarized in Table 1.

Table 1: Deficits at disasters' management.

SECURITY ITEMS	**RESEARCH RESULTS**
Security challenges that can be considered to have a big impact in the 2035 time frame and currently are not sufficiently addressed in the planning of research	The list of following disasters is necessary to be supplemented by phenomena in: ▪ ***Nature:*** geomagnetic storms; soil salinization, fall of a cosmic body, sand storms, and sudden change of weather (cold wave or heat wave); ▪ ***Technology:*** organising accidents in technological facilities, accidents connected with biotechnologies, disuse of technologies (nuclear, nano and IT), disuse of genetic engineering, and disuse (abuse) CBRNE agents; ▪ ***Human activities' organisation:*** education infrastructure breakdown, research infrastructure breakdown, breakdowns (organising accidents) in public governance, defects of supply chains; ▪ ***Environment (including human):*** stress and movements of territorial plates; rapid natural subsidence of surface, defects in water circulation in environment; defects in substance circulation in environment, defects in human food chain, defects in planetary processes, planet defects as results of interactions of solar and galactic processes, incurable diseases in systems of humans, animals and plants; ▪ ***Environment reactions to human activities:*** artificial surface subsidence due to undermining, and interaction due to militarization of outer space;

	▪ ***Society:*** illegal production and distribution of narcotics and psychotropic substances, illegal migration, proliferation of weapons of mass destruction.
Most severe security challenges that should be addressed by research planning in the 2035 time frame	The disaster order with regard to the impact severity is: ▪ ***Nature:*** fall of a big cosmic body on Europe, extreme earthquake, extreme floods, extreme forest fires, and extreme drought; ▪ ***Technology:*** beyond design accident with presence of radioactive substances, beyond design accident with presence of substances mutagenic, carcinogenic and harmful to reproduction; ▪ ***Human activities' organisation:*** corruption, disuse of power, insufficient respect to public interest, education infrastructure breakdown, research infrastructure breakdown, breakdowns (organising accidents) in public governance, defects of supply chains; low robust technical and finance infrastructure that causes long-term outage of electrical infrastructure, long-term stoppage of drinking water supply, long-term outage of food and long-term financial market disorder; ▪ ***Environment (including human):*** disruption of water circulation in environment, disruption of substance circulation in environment, huge pandemics and epidemics, and incurable diseases of humans, animals or plants and across them; ▪ ***Environment reactions to human activities:*** contamination of air, water, soil and rock missive's, uncontrolled human population explosion, migration of large groups of people, the militarization of space, and climate variations; ▪ ***Society:*** abuse of power, corruption, decay of human society into intolerant groups, abuse of technology, abuse of authority, illegal access to information systems, cybercrime, terrorist attacks, corruption in government and public administration, including the political scene, serious economic crime including money laundering and tax evasion, trafficking with human beings and illegal migration, illegal production and distribution of psychotropic substances, extremism, and all forms of discrimination and intolerance.
Challenges for future security research for prevention, preparedness, response, and renovation	▪ To implement the system of management based on integral safety and to improve the prevention, preparedness, response, and renovation; ▪ To build a systematic approach for a response to disasters (individual Member States have the systems of response on various levels); ▪ Especially to improve the response to critical situations because extreme disasters cause big economic and social impacts (see lesson learned from Fukushima accident). They actually affect infrastructure (buildings, transport, energy and water supports), which represents specific damage and losses in densely inhabited areas; ▪ To target the crisis management in the case of extreme situations is necessary; ▪ To process norms and standards for infrastructures that will: ensure their sufficient capacities; enhance their robustness and resiliency; ▪ To upgrade the sector and cross-sector management – to consider the cross-sectional risks (systemic management) and to put the cross-sectional risks (systemic engineering) under control; ▪ To compile robust measures to prevent the disuse of technologies; ▪ To introduce early warning systems in the case of disasters for which there are known symptoms that enable warning;

	▪ To prepare tools for systematic regulation of the recovery process; i.e. a recovery plan and plan for the prevention of losses at renovation; ▪ To improve the humanitarian assistance in the case of extreme disasters. ▪ To implement the systematic use of disaster insurance policies; ▪ To improve the attention to land degradation - lack of European legislation and objectives of soil protection; ▪ To improve the EU preparedness for climate change because it is lagging behind in the sphere of adaptation (in contrast to the absurd emphasis on the causes of the greenhouse effect); to increase attention to adaptation in a cross-border dimension (e.g. the possibility of international coordination and construction of dams and reservoirs) - attention paid not only to economic, but also to social criteria; ▪ To upgrade management of social disasters - Prevention is not systematically carried out for any of the social disasters, prevention is often declared by signed treaties, conventions, treaties or bilateral/multilateral agreements but in reality no effective tools. It is necessary to improve: close interdisciplinary cooperation of all parties involved at national level and consistency with other central institutions within the EU states; and sharing good practice, continuing education and training of experts responsible at the pan-European level. Preparedness for coping with the given disasters is the most well established and best on a theoretical level but the level of practice is greatly affected by the economic stability of a particular Member State; and level detection (intelligence services, technical means, and the level of experts...) is variable and not interconnected. Because of a highly unacceptable impact on the current situation in EU countries having long-term consequences of an economic crisis, it is necessary to find an effective tool for inhabitants to survive and for the stabilization of the economic situation that evocates a lot of followed disasters; ▪ To upgrade the process management – type "just in time" is not suitable for goods, measures and activities that are important for human survival.
Related main vulnerabilities to be addressed for future security research	▪ Most infrastructure and objects are only protected to the size of design disaster, i.e. at extreme disaster sizes they fail, which represents a specific threat for densely inhabited areas. The situation can be made worse at the coast with the rising of the sea levels; ▪ The insufficient level of civil protection in critical situations that is ensured by the public administration of states; ▪ The low support to human daily needs from the public administration of states; ▪ The incapability of inhabitants to take care of himself/herself and his/her family, to secure his/her property, to have basic food and water for at least 24 hours; ▪ The incorrect behaviour of humans in critical situations; ▪ Strategic and long-term approach is not systematically included into the territorial planning on both the continents and the coastal areas, including transport, regional development, industry, tourism, and energy politics; ▪ Low attention to land degradation - lack of European legislation and objectives of soil protection; ▪ No sufficient EU preparedness for climate change, because it is lagging behind in the sphere of adaptation (in contrast to the absurd emphasis

	on the causes of the greenhouse effect); ▪ Lack of knowledge on: stress and movements of territorial plates, rapid natural subsidence of surface, water circulation in environment, substance circulation in environment, human food chain, planet processes, interactions of solar and galactic processes; ▪ Low attention to adaptation in cross-border dimensions (e.g. the possibility of international coordination and construction of dams and reservoirs) - attention to economic and social criteria; ▪ The knowledge on the vulnerabilities of protected assets at different disasters is only fragmental; ▪ No targeted crisis management for critical situations that can be caused by: beyond design nuclear accident, long-term outage of electric energy supply, long-term stoppage of drinking water supply, long-term shortage of food supply, and long-term failure of the financial infrastructure; ▪ The deficiency of early warning systems in the case of disasters for which there are known symptoms that enable the warning; ▪ Lack of technical resources, inadequate knowledge and training of managerial staff, poor response management and lack of finances; ▪ Lack of supply chain organisation at emergency and critical conditions; ▪ In many cases not enough care is given to prevent human errors in processing plants and public affairs governance.
Related main knowledge gaps to be addressed for future security research	▪ Missing the systematic collection of data on disasters of all types and their impacts; ▪ No in-depth research based on data - key step - Missing data catalogues for the disasters, qualified monitoring, systematic detection systems, and systematic research. Special attention must be paid to social disasters because data for research are pure - collection and processing of data are at a low level from a methodical viewpoint, and therefore, it is necessary to create: consistent data sets, effective mutual consultation and co-ordination of procedures and their flexible adaptation to the rapidly evolving global (trans-national) conditions that bring new threat scenarios, and, therefore, it is necessary to apply the adequate methods determining the reliable scenarios for decision-making with the aim to upgrading the security; ▪ Missing knowledge for a solution to the lack of: drinking water, raw materials, resources, energy, and food in the case of uncontrolled human population explosion and the migration of large groups of people; ▪ Missing tools for robust crisis management in the case of extreme disasters; ▪ No verification of every result, before its implementing in practice by a public management opponent and by real experts who demonstrate professionalism, objectivity and support of public interests - the way how to avoid the influence of lobbyists; ▪ No specification of standard methods for defining the scenarios for the identification, analysis, assessment, management of risks and dealing with risks are defined, no standards guaranteeing that the results of different methods are comparable; ▪ No data and methods for investigation of interdependences, rules of co-existence of overlapping systems and of management and trade-off with cross-sectional risks.
Proposed type of future	▪ Monitoring of all kinds of disasters and their impacts; ▪ To find a way how to implement in practice the strategic management

security research	of integral safety that is systemic and proactive and is not influenced by lobbyists and other pressure groups; ▪ To find a way how to implement the strategic territory safety management in a dynamically variable world in which the aspects connected with the following will be taken into account: - Human lives and health as a protection of the physical body, food, drinking, comfort, homeland; - Human security as protection against psychological harm and loss of security; - Property as protection in the case of: buildings and fittings – loss, damage, domestic animals - death loss, loss; - Public welfare as protection against: deterioration in the atmosphere among humans, and the loss of security; - Environment as protection of: air, surface water, ground water, soil, rocks, landscape, forest, flora and fauna; - Infrastructures and technologies as protection in the case of the failure of: energy supply (electricity, heat, gas), drinking water supply, utility water supply, sewage system, the transport network, cyber infrastructure (communication and information networks), the banking and financial sector, emergency services (police, fire-fighters, paramedics), essential services in the area (food supply, waste disposal, social services, funeral services), industry, agriculture, and state and local governments, i.e., of area management and management of human society. To compile principles of continuity plans and contingency plans. ▪ To find a way how to arrange the stability of the financial and banking sectors in dynamically variable words; ▪ To find a way how to implement professional knowledge for the benefit of the public interest; ▪ To find a way how to prevent big impacts of the brain drain and the exodus of professionals, i.e. how to create experience databases; ▪ To find a way how to upgrade: the co-operation in security research, the implementation of existing directives and legislation, and the individual response tools of the EU to appurtenant disasters; ▪ To find a way how to establish: effective tools and legislation in the prevention, preparedness, response and renovation (e.g. with incorrect governance of public affairs to force sanctions); qualified research based on real qualified data; and corresponding levels of education; ▪ To ensure the collection of qualified data (monitoring, qualified catalogues), selection of processing data methods and the creation of standards and norms that will be codified in the legislative; ▪ To ensure qualified research of disasters targeted to human security and an improvement in population education; ▪ With regard to the lessons from Fukushima to improve the methods associated with the determination of terms of references for design, construction and operation of technological buildings, equipment and infrastructures, deterministic and stochastic approaches must be supplemented by expert judgement that considers the influence of epistemic uncertainties; ▪ To improve: system of management of territory and objects; and integral risk management because procedures applied so far do not consider

	cross-cutting risks, which are the cause of cascading failures of complex systems; ▪ To operate systematic disaster monitoring; to create legislation for the prevention, preparedness, response and renovation with special attention to the response to critical situations (crisis management, warning systems etc.); ▪ To study disaster characteristics in-depth; to improve the population education with the aim of reducing its vulnerability to these disasters; ▪ To propose and implement sanctions for the contamination of air, water, soil and rock mass; ▪ To propose response plans for the erosion of soil and rock massifs; ▪ To find the safeguard procedures for landscape uniformity; ▪ To apply effective protective measures and activities of supply chains.
Expected most needed topics of future security research	▪ To find a way how to implement into practice the strategic management of integral safety that is systemic and proactive and it is not influenced by lobbyists and other insisting groups. ▪ To find a way how to implement professional knowledge for the benefit of the public interest. ▪ To specify the cases in which the system "JUST IN TIME" is impossible to use from the viewpoint of human survival. ▪ To find a way for: the reduction of big impacts of the brain drain and the exodus of professionals – the creation of experience databases, elimination of reasons for migration, such as poverty, climate change and hunger, establishment of comprehensive migration policy – e.g. measures and activities for the case of sharp climate change, deforestation, desertification, biodiversity loss, etc. ▪ To propose human countermeasures against disasters and their impacts, if possible.

6 ORIGINATORS OF DISASTERS' MANAGEMENT FAILURES

From the analysis in Table 1 it follows that many critical situations in the human system are connected with the management of disasters for which humans are responsible – behaviour of humans; human factors; and disturbances in human society behaviour. Generally it is possible to say that the cause of critical situations are organisational accidents that are connected with a human factor; especially with phenomena such as corruption; abuse of power; suppression of the public interest; low respect to knowledge and engineering experiences; and low professional level of management. Their consequences are: government default; technologies failures; infrastructure failures; research failure; social system failure; decay of human society into intolerant groups; increasing number of impoverished people – seniors, dossiers, jobless – problem young people who are out of work and without education; disturbances of daily civil protection human needs; disturbance of daily civil protection, human security and public welfare; disuse of technology, space militarization – real data are shown in Table 2.

Table 2: Phenomena that cause the disturbance of social relations, public welfare and human security.

Domain	Defects leading to critical situations
Top governance	The domain management: is predetermined to political and military aspects; is short of a human dimension and gives low support to EU

	inhabitants; does not govern on the basis of qualified data processed by qualified methods; is often determined by fixed ideas without real assessment of their realisation; is based on the image that all is stationary and it does not respect dynamic development of the world that is necessary to prepare for the possible extreme scenarios and measures for human's survival; and is not realised on the principle "Safety management system for system of systems".
Technical domain	In domain management: no standards and norms for underground and high-rise buildings with regard to human security and public welfare; missing essential services provided to the citizens; scenarios for decision-making are prepared only by simulation without verification with use of real data – sometimes scenarios used were derived for different conditions, i.e. conditions of technology transfer were not fulfilled; no norms and standards for interoperability; no standards and norms for the co-operation of diverse systems; no co-ordinated emergency plans on all levels (EU-wide to regional) – all must be on a professional level respecting knowledge and experiences, continuity and contingency plans.
Organisational domain	In domain management: missing the effort directed to the reduction of weakness (low number of resources, contamination of environment, work price, unemployment) and to the use of strength (qualified technician population); no effective tools against corruption, power misuse, lobbying etc.; missing the support of co-operation on mutual partner principle; missing the basis for mutual understanding and mutual co-existence; no effective international teams of first responders; no basis for close co-operation of first responders; no norms and standards for interoperability.
Knowledge domain	In the knowledge domain used for decision-making: missing systematic respect to present world nature – dynamic open system of systems; low effort is directed to the collection of qualified data on disasters and on lessons learned from responses to extreme disasters; is an underestimation of disasters at disasters' management; is neglecting the creeping disasters such as ground water stores, contamination of human food chains etc.; no qualified disasters scenarios for decision making.

A proposal for solving the above-mentioned problems consists of the finding a way how to implement in decision-making and governance of public affairs: a systematic use of knowledge and experiences at decision-making; strategic safety management and strategic safety engineering based on the system of system approach and on principles integral safety, which are based on integral risk management and trade-off with risk with the aim of averting organisational accidents; the human dimension into governance (daily public protection and public protection at normal, abnormal, and critical situations); rules for removing corruption, lobbying and the abuse of power; the solidarity principle; responsible co-operation among partners; good governance based on qualified data and on strategic, systemic and proactive management; systematic inspection by professionals, deputies and by the public; legislatively supporting the public's interests in the state and sector management; solution of possible conflicts through peaceful means; special family politics, ensuring the availability of further education, etc. It is also necessary to find a way how to establish and implement into daily practice the basic EU functions, because the economic basis, political and military bases are not sufficient for the security of EU inhabitants and for public welfare. For all these problems solving them is necessary to ensure: systematically building the knowledge base; systematically building material and a technical base; qualified engineering procedures; management based on qualified data; realising EU governance that supports the EU inhabitants. The most effective seems to be a systemic prevention of organisational accidents that lead to government defaults on all levels. It is necessary to stop talking and to work with the goal of "security and the sustainable development of humans".

7 CONCLUSION

The formulation of tasks for future research is based on the philosophy that each responsible government must protect inhabitants both in daily and in critical situations, i.e., the EU must also preserve the basic functions of a state; the real tasks are given for each public protected asset separately (Demster, 1967). The basic requirement is so that the research: was targeted, i.e., the already-known was not researched without good reason; sought and solved open problems, namely correctly with regard to current knowledge and experiences on ensuring the safe community and its sustainable development; demanded objective results under given conditions, i.e., to systematically present the results in front of a relevant expert community and to make them be subject to public opponent control. With this, plagiarism can be avoided, the real protection of intellectual property will be ensured and the development of creative abilities of individuals who have a creative potential and who are willing to give it for the benefit of the EU and its inhabitants' development will be supported; and would not distort the results – the style "the fundamental is what an authority says" holds development back. Therefore, it is necessary not to dissimulate conflicts among outcomes of projects since their existence is normal. Under the effort of finding the right solution, it is necessary to make it a subject of a thorough investigation with the aim of finding the causes of problems and to define an optimal solution for them within given conditions and within the given possibilities. The main task of future EU security research is to create systems for knowledge-based decisions and effective utilisation of land and nature. Therefore, the EU must remove prejudice in favour of lobbying groups the interest of which may be different from the public interests. The main deficiencies in the EU disasters' management are the following items: all hazard approaches are not systemically applied; some disasters are underestimated (mainly in the social domain); systemic, strategic and proactive management is not always implemented into practice; co-existence of systems with a different nature is not followed; gaps in risk management, risk engineering and in a trade-off with risks; present research does not determine priority orientations, its targets are influenced by politicians or lobbies; application procedures and orientation of strategies are not regularly verified; a reasonable strategy for disaster management is missing; the disaster management does not often respect disaster life cycles; accent to problem solving is missing, still being merely a lot of discussions on the problems; a lack of resources; a lack of instruments for ensuring EU finance stability; and a lack of management supporting public protection and sustainable development.

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Open Problems in Protection of Life-Giving Infrastructures and Supply Chains

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ABSTRACT: Based on the concept of safe community there are followed couplings created in the human system by life-giving infrastructures and supply chains. The assessment of harm caused by their failures and the level of management of these failures reveals open problems in the followed domains and these were used for formulation of requirements for future research.

KEY WORDS: Security, safety, life-giving infrastructures, critical supply chains, failure, requirements for future research.

1 INTRODUCTION

The present time characteristics consists in note that: demands of humans on life quality increase; it increases the human vulnerability connected with number of humans and with human dependence on new technologies; it is lack of resources in densely populated areas; and new way of management “JUST IN TIME” limited stocks and reserves and introduces the dependence on early supplies and early services. The security, economic prosperity, and social well-being of humans depend on the safe and reliable functioning of the increasingly complex and interdependent infrastructures that make up the system of systems - hereafter “SoS” (Procházková, 2009). Highly efficient, complex, and interdependent infrastructure systems, including electric power, telecommunications, transportation, water utilities, food distribution, housing and shelter, public health, finance, banking and public governance, are the foundations of modern societies. In the new economy, these interconnected infrastructures have become increasingly fragile and subject to disruptions that can have broad regional, national, and global consequences.

The paper summarizes the results of assessment of failures of life-giving (vital) infrastructures and of the level of management of these failures in Europe, where special attention is paid to failures of supply chains.

2 NATURE OF LIFE-GIVING INFRASTRUCTURES AND SUPPLY CHAINS

Infrastructures assure the quality of human life, enable protection for humans and their survival in critical situations. They represent large technological facilities, the technological systems, which are more than just a set of technical equipment parts and components. They reflect the organizational structure, management, operating rules and culture of design organizations that created them and are usually also reflections of the society in which they were created (OECD, 2002; Procházková, 2009, 2011a; Procházková et al., 2008). Accidents are often blamed on operator error or equipment, without distinction of industrial, organizational and managerial factors that caused the errors and the shortcomings in question to become unavoidable. The causes of accidents are often, if not almost always, rooted in the organization - in its culture, management and structure. All these factors are critical to the safety of technical systems. Analysis of the causes of past accidents shows that the issue is very complicated and its solution requires a high professional perspective and a genuine desire to solve problems, both in the management and in the engineering disciplines (Procházková et al., 2008).

In terms of exact sciences, each technology sub-system consists of the controlled object and the control system. The controlled object is usually a complex nonlinear system: it consists of numerous elements, where each one is uniquely described by a finite number of measurable variables. Interactions between elements are clearly formulated. Dynamic properties of the controlled object can be described by differential equations, the solution of which is the state vector. The state vector allows determining the state of the system at any point in time using the minimum number of variables. The control system must maintain specified physical quantities at predetermined values. In the process of regulation, the control system changes the state of the technological system by affecting the action variables in order to achieve the desired state. When managing the control system (according to the recent concept that places the highest emphasis on safety) the priority order of features such as: safety (level of compliance with the conditions of operation and non-creation of harmful (unacceptable) impacts on the system itself and its surroundings); functionality (level of performance in execution of required acts); operability (level of performance in execution of the required actions depending on normal, abnormal, and critical conditions); operational stability (level of compliance with the conditions of operation at the time); and inherently built-in resilience to possible disasters (Ellul, 1980).

The human system like any other system is described by the basic elements (assets), links among elements (physical - material, territorial, cyber, logical) and flows that make more or less important couplings, which in some cases fundamentally determine the behaviour of the human system (Procházková, 2011a). With regard to the uneven spread of humans and unequal distribution of food and other resources, the quality of the supply chain is highly significant for human life. Events in recent years, such as the interruption of oil supplies to Central and Western Europe due to disagreements between Ukraine and the Russian Federation, have shown the high vulnerability of selected commodities and they led to the consideration of a new problem that the EU must solve for its security and development. The present research specifies some security problems of supply chains.

Supply chains are multistage systems that are comprised of suppliers, manufacturers, distributors, retailers and customers and in where among the individual levels in both directions there run flows of materials, finances, information and decision. Material flows include flows of raw materials, intermediate products and finished products from suppliers to customers. Conversely, there are oriented flows of products for repair, recycling or disposal. Financial flows include various types of payments, loans, cash flows arising from the ownership, etc. Information flows linking the system with information about orders, supplies, plans, etc. The decision flows are sequences of decisions of participants affecting the overall performance of the chain, i.e. among the final contractor and all sub-contractors who are involved in the completion and delivery of the supply according to the contract between the final supplier and the delivery customer. The supply chain can contain more levels of co-operation stages and it always relates to the performance of one supply. Mutual relations among the co-operative stages are based on a contractual basis.

The supply chain includes all transport and activities related to transport and procedures, starting from the production plant and ending at the cargo destination, i.e. it is a network of autonomous or semiautonomous business entities collectively responsible for procurement, production and distribution activities associated with one or more related manufacturers.

The theory of the supply chain involves the planning, implementation and control of operations applied to the supply chain as efficiently as possible. Supply chain management encompasses all the movement and storage of raw materials, inventory and movement of finished goods from the point of origin to the point of consumption. In theory and in management a specific term, “outsourcing”, is used (Zemánek, 2008). Outsourcing is the division of labour, the purchase of semi-finished products, financial loans and almost all other activities at the store. All the outsourcing issues are contained within the problem of deciding whether to “make or buy” (make vs. buy) or “to own or rent” (own versus lease). In the domain of information sharing one of the many questions is raised when considering the possibilities of outsourcing, the question of safety. Safety can be further divided into two categories. One is data security, i.e. ensuring data from loss (backup). The second category is to protect data against unauthorized abuse, i.e. defence against intrusion into the system and transfer of the information stored in the information system to third parties by employees.

It is a question of both who ensures that the information stored in the system will not be abused by the company that governs (administrates) the system and how this is ensured. A possible answer is the look to statistics, but it is necessary to consider that the amount of penalties that a company may apply to the company’s own employees (insiders) is, as a rule, lower than the possible financial penalty of an outsourced company. The security aspect is managed by a contract in which this domain may be a part of the contract on outsourcing or it may be included in a separate agreement on confidentiality.

The Supply Chain Management (SCM) is turbulently evolving discipline that uses concepts that were developed in various other disciplines such as logistics, marketing, financial and operational management, information systems, economics, dynamics of systems and operational research. Quality of governance (management) of the supply chain is considered to be the key to its future competitiveness, and, therefore, it raises considerable interest with managers and researchers. Modelling the supply chain is a frequent topic of conferences and professional communication.

Supply chain management deals with the mutual relationships among supply chain components, i.e. among suppliers, carriers, customers, vendors, managers for waste management, including those who work with products after the end of their lifespan. These interactions are likely to change in the chain up and down depending on what the subject of interest of an organization in the supply chain. It is clear that effective communication can strengthen co-operation, reduce the potential for misunderstanding and influence the measures taken by organizations in the supply chain.

In a modern operating company it is necessary that the company’s management is capable of managing the supply chain very efficiently. An important component of these chains is an understanding of subcontracting or also of the outsourcing domain, which is used by almost every company today. Firms must know which activities should be delegated to external institutions specialized in the implementation of these operations. An optimal decision on what operations and to what extent to delegate leads to a reduction in costs or to the possibility of focusing on more important tasks related to the firm’s competitiveness.

Every company is trying to assert itself on the market, to define its mission, the so-called company mission. From this mission targets are determined, i.e. objectives, which the company may achieve in a particular market in a certain timeframe. Based on these stated objectives a corporate strategy is then formed, i.e. the determination of the procedure, the means and methods with which to meet those objectives. Together with this, the question arises of the necessity of “correction” of the strategy outlined or its new creation, with the view of changing the scope of the dominant factors affecting the company both internally and externally. In most cases, vicinity factors are simply the main cause of the prosperity or decline of a company.

Enterprises are increasingly confronted with global competition, which is caused by increasingly demanding customers. In order to succeed, they try to control the efficiency of their operations that create and provide products for the attention of end users within the supply chain. In recent years, supply chain management is becoming more important for firms as a competitive advantage. Fierce competition in today's global markets, marketing of products with shorter life cycles, rising customer expectations, forcing companies to focus their attention on the supply chain influence the situation.

The aim of supply chain management is to ensure the safety of all participants of supply chains to which they belong: participants' prosperity; fulfilment of tasks for which they were established; a harmonious relationship with the state on whose territory they perform the activities (Procházková, 2011a).

3 DATA AND METHODS OF SPECIALISED RESEARCH

For the investigation of infrastructure and supply chain failures and of their management published original data were used, e.g. on blackouts in the US, Italy, Switzerland, Czech Republic; disruption of oil and gas from Russia to Central and Western Europe (EU, 2012a); and a simulation of failures of networks which create the basic part of infrastructures (Procházková, 2009). The outputs described in the next paragraphs were created by pure scientific methods, i.e. analysis and synthesis of obtained published results on disasters; specific investigation of disasters by analytical and heuristic methods. Heuristic methods were first tested on real data to see if they are suitable for security tasks solution; specific investigation of the level of disaster management with the help of a special questionnaire; and specific investigation for the identification of critical items in territory management from a viewpoint of human survival performed by special logical tools specially tailored for the FOCUS targets (Procházková, 2012a).

Table 1: Form of questionnaire.

Protected asset		**Problems**	**Proposal of countermeasures**
Lives and health of humans			
Human security			
Property			
Public welfare			
Environment			
Critical Infrastructure	Energy supply (electricity, heat, gas)		
	Supply of water drinking / utility		
	Sewage		
	Transport network		
	Cyber infrastructure (communication and information networks)		
	Banking and financial sector		
	Emergency services (police, fire fighters, paramedics)		
	Essential services in the area (food supply, waste disposal, social services, funeral services), industry, agriculture		
	Local government		

The sources of risks connected with supply chains were derived by considering the all hazard approach (FEMA, 1996), the list of disasters (Procházková, 2011a) and by application of the What, If method (Procházková, 2011b) in the form shown in Table 1.

The detailed study on failures and failures´ management in the EU (2012a) was concentrated on ten domains the outputs of which are concisely summarized in papers (EU, 2012; Procházková & Kopecký, 2012; Procházková & Říha 2012; Procházková et al., 2012). The work (EU, 2012a) also obtains results of a theoretical study dealing with the form of an EU security concept: it must be based on systemic (holistic) thinking, a typical feature of which is the focusing on the whole view of systems and on the research of relations among their individual parts; a proactive approach; an all hazard approach (FEMA, 1996); respecting the co-existence of overlapping systems (Procházková, 2012b). For its realisation sophistically managing the failures that damaged the security of community and its assets is necessary, i.e. to apply measures and activities of prevention, preparedness, response and renovation. For practical purposes good technical solutions are necessary based on recent findings and experiences and correctly aimed governance of public affairs supported by a legislative with a sufficient legal force, finances, qualified human personnel and material base.

4 RISKS OF SUPPLY CHAINS

The synthesis of data from quoted publications and simulations performed by the described What, If method revealed that there are two broad categories of risk that must be controlled in the case of supply chains:

- The risk that is the cause of a lack of co-ordination of requirements and supply;
- The risks associated with the failure of normal operation, which is caused by disasters of all kinds, i.e. natural disasters, technological accidents, terrorist attacks, power failures, strikes, etc.

According to the analysis in EU (2012b) there are particularly important strategic risks, financial risks, operational risks and risks associated with threats according to the approach followed by the All Hazard Approach (FEMA, 1996). According to ISO 28000:2010 (ČSN, 2010) major damage in supply chains causes: physical failure (e.g. failure of the equipment, intentional physical damage); operational failure (technical failure, human error); natural disasters (e.g. floods, storms); external threats (e.g. failure of outsourced activities or externally ensured activities); and threats from interested parties (e.g. the State – the failure of complying with legal and other regulations).

According to the EU documents, shown in Dequae (2012), the supply chain must adhere to the following sub-categories of risk: construction and design and technological risks; credit risks, market risks, external risks, operational risks, and risks associated with management and decision-making. Analysis and evaluation of these risks are required when applying for the European Union's projects (Procházková, 2011b). Construction, technological and design risks include: construction and design risk; site risks, and the risk of erroneous technologies, networks and related services. Construction and design risks that include the risk associated with the design documentation (good/bad, error); risk connected with construction; risk connected with exceeding construction costs; risk connected with the pollution of the site/site vicinity during the project's realisation which is caused by public administration; risk connected with the pollution of the locality/neighbourhood during the project, which is caused by the supplier; the risk associated with the impact of the project on the environment during the project's life that is caused by bad decisions of public administration; and risks connected with the project's impact on the environment during the project's life that were caused by the contractor and operator). The risk of a given site includes the risk associated with the current entity; risk associated with the availability of site; risk associated with ownership of the site; risk associated with the state of a site; risk associated with networks (utilities) located on the site (construction site); risk associated with the land-use plan; risk associated with a construction permit; risk associated with cultural/archaeological heritage; and risk associated with the protected landscape area. The risks associated with faulty technologies, networks and related services include: risks associated with a defect during the implementation of the project; risk associated with a defect within the lifetime of the project; risks associated with using the wrong technology; risks associated with technological insufficiency; the risk associated with an unexpected disruption of power supply, loss of services and support systems provided by the private sector; and risk associated with an unexpected disruption of energy supply, loss of services and support systems provided by public administration. Credit risks include: liquidity risk; and risk of default/i.e. the availability risk, which is further divided into: risk associated with availability (default by the private sector); risk associated with the failure of counterparty and with the loss for public administration; risk associated with the failure of the counterparty and loss for the supplier; risk associated with concentration (for all deliveries there is only one supplier); and risk associated with rejection of partnerships (public administration does not support the project). Market risks include: demand risk in the case that the contractor is a public administrator; demand risk if the supplier is a private entity; the risk that the benefit is for rival; and other market risks such as: currency risk; inflation risk; and interest rate risk. External risks include: political risks; force majeure; and other external risks. Political risks include: risk associated with the national or international situation; risk of government default; and supranational political risk associated with the duties of the state in the EU and NATO. The risk associated with force majeure includes: risk associated with natural disaster with the size of catastrophe; risk associated with terrorism; and the risk associated with war. The item "other external risks" includes: the risk of legal/tax of a general nature associated with changes in legislation/taxes; risk of legal/tax of a specific nature; the risk associated with the need for additional authorizations; and the risk associated with the situation in the sector (strikes). Operational risks include: risks related to the equipment; the risks associated with people; and risks associated with human negotiation. Risks associated with the device include: the risk associated with the device inputs (material); risk associated with maintenance, repairs, modifications and adaptations; and the risk associated with small amortized cost. Risks associated with humans include: risks associated with inadequate labour; risk associated with non-replaceability; risk of scarce human resources; risk associated with labour-legal disputes; and risk associated with human error. Risks associated with human negotiation include: risks associated with fraudulent negotiations; risk associated with illegal negotiation; risk associated with the safety of technological systems; and risk associated with derogation and theft.

Risks associated with management and decision-making include: contractual risks and other risks associated with management and decision-making. Contractual risks include: risks associated with the responsibility to third parties; risks associated with the change of contract; and the risk associated with the violation of generally binding regulations. Other risks associated with governance and decision-making include: risks associated with strategic decisions; and the risk associated with reputation. The definitions of partial risks in the financial sectors are given in Procházková (2011b).

The risks of supply chains according to work (EU, 2012b; Minárová & Dejnega, 2009) and performed simulations provide the following phenomena: traditional property risks - fires, natural disasters, power system outages and downtime of devices; theft, violence and terrorism; political instability and risks, fluctuations in exchange rates, supply interruptions due to political problems in the country of the supplier; fraud and some consequences of centrally planned economies; failures of computer and telecommunication networks; very demanding customers requiring fast and precise delivery; short product life cycles as a result of the diversity of products, their substitutability and emphasis on their continuous innovation and flexibility; complete conformity of the products according to the laws of individual countries; and failures in communication with suppliers. The risks associated with supply chains are very serious, and therefore, they are the subject of current research and investigations (Kinder, 2012). The overall objective of risk management of the supply chain is to identify current sources of risk in supply chains, to perform a distribution of risks according to the size of damage that could be caused their occurrence, and to find a suitable trade-off with risks so that the operational organizations may be safe and no adverse impacts on public interests may occur.

Based on the documented statistics (Kinder, 2012) the following five most frequent risks to the supply chain are: failure of suppliers; production interruption; logistical difficulties; IT failures; and the rising prices of oil and energy. These risks are predictable, their trade-off is essential for a safe organization, and hence, organizations pay critical attention to their management.

The international supply chain has many participants and covers a huge amount of goods. The vulnerability is double: on the one hand there is a large risk of failure for the origination due to a terrorist attack, and on the other the goods are used for a means of attack. At the same time there is vulnerable to the economy of the countries, which directly depends on the reliability of the supply chain. International supply chains also suffer from the consequences of abduction (Kommerskollegium, 2008). Therefore, internationally and within the EU there are extensive programs for the protection of the international supply chain, especially transport shipment, sea freight, air, rail and automotive (Kommerskollegium, 2008). An important role in the international scale of safety is played by a non-profit organization TAPA (TheTransportedAssetProtectionAssociation) that was founded in 1997 in the USA; in Europe it started to be active in 1999 and in Asia in 2000.

In practice it holds the generic standard for the management of security systems, ISO 16125, which deals with security systems related to all forms of threats to organization by fraudulent, malicious, dishonest or intentionally negligent individuals or entire organizations. To ensure safety it means to establish, implement and maintain an adequate level of protection and measures against such threats. The purpose of the document is to provide a security team of organization the systematic approach and guide for the assessment and management of security risks with the target of reaching an overall safe level for the operation of the organization and other stakeholders.

The detailed guidance annexed to this standard states that threats are specific for different sectors, and it gives solutions in line "with good practice" that can be applied in the security policies, procedures, infrastructure, systems and tasks in order that it may be possible to face individual risks. A generic document builds on the existing ISO standards relating to safety and adds them, as e.g. standards that specifically deal with information, information technology, intellectual property and the safety of supply chains (ÚMNZ, 2011).

The logistics of the supply chain is based on information sharing between enterprises based on electronic technologies with reality that the technologies used and their applications are different. From a technological standpoint, these are systems of Supply Chain Management - Supply Chain Management (SCM) based on standard principles characteristic for the implementation of relations company with company, a Business-to-Business (B2B), i.e. on electronic data interchange (Electronic Data Interchange - EDI), applications based on XML technology and standards (eXtensibleMarkupLanguage) and on web applications. Functionality for APS (AdvancedPlanning and Scheduling) is based on transactional applications (e.g. ERP-type - EnterpriseResourcePlanning), possibly in combination with applications and tools for business intelligence. Under the term APS it is understood as a system ensuring production planning whilst considering all possible restrictions of the production system, such as material, labour capacities etc.

Support for supply chains in the EU focuses on support of the so-called intermodal transport logistics, which is a key element of European transport policy. It aims to create a technical, legal and economic framework conditions and innovative concepts for the optimal integration of different modes for services provided by the "door to door" method. In particular it goes on to ensure that modes that are more environmentally friendly may be integrated into the transport chain, such as rail, inland waterways and maritime transport for short distances. The EU adopted a number of regulations and directives in order to create a single European transport market. The legal basis for this Title V of the EC Treaty, in particular Article 71 (Treaty of Lisbon: Title VI, particularly Article 91 of the Treaty on the European Union).

Supply chains according to standard (ČSN, 2010) include all interconnected components of the delivery process, starting from collecting the raw materials and ending with the delivery of the product to the consumers (end users). The low professional level within the EU is highlighted in the work (Burian, 2003) according to which it is necessary "to improve co-operation and communication between Member States on a multidisciplinary approach. In this area it will be necessary to create a set of equivalent methodologies for the evaluation of safety and vulnerability in specific areas".

The work (Setola, 2009) shows that in the EU countries, in terms of global risk, insufficient attention is paid to threats to the food chain, to which drinking water belongs. According to experience it is necessary at the supply chain management level to pay attention to organized crime, which in recent years has become an economic threat. With theoretical considerations a global perspective is necessary and in practice it is necessary to pay attention to the protection of insured partners along the whole chain, as insurance is one of the basic tools for the trade-off with risk (Procházková, 2011b). The present style of management called “Just in Time” (Procházková, 2011a) facilitates the situation to enterprisers and businessmen on one side – they do not pay attention to reserve resources, however, on the other hand it causes a strong dependence on early perfect supply chains.

5 DEFICITS REVEALED IN THE MANAGEMENT OF THE PROTECTION OF LIFE GIVING INFRASTRUCTURES AND SUPPLY CHAINS

The results of a study of the level of management of infrastructures’ and supply chains’ failures documented in detail in works (EU, 2012a, 2012b; Procházková, 2009, 2012b; Procházková & Říha, 2012; Procházková et al., 2012) are summarized in Table 2.

Table 2: Deficits at failures' management from the viewpoint of the safe community concept (EU, 2012b).

SECURITY ITEMS	RESEARCH RESULTS
Security challenges that can be considered to have a big impact in the 2035 time frame and currently are not sufficiently addressed in the planning of research	The list of followed disasters is necessary to supplement with: ▪ Disuse of research infrastructure. ▪ Disuse of educational infrastructure. ▪ Disuse of social infrastructure. ▪ Disuse of supply chains for terrorist attack. ▪ Disuse of supply chains as a political attack.
Most severe security challenges that should be addressed by research planning in the 2035 time frame	The disaster order with regard to impact severity is: ▪ Mid-term failure of social infrastructure (disintegration of human society into intolerant groups). ▪ Failure of public administration infrastructure due to corruption, disuse of power and non-respect for the public's interests. ▪ Long-term outage of electrical infrastructure. ▪ Long-term stoppage of drinking water supply. ▪ Long-term shortage of basic foods.
Challenges for future security research for prevention, preparedness, response and renovation	It is necessary to establish norms and standards for infrastructures that will: ensure their sufficient capacities; enhance their robustness and resiliency. To create an effective system for response, especially in case of failure of finance infrastructure and in the case of failures of critical supply chains. To create a system for renovation (recovery) after critical infrastructures' failures.
Related main vulnerabilities to be addressed for future security research	The massive collapse of the financial market. Long-term outage of electrical energy supply. Long-term stoppage of drinking water supply. Long-term shortage of food supply. Long term failure of critical supply chains. Lack of technical resources, inadequate knowledge and training of managerial staff, poor response management and lack of finances.
Related main knowledge gaps to be addressed for future security research	Methods used are based on deterministic and stochastic approaches and on the assumption that each system is steadily in a steady (stationary) state or close to it, which is not always true. In practice it is necessary to include non-linear thinking and a way to live with risks connected with interdependences. E. g. lessons learned from the Fukushima accident (Procházková, 2012b) show that it is necessary to improve the methods associated with the determination of terms of references for the design, construction and operation of technological buildings, equipment and infrastructures.

	An effective strategy for the robustness and resilience of critical supply chains.
Proposed type of future security research	System of management of territory, entities, sectors, infrastructures and chains of critical resources, goods and needs. Integral risk management – because procedures applied so far do not consider cross-cutting risks, which are the cause of cascading failures of complex systems. Respect for public interest and principles for integral safety management.
Expected most needed topics of future security research	Strategic, proactive and systemic management of territories, sectors, infrastructures and chains that respect public interest and the principles for integral safety management.

6 CONCLUSION

Current practice requirements require in order that each system may be safe under all conditions, not only to themselves but also for their surroundings (i.e. they do not endanger their surroundings through their failure). Therefore, it is necessary to base their management on current knowledge, see, for example, the application of the theory of possibilities in practice (Procházková, 2012b), and especially complies with the principles of good management (governance), which except the responsibility and respecting the public interest, includes early recognition of emerging risks and timely application of corrective measures and actions. To ensure safety in both domains, the critical infrastructure and the supply chains, it is necessary to determine, introduce and keep an appropriate level of protection and countermeasures against real risks.

Among the important supply chains belong: the Food Chain; and the plan of the necessary supplies, and, therefore, in the EU and the Czech Republic a considerable amount of attention should be paid to their safety. Generally speaking, in the EU the issues associated with supply chains are not completely solved and it is necessary to make some major modifications.

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