INNOVATIVE PERSPECTIVE OF TRANSPORT AND LOGISTICS

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ABSTRACT

The need to create and implement innovation in transport results from the continuing low efficiency of many of its technical elements and processes, leading to unsatisfactory levels of productivity, capacity and reliability, waste of time and resources, and higher operating costs. The need for innovation exists both within entire transport systems (of a country or city) as well as within individual modes or forms of transport. Transport innovation processes are the main driving force behind technological progress and increase in service productivity, but they are accompanied by high risk. An innovation-oriented transport company takes a risk that innovations introduced may become a failure, or rejected by the market, or their cost will be higher than originally planned. To main directions of the innovative development of present transport systems belong: intelligent transport system management, carbon neutral transport solutions, alternative fuels and sources of energy, innovative ideas for reducing transport costs, city logistics ideas, new mobility strategies, liveability solutions. In every branch of transport there exist different conditions for the initiation and spreadings of innovations.

Keywords: alternative fuels, disruptive technology, electric cars, innovation, innovation risk, innovative transport, new generation transport infrastructure, transport development,

INTRODUCTION

The motives for creating innovations are both the creative capabilities of scientific research centres and industry as well as pressure from consumers for a greater higher of products and services, and elimination of faults in things and processes commonly used. In the modern world, innovative intensity is not distributed evenly, neither in spatial nor in sectoral scales.

An innovation is the most universal change in human skills and knowledge, consisting in a constant sequence of improvements based on previous discoveries and inventions. Innovations affecting large groups of population can be created only with close cooperation between science and industry, enterprises introducing new technologies, public and local government institutions and consumer organisations. The classic theory of innovation distinguishes between five types of innovations: the introduction of a new good or permanent change in quality of existing good, the creation of a new market, the introduction of new source of supply of energy/raw materials or half-manufactured goods, the carrying out of the new organization (Schumpeter, 1934). Innovation theory applies to many fields: economy, technique, politics, health, science and others. Often innovations in one field impact those in the other. The modern world puts emphasis on better use of knowledge as instrument rapid innovation.

More generally innovation could be of either organisational or physical type. In the first case the change contributes to improvements in organisation, processes and behaviours. In the organizational context, innovation may be linked to performance and growth through improvements in efficiency, productivity, quality or market expansion. In the second consequent improvements depend on technical breakthrough – introduction of new product, equipment etc. There is also significant difference between terms "innovation" and "invention". A change or an improvement is only an innovation when it is put to use and effectively causes a social or commercial reorganization. Therefore innovations result from inventions which materialise. Transport sector is not different in this regard, innovative process in this sector is determined by successful introduction of transport inventions either of organisational or technical nature.

In last years different research centres publish world rankings of most innovative states, regions, sections and firms. In 2008, according to INSEAD the ten of most innovative countries of the world were as follows: U.S.A., Germany, Sweden, United Kingdom, Singapore, Republic of Korea, Switzerland, Denmark, Japan and Netherland (Insead, 2009). There are regions or conurbations being traditional cradles or driving forces of innovation: the famous Silicon Valley, the European autocluster BelCAR, Kansai Science City in Japan, Tsukuba Science City in Japan, and others. In the Businessweek list of 50 the most innovative world's companies leaders on top are: Apple, Google, Toyota Motor, General Electric, Microsoft, Tata Group, Nintendo, Procter & Gamble, Sony, Nokia, Amazon, IBM, Research in Motion, BMW and other (Businessweek, 2008).

Innovations in transport and logistics are dynamic, short-lived and obsolescent, but they create the biggest chances for the future of the sector. Careful observation of innovation processes in the world shows that the second decade of the 21st century may become a period of a concentrated technological breakthrough in transport. Innovative prospects of the TL sector must be perceived and programmed on the basis of previous long-standing experience (both success stories and failures) in the development of the technical and organisational civilisation of the sector, created by discoveries, inventions and innovations.

Transport innovative solutions are stimulated by the world of science as well as the automotive industry, infrastructure managing organizations, transport companies, logistics providers, consumer organisations and users of means of transport. Mature concepts and breakthrough transport technologies result from repeated and modified ideas and selected material means in the form of multi-partite consultations and brainstorming between the above-mentioned groups of entities. Innovations that meet efficiency, effectiveness and social convenience requirements can be created only when complementary technical, economic, natural and social verifications are carried out in the whole process of theoretical analyses and engineering work.

1. CHRONIC TRANSPORT WEAKNESSES AND INNOVATIONS

In the programming of the course of innovation-oriented activities and processes in the sector of transport and logistics, the starting point is a diagnosis of the efficiency and productivity of the currently existing systems. Such a diagnosis is difficult, both in terms of methodology and information available. There is a difference between highly-developed nations and those at a lower stage of economic development. In this diagnosis, the deficiencies in the development of the existing transport systems should be grouped as follows: (a) symptoms of technological stagnation (conservatism); (b) distortions in technology and attitudes (pathologies); (c) excessively ambitious innovation efforts, inconsistent with the current level of civilisation and development.

The whole transport systems of countries or large urban areas can be made more efficient by capital spending and by innovations removing their chronic weaknesses. This goal, however, cannot be achieved by innovation alone, if it is not accompanied by the necessary investment in order to replace traditional elements of the system. Innovation becomes a must if traditional heavy spending on the existing transport systems produces no results. There may be situations, when local transport systems function well enough for efficiency to be ensured by replacement expenditure alone, without innovation. There are no transport systems in large urban areas, however, requiring no innovation to reduce congestion, which is not very responsive to traditional infrastructure upgrading and extension. It has to be remembered that system innovations must not bring positive effects for a small group of the chosen ones, with easy access to the new generation service or infrastructure, but must benefit all the inhabitants using the given transport system.

The prime module of modern transport systems, i.e. the car module, does need innovation due to its inherent deficiencies, like insatiable demand for road and parking infrastructure, the amount of land that road infrastructure takes, total dependence on the availability of liquid fuels and their prices, the need for the driver to concentrate at any time during the journey and disorderly traffic in roads and streets, resulting in congestion and accidents (Burnewicz, 2009b).

The deficiency of rail transport common to all countries and enforcing a search of new concepts and technologies for its operation are low spatial accessibility, determined by whether or not operable rail tracks are available in a given area, an intricate pattern of national or regional differences in rail technology, requiring interoperability efforts, the closed nature of railway network – accessible to specific rail vehicles – and low urban planning adaptability, which is seen in large urban areas.

Inland water transport is a most difficult area when it comes to seeking and implementing new technological concepts or operational innovations. The deficiencies that encourage the pursuit of innovation are low speed of navigation, making it unattractive to logistics systems, high dependence on hydrological conditions and limited spatial accessibility of waterways and ports.

Maritime transport is an element presenting a major challenge for innovative solutions. Its greatest deficiencies are the failure of even the largest ships when confronted by the dangerous element of the sea (an unsinkable vessel has not yet been conceived), the low speed of sea shipping, accessibility to the service that is limited to coastal locations fitted with technically complex and capital-intensive port infrastructure, and the onerous nature of work at sea.

Aviation, which is representative of the greatest technological advancement in transportation, also has a number of intrinsic deficiencies. These are the complex and hazardous take-off and landing, great threat to the safety of aviation from abrupt weather changes (gale, fog, blizzard), aircraft icing, heavy dependence on liquid fuels and on technically advanced systems, and accessibility limited to areas with well-equipped airports.

The existing deficiencies of particular systems and modes of transport encourage research and innovation in both, means of transport and their propulsion as well as in node and linear infrastructure that they have to use. Innovative trends in this respect are of three types: (1) innovation adjusting means of transport to the technologically or naturally limited parameters of the infrastructure, (2) new generation transport infrastructure, better suited to the parameters and operational characteristics of the means of transport, (3) new transport subsystems built from scratch, involving previously unknown solutions – both mobile and stationary. The first type of innovative trends can, for instance, be seen in inland water transport, where new concepts emerge of ships adjusted to the navigation in shallow rivers. An example of the second trend in the construction of new generation seaport and airport terminals and new generation infrastructure in intermodal transportation. The third type of innovative change may emerge in the future, provided research and construction efforts in transport systems are properly organised and funded. Traditional systems of moving cargo by rail or by road may partly be replaced by automated transport technologies.

2. DETERMINANTS OF INNOVATION IN TRANSPORT

Since the train, the car and the aircraft were invented, no breakthrough transport technologies have emerged. There seems to be no substitution prospect for the technique of wheel-based movement on land, or combustion-propelled movement in the air.

Transport innovation of today is adopted to attain different goals than in the 19th and 20th centuries. In the past decades, progress initially meant replacing the muscles of living creatures (animals and humans) with machines and increasing the volume of cargo and passengers carried. Later, innovation was connected with the need for greater speed, safety, reliability and comfort of transport. Transport innovations of the 21st century face a different challenge – they are supposed to reduce the oil-dependence of transportation, its environmental impact and the demand for transport (through advanced logistics systems and better placing of transport systems within economic and social space).

Transport inventions are no longer made by chance, but are ordered to satisfy an important need and a large market. In the old days, an invention could be made by a brilliant hobbyist with little resources. Transport innovation of today is so complex technologically that it can only be made by teams of cooperating research centres, supported by business community and public authority. Necessity has always been the mother of invention, but its role in innovative processes today is more conspicuous than ever.

A symptom of technological stagnation in the transport of the developed nations is the excessive reliance on the internal combustion engine. Road vehicles, ships and aeroplanes alike have so far been propelled by combustion engines alone; it is only rail transport that has used stationary electric power supply to a greater extent. This could have been tolerated until the threat of global oil depletion emerged. The proven deposits of crude oil (feasible for extraction) globally amount to 160-181 bn tonnes, while average global output stands at 3.5 bn tonnes annually (US Energy Information Administration, 2009). This means oil will run out in a matter of 46 to 52 years. The economy (transport inclusive) must gradually make a shift to renewable energy sources (RES) like biomass, hydropower, wind, solar, geothermal, tidal power and others. Innovations must be oriented at the development of alternative fuels and alternative types of propulsion.

Quality of life stops rising when the percentage of private cars has reached a high level (more than 400 cars per 1,000 inhabitants), calling for innovations as an alternative to traditional car use resulting in constant traffic jams. The problem of land cargo transport systems is the technical separation of rail and road transport caused by the fact that in the 19th century the concepts of mechanical vehicles with iron wheels and rubber-tyres went separate ways. Innovations are needed to integrate the two modes of transport in a better way than the multimodal transport systems known so far.

The need to create and implement innovation in transport results from the continuing low efficiency of many of its technical elements and processes, leading to unsatisfactory levels of productivity, capacity and reliability, waste of time and resources, and higher operating costs. Another reason behind the search of new solutions in transportation is the necessity to improve its relations with the world outside by greater accessibility in time and space, better quality of service and lower environmental impact. Many years of observation help to identify the weaknesses of the transport systems requiring innovative action. Efforts of research centres should focus on solutions that will mitigate the permanent faults and inefficiencies or eliminate them altogether. By using the classical scientific method of induction, one may – on the basis of observation and analysis – formulate a list of major shortcomings of the present forms of transportation. This may be used as an indicator of the direction in which innovation efforts should go in order to mitigate or eliminate the deficiencies.

The need for innovation exists both within entire transport systems (of a country or city) as well as within individual modes or forms of transport. In the former case, innovation should result in giving the user a new generation service; in the latter, successful innovation is new generation means of transport, infrastructure, new traffic control methods, new ways of improving safety or reducing environmental and social impact.

The most important thing for future development of transportation systems will be the implementation of the most promising breakthrough innovations (disruptive technology) on which many research and industrial centres in the world are working.

Successful innovation is in large measure an issue of identifying and controlling risk. The more critical the innovation, the more likely it is that survival of its originator will depend on effective risk management. The term risk is not clearly defined in economic field. In general it relates to possibility of loss or adverse effects and decrease of value. But there are also definitions which concentrate on possibility of attaining different results (positive or negative) from originally planned (Borge, 2001). Nevertheless in company planning negative side of risk is what puts company in danger of falling revenues, shrinking market share or even bankruptcy. More specifically, risk is seen as the possibility that expectations will not be met. It is commonly associated with danger, and with the possibly adverse consequences that flow from choices, decisions and actions (Bernstein, 1996). In transport innovation process risk will mean failure in provision of new services, failure to improve existing solutions or failure to deliver improved technical solutions. Risk in transport is associated both with infrastructure (for example use of innovative concepts in infrastructure design which may lead to unprecedented increase in its cost questioning their usefulness) and service provision. But transport innovations are also related to makers of transport equipment whose designs might be lacking in one aspect or another.

Innovation could take either form of a sudden change or be a step by step process of small innovations. They may achieve a smash-hit breakthrough, or simply make a slight improvement in a technology that humans already feel comfortable with.

Many examples of incremental innovations exist, but the transport sector does have a good record of more radical innovations. Breakthrough innovations mark a single event which reshapes transport sector (like automobile, plane, container). Modern transport innovation process is rather result of small incremental changes – improvements in existing solutions.

All possible innovations face barriers. Sometimes barriers are so strong that they prevent innovation from practical introduction into transport system. Barriers are of four major types: technology, social acceptance, economic efficiency and organisational.
Technology barrier results from use of not fully developed technical ideas. Design is either flawed or so complicated that it makes possible use hideous. Economic efficiency barrier results from weak cost/benefits ratio. Innovation itself could be considered useful and technically viable but is not introduced due to excessive costs. Over time when technology improves usually economic barrier disappears as costs decrease. However sometimes it is already too late as in the meantime different competitive solutions have already been introduced. Social barrier results from lack of acceptance by users. People get used to some ways of doing things if innovation is not offering significant improvements over previous means of transport it will be skipped in favour of simplicity. For those reasons innovations which are most easily accepted are either those of revolutionary character which change behaviours or incremental innovations which build on step by step improvements in existing solutions. Fourth barrier group results from administrative, legal and organisational problems. This applies mostly to organisational not technical innovations. Barriers result from different responsibilities of administrative units, competence conflicts and inertia in decision making. Research of real life case studies shows that there are significant risks associated with introduction of innovation in transport sector (see table I).

Table I Barriers in introducing innovations in transport sector

Innovation	Barriers for implementation
Intelligent transport systems	technical barrier, lack of social acceptance to some solutions
Traffic control systems	often poor calibration of system leading to increased congestion instead of decreased
Satellite navigation	insufficient coverage, rise in local congestion (all trucks using same advice)
Electric cars	high cost of production, high operating costs for users, lack of adequate infrastructure (charging stations), poor range due to battery capacity
Fuel cell cars	not fully developed technology, inefficient design, high cost, design safety concerns
City logistics	problems with coordination of city network, lack of space, high cost of technical equipment
Fare integration	administrative problems, imperfect division of revenues, need to integrate many small providers
Environmental zones	reduced mobility, reduced accessibility, citizens opposition, lack of political will
Logistic centres	high costs, increased local congestion
Passenger hubs	lack of sufficient information for passengers, scope of investments necessary, increased problems with security
City rapid transit systems	high cost, lack of space
Road Automated Guided Vehicles	not fully developed technology, high cost
New types of high speed trains	technology although in use for 40 years still not at full potential, safety problems, high cost
Variable wing geometry planes	technical solutions not fully developed, high cost,
Hydrogen powered planes	technology and safety barriers
Larger traditional planes	safety and security, operational barrier (need for specially designed airport facilities), long boarding times
Merger of airports and cities (aeropolis)	environmental problems, need to interconnect with mega-city internal network), problems with cost efficiency of close-by airports
Self service at airport	lack of acceptance by passengers
High-speed passenger ships	still non-competitive over long distances, high costs
Automated container handling ports	technology not fully developed, need to integrated different transport modes
Integration of city public transport	organisational and competence barrier, too many providers, social opposition against resulting exclusion of private cars from city centres
Automatic Personal Rapid Transit	high costs, lack of space
Alternative materials in infrastructure construction	high costs

Source: own elaboration.

Transport innovation processes are the main driving force behind technological progress and increase in service productivity, but they are accompanied by high risk. An innovation-oriented transport company takes a risk that innovations introduced may become a failure, or rejected by the market, or their cost will be higher than originally planned.

The highest innovative risk will occur in projects with large capital expenditure (because losses may be high) and those involving a large number of people (because errors may be made at more implementation stages). Another element increasing the risk is the division of the project into many ˛constituent parts, which are very difficult to control. This also leads to blurred responsibility, where responsibility for the risk is not individually assigned.

Another important risk factor is lack of commonly accepted norms and legal regulations in the area of innovation. Sometimes appropriate regulations are established after the innovation has been introduced (which often happens in transport – for example, traffic regulations were created after the car had been constructed, and air traffic regulations were worked out after the aeroplane had been constructed). On the one hand, this is an advantage for early innovators, because they decisively influence future regulations, but on the other– in a long-time perspective – it may be a factor limiting the profitability of the undertaking due to stricter transport safety standard of service regulations.

Furthermore success of failure of innovation is highly correlated with its adoption by transport sector. An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption. The innovation, to spread and be adopted should show: a) relative advantage, b) compatibility, c) complexity, d) trialability, e) observability to those who will use it. Those features of adoption process are exposed to innovation risk. We can identify four kinds of errors transport companies make, thus exposing themselves to innovative risk. Firstly, they are mistakes in development strategies, which make technological progress impossible. Secondly, lack of imagination, which means inability to put an invention into practical innovative use. Thirdly, lack of vision, when a company does not realise possible interrelations between the current technology and innovations, and the impact the innovations can have on the market, population, culture and customers' habits. Fourthly, lack of resilience, necessary to implement one's own good project (Borkowski, 2009).
Uncommon features of innovations become a specific source of risk. This category includes all the unique elements of innovation which determine the level of the company's risk. And because they are of unique nature, they can hardly be anticipated. They are an inherent part of the innovation process – in fact, innovations, by definition, must generate unique and unprecedented hazards. Efficient operation, flexibility in dealing with unexpected threats and highly-skilled staff will provide protection in this respect.

Technical innovations are core of transport innovative process. But risk associated with failure in provision of what market demands could be high. Technical mistakes are related not only to flawed design but to hidden problems of particular design. What is also important there might be technically sound concept but failed market analysis. Innovation could simply not be introduced because there is no infrastructure to serve it (as was case with early electric cars) or society as a whole does not need it. In terms of society people usually chose simple (or cheaper) solutions while most advanced technical concepts have a feature of being complicated and costly.

Risk in transport design could have many forms: technical breakdowns, high costs of operation, safety issues, cumbersome features, step learning curve to operate.

Another field of transport risk is innovative approach to service provision. There are certain ideas which are based on commonly accepted principles (like protection of environment) but when it comes to their introduction those values become secondary to personal cost and benefit calculation. Innovative organization of traffic, special vehicle free zones failure to introduce public transport in areas of heavy congestion they all represent organizational innovations which are often rejected by public although there seem to be agreement as to the underlying principle for their introduction. The services innovation can certainly result in local improvements in nuisance from parked and driven vehicles, noise and air pollution. But they are widely accepted only by inhabitants of certain areas which directly benefit from reduced externalities. For others service innovations could be perceived as nuisance or barrier in free access to city centre, work place, recreation area. Many service innovations are simply forced by local authorities. What is important in many cases the innovative service solution is not as much in expensive, high-tech measures, but in very simple but creative ways of using existing possibilities.

The role of research differs considerably among the innovations, sometimes being of crucial importance, but sometimes hardly relevant. In commercial airlines, for example, the ultimate innovation is that pilots are not innovative at all when they fly. They strictly follow the rules to ensure safety, comfort and timeliness for passengers. The whole concept of intelligent transport systems utilizes on one the hand technical achievements but on the other simple inclusion of existing but often fragmented elements of everyday infrastructure and services.

There is also huge area of behavioural risk in transport innovation introduction, which is further interlocked with culture and thinking patterns.

Whether humans will embrace or resist an innovation is the billion-dollar question facing designers of novel products and services. Why do people adapt to some new technologies and not to others? Great innovations have foundered over human stubbornness. Most of the contemporary rapid transit systems concepts have been developed in late 19th century and shaped the cities we know today. However, during 19th century numerous alternative solutions have been proposed to solve the question of traffic congestion. Some of them, if implemented in large scale, could significantly change the way the cities look like today. But the consumers didn’t think so. Examples of this include pneumatic rail, hovercraft rapid transit systems or conveyor passenger systems. Resistance to technology is an omnipresent risk for every innovator. But this risk could be reduced by quality of innovation. Adaptable humans usually trade one technology for another, rather than reject any and all. To be accepted, innovations must deliver benefits — enough benefits to make change worthwhile. There are also many consumers who are enthusiastic about changing their behaviour if they believe that by adapting to new technologies they will serve better good, an example of rocketing sales of electric cars in California could illustrate this trend.

Finally there is a question of risk management in innovative process. Being innovative means doing new things, doing old things in new ways, and dealing with uncertainties by taking risks. Risk is unavoidable. The question arises, is the transport entity willing to tolerate risk? Is it able to deal with risk in a productive way?

A common mistake is to perceive risk management in transport innovation processes as strict keeping to the plan, as a process the aim of which is to eliminate any deviations from the original path, whereas the innovation process is determined by a multitude of options, a possibility of departures and alterations – the nature of innovation makes its "planning" problematic.

The innovative risk is one of the least measurable risks. On the one hand, it is difficult to determine a priori the impact of abortive innovations on possible decrease in the company's value, and on the other – there is no benchmark with which to compare it. Because of this, and because of the difficulty in estimating the cash flows the innovation can generate in future, it should be recommended that risk be evaluated by qualitative rather than quantitative methods. There are multiple tools to conduct this process, in transport most often used are risk lists, risk maps or matrixes (Shimpi, 2001).

An important factor for transport innovations is a knowledge base of unique or abortive inventions. The history of transport technology demonstrates that inventions were a failure not only when they were not founded on a specific need, but also when based on very risky concepts (airships, vacuum tube train, supersonic plane, jet train, gravity control propulsion vehicles); inventions taking the form of gigantic structures (gigantic vehicles, superships, superplanes); inventions with innate faults that are difficult to eliminate by upgrading (pneumatic railway, hovercrafts, lighter aboard ships, mobile passenger lounge systems, automated container handling terminals, monorail, gyrobus) and the like (Burnewicz, 2009a).

The risk of creating and endorsing miscarried transport innovations is augmented by the following factors: (1) limited applicability (little demand, small market), (2) great capital intensity of the research, the implementation and related investment, (3) incurable faults (heavy environmental impact, high failure incidence, high energy consumption), (4) quick obsolescence of underlying idea (many possible substitutes), (5) low competitiveness vis-à-vis existing traditional technologies.

Risk in innovative process in transport could be controlled if some risk management techniques are used. There is no possibility to enumerate all actions which might be taken to prevent risk in innovative processes due to nature of transport – its diversity and resulting diversity of risks. But there are some common ideas that help reduce exposure (Tushman and O'Reilly, 1997):

1. Use of enterprise wide and integrated risk management;
2. Keep the process of innovation and risk management as simple as possible;
3. Identify risk sources;
4. Actively manage threats;
5. Set clear roles and responsibilities;
6. Establish maximum level of risk acceptance;
7. Look to embed risk management with innovation inventing process;
8. Use modern risk management techniques.

Obviously innovations are not equal. The risk management tools could be costly and their employment should be dependent on possible profits from innovation. The problem that all innovators face is that it is often hard to tell in advance what financial result will innovation produce. Those questions must be answered by each company and innovator individually. But in general if those rules could be adopted by transport innovators we could still benefit from innovations without bearing to much risk. But innovative risk cannot be fully removed from innovative process in transport, the very nature of innovation demands presence of risk, we could only try to reduce its impact thus facilitating modern transport development.

Careful analysis of successful and failed innovations shows that it is almost impossible to predict which innovation will be success story. There are so many factors influencing chances for successful adoption to the market that it is painfully difficult to arrive with common features of successful innovation. In other words one cannot "plan innovation" as it is contrary to the very idea of innovation. Nevertheless it is possible "post factum" to identify some general features of successful risk avoidance in innovation adaptation process:

1. They have to be accepted by the market;
2. They have to either change consumer behaviour (thus creating demand for themselves) or provide small improvements in ease of use of existing solutions;
3. They have to be cost efficient and be cost-benefit attractive for potential users;
4. They cannot be too complicated in terms of operational design (ease of use for end user must be ensured);
5. They must save time;
6. They have to be easily accepted by authorities.

The success and failure stories of most recent innovations are given in following chapter which try to assess individual capabilities of technologies of tomorrow.

3. INNOVATIONS USEFUL FOR ALL MODES OF TRANSPORT

Innovations important for the TL sector are very often created outside it, in sectors providing it with factors of production (mainly in industry). The implementation of innovations, however, depends on absorbing capacity of the transport and logistics sphere (in the wide sense of the term), driven by both current and long-term reasons and various motives for making decisions. In industry, there are production sectors regarded as innovative and creating grounds for the development of other sectors. These are now sectors specialising in nanotechnology, biotechnology, information technologies, ecology technologies, power-production technologies, quantum engineering, spintronics (mesoscopic electronics) and other emerging technologies (high-tech industry). Traditional production sectors create ever higher demand for innovative segments specialising in creating new generation sub-assemblies, instruments and recycling systems.

To main directions of the innovative development of present transport systems belong (Goldman and Gorham, 2006):

1. Intelligent transport system management (congestion charging, comprehensive bus system management, automated traffic enforcement);
2. Carbon neutral transport solutions (truck Euro V, light aluminium road units);
3. Alternative fuels and sources of energy (all electric vehicles, fuel cell vehicles);
4. Innovative ideas for reducing transport costs (satellite navigation for better utilisation of transport capacity, automatic localisation of unused vehicle capacity);
5. City logistics ideas (neighbourhood drop-off points, centralized urban distribution and logistics centres, construction logistics, environmental zones);
6. New mobility strategies (distributed travel information, fare integration, carsharing, bikesharing, auto-free housing);
7. Liveability solutions (pedestrian realms, car free days, bus rapid transit);

8. Others.

The market for Intelligent Transport Systems (ITS) is global. The main ITS innovation is the integration of existing technologies to create new services. ITS can be applied in every transport mode (road, rail, air, water) and services can be used by both passenger and freight transport. Thanks to telematics elements (ICT networks, traffic control systems, electronic location of vehicles and cargo, electronic exchange of documents) vehicle routes can be optimised, which greatly shortens shipping time. It is not possible to achieve the goals of sustainable development of transport in Europe today without widespread use of satellite navigation. Satellite positioning improves the effectiveness of fleet management by transport companies (both in passenger and cargo transport)(Lacny and Zalewski, 2009), forwarding and logistics companies, or taxi corporations (Bak, 2009).

All the activities related to the construction and maintenance of transport infrastructure form a very important area of transport innovations. The effectiveness and efficiency of these activities can be improved by: (a) innovations in designing and integrating infrastructure with its environment, (b) innovations in the use of materials, (c) concepts of extra fittings and furnishings, (d) systems improving traffic flow and safety, (e) intermodal solutions. The current knowledge about construction and materials engineering makes it possible to build roads, railway tracks, runways at airports and sea terminals from materials with specific features (nanomaterials) that improve utility value and durability of infrastructure facilities. Another symptom of advancement and innovativeness is equipping traditional linear and nodal infrastructure with smart traffic control systems, security control systems, and electronic tolling systems.

The main motive for innovations in logistics is a necessity to make companies more modern and competitive through greater effectiveness and customer satisfaction. Logistics companies must focus on establishing cooperation and creating networks in order to improve the effects of their services in the movement of cargo and its control, information flow technologies and other advanced processes. There are two kinds of logistics innovation processes: ● innovative concepts and solutions in organisation, ● technological innovations. Organisational innovations are modern forms of outsourcing in logistics services and new business models, from simple supply chains to complex logistics networks defined as 5PL. The development of modern information technologies is related to the integration of various IT systems and the use of current data interchange standards. These modern technologies applied in logistics include Electronic Data Interchange (EDI), the Internet, Value-added Networks (VAN), Logistics Information Systems, Points of Sale (POS), Electronic Ordering Systems (EOS), Internet telephony VOIP, and enterprise information portals (Kozlak, 2009).

4. INNOVATIVE ENVIRONMENTALLY CLEAN ROAD VEHICLES

A wide range of innovations in motor vehicles and their equipment deal mainly with new types of propulsion and alternative fuels. Most significant examples of specific solutions include: a) vehicles entirely powered by electricity (All-Electric Vehicle, Battery Electric Vehicle - BEV) (European Association for Battery Electric Vehicles, 2008), b) Fuel Cell Vehicles – FCV (Davis et.al., 2008 and Fuel Cells 2000, 2009), c) Hybrid Electric Vehicles,

d) Compressed-Air Cars (CAT) (Thipse, 2008), e) Road Automatic Guided Vehicles (AGV) (WIPO, 2009), f) Full Transparent Front Vehicles (Freshpatents.com, 2009), g) Road Trains (Bradtke, 2010) – developed chiefly in Australia, the USA and western Canada.

In recent years, a great opportunity has emerged of making a technological breakthrough in motor transport, based on a mature concept and successful prototypes of electric vehicles. The ambition of inventors and designers is to preserve their feature as an individual means of transport that does not depend on power supply infrastructure (as is the case with trolleybuses). If the electric vehicle is to retain all the functional values of the combustion vehicle and become a symbol of Zero-Emission Vehicle (ZEV), it must: (1) be equipped with new generation, electronically controlled, high-power batteries, fixed or replaceable, much lighter than the traditional ones, performing well in both hot and cold climates, (2) ensure a satisfactory range after a single charging of the batteries, requiring no frequent disruptions of the journey (80-200 km in cities, at least 300 km in rural areas), (3) be equipped with reasonably priced batteries, with running costs equal to or lower than the cost of fuel and high-temperature lubricants used in traditional vehicles, (4) have a well-developed power network at its disposal throughout the country, for quick recharging or replacement of the new generation high-power batteries. The first requirement – efficient powerful new generation batteries – has largely been met, since 2008. For the past few years, producers have been able to install the following new generation batteries in their electric vehicles: ● sodium batteries (resistant to low temperatures), ● lithium-titanium batteries, ● lithium-phosphate batteries, ● lithium-ion (SCIB), lithium-polymer batteries.

The need to substitute the battery electric vehicle (BEV) for the traditional combustion vehicle is the greatest in large cities and urban areas. In these populous places there is not enough room any more for the traffic or the parking or garaging of presently bought and used typical-size cars. At the beginning of 2009, there were over 100 electric model and prototype cars of various makes ready to be launched on the market in the nearest years to come (Burnewicz, 2009a). It has become a matter of honour for major automakers to create their own model of electric vehicle adapted to city traffic or long-distance traffic or as a highway vehicle (so far, most often as a sports car). A group of several dozen companies from various industries make the electric car their flagship product.

Of all the city BEVs already launched and marketed, the following models have attracted the greatest interest so far: ● the Norwegian electric car TH!NK city, with a range of 170-180 km, prepared for mass production for the Nordic and American markets ● Indian electric cars made by REVA Company, ● small city cars made by the British NICE Company, ● Italian electric microcars made by Micro-Vett Ydea Company, ● American Tango T600 – a narrow (99 cm), extremely fast and efficient in traffic jams electric car by Commuter Cars Corporations, ● the Canadian electric car by ZENN Company, ● big electric city cars made by Dynasty Electric Car Corporation, ● small, electric two-seater Kurrent made by American Electric, ● small electric city car Maya Mobility by the Canadian Electrovaya Company, ● small Chinese electric city car Flybo XFD-6000ZK, ● electric minicar Toyota FT-EV (Burnewicz, 2009a). The day when vehicles of this category will be in common use is very close, because of their high technical and operational values, sufficient range and reasonable prices. After 2020, many countries will introduce traffic regulations banning the use of vehicles other than electric, hydrogen and compressed-air ones.

The perspective of electric long-distance cars being in common use is a little more remote. Battery-powered cars must have a range, after one quick charging, long enough to be suitable for long-distance travel. Therefore, they must be equipped with a larger block of state-of-the-art batteries, which makes them heavier and more expensive. In early 2009, the following long-distance BEVs were among the most mature ones in operational and commercial terms: ● intensely promoted sports Tesla Roadster made by American Tesla Motors (Google), with a range of 390 km, ● Toyota eBox, with a range of 240 km, available on the Californian market ● very expensive luxury sports Lightning GT of the British Lightning Car Company, to be marketed in 2010, with a range of 400 km, ● the Californian ZAP-X Crossover EV, with a range of 350 km, ● Chrysler Dodge ZEO, with a range of 400 km, ● highly advanced technologically Koenigsegg NLV Quant, equipped with flow batteries made by NLV Solar AG Company, which guarantee a range of 500 km. Apart from cars, prototypes of long-distance battery buses and trucks are being made. A leader in propagating electric vehicles is the Swedish government, which plans to eliminate all the combustion-engine vehicles after 2030 (ETA, 2009). Even now, the Swedish government supports electric cars financially, giving bonuses for buying them twice as high as those given at the purchase of biofuel cars (The Local, 2008).

Hydrogen propulsion is becoming another ground-breaking technology in road transport. Hydrogen is generally regarded as the cleanest and most environment-friendly fuel, because what is liberated in its combustion process, whether it takes place in air or in oxygen, is water only. Fuel Cell Vehicles (FCVs) are a technological innovation designed to reduce exhaust emissions to the atmosphere (US Department of Energy, 2009, accurate information on the subject is also given in: Wikipedia, 2009b). The first fuel cell vehicle launched (in 2008) was Honda FCX Clarity (Wikipedia, 2009a). An optimistic prospect for hydrogen-powered vehicles results from the fact that automotive industry all over the world has been testing their successful prototypes. The advantages of fuel cells as propulsion for vehicles are: ● high efficiency (65% as compared with 35% for the combustion engine), ● no vibrations and noise in energy-production process, ● generation of energy that directly powers electric engines, ● no fuel burning when a vehicle is not moving, ● constant torque, and many others. The main problem in marketing FCVs is their high price.

Between 1994-2009, some 105 model hydrogen and hydrogen/combustion vehicles were built and tested in the world (Burnewicz, 2009a). At the beginning of 2009, the product range of technologically mature hydrogen-powered vehicles included: ● Honda FCX Clarity with a range of 430 km, after a single refuelling with compressed hydrogen – it is the first car in the world powered by hydrogen solely, ● BMW 7-series Hydrogen with a dual propulsion engine: hydrogen- and petroleum-powered, ● Toyota FCHV equipped with high-pressure (70 Mpa) hydrogen tanks, which gives the vehicle a range of ca. 830 km, ● petroleum/hydrogen-powered hybrid Mazda RX-8 Hydrogen RE with a Wankel engine, equipped with an additional 110-litre compressed-hydrogen tank, which enables a 100-km drive solely in a hydrogen fuel mode, ● hydrogen/electric Nissan X-Trail FCV with a range of 500 km in the hydrogen mode, ● Suzuki Hydrogen Fuel-Cell SX4-FCV with a range of 250 km, ● the DaimlerChrysler Mercedes-Benz B-Class F-Cell Tourer with a range of 410 km, ● the Fiat Panda Hydrogen with a range of 200 km. Particular attention is drawn to more common use of hydrogen-powered buses in big cities because of the need to decrease the level of smog and noise. At the beginning of 2009, there were 44 projects carried out in the world, aimed at the implementation of hydrogen- or methanol-powered city bus technology. Technologically successful hydrogen- or methanol-powered model buses include: ● Daimler Mercedes-Benz Citaro fuel cell bus, ● gas/hydrogen Flyer Invero LF Bus (F40LF), ● hydrogen-powered Toyota FCHV-BUS, ● hydrogen-powered MAN Lion's City (H2ICE), ● hydrogen-powered Irisbus Iveco (Fiat) City Class hydrogen.

An important goal for electric vehicles is overcoming the disparity between their costs of development, production, and operation, with respect to those of equivalent internal combustion engine vehicles. The energy efficiency comparison is difficult to make because the two vehicles operate on different principles. When comparing the efficiencies of an electric vehicle to a gasoline vehicle, the efficiency of the source of generating the electric energy must be included in the comparison. An electric car's efficiency is affected by its battery charging and discharging efficiencies, which ranges from 70% to 85%, and its engine and braking system. The greater efficiency of electric vehicles is primarily because most energy in a gasoline-powered vehicle is released as waste heat (with an engine getting only 20% thermal efficiency (INL, 2005b).

As showed in research and tests passed by the Idaho National Laboratory, based on an electric vehicle efficiency of 3 miles/kwhr and the cost of electricity at 7" per kwhr, the electric vehicle will travel about 43 miles for $1.00. Based on an average of 22 mpg for gasoline vehicles and a gasoline cost of $1.25/gal, the gasoline-powered vehicle will go about 18 miles. Thus, the distance that can be traveled for a fuel cost of $1.00 is more than twice as far with an electric vehicle (INL, 2005b).

Another significant difference between electric vehicles and gasoline-powered vehicles is the number of moving parts. The electric vehicle has one moving part, the motor, whereas the gasoline-powered vehicle has hundreds of moving parts. Fewer moving parts in the electric vehicle leads to another important difference. The electric vehicle requires less periodic maintenance and is more reliable. The gasoline-powered vehicle requires a wide range of maintenance, from frequent oil changes, filter replacements, periodic tune ups, and exhaust system repairs, to the less frequent component replacement, such as the water pump, fuel pump, alternator, etc.

Another promising innovation, although revived, is the concept of the development of the Air-Powered Car technology. This technology will be less competitive as compared to electric and hydrogen-powered vehicles because of the laborious process of compressing and accumulating compressed air for distribution, yet it has a high environmental value in cities with compressed air distribution infrastructure.

5. INNOVATIONS UPGRADING RAIL SERVICES

There is an urgent need for innovations in rail transport to improve its corporate image and strengthen its position on the market. High-speed rail is no longer a novelty, it is a technology known in Japan for 40 years and in Europe (French TGV) since 1981. Its development is becoming an element of classical innovation process in different countries. However, there are numerous new concepts and innovative technologies discussed in publications and the Internet, and some of them deserve particular attention: ● passenger double-deck high-speed trains (Double-Deck High-Speed Trains show a productivity that is 1/3 higher than with conventional high-speed stock) (Economist, the, 1998 additional accurate information is available also at Wikipedia, 2009c), ● the tram-train (Railway-technology.com, 2010), ● train scheduling optimizers (Innovativescheduling.com, 2010), ● telematics rail cargo transport control systems (Innovations – report, 2005), ● advanced bimodal and underground urban cargo transport systems (Robinson and Mortimer, 2004), ● energy-efficient rail vehicle propulsion systems (hybrid trains) (Chunichi Shinbun, 2009).

The amount of attention given to rail innovations by research and industrial circles, much lower than to innovations in the automotive sector, partly results from the little role of the rail services in the lives of households (less than 1% of expenses, while motor transport accounts for 10-12% of their budgets). The smaller a sector and its market, the greater is its reluctance to invest in innovation changing technological quality and development prospects. Despite the limitations, innovative solutions can be applied in the rail transport, even the same as in road transport. Regeneration of regional railway lines may be assisted by the new generation propulsion of rail buses. They can move more efficiently and cause lower fume emission if equipped with hydrogen engines or electric motors. It is a priority for major international rolling stock manufacturers to seek innovation, so they present prototypes of new generation trains for long-distance, regional and urban traffic.

Major rolling stock producers in the world regard it as a priority to seek innovative solutions, presenting prototypes of new generation trains adopted to long-distance, regional or urban traffics. However, there are serious barriers to innovation in rail transport, such as the monopoly-based model of the sector, political nature of decisions on structural and technical changes, insufficient rail companies' own funds for investment, insufficient skills of personnel, national orientation of rail companies, etc (Nash and Weidmann, 2008).

6. INNOVATIVE PASSENGER AIRCRAFTS AND AIRPORTS

Modern innovative processes in civil aviation include: (1) concepts of new generation planes, (2) new generation navigational equipment of existing aircraft, (3) air transport systems based on IT and satellite technologies, (4) new generation airports and airfields. Major innovative tendencies in this mode of transport are as follows (Burnewicz, 2009a):

1. Concepts and prototypes of variable wing geometry, vertical takeoff aircraft (Rotorcraft, Tiltrotor) of such manufacturers as Textron, Erica and others;
2. New generation cargo airships (Airship, Dirigeable);
3. Designs of low-noise, low-CO_2 eco-friendly planes, like the hydrogen powered Cryoplane;
4. New generation "flying wing" planes (with no traditional fuselage);
5. Very large passenger airliners (like the Airbus 380, the prototype of a one-thousand-seat Boeing 797 Blended Wing, an experimental craft developed by Boeing and NASA X-48B) to limit the number of takeoffs and landings and thus reduce congestion;

6. New generation airports (including Smart Automated Airports, Highway in the Sky, Off-Shore Air Stations);
7. Merger of huge airports with cities and transforming them into logistics centres (Aéropolis);
8. Technologies of safe, automated air traffic management (ATS).

Apart from these really disruptive technologies, numerous innovative experiments are made in aviation, like the test flights of solar power planes (HP-SIA Solar Impulse plane designed by Bertrand Piccard of Switzerland).

Traffic overload is the problem of large airports and their expansion is limited for spatial and environmental reasons. If airports are to operate more efficiently, innovative concepts of their location must be worked out as well as greater harmony in the make-up of individual modules of an air terminal, fast and reliable transfer of passengers between the terminal and the city and new technologies of passenger and baggage handling. Meeting the demands of the constantly growing air traffic is not possible through traditional investment projects, but only through seeking innovative solutions, of which the most promising are the concepts of:

1. Offshore airports (Maritime Journal, 2008);
2. Common-use self-service kiosks, Self-service baggage check, high-capacity flow-through elevators (TRB, 2008, SITA, 2008);
3. Quick check-in;
4. New designs of airport structures;
5. Innovative passenger transfer between the airport and the city.

The originality of aviation innovations does not directly translate into their large-scale application in passenger traffic. Their commercial and operational success largely depends on such factors as:

1. Technical reliability of aircraft, especially in difficult and changing weather conditions (will a "solar plane" with a wingspan of 60 metres handle air turbulence?);
2. Usability for passenger traffic, not only military or sports application (will passenger accept the "flying wing" with hardly any windows at all?);
3. Possibility of getting the aviation industry interested in the concept of a new plane and spreading new technology (will VTO planes be commercially produced and operated?);
4. The possibility of traditional airport infrastructure being used by new generation planes, without costly modernization (will there be airport authorities ready to adjust infrastructure to large wingspan planes?);
5. Certainty that the costs of operating new generation planes will continue to be lower than the costs of operating the models used so far.

Civil aviation is by nature mostly international or intercontinental, owing to which innovative efforts of aviation companies and the interested countries can be integrated. The ample variety of technological concepts existing today may soon be implemented. This process will be accelerated under the threat of price increases of traditional aviation fuel caused by oil depletion. There is also intensive demand pressure on aviation, without which the development of modern economy, trade and tourism is not possible.

7. PERSPECTIVE OF NEW SOLUTIONS IN WATER TRANSPORT

Despite intensive research and implementation efforts, innovation in maritime transport is rather slow and not very spectacular. Of the solutions described in various publications, the following attract attention:

1. Designing and building High Speed Craft for passengers (HSC), reaching a speed of 35-45 knots and Super High Speed Container Ships (HTH) of more than 50 knots (UKHO, 2007, Hydrolance Corp., 2009);
2. Implementing advanced systems of safety and security of shipping (Automatic Identification Systems – AIS, Ship Security Alert Systems and Long-Range Tracking – SSAS, US Container Security Initiative - CSI) (Beckman, 2006);
3. Concepts of environmentally friendly ships propelled by compressed natural gas (e.g., concept vessel E/S Orcelle developed by Wallenius Wilhelmsen Logistics) (Maritime-forum, 2007);
4. Automated container handling in ports (Automated Container Handling Technology) (ETP, 2001);
5. Concepts of automated logistics systems in seaports (including virtual deep-sea terminals) and new generation containers (foldable container is a concept which may solve the problem of container repositioning) (Konings and Thijs, 2001).

Future shipping and seaports will be based on new generation technologies based on process automation systems, IT and satellite traffic control and management, integrating the functions of traditional operators and subcontractors. The idea of sea-going All Electric Ships (AES) may seem too futuristic, even though electric ships do sail some lakes, especially those under strict conservation. There is greater possibility of replacing the traditional fuel propulsion of ships with one using natural gas or hydrogen.

The greatest technological breakthrough in shipping will be the design of a ship that will not sink even after an accident or break-up, as well as a ship powered by natural gas or hydrogen. Breakthrough technologies in seaports will be those which automate cargo handling and optimize port logistics.

Innovative solutions are most difficult to develop and implement in inland shipping due to natural limitations of the waterways. Despite the limitations, innovative processes do take place in this mode of transport, of which the following deserve special mention:

1. New generation inland craft (including energy-efficient, "clean" inland container vessels, ro/ro catamarans or articulated container vessels with pivot system as well as INBAT vessels capable of navigation in shallow waters) (Wiegman and Konings 2007, Danube Campaigne, 2010 and INBAT, 2005);
2. Solutions promoting road-to-water cargo shift (Creating Project, 2006);

3. Advanced River Information Services (RIS) systems and technologies (EC, 2005);
4. New technologies of winter inland waterway navigation (US ACE, 2005).

A technological breakthrough that would grossly mitigate the major weaknesses of inland waterway navigation (low speed and limited spatial accessibility) is hardly possible. There is a limit to the speed of inland craft which must not be exceeded because of environmental constraints. Possibilities of developing new generation vessels are greater in large inland or coastal water basins. What would be a breakthrough is the introduction of low-noise hydrofoils, powered by natural gas or hydrogen.

8. INNOVATIONS CHANGING URBAN TRANSPORT

In order to reduce pollution, noise, accident rate and general degradation of the quality of life in urban areas it is necessary to develop alternative solutions to the private cars capable to ensure the same flexibility. Intelligent transport systems are a good solution to alleviate mentioned problems.

Large urban areas are places where the chronic transport burden and difficulties concentrate. Despite the development of underground transportation (the metro) and the implementation of electronic traffic management systems, we are still unable to create a model city with fully efficient motor transport of passengers and cargo. The situation gets particularly difficult when free movement of all kinds of motor vehicles (including heavy goods vehicles - HGV) is allowed.

There are many institutions, centres and initiatives in the world, which are supposed to generate innovation and develop systems of sustainable urban transport. Increasingly often they concern not only the transport of passengers, but also urban freight. Overall measures in this respect have been formulated and are generally approved. They include: • Intelligent Transport System (ITS) applications, which optimize passenger transport, • telematics and satellite systems (GALLILEO services), with digital city maps and congestion-reducing systems of navigation, • "green vehicle" technologies (environment-friendly), • parking space and time management, • access restrictions, • access fees in most sensitive areas of the city.

Literature of the subject and the Internet describe the following significant innovations, mature in terms of technology and organization and designed for the sustainability of urban transport:

1. Radical redirection of urban traffic towards public transport through reorganization and redevelopment of city districts in terms of urban planning (The Swedish city of Göteborg is an example, where the Lundby district is an area of efficient public transport. (EC, 2004);
2. Environmentally clean vehicles in urban traffic (powered by electricity, natural gas, hydrogen, compressed air or hybrid propulsion) (EC, 2009);
3. Automatic Personal Rapid Transit (PRT) systems – PRT vehicles work like taxis and move, depending on the type, along various specially prepared and dedicated routes (ground, elevated or suspended) (PRT, 2010; for other examples see: Wikipedia 2010; Ultra, 2010; ATA, 2009; VIT, 2009);

4. Low Emission Zones (LEZ) with strict rules of access and parking for internal combustion vehicles. E.g. Low Emission Zone was established in Greater London in Feburary, 2008. (Guliano, 2008);
5. Urban Lift-sharing Services, also called Car-Pooling, Car-Sharing or Ride-Sharing (Buhrmann, 2006a);
6. Systems of on-demand minivan transport (Call-a-Bus Services also referred to as Demand Responsive Transport – DRT) (Buhrmann, 2006b).

A solution to the car congestion may be the propagation of a system which the public still find difficult to accept, under which cars are used jointly by residents (carsharing, known in French as partage de véhicule or autopartage), or used by different people at various times of the day (carpooling, known in French as covoiturage), which are more universal systems than rent-a-car. Also innovative are some forms of non-motor urban transport – among them the bike-sharing system, increasingly popular in European cities, not only those with moderate climate. Owing to it, some of car traffic changes to bicycle traffic.

The NICHES Project (New and Innovative Concepts for Helping European Transport Sustainability), completed in 2006, was aimed at creating a set of most promising solutions in the widely perceived area of urban mobility. In particular, the project was to increase the quality of natural environment, competitiveness of public transport and quality of life in urbanized areas. The project resulted in the development of twelve solutions which can be classified into the following four categories: a) new seamless mobility services, b) innovative approaches in city logistics, c) new, non-polluting and energy efficient vehicles, d) innovative demand management strategies.

Idea of urban cybercar in city centre area is rather futuristic (Delle Site and Salucci, 2009). But those scenarios should be considered for future use. In a scenario in which city centre areas are reserved to public transport, cybercars can be used as a supplement to mass public transport. Simulations have shown cybercars have positive impacts on traffic at a network level in terms of reduced total trips and increased speeds.

9. INNOVATIONS IN TRANSPORT INFRASTRUCTURE

Innovation processes in the field of transport means and their propulsion cause the need for new generation transport infrastructure. Rationalization of construction and operation of transport infrastructure takes many forms, which can be grouped as follows (Burnewicz, 2009a):

1. Innovations in infrastructure design and integration with the environment;
2. Innovations in the use of materials;
3. Concepts of extra fittings and furnishings;
4. Systems improving traffic flow and safety.

The adjusting of the transport infrastructure capacity to economic and social needs requires the application of a whole range of measures covering the conventional construction of new connections and facilities as well as giving new properties to the existing infrastructure by implementing the Intelligent Transport Systems and Services concept (ITS).

A very important innovative trend in transport infrastructure is the concepts and application of new materials and prefabricated elements for its construction. Even though a technological revolution in this respect is not to be expected and asphalt and concrete will continue to be the main materials in road building, just like ballast and steel rails in the construction of rail and tram tracks, but the infrastructure will contain more and more new generation materials. There are two reasons behind innovation in this area: (1) infrastructure quality, durability and safety enhancement, (2) the use of wastes that are difficult to manage otherwise. The former objective is met in road building by alternative subgrades and base courses, anti-skid surfacing as well as materials and installations for monitoring (optical fibre and others), the latter by the development of new possibilities of large-scale management of industrial and construction wastes.

The most complex and material intensive is the construction of and operation of road and bridge infrastructure, requiring huge amounts of (coarse) crushed aggregates, sand, gravel and the like. Such large consumption of natural resources degrades the environment and the landscape, while the mining and processing of these materials is costly and energy intensive. Innovation in terms of materials in road building means the use of alternative materials and ones refining asphalt, concrete and road foundation. Quality aggregates in short supply can be replaced by clinker aggregate and cement clinker mixes. Innovative solutions and technologies are developed and implemented based on high-strength materials. To this end, nanotechnologies, microtechnologies and biotechnologies are used, modifying the structure of materials, e.g.:

1. Alternative materials in road construction, recycled materials in road construction (Sherwood, 1995 or Françoi et.al., 2008, interesting examples are also given in: Schroeder, 1994);
2. New materials that are added to conventional asphalt, concrete or asphaltic concrete (geotextiles, geosynthetics, composites, polymers and others) (Ajdukiewicz, 2007);
3. Skid-resistant road surfaces (ACISC, 2006, for comparative test results see: Road and Safety Co, 2003 or Krestel Thermoplastics, 2007);
4. Solar collectors to de-ice the road surface in winter (Materials, 2003);
5. New noise-absorbing road surfaces in housing estates (Maagdenberg, 2006 and BASt, 2009), etc.

Innovative non-organic stabilizers like Durabind, recycled materials, recycled glass or recycled cold asphalt are used more and more often in road building. These materials must be adapted to local weather conditions, in particular great temperature variations between the summer and the winter.

Innovative materials in railway construction do not emerge too often. A review of information published by rail manufacturers does not reveal significant innovation in terms of rail shape and the metals used. Usually, efforts are made to enhance rail durability, which greatly affects Life Cycle Cost (LCC). Of great importance for rail traffic safety and quality is the application of such innovative materials and subsystems as: • noise absorbing sleepers and fixing, ● pre-formed surfaces that eliminate road vehicle bumps at rail/tram crossings, ● innovative materials for the construction of rail noise screens.

Aviation infrastructure is basically nodal, which means lower material intensity in its construction in comparison with road or rail networks. Research work on new technologies concentrates on heavy-duty materials for runway construction. New building materials in aviation infrastructure are most useful in the construction, upgrading and recycling of runways. The properties sought in these materials are greater durability (crack resistance), better visibility for pilots (concrete or asphalt mixed with granulated glass), proper surface texture, hydroplaning prevention in heavy rain. Innovations in this area do not mean, however, replacement of the conventional concrete, asphalt or mixtures of the two, but refining them with innovative additives.

In port construction, innovative materials are inspired by the challenges of protecting the infrastructures against the destructive impact of the waves, preventing siltation of port basins and canals (caused by sea currents). Innovations in the area of materials used in this transport mode are much more difficult than in land transportation, as recycling opportunities are limited (materials used in hydroengineering must not be toxic, must have a long life cycle and be friendly to the marine environment).

The greatest added value is contributed to transport infrastructure by intelligent systems (ITS), which are a large set of various technologies (ICT, IT, automation and measuring), as well as management techniques used in transportation to protect the lives of traffic participants, boost transport system efficiency and protect the natural environment. ITS systems provide an ample set of information for motorists and passengers, help in traffic management, enrich the vehicles with useful equipment, make help more easily available in an emergency, make electronic toll collection possible.

Intermodal transport systems are still waiting for breakthrough technologies. The existing solutions have little to do with intermodality understood as the ability of a means of transport to move swiftly in various transport environments (roadway, railway, waterway). The DMV concept of road-rail vehicles, (road-rail buses, dual-mode vehicles) goes in this direction. One example is an articulated road-rail minibus in the Japanese island of Hokkaido. Innovative intermodal solutions are created to eliminate or mitigate the faults and weaknesses of traditionally understood intermodal systems. Generally speaking, they include the development of new technologies of transport means operation, new ways of cargo handling, new design concepts of loading units and new communication techniques between entities in the intermodal supply chain. Infrastructural innovations aim at adjusting railway lines and terminals to the requirements of the new systems. The most promising innovation area is rail terminals, which are highly absorptive of information and IT systems, leading to a reduction in operational time and costs. There is not much progress, however, when it comes to innovative solutions that would swiftly and effectively improve elements of road-rail technology adapted to the loading gauge limitations of the railway lines.

CONCLUSIONS

Innovation is a social phenomenon that entails creating pro-innovative culture, entrepreneurial activities, social acceptance and recognizing the innovation as a key element of economic development. Innovations created in closed scientific circles are not very significant. Innovations are usually thought to be progressive, but we must not fail to notice cases of creating harmful innovations (new weapons, substances and drugs, fast foods, etc.). Such negative innovations appear in transport as well, and they are usually created in order to disable or neutralize certain bans or regulations (radar detectors, CB radio, noxious fuel additives) or to make leisure activities more attractive (quads, mini-hovercraft). However, only progressive innovations (facilitating processes, cutting down energy consumption, improving safety, etc.) are introduced into national and regional transport systems.

Innovation is risky process and thus often is avoided. But there is no possibility for innovation without taking chances. Risk must be accepted if progress in transport sector is to be made. Resistance to innovations could be overcame by testing new approaches over a period of several years and, upon completion, drawing conclusions for a more general application of such approaches. In transport there are private enterprises whoi are still willing to take risks and innovate but predominantly in automotive industry or on competitive service markets. Huge part of transport is governed by public sector – some services and majority of infrastructure. Here special incentives to innovate have to be forced upon managers and operators. It could be achieved by introduction of special codes of conduct which prevent stagnation in government transport branches (this type of codes have been introduced in New Zeland, UK, Australia). Under those regulations public sector is obliged to some degree to take risk and innovate in order to better fulfill popular demand for transport.

A strategic (superior) objective of pro-innovative policy in transport is creating a sustainable transport system that would facilitate efficient and rapid socio-economic development of the country, with due regard to present realities of social, economic and political life. The transport system with all its elements must contribute to higher competitiveness and productivity. The implementation of this policy requires constant adequate funding of scientific research and innovations (at least 2% of GDP, including at least 0.2% of GDP for transport research), creation of pro-innovative attitudes (fighting technological conservatism), and removal of bureaucratic, procedural and fiscal barriers.

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