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THE ROADS OF THE FUTURE

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Abstract. Infrastructure development is a global priority. Most countries are investing enormous financial resources on high-quality, safe and sustainable roads. Taking into account the pace of technology development, it is currently not only building roads but complex projects. In the Republic of Moldova, as is well known, the situation with the roads is very difficult, in some regions they are practically only on paper. The article contains a description of the modern practices and technologies implemented in some countries regarding the construction and materials used for road clothing, as well as smart solutions on motorways.

Keywords: *road clothing, terrestrial communication, intelligent motorways, concrete road, plastic road, rubber road, paved road with solar panels, geogrid, intelligent road.*

The first roads were simple paths traced by the animals that migrated and followed by the primitive man in an attempt to widen his area of existence. Although all primitive societies had roads – either natural paths or straight roads made by cutting trees and leveling the ground – the first true roads builders are considered to be romans. Through their engineering skills, they have transformed the construction of roads into a science. They have built the first cobblestone paths, often made of tiles put over real masonry foundations, some of them have resisted to nowadays.

The engineering ideas of the romanian drummers are still being applied. Modern roads still use four roman features: multi-layered pavement, curved edges for rain drainage, elevation above ground level, and use of parallel ditches to ensure rainwater drainage.

The origin of the modern paving technique dates back to 1775, when *Pierre-Marie Tresaguet* built the first stone crushed, beaten through use, cemented by mud roads, these ones being a resistable and durable ground. Restored by the scottish *John McAdam*, this technique became at the beginning of the nineteenth century the technique, called „*macadam*”, a mixture of crushed stone and sand, compacted by stone or cast iron rollers drawn by horses. Another scottish, *Thomas Telford*, facilitated leakage of infiltrated water by laying the macadam bed on a large, unblemished bed of stones. Finally, their compaction was improved, starting with 1860, by the use of steam-driven heavy duty compressors, and after in 1925, of Diesel engine compressors.

Towards the middle of the nineteenth century began to study a new technique – ***asphalt.*** In 1838 the first pavement in *Paris* was paved, and in 1854, in the same city, *Merian* paved the first road. In 1867, the engineer *Charles Tellier* had the idea of covering the macadam with a very fine layer of tar and sand. In 1892, the first concrete road was built in *Ohio (USA)*.

In the *USA*, ***concrete roads*** account for 60% of all motorways in the country, in *Europe* – about 40%. At present, concrete road construction technology is so popular that it is used throughout the world for mass construction. Concrete casting is not easy to achieve, but high costs are redeemed due to the durability of these roads.

Despite the complexity of the technology, this road has several advantages. The first is durability: the concrete is resistant to heavy loads, temperature drops and different humidity levels. Second advantage – simplicity of operation: their repair is simpler and cheaper than repairing asphalt roads. Depending on the quality of the concrete, roads can serve up to 40 years without capital repairs. In two *USA* cities – *Houston and Dallas* – there are roads built in the 1960s, which have never been repaired, being in good condition. The experience of concrete road construction today is taken over by *China, Japan, Australia*, some european countries. The prospect of building concrete roads in the *Republic of Moldova* is vague due to the complexity of expensive construction technology and equipment.

Throughout history, the road has seen various types of road clothing: stone, brick, wood, sand, concrete, asphalt, etc. – the epochs and civilizations dictating its construction rules. It would seem that the road has reached perfection, the ideal smooth and durable asphalt of the German motorways is suitable for any kind of transport.

„The road is a terrestrial communication path, consisting of a narrow and continuous strip of ground, stoned, paved or asphalted." The given definition, offered by *Wikipedia*, the free online encyclopedia, is at first sight correct, but the 21st century comes with its changes in this explanation. Today, not, but in the near future this definition might sound like this: „The road is a terrestrial communication path, consisting of a narrow and continuous strip of ground, paved, sroned, concreted, asphalted or being made our of plastics, rubber and solar panels etc."

Mankind has long understood that road is a considerable necessity and its development will depend on its quality. Due to the fact that fom the antiquity man wanted something better, today, we have a much more developed street infrastructure. With all its advantages, the road network is not perfect, with a series of weak points including:

- the construction and maintenance of asphalt roads require large investments;
- the construction of asphalt roads takes a long time;
- roads with traditional clothing have a low durability and reduced service life;
- are prone to cracks and holes;
- are sensitive to climatic conditions etc.

At present, one of the major sources of environmental pollution is chemical wastes, such as waste paper, rubber, textile, glass, plastic etc. Intelligent recycling and re-use would solve this problem to a great extent. Many research has found that some waste can be used to construct *„roads of the future"*.

Plastic roads. Plastic is one of the most badly biodegradable compounds, even for hundreds of years to break down. Plastic waste is produced in huge quantities and its recycling does not keep up.

A scottish startup, *McRebur*, is going to give a new utility to the plastic that gets into the garbage dump. This could be the basis of the roads we are running. The method involves the transformation of plastic waste into granules that can be used for asphalting. Asphalt plastic manages to replace most of the bitumen needed to create the finished product. Granules, practically, can be made of any kind of plastic, whether from household or commercial waste.

British engineer *Toby McCartney* has developed an innovative project that allows the replacement of a large amount of petroleum bitumen asphalt base with small plastic granules made from processed bottles. *Toby McCartney* worked in *India* and became acquainted with the technology used by the indians, which consists of filling the pits with plastic waste melted right on the spot. Plastic is more durable than normal asphalt, safe for the environment and allows for bitumen saving.

India today is the world leader in creating plastic roads. According to the World Economic Forum's 2015 report, about 33796 *km* of recycled plastic roads were built in *India*. Indian road construction technology consists of the following. First the waste is sorted, then cleaned, dried and crushed. The shredded plastic is blended and melted at a temperature of 170 *°C*. Then hot bitumen is added to the molten plastic. After mixing, the content is set as an ordinary asphalt. Analysts are convinced that this cheap technology can be used to restore global roads.

In general, asphalt on roads is a mixture of gravel, limestone and sand in the proportion of about 90%, while the rest is bitumen, which „*binds*” all of these ingredients. But the technology can be improved. Plastic bottles are recycled to be turned into toys, furniture or even jeans, and in the future these bottles could be turned into roads!

The *Netherlands* could become the first country in the world, and *Rotterdam*, the first city to replace classical asphalt on its roads with a new plastics composite, after the *Rotterdam City Hall* announced that there is the possibility of implementing this idea on its streets. The construction company *VolkerWessels* started a project together with the city of *Rotterdam* called „*PlasticRoad*".

The *Rotterdam* authorities hand over a lot of land to *VolkerWessels* where they can test their plastic road. According to the creators, the pluses of the plastic road are very large. It can be manufactured at the plant in blocks by special molding of a mixture based on recycled plastic, and installed very quickly on the required surfaces, which reduces the cost and time of work on the road.

Inside, the plastic blocks are empty (*figure 1*), they can serve as a shelter for communications and water drainage channels, so along these roads it will not be necessary to drill the special ditches to install the communications. Moreover, the plastic road is resistant to corrosion, and for repairing it, it can easily replace a section of it like a *LEGO*. This road can be mounted on all types of soil, being placed on even sand. The plastic road is very easy, which reduces the pressure on the ground. The installation of plastic roads takes a few weeks, unlike traditional technology, where the works take several months, sometimes even a few years. Respectively, this allows both time and money to save, one kilometer of motorway varies at asphalt casters between 5,6 – 14,7 million euro.

VolkerWessels mentions that the plastic road resists temperatures from -40 to +80 *°C* and is very environmentally friendly in production – annual production of traditional asphalt emanates 96 million tons of CO_2 in the atmosphere. Additionally, it is resistant to chemical reactants and does not require practical maintenance, with low chances of creating pits. The lack of the need for repair works reduces the number of traffic jams. The lifetime of these roads may be 3 times higher than those of the asphalt.

Figure 1. *VolkerWessels* plastic road.

The only downside of the plastic road consists in the fact that during rain it may present a slip hazard, requiring the assignment of a rough surface to increase adhesion.

Rubber Roads. The asphalt manufacturing process of rubber granules is a powerful extension of recycling technologies. The experiments on the creation of a rubber road have taken a long time. The first attempts were about 70-100 years ago in the *UK*, when the rubber was used as pavement clothing to reduce the noise level. A century later, the polish remembered this idea. In 2015, polish asphalt producers invented a method of producing bitumen with rubber additions. In other words, they have developed and implemented the mass construction of rubber roads.

The tires are disassembled, shredded and added in liquid state to bitumen, a material for the construction of the upper layers of the road surface. To produce a mix for 1 *km* of road, 400-1200 tires are needed. The polish have already built over 200 *km* of so-called „*quiet roads*."

Tire recycling is a difficult problem in many countries, as millions of used tires reach the landfill and pollute the environment. Each year, around 42 million used tires are collected in *California*. Of these, about 75% is recycled, and the remaining about ten million used tires are thrown to the dump. Because the storage of rubbish rubbers and especially the burning of rubber wastes are highly polluting for air and soil, rubber recycling firms remain the only waste tire collection solution to protect the environment.

Starting from these problems, *California* has developed an ingenious program of recycling used tires and transforming them into the asphalt in a proportion of 100%. By recycling old tires, an asphalt with a high degree of elasticity and less noisy is achieved. Due to its increased elasticity, this asphalt is harder to be deteriotated than regular asphalt.

The recycling project, created by the *California Integrated Waste Management Board* (*CIWMB*), cost *$* 325000 and uses the raw material from 21000 used tires. The amount of asphalt obtained is used for paving about 17 *km* of road. The implementation of this project allows the *Californian* state to save *$* 100000 for every kilometer of the road, making the *$* 325000 invested in the project cost to save of about *$* 525000 on asphalting roads.

The new requirements imposed in road construction for asphalt mixes have determined, from the outset, the constant involvement of the companies in the research and development activity of these materials. It was therefore not surprising that *GENAN*, the world's largest recycling tire manufacturer, with three recycling units in *Germany*, one in *Denmark* and one in the *USA*, is actively involved in the production of some synthetic polymer replacement components. It was, therefore, a great economic and technological achievement when *GENAN* launched *ROAD*+ as an alternative to synthetic polymers, more environmentally friendly than other modifiers used so far.

ROAD+ is an elastomer bitumen and asphalt modifier. The basic component of the *ROAD*+ product is high quality rubber powder, manufactured by *GENAN*, which, in combination with the *VESTENAMER* product, invented and patented by *EVONIK*, replaces the synthetic polymers used so far to modify the asphalt.

The manufacture of the *ROAD*+ product does not present any difficulty, as it is obtained by recycling used tires. By applying *GENAN* to recycling used tires, significant CO_2 emissions (1 to 2 *tons* of CO_2 per tonne of used tires) are avoided and fossil fuels are saved.

Compared to modified bitumen mixes based on other polymers, *ROAD*+ modified asphalt has the resistance to digging and cracking, ductile deformation and aging, which are clearly superior, and due to the elasticity characteristic of an elastomer, the product has the ability to compensate for internal tensions due to extreme variations of daytime to night temperature, regardless of the climate zone. Asphalt modified with *ROAD*+ turns out to be a silent asphalt, with a 5 to 6 *dB* reduction in noise generated by vehicle traffic, as compared to conventional asphalt.

The addition of *VESTENAMER* in *ROAD*+ reduces the emissions occurring in the preparation of asphalt-based bitumen based on native polymers and at the same time reduces the migration of organic substances into groundwater. *VESTENAMER* improves the dispersion of rubber powder in bitumen and forms a strong chemical bond with the powder, resulting in a homogeneous mixture. *ROAD*+ provides very good machining properties that greatly facilitate *ROAD*+ modified asphalt casting even manually or in layers of low thickness.

ROAD+ can modify any type or assortment of bitumen, regardless of origin. This proves to be a great advantage given the extremely varied quality of bitumens used. It can be used as a modifier, directly to asphalt mix in the asphalt production plant (dry process) or indirectly, by pre-treatment of the bitumen (wet process).

Compared to other products similar to *ROAD*+ modified asphalt, it can be stored at lower temperatures, so it can be transported over longer distances, consuming less energy and reducing pollutant emissions. The asphalt mix with *ROAD*+ is 100% recyclable, without producing significant pollutant emissions during the process compared to other types of asphalt.

The disadvantage of the rubber road lies in the sensitivity to low temperatures, which is more recommended for countries with a warm climate.

Advantages of the rubber road:

- first of all, it is environmentally friendly: during processing, the rubber is not burned but is recycled with a minimal amount of waste;

- secondly, this component gives the mixture a major viscosity so that the coating becomes resistant to cracks and age. This increases the life of the roads and the money saving for their maintenance and repair. Adding this mixture to the asphalt makes it possible to increase the durability of clothing by 15 to 20 years.
- thirdly, the the rubber added in asphalt reduces the noise produced by the car movements by 3-6 *dB* compared to traditional roads, thus reducing the noise pollution.

Roads paved with solar panels. Concepts of turning the road into an interactive and intelligent system are diverse. Though technological innovations in the field of automobile construction are becoming more and more spectacular, there is an increasing interest in roads as well as improvements that can be made to them. *USA* engineers *Scott* and *Julie Brusaw* have developed a scheme to transform the road network into a large solar power station. The project was called *Solar Roadways (figure 2)*, and its essence is quite simple. The *Brusaw* spouses propose replacing road clothing with solar panels, covered with transparent and resistant glass material, able to withstand a constant transport load. This road accumulates the sunlight and turns it into energy for street lighting, electronic road signs, road signs and markers, as well as heating roads, preventing the formation of ice and snow.

The *Solar Roadways* pavement is made up of three layers. The outer layer is the main problem of the producers. Special glass, strong enough to hold the weight of trucks without bending and destroying fragile solar panels, is very costly. Also, it should be remembered that the coating must be waterproof and sometimes very severe weather conditions. The second layer is electronic. This includes microprocessors, snow melting heaters, solar panels, *LED* lighting. The third layer is basic, communication. It is through him that electricity, „*developed*” by road, feeds external consumers. *Solar Roadways* can be telephoned, high speed internet instaled etc.

The positive and negative arguments of *Brusaw* are obvious. Positive: cheap and affordable electricity, a huge autonomous power plant with the ability to connect to it anywhere, easy and convenient management of the raod marking and information, environmental benefits.

The main drawback of the project is its high cost. A panel, according to the most modest calculations, costs 7-10 thousand dollars (asphalt with the same surface costs about *$* 250), but also the reliability of the system is a big question. One thing is testing an experimental square under laboratory conditions, and another is daily traffic, rain, snow, dirt, mud covering the solar panels, and not cleaning with heating.

France, another country testing this concept, decided to combine utility with the pleasure of developing a project to build highways in solar panels. Until 2021, 1000 *km* of french roads will be covered with photovoltaic panels.

Engineers claim that technology is simple and efficient. Roads will be built from *Wattway* panels (*figure 3*). The project does not involve the construction of new road sections, but proposes the attachment of thin solar panels made of polycrystalline film called *Wattway* on the already existing road surfaces. The thickness of this *Wattway* is only 7 *mm* thick.

The main advantages of these roads are energy generation, high wear resistance, automatic adaptation to temperature changes. Such a road can withstand up to 115 *tons* without deformation. The disadvantage of these roads lies in the construction and the materials used are quite costly. The project will provide energy for 5 million people or 8% of the *French* population. According to calculations, these „*sunny*” roads will be occupied by cars only 10% of 24 hours. Researchers also note that these roads are environmentally friendly, which will contribute to the future of improving the world's climate.

Figure 2. *Solar Roadways* pavement.

Figure 3. *Wattway* panells pavement.

Geogrill is a type of geosynthetic, which is a two-dimensional or three-dimensional cellular structure made of polyester cloth strips or polyethylene and polypropylene tapes fastened together with high strength welds. Stretched in the work plane, it forms a horizontal and vertical stable frame, designed to strengthen the soil, crushed stone, sand and other building materials that fill the cells of the geogrid.

The main functions of geogrid are: to prevent soil deformation and slippage; ensuring good drainage on the protected area; fixation of sand or crushed stone on a slope or slope; the protection of road clothing against slipping and the formation of irregularities; increasing paving capacity; ensuring environmental safety etc.

Geogrids can be ***uniaxial*** and ***biaxial.*** In the final production stage, the geogrid is stretched, orienting the molecules of the material in a certain way. The grid stretched in one direction – longitudinal – is called uniaxial and has rectangular cells. If the grid is stretched in two directions at the same time, it is called biaxial, having square-shaped cells.

In addition, geogrids are divided into ***flat*** and ***volumetric.*** The flat geogrid (*figure 4,a*) is itself a regular geometric mesh of thick polymer bands backed into intersection points for additional curing and better adhesion to the soil. Geogrids of this type are used practically in all spheres and construction sectors as well as landscaping. They are highly demanded in road construction: their use reduces the cost of materials and significantly the levels of their consumption.

Depending on the manufacturing material, flat geogrids are divided into several types:

- *glass fiber geogrids* are used to reinforce asphalt concrete layers to reduce cracks and mitigate the effects of climate change;
- *basalt geogrids* are used to strengthen asphalt clothing and reinforce the masonry during construction;
- *polyester geogrids* are designed to strengthen and strengthen unstable soil, sand or broken stone, as well as reinforcement of asphalt clothing;
- *polypropylene geogrids* are capable of stabilizing and reinforcing soils with reduced bearing capacity;
- geogrids made of polyethylene are used for reinforcing stone walls and soils with extremely low load bearing capacity;
- polyvinyl alcohol geogrids made with modern technologies are distinguished by the possibility of extension by 3-5% compared to other types.

Volumetric geogrid (*figure 4,b*) is a volumetric cellular construction of polymeric or synthetic bands fixed between them. In working order it forms a modular cellular structure. The material is not exposed to putrefaction, action of acids, alkalis, being easy to install. Life expectancy is at least 50 years. For mounting the volumetric geogrid module, special plastic anchors, metal anchors with a length of 500 (800) *mm* or iron fittings are used. The material is manufactured in modules, the coverage area is 10-25 m^2, the cell height 50-300 *mm*, the cell diagonal 150-300 *mm*, the wall thickness of the band 1,1-4,5 *mm*, the working temperature range from -60 - +60 °C. The volumetric geogrid walls can be perforated to enhance adhesion with large granulation materials and improve soil drainage.

Volumetric geogrids are used for the loose soil consolidation process, the protection of erosion slopes, the lifting of support structures and the strengthening of the channel or shoreline of an aquatic reservoir. Nearly all the slopes of the bridges are now reinforced by volumetric geogrids. But in order to fulfill its function, the volumetric geogrid is used together with additional materials, such as anchors and geotextiles.

The unmistakable advantages of volumetric geogrids are: Simplicity of installation without special technique, favorable price for 1 m^2, long operation period, corrosion resistance, no repairs needed during the whole operation period, ensuring ecology, high load bearing capacity, reduced weight etc.

Geosite 3D (*figure 4,c*), as well as the geogrid, features a three-dimensional material in itself, varying substantially through the height of the cells. In geosite, they do not exceed 5 *mm* and are capable of retaining only fertile soil particles in which plants are sown to create a natural cover of the slope. Over time, the vegetation layer assumes the functions of a protective layer, effectively fighting against erosion and landslides. The ground's particles are firmly held in the cells of the net, which contributes to the growth of plants and to the sliding of the slopes.

Geomat (*figure 4,d*) is a two-dimensional structure made up of several layers of extruded polypropylene grids. The grids are superimposed on one another and are joined by means of a polypropylene thread by the thermal method. Geometries are usually used to straighten grass or small roots in the slope, creating a sustainable and reliable slope coverage. Due to its structure, the geomate retains soil particles more efficiently than a geosite, creating ideal conditions for plant root growth. To obtain tear resistance, geomats are sometimes combined with geosite or geotextile.

a) b) c) d)

Figure 4. Geogrids: *a) – flat geogrid; b) – volumetric geogrid; c) – 3D geosite; d) – geomat.*

Smart roads and motorways are terms used in many proposals to incorporate technology into the road to get solar or wind energy used for lighting and weather monitoring. The „*Intelligent Highway*" will use the latest road construction technologies, its designers claim to be „*more durable, safer and more intuitive*." The companies behind the project, dutch companies *Studio Roosegaarde* and *Heijmans Infrastructure*, who have been awarded the „*Best Future Concept*" in the *Dutch Design Awards*, say that their goal is to transform ordinary transport, focusing on the highway rather than on the vehicles they use. Here are some of the most spectacular innovations.

Electric Priority Lane (*figure 5*). An ambitious idea for the future of road transport is the special lane that allows electric vehicle drivers to recharge their electric vehicle accumulators as they travel alongside them. Special traffic belts are equipped with under-electric electrical cables that generate electromagnetic fields, and with the help of *Wireless* Technology, the battery of electric vehicles is charged during the journey. For example, a *BMW i3* can be charged in about 80 **miles**, a *Nissan Leaf* in about 84 *miles*, and a *Chevy Volt* in about 35 *miles*. This innovation simplifies the use of electric cars by reducing the need to use recharging stations.

Interactive Light (*figure 6*). Another plan is to light motorways with special installations, based on several sensors that generate light, gradually increasing in intensity as the vehicles approach and then go out after passing, saving electricity (the energy consumed when roads are uncirculated) without endangering road traffic safety at night. Interactive lights are perfect for highways that are less circulating or for roads where parking is prohibited.

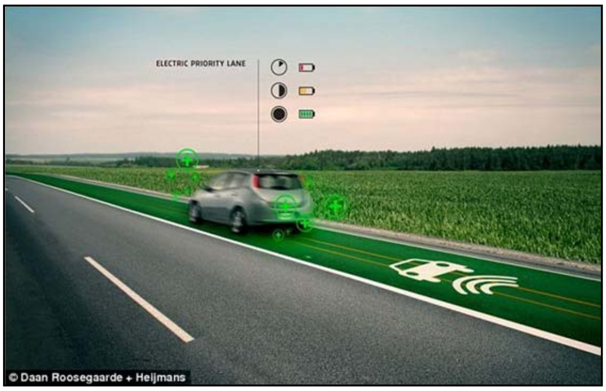

Figure 5. Electric Priority Lane.

Figure 6. Interactive Light.

Glowing Lines (*figure 7*). Another idea is that road markings on motorways and roads are painted with a photo-luminescent powder that charges from the sunlight and can provide their shine up to 10 hours at night. Phosphorescence markings increase visibility and safety at night. Besides the advantage of providing better guidance on roads outside the localities (where there is no public lighting), the phosphorescent mark can lead to lower electricity consumption on low-circulation roads and public lighting.

Dynamic Paint (*figure 8*). Another technology is the dynamic paint, which is a paint that becomes visible due to temperature fluctuations and allows the road surface to show important information about traffic to drivers. For example, snowflakes become visible on the road when the weather is cold (at -5 *°C*) and the surfaces become slippery, and if the ambient temperature is higher than +20 *°C* on the road, the sun symbol is visible.

Figure 7. Glowing Lines.

Figure 8. Dynamic Paint.

Wind Light (*figure 9*). Dutch designers and engineers have thought of a highly intelligent lighting system based on wind power. A chain of small wind farms are mounted on the edge of the road, using the wind power to produce energy that powers the lighting system. Unlike interactive lights, wind energy-based lights illuminate with a propeller that generates electricity. The spikes rotate due to the wind produced by the vehicles passing through the area, so the energy from the propeller starts the road lighting system. As winds are needed to put them into operation, the lights only turn on when the vehicles pass through their area of action.

Figure 9. Wind Light.

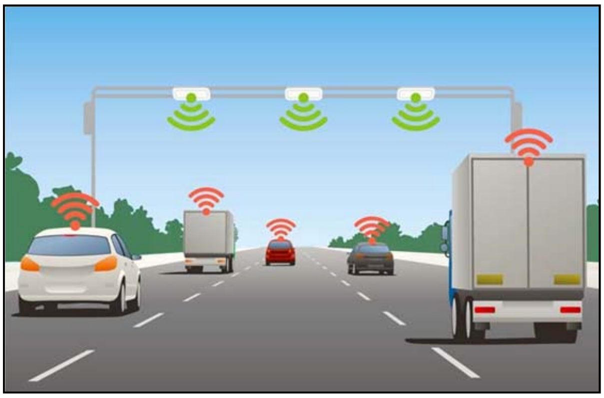

Figure 10. Interactive Highway.

Interactive Highway. *Ohio* State University of the *United States* proposes launching a motorway testing segment that can „*communicate*” with the drivers. It is the *vehicle-to-infrastructure* data *v2i* system capable of delivering various road infrastructure information to the vehicle (*figure 10*). Thanks to the *v2i* model, the car picks up information from installed sensors over every 600 *m* and alerts drivers about traffic jams and road accidents, providing optimum traffic. The inventors are confident that their future roads will increase road crossing capacity and reduce the frequency of road accidents. However, the system requires all vehicles with *v2i* to be equipped.

Battery-Road. The Polytechnic University of *Milan* has developed the *Lybra* underground feeding technology (*figure 11*). The idea is to convert the kinetic energy taken from the wheels of cars into electricity. The transformation device resembles an „*artificial road roughness*” located at intersections and pedestrian crossings, car parks etc. Cars passing this device produce 100000 *kW* of electricity per year (meanwhile, 10 devices are tested). According to the developers, the same amount of energy is produced by burning 19 *tons* of oil. This is enough to provide electricity for one year to 40 families.

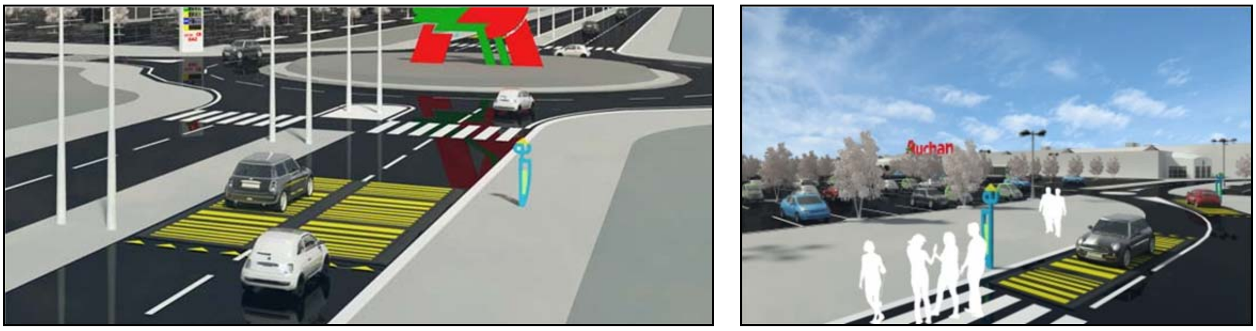

Figure 11. Battery-Road.

The Intelligent Traffic Light System (*figure 12*) is designed to increase the intersection crossing capability by using the dynamic signal control of the traffic lights. The system consists of remote controllers, cameras and sensors, which in real time assess the intersection load and transmit it to the central management server information. Communication with the central server is done through radio waves or optical communication lines.

The intelligent traffic light recognizes in which direction and how many vehicles have accumulated, giving priority to one or another flow. The more cars are in traffic, the greater the time for them to operate the green light signal. The peculiarity of the system is that it takes into account not only the traffic that is approaching the intersection but also the ability to anticipate the emergence of new vehicles that could create traffic jams in the sector.

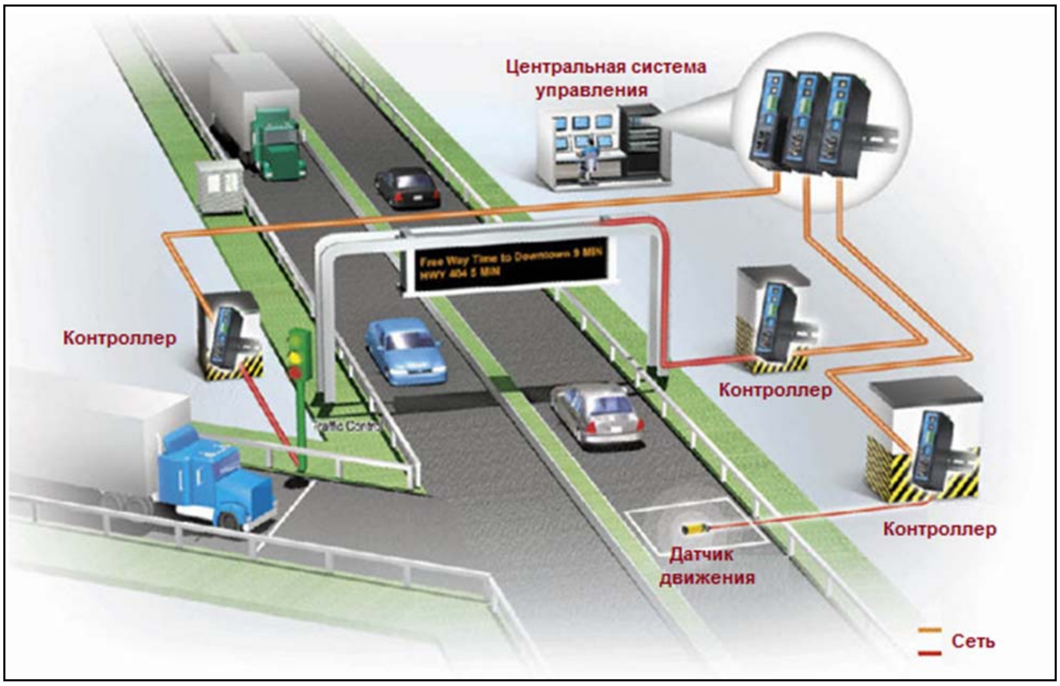

Figure 12. The Intelligent Traffic Light System.

The system is able to predict the traffic situation 15-30 minutes before and to develop an efficient traffic management plan in advance. In the case of an intersection road accident, this plan is automatically adjusted. Depending on the types of sensors, the system may consider the priority of public transport, emergency services, etc. in relation to other road users. In the event of a malfunction, the traffic lights switch to stand-alone mode and intersections start to be adjusted in the usual way. This avoids traffic collapse when emergency situations are created.

Another idea of „*intelligent traffic light*”, called *Eko* (*figure 13,a*), comes from a serbian designer who invented a „*intelligent traffic light*” for those who are accustomed to starting immediately when the green signal of the traffic lights. It informs the drivers when the motion transmission signal will be connected, so that they can appreciate the moment of gear coupling or keeping the neutral stage with the release of the clutch pedal. According to the designer, such a traffic light reduces emissions of harmful substances into the atmosphere, as well as fuel consumption, if drivers stop cars at „*long*” traffic lights. The same principle can be applied to the green signal of the traffic light (*figure 13,b*) to avoid risky entry of vehicles at the intersection in the last passing times.

a) b)

Figure 13. *Eko* Intelligent Traffic Light.

The resonant or noise band (*figures 14,a and b*) is one of the means of organizing road traffic with artificial roughness, made in the form of alternating transverse strips on the road surface, causing vibration of vehicle suspension elements and increased noise at running wheels to warn the driver of approaching a dangerous road sector or leaving the lane. Resonant bands are one of the means to improve road safety. When driving with the wheels of the vehicle on the resonant lane, the driver feels significant vibration and noise action, which in turn contributes to the increased attention to the road situation.

Unlike the elements of forced speed reduction („*artificial road roughness*”), the resonant bands, without causing considerable damage to the suspension of the vehicle, generate significant discomfort to both the driver and the passengers, signaling an unpleasant traffic situation. The resonant bands are applied to dangerous sectors of the high-traffic road, which require a change in speed or traffic direction. In city streets, resonant bands are rarely used because of the reduced noise effect due to the speed limit of 50 *km/h*.

The positive experience of using resonant tapes in different countries indicates the high efficiency of this road safety technology. In the *USA*, resonant bands are used in 85% of countries, significantly reducing the number of deaths. On the motorways of *Japan*, the construction of roadside and line resonator bands, separating the opposite transport flows, has reduced the number of collisions with opposite direction traffic to 55%. In *Finland*, *Denmark* and *Sweden*, the use of resonant bands has also led to a significant reduction in the frequency of accidents and is mandatory for new road constructions.

In some cases, the role of the resonant band can be achieved by structural road markings (*figure 14,c*) made of thermoplastic or cold plastics applied to the road as separate fragments (droplets).

a) b) c)

Figure 14. Resonant band: *a) on the side of the roadway; b) separating the road in opposite directions; c) Structural thermoplastic or cold plastics.*

Conclusions

Today, our primary goal is to create a road with a less environmental impact, with a wear resistance as high as possible and with a high degree of safety. Traditional road clothing has its advantages, but scientific progress is about innovations, not traditions, the roads of the future are an innovation that can solve many of the current problems, the development and implementation of these innovative technologies is a right decision that we owe to achieve for our own sake and the next generation. Implementing intelligent solutions on highways would increase the safety of road traffic, resulting in the salvation of many human lives, both among drivers and pedestrians.

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