SUSTAINABLE DEVELOPMENT OF ROAD NETWORK AND ENVIRONMENT

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Abstract. In the first decade of this century considerable changes took place in the world and in Lithuania, and together with a 20-year experience of road development and maintenance in independent Lithuania they force to re-assess the attitude towards motor roads, their infrastructure, development trends and priorities. The aim of the paper is to analyze sustainable ways of road network development, to identify main goals and objectives in accordance with EU and national sustainable development principles. The analysis is based on feasibility studies, environmental impact assessments of road projects in Lithuania. Sustainable road network development should meet 3 essential principles of sustainability – to reduce the impact on climate change; on human health and biological diversity. The main tasks for achieving the aims of sustainable development were defined and the measures for their implementation were anticipated: to reduce the use of natural resources, fuel consumption and emissions of green-house gases (CO₂ carbon dioxide); to reduce traffic generated emissions to such degree that the impact on human health and environment is decreased; to reduce traffic-generated noise in the environment and at source by implementing noise mitigation measures in order to minimize the impact of total noise level on human health; to increase road traffic safety; to reduce the impact of existing roads on biological diversity, to stop increasing the impact on biological diversity when building roads. The paper also gives a forecast on the possible economic effect of the purposeful implementation of sustainable development measures.

Keywords. environment, strategic planning, sustainable development, road, street, network, infrastructure.

INTRODUCTION

Human beings should be at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature. However the spreading and growing nature of transport is recognized as a major factor having considerable side effect. Traffic jams reduce the attractiveness of cities and worsen the effectiveness of transport system due to the increase in travel times, fuel consumption and costs of transportation as well as stress. Moreover number of accidents as well as pollution also increases.

In a new vision of the future transport system in European Union and the strategy of EU transport development for the next decade, which is formed by European Commission, that is submitted in EC White Paper, special attention is drawn to the sustainable development of transport infrastructure and the aim to lower the environmental pollution without the reduction of mobility of people and goods. The authors of this article provide the analysis – how and what measures can be used to reach that goal under the Lithuanian conditions. The analysis submitted is just a part of the larger research study carried out in 2011 [Infraplanas, 2011] as well as the long-term experience of the authors themselves while planning the maintenance and development of roads and streets, preparing the feasibility studies of transport infrastructure projects, assessment of the environmental impact and effect on human health. Results were obtained having analyzed tens of projects concerning the construction, reconstruction and repair of roads and streets in Lithuania as well as having performed the mathematical simulations of fuel consumption, emissions and environmental pollution under the determined general trends.

1 STRATEGY OF SUSTAINABLE DEVELOPMENT OF ROADS

While determining the factors of sustainable road development strategy, we considered the documents, which describe the sustainable development of economic activity both in EU and in Lithuania:

2. Renewed Strategy of Sustainable EU Development, Brussels, 26 June 2006. (29.06) (OR. en)

White Paper, EU and National strategies of sustainable development indicate the need for the economic growth at the same time protecting biological diversity, reducing the use of natural resources, pollution and effect on human health. All three documents provide the vision, objectives and tasks of sustainable road development, which are substantiated by specific measures in this article. The common vision of sustainable road network development: to develop such infrastructure, that guarantees free movement of people and goods and which helps to reduce the impact on the environment and human health, is resistant to the impact of potential climate change and increase the security of consumers.

Sustainable development of road network has to meet the 3 main purposes of sustainability, i.e. to reduce or at least to stabilize a harmful impact on climate change, human health and biological diversity. To achieve the goals of the sustainable road development certain tasks have been determined and the measures for their evaluation have been assessed.

1.1 The 1st principle of sustainability – to reduce/not to increase the impact of climate change.

The emissions, which cause greenhouse effect and climate changes, should be reduced by decreasing fuel consumption. This task may be implemented by building bypasses, reconstructing streets and roads as well as paving gravel roads.

Having diverted the transit transport to bypasses, capacity of streets and roads increased, gravel roads paved and driving conditions improved (eliminated traffic jams, speeds increased up to optimal level regarding pollution, smoother driving) effects the economy of fuel consumption as well as the emission of gas causing greenhouse effect.

Based on the feasibility studies of constructing bypasses in cities and towns that were carried out during the last few years in Lithuania (10 projects regarding bypasses have been analysed), we have determined the following trends:

- Bypasses increase the driving speed and fuel economy significantly. Average speed on bypass is 90 km/hour, meanwhile in the city it is about 30-40 km/hour or less. The least fuel consumption is while driving 60-90 km/hour. Driving on bypass is smoother, i.e. there hardly are factors causing speeding up/down cycles – at level junctions, pedestrian crossings, slow public transport etc. It was determined that in case of the same average speed, fuel consumption is 24 per cent higher while driving in the city rather than driving in suburbs [Ford Motor Company, 2008].
- When the bypass makes the travel route shorter, the travel time is saved, the economy of car mileage is received and it result in high pollution and fuel economy. However most often when bypassing the city the route does not get shorter but even longer. Even in such cases the building of bypass may be useful and the total consumption of fuel gets lower due to the travel speed increase.

The economy of CO2 subject to the economy of fuel consumption is calculated after the evaluation of the fact that when 1 l of fuel gets burnt, 2.5 kg of CO2 is released to the atmosphere [EMISSIA, 2011].

Based on the analyzed data on the projects implemented in Lithuanian we have determined that:

- On average, construction of 1 km of bypasses results in 1060 thousands litters of fuel saved and 2700 t of GCGE (CO2 gases) avoided within 25 years;
- Reconstruction of 1 km of urban roads (with capacity improvement) results in 680 thousands litters of fuel saved and 1700 t of CO2 gases avoided within 25 years;
- Rehabilitation and strengthening of 1 km of urban roads result in 200 thousands litters of fuel saved and 500 t of CO2 gasses avoided within 25 years;
- Reconstruction of 1 km of rural roads (with capacity improvement) results in 300 thousands litters of fuel saved and 700 t of CO2 gasses avoided within 25 years;
- Rehabilitation and strengthening of 1 km of rural roads result in 200 thousands litters of fuel saved and 500 t of CO2 gases avoided within 25 years;
- Paving of 1 km of gravel roads results in 230 thousands litters of fuel saved and 580 t of CO2 gases avoided within 25 years.

![Pie chart showing the distribution of benefits for different road measures](image)

**Fig. 1.** Decrease in CO2, thousands of tones per 1 km of road with measure applied (in 25 years)

1.2 The 2nd principle of sustainability – to reduce or stabilize the impact on human health

The main factors of transport impact on human health are pollution, noise and traffic safety. These factors also may be managed by building bypasses, reconstructing roads and streets and asphalting gravel roads.

An average car in the city which has burnt 1 l of petrol emits about 50 grams of carbon monoxide, 4 grams of volatile organic compounds, 6 grams of nitrogen oxides, whereas an average truck which has burnt 1 l of diesel fuel emits about 22 grams of carbon monoxide, 15 grams of volatile organic compounds, 27 grams of nitrogen oxides, 3 grams of solid particles [Web Air].

The building of bypasses has rather significant impact on the pollution change in the city streets as well as the whole region. Having diverted transit transport and heavy vehicles to bypasses, the total emission of pollution to the atmosphere decreases due to the traffic conditions that have changed. After the analysis of the emission of pollution from auto transport in the city streets and country roads (bypasses) with DMRB (Design manual for roads and bridges screening method) calculation method, having evaluated only the speed change, we have received the results that 1 km of bypass reduce 2 t of pollutants per year. The higher mileage on bypass achieved, the better effectiveness of pollution emission.

![Graph showing the decrease in pollutants](image)

**Fig. 2.** Decrease in emission of pollutants due to the effect of city bypass
On a gravel road of medium traffic flow, 1-2 cm thick layer of gravel dusts off over the period of one year, which in a form of dust or in other shape settles on nearby fields, plants and living environment of the people. The most effective measure to avoid this pollution is to pave the gravel road. Having 1km of gravel roads paved, it is possible to avoid 0.198 tonnes of PM per year [HEATCO, 2006].

Transport is the main source of noise pollution. Noise is measured by decibels (dB). Human ear feels noise of different frequency unequally. Low frequencies are felt the least, and medium frequencies are felt stronger. Audiability limit is 0 dB; it depends on health, age etc., pain threshold is 120 – 140 dB. The most specific noise levels are:

- 10 meters from a fast going light duty vehicle is 75dB;
- 10 meters from a fast going truck is 85dB.

Human being reacts to noise in most general cases in the following way: the least change (alteration) in noise level that a human ear can feel is 1 dB, 5dB change is definitely audible; noise level change from 8 to 10dB is sensed as redoubling or halving of noise level.

There are indirect effects particularly on sleep disturbance, ischaemic heart disease, stress levels. The ambient noise level near the roads mainly depends on the traffic volume, driving speed and the amount of heavy-duty vehicles.

<table>
<thead>
<tr>
<th>Decrease in traffic volume, %</th>
<th>Decrease in noise level (LAeq), dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>30</td>
<td>1.6</td>
</tr>
<tr>
<td>40</td>
<td>2.2</td>
</tr>
<tr>
<td>50</td>
<td>3.0</td>
</tr>
<tr>
<td>75</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Vehicles of different types (categories) differ in the noise they generate: emission of noise from heavy-duty vehicles is ~10 dBA higher than from the passenger cars. When the speed of driving is reduced, the level of noise also becomes lower.

<table>
<thead>
<tr>
<th>Change in average speed, km/h</th>
<th>Decrease in car generated noise level (LAeq), dBA</th>
<th>Decrease in truck generated noise level (LAeq), dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>from 130 to 120</td>
<td>1.0</td>
<td>–</td>
</tr>
<tr>
<td>from 120 to 110</td>
<td>1.1</td>
<td>–</td>
</tr>
<tr>
<td>from 110 to 100</td>
<td>1.2</td>
<td>–</td>
</tr>
<tr>
<td>from 100 to 90</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>from 90 to 80</td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>from 80 to 70</td>
<td>1.7</td>
<td>1.2</td>
</tr>
<tr>
<td>from 70 to 60</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>from 60 to 50</td>
<td>2.3</td>
<td>1.7</td>
</tr>
<tr>
<td>from 50 to 40</td>
<td>2.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Having retreated 75 % of transit traffic to bypasses, it is possible to reduce noise level in city streets up to 10 dBA and to protect several hundreds of people from the influence of noise that is harmful for their health.

Level of noise in the environment also depends from the type of road surface and its degree of deterioration. Irregularities of the pavement, ruts, traverse and longitudinal cracks, as well as patches of old, renovated cover just increase the noise. Asphalt concrete pavement (type AC 11) noise increases about 3 dBA within 6–7 years of usage and in later years of usage it can increase up
to 4 dBA. In some cases when driving through bulging wells, potholes noise can get impulsive attribution and maximal level of produced level of noise can increase up by 6 dBA.
When reconstructing the roads, not only the pavement is changed, but also measures that reduce the noise could be installed. By these measures it is possible to reduce the noise up to marginal level that meets the requirements of the environment not harmful for the health.

1.3 The 3rd principle of sustainability – to reduce the effect to biological diversity
Road reconstruction could help reduce the negative impact to biological diversity and a new road construction could help to fully avoid the negative impact. The most significant effects of road infrastructure and transport to biological diversity can be:

- loss of territory;
- barrier effect;
- changes of hydrological regime;
- temporary effect during the period of construction because of erosion, violation of hydrological regime, pollution of water bodies and traps.

Barrier effect is the biggest and the most frequent negative ecological effect of the road. The road becomes barrier for the animals if it makes migration difficult and demographic pit if crossing it could cause the death of an individual. Most of the animals die on the roads with the traffic flow of 2500–10000 vehicles per day (Fig. 3). When such intensity exists, animals try to cross the road, but about 60% of them get killed and they in some way get into the traps. When the traffic flow is less than 2500 vehicles per day, ≤35% of the animals trying to cross the road die. Huge traffic flow (≥10000 vehicles per day) frighten the animals and they try to cross the road rarely, that is why their mortality on such roads reduces [COST 341], but the barrier effect is maximized.

**Fig. 3.** Dependency between the number of animals, trying to cross the road, and the intensity of the traffic [COST 341]

Indirect negative ecological effect is: pollution, noise, illumination, increased attendance of people in the territory, spread of adventitious species. Infrastructure of the roads can perform a positive function of roadsides as well; it can facilitate migration of the animals or create a new habitation. When constructing or reconstructing the roads, animal fencings are installed to protect animals from getting on to the road. Together with fencing, measures that maintain and promote the migration of animals are installed as well as measures for the animal that accidently appeared on the fenced road could safely go out of it. When fencing the road that is constructed within the habitation of the animals, there needs to be implemented measures for animals to cross the road safely. The road that
is fenced, even though it reduces the danger of cars colliding with the animals, it highly increases the barrier effect in the territory of the population.

2 ECONOMICAL EFFECT OF SUSTAINABLE DEVELOPMENT OF ROADS

Purposeful implementation of road network sustainable development measure also gives tangible economical effect. We have estimated this effect by having analysed projects that were held or are held at this moment and their results of economic evaluation and by taking into account the changed tendencies of economy and transport, reduced traffic and their development tendencies that are reduced, the reduced amount of accident. By our evaluation, one LTL that will be invested into the implementation of sustainable development measures within the next 5 years in the long-term perspective (according to recommendations of European Commission the investments to the roads should be evaluated for the perspective period of 25 years) it will not only come back, but also will give an average of 2.2 to 3.2 LTL of net present value of benefits even without considering the earlier mentioned positive ecological effect.

The construction of bypasses in the cities of Lithuania still remains strategically important measure of sustainable transport development and their economic benefit remains to be as big as it was some years ago or even bigger. By our evaluation, one LTL that would be invested into the construction of bypasses in cities and towns, in the long-term perspective, gives approximately 3.2 LTL of net present value of economic benefits, that consist of travel time savings, savings of transportation costs and the benefit of the reduced amount of the accidents.

![Net benefit forecast from 1 LTL invested into the roads and streets within the next 5 years](Infraplanas, 2011)

The benefit of the investments to the reconstruction of the road is currently slightly reduced due to the reduced traffic growth and accident rates. It amount to 2.5 LTL in average (for the investment of 1 LTL). The importance of reconstruction of rural roads and capacity improvement of street network in the cities is however bigger, because as it is known, the traffic in the streets is greater and with the problems of the lack of capacity, that result in traffic jams and travel delays, it is encountered more. One LTL that is invested into the reconstruction of streets or their crossroads gives approximately 2.8 LTL of net present benefit.

Whereas in the last decade in the state road network of Lithuania the gravel roads were intensively paved (starting from the most intensive or those that cross the settlements), this activity is not so beneficial anymore. The greatest attention should be paid to the paving of the gravel streets (also streets with the cover of the soil) in the cities or villages because their part in the network of the
local roads (and streets) is rapidly getting bigger. Also it relates to the rehabilitation of streets because the condition of street carriageways is noticeably worse than that of the state roads. By our evaluation (conducted based on the analysis of the Gravel roads paving program, the acquired information about the street paving projects and urban and rural road rehabilitation projects in Lithuania), the net benefit of one LTL, that is invested into the paving of gravel roads is about 2.2 LTL. If invested into the rehabilitation of the rural road, it gives the benefits of approximately 2.4 LTL, and if it is invested into the rehabilitation of urban roads and streets – approximately 2.6 LTL.

CONCLUSIONS

1. Sustainable development of road network has to content 3 main principles of sustainability, without limiting mobility of people and products, to reduce the effect for the climate change, health of people and biological diversity.
2. The first objective of sustainable development of the road network is to reduce the usage of natural resources, fuel consumption, in this way reducing the greenhouse effect and the emission of gasses, which cause the climate change.
3. The second objective of sustainable development of the road network is to reduce the negative effect on the health of the people and it can be reached by reducing the amounts of pollutants and noise in the living environment and by increasing the safety on the roads.
4. The first and the second objectives that were mentioned can be effectively achieved in Lithuania by constructing bypasses, purposefully reconstructing the streets and roads, as well as by paving gravel roads.
5. The third objective of sustainable development of the road network is to reduce the negative impact on the biological diversity. When installing mitigation measures it is possible to reduce this negative effect or even to liquidate the threat of the transport and to reach the goal so that the roads would not have negative effect to biological diversity.
6. Sustainable development of the road network does not put limitations on mobility of people and goods and at the same time it allows reducing the pollution, saves the environment and road users. The purposeful implementation of sustainable development measures on the road network gives tangible economic benefit. According to our evaluation, one LTL invested into the implementation of sustainable development in long-term perspective gives the average of 2,2 to 3,2 LTL of net economic benefit.

REFERENCES