Sustainable Highways: The challenges of the future

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Abstract. Road transport and infrastructure are keys to the evolution and prosperity of modern society. Connecting people and places, goods and services in safe, efficient, and sustainable way is essential for creating and maintaining sustainable and inclusive growth across society and the economy. A sustainable highway should satisfy lifecycle functional requirements of societal development and economic growth while reducing negative impacts to the environment and consumption of natural resources. In the future, highway infrastructure will face increasing pressures and impacts from a range of issues including changing weather patterns, population growth, capacity constraints, shortage of land and capital and rapidly changing technologies that outstrip the pace of new infrastructure development. From the other point, advanced technologies and intelligent transport solutions will play a significant impact on the transport solutions in the future. In this paper, the increasing environmental pressures that highway face and the new advanced technologies that might shape the highways infrastructure are presented.

Keywords: highway, sustainability, infrastructure, advanced technologies

1. Introduction

The theory of sustainability, defined in the "Our Common Future" report in 1987, has become a fundamental strategy on the political agenda, focusing on the coordinated development of economy, society, and environment in every type of system (Shi, et al, 2019). The emerging discipline of the sustainability was a response to the growing aware that the growth and development of countries must be related to the policies of environmental protection and social development of their communities.

In this context, sustainable highway may be an integral part of sustainable development. The aims of sustainability in the road project can be achieved through a set of compromises among environment, economics and social fields finding a way for integration.

The UN 2030 Agenda for Sustainable Development lays out 17 goals that support societal aims, spanning from abolishing poverty and hunger to gender equity, peace, and partnerships. A well-designed and constructed road infrastructure may help to deliver this agenda. Road transport and infrastructure are keys to the evolution and prosperity of modern society. Connecting people and places, goods and services in safe, efficient, and sustainable way is essential for creating and maintaining sustainable and inclusive growth across society and the economy.

Some of the most important benefits of roads are mentioned in the PIARC Report (2020SP01EN):

- stimulating economy and increasing productivity and GDP via reducing the cost of producing and trading goods, improving access to more productive jobs and encouraging inward investment
- reducing poverty through improved access to education, healthcare and jobs and fostering a more healthy and productive society
- crossing borders and creating regional synergies though trade and mobility
- reducing rural isolation and boosting development
- increasing society wellbeing and sustainability through improved access to services-health, education, culture

The boost observed in the road construction domain has been driven by innovation and technological progress. New materials, products, equipment, and techniques have been introduced in the road engineering industry. However, despite this undeniable progress, major impediments and respective challenges to road authorities and operators still remain. In each country and over each network, challenges and concerns may vary, but, in most cases, competent authorities, engaged in road development policies, have to deal with most of these issues.

From the other point, advanced technologies and intelligent transport solutions will play a significant impact on the transport solutions in the future. Technological drivers such as automation, connectivity and low-carbon technologies, coupled with new sharing trends are completely redefining the business of getting around. Road infrastructure is at the heart of the development of these new types of mobility. New technologies have the potential to make radical changes to the construction, management, and efficiency of road infrastructure.

The European Commission's Green Deal recognizes that sustainable road infrastructure will keep Europe's highways at the core of the continent's economy. Climate change represents a main challenge for the EU, requiring urgent actions for the new ambitious targets of reducing greenhouse gas emissions by at least 50% by 2030 and carbon neutrality objective in 2050. The European road infrastructure sector is a key player in achieving this objective by providing appropriate solutions to make the

road environment and infrastructure more sustainable thus contributing to the reduction of greenhouse emissions.

The aim of this paper is to present the increasing environmental pressures that highway face and the new advanced technologies that might shape the highways infrastructure.

This paper is structured as follows: firstly, a presentation of current environmental and social challenges that a road infrastructure face in Section 2. Section 3 presents the meaning of Sustainable highway as a response in the environmental pressures. Section 4 explains the new technological challenges that are shaping the future of road infrastructure. Finally, Section 5 are the conclusions.

2. Current challenges

Transport generates important benefit for its users and for society in general, but it also generates costs for society. The road sector plays a substantial role in the socio-economic development of Europe; about 81% of the inland passenger transport and 73% of the inland freight transport are carried by roads. As the second-largest area of expenditure for European households, the transport sector contributes 5% to European GDP and directly employs around 10 million workers.

It is unquestionable that transport infrastructure, in Europe, faces specific challenges.

There are various environmental costs related to land transport and its emissions of greenhouse gases and air pollutants, noise pollution and the uptake of the land. Transport also gives rise to broader challenges of which traffic accidents and congestion are the most important.

Specifically, in 2017, energy consumption in the transport sector accounts for the 30.8% of the total energy consumption. Emissions of the main air pollutants (NOx, PM, CO, NMVOC) from transport have generally declined over the past two decades. However, the latest air quality assessment published by the European Environment Agency reveals that a significant percentage of the European urban population was exposed to air pollution levels exceeding EU air quality standards over recent years. The contribution of road transport to EU28 emissions in 2016 was 39% for NOx, 11% for PM2.5, 20% for CO, and 9% for NMVOC.

While greenhouse gas emissions from all other main sectors of the economy have fallen in recent decades, those generated from transport have increased relatively. Transport is a major contributor to greenhouse gas emissions in the EU-28; it was responsible for 24.6% of total emissions in 2017, while the transport sector road transport accounts for 71.7% of emissions. This contribution has almost doubled in comparison to 1990 levels.

Road traffic is the most important source of noise pollution or exposure to ambient sound levels that are beyond the usual comfort levels. Road infrastructure takes up land and its design and use alters the quality and connectivity of habitats and can create physical barriers to the movement of plants and animals between habitats. The high levels of road traffic compared with road capacity at certain locations and times of day lead to congestion, substantial time losses and a lack of travel time reliability. Finally, 22,660 people lost their lives on EU roads in 2019.

Other main challenges are mentioned following. Financing road construction projects is a main issue. Traditionally, the construction of toll motorways is a profitable investment but, in times of recession, funding may be rare or non-existent. Although for most member states the last recession saw a period of negative growth in transport demand, mobility is expected to grow. Powerful national economies may be able to efficiently tackle the problem, but weaker economies can hardly find the financing sources for road construction projects, the drivers of economic development.

Road serviceability is a general term which includes pavement ride quality, level of safety, traditional and electronic information, and service stations. Road capacity and level-of-service may also be included in a wider concept of serviceability. Drivers and travelers demand high standards of road performance and look forward to improved serviceability over time. Undoubtedly, this requires human and capital resources, not only for the on-site operations but also with view of anticipating maintenance needs and planning effective engineering interventions. Europe has a highly developed but ageing road network. Its maintenance and upkeep represent high costs, mainly from public funds which experience a difficult budgetary context. Competitive cost pressure incentivizes infrastructure owners to avoid necessary maintenance and asset replacement work.

There is an increasing demand for high standard of service. Transport systems are increasingly expected to keep fully operational during severe weather events. This demand for increased reliability is compounded by a user expectation that transport infrastructure will be always available and not closed for routine maintenance. The road sector is vulnerable to climate change impacts. Climate change and extreme weather events pose a significant challenge to the safety, reliability, effectiveness, and sustainability of road transportation systems. National road authorities and motorway operators must adapt the infrastructure to climate change and increase the resilience of road transport to extreme weather (Figure 1).

Figure 1. Climate adaptation will require significant changes for transportation.

3. Sustainable Highway

Sustainable highway is a system of roads which limit their impact on the environment to a minimum through different sustainable practices. The goal is to maximize the lifetime of a highway while restricting its environmental consequences.

The European Road Federation defines sustainable roads as "effectively and efficiently planned, designed, built, operated, upgraded and preserved roads by means of integrate policies respecting the environment and still providing the expected socio-economic services in terms of mobility and safety".

A sustainable highway should satisfy lifecycle functional requirements of societal development and economic growth while striving to enhance the natural environment and reduce consumption of natural resources. The sustainability characteristics of a highway or roadway project should be assessed and considered for implementation throughout its lifecycle, from conception through construction, operations, and maintenance. However, the relative importance and consideration of each of these factors are context sensitive and much driven by the goals, demands, characteristics, location, materials, and constraints of a given project as well as the overarching goals of the sponsoring agency.

Sustainable infrastructure requires a low-carbon vision along the entire value chain, from the products used to build a long-life infrastructure to the service that the infrastructure provides to the citizens during its whole lifetime. The whole life-cycle of the construction should be considered during the design phase of a given project in order to reduce the number of interventions, specially the maintenance periods and the design life and options for the end-of life for the project.

While decarbonisation represents a main concern for the EU the road infrastructure sector has undertaken significant efforts to promote greener practices which could decrease energy consumption, reduce GHG emissions, and natural recourse consumption during the lifetime of the road. Within the road construction industry there is increasing interest in improving the sustainability of construction to conserve resources and reduce carbon emissions. The industry has made great strides towards improving the sustainability of pavements, such as improvements in durability, incorporation of secondary materials and reuse and recycling of pavement materials, the establishment of an ecosystem management, the implementation of energy reduction actions or stormwater retrieval systems.

Green highway rating systems were introduced to determine the level of greenery and environmentally friendly of the highway. Some of them are Greenroads, GreenLITES, I-LAST, INVEST which are used environmental criteria as water quality, energy efficiency, materials in order to categorize the green highway.

Asphalt and concrete industries can facilitate the completion of this plan, considering their predominant role in the road sector. In the PIARC Report (2019R32EN) strategies and practices to minimize consumption of natural resources, to reduce energy consumed and emissions generated in mixture production and associated with different pavement materials are presented. Pavement materials should be assessed from a life-cycle perspective to determine their contribution in the sustainability of a pavement system. A broad variety of software tools is available to assess the carbon footprint of the pavement Some of them are ECORCE, HACCT v5, asPECT v4.0, GHGC v4, CHANGER v1.0.2.2, SEVE v2.0.0., PALATE v2.2, DUBOCALC v2.2.2, EKA, TAGG which most of them cover the production stage and construction stage, although some tools have a greater focus on the mixture composition, others on the construction phase.

Moreover, sustainable road infrastructure is adapted to and helps to mitigate climate change. Therefore, infrastructure planning must follow a life cycle approach. This entails systematic maintenance, preservation, and upgrade actions during the operational phase of the infrastructure for reaching sustainability targets (Figure 2). Given the importance of climate change the current downward trend in public sector road infrastructure investment is unsustainable and must be reversed. Otherwise, road infrastructure quality will continue to decrease and with considerable socio-economic and environmental consequences.

Figure 2. Wildlife crossings in Netherlands

4. The challenges of the future

The main challenges for the transport sector in the EU include creating a well-functioning Single European Transport Area, connecting Europe with modern, multi-modal and safe transport infrastructure networks and shifting towards low-emission mobility which also involves reducing other negative externalities for transport.

The European Commission through a set of initiatives and legislative proposals guides road transport in the new era:

- *Europe on the Move*, 2017: an agenda for a socially fair transition towards clean, competitive, and connected mobility for all

- Delivering on low-emission mobility, 2017: a European Union that protects the planet, empowers its consumers and defends its industry and workers
- Europe on the Move-Sustainable Mobility for Europe, 2018: safe, connected, and clean
- A Clean Planet for all, 2018: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy
- Sustainable and Smart *Mobility Strategy, 2020*, putting European transport on track for the future

The advance of vehicle technology is placing new demands on transport infrastructure for data connectivity and changing operational practices. This is placing a new challenge for road infrastructure to be more flexible in use and easier to adapt quickly to changing and especially rising demands.

The adaptation of infrastructure to new mobility patterns and the deployment of infrastructure for clean, alternative fuels, poses additional challenges that require new investments and a different approach to the design of networks and business models. A digital infrastructure is also one of the keys to the transformation of our economy. The future mobility trends, such as high-capacity charging stations and greater connectivity between the infrastructure and road users will allow for better planning and organizing of road construction and traffic flow. This will minimize emissions, increase transport safety, optimize maintenance operations, and contribute to the objective of decarbonising the European economy.

Growing digital connectivity enables individuals to use transport systems in different ways and to have access to large amounts of real time performance data. This growing connectivity presents challenges to transport operators and infrastructure owners as better real time information that enables users to plan their own alternative routes during times of congestion or disruption (Figure 3).

Continuous advances in Big Data architecture and technology have increased the potential for businesses and governments to analyze their data, and to use actionable insight to make informed decisions. Big Data is being used by public agencies and consultancies to answer numerous transportation questions. The prospect of using Big Data in the highways sector is intriguing and innovative as it offers previously unimaginable advantages in comparison to traditional data sources.

The traditional role of roads will certainly be subject to major changes. Changing expectations and needs in terms of mobility will increase the demands on road infrastructure and lead to a transfer of new competences to road authorities, as well as the development of new partnerships with the private sector. Infrastructure managers will no longer be considered only as providers of a transport mode but also as providers and managers of mobility. Regarding the function of the road infrastructure, it will evolve to a service-based approach. Managers will have to be able to meet the technical and energy needs of new vehicles through the provision of a connected and digital road, an ability to exploit the data produced and transmitted and to regulate traffic more effectively.

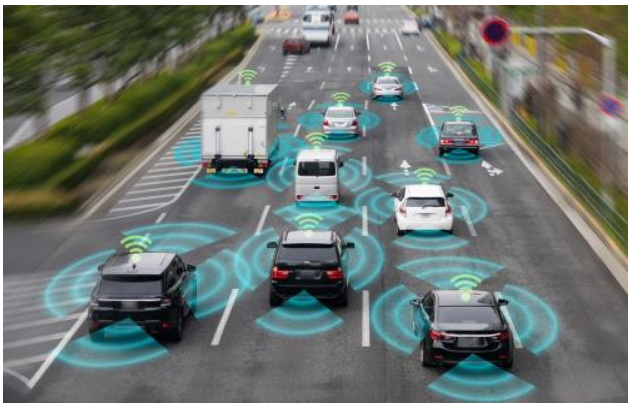

Figure 3. Digital technology is placing new demands on transport infrastructure

5. Conclusions

Efficient road infrastructure is vital to exploiting the economic strengths of European regions and to supporting the internal market and growth. However, we are witnessing nothing less than a revolution in transport. Automation, connectivity and low-carbon technology coupled with new sharing trends (self-service bicycles, free-floating machines, car-sharing), integration of different modes of transport via digital technologies such as Mobility-as-a-Service, are completely redefining the business of getting around. The traditional role of roads will certainly be subject to major changes; roads remain a central element of mobility and it is essential that they be integrated into its evolution. Road infrastructure should be capable of allowing these new forms of mobility to coexist. These technological changes are likely to impact the design and construction of roads.

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