SOCIAL RESPONSIBILITY, TECHNOLOGY AND AI

Edited by David Crowther and Shahla Seifi

DEVELOPMENTS IN CORPORATE GOVERNANCE AND RESPONSIBILITY

VOLUME 23

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PART 1

TECHNOLOGY AND SUSTAINABILITY

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SUSTAINABLE TECHNOLOGIES FOR ROAD MAINTENANCE AND REHABILITATION

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ABSTRACT

Human society is going through an interesting period in terms of the challenges it faces. The most interesting problems are environmental problems. In support of protection of the environment in which we live, we must find efficient and clean (ecological) solutions, at the same time, for the materials and technologies that are the basis of the goods production. In this context, the problem of means of transport, in general, and land road transport, in particular, will remain one whose solution will probably mark multiple stages in the attempt to abandon fossil fuels. Even if this problem will be solved, the travel routes – roadways – represent an additional challenge in terms of construction materials and technologies but also in terms of maintenance and rehabilitation technologies. In the context of Industry 4.0, the concerns in the field of road execution and repair are more and more obviously aimed at elements of the circular economy. Solutions are sought and experimented for: reuse of degraded asphalt material, incorporating reused/reusable materials into the asphalt mixtures and the implementation of ecological execution technologies. In this work, it is intended to carry out an analysis regarding the technical and technological solutions implemented or in the proposall experiment stage that respond to the desired "Sustainable technologies for road maintenance and rehabilitation".

Keywords: Ecological solutions; environment; sustainable technologies; maintenance; transport infrastructure; sustainable construction

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1. ASPECTS SPECIFIC TO ROAD CONSTRUCTION, MAINTENANCE AND REPAIR ACTIVITIES

Millions of kilometres of paved roads and highways exist worldwide, with several hundred 1000 of them in need of significant rehabilitation efforts. Governments and local authorities around the world allocate approximately $100 billion annually to maintain the functionality and safety of these road networks ("Martec - Recycler Comprises", n.d.). However, even with this substantial investment, there remains a considerable global shortfall in modern roads. This shortfall is primarily due to insufficient budgets allocated for transportation and the steep expenses associated with conventional road rehabilitation methods.

Technologies used in road construction have evolved throughout human history. From the mundane paths blazed by camels 8,000 years ago to the scientific paper published by Clifford Richardson in 1905 establishing the composition of asphalt as we know it today, technology has always adapted to the new types of vehicles used, from those with animal traction and up to motorised vehicles that appeared more than 100 years ago (Popescu, 2022).

If we are to refer to what, generically, we call the road, i.e. the asphalt or cement concrete surface on which vehicles move, we must say that this represents only the "visible part of the iceberg". The structure of the road, in the section, is much more complex, the successive layers fulfilling several roles (Fig. 1 ["What are the functions of layers in a flexible pavement?", n.d.]): a protective layer – having in its composition a varied range of materials, from gravel to sand, but various resulting materials can also be used following some demolished constructions – with the role of water drainage and frost protection; a base layer – composed of gravel and sand, and in some cases bitumen for compacting the materials or cement – with the role of evenly distributing the forces generated by road traffic to the foundation; a binder layer, with the role of absorbing the forces generated by road traffic and distributing them to the basic start of the

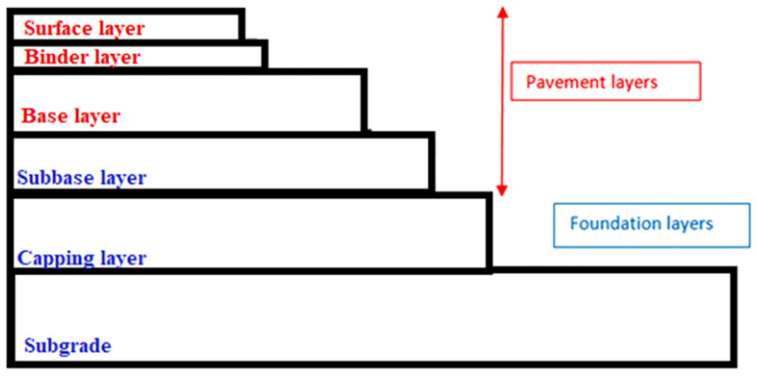

Fig. 1. The Conventional Structure of an Asphalt Road.

foundation; the surface (wear) layer, resistant to pressure forces generated by traffic and waterproof to avoid water seeping through the lower layers.

Usually, to create each of the four layers, mineral aggregates (ground rock, river gravel, sand) of various sizes are used; materials specific to the recipe, to give the mixture elasticity and strength; bitumen (artificially obtained by processing petroleum) to ensure the adhesion of the components and to obtain a compact mixture.

Specialists estimate that the manufacturing process of the foundation of a conventional two-lane road with a total width of 4 metres generates emissions of about 276 tons of carbon dioxide for each kilometre worked, without taking into account aspects such as pouring the wear asphalt layer – i.e. the actual running surface – or the long-term maintenance of the road (Popescu, 2022).

At present, there is a global emphasis on enhancing mechanisation within the realm of road infrastructure projects. This includes the integration of cutting-edge technologies aimed at boosting both technical and economic efficiency. The primary goal is to promote the judicious utilisation of resources and equipment in road construction and maintenance endeavours ("https://documents1.worldbank.org/curated/en/240821468196173343/pdf/Solu%C5%A3ii-tehnice-%C5%9Fi-tehnologii-eficiente-%C5%9Fi-inovatoare-pentru-investi%C5%A3iile-%C3%AEn-infrastructura-public%C4%83-din-Rom%C3%A2nia-raport-final.pdf", n.d.). The interest in identifying new solutions in the field of road construction is all the greater as the degree of damage and, consequently, the volume of repairs increases.

As can be seen in the graph in Fig. 2 ("Martec - Recycler Comprises", n.d.), the asphalt road surface undergoes an accelerated deterioration process a few years into its operation. However, implementing timely rehabilitation measures

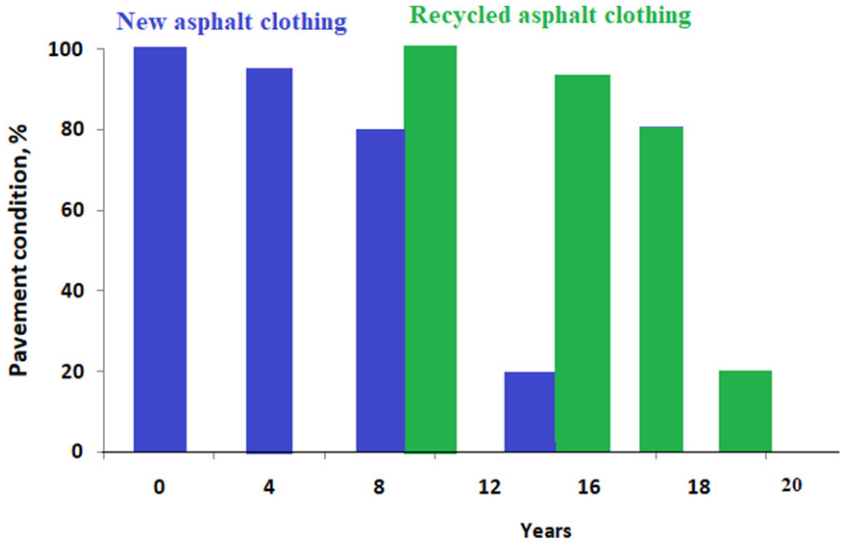

Fig. 2. The Process of Damage to the Asphalt Pavement.

such as reasphalting or recycling can effectively restore the quality of the road surface, ultimately prolonging the lifespan of the road.

Maintaining the road in optimal operating parameters requires monitoring the evolution over time of the state of degradation and carrying out maintenance by immediately remedying the defects. Road maintenance requires, on a case-by-case basis, the implementation of corrective actions – as part of current maintenance works, especially – or preventive – as part of periodic maintenance works – with the aim of partially compensating for wear and tear and maintaining the respective road structure in the technical conditions necessary for uninterrupted traffic in safety and comfort, as well as for maintaining it in a permanent state of cleanliness, order and appearance aesthetic, corresponding to the functional category of the road ("Normativul privind reciclarea la cald a îmbrăcăminților rutiere bituminoase, indicativ NE-026-2004 din 16.03.2004 - Lege5.ro", n.d.; "Referat Drumuri | PDF", n.d.; "Sr-599-Lucrari-De-Drumuri-Tratamente-Bituminoase-Conditii-De-Calitate 2022 | PDF", n.d.).

The current maintenance works aim at the maintenance of the asphalt coating, the degraded surfaces and their protection measures, sealing, combating cracks and fissures.

Periodic maintenance works refer to those activities that are performed periodically and planned for the purpose of partially compensating the wear produced on the road structure, works of art, road safety or in order to completely remove the effects of wear produced on the road structure, to return the technical characteristics to the initial technical condition by replacing, restoring or repairing sectors or parts that have suffered degradation. In this category are mainly included the periodic maintenance operations of the running surface through bituminous treatments. The treatments are thin layers made by spraying with bituminous binder, screening and fixing by rolling. The role of the treatments is protection (waterproofing) and roughening of the surface on which it is performed ("Referat Drumuri | PDF", n.d.; "Sr-599-Lucrari-De-Drumuri-Tratamente-Bituminoase-Conditii-De-Calitate 2022 | PDF", n.d.).

In the situation of excessive degradation of the roadway – manifested by local degradations with very great depth and/or expansion, cumulated, very large – it is recommended to execute asphalt carpets (bituminous road clothing made up of a single layer, executed from an asphalt mixture that meets the conditions of a wear layer).

2. CONCERNS REGARDING THE DEVELOPMENT OF SUSTAINABLE TECHNOLOGIES IN THE FIELD OF ROAD CONSTRUCTION AND MAINTENANCE

Road construction technologies require high consumption of non-renewable resources (Luo et al., 2013). The specialised literature (Montoya-Alcaraz et al., 2019) provides interesting information regarding the approach to the sustainability of road construction technologies. Along with policies in the field of road construction and maintenance, sustainability assessment programmes have been developed. Among them, we can mention (Montoya-Alcaraz et al., 2019): the

Greenroads programme ("Greenroads Manual v1.5", 2011), FHWA's Voluntary Infrastructure Sustainability Assessment Tool (INVEST), European Union Road Federation (ERF) Sustainability Programme (Mendoza Sanchez, 2014), Environmental quality in civil engineering (CEEQUAL) (Bryce et al., 2017). These programmes offer a comprehensive set of strategies and facilitate the integration of sustainability criteria across various stages of the road life cycle, encompassing aspects such as material selection and production, road design and construction as well as road operation and maintenance (Montoya-Alcaraz et al., 2019; Ozer et al., 2016).

The matter concerning the sustainability of road construction technologies extends beyond considerations solely focused on road design and construction. It encompasses various elements related to road construction and maintenance technologies, which have environmental and natural resource implications. These elements encompass:

- The sourcing, transportation and processing of road construction materials, including materials like rock, gravel, concrete and bitumen.
- The fuel consumption associated with construction and maintenance machinery, along with its environmental impacts.
- The production and application of paints used for road markings.
- The manufacturing and processing of semi-finished products derived from plastic materials, which are utilised in road safety equipment production.

These factors collectively contribute to the broader sustainability picture within the realm of road infrastructure.

In this context, a sustainable strategy in the field of road execution and maintenance must benefit from (see also Fig. 3):

- The choice of construction/maintenance materials in accordance with environmental protection policies.
- Planning the stages of road construction taking into account the efficient use of equipment and machinery, to reduce fuel consumption.
- Planning of road maintenance works based on a systematic road condition evaluation programme.
- Evaluation of maintenance costs by reference to the implementation of a new roadway.
- Assessment of the situation of roads with exceeded life span.

The paper (Montoya-Alcaraz et al., 2019) offers an overview of the key economic, social, and environmental principles related to the sustainability of roads and their construction technologies: in (Mao et al., 2018) is proposed a method to enhance pavement durability under reasonable traffic conditions. Corriere and Rizzo (2012) offer guidance on approaching sustainability in road design. The factors contributing to traffic safety were analysed by (Demasi et al., 2018; Farooq et al., 2019; Yang et al., 2018). Regarding the

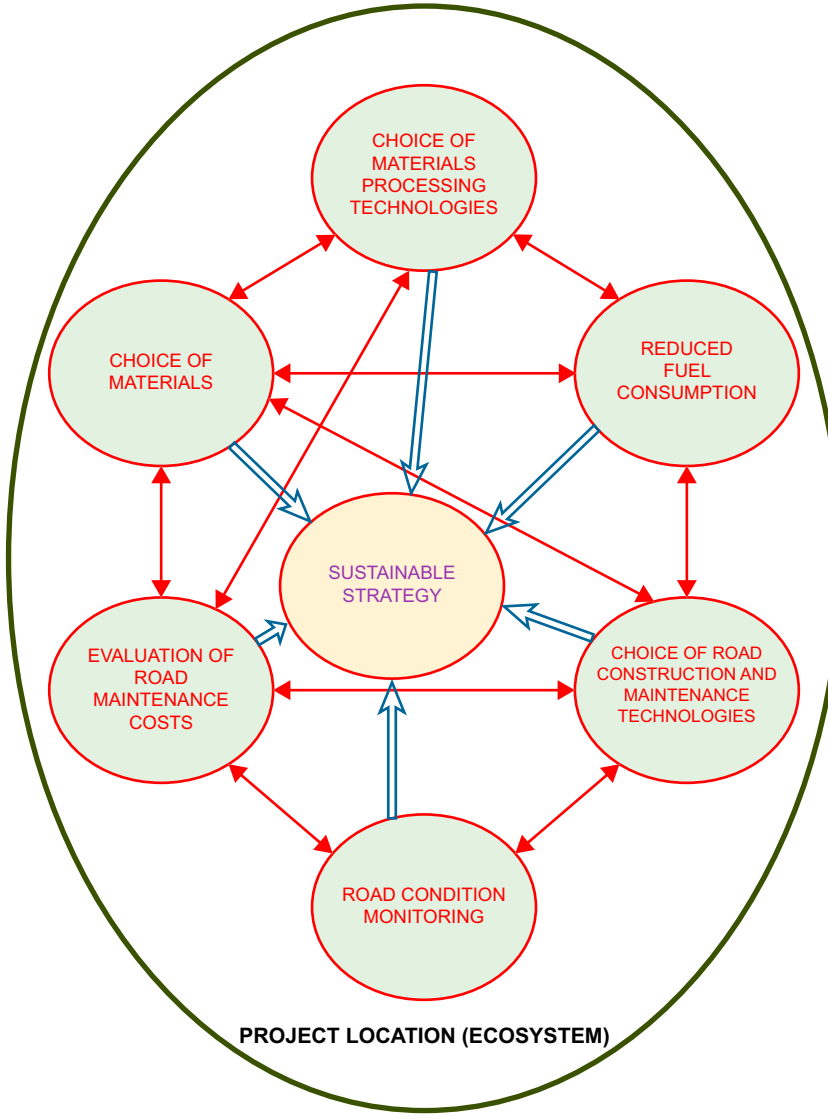

Fig. 3. The Issue of Strategies for Road Construction and Maintenance. Connections of Determining Factors (in the View of the Authors).

environmental sustainability, (Montgomery et al. (2015) present numerous ideas to incorporate environmental considerations across the road project life cycle; adapted structural failure models for Moroccan conditions were developed by Bannour et al. (Bannour et al., 2015); Jain et al. (Jain & Thube, 2007) present calibrated pavement damage models for general network conditions in