Smart solutions for more sustainable and safer infrastructure for transport

Abstract

The SafeSmartInfra Cluster aims to provide concrete solutions to make cities smarter, safer and overall more sustainable, both in terms of transport infrastructures at large and pavements, in specific. In fact, SafeSmartInfra has recently developed a set of outcomes to be exploited in the fields of smart, safe and sustainable infrastructures. The innovative solutions are conceived for the urban and inter-urban paved environment of the future and for the future transport infrastructure for all kind of mobility. Footpaths, bike lanes, roads, intersections and all other walkable surfaces that we all use every day are to be designed adopting the sustainability, safety and accessibility criteria in the form of recycled materials and impact absorbing surfaces. In parallel, smartening of the transport infrastructure and networks is today mandatory and shall include composite sensors for monitoring of structures and infrastructures as well as guidelines with smart solutions for design, construction, management and end-of-life of transport infrastructures.

Key points

To redefine urban pavements' design, construction, and management approaches to provide cities with more liveable environments and safer, more accessible, and sustainable spaces for mobility.

To develop transport infrastructure's components, decision-making frameworks, asset management methods and new technologies for Sustainable multifunctional Automated and Resilient Transport Infrastructures.

Introduction

Transportation infrastructures are the mean by which people travel every day for work or leisure, and they are at the heart of the EU's transition towards climate neutrality. To reach the goal of reducing transport-related emissions, transport systems need to become more resilient, resource-efficient, climate- and environmentally friendly, but also safe, smart, sustainable, inclusive and seamless for the benefit of all citizens, the economy and society. In a near post-pandemic scenario, all the urban and peri-urban transport infrastructures including all kind of pavements must accommodate all users (also vulnerable ones) in the most efficient, safe, sustainable, and smart way. A key factor to increase the liveability and inclusivity of tomorrow's smart cities, while reducing the transportation carbon footprint, will be transforming the way mobility infrastructures are perceived, designed, built and maintained, re-thinking the future of transport infrastructures.

The solutions developed by the SafeSmartInfra Cluster cutting-edge research will allow this, as it envisions transport infrastructures that are:

- designed to last by maximizing recycling and minimizing impact (Sustainable),
- conceived not for transport purposes only and towards optimization of land use (Multi-functional)
- equipped for communicating with managers and users, to allow a more intuitive use and a simplified management (Automated)
- built to be adaptable to natural and anthropogenic hazards (Resilient),
- and to be safer and more accessible (Safe) to all users.

A **portfolio of results** has been created that features the outcomes from the SafeSmartInfra Cluster that have high TRL and are applicable on existing and newly constructed transport infrastructures. These should be taken as the most relevant examples, as other results are also available from the SafeSmartInfra joint research effort.

R1: Recycling of End-of-Life Tyres Rubber for protective paving applications

Cyclists, pedestrians and elderly people's specific needs in urban road infrastructures are often neglected. They rarely benefit from safety measures or innovations. Inspired by playgrounds and aiming to reduce vulnerable road users (VRUs) injuries, the development of the recycled rubber and RAP-based impact-absorbing pavements (IAP) offers a possibility to rethink the design of urban pavements and address safety on roads, which constitutes a major challenge in terms of attaining more sustainable, resilient, and safe cities. All results confirm the feasibility of the IAP concept and its positive effect on future injury-prevention applications.

R2: Asphalt recycling and long-term performance characterisation methods

A specific research focused on implementing the so-called "urban mining", using asphalt 100% mined in cities for producing new asphalt mixtures. The aim is to reduce the life cycle greenhouse gases emissions from road construction, which will make the environment safer for road users, as well as for construction workers. It will also reduce the overall cost of pavement construction, giving huge benefit to taxpayers of the country. The reduced environmental and economic cost will encourage governments to expand/maintain existing road networks to connect residential and recreational areas outside the city, which are now more attractive in a post-pandemic scenario.

R3: Self-healing materials and fast-repairing solutions for road pavements'

Self-healing technology is a new field within material technology. It represents a revolution in materials engineering and is changing the way that materials behave. Incorporating self-healing technology into the road design process has the potential to transform road construction and maintenance processes by increasing the lifespan of roads and eliminating the need for road maintenance. As for fast-repairing of pavements, the SmartSafeInfra outcomes propose the use of onsite technologies to repair road cracks in a fast and effective way, by means of a robotic arm.

R4: Smart composite sensors for monitoring of structures and infrastructures
The result is based on the development of smart pavement sections to manage traffic, automatic systems and evaluation of damage in pavements using smart layer outputs acquiring continuous data on traffic, better regulating the flows of urban life better and enabling more engineers to save time. At the heart of this, there is an automated infrastructure monitoring system that will help cities, roads, railways and airports to get smarter.

R5: Pavement systems able to capture energy
The word energy consumption is constantly increasing and the research is focusing on the development of new energy harvesting technologies. In the field of pavement engineering exploitable sources are the solar radiation as well as the energy provide by the traffic itself. Several solutions are available and two of them, namely a solar and a mechanical harvester, have been studied within SafeSmartInfra.

R6: Guidelines towards smarter transport infrastructure in EU and Developing countries
Taking advantage of the results of the platform offered by the ITN, with several brainstorming happened during the thematic training weeks and project meetings, the consortium refined the concept of SMARTI. This has led to assess the state of the art of each of the features investigated in this project, as well as draw the remaining stepping stones towards the implementation in the next two decades. Hence, the Guidelines provide a refined definition of Sustainable, Multi-Functional, Automated, Resilient Transport Infrastructure together with roadmaps towards their implementation in 2030.

Conclusions and Policy Recommendations

The SafeSmartInfra joint effort has generated a set of key exploitable results that can be taken as reference in real applications for the construction and maintenance of existing and new transportation infrastructures. Policy-makers and stakeholders can adopt the proposed solutions within their regions and municipalities to support the smart and sustainable transition of cities and their suburbs.

Paving solutions
With the aim of reducing the environmental impact of the road construction sector, while increasing the safety and accessibility of road pavements, SafeSmartInfra proposes:

- innovative impact-absorbing paving materials made of recycled rubber and RAP for the protection of users, in particular, those who are more susceptible to falls and impact injuries. These materials can be laid with traditional paving machinery and can be produced in standard cold mix plants or in smaller batch plants. Their maintenance can be performed with common patching solutions and they are fully recyclable.

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- Urban mining of RAP for 100% recycled pavements is today possible and proven to be environmentally friendly and cost-effective, other than being a consistent alternative to traditional hot mix asphalt fully or partially made with virgin aggregates. Most of the plant producers have developed innovative plants that allow up to 100% RAP recycling making today truly possible the transition to full-RAP pavements. The SafeSmartInfra outcomes have developed and tested a complete mix-design procedure applicable to different kinds of bituminous paving materials for urban and peri-urban infrastructures.
- Self-healing asphalt can reduce the amount of natural resources used to maintain road networks, decrease the traffic disruption caused by road maintenance processes, decrease CO_2 emissions during the road maintenance process and increase road safety. In addition to environmental savings, self-healing materials have the potential to deliver significant cost savings for road network maintenance across the EU.
- Energy can be harvested from pavement through hybrid system able exploit solar radiation, by directly converting it into electricity thanks to the the photovoltaic effect or it can be harvested through heat-transfer fluid pumped in a pipe network imbedded into the asphalt. Furthermore, piezo-electric systems can harvest energy from the traffic to provide energy supply for pavement monitoring.
- Smart pavement monitoring systems (Automated pavements) can help asset managers in pro-actively intervene to maintain roads. The SafeSmartInfra outcomes provide a vision for the implementation, as well as a series of technologies, to evaluate damage in pavements and pro-actively communicate with asset managers for optimising maintenance and rehabilitation strategies.

Frameworks and guidelines for future transport infrastructure in EU and Developing Countries:
With the aim of promoting a paradigm shift towards a fundamentally better way of conceiving transport infrastructures, SafeSmartInfra proposes: the Guidelines towards Sustainable, Multi-Functional, Automated, Resilient Transport Infrastructure including the definition of the SMARTI vision, the necessary steps to educate the new generation of professionals, a series of technology and roadmaps towards their implementation in 2030.