# Developing a Framework for Life Cycle Assessment of Green Transportation Infrastructure (Railway and Super pavements)


Manouchehr Shokri[1], Rose Mankaa[1], Marzia Traverso[1]

[1] Institute of Sustainability in Civil Engineering (INaB), RWTH Aachen University, Germany
Email: Manouchehr.shokri@inab.rwth-aachen.de


## Context

Analyzing the sustainability of alternatives considering design methods, construction techniques, and materials used to build the infrastructure are necessary to achieve Sustainable Development Goals(SDG). To attain these goals, sustainable production and construction related to transportation infrastructures are part of the European policy. As it is well known, the transportation industry and its related infrastructure including railway and roads, require very high construction costs. In addition, the excessive use of natural resources and energy for related construction and maintenance has highlighted the need for adapting purposeful planning with regards to sustainability related impacts. In transportation infrastructure, the focus should be to minimize energy consumption, related Greenhouse Gas emissions and other environmental impacts over their entire life cycle. In this study a new design of substructure with a layer of recycled Polypropylene (PP) is presented and compared with scenarios using virgin PP and conventional ballast. The outcome of LCA indicates that the recycled PP scenario causes the lowest environmental impact for the service life of 100 years. In the case study an LCA model was developed that can adequately evaluate the resource use and environmental effects of various use scenarios of Electric Arc Furnace (EAF) Steel Slag and Geosynthetic (recycled Polypropylene) materials in road and rail construction layers in comparison to primary raw material. The model takes into consideration technical properties investigated through finite element simulations in order to decouple increase of technical performance from environmental impacts.

## Methodology

Firstly, the mechanical effect of the Polypropylene (PP) as a reinforced layer inside the substructure is investigated by Finite Element simulation. Next, the environmental impacts of the design are studied by the Life Cycle Assessment (LCA) methodology.
LCA according to ISO 14040 & 14044 standards is carried out and the outcome of the LCA is used to develop the decision support model specific to the transportation infrastructure sector. The Finite Elements Method(FEM) is implemented to analyze the dynamic axel load response of railway track components (conventional and new design).

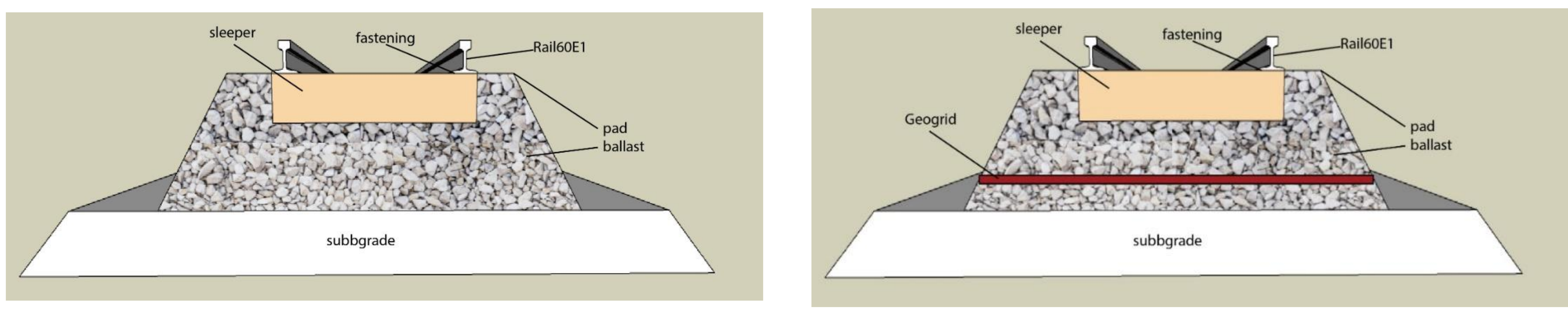


*Figure 1: Cross-section of a conventional and geosynthetic reinforced railway track*

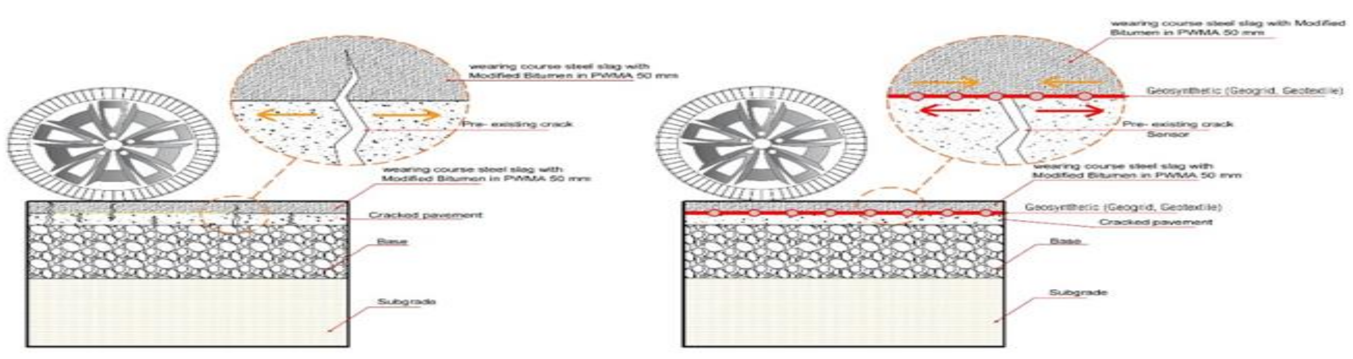

*Figure 2: Performance of reinforcement pavement with Geosynthetics and EAF compared with conventional pavement*

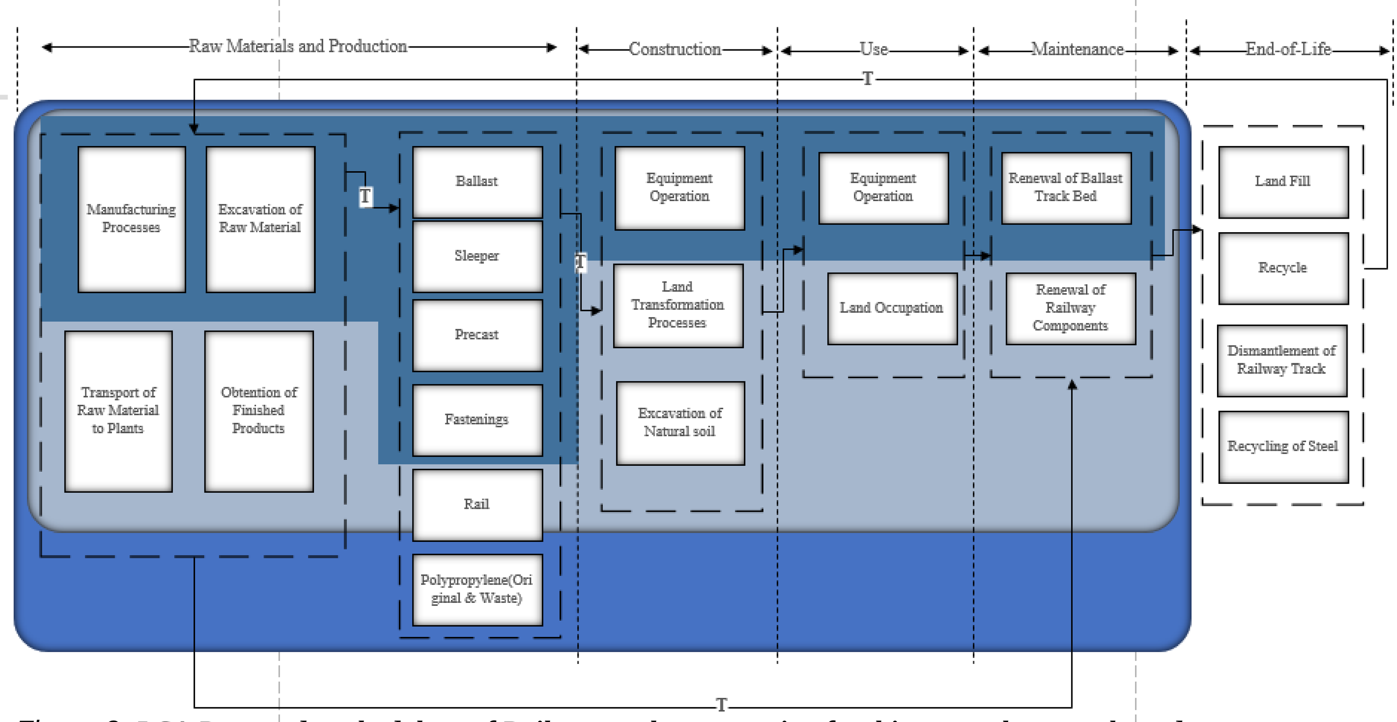

*Figure 3: LCA Proposed methodology of Railway track construction for this research system boundary area*

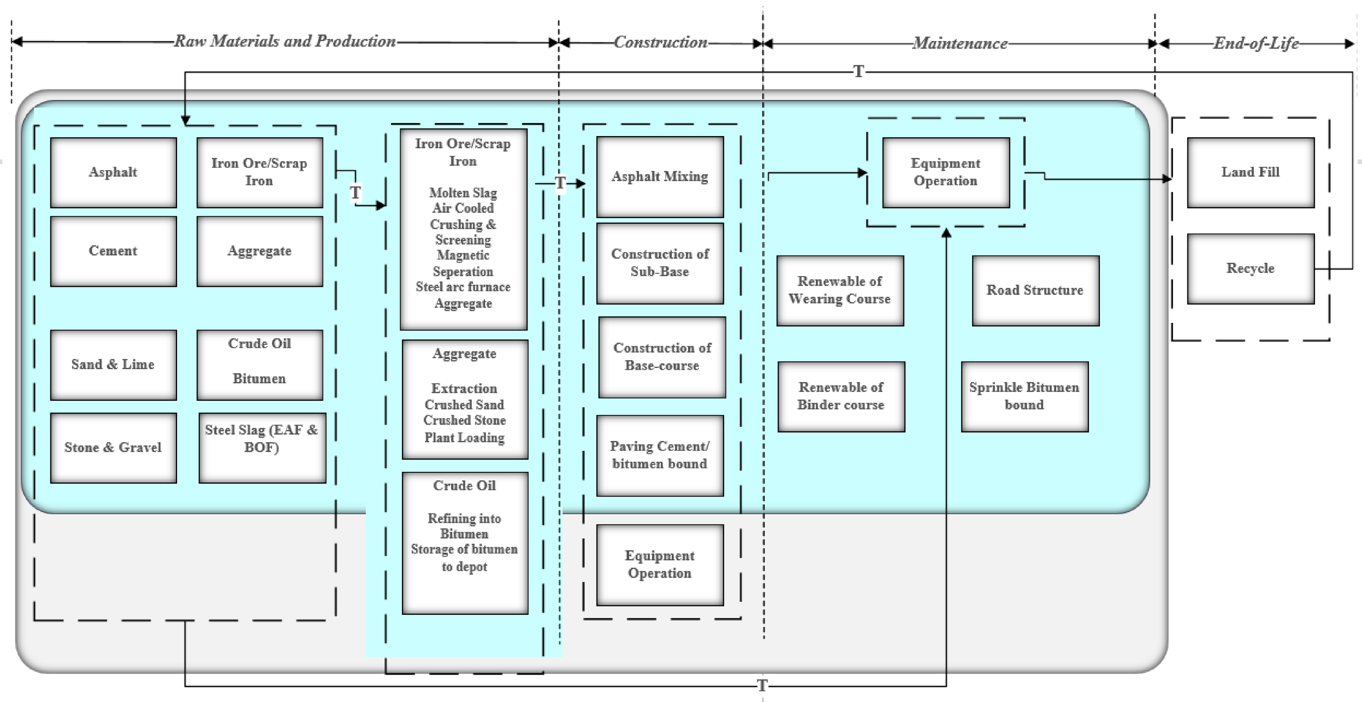

*Figure 4: LCA Proposed methodology of road pavement construction for this research system boundary area*

## Results

The recycled PP reinforced scenario leads to lowest emissions for production and the whole LCA service life of 100 years. The virgin PP reinforced scenario is the worst option considering $CO_2$ emissions regardless of its service life, primarily because of its reinforced layer. The ballast beds of all scenarios require contribute to high emissions because of the needed ballast for their construction, however, virgin reinforced PP and conventional ballast scenarios have a higher share compared to the recycled PP scenario. In this investigation, EAF steel slag aggregate was used to partially replace conventional aggregate in the production of hot mix asphalt mixtures. The work presented provides confidence for increased and more efficient use of EAF slag in asphalt towards more sustainable construction. The LCA preliminary results show that placing EAF aggregates and Geosynthetic layer at the surface and base–subgrade interface lead to improvements in both technical performance and environmental impacts. In particular, the results show significant contribution to the reduction of dynamic load damage and global warming potential.

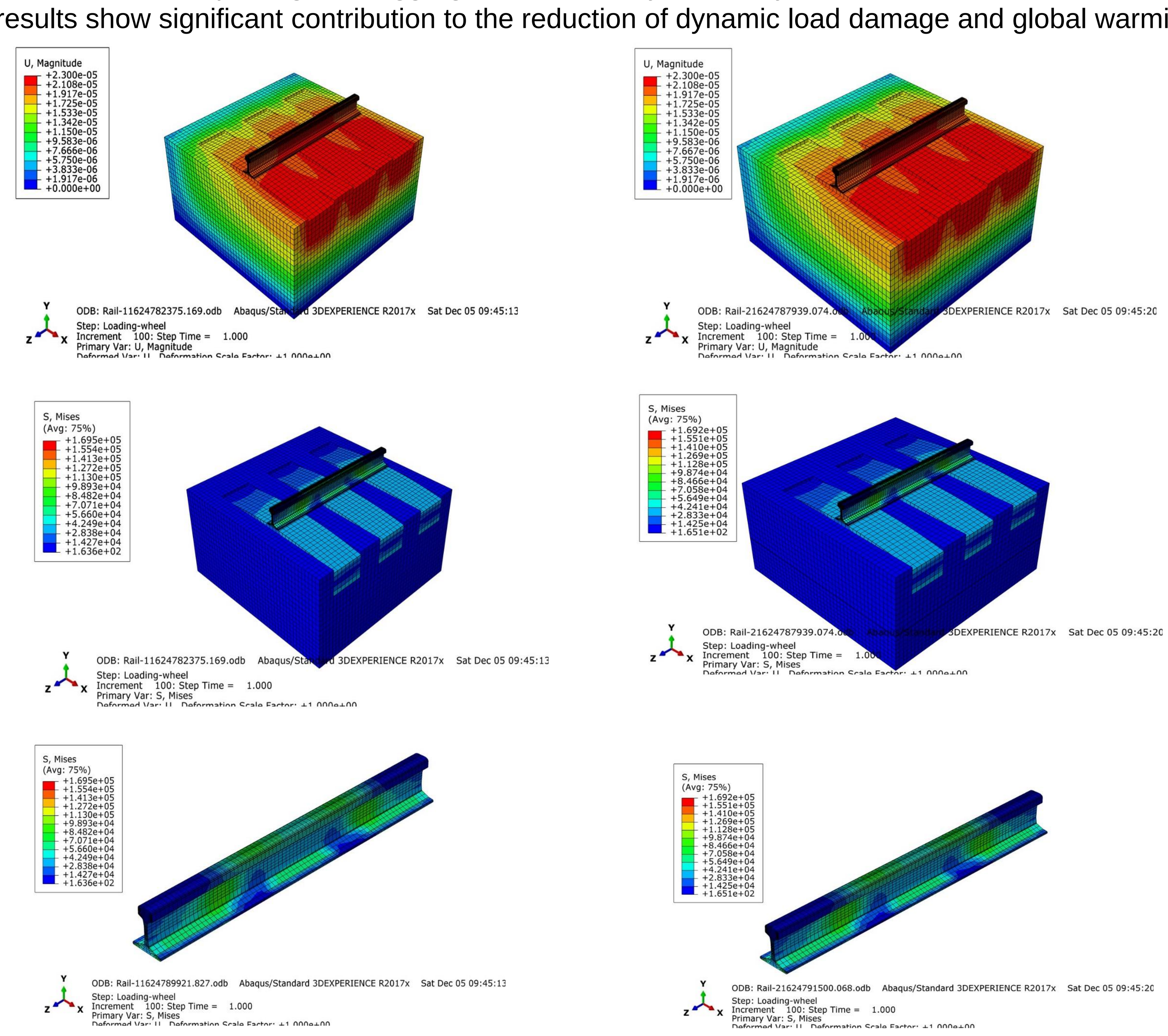

*Figure 4: FEM results for conventional and reinforced design in railway track during dynamic load*

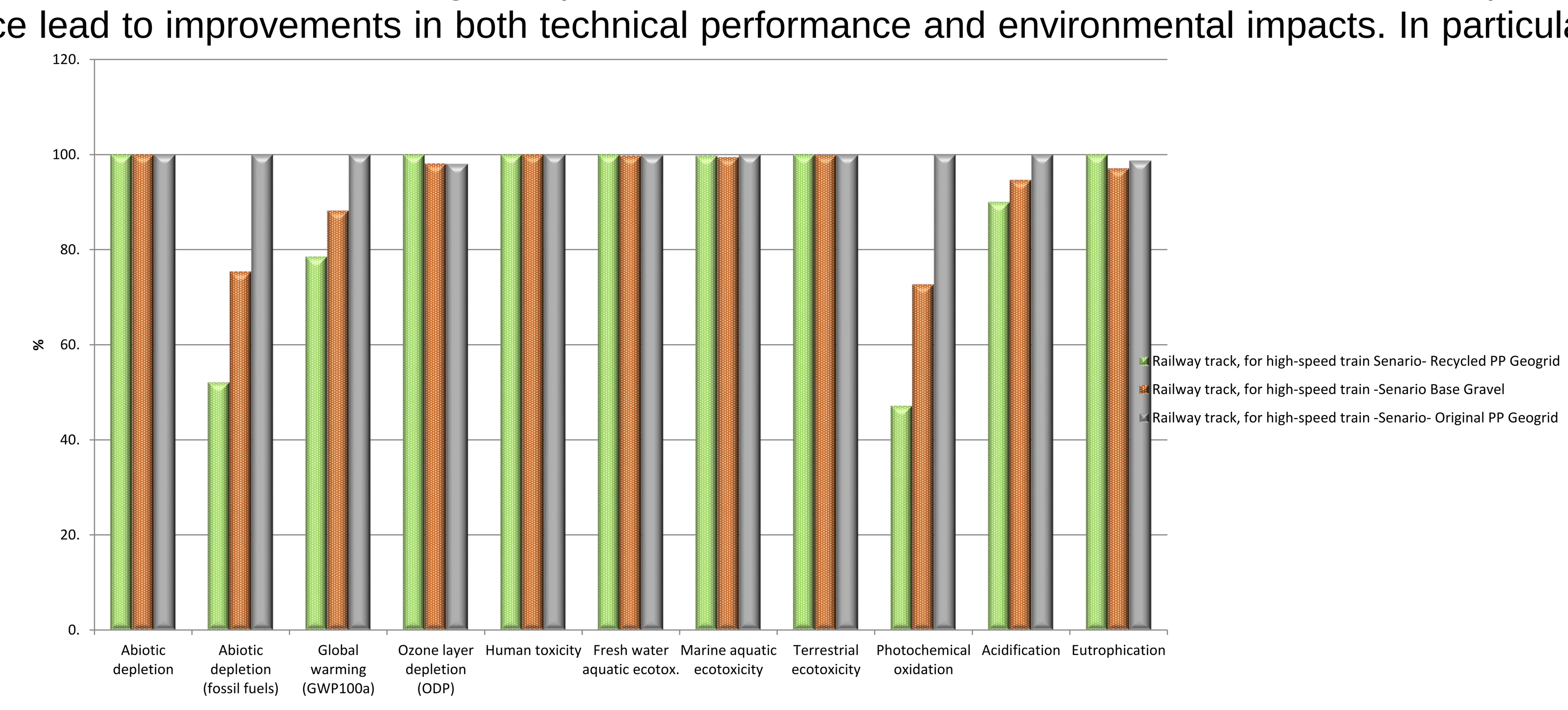


*Figure 5: Comparing Recycled PP, Original PP and Ballasted railway track*

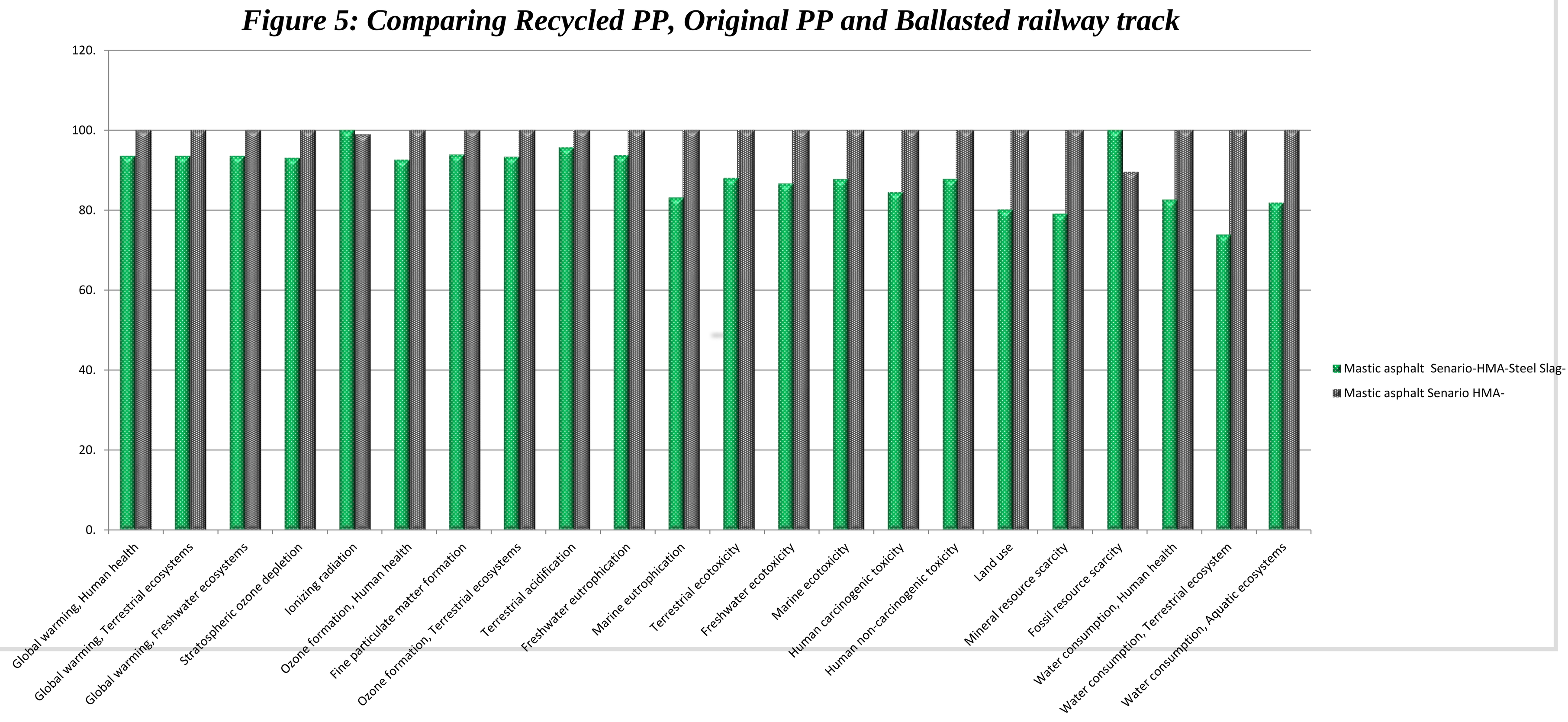

*Figure 6: Environmental impacts of scenarios for conventional pavement and that using EAF*

## Conclusions

This study evaluated the potential of employing a layer of recycled PP as geogrid material in railway track substructure. The mechanical impacts of the layer were assessed by the finite element simulation and results showed significant advantages, such as longer useful life and reduction in maintenance costs for both rail system and substructure. Regarding results gained by the LCA approach for a service life of 100 years, the substructure with the recycled PP layer was often the best solution in terms of environmental impacts. This scenario showed important potential for reduction in $CO_2$ emissions and energy consumptions compared to the others. Also, the global warming potential of the scenario indicated that most of the emissions are associated with the production and use phases including maintenance. In parallel, the LCA of Steel Slag as secondary raw material in road pavements was implemented and revealed that using EAF steel slag to replace natural aggregates in road construction has much better environmental impacts. The model developed aides decision making on material resource options to improve mechanical and technical performance while keeping environmental and economic impacts low.