Cradle-to-Gate Environmental Life Cycle Assessment of Reclaimed Asphalt Pavement Materials for Sustainable Road Construction

M.M. Hanafiah[1,2]

[1]Department of Earth Sciences and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]Centre for Tropical Climate Change System, Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
Presenting author email: mhmarlia@ukm.edu.my

Abstract

One of the materials that has been gaining interest in the road construction sector to maximize both economic and environmental benefits is reclaimed asphalt pavement (RAP) (Wu and Montalvo, 2021). The incorporation of RAP reduces usage of raw materials and lowers the overall cost of an asphalt mixture benefitting road owners economically (Yang *et al.,* 2015). Using reclaimed asphalt pavement (RAP) in asphalt mixture to replace virgin aggregate and binder offers a promising solution towards circular economy and resource efficiency in pavement construction industry (Tarsi *et al.*, 2020, Williams *et al*., 2020). Despite advances in technology in recent years, there is only limited understanding and information regarding its environmental performance (Yao *et al.,* 2022). Thus, this paper provides a comparative study of the environmental and performance of different recycling method and mixture scenarios. The environmental performance was evaluated using a Life cycle assessment (LCA) following the International Organization for Standardization (ISO) framework. Simapro ver. 9.0 software and ReCiPe 2016 impact assessment method at both midpoint and endpoint levels were adopted to assess the cradle-to-gate performance of the methods and materials compositions used in the RAP mixtures of a functional unit of 1 km-lane pavement area of 2 carriageways with an individual width and thick of 3.75 m and 10 cm, respectively over a 20-year lifespan.

The method section consists of two parts: i) LCA performance; and ii) Economic performance. In this study, LCA was used following the International Organization for Standardization (ISO); ISO 14040: 2006 "Environmental management—Life cycle assessment—Principles and framework" and ISO 14044: 2006 "Environmental management—Life cycle assessment—Requirements and guidelines" (ISO, 2006a; 2006b). LCA consists of four main phases: i) Goad and scope definition; ii) Life cycle inventory; iii) Life cycle impact assessment; and iv) Life cycle interpretation (ISO, 2006a; 2006b). Figure 1 illustrates the flow input-output process of LCA of RAP materials, where all possible inputs and outputs from processes involved from the beginning of the raw materials extraction to the final end-of-life of the material have been identified.

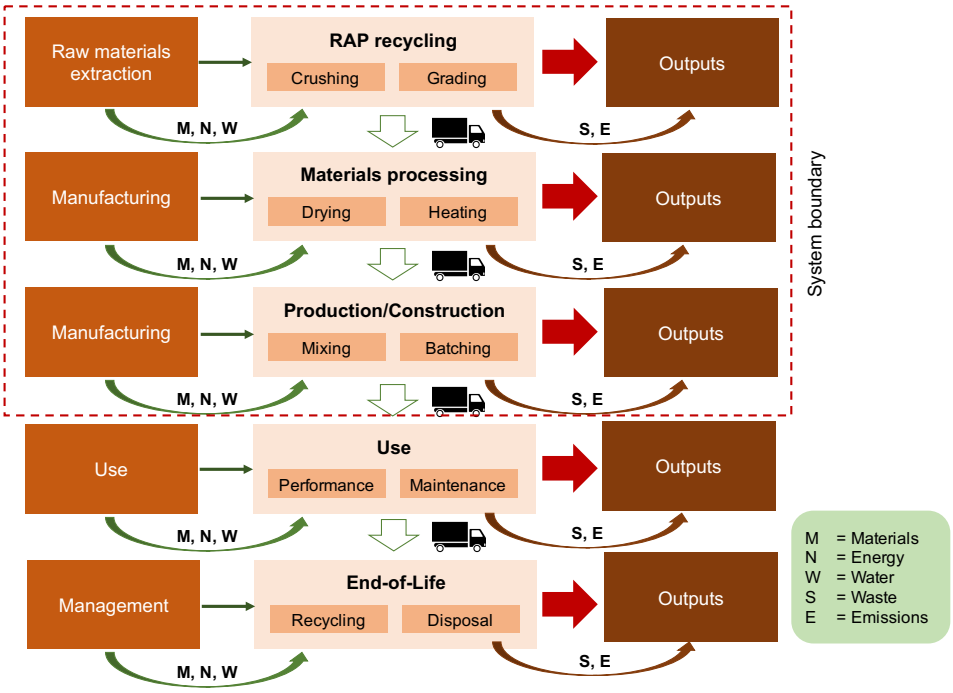

Figure 2. Flow process of LCA of RAP

The findings found that the maintenance stage of road pavement contributes to a higher impact throughout the supply chain of the process. Resources consumption relevant to certain impact categories, *i.e.* global warming and resource (mineral) depletion showed that mixed-in-place production greatly reduces the environmental impacts compared to central-plant-mixed production. In addition, the environmental performance of road pavement multi-recycling using asphalt mixtures with high rates of RAP compared to the use of virgin materials has lower environmental burden.

In conclusion, findings from this study allows authorities and companies to understand the environmental performance of the RAP-based pavement materials production as well as to perform site-specific comparative analysis of relative contribution of different techniques and materials used in pavement construction sector.

Keywords: *Reclaimed asphalt pavement, road construction, life cycle performance, economic benefit, sustainability*

Acknowledgement: Marlia M. Hanafiah was funded by the Universiti Kebangsaan Malaysia (ZF-2021-004 and GP-2021-K014834).

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