Literature Review on Energy Consumption in Road Construction Projects

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Abstract. At the initiation and design stage, the stakeholders (owners and planners) are faced with the choice to determine which type of pavement will be used in accordance with the budget provided yet they must also consider for the long-life maintenance and the environmental aspect of the road pavement project. One indicator of an environmentally friendly road pavement project is that it must be low in energy and low in emissions. The aims of this study are to conduct a literature review to determine the extent of the previous research that have been carried out, as well as the consumption of energy in the construction projects. The results will be used as a basis for developing critical thinking and conceptual frameworks to fill the research gaps and provide novelty for further research. The study was conducted using a qualitative bibliometric analysis method by identifying selected academic publications from Scopus database with the use of VOSviewer software to process the data. The results of this study indicate that there is an opportunity to conduct research in order to develop energy optimization models for green and sustainable road construction projects from the design, construction, operation and maintenance stages.

Keywords: energy, consumption, road project

1. Introduction
This paper presents a literature review on energy consumption in road construction projects from selected papers in order to analyse the results of previous research especially on road pavement construction projects. According to Thives and Ghisi, Zhang et al., in general, there are three alternatives of road pavement construction, namely flexible pavement, rigid pavement and a combination of both (composite pavement) [1, 2]. At the initiation and design stage, stakeholders (owners and planners) are faced with the choice to determine which type of pavement will be used in accordance with the budget provided, but they must also consider the long life maintenance and the environmental aspect of the road pavement project [3, 4]. In another field Airport authorities are interested in choosing the best development and rehabilitation approach, taking into account economic and environmental considerations and quality criteria [5]. One indicator of an environmentally friendly road pavement project is that it must be low in energy and low in emissions, starting from the construction, operation and maintenance to demolition stages [6, 7].

The aims of this study is to conduct a literature study to determine the extent of the previous research which have been carried out, specifically on how to calculate the amount of embodied energy and the operational energy, as well as the optimization of energy in the construction projects. The results will be used as a basis for creating critical thinking and conceptual frameworks to fill the research gaps and provide novelty for further research.
2. Previous work
Several research of literature studies, especially review papers, have been carried out over the past eleven years on energy use in buildings and roads which include research in the construction phase, and operation and maintenance stages. Base on the publication years, the main review papers include:

1. Pérez-Lombard et al., reviewed the research on energy building consumption. They analyse available information concerning energy consumption in buildings particularly related to HVAC systems and the comparisons between different countries (USA, Spain and UK) are presented specifically for commercial buildings [8].

2. Dixit et al., conducted a review by identifying parameters to measure embodied energy. They concentrate on reviewing existing literature to define various parameters to promote the creation of a reliable and comparable database [9].

3. Kavgic et al., reviewed the bottom-up building stock models for energy consumption in the residential sector. They have found three major issues which need to be addressed: a) the lack of publicly available detailed data relating to inputs and assumptions as well as underlying algorithms which render any attempt to reproduce their outcomes, b) the lack of data on the relative importance of input parameter variations on the predicted demand outputs, and c) the uncertainty related to the socio-technical drivers of energy consumption – how people use energy and how they react to changes in their home as a result of energy conservation measures [10].

4. Ramash et al., studied total use of energy during the life cycle was analyzed to define the processes with the greatest use of energy and to establish reduction strategies. A critical review of the life cycle energy analyses of buildings from 73 cases across 13 countries is presented to investigate the embodied energy parameters [11].

5. Zhao and Magoulès reviewed previously developed models of Simplified methods of engineering, statistical methods and artificial intelligence to forecast energy consumption in building [12].

6. Thives and Ghisi conducted a review of asphalt mixtures emission and energy consumption in road pavement construction [1].

7. Wang and Srinivasan carried out a review on artificial intelligence-based building energy use prediction by comparing the capabilities of single and ensemble prediction models. They conducted an in-depth review of the single AI-based methods such as multiple linear regression, artificial neural networks, and support vector regression; and of the ensemble prediction method which combines multiple single AI-based prediction models to improve the prediction accuracy several manifold [13].

8. Zeng and Chini examined previous research on the energy consumption of buildings using bibliometric methods to better understand the field as a whole. A bibliometrical approach is applied to build an information map and to find out more about the subject. [14].

9. Dixit presented a rigorous literature review on the life cycle embodied energy in residential buildings in order to investigate the embodied energy parameters and their impact on the embodied energy calculations [15].

10. Amasyali and El-Gohary reviewed various studies on data-driven building energy consumption prediction, with a specific focus on the prediction scope, data properties and methods for the data pre-treatment, machine learning algorithms and evaluation performance measures used [16].

11. Dixit conducted a review of life cycle recurrent embodied energy calculation of buildings. The findings this review help to streamline the process of life cycle embodied energy calculation [17].

In Indonesia, Mulyana and Wirahadikusumah (2017) conducted a research to estimate the energy consumption and greenhouse gas emissions resulting from the activities on Cisumdawu freeway construction as well as to calculate how much the contribution made from the materials, transportation activities and construction activities to the environmental impacts. They found that the rigid pavement work contributed 78.78% to the amount of environmental impact produced, while the sub base work contributed 17.04% and the sub grade work contributed 4.18%. They also identified that the materials contributed 92.80% of the total amount of environmental impact produced meanwhile transportation activities contributed 1.97% and construction activities contributed 5.23% [18].
There are eleven literature review papers that have been carried out; but there is only one article that discusses the use of energy in road construction, so that further research is still needed for the use of energy in road construction projects.

3. Research Method
The study was conducted using a qualitative bibliometric analysis method by identifying and reviewing selected academic publications from Scopus database with the use of VOSviewer software to process the data. Due to its relatively broad scope, inclusion of conference papers, faster indexing and availability of newer publications compared to other databases, Scopus was selected [19, 20]. This method has been used on review paper by Hosseini et al., on their review paper on citation networks in building information modelling [21], by Yin et al., on building information modelling for off-site construction [22], by Fahimnia et al., on Green supply chain management A review and bibliometric analysis [23] and by Feng et al., on their review paper on Corporate social responsibility for supply chain management: A literature review and bibliometric analysis [24].

The selected articles are taken from year 1974 to 2019 using the keywords: energy, optimization, construction, and road. Below are the steps used to collect the papers and data:

3.1. Collecting the papers’ metadata from Scopus website
1. Enter the keywords: ‘energy’, ‘optimization’, ‘road and construction to find related paper by using Scopus document search function
2. There are 170 documents related to the keywords, then select all documents
3. By using the export facility all information related to article data is then converted to an MS Excel file (CSV extension)

3.2. Using VOSViewer software to create bibliographic data maps
1. Choose data source by reading data from bibliographic database files
2. Select a Scopus database file
3. Choose the type of analysis: Co-occurrence and counting method: full counting
4. Choose the threshold with minimum number of occurrences of a keyword: 5 (five)

4. Results and findings

4.1. Data analysis using Scopus data
Based on the results of the keywords search with in Scopus:
1. There were 170 articles published from 1974 to 2019 that are related to the keywords (Figure 1). After 2010 there is a sharp increase of the number of papers published on the keyword topics.

![Figure 1. Documents by year of publication.](image-url)
2. Most articles coming from engineering subject area (45.1%) followed by environmental science (10.5%), and computer science (9.0%) and the rest is divided into several other subject areas (Figure 2).

![Figure 2. Documents by subject area.](image)

3. Based on the country or territory, most research on these keyword topics (Figure 3) are largely conducted in China and America.

![Figure 3. Documents by country or territory.](image)

4. Based on the type of document, there are three main types namely: articles, conference paper and conference review with relatively the same percentage of around 30% among them (Figure 4).
4.2. Data analysis using VOSViewer

1. The keyword ‘optimization’ is the most related or connected to the other keywords: ‘road construction’, ‘pavements’, ‘concrete’, ‘asphalt’ and ‘design’ (Figure 5).

2. The keywords: optimization, road construction, concrete, asphalt and pavement are relative new research which is not available in publications more than 10 years ago (Figure 6).
Figure 6. Documents overlay by the year of publication.

The label's size and an item's circle are determined by the item's weight. The higher an item's weight, the greater the item's tag and ring. An item's color is determined by the cluster that the item belongs to. The gap in the diagram between two journals is approximately representative of the journals relationship in terms of co-citation links. Generally speaking, the closer two papers are to each other, the greater their connection. Lines also reflect the strongest ties of co-citation between journals [25].

5. Discussion
In this literature review, thirteen papers have been reviewed and according to the analysis the keyword ‘optimization’ is highly connected to: ‘road construction’, ‘pavement’, ‘asphalt’ and ‘concrete’. Based on these keywords researchers then selected certain papers and conducted some review on the papers. Based on the publication years a number of important points are described as follows:

1. The energy required and precipitation rates are strongly correlated. Aggregate water content and rainfall are strongly correlated and water content is an important determinant on the amount of energy needed [26].

2. In the first three phases of a road life cycle, such as: extraction of raw materials, manufacturing, and placing of course pavement materials, Portland cement concrete (PCC) pavement demand more energy. The manufacturing of bitumen requires less energy than the production of cement. Furthermore, the major consumption of energy in the production of asphalt pavement occurs during the asphalt mixing and aggregates drying [6].

3. Energy consumption for the recycled pavement is lower than the other rehabilitation alternatives, such as: asphalt overlay and reconstruction. Based on the sensitivity analysis it was found that the material haulage distance (mainly aggregate) was the most sensitive parameter [27].

4. Warm Mix Asphalt (WMA) production technologies have a big potential in reducing the demand of non-renewable energy sources. The result showed 7%-8% energy save for the WMA in comparison with the Hot Mix Asphalt (HMA) [28].

5. This study presents a model for estimating the GHG emissions of CO₂ and CO₂ equivalents resulting from the use of energy in infrastructure projects. The model covers the first three life cycle phases associated with the embodied energy, namely: the material, the transportation and the construction phase. Material production is the main user of energy with 78% of the total embodied
energy and produces the highest emissions of CO\textsubscript{2}. However, due to differences in the energy sources used the CO\textsubscript{2} equivalent emissions don’t fully reflect the energy use [29].

6. Increasing production capacity, reducing water content and reducing asphalt mixture temperatures production can produce significant savings in energy consumption [30].

7. The planners and estimators during the planning phase need to know the model to predict energy consumption and CO\textsubscript{2} emissions resulting from the transportation in order to develop work plans that will meet the relevant environmental regulations [31].

8. Tunnels and toll stations are key factors affecting the overall energy consumption of the entire road. The decomposition in the departments of toll stations and maintenance centres reveals that the energy efficiency improvements with the use of alternate materials and energy-saving technologies can greatly contribute to energy conservation [32].

9. The pavement cement consumes more energy than the hot mix asphalt. Warm mixing asphalt engineering can save 20-70 percent energy in contrast to the hot mixture asphalt because the mixing system lowers temperatures. In addition, asphalt mixtures and alternative technologies consume less energy and gas emissions than Portland cement mixtures. [1].

10. A model to estimate the hourly energy consumption and CO\textsubscript{2} emissions of an excavator under various site conditions an Artificial Neural Network (ANN) and the influencing factors as input parameters are: digging depth, cycle time, bucket payload, engine horsepower, and load factor [33].

11. Rubberized asphalt technology is an important green technology for lowering the Green House Gas (GHG) emissions, saving energy and raw material as well reducing noise level of pavement. This technology should be widely used to reduce environmental impacts [34].

12. Artificial Neural Network (ANN) model can help evaluate the impact of independent variables on the dependent variable observed. It is possible to successfully use ANN in predicting consumption of natural gas in the production of hot mixed asphalt, where the asphalt composition and production specificities should be considered [35].

13. The coefficient for the effect of energy consumption was obtained from support vector machine (SVM) and piecewise least-squares regression (PLSR) and was found to be consistent with the test results. The energy consumption caused by the prediction and test models was about 5 percent error. This mistake nevertheless meets the criteria for engineering in the Asphalt Mixing Process [36].

According to previous research, there are several topics that became the concentration of researchers, namely: find correlation between equipment factors and their impact on energy consumption, compare the amount of energy needed to make asphalt base on the temperature of the mixture, comparing the amount of energy and emissions between road with flexible pavement and rigid pavement, making models to predict the amount of heavy equipment energy in excavation and mass hauler and looking for alternatives and breakthroughs from using new materials and methods to reduce energy consumption and emissions generated by road construction projects.

6. Conclusion
The results of this study indicate that there is an opportunity to conduct research on the development of energy optimization models in road pavement construction projects from the design, construction, operation and maintenance up to demolition stages in order to achieve a green and sustainable road pavement construction. The resulting model can then be used basis for the decision making to choose the best road pavement design in terms of the energy use during the road construction project cycle whether it is flexible pavement or rigid pavement.

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