Development of the Statistical Model for Carbon Footprints, Embodied Energy and Global Warming Potential for Sustainable Roads

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ABSTRACT:

Road infrastructure is one of the main contributors in increasing Carbon Footprints, Embodied Energy, Global Warming Potential. Consequently, aggravating global warming but it is also one of the sectors that mostly suffer from climate change, which causes extreme weather events. Climate change poses a critical threat to future development, particularly in areas where poverty is widespread and infrastructure are underdeveloped for even current roads. Climate change poses major impacts which can be avoided by adaption measures whichneeds to be linked to current and future risk reduction practices and management initiations toincrease transport resilience and reduce the impact of extreme weather events. Infrastructure impacts are determined based on civil engineering material research, field studies of actual impacts on roads and buildings and additional data. This paper focus mainly carbon footprints, embodied energy and global warming potential for road infrastructure to above said problems.

Keywords: *Carbon Footprints, Embodied Energy, Global Warming Potential, Road Infrastructure.*

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A) INTRODUCTION:

Carbon footprints is a commonly used term to describe the total amount of carbon dioxide and other greenhouse gas emissions for which an individual or organization isresponsible. It is usually called as the total amount of CO2 and other GHG emitted. Carbon emission are calculated at national level, using different methodology suggested by Intergovernmental panel on climate change (IPCC) [3]. With an increase in India's population growth, the rate of urbanization and industrialization will also increase substantially with a need for higher energy and energy consumption. This increase in urbanization and industrialization would also generate higher energy demand for infrastructure development and associated work. The Intergovernmental Panel for Climate Change (IPCC) estimates that the transportation sector annually produces 13% of the total greenhouse gas (GHG) emissions at the global level (IPCC Climate Change 2007) [23]. India ranks third in the annual carbon dioxide (co2) emissions, which comprises of 6% of emissions worldwide [25].

Environmental issues have become of crucial importance in the transport sector. Transport is the second biggest greenhouse gas emitting sector after energy and is responsiblefor 25% of the EU's total emissions. The challenges posed by climate change have added to the urgency for developing low-

carbon transportation. Climate change resulting from human activities is recognized as one of the most urgent environmental issues facing the global community. The sectors cannot afford to ignore the ecological consequences of its activities and the growing potential for enhancing positive, while reducing negative, impacts. Representing around 15% of global greenhouse gas (GHG) and 23% of energy-related carbon dioxide (CO2) emissions the Organization for Economic Corporation and Development (OECD 2010), the transport sector clearly has the scope and means to make a significant contribution in terms of eco-friendly techniques and technologies. The road sector has developed an array of emission assessment tools, as part of an effective way to help translate into reality the low-carbon transportation strategies set up by governments. Carbon foot printing(CFP) is a measure of the carbon dioxide (CO2) and other GHGs of an activity or product thatallows the sources of the impacts to be understood, investigated and managed [21].

Carbon footprint has managed to get the life cycle thinking into public attention and organization's decision-making process (eg. procurement, tender selection etc). However, global warming is not the only environmental problem. Other impacts associated with a road (e.g. leaching, fuming, noise), especially when recycled materials are increasingly used, shouldnot be traded off for GHGs. Companies aiming for environmental labelling need to ensure thattheir pursuit of 'green' construction is not simply based on a single aspect such as CO2 savings [22].

Cap and trade and its close cousin a carbon tax are the approaches that most economistsfavor for reducing greenhouse gas emissions. California and the several northeastern states forming the Regional Greenhouse Gas Initiative have each already implemented a regional cap-and-trade system. In addition, the European Union has operated a cap-and-trade system since 2005. The U.S. House passed a cap-and-trade bill in 2009 (the American Clean Energy and Security Act, known as Waxman-Markey after its sponsors), but the Senate did not [19].

Embodied energy is the energy associated with the manufacturing of a product or services. This includes energy used for extracting and processing of raw materials, manufacturing of construction materials, transportation and distribution, and assembly and construction [2]. In the context of the intensifying development of economic globalization and prosperity of international trade, embodied energy is considered as a better indicator to comprehensively reflect the nature of a country's energy use than the direct energy use [3].

China is the largest energy consumer and CO_2 emitter in the world, and its energy issue has attracted worldwide attention. In recent years, China's huge international trade surplus has received unprecedented attention, and it has become a reason for bilateral trade friction. Compared with imported products from developed countries and regions, China's export products have lower value added and higher energy consumption and emissions per unit export trade volume, which will inevitably lead to the imbalance of energy consumption and emissionflows. On the one hand, it has brought great pressure on domestic energy resources and the environment; on the other hand, it has also aroused international concern and even criticism about the growth of China's energy demand and emissions [18].

Global warming potential is the heat absorbed by any greenhouse gas in the atmosphere,as a multiple of the heat that would be absorbed by the same mass of carbon dioxide. GWP is 1 for CO_2. For other gases it depends on the gas and the time frame. Carbon dioxide equivalentis calculated from GWP [4].

Human activities have leads to increases in the concentration of number of gases whichare effective in absorbing and re-emitting radiation ion the infra-red part of electromagnetic spectrum, leading to strengthening of the green-house effect [4].

According to Batista, Almeida, Aurelio [31], the work on climate adaptation in transport infrastructure, greenhouse gas emissions caused significant changes in the environment, and the consequences of these effects for the planet have become threats to transport assets. Therefore, to identify the main sources of impacts and emissions in the transport sector researchers have conducted studies in the field of road transport, when recommending the inclusion of environmental criteria in public tenders for road projects by identifying and validating

environmental factors indicative of sustainable road transport performance.

Problems Due To Increasing Amount of Carbon Footprints, Embodied Energy and Global Warming Potential:

These increases the earth's atmospheric temperature and are emitted from fossil fuel used in electricity and other by products of manufacturing. Major effect of such practices mainly consists of climate change such as extreme precipitation, acidification and warming ofoceans [4].

Solution to reduce amount of carbon footprints, embodied energy and global warmingpotential:

P. Aruna, B. Rupini has found that, to reduce carbon emission by applying green technologies around the world is the construction of green highways. The research mainly focuses on three green highway interventions related to materials & methods used for road construction in India [11].

The review has also conducted green initiatives of best practices adopted as a pilot study for better planning and construction management to provide greener ways and estimationof the carbon footprint for road construction projects [4].

The aim of this research paper is to conduct a literature study to determine the previousresearch and to calculate Embodied Energy, Global Warming Potentials & Carbon Footprints of conventional materials, alternative materials & to do optimization of energy in the road construction projects. Embodied energy is the total direct and indirect energy consumption required for the production of goods and services [2].

B) LITERATURE SURVEY:

Global warming is the consequence of the long-term incline in the amount of greenhouse gases in the upper layers of the atmosphere. The emission of these gases is causedby human activities that are intensely harmful to environment. The main focus of this researchis the case study in Sungai Petani, Kedah is to calculate the carbon footprints of highway and evaluate its road pavement rehabilitation [1].

Harish Kumar and Manish Goyal found that, the carbon footprint estimation of the sample projects indicated that the emission from the construction and maintenance phases arerelatively insignificant when compared with emission from vehicular movement on roads for its total life [3]. Hammond & Jones has developed an open-access, reliable database for embodied energy and carbon (dioxide) emissions associated with the construction industry has been described [2]. The potential to generate environmental input data in the design and planning stage of a construction project and therefore make the assessments of embodied energy and associated GHG emissions more project specific. This is beneficial for the development of more environmentally-friendly products and processes in the project-based construction industry [12]. Energy consumption and climate change are directly linked; the energy sector is 86% of total direct GHG emissions. The energy requirements of each economic sector (transportation, industry, commercial, and residential) are responsible for the bulk of allman-made climate change gases. Transportation represents a significant portion of emissions in the IPCC energy sector [9].

In 2009, the transportation sector consumed 27 quads of direct energy, mostly in the form of refined liquid fuels, chiefly gasoline and diesel. Transportation share of energy consumption is similar to its share of greenhouse gas emissions, at 32%. The linkages betweenenergy use and climate gases are evident in all economic sectors [28].

Harvey has found that, the computation of global warming potentials (GWPs) is subject to large uncertainties as well as conceptual difficulties, in contrast to the relatively simple case of ozone depleting potentials (ODPs) which were used in formulating international agreementsto protect the ozone layer [4].

Developing countries will incur a higher relative cost of climate change impact to the road infrastructure networks through 2100, but starting as early as the 2020 decade. For all countries analysis, proactive adaptation measures can significantly reduce impacts and costs when compared with the reactive no adapt scenario [9].

Climate impacts will have implications for existing global infrastructure investment needs, including

increasing, decreasing, or re-directing particular investment needs in relevant sectors, particularly flood defenses, and water supply and sanitation. The use of tools for decision-making under uncertainty can reduce the need for costly retrofitting while reducing upfront costs. Natural infrastructure and other flexible or innovative approaches to climate-resilient infrastructure may even be cheaper than traditional approaches in some circumstances.Global studies find that the benefits of investing in resilience outweigh the costs with high benefit-cost ratios, for example of investment in flood defenses for coastal cities [24].

Emissions from land transport, and from road transport in particular, have significant impacts on the atmosphere and on climate change. We also get an overview of past, present and future emissions from land transport, of their impacts on the atmospheric composition andair quality, on human health and climate change and on options for mitigation. In the past vehicle exhaust emission control has successfully reduced emissions of nitrogen oxides, carbon monoxide, volatile organic compounds and particulate matter. This contributed to improved air quality and reduced health impacts in industrialized countries. In developing countries however, pollutant emissions have been growing strongly, adversely affecting many populations. In addition, ozone and particulate matter change the radioactive balance and hence contribute to global warming on shorter time scales. In the future, road transport's emissions of these pollutants are expected to stagnate and then decreases globally. Consequently, road transport's impact on climate is gaining in importance. The expected efficiency improvements of vehicles and the introduction of biofuels will not be sufficient to offset the expected strong growth in both, passenger and load transportation. Technical measures could offer a significant reduction potential, but strong interventions would be needed as markets do not initiate the necessary changes. Further reductions would need a resolute expansion of low-carbon fuels, atripling of vehicle fuel efficiency and a stagnation in absolute transport volumes. Land transport will remain a key sector in climate change mitigation during the next decades [26].

India is both a major greenhouse gas emitter and one of the most vulnerable countries in the world to projected climate change. The country is already experiencing changes in climateand the impacts of climate change [7].

The results of this research paper 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 [11].

C) Computations of Embodied Energy, Global Warming Potentials & Carbon Footprints of Conventional Materials and Alternative Materials used for road construction:

Sustainable Development Goal No. 12 (Responsible Consumption and Use), represents that goal which has maximum impact on project pre planning of the road infrastructure. The subsequent part of this research therefore focuses on computations which are very important from the perspective of responsible consumption and use. These details are presented below in the form of a comparative analysis of embodied energies used for conventional road materials like Soil, Aggregate, Asphalt, Bitumen, Concrete and the carbon footprint, vis-à-vis the alternative option of use of sustainable construction materials like Construction and Demolition Waste, Recycled asphalt, Crushed concrete, Fly ash and Slag from Thermal power plants, Metallurgical Slag, Lime, Silica fume, Foundry sand, Waste-rock, Ash from incineration plants for solid municipal wastes etc.

Project-01: Proposed Improvement & Maintenance of Road from MDR-13 Nirgudsar to Cholichamala Road CH Km 0/000 to CH Km 2/640 in Taluka: Ambegaon, District: Pune

Table 01: Embodied Energy Calculations of Conventional Materials used for road construction:

Sr. No.	Used Material	Mass (kg)	Embodied Energy per kg (MJ)	Embodied Energy (GJ)	GWP (KgCO2 eq.)	GWP (tonsCO2 eq.)
1)	Asphalt	1188000	11	13068	0.24	285.12
2)	Aggregate for Base Course	3564000	0.11	392.04	0.0090	32.07
3)	Cement Concrete	731500	1.1	804.65	0.14	102.41
4)	Granular Sub base (Sand)	311670	0.11	34.28	0.009	2.81
5)	Soil	2203630	0.11	242.39	0.010	22.04
			Total	14541.36	Total	444.45

From the table 01, it is seen that 444.45 equivalent Carbon Credits lost due to emission of CO2 for project-01.The lost equivalent carbon credits can be earned if the conventional materials are replaced/alternative options are used.

Table 02: Embodied Energy Calculations if Alternative Materials used for road construction:

Sr. No.	Used Alternative Material	Mass (kg)	Embodied Energyper kg (MJ)	Embodied Energy (GJ)	GWP (KgCO2 eq.)	GWP (tons CO2 eq.)
1)	Lime (Replacing Asphalt)	1188000	1.6	1900.8	0.43	510.8
2)	Fly ash Aggregate (Replacing Aggregate)	3564000	0.1	356.4	0.008	28.5
			Total	2257.2	Total	539.3

From the table 02, it is seen that 539.3 equivalent Carbon Credits will be gained if conventional materials such asAsphalt, Aggregate are replaced non-conventional such as Lime, Fly ash Aggregate materials.

D) CONCLUSION

The current research showed consistent findings with the study conducted by the authors of 31 research papers. Although it is observed that the developing countries will pursue a higher relative cost of climate change impact to the road infrastructure networks through 2100, but starting as early as 2020 decade. According to various studies we also initiated that each one facilitates to resolve the hazardous impact of climatic change on the infrastructure by reducing the carbon footprints, embodied energy and GWP for making the roadways most sustainable. As there is tremendous increase of global warming all over the world, due to these increase in the number of environmental problems are also raising day by day like heavy rain, storm, heat waves, etc. For the reduction of green-house gases emission along with the global warming effects the road construction industrial sector plays a vital role. Accordingly deeper analysis needs to be performed to find better ways for reducing Carbon Footprints related to pavement road and infrastructure.

Embodied energies, global warming potentials and carbon footprints of road infrastructure can be reduced by replacing conventional materials such as asphalt, aggregate with alternative materials such as lime, fly ash aggregate for road construction to achieve the sustainability in roads.

Development of the statistical model for Carbon Footprints, Embodied Energy and Global Warming Potential for sustainable roads seems a prominent solution for the problems.

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