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Applying life cycle thinking to reduce greenhouse gas emissions from road projects

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ABSTRACT

In this article, the evaluation of Greenhouse gases in road construction projects is approached from a life cycle perspective. The elements which have a major contribution to emissions are identified in order to develop a strategy to control and reduce them. For this purpose, a management information system (CO_2NSTRUCT) was developed, supported by a database obtained through specialized bibliography. The information in the application is organized in a manner that permits a wide variety of queries with several grades of detail in order to study the results. Four new construction projects in Spain were analyzed. The scope of the analysis and the results are contrasted with an extensive revision of the state of art. The total emissions obtained in the life cycle range from 8880 to 50 300 t CO_2e/km, most of them related to road construction activities; the maintenance stage has a secondary role. Earthworks are the main activity involved, with 60–85% of the emissions in the construction stage, strictly related to the emissions generated by the performance of off-road machinery. Materials, land use and land-use change result significant and crucial contributions. The obtained results constitute a necessary base in order to accomplish an adequate dimensioning of emissions in the road construction sector.

1. Introduction

1.1. Background

Nowadays, anthropogenic global warming is considered to be a first degree environmental challenge (United Nations, 1992). In order to face this problem, knowledge of the dimension of greenhouse gas (GHG) emissions related to human activities is necessary. The implementation of a control and the quantification of these emissions are based on global scale agreements such as the Kyoto Protocol (United Nations, 1998), and come into effect through measures such as the European Emissions Trading regulated by Directive 2003/87/CE (European Union, 2003). Promoted by the growing relevance of this problem to stakeholders, many companies are also voluntarily trying to control their emissions as part of their Corporate Social Responsibility (CSR).

The construction sector, and more precisely road construction, is one of the three main drivers of resource use in the European Union (Steger and Bleischwitz, 2011). In infrastructure projects GHG emissions is a key indicator when sustainability is being assessed (Fernández-Sánchez and Rodríguez-López, 2010; Gasparatos et al., 2008). In addition, due to its characteristics (high energy consumption; use of resources, raw material and surface; generation of high volumes of waste; quantity of linked transports and long service life), it is a sector which contributes highly to global warming (Cass and Mukherjee, 2011). This sector has a broad margin for environmental improvement (Santero et al., 2011a,b) with particular characteristics which ensure the interest of this study. The construction sector is not included in the scope of Directive 2003/87/EC regarding the European Union Emissions Trading System (EU ETS) – even though production of some related materials (concrete, metal, electricity etc.) is – since it is an industrial activity where the contamination sources are vague. Construction projects have a high grade of uniqueness, the locations are often widely dispersed and the presence of installations and equipment for the construction stage is transitory, thus making it difficult to follow the projects systematically. Moreover, boundary definition is not simple due to the large quantity of actors and activities that are implied, the long duration of the construction and its service life. However, the calculation of GHG emissions in these

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projects is becoming a primary target of civil engineering companies since it can bring added value to the product and it can be seen as an instrument of environmental commitment within their CSR.

This growing interest in the topic is reflected in the number of studies published recently. There are many studies on Life Cycle Analysis (LCA) and LCA based on the carbon footprints of road surfaces (Athena Institute, 2006; Nisbet et al., 2000; White et al., 2010), including some focused on precise phases such as the preservation and reconstruction of road surfaces (Cass and Mukherjee, 2011; Huang et al., 2009a Weiland and Muench, 2010). The first study on LCA of an entire road construction project was achieved by Stripple (2001). Other studies have evaluated the impact from other points of view, including interesting aspects such as the extension of land use changes (Mroueh et al., 2000), decomposition and recycling of materials (Park et al., 2003), use of recycled waste as raw materials (Birgisdóttir et al., 2006; Milachowski et al., 2011), impact of maintenance activities on traffic (Huang et al., 2009b), including the traffic itself within the analysis (Milachowski et al., 2011; Treloar et al., 2004) and changes in radiative forcing produced by the different albedo of the road surfaces (Loijos, 2011). In Europe, we have an example of extensive project research in Greece (SUSCON, 2006). So far, in Spain, the only approach that has been taken (Garraín and Vidal, 2008) solely examined the road surface structure by inferring data from the Ministry of Public Works and Transport. These authors have estimated approximate national emissions of the activities of road construction between 2004 and 2006; in a similar way to other input–output analysis such as the one done in China by Chang et al. (2010).

Table 1 shows some attributes (country, date, type of LCA approach used and scale of analysis) of the above quoted studies. Studies that take into account the processes involved in the life cycle predominate against economical Input-Output based studies and also against hybrid approach studies. The most common scale of analysis is road project, although studies focusing solely on pavement materials are also frequent.

There are almost no contributions which include all life cycle stages of an entire road construction project and usually certain aspects are either omitted or underestimated. For example, the carbon balance associated with land use change including the destruction of environmental systems or their resetting (reforestation of slopes), is not contemplated by any of the existing studies except Melanta et al. (2012). Santero et al. (2011a) also recommended including the influence of elements which vary within the location and the context of the works (mix of electricity, distance of transport etc.) These same authors identified (Santero et al., 2011b) other aspects such as the carbonation of road surfaces and concrete structures (understood as the formation of $CaCO_3$ by the reaction of cement $Ca(OH)_2$ with the CO_2 from the air), a widely studied aspect, even in Spain (Galán et al., 2010). All this justifies the creation of a comprehensive study of emission sources from road construction projects, which assesses the contribution of every element in the adequate context. Moreover, this is the necessary starting point to evaluate emissions of road construction projects at a national level.

1.2. Objectives

The primary objective of this study is to achieve a first integral approach to the GHG emissions linked directly and indirectly to road construction, using current available technology and information. This analysis covers the life cycle of the projects, and intends to provide a functional and operative knowledge of the involved processes that allows to:

- Provide a life-cycle based, environmental evaluation of road construction projects in the category of climate change.
- Identify the main elements of the system; quantifying and evaluating them in context by determining the importance of their contribution to the final balance of emissions.

Regarding the methodological approximation needed to reach these objectives, the development of a management information system is required, in order to deal with the complexity of elements, contamination phases and actors included in this analysis.

1.3. Scope

The scope of the analysis corresponds primarily to the whole life cycle of the infrastructure; with the exception of road dismantling, which is not considered (Fig. 1). This limits results from the evidence that obsolete roads in Spain are mostly kept or restructured, rather than being removed. The maintenance stage was contemplated, including restoration activities and operation of the road (street lights, road cleaning etc.), but not traffic. Operation of vehicles (traffic) is a relevant stage of road transport LCA

Table 1
GHG quantification studies on road projects.

Authors	Year	Country	LCA method			Scale of analysis		
			Process	Hybrid	I/O	Pavement materials	Road projects	Construction sector
Mrueh	2000	Finland	•				•	
Stripple	2001	Sweden	•				•	
Nisbet et al.	2000	USA	•			•		
Park	2003	Korea		•			•	
Treloar	2004	Australia		•			•	
Athena	2006	Canada	•			•		
Birgisdóttir et al.	2006	Denmark	•				•	
SUSCON	2006	Greece	•				•	
Garraín and Vidal	2008	Spain			•			•
Huang et al.	2009a	UK	•				•	
Huang et al.	2009b	UK	•				•	
Chang et al.	2010	China			•			•
White et al.	2010	USA	•			•		
Weiland and Muench	2010	USA	•			•		
Milachowski et al.	2011	Germany	•				•	
Loijos	2011	USA	•				•	
Cass and Mukherjee	2011	USA		•			•	
Huang et al.	2012	UK India UAE	•				•	
Melanta et al.	2012	USA	•				•	