A Cradle-to-Gate Framework for Optimizing Material Production in Road Construction

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Abstract
In road construction, large quantities of raw materials are extracted and transported during several stages of its life cycle. Consequently, processing and preparation of raw materials for different purposes inevitably result in considerable amount of energy use and emissions of air pollutants. The Swedish Transportation Administration has an ambition to minimize environmental impacts from transport infrastructure projects by, for instance, reducing the energy use and emissions of greenhouse gases. This can be achieved by implementing specific strategies and techniques during various stages throughout the life cycle of the project. In this paper a framework is proposed to manage the energy use and greenhouse gases emissions from raw materials extraction processes in road construction projects. A prototype is developed based on the framework and demonstrated in a small case study.

Keywords: extracting raw materials; LCA; energy used; emission; product stage; road construction

1 Introduction
Reducing greenhouse gas (GHG) emissions and energy use in road construction processes is becoming an increasingly important topic for the Swedish Transport Administration (STA) [1]. Material extraction and production processes in road projects contribute considerably to greenhouse gas (GHG) emissions [2, 3]. Rock quarries or borrow pits are commonly used to extract materials for producing the aggregate used as base course, sub base or as a compound in bound layers of the road. This is often a time consuming process that involves several steps including rock extraction, hauling, loading and crushing in several steps [4]. Rock extraction is often conducted by drilling holes in specific patterns which are filled with explosives [5]. The result is fragmented rock of different dimensions from fines to coarse fragments [6]. Aggregates used in road projects usually require certain particle size intervals; hence particles that are too fine are waste [7], whereas particles too coarse can be in need of additional blasting [8]. After blasting the rock it is often crushed to more uniform particle sizes before used in roads. Rock crushing is conducted at crushing plants usually containing several different crushers, screens and conveyors in order to produce aggregates with different particle sizes [4, 8]. These processes in combination constitute cradle-to-gate when viewed from a life cycle perspective [9]. This includes all steps occurring prior to the material being transported to the construction site [10]. Life cycle assessments (LCA) tools are particularly useful for assessing environmental impacts throughout the different stages of the life cycle of products or processes [11]. However, despite the large number of previous LCA studies of road projects [12, 13, 14, 15], limited attention has been put on the energy use and GHG emissions of material production processes off-site.

In this study, we propose a framework that can support the selection of borrow pit locations, extraction methods, crushing and equipment. A