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A methodology for measuring the sustainability of car transport systems

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ABSTRACT

Measuring the sustainability of car fleets, an important task in developing transport policy, can be accomplished with an appropriate set of indicators. We applied the Process Analysis Method of sustainability assessment to generate an indicator set in a systematic and transparent way, that is consistent with a declared definition of a sustainable transport system. Our method identifies stakeholder groups, the full range of impacts across the environmental, economic and human/social domains of sustainability, and those who generate and receive those impacts. Car users are shown by the analysis to have dual roles, both as individual makers of decisions and as beneficiaries/sufferers of the impacts resulting from communal choice. Thus car users, through their experience of service quality, are a potential force for system change. Our method addresses many of the well-known flaws in measuring transport sustainability. The indicator set created is independent of national characteristics and will be useful to transport policy practitioners and sustainable mobility researchers globally.

1. Introduction

Over a period of one hundred years the motor car has come to occupy a central role in all developed economies. It has transformed our ability to travel easily and cheaply for work or leisure purposes, and it has changed the design of our urban spaces. Since 1913 the UK car fleet,[2] for example, has grown from a negligible size to nearly 30 million units, and the vehicle-kilometres driven are now approaching 460 billion annually (DfT, 2012). The benefits of increasing personal mobility nevertheless come at the cost of negative impacts, some of which are well known (accidents, pollution), though others are not widely recognised. In view of the importance of motor car transport, it is perhaps surprising that more work has not been done to monitor its overall impact despite the availability of much statistical data that would support a regular comprehensive assessment. Studies which focus solely on benefits or on problems, neither give a fair picture nor illuminate the difficult balance in preserving the freedom of near-ubiquitous mobility whilst mitigating the various disbenefits. Making that comprehensive assessment is the role of a sustainability analysis.

Measuringing the sustainability of a car fleet requires an objective framework. Such a multi-component complex system can only be characterised by carefully chosen indicators which capture the interactions within the system as a whole. A number of studies in the literature describe indicator sets for sustainable transport but the selection of indicators remains difficult, either due to a lack of clear goals (such as, what *is* a sustainable outcome for a transport system?) or to the lack of a systematic process. Many studies perform numerical analyses for indexing, ranking and benchmarking purposes, selecting from indicators found in the literature (Shiau and Jhang, 2010, Haghshenas and Vaziri, 2012; Bojkovic et al., 2010; Yigitcanlar and Dur, 2010). This approach, whilst pragmatic, does not give us confidence either that the indicator set will be complete, or represent a defined view of sustainability. Miranda and Rodrigues da Silva (2012) offer an alternative approach, using extensive stakeholder consultation to generate the indicators; whilst this ensures relevance and transparency, it is susceptible to bias in terms of the stakeholders chosen to participate. Several authors emphasise the importance of understanding what a sustainable transport system entails (Black, 2002; Marsden et al., 2010; Too and Earl, 2010; Henning et al., 2011; Jeon et al., 2013). Amongst these, Henning et al. draw on national transport policy to guide indicator selection, and Jeon et al. derive indicators based both on sustainability issues and the goals of regional transport policy. Ramani et al. (2011) conducted interviews with selected US and international transportation agencies to identify suitable elements for a framework to be used by such agencies to promote sustainable transportation. Castillo and Pitfield (2010) present a method for

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[1] Tel.: +44 1895 267 932.
[2] The car fleet in the UK is defined as vehicles belonging to the 'private and light goods' tax class.

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ranking and selecting transport indicators found in the literature, linking the indicators to top level goals and assessing them in terms of clearly stated criteria. However, they do not address the issue of how to *generate* the indicators in the first place. Several studies present seemingly complete, comprehensive indicator sets but lack a clear framework or method by which the indicators were generated, which means that it is difficult to check that all the impacts have been captured (Kennedy, 2002; Walker et al., 2006; WBCSD, 2004; Nicolas et al., 2003; Joumard and Nicolas, 2010; Fedra, 2011). Using indicators as a tool for driving change by focusing on just a few, such as CO_2 emissions, provides an incomplete picture of the issues (Roth and Kåberger, 2002; Grimes-Casey et al., 2009; Zachariadis, 2005).

Chee Tahir and Darton (2010) present a method for generating indicators to describe the sustainability of a business, called the Process Analysis Method (PAM). Whilst it was developed for the assessment of a manufacturing business, the method addresses many of the weaknesses identified above. It has a clear framework that ensures both relevance and completeness and that links the indicators to top-level goals. This method thus follows the suggestion of Dalal-Clayton and Bass (2002) that a well-designed indicator framework be systemic, hierarchical, logical and communicable.

It is clear that the indicator set should reflect the stated goals of the analysis. In our study we aimed to quantify the sustainability performance of the UK car fleet as it changed over a recent 10-year period. The indicator set is therefore intended to measure the sustainability performance of the car fleet as an entity. We aim to give a full picture of the car fleet, which is a major provider of personal mobility in the UK. We do not consider other transportation options, nor how policy could be framed to provide mobility in a different way, nor how society's need for mobility might be reduced. Our analysis of the car fleet does reveal aspects of good and poor performance which are relevant for policy formulation.

2. Applying the PAM to transport

The Process Analysis Method (PAM) consists of a series of steps that formalise the process of generating sustainability indicators for a specific system. The fundamental proposition of the methodology is that impacts are the result of processes occurring within the system (Chee Tahir and Darton, 2010). The first step involves breaking the system down into individual processes, choosing a definition of sustainability and setting a system boundary. Each process within the boundary is then evaluated in terms of its impact on the three sustainability domains: environmental, economic and social, the "triple bottom line" approach introduced by Elkington (1998). Each domain represents a store of value which can be affected by this impact, either to enhance, diminish or leave unchanged the quantity or quality of the capital. Impacts cause one or more issues, which affect one or more stakeholders, known as external impact receivers (EIR). Issues are consequences of these impacts: for example, *Primary energy resource depletion* (impact) results in *Fewer available resources to meet future needs* (issue); *Mobility is provided* (impact) results in *People are able to travel* (issue). Indicators are then selected to describe these issues. Fig. 1 illustrates how the different steps in the method relate to each other. The definition of sustainability is used to ascertain which impacts are causing sustainability issues for particular stakeholders (either positive or negative), which provides a means of checking whether a particular impact is relevant. Since the issues are checked against the definition of sustainability, the method should produce consistent results for a given definition. Furthermore, each indicator is linked to a specific issue, affecting a specific stakeholder group, and each issue is linked to a specific impact. In this way PAM produces transparent results, as indicators can be linked back to a specific system process.

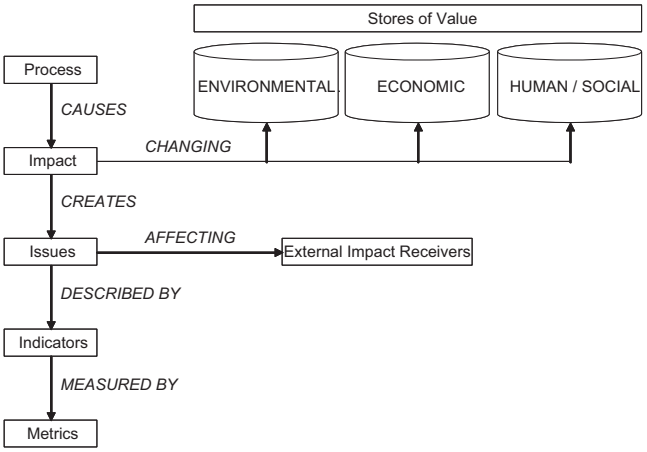

Fig. 1. The Process Analysis Method.

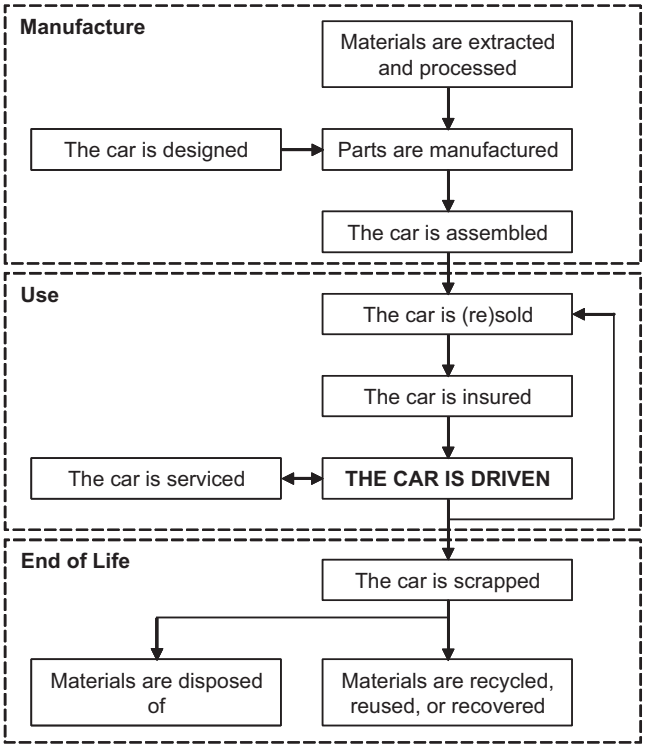

Fig. 2. Processes identified in system overview.

As a case study, we apply the PAM to the UK car fleet to generate a set of sustainability indicators for car-based transportation. Since the methodology was originally designed as a means of assessing the sustainability performance of a manufacturing business, applying it to a decentralised, service-based system such as the car fleet presented a new challenge.

2.1. Overview of the system

The first step is to construct a comprehensive overview of the system to identify the major processes and the associated input/output and stakeholder interests. The main processes, shown in Fig. 2, loosely describe the car life-cycle. Generally speaking, the impact of a process can be linked either to the resources used (inputs) or to the resulting products and waste (outputs). We considered the resources in five categories: energy, materials, land, water and workforce. Once the analysis is complete, the system