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LIFE CYCLE ASSESSMENT TO SUPPORT DECISION-MAKING IN TRANSPORTATION PLANNING: A CASE OF FRENCH BUS RAPID TRANSIT

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ABSTRACT

This article discusses the potential of Life Cycle Assessment (LCA) as a support tool for decision-making in transportation planning.

After summarizing the LCA method, it applies it to a bi-articulated Bus Rapid Transit system built around Fort de France, in Martinique, and a standard diesel bus rolling stock alternative. The system boundaries include operation, and the vehicle and infrastructure components. This case study forms the basis for discussions over the inclusion of LCA in project processes, the issues and impediments, and its incorporation into mandatory Cost-Benefit Analysis in France.

The results show the project's contributions to environmental impacts, captured via a set of 13 indicators. Bus fuel has a low impact on some indicators like solid waste or aquatic toxicities but a substantial impact (35 to 57%) on acidification, eutrophication, and climate change, demonstrating the importance of considering the entire system. With regard to infrastructure, hubs account for 25% of impact, while lighting can be substantial (up to 20%). Bi-articulated buses are a better option than standard diesel buses on most indicators under the assumptions of this study. However, modal environmental performances are highly context-sensitive. The impacts are normalized against those of the average passenger car, and compared with those of high-occupancy car modes.

LCA could be used at every stage of project or policy design, with varying precision. However, its implementation is restricted by several factors, notably understanding and adoption by decision-makers, which are affected by issues such as results interpretation, extra workload and lack of dedicated tools.

Keywords: Decision making support, Life Cycle Assessment, Transportation planning, Bus Rapid Transit, Environmental alternative, rolling stocks, normalization

INTRODUCTION

Context

Transportation is very valuable to territorial socioeconomic development. Urban populations are expected to go on rising in future decades, leading to a concentration of mobility needs in cities. The objective of transportation planning is to meet, anticipate and steer travel demand, through policy design and investment decisions. Standard selection processes use a range of established methods, common to much of the international community of transportation specialists. Cost-Benefit Analysis (CBA) in particular, also called socioeconomic analysis, offers simple indicators like Net Present Value (NPV) to assess project benefits.

Useful to society though it is, transportation is one of the biggest contributors to human environmental stresses on the planet. In France, for example, transportation accounts for 20% of greenhouse gas emissions (1). While some environmental impacts are taken into account in CBA, given the growing importance of ecological factors, their role and representativeness have to be addressed. In France, these effects encompass emissions of Greenhouse Gases (GHG) and atmospheric pollutants (e.g. NO_x, $PM_{2,5}$, VOCs and SO_2) from operation, noise and, more recently, some of the energy consumption. However, CBA omits other issues such as resource depletion and waste, or damage to habitat (2). Moreover, the scope of CBA is typically restricted to operation. On the contrary, Life Cycle Assessment (LCA) is a multicriteria assessment methodology that takes into account broad-spectrum environmental performance as well as the full physical system and life cycle of transportation modes.

Objective and background

The objective of this paper is to borrow from LCA the elements missing from the CBA method of assessing the environmental performance of transportation modes in France, in order to make the latter more holistic. A LCA case study is conducted on a French Bus Rapid Transit project, to capture the impacts of infrastructure, vehicles, and operation. Two alternative rolling stock types are presented. The key parameter of passenger travel demand is discussed.

Applied to roads, LCA is now a fairly well-defined field ((3)), despite some difficulties (4). It has sometimes been applied from a consequential perspective, which considers the impact on operations of roadway condition or maintenance (4). Numerous LCAs have also been conducted comparing bus operations ((5), (6), (7), (8), (9), (10)), excluding the nonoperational components of vehicles. Very few Life Cycle Inventories (LCI) have been carried out on bus body frames. EcoInvent provides the LCI of “standard” bus body frame production in Europe, based on an Environmental Product Declaration for the Volvo 8500 bus, as well as standard bus maintenance and end-of-life LCIs (11). Chester and Horvath (12) developed LCIs of standard US buses, based on sales statistics. There are few references for LCAs on entire bus modes ((11), (12), (13)), though one has covered a real Bus Rapid Transit (14) system with a large perimeter, excluding end-of-life of infrastructure and vehicles. The bus body frame is adapted from EcoInvent LCIs.

This article begins by summarizing the LCA framework and its key steps. It then goes on to detail the case study of a French Caribbean BRT line by comparison with an alternative vehicle, followed by an application of the assessment methodology together with an explanation of the chosen set of 13 indicators. It then discusses the main findings of the case study, before tackling the broader question of LCA as a potential aid to decision-making in transportation planning.

LIFE CYCLE ASSESSMENT FRAMEWORK

Overview

LCA is a methodology used to estimate the material and energy flows – then the potential environmental impacts – of a system throughout its life cycle: extraction, transportation and processing of raw materials, system production, use/operation, maintenance, and end-of-life processing. It is covered by ISO standards 14 040 and 14 044 ((15), (16)). LCA results show the potential environmental impacts of the system from cradle to grave, in relation to a functional unit.

ISO standard 14040 defines the different steps in performing a LCA, which will be described later. Throughout this process and at each stage, the analyst needs to check, interpret, and monitor work in progress, in order to enhance the assessment and avoid mistakes.

Goal and scope

The first step is to define the objective of the study, in order to develop the best methodology for a given question. This objective will help set the boundaries for the system assessment and to pre-select environmental indicators (impact categories, damage).

At this stage, a functional unit is defined in order to quantify the system's function so that it can be compared with another system. The function of a transportation system is to carry passengers a certain distance, so an appropriate functional unit is the passenger-kilometer.

Inventory analysis (17)

Related to the functional unit, the inventory analysis is a quantitative description of inputs and outputs (emissions in the three different natural domains: water, air, and soil) going through the system, in the form of elementary material and energy flows. For generic processes, one can draw on Life Cycle Inventories (LCI) databases, for example 1 kWh LCIs for average electricity consumption in different locations. This means that a production inventory listing all quantified processes occurring during the life cycle of a system can be enough to conduct a LCA with an adequate LCI database.

Whether a LCI database is used or not, data collection is a long and unavoidable part of preparing a LCA.

Environmental impact assessment

The purpose of this step is to link flow inventories to the potential environmental impacts associated with what happens to those flows. To do so, characterization methods have been developed, based on cutting-edge knowledge in the different disciplines.

There are 2 mandatory steps in a LCI Assessment (LCIA) process (15):

1. selection of impact categories and classification: choice of environmental impacts relevant to the specifics of the study, assignment of elementary flows to impact categories;
2. characterization: application of "characterization factors" to every flow in each category, e.g. application of an "impact score" with a common unit in order to calculate an indicator.

This stage can be followed by two optional steps: normalization and weighting.

Interpreting an impact assessment

In addition to the analyst's continuous interpretation throughout the LCA process, the final step in the LCA is to interpret potential impacts, draw conclusions, and make

recommendations, in order to meet the initial goal. Caution is needed, as there are uncertainties at every stage of the LCA process, which can lead to uncertainty over impacts.

CASE STUDY: THE BUS RAPID TRANSIT PROJECT IN FORT DE FRANCE, MARTINIQUE

Transportation planning context in Martinique

The French island of Martinique is located in the middle of the Caribbean archipelago. Its administrative capital, Fort de France, is home to almost 25% of the population and, with the nearby town of Lamentin, accounts for half the island's employment (18).

According to the Household Travel Survey (19), around 70% of passenger trips are made by car, rising to 83% in Fort de France. The occupancy rate of passenger cars is around 1.5 people per vehicle. Walking is a more common mode than public transit (number of trips). As only 10% of people use public transit to commute, congestion has become a daily problem at peak hours, particularly around Fort de France, where the concentration of activities is high (20). This situation has prompted a number of transportation schemes, most recently the 2011 regional reform of Martinique Transportation, which promotes the use of public transit and low environmental impact modes, the development of intermodality, and alternatives to single occupancy vehicles (20).

The Bus Rapid Transit project in Fort de France

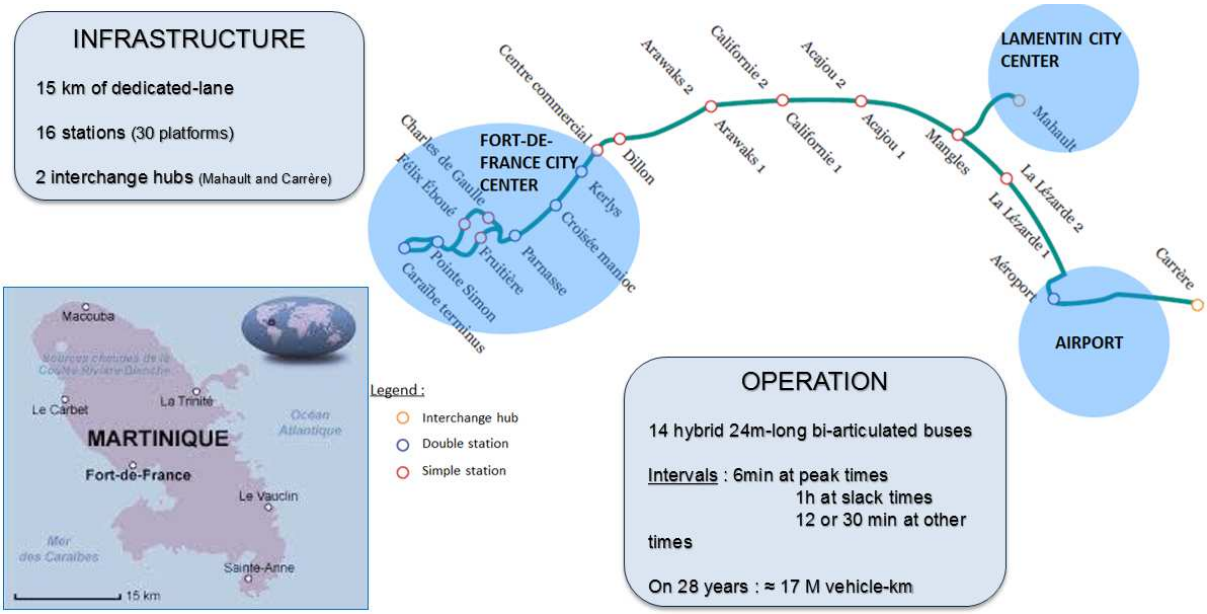

FIGURE 1 Principal information on the assessed transportation project

In response to these different planning orientations, a dedicated lane bus transit project was launched few years ago. It was designed to reduce congestion on existing roads around Fort de France, to offer an alternative to the existing unreliable and uncomfortable public transportation provider "Taxico", and to promote intermodal travel.

This forking line, running along a dedicated corridor for a distance of 15 km, will link the center of Fort-de-France to the town of Lamentin and to the airport. It includes 16 stations and 2 interchange hubs, and will be served by 14 hybrid 24 meter-long bi-articulated buses with a capacity of 140 passengers each (see main specifications in FIGURE 1). The line was set to open at the end of 2015.

Whereas this article presents figures for an ex-post LCA with respect to physical components, and an ex-ante LCA with respect to operations, it aims to compare the type of vehicle chosen for this project with another type of rolling stock, as would have been possible during the project process, for instance in concept or preliminary designs.

Bus vehicle alternative: standard diesel bus

The alternative assessed is a 28 vehicle rolling stock of 13 meter long, standard diesel bus weighing 11 tons, with a capacity of 70 passengers. They are assumed to have the same 14 year lifespan as the buses on the real line. This is low considering the potential mileage, but a high level of comfort is expected. Usually, such rolling stock is then reused in the regions, and then abroad, but these further leases of life are not considered here.

METHODOLOGY

This section provided a summary of the assessment methodology. Extensive details can be found in de Bortoli et al (21).

System boundaries

FIGURE 2 presents the line as modeled in the study. A very wide range of infrastructure has been considered, including green spaces, interchange hubs, and street furniture (including lighting). Interchange hubs include parking lots. For the vehicle fleet, electric batteries have been modeled separately.

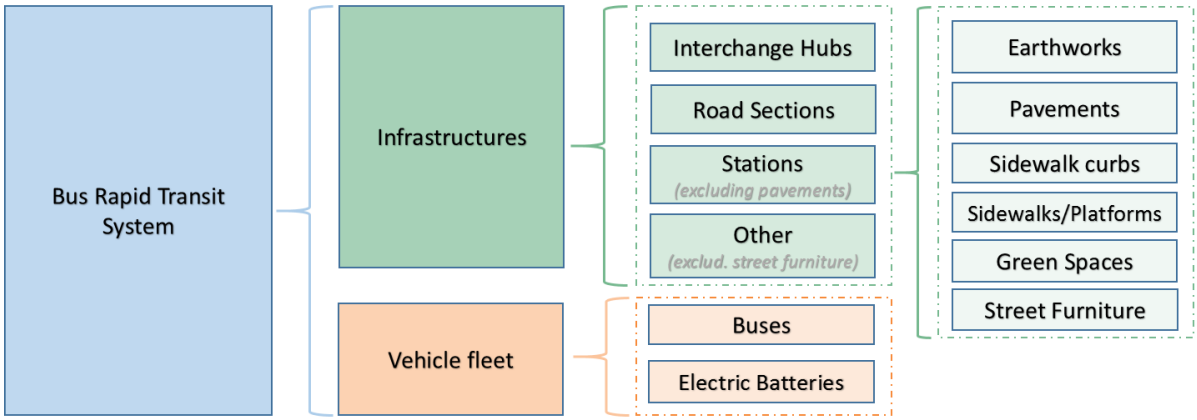

FIGURE 2 Description of the system studied: model per subsystem (column 3) and per construction batch (column 4)

The following elements were excluded in the absence of data: changing of lightbulbs, cleaning and maintenance of streetlamps; management and maintenance of green spaces and other street furniture like benches; incorporation of reclaimed asphalt pavement into new mixtures, and maintenance of the sidewalk curbs.

Database and software

We used EcoInvent 2.1, the benchmark European multi-topic database. It contains international industrial data from life cycle inventories on energy supply, resource extraction, chemical products, metals, agriculture, waste management services, and transportation services. LCIs have been reasonably adapted to the context of the project, in particular in terms of the transportation of materials and electricity supply.

We chose the OpenLCA 1.3.1 open source software, which allows users to adapt existing flows in EcoInvent. It has been particularly useful to create a specific process for the

operation of bi-articulated buses on the line, as consumption and emissions are completely different from those of the existing bus process in EcoInvent.

Data collection and assumption

Overview

Data were collected through the participation of industrial companies involved in the project, verified and/or completed by literature review and estimates by sectoral experts.

Infrastructure

This was assumed to be of entirely new construction, whereas in reality parts of the infrastructure were already built. Usage of materials and construction machinery, energy consumption and transportation are based on the Bill of Quantities and supplier information, for instance in the case of lighting or transportation. Bitumen and plasticizers are from Europe, whereas aggregates come from a quarry 3 km away.

Chosen vehicle fleet

The bus body frame is modeled using the EcoInvent process, based on a Volvo 8500 Low Entry bus vehicle, including manufacturing of metal parts, engine production, and final assembly in Europe. The Ecoinvent bus process excluding internal combustion engines has been scaled up to the mass of the VanHool bus. The calculation has been modified compared with de Bortoli et al (21) following a misinterpretation in the EcoInvent process description, which corresponds to an 11-ton bus, but gives data based on the 18.4 ton Volvo 8500. Moreover, the bus maintenance process has also been modified to match the Martinique context with regard to the electrical mix used in garages.

The transportation of buses from Europe includes the 450 km from the manufacturing plant in Koningshooikt, Belgium, to the Port of Le Havre in France, then 7000 km to the Port of Fort-de-France by sea (EcoInvent process : "*operation, transoceanic freight ship*").

Operation is modeled using the "*operation, regular bus, CH, [vkm]*" process, which represents the operation of an average Swiss regular bus, modified with manufacturer's data based on consumption measured on a SORT cycle of 56L/100 km and NOx, CO2 and CO emissions measured by the World Harmonized Stationary Cycle procedure

Batteries have been modeled on the basis of EcoInvent lithium-ion cells, and a package extrapolated from Li et al (22).

Alternative vehicle fleet

The LCIs for these standard buses have been put together directly with EcoInvent processes, excluding transportation and maintenance.

Buses run 200 km from the Volvo manufacturing plant in Säffle, Sweden, to the Port of Gothenburg, then 7900 km to the Port of Fort-de-France by sea.

The electricity mix in the maintenance process has been modified.

Selection of environmental criteria

Hundreds of indicators can be calculated using LCA. As decision-making is harder the more indicators there are, the set of indicators chosen in this study is presented briefly, with a policy approach to the categorization proposal.

Climate and energy

Energy consumption Energy resource management is a fundamental environmental issue for the 21st century. In this study, primary energy consumption is calculated in megajoule

equivalents, using the Cumulative Energy Demand method and combining all sources: wind, fossil, water, primary forest, solar, biomass, geothermal and nuclear energies.

Climate change As this is a major environmental concern, the indicator selected uses the 2001CML characterization method (Institute of Environmental Sciences - Leiden university), based on the Intergovernmental Panel on Climate Change's global warming potentials for a 100-year time horizon, in CO2 equivalents.

Stratospheric ozone depletion Stratospheric ozone works as a shield that reflects a proportion of ultraviolet radiation (UVR) away from the Earth: it reduces global warming and protects people from the harmful effects of UVR. The transportation sector is responsible for a significant proportion of depletion through air conditioning and refrigerating systems. The CML method provides an indicator for calculating stratospheric ozone depletion expressed in kilograms equivalent of Freon-11 (CFC-11).

Resources and waste

Depletion of abiotic resources Rapid societal development is leading to a shortage of abiotic resources. Aggregates are already scarce in some French regions. Reducing resource consumption is a priority for sustainable development, and is expressed with a CML indicator in kilograms equivalent of antimony.

Solid and radioactive waste In a context of increasing resource consumption, reducing waste by repurposing is important. An indicator for solid waste production is calculated using the EDIP characterization method and adding different landfill waste masses: bulk waste, slag and ashes, as well as hazardous waste. A special indicator on radioactive waste is also calculated directly with EDIP, as energy pathways are of interest in current policies and relate to transportation policy choices.

Health and ecosystems

Human toxicity Increases in toxicity in the human environment is a public health issue that requires evaluation. A CML indicator on human toxicity is selected, expressed in kilograms equivalent of 1.4-DCB on a time horizon of 100 years.

Photochemical oxidation Occurring as summer smog, photochemical oxidants are secondary air pollutants that cause damage to plants (23) and as well as a range of human health disorders (24). Since their complex chemical formulae include nitrogen oxides and reactive hydrocarbons, they are an obvious indicator for transportation assessment. A CML indicator (high NOx) in kilograms equivalent of ethylene is proposed.

Ecotoxicity Three indicators for ecosystem toxicity are proposed, based on the CML method and using the same units as for the human toxicity indicator: terrestrial, marine aquatic and freshwater aquatic ecotoxicities. This choice represents toxicity of soil and waters.

Eutrophication potential Excessive discharges of rich nutrients into a body of water can lead to excessive plant growth, which destroys ecosystems by consuming sunlight, space, and oxygen. As this can totally devastate ecosystems and have a direct effect on toxicity (even for humans), a CML indicator has been selected, for a generic location, in kilograms equivalent of phosphate.

Acidification potential This encompasses potential acidity increases in water as well as in soil caused by the deposit of atmospheric acids mainly through rainfall. The main sources of acidification are industries, vehicle traffic, and power plants. The CML indicator for generic location has been used in this case study, in kilograms equivalent of sulfur dioxide.

EVALUATION RESULTS

Potential environmental impacts of the real transportation service

Complete system

As shown in FIGURE 3, the majority of environmental impacts are due to bus life cycles:

- especially toxicity impact from nonoperational bus components, which account for between 30 and 55% of total impacts. These are primarily caused by aluminum, chromium, copper, and motor resistors;
- fuel accounts for between 35 and 57% of eutrophication (mostly due to nitrogen oxides), photochemical oxidation (50% due to atmospheric emissions of sulfur dioxide, formaldehyde, and acetaldehyde), stratospheric ozone depletion (99% due to bromotrifluoromethane atmospheric emissions), acidification (80% due to nitrogen oxides), climate change (95% from carbon dioxide emissions), abiotic resources (92% from crude oil), and energy consumption

Nevertheless, infrastructure (including green spaces) contributes substantially to environmental burden, from 20% for aquatic toxicities to 75% for radioactive waste. The impact of pavement is particularly high, but components that typically lie outside the scope of LCA, such as green spaces, street furniture, sidewalks, and platforms, are not insignificant, accounting for between 5% (stratospheric ozone depletion) and 20% (terrestrial ecotoxicity) of impacts.

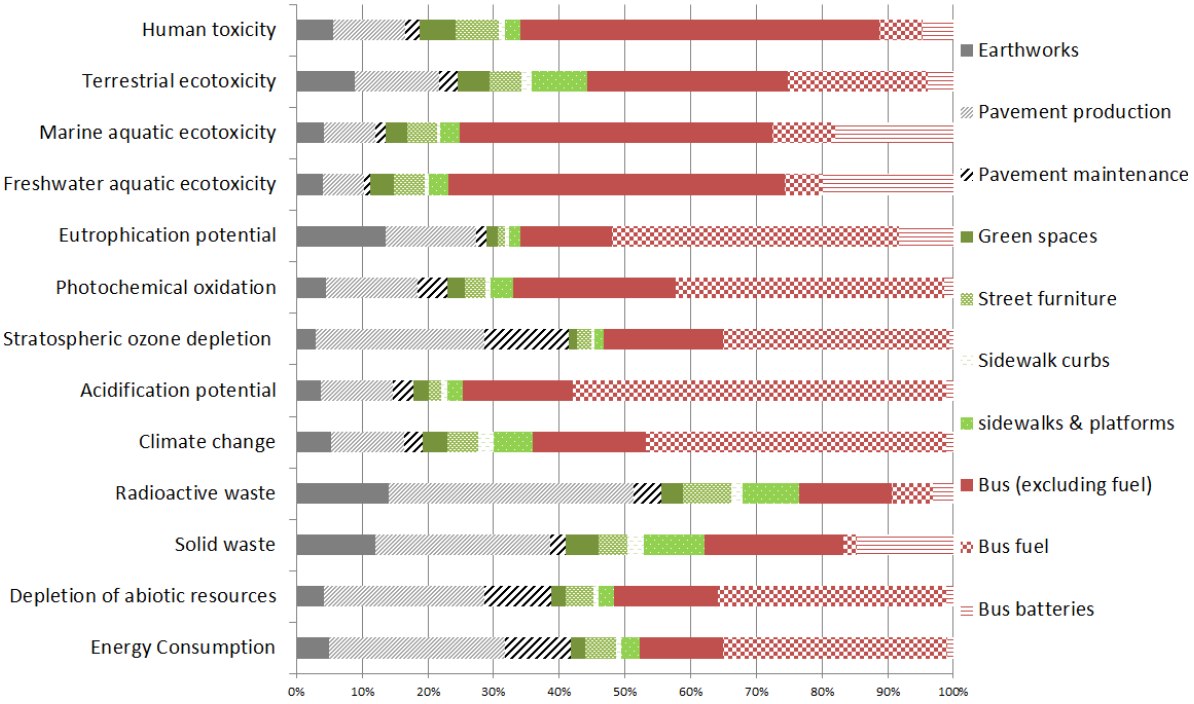

FIGURE 3 Subsystem contributions to potential environmental impacts

Infrastructure

Among infrastructural subsystems, road sections account for the major proportion of the impacts, between 60 and 75%. Nevertheless, as authors have noted (14), other subsystems are not insignificant: while stations represent 2 to 10% of the impacts, hubs are substantial, accounting for 20 to 30% of environmental burdens.

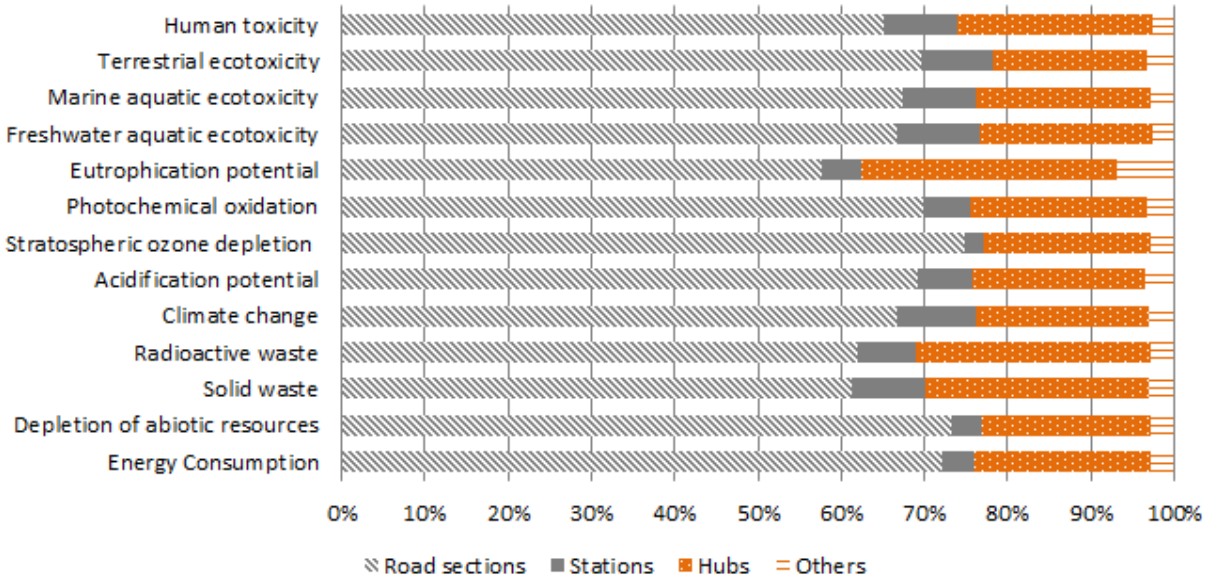

FIGURE 4 Contribution of the different infrastructural subsystems to different impact categories

Street furniture

This item includes the production of the equipment in Europe, transportation to Fort de France, and electricity consumed by streetlamps and access barriers.

In Figure 3, only 20% of lighting impacts have been allocated to the BRT line, given that it also benefits users of adjacent mixed-traffic lanes. Otherwise, with one streetlamp every 50m, a lighting system can account for up to 20% of line impacts over 28 years in energy consumption, climate change, or natural resource depletion. These impacts largely depend on the electricity mix: the use phase is predominant, accounting for 45 to 95% of impacts in terms of electricity consumption alone.

Although the street furniture comes from France, the overall impact of transportation is negligible.

Comparison of bi-articulated hybrid buses with standard diesel buses

Based on 100% occupancy over 28 years, the best vehicle option depends on the indicator (FIGURE 5): bi-articulated buses are better on every indicator except marine and freshwater ecotoxicities, and solid waste. The two options are similar on radioactive waste and human toxicity performance.

As ecotoxicities are mostly related to metals, it would be of interest to refine the data collection and LCIs on propulsion systems.

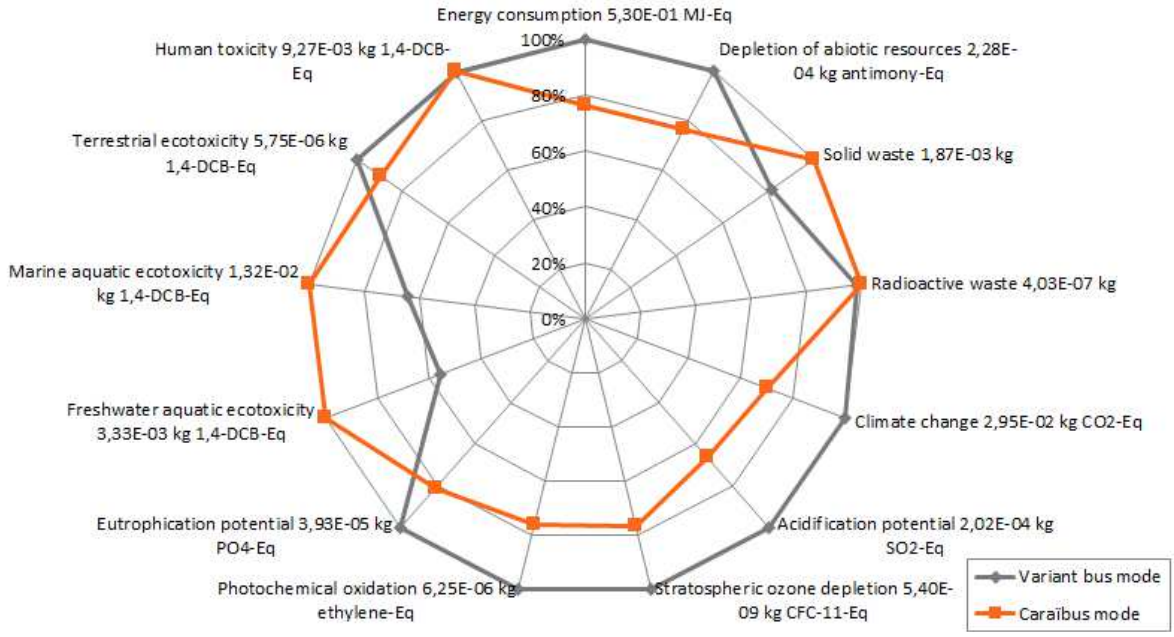

FIGURE 5 Environmental impact comparison of bi-articulated hybrid bus mode with standard diesel bus variant mode

Even though the performance ranking per indicator remains the same when comparing the impacts of rolling stock life cycle and modes, relative impact differences tend to diminish compared with vehicle-only life cycle comparison. The infrastructure contribution for these bus modes is quite high compared with shared lane modes, where infrastructure accounts for only a few percent of the impacts on energy consumption and climate change (25). Indeed, dedicated-lane roads are less intensively used – Annual Average Daily Traffics (AADT) are between 54 and 72 buses for the Caraïbus mode and between 108 and 144 for the alternative standard bus mode over 28 years – than shared roads used by an average passenger car mode, with AADTs ranging from the thousands to the ten thousands.

DISCUSSION

LCA for transportation systems: what challenges?

Assessment of complex systems: systemic approach and contextualization

Assessing complex systems is difficult: capturing the interactions and feedbacks between subsystems may be hard, demands transdisciplinary research, and is globally time consuming. The partial or complete omission of interaction and subsystem feedbacks may lead to mistakes in quantifying environmental impact, and therefore to misleading input into decision-making.

Moreover, context-specific data and modeling are particularly important in reducing the variability of results and providing environmental assessments relevant to decision-making (26). However, they are very time-consuming and a possible source of error when using generic LCI databases, characterization methods, and LCA software. Choosing the right characterization method is an important step toward contextualization, but is still tricky, particularly in very particular conditions, such as those of a Caribbean island.

A need for traffic microsimulation

In ex-ante transportation appraisal, accurate traffic simulation forecasts are essential in order to quantify the occupancy rates for a functional unit. Here, a 100% occupancy rate has been considered, e.g. full capacity. In fact, as demand rises with higher frequency, demand on bi-articulated and standard buses is unlikely to be the same. Although other factors such as

ticket price, modal image, or comfort also affect traffic demand, standard bus demand is likely to be higher since frequency on the standard bus mode is twice as high as for the bi-articulated bus mode. Defining occupancy rate scenarios is possible, even advisable, when conducting comparative LCAs for transportation modes ((30), (21)). Nevertheless, this is not sufficient in this case study, which requires traffic microsimulation.

Microsimulation would also be needed to assess the impact of doubling bus traffic on the rest of the network. Indeed, as buses have priority at traffic signals, vehicles in other lanes are affected, possibly increasing the total environmental burden. These side-effects can be captured either by enlarging the system boundaries or by conducting a consequential LCA.

Other biases

The alternative does not consider the impact of the vehicle type on infrastructural design and maintenance, whereas pavement design is based on expected heavy vehicle axle loads, using Burmister models.

Moreover, the impact of passenger load on fuel consumption has not been explored.

In addition, BRT systems entail a high level of service, meaning good passenger comfort. In Martinique, capacity is only 140 passengers, whereas a 24m-long bus can accommodate around 200 passengers. If demand is high, the BRT line would be more environmentally efficient with fewer seats.

LCA as a tool for supporting decisions on transportation planning

Background

LCA is only occasionally used as an aid to decision-making on transportation issues. In recent years, eco-comparators have been developed in France to compare road pavements based on a truncated LCA (28). They can be used in bidding processes if environmental alternatives are allowed. Nevertheless, system boundaries miss out the key environmental impacts relating to vehicle-pavement interaction (29). LCA-based tools are used by some companies in Europe to improve the mobility practices of employees (13). Transportation projects have been assessed by some authors, in particular in California ((30), (14), (27)). Some decisions, though driven by environmental objectives, are taken without performing a LCA, such as policies in favor of e-mobility. The case of Paris, which is planning to convert its entire bus rolling stock to e-buses, is emblematic. Indeed, while e-mobility is currently seen as an obvious way to reduce GHG emissions from transportation in France, a massive change in electricity consumption – and therefore supply – might change this assumption, and could be captured by a consequential LCA. LCA on alternative mass transit bus powertrain solutions has already been used to produce recommendations, for instance in the United States, relating to the electricity grid (9). Nevertheless, LCA is not sufficient for the assessment of e-mobility, notably two of its main urban benefits, i.e. reducing air and noise pollution. The latter is not yet assessed in LCA ((31), (32)).

At what stage(s) of transportation development?

At the project level LCA can be used at each stage of the project process, with different levels of precision, to aid decision-making on environmental performance. As illustrated in this article, ex ante LCA can be performed to choose between technical options. Nevertheless, it demands expertise as well as caution to model likely scenarios. Moreover, since it comes on top of a tough appraisal process – including environmental impact assessment, CBA, and other analyses – it can be perceived as additional workload. This is especially true with regard to the current lack of LCA-based decision tools in the transportation field, by contrast with the building sector which is significantly ahead in the development of sectoral tools.

For policies Before the start of projects, in the policy design phase, attention should be paid, as already said, to travel demand and occupancy rates, in order to avoid condemning or approving embryonic transportation modes without regard for the specifics of the context ((30)). In FIGURE 6, it is interesting to note that with three people in a car, a European passenger car mode is more efficient on most indicators than the two public transit modes in Martinique with a 50% occupancy rate. For a specific context, however, a systemic approach is called for, taking network effects into account, since multimodality is now standard in urban trips.

Adoption of multicriteria results by decision-makers

One of the difficulties in using LCA results to support decision-making is the multicriteria aspect: teaching skills and communication are important when presenting a number of indicators over which there is some uncertainty. Indeed, climate change and energy resources are not the only environmental issues.

When it comes to visualizing results, questions arise, e.g.: are spider charts sufficiently comprehensive? Are histograms clearer? Are there better diagrams? How many indicators can reasonably be presented simultaneously? In the case of multiple indicators, should criteria be packaged by theme or ranking? Comparisons of multiple scenarios are even trickier for LCA analysts to present.

Interpretation of figures

As there can be multiple indicators, with unfamiliar units, decision-makers can find the results hard to understand. On top of this, impact figures and their relative importance seem to be a hotspot.

One option in the LCA framework is to normalize results, i.e. to compare them with a standard, which gives the order of magnitude for the different impacts. In the transportation sector, where passenger car transportation is the dominant mode, normalized results are presented on the basis of the impacts of this mode (average occupancy 1.2), a standard that could also be spatialized to be more meaningful. Introducing this specific standard would be a positive way to encourage the use of LCA as a decision support tool, as the passenger car mode has the highest impact: alternatives would always be better.

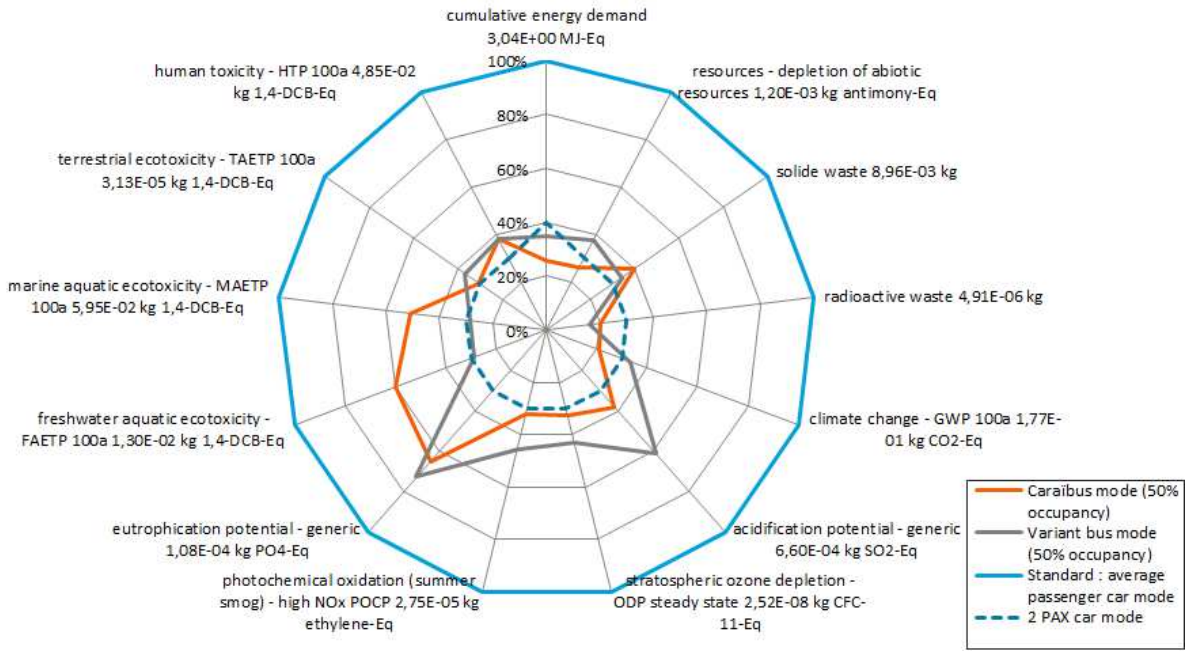

FIGURE 6 Environmental comparison of the BRT mode (50% occupancy), the standard bus alternative mode (50% occupancy), and a proposed normalization standard: the European average passenger car mode

On the other hand, developing a more challenging standard, for instance including existing environmental transportation targets for every indicator in the normalization standard, would be more ambitious. Nevertheless, for some impacts there are no official targets.

Use of LCA in the standard cost-benefit analysis

Monetization of LCA impacts

Since performing LCA requires a significant investment of time, incorporating it into France's compulsory CBA could be a helpful compromise to achieve a better representation of environmental burdens in transportation assessments. CBA uses tutelary values to monetize every externality, whereas there are a dozen valuation methods for monetizing some LCA impacts, all based on different approaches (33). Integrating LCA into CBA would require to make coherent monetization methods as well as boundaries.

Impact of weighting in decision-making

The choice of tutelary values has a significant impact on results, because it entails a weighting process. In CBA for transportation projects, travel time cost effects are usually the dominant factor in the Net Present Value of projects. Carbon dioxide emissions are already taken partially into consideration, but are mostly insignificant with current tutelary values. If tutelary values do not show the environmental burden in NPV, there is no point in including LCA indicators in CBA.

CONCLUSIONS

Even though environmental burden is a common component of decision-making processes, assessment practices rarely properly quantify it. In fact, CBA does not reflect ecological concerns. LCA could be used to clarify environmental performance, but remains a tool that is used only occasionally. In France, environmental alternatives are not always accepted in tendering processes. Some companies seem to be interested in LCA as a decision support tool, but regret the lack of public policy direction or incentives.

Moreover, the compulsory ministerial CBA process is already complex, and French practitioners are still working on the application of a new circular. In these circumstances, it is difficult to convey the importance of adding LCA criteria that are not addressed in the CBA appraisal protocol. Nevertheless, LCA can be seen as a way to achieve multi-stakeholder consensus, on account of the wide spectrum of environmental impacts it encompasses.

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