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Combining the analysis of resource demand and Ecological Footprint

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1. Introduction

In this paper, the utility of the Ecological Footprint method to assess the environmental impact of a public transport system is discussed, and a new method to supplement the Ecological Footprint to consider resource demand is shown. The method was used to determine the Ecological Footprint of the biggest provider of public transport in Vienna, namely the Wiener Linien. The study assessed the contribution of the individual modes of public transport -subway, tram and bus- as well as the impact of management and service infrastructure by defining and analysing three distinct scenarios. In this paper, we will show the contribution of the business categories –electricity and fuel; buildings; mobile and immobile assets; consumables; vehicles; buildings- to the Ecological Footprint of the Wiener Linien, and supplement that information with data on resource demand. In our study, we compared three scenarios. The first scenario set the reference for “business as usual”, the second scenario added one subway line while the third scenario significantly expanded tram-service. While the Ecological Footprint, normalised for seat-km, stays about the same, a considerable difference in resource demand, normalised for seat-km as well, was found. For this study we followed a data-heavy bottom-up approach for data acquisition, which will be presented in this paper as well.

2. The Ecological Footprint

The Ecological Footprint method, as defined by Wackernagel [3], aims at measuring the impact of goods and services on the environment based on a calculation of the land used for providing said goods and services of interest. The main advantage is the aggregation of complex information into an easy to understand unit (“area”) and number, enabling e.g. the communication of environmental issues in a widely understandable manner. The drawback is that the Ecological Footprint is a rough simplification, and that there are some specific issues with the dominance of CO₂ on the result of the Ecological Footprint. For one, the resulting Ecological Footprint is highly sensitive to variations of the sequestration-rate for CO₂ – which is an empirical entity. Additionally, the area obtained by using a sequestration-rate for the absorption of CO₂-emissions does not correspond to an area in reality. The area needed to absorb a certain amount of CO₂ varies over different regions, whereas CO₂ is spreading globally.

Another issue is the environmental impact of resource production being dwarfed by energy consumption. In context of public transport, the Ecological Footprint contribution of producing the materials for, e.g., a public bus is irrelevant compared to the energy used during the lifetime of the bus. So the major contribution to the Ecological Footprint stems from the energy used in the public transport system. Whereas in reality, significant environmental issues, which are not CO₂ related, arise with during the production of resources. Direct land use is considered in the Ecological Footprint, but the emission of hazardous substances does not have an impact on this indicator.

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Knowing which resources are being used keeps those hazardous substances in the foreground of the assessment.

When using the Ecological Footprint to assess environmental impact, information on the kind and amount of resources – together with the hazardous substances incorporated in them - used is nearly lost. Even when infrastructure is considered separately, CO₂ is the dominant factor, as the production of cement commonly leads to massive emissions [2].

3. Grasping Resource Demand

To supplement the dominant information on CO₂ emissions, the most important materials used are sorted into five categories. This way, in addition to the Ecological Footprint, the amount of concrete, steel, aluminum, copper and plastics necessary to provide the public transport systems infrastructure and mobile assets is included in the assessment, too.

In the context of public transport, this methodology enables the user to evaluate a public transport system in two ways:

1) The Ecological Footprint – dominated by fossil CO₂ emissions – mainly shows energy use for operation of the public transport system. Even though the “grey energy” that was used to produce the materials incorporated in the public transport system is allocated to the material itself, the category “fuel and electricity” is contributing >85% to the Ecological Footprint of the Wiener Linien. (Figure 1; left column) Thus, when comparing different traffic solutions using scenarios, the comparison will effectively be between the fuel and electricity consumption. This in return gives the choice of the source of electricity the single most impact on the evaluation of the scenarios, although the underlying traffic system itself stays the same.

2) Resource information on the other hand enables the comparison of different public transport solutions regarding Infrastructure and vehicle intensity. The amount of concrete stays the same, whether it is bought “green” or not. Therefore, the result of the environmental assessment is not affected by management-decisions on the energy supplier. To change the (projected) resource demand of a traffic solution, the actual scenario has to be designed differently. While there is no doubt on the importance of an energy-assessment, a discussion about material intake and substance flows has an equal importance for the environment.
In our study for the Wiener Linien we saw that for three different scenarios, the Ecological Footprint is about the same (Figure 2).

Considering resource demand for the same scenarios, the picture is quite different. (Figure 3) Here, an increased resource demand for Scenario 2 can be seen. This increased demand on resources was not visible with the Ecological Footprint. The way we set up the scenarios, Scenario 1 describes “business as usual” – only started projects are finished, with no further investments. Comparing Scenarios 2 and 3 to this reference, the relative difference between the scenarios becomes evident. (Table 1)

<table>
<thead>
<tr>
<th>Resource category</th>
<th>Relative resource demand Scenario 2</th>
<th>Relative resource demand Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>+290%</td>
<td>+106%</td>
</tr>
<tr>
<td>Steel</td>
<td>+236%</td>
<td>+49%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>+74%</td>
<td>+3%</td>
</tr>
<tr>
<td>Copper</td>
<td>+154%</td>
<td>+32%</td>
</tr>
<tr>
<td>Plastics</td>
<td>+54%</td>
<td>+10%</td>
</tr>
</tbody>
</table>

Table 1: Relative resource demand of Scenarios 2 and 3 compared to Scenario 1
While the scenarios look equivalent regarding the Ecological Footprint, the difference in resource demand is considerable.

4. Data acquisition

Analysing a public transport system requires reliable information. This can be obtained by careful analysis of the inventory data of the public transport systems provider. A previous study (Lederer et al, 2010), which dealt with the extension of the subway line U2, proved that such a methodology requires a large amount of data, even if only a small part of a public transport system is investigated.

In the current study, the scope encompasses the Wiener Linien as a whole. The amount of data provided by the Wiener Linien required us to cut some corners in order to keep the workload on a practical level. Especially the database on mobile and immobile assets and the database on consumables were too big as to account for the Ecological Footprint or resource demand of every item separately. Of 22,000 physical assets, 4,000 were excluded due to low weight or low numbers. The remaining 18,000 assets were distributed to 160 categories.

To get a realistic estimate of the material inventory of the Wiener Linien, the categories were connected with assumptions on the average mass and material composition of that category – e.g. the “average printer”. For this step, the ecoinvent database contributed first estimates [1]. This first inventory analysis then enabled us to identify where the major resource stocks are and where to investigate with priority, thus allowing a heavy reduction of the amount of goods to consider in the second step. In the study we found that for mobile and immobile assets, five categories accounted for more than 50% of the Ecological Footprint of mobile and immobile assets. In the case of consumables, 10 categories contributed over 80% of the Ecological Footprint of all consumables. This procedure was carried out for the buildings, the rolling stock and all waste as well.
A typical distribution of contributions to the Ecological Footprint of a business section is shown in Figure 4. For all business sections we found a similar resemblance of important categories. This list functioned as a priority for our in depth-research to improve data quality. Additionally, these rankings are useful for internal decision making as well.

![Ecological Footprint of consumables >500 m²/a; >1000 orders/a or >150kg](image)

*Figure 4: Generic display of the contribution of individual categories of consumables to the Ecological Footprint of all consumables. The ten largest categories contribute about 90% to the total.*

The inventory data on the biggest categories was then reviewed and updated. This methodology to reduce the amount of data to manageable levels provides a ranking of the relevant goods. For large stocks more thorough investigations are needed. This results in the data of the biggest contributors to material consumption having the least uncertainty.

5. Conclusion

Overall, supplementing the Ecological Footprint with data on resource consumption mitigates some weaknesses of the Ecological Footprint – namely simplification through aggregation and domination of fossil CO₂. The data on resource consumption enables informed decision making in ecological and economic terms. Knowing which resources are necessary for providing public transport is a piece to the puzzle of planning for the future.

The material inventory, as well as the data on resource consumption is highly valuable in aspects such as resource recovery and environmental protection as well. In the future, when trains and
busses are being replaced, information on what materials are inside these assets waiting to be recovered leads to an ecologically and economically effective management.

Furthermore, rising efforts in information gathering related to Urban Mining profit from extended resource stock information. Especially underground networks embody large amounts of recoverable steel, aluminium and copper. If underground networks need to be renewed, these material stocks may turn into valuable resources.

The interpretation of data about traffic systems is not trivial. Just as the energy requirements vary dependent on the mode of transport, not only in quantity, but also quality – electricity, heat, and fossil fuels – each mode of transport is different in resource requirements. But this view is not suitable for assessing a public transport system. A public transport system relies on the interaction of the different modes, in the case of Vienna these are subway, tram and bus. Assessing the individual modes may lead to the suggestion of providing the whole capacity of the public transport system with the mode which effects minimal resource demand or CO₂-emissions. A system designed in this way would not be effective in any way however. Only the interaction of different modes fits the needs of a modern city. Social and political acceptance, as well as financial practicability all stand besides ecological concerns.

References