It's the Footprint, Stupid! Urban Assessment by Footprinting Public Transit

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1 ABSTRACT

In terms of energy consumption, emissions and the necessary sealing of surfaces, transport systems play an important role in the city. Roughly 37 % of the final energy used (City of Vienna 2009) are required for transport. Transport is also the main source of greenhouse gas emissions, accounting for 42 % of Vienna's total greenhouse gas emissions and recording the greatest increase of such emissions (up 37 % for the period 1990-2005, see ANDERL, GANGL et al. 2009). As regards building materials, civil engineering structures house roughly one fifth of such materials in Vienna .

Hence the solutions chosen for transport are essential for the sustainable development of cities.

Public transit is said to be environmentally friendly and, a more recent development, also sustainable. An interesting approach is to think of ways and means of illustrating its eco-friendliness or sustainability. In fact, the terms "environmentally friendly" and "sustainable" are regional compacts on how much our natural environment (including animals) can tolerate in terms of ultimate sink. This also refers to its absorption capacity. There are no generally recognised standards available as yet for sustainability. Therefore the present paper proposes to use a highly aggregated quantity as a starting point for orientation in (ecological) sustainability considerations. To put it more succinctly, the paper addresses the issue of the ecological footprint (EF) which serves to measure the appropriation of "nature", i.e. of ecosystems, by humans. The EF approach juxtaposes the biologically productive land surfaces appropriated for human use with the biologically productive areas that are available. This is measured in surface units (e.g. hectares). EF accounting is intended to show the relationship between nature's exposure to human demand and the amount of biological capacity available to nature.

2 URBAN ASSESMENT

2.1 Result – the ecological footprint

To identify this footprint, Vienna's public transit provider WIENER LINIEN commissioned the Institute of Water Quality, Resource and Waste Management of the VIENNA UNIVERSITY OF TECHNOLOGY to conduct a study (BRUNNER et al. 2011). Within the given framework of Wiener Linien, it has been calculated that one trip on the metro leaves an ecological footprint (EF) that is three times smaller than the one left by a person travelling by car. Provision of infrastructure and rolling stock accounts for 43 % of the metro's EF, metro service and the upkeep of station services account for 57 %. In terms of urban planning, the surface needed for the extension of the U2 line is six times smaller than the one needed by the MPT reference system. One of the strategic aims of the City of Vienna is to achieve a 40 % share in the modal split for public transport; this would result in a reduction of the EF of one U2 ride by 10-20 % (~0.14 m2/passenger kilometre/year). (BRUNNER et al. 2011). But first the benefits of the ecological footprint versus conventional methods will be shown based on cost benefit analysis, as this is the method which is most widely used in the world, including Austria, where guidelines issued by the Austrian Association for Research on Road, Rail and Transport (FSV) mandate such an analysis for any infrastructure investment.

2.2 Economic assessment and use of resources

As a rule, economic analyses assume an unlimited amount of resources. Such assumptions can only be understood if we take a closer look at the times when these theories were developed. The very idea of finite resources was alien to representatives of both the classical and the neoclassical schools of economic thought. This is why the two theories are based exclusively on the exploitation of existing raw materials, but they ignore the changes in natural deposits and fail to reflect the risks of supply. Even an economy that is supplemented – in ecological terms – by a closed substance cycle does not take material deposits into consideration; furthermore, the raw materials included in this cycle will ultimately enter ecological processes as emissions. Therefore it only considers the input side of materials, while on the output side it focuses exclusively on the benefit components of goods, with the materials as such being ignored. An examination of the economic benefit or of the social welfare gains based on economic considerations or simply the application of the Kaldor-Hicks criterion (benefit cost quotient of the cost benefit analysis) are ultimately always summaries of current assessments, i.e. unrealised gains. Since at the end of the day the balance of savings and debts will always be zero, i.e. money has no value of its own, it will be the material goods which decide whether the individual and/or the state or humankind as a whole have become richer or poorer in the context of any given measure. Therefore the material or resource base is of key interest for political decision-making. It is surprising that so far the issue of resources has been addressed mainly in philosophical sustainability terms or under the aspect of primary energy sources. In this context one question is essential: how can one capture and account for the available "stock", i.e. the existing natural resources and the raw materials (goods) already processed?

One of the central tenets of neoclassical economic thought is that of the relative scarcity of resources. Lionel Robbins (1935) is one of the authors who established this as a cornerstone of modern economics. His approach went hand-in-hand with the fact that only the scarce resources traded at market prices were taken into account far into the 1960s. Resources having no market price were considered either not at all or only in terms of public goods. To this very day they eke out a rather wretched existence in economic theory as "external effects" and play only a minor role in decision-making processes.

Maybe many economists, politicians, but also engineers, are still under the strong influence of classical economic thought as propounded by Adam Smith, whose assumptions concerning future production methods were very optimistic. They must be understood in the social context of his time, but they were relativised as early as 1800 when Robert Thomas Malthus asked the question of whether the quality of available land would suffice for meeting people‘s food requirements. In the first half of the 19th century classical economists paid much attention to the issue of natural resources. This implies that they still had an integrated picture of economic and ecological processes. Their thought linked the limits of production with the extent of raw materials that can be taken from nature without having a negative impact on agricultural production. Today we would probably describe this approach as "adjusting to ecological cycles". But what is important is that in those days economic and environmental processes were seen to be inextricably linked.

This changed abruptly in the second half of the 19th century when economists turned their attention to the "market", to "market mechanisms" and, first and foremost, to the "benefit concept" as a basis for the "value concept".

Technical progress relies on the use of "stock goods", i.e. of "non-renewable" resources, which are mostly fossil raw materials and metals. This has two essential effects:

- There is a limit to the extraction of stock goods, i.e. one day they will no longer be available.
- Having been used in production and consumption processes, they enter ecological processes as emissions. This is particularly true of metal alloys, smoke and/or air emissions and plastics. Once emitted, they form part of an environment where normally they are not present in such large quantities. The Industrial Revolution was a period of transition from a more or less closed cycle of production and consumption to an open economic system based on the consumption of these co-called "stock resources".

This had and still has a major impact on the "problem-solving capacity" of our economic system (of neoclassical make).

- Focusing on the "market" as a place where goods are traded at certain prices has resulted in a situation where seemingly unlimited renewable resources such as air, water, etc. are given no or low prices and are therefore considered to be of no relevance to decision-making or to the market as such.
- No-price resources, though scarce, have been ignored by economic theory. This might have been appropriate for classical 18th century economic thought, but it certainly is no longer appropriate today.
- In neoclassical theory the available factors of production - no matter whether prices are attached to them or not - are assessed by individuals. This engenders major ecological and thus economic risks whenever the value of nature is dissociated from human needs. If in the long term the economy is to make appropriate adjustments to the quantity of available resources and the tolerance limits for exposure in the various spheres (especially the biosphere and atmosphere), we need a clear overview

of the flows of the resources concerned (INPUT/OUTPUT) in order to understand the cycles we want to create and control in the end. But this is not enough! A renewed transition to a sustainable economic order is fundamentally different from the one that led away from the closed production and consumption cycles of pre-industrial periods. Nowadays we need to manage and keep flowing not only the “renewables” but also and in particular the “stocks”. The latter are not renewable and their quantity remains constant. Therefore they need to be addressed in a manner similar to the one used for fertile soil, which is not available in unlimited supply either.

This signifies that sustainable economies need detailed knowledge of flows and stocks, as otherwise we are unable to identify the availability of resources in future. In terms of materials and substances we also need to know the precise amount of discharges and emissions into the ecosystem referred to above, which would be impossible without detailed knowledge of flows and stocks.

2.3 Consequences for the assessment of urban areas and functions (urban assessment)

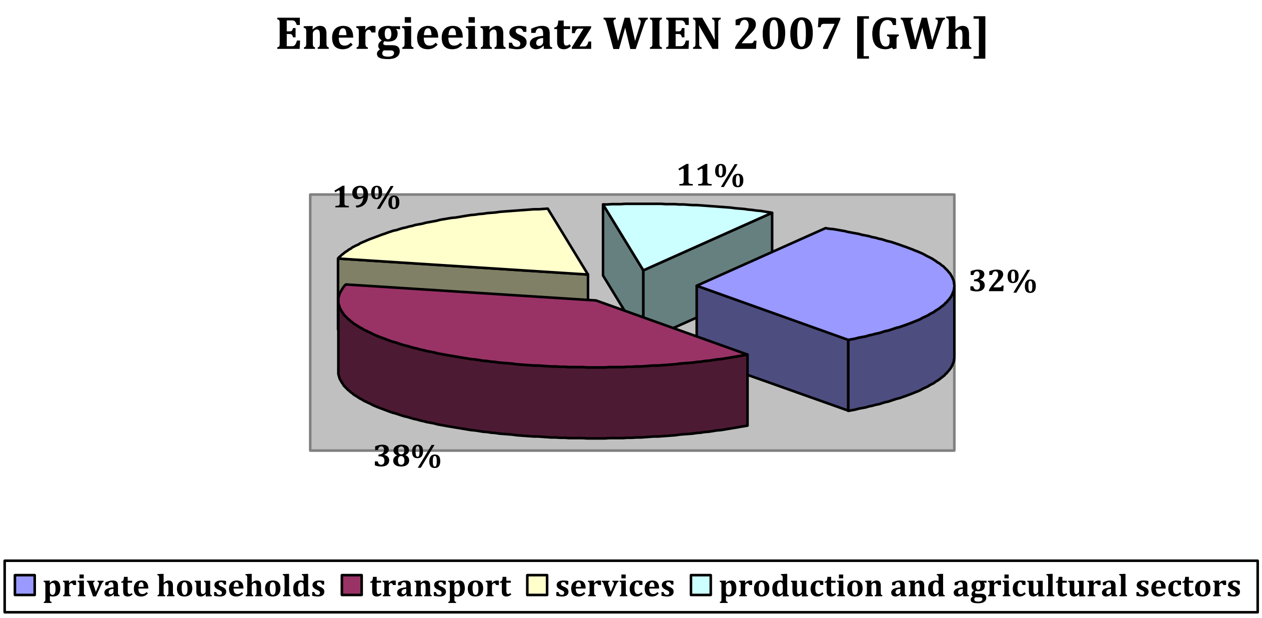
The above brief introduction into neo-classical theory and cost-benefit analysis clearly illustrates that the assessment of any given city’s policies and ecological situation cannot be based on economic considerations. Not because economics were one-sided. But because economics simply do not have the relevant information on materials, substances and energy flows. What options are available to us?

In order to assess the situation of a city we need a complete picture of its resources and energy flows.

Vienna offers a number of interesting data sources to give this picture.

Every year Vienna’s Municipal Department 20 (MA 20) issues an energy flow diagram for the city.

For instance in 2007 final energy consumption was 131,580 TJ (36,550 GWh) according to the city’s energy balance. Fossil fuels and combustibles account for 62 % of this amount. A breakdown of the sources of energy shows that oil accounts for the largest portion (two fifths or 42 %) followed by natural gas and electricity (20 % each). District heating supplies 15 % of final energy. Renewable energy sources account for 3 %, ambient heat for 0.3 % and coal for 0.2 %.



Energy use for Vienna in 2007 [GWh]

Final energy consumption by sectors is as follows:

- Private households account for 30 % or 39,735 TJ (11,852 GWh)
- Transport accounts for 40 % or 52,100 TJ (14,472 GWh)
- Public and private services account for 19 % or 25,226 TJ (7,007 GWh)
- Production and agricultural sectors account for 11 % or 14,520 TJ (4,033 GWh)

53 % of the final energy consumed in Vienna was used for power and lighting, 32 % for space heating and 14 % for process heating. Since then these figures have risen continually.

Total consumption was 46,627 GWh in 2010, with transport accounting for only 31 % of the energy used in that year (14,414 GWh). This goes hand-in-hand with a changed modal split: public transport (PT) up from 35 % to 37 % and motorised private transport (MPT) down by the same percentage.

This clearly illustrates that the targets to be attained by the transport master plan of the City of Vienna are major steps towards a sustainable transport system featuring a modal split of 25 % for MPT and 40 % for PT.

Various renewable energy sources are used to generate electricity and heat in Vienna. The identified installations for the use of renewable energy account for over 16 % of all power plants in Vienna with a total installed capacity of 210 MW of electricity generation. The most important renewable energy installations in Vienna use hydropower, wind power and – since completion of the biomass power plant in the district of Simmering – also solid biomass.

If we include the small-scale hydropower plants of Wildalpen, Hirschwang, Hinternaßwald and Gaming, total installed capacity will rise to 270 MW of power generated by renewable energy sources, i.e. more than 20 % of Vienna's portfolio of power plants.

A closer look at the energy flow diagram shows the superiority of Vienna's PT in energy terms.

Meanwhile, only some 625 GWh (traction power, diesel and liquefied petroleum gas; figures for 2010; source: Wiener Linien) are used for 37 % of trips (PT), whereas motorised private transport (including fuel tourism from the eastern region) and goods transport consume 13,246 GWh. This corresponds to a ratio of energy consumption of roughly 1:20 in favour of PT. If this ratio is reduced by fuel tourism and goods transport, it still amounts to more than 1:5.

Energy sources as contributors to substance flows only account for 3 metric tonnes per inhabitant and year compared with a total of 200t per inhabitant and year. True, this is a small quantity, but it has major system implications, in particular for transport.

An analysis of material and substance flows should start with water, as for the most part it is nothing but a throughput quantity.

Brunner shows for Vienna that roughly 147,000 litres of water per inhabitant and year enter the city (system boundary = city boundary) to enable Vienna to meet all functional requirements, 143.000 of which 143,000 litres exit the system in the form of waste water. Wiener Linien, by contrast, need a mere 96 litres per inhabitant, more than half of which is used for metro construction.

A closer look reveals that building materials and consumer goods are essential for monitoring the city's flows. These two form so-called anthropogenic stocks, i.e. man-made deposits of resources which are currently explored in great detail concerning their recyclability under "urban mining" approaches.

The size of these deposits is enormous. Already now every inhabitant of Vienna "carries a backpack" of such deposits of resources weighing roughly 350 metric tonnes. Each year it grows by another 8-12 metric tonnes, primarily due to brisk construction activity.

This clearly illustrates that urban assessment must be based on closed-system accounts of energy and resources in order to identify the relative proportions of energy consumption (PT:MPT) and be able to provide appropriate estimates of air emissions, fine dust particles and so-called fugitive emissions based on the use of energy and the increase of anthropogenic deposits. This paves the way for any kind of impact assessment supported by an objective quantity structure that can be used as a basis for such assessments.

The importance of micro-simulation, in turn, loses in importance as the macro-level can show where the actual potential resides.

Example: If we reduce the energy used in Vienna on the basis of fossil fuels (according to the energy flow diagram of 2010) by one percentage point, 130 GWh will no longer be needed. This amount corresponds to almost 20 % of the energy use of Wiener Linien. In emission terms this signifies that the current 3.3 million metric tonnes of CO2 are reduced by 33,000 t or by 24 % of what Wiener Linien emit.

A consistent analysis of the targets defined in the transport master plan reveals: motorised private transport (MPT) must lose one quarter of its market share, i.e. reduce CO2 emissions by 825,000t, while public transport (PT) emits an additional 15,000t at most due to this shift in the modal split. In actual terms, the increase for PT is less as the limiting energy and thus also the limit emissions are almost zero owing to the more favourable dynamics of vehicle movements.

I will not go into more details. The above explanation was meant to show that closed-system accounting for materials and substances, as well as linking them up with the energy flows, will greatly facilitate urban assessment and lift the veil of mysticism that currently shrouds such assessment.

Urban metabolism today primarily works like a linear throughput reactor: water and air flow from the supplying hinterland to the city and on to the disposal hinterland mostly in linear form. With current urban growth we see that the closed substance cycle can meet the rising demand for long-lived goods (e.g. building materials) only to a very limited extent. Demand of the growing city greatly exceeds the supply of secondary substances. The materials and substances accumulated in the city, i.e. the "urban stock", constitute a future source of raw materials (recycling) on the one hand. But on the other hand this stock is a long-term hazard to the quality of water, soil and air if it is not managed with due consideration of its environmental impact. Substance flows entering the environment of the local, regional (or global) hinterland can be more significant than those within the city itself.

Therefore it is essential to restrict oneself to the appropriate quantity structure and adhere to a clear distinction within the impact assessment itself where actions form part of subjective and value-linked decisions. This will not be addressed in the present paper. What is much more important is that the sum total of material and energy in the ecological footprint provides a highly aggregated indicator for assessment at the highest level, i.e. in the thin atmosphere of policy-making.

2.4 On the eagle's wings - the ecological footprint

The Canadian William Rees and the Swiss Mathis Wackernagel developed the model of the ecological footprint: it indicates in hectares how much surface area is needed by any given individual based on the consumption patterns this individual chooses to satisfy his or her needs.

If the entire productive surface of the earth were evenly distributed among all people, this would result in an average of 1.7 hectares or 17,000 square metres. This is equivalent to the size of 3.5 football fields. Currently the average ecological footprint worldwide amounts to 2.2 hectares per person. In other words: we use up more area than is available. Our planet earth is not big enough to satisfy our needs the way we are satisfying them today. We not only live off the interest payments but we are already living off the "ecological capital". The ecological footprint shows that our current consumption pattern is not sustainable.

In future our needs will have to be satisfied in a way which ensures that we make ends meet with the surface area available. For this reason we try, for example, to reduce CO2 emissions and to promote organic farming and local supply chains .

The City of Vienna could, for instance, set itself the target of reducing the ecological footprint from currently 3.9 ha/inhabitant/year to the globally compatible amount of 1.8 ha/inhabitant/year. The use of energy and material would have to drop to the same extent along the entire cycle of production and use, i.e. the life cycle. What would this signify in practice?

For this purpose let us take a closer look at the urban footprint itself.

In 2001 the Municipal Department for Environmental Protection – the MA 22 – had the ecological footprint measured for the City of Vienna. Each Viennese needs an average of 3.9 hectares of surface area. This is far beyond the target value of 1.8 hectares per capita. But in comparison with other large cities in the world Vienna fares very well.

Nevertheless the ecological footprint shows that we consume too many goods and agricultural products, too much energy and water, i.e. too much of what is termed "resources".

"Resources" include natural resources such as soil, water and air. They also include the material and substance flows triggered by human activities and the accumulated "stocks", such as building materials, consumer goods, waste, carbon dioxide, nitrogen and heavy metals.

Resource management means analysing the metabolism of the city and evaluating it based on viable criteria and indicators. This is how urban metabolism can be controlled by efficient measures. Resource management is a central component of sustainable development. Sustainable exploitation of our environment means that the consumption of renewable raw material, water and energy resources must not exceed their rate of renewal. We must not consume non-renewable resources at rates which exceed their replacement by durable renewable resources. Sustainable use of the environment also means that the emission of pollutants must not be greater than the capacity of air, water and soil to absorb and decompose such pollutants.

2.5 The ecological footprint left by transport in the City of Vienna

The ecological footprint of the City of Vienna is comparable to that of other major cities and at 3.9 hectares per inhabitant of sub-average proportions. In order to come close to the environmentally sustainable limit value of 1.7 ha per capita, other measures for reducing this footprint are necessary.

In this context the policy area of mobility plays a major role. In the whole of Austria mobility accounts for 22 % of the national footprint, with 90 % of it being caused by motorised private transport and air travel. Although 34 % (meanwhile 37 %) of all trips in Vienna are made by public transport (PT), i.e. twice as many as nationwide, the city continues to pursue the policy goal of further shifting the modal split towards soft forms of mobility (PT, bicycle, walking). These plans are a significant contribution to reducing the ecological footprint of Vienna.

The objective of a joint project of the VIENNA UNIVERSITY OF TECHNOLOGY and of WIENER LINIEN was to compare two advanced modes of transport, i.e. "metro" and "motorised private transport" (MPT), with the help of the "ecological footprint" assessment indicator. The unit of reference chosen for this purpose was the ecological footprint expressed in one passenger kilometre units for the two means of transport. The study involved the newly built extension of the Vienna metro line U2 from stations Schottentor to Seestadt and a MPT reference system with the same transport capacity. To reduce the ecological footprint of Vienna's transport sector, greenhouse gas emissions must decrease. Energy efficiency measures in public transport will not produce the kind of economic and environmental outcomes as those achievable by the reduction of greenhouse gas emissions caused by MPT. Moreover, it may prove to be expedient for Wiener Linien to slightly expand the scope of public transport by widening its range of services and lines in order to achieve a shift from MPT to PT. However, such measures might reduce the coefficient of utilisation of metro capacity, which in turn would increase the ecological footprint of Wiener Linien. Within the given framework of Wiener Linien, it has been calculated that one trip on the metro leaves an ecological footprint that is three times smaller than the one left by a person travelling by car. The annual share of the U2 extension in Vienna's ecological footprint (EF) amounts to roughly 0.05 %, while choosing to travel by private car equals a share of 0.16 %. Provision of infrastructure and rolling stock accounts for 43 % of the metro's EF, metro service and the upkeep of station services account for 57 %.

With a share of 99.9 % in the entire EF of the U2 extension, energy surfaces are the dominating factor for absorbing CO2 emissions. Footprint analysis is very sensitive to the chosen electricity mix and energy requirements (which may range from 0.16 to 0.25 m2/passenger kilometre/year). Land required by soil sealing has no appreciable influence on total EF. But in terms of urban planning it is significant. The surface needed directly for the extension of the U2 line is six times smaller than the one needed by the MPT reference system. One of the strategic aims of the City of Vienna is to achieve a 40 % share in the modal split for public transport; this would result in a reduction of the EF of one U2 ride by 10-20 % (~0.14 m2/passenger kilometre/year).

2.6 Outlook: moving towards resource management

The ecological footprint is well and widely known since it is easy to understand and offers a great variety of applications. Such features make it an ideal candidate for media communication. However, the results of individual EF studies are of only limited comparability due to greatly varying system boundaries, allocation rules, conversion factors and functional units. The move from EF to resource and environmental management requires a broader set of methods. Owing to its methodological restrictions and its function as a highly aggregated indicator the ecological footprint is not ideally suited for supporting operational management in taking decisions. Both aspects imply the need to develop an information pyramid of graded levels depending on the target group concerned. The pyramid's apex would be formed by indicators that can be easily communicated by the media to the general public, while the base would be formed by fundamental analysis to inform operational management. The material and energy balances of an enterprise would be part of this knowledge base. Alongside the quantification of direct effects they serve as a point of departure for taking stock of the indirect effects (hinterland). If only the ecological footprint of Wiener Linien were to be reduced, the future focus would have to be on: a) using those types of concrete and steel for construction which have caused fewer CO2 emissions in upstream processes; b) prioritising an electricity mix for operation which involves fewer CO2 emissions; c) reducing the energy consumption of rolling stock and stations; d) increasing occupancy rates; and e) finding the optimum mix of trams, buses and metros with due regard to the function of each of these modes of transport. Individual measures resulting from the EF concept may conflict with the targets set by transport politics and economics. Example: one method of increasing occupancy rates could be to restrict the service times of public transport. This illustrates that, in the total assessment process, an ecological footprint analysis is only one indicator which needs to be supplemented by other instruments better suited to map the objectives of passenger services offered.

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