An environmental assessment of the bicycle and other transport systems

Mirjan E. Bouwman, Lecturer, University of Groningen, Faculty of Spatial Sciences
Landleven 5, P.O. Box 800, 9700 AV Groningen, The Netherlands
M.E.Bouwman@frw.rug.nl

Summary

The bicycle is often referred to as an ideal transport system from an environmental point of view. However, it could be stated that walking is even more favourable, as the energy use and emissions associated with the production and maintenance of bicycles are absent for transport on foot. In order to make a comparison between the bicycle and other transport systems from an environmental point of view, four different characteristics of transport systems are taken into account: space use, energy use, travel time and costs. With the aid of a computer model the current best transport system in the Netherlands can be determined, based on the score of various transport systems on each of the characteristics. Four scenarios (placed along an economic growth axis and a sustainable development axis) are used in order to perform the same analysis for 2025. None of the transport systems taken into account shows favourable scores on each of the four characteristics. The analysis points out that the bicycle best supports both individual and societal interest on short distances, while the train (in combination with the bicycle) is the most interesting system for longer trips.

1 Introduction

Bicycling is generally accepted as a good transport mode, especially from an environmental point of view. As the bicycle makes no use of fossil fuels, no harmful emissions are associated with its use. However, contrary to walking, emissions can be related to the production of the bicycle itself. This implies that from an environmental perspective, walking is fundamentally better than bicycling.

Nevertheless, more arguments play a role in comparing transport systems. Qualities such as the costs associated with using a mode or the speed of a system are also relevant characteristics for an individual user. Moreover, also from a societal perspective, environmental issues are not the only relevant characteristic; spatial requirements may also be an argument.

Consequently, this paper describes four characteristics (energy use, space use, costs and travel time) of several Dutch passenger transport systems over land and compares the outcomes with the characteristics of the bicycle. Calculations have 2000 as base year, and are based on the actual Dutch transport volume, as measured with surveys (CBS 1998). A complete overview of all data used can be found in Bouwman (2000)1. In order to compare the various systems with the bicycle, three different trip length categories are distinguished, representing the full 'user range' of the bicycle. Based on these characteristics, statements can be made on the position of the bicycle compared to other systems from an environmental point of view.

2 Collectively relevant characteristics

The first collectively relevant characteristic to consider is the energy use of transport systems. The energy use associated with the production and maintenance of vehicles is commonly referred to as the indirect energy use. This indirect energy use comprises all energy flows in the various life cycle phases of a product, i.e. in the production, maintenance and discarding of a product. The energy flows related to the use phase are consequently referred to as the direct energy use. For a systematic calculation of the indirect energy use of a transport system, not only indirect energy use of the vehicle, but also the indirect energy use comprised in the infrastructure should be taken into account. Energy use can be adequately used as an indicator of the environmental impact of transport systems.

A few more assumptions are required to enable a comparison among transport systems. As not all systems have the same network density, a correction factor is introduced to be able to compare transport distances among distances. This correction factor is called route factor, and is defined as the measured distance between two points travelling over an infrastructure network divided by the distance between these points in a direct line. Due to the differences in infrastructure density, the resulting route factors differ per transport system. The route factors used are based on theoretical considerations (Timbers 1967, Beckett 1976, Blunden 1971, Vaughan 1987).

The calculated energy use figures are shown in the upper part of table 1. The first three columns present energy use figures per travelled kilometre for various trip length categories. The next three columns present the route factors. The last three columns present the resulting energy use figures per trip kilometre (i.e. per kilometre distance in a straight line between two points).

Clearly, the energy use figures of the soft modes walking and cycling are favourable over other modes. The differences in energy use between bicycling and walking are negligible. All motorised modes have energy use figures in the same magnitude, with the train having a favourable energy use on distances larger than 5 kilometre.

Table 1. Collectively relevant characteristics of Dutch transport systems by trip length, 2000

Charac-teristic	Mode	Score per kilometre			Route factors			Score per trip kilometre		
		< 2.5 km	2.5 - 5 km	5 - 10 km	< 2.5 km	2.5 - 5 km	5 - 10 km	< 2.5 km	2.5 - 5 km	5 - 10 km
Energy use (MJ/km)	ppc	1.87	1.86	1.80	1.26	1.21	1.19	2.36	2.25	2.14
	dpc	1.49	1.47	1.42	1.26	1.21	1.19	1.87	1.78	1.70
	gpc	1.51	1.49	1.44	1.26	1.21	1.19	1.90	1.81	1.72
	tra	0.96	0.98	0.98	2.26	1.74	1.43	2.16	1.70	1.39
	btm	1.18	1.18	1.15	1.47	1.47	1.47	1.74	1.73	1.70
	bic	0.04	0.04	0.04	1.21	1.2	1.19	0.05	0.05	0.05
	wal	0.03	0.03	0.03	1.21	1.2	1.19	0.04	0.04	0.04
Space use (10^{-2} m^2/km)	ppc	1.02	0.95	0.79	1.26	1.21	1.19	1.29	1.15	0.94
	dpc	1.02	0.95	0.79	1.26	1.21	1.19	1.29	1.15	0.94
	gpc	1.02	0.95	0.79	1.26	1.21	1.19	1.29	1.15	0.94
	tra	0.19	0.21	0.21	2.26	1.74	1.43	0.43	0.37	0.30
	btm	0.95	0.88	0.76	1.47	1.47	1.47	1.40	1.29	1.11
	bic	0.77	0.72	0.67	1.21	1.2	1.19	0.94	0.87	0.79
	wal	1.70	1.69	1.68	1.21	1.2	1.19	2.06	2.03	2.00

Legend: ppc = petrol passenger car, dpc = diesel passenger car, gpc = LPG passenger car, tra = train, btm = bus, tram and metro, bic = bicycle, wal = walking

The second collectively relevant characteristic is the space use of transport systems. The space use is calculated by dividing the total area occupied by a type of infrastructure with the annual number of kilometres travelled on this type of infrastructure. This results in an annual space use figure per travelled kilometre. The calculated values for 2000 in the Netherlands are presented in the lower part of table 1.

Table 1 clearly indicates a lowest space use for train travel. With over twice as much space use, the bicycle is the second most economic space user, directly followed by several motorised vehicles. Walking has the largest space use, due to the small amount of kilometres travelled on pavements.

3 Individually relevant characteristics of transport modes

The costs of using a mode are the first individually relevant characteristic of transport modes considered. The use of most transport modes is associated with costs for the individual user. A variety of cost components play a role: fixed costs like vehicle purchase costs, season tickets, and taxes, semi-variable costs such as maintenance, and variable costs, such as fuel and tickets. Only costs for individual users are taken into account; societal costs for the construction of infrastructure and external costs of transport are not included in the analysis. The resulting costs per kilometre are listed in the upper part of table 2.

Clearly, walking is the cheapest transport mode, as it requires no vehicle. Using a bicycle costs is considerably cheaper than most other modes. The petrol passenger car is by far the most expensive transport mode.

Table 2. Individually relevant characteristics of Dutch transport systems by trip length, 2000

Charac-teristic	Mode	Score per kilometre			Route factors			Score per trip kilometre		
		< 2.5 km	2.5 - 5 km	5 - 10 km	< 2.5 km	2.5 - 5 km	5 - 10 km	< 2.5 km	2.5 - 5 km	5 - 10 km
Costs (DFL/km)	ppc	0.37	0.37	0.37	1.26	1.21	1.19	0.47	0.45	0.44
	dpc	0.24	0.24	0.24	1.26	1.21	1.19	0.31	0.29	0.29
	gpc	0.25	0.25	0.25	1.26	1.21	1.19	0.32	0.30	0.30
	tra	0.16	0.16	0.16	2.26	1.74	1.43	0.37	0.28	0.23
	btm	0.19	0.19	0.19	1.47	1.47	1.47	0.28	0.28	0.28
	bic	0.10	0.10	0.10	1.21	1.2	1.19	0.12	0.12	0.12
	wal	0.00	0.00	0.00	1.21	1.2	1.19	0.00	0.00	0.00
Travel time (min/km)	ppc	3.40	2.44	1.81	1.26	1.21	1.19	4.28	2.96	2.15
	dpc	3.40	2.44	1.81	1.26	1.21	1.19	4.28	2.96	2.15
	gpc	3.40	2.44	1.81	1.26	1.21	1.19	4.28	2.96	2.15
	tra	6.08	2.90	1.83	2.26	1.74	1.43	13.75	5.04	2.62
	btm	7.19	3.86	2.59	1.47	1.47	1.47	10.57	5.68	3.80
	bic	6.05	5.36	5.16	1.21	1.2	1.19	7.32	6.43	6.14
	wal	11.11	10.35	10.12	1.21	1.2	1.19	13.45	12.42	12.04

Legend: ppc = petrol passenger car, dpc = diesel passenger car, gpc = LPG passenger car, tra = train, btm = bus, tram and metro, bic = bicycle, wal = walking

The last characteristic in this analysis concerns the travel time. Travel time is measured as the average travel time for individuals, where no distinction is made to waiting time and in-vehicle time. The calculated travel times are listed in the lower part of table 2. One should keep in mind that the travel times listed in table 2 only use one mode, while in reality the use of the train and/or bus, tram and metro will always be combined with the use of other modes.

In terms of travel times, both soft modes score considerably worse than motorised modes, although the bicycle is about twice as fast as walking. The passenger cars show the fastest travel times, especially at very short distances, due to their relatively short route factors compared to the public transport systems.

4 Aggregated results

As none of the transport systems shows favourable scores on each of the characteristics, some kind of summarisation is required to rank transport systems with one value. For doing so, each calculated characteristic is represented as the share of the largest value calculated for that characteristic on the average trip length. This is shown in figure 1 for trips with a length between 2.5 and 5 kilometres. Due to the introduction of route factors, and the fact that calculated values tend to decrease with increasing trip length, scaled values can be larger than one.

Figure 1. Scaled radar diagram of characteristics of transport systems, the Netherlands, 2000, 2.5 - 5 kilometre

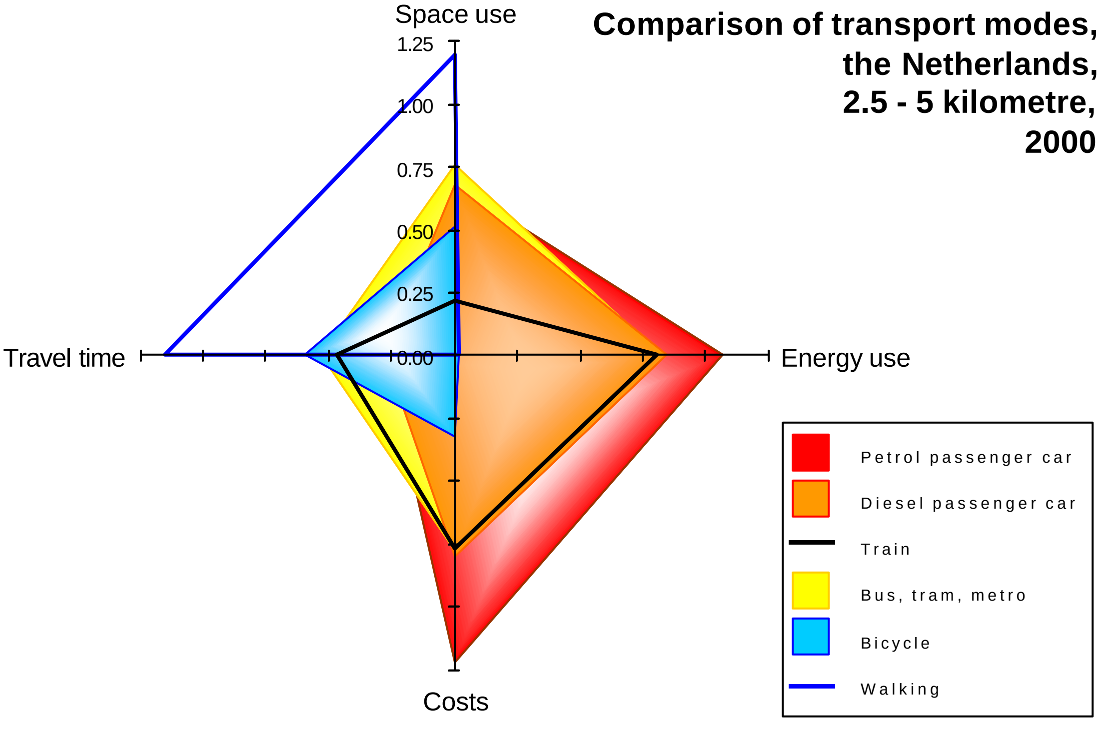
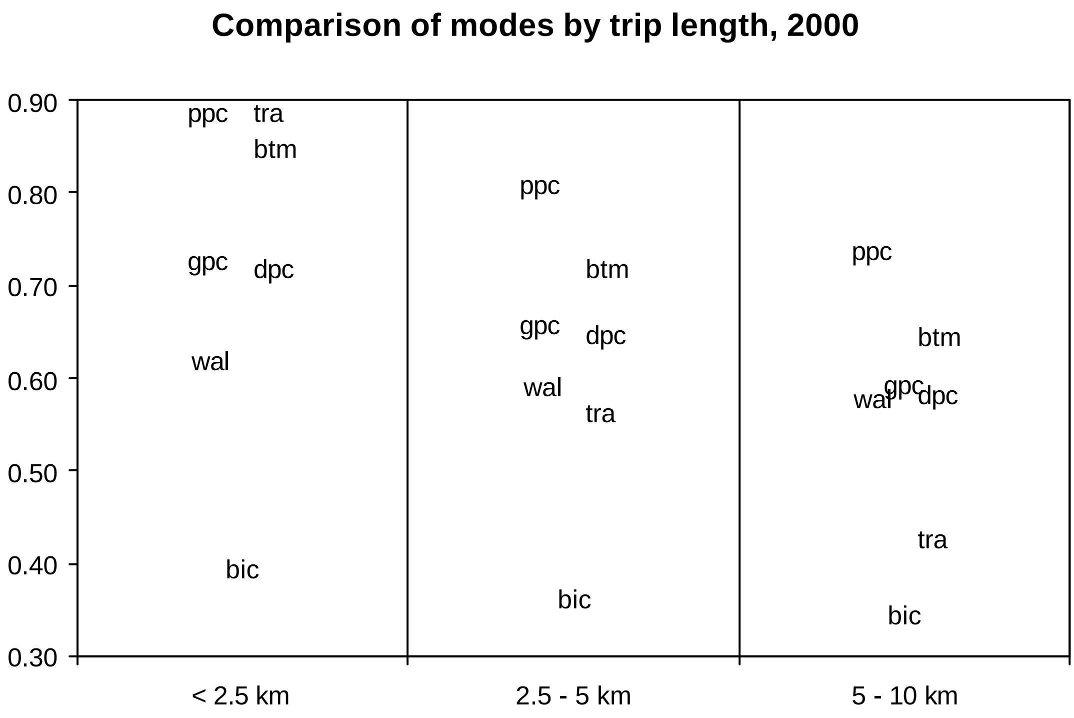


Figure 1 makes clear that the bicycle and the train in general score better than the passenger cars. Likewise, the scores on each axis can be represented with one value, by multiplying each scaled value with 0.25 and summing the values of the four characteristics. The resulting scores can be regarded a ranking order and is shown in figure 2. Each column in figure 2 represents a trip length category. The lower a mode can be found in figure 2, the better its overall performance. The horizontal position in each column has no meaning, but is used for reasons of clarity.

Figure 2 clearly shows a best position for the bicycle on all trip lengths. For trips shorter than 2.5 kilometre, the bicycle is the only best mode, followed by walking on a considerable distance. On trips between 2.5 and 5 kilometres, the bicycle is still the best mode, but the scores of walking and the train are almost equal. Trips with a length between 5 and 10 kilometre show a train score that is almost comparable to the score of the bicycle. Two of the three passenger cars show a comparable score with walking. The position of the train improves rapidly with increasing trip length, mainly due to the decrease in route factor. On even longer trips, the score of the train becomes better than the score of the bicycle.

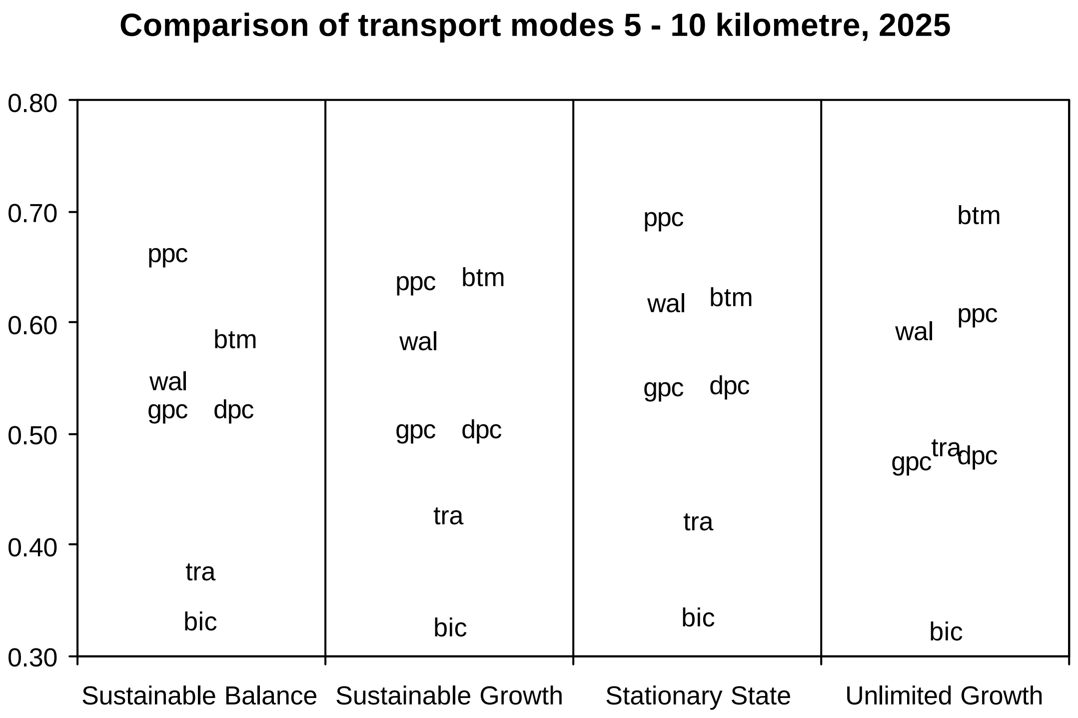
Figure 2. Ranking of transport systems by trip length, the Netherlands 2000



5 Ranking orders in future years

As most of the calculated characteristics could change with changing future circumstances, calculations are also made until the year 2025. Changing infrastructure, technological developments, congestion, price developments, etc. can all influence future ranking orders. Such developments are represented in four scenarios (see van Gerwen and Toussaint 1998), ordered along an axis with different economic growth, and one with varying acceptance of the concept of sustainable development. These scenarios are used to calculate ranking orders for future years. Although calculated characteristics vary among the scenarios and deviate from 2000 values, the resulting ranking order is remarkably stable. Figure 3 shows the ranking order for 2025 for four different scenarios for trips with a length between 5 and 10 kilometre. All scenarios show the same ranking orders for 2025 as for 2000 (see figure 2). The train approaches the score of the bicycle in the Sustainable Balance scenario.

Figure 3. Ranking of transport systems 5 - 10 km, the Netherlands 2025, various scenarios



6 Conclusions

Based on the analysis concerning two societally relevant characteristics of transport systems (energy use and space use) and two individually relevant characteristics (travel time and costs), one may conclude that none of the systems taken into account has a favourable score on each of the characteristics. This does not indicate a systematically better position for the bicycle than for other modes. However, when summarising these characteristics into one value, the bicycle shows the best overall performance, and can therefore be regarded as the best transport systems on short distances. On longer distances, the summarised score of the train is better than that of the bicycle. A dynamic analysis for future years indicates that, although characteristics of transport modes vary among scenarios, no major changes in ranking order could be expected.

Notes

1. This paper presents a selection of the results of a larger research project, described in Bouwman (2000). This project is realised at the Center for Energy and Environmental Studies IVEM of the University of Groningen

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