Influence of more elastic demand models on the cost benefit analysis of road infrastructure projects in Germany

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Short summary

Every approximately 15 years, Germany undertakes a national transport infrastructure assessment, called Bundesverkehrswegeplan (BVWP). It covers roads, railroads, and waterways, and includes extensions of existing infrastructure as well as new infrastructures (BMVI, 2016). Part of the assessment is a benefit-cost analysis (BCA). There are discussions if the assumption of the last BVWP are (still) valid. In this study we discuss different calculation approaches for the additional Vehicle Kilometers (vkm) travelled and its influence on the BCA.

Keywords: benefit cost analysis, BVWP (Bundesverkehrswegeplan), induced traffic, infrastructure.

1 Introduction

Every approximately 15 years, Germany undertakes a national transport infrastructure assessment, called Bundesverkehrswegeplan (BVWP). The last such assessment is from 2016; it is named Bundesverkehrswegeplan 2030 (BVWP 2030) after its target year. It covers roads, railroads, and waterways, and includes extensions of existing infrastructure as well as new infrastructures (BMVI, 2016).

As part of the preparation of the BVWP 2030, the projects were assessed using a defined methodology (PTV et al., 2016). The results are published in a web-based project information system (Projektinformationssystem (PRINS); see BMDV (2024b)). For each project, the following information is provided:

1. General information about the project, such a project type, length, informational maps, etc.
2. Physical impact of the project, such as changes in Vehicle Kilometerss (vkms) or emissions.
3. Intermediate and final results of a benefit-cost analysis (BCA).
4. Other non-monetized criteria, such as additional environmental impacts or changes regarding the spatial and/or urban planning

The resulting benefit-cost ratio (BCR) is used as input for the political decision; it is, however, not the onl!y criterion. Still, projects with a BCR<1 face much larger difficulties of realization.

Over the time, some questions arose regarding the actuality / validity of the assumptions. These are, e.g., the increases of the investment costs (BMDV, 2023) or significantly higher carbon dioxide (CO_2)-prices (Umweltbundesamt, 2020) compared to the values of the assessment method (PTV et al., 2016) from 2012. Another recurring argument is that the additional vkm travelled in the BVWP 2030 are underestimated for the construction of more infrastructure (Heyl, 2023).

2 Methodology

To quantify the effects of changing various assumptions for BVWP 2030, we are recalculating the BCR of the motorway projects of the BVWP. For this, we extracted all relevant data for all motorway projects from the web-based project information system (PRINS; see BMDV, 2024b): In total, 221 motorway projects with approx. 7'560 lane-km are planned to be added to the system; this compares to a current size of the system of about 61'000 lane-km (BMDV, 2024a).

Based on the extracted values, we recalculate the BCR as described more in the following. We are interested in the influence on the project plan: how sensitive do the project evaluations react to these changes? Which (types of) projects remain profitable, and which projects should be withdrawn?

In total, we have three values that we will update for the recalculation of the BCR:

1. additional *vkm*s travelled in the BVWP 2030 are underestimated for the construction of more infrastructure.
2. the costs of CO_2 are too low
3. the investment costs of the projects have significantly increased.

For the items 2. and 3. we refer to Martins-Turner et al. (2024), where we did some analysis, showing that both: Updating the CO_2 costs, and using the updated investment costs already have a significant impact on the project assessment. In the current study, we focus on the induced traffic / additional *vkm*s travelled due to construction of more infrastructure. Nevertheless, we will use for the overall results also the updated CO_2 and investment costs to show the results based on today's knowledge.

BVWP 2030 calculates additional road traffic (*vkm*), on which we will concentrate in the present study, out of the following three elements:

(A) Re-routing, which is part of the assignment.
(B) Modal shifts, which are part of the mode choice model.
(C) Trip distances, which come out of a recomputed destination choice.

Note that this additional road traffic is different from so-called induced traffic, since that only includes item (C) of the above list, and then additionally consequences of re-organized land-use; the latter is, however, not included in BVWP 2030.

The conceptual approach of BVWP is based on origin-destination (OD) relations. For example, an improved connection between two zones will normally increase the number of trips between these zones, and reduce those between other zones, thus normally leading to overall longer trips. The preferred approach to recompute OD flows is a transport model, in particular including the generalized costs of travel between the various zones into the computation, and this is indeed what BVWP 2030 does.

However, it is also useful to check the model output using more aggregate methods, e.g., elasticities. The quantity of interest for the present study, as stated earlier, are the additional *vkm* after the road construction. Indeed, there exist studies about the elasticity of *vkm* with respect to capacity expansion, measured in Lane Kilometers (*lane-km*). WSP & RAND Europe (2018) review various approaches of how additional *vkm* can be computed from this information, in general via elasticities. For example, if a 10% capacity expansion of the motorway network results in a 6% increase in *vkm* on the motorway network, then this implies an elasticity of 0.6.

The studies find elasticities around 0.6 for urban areas, and 0.3 for rural areas. The difference can be attributed to the fact that additional *lane-km* in urban areas normally are bottleneck removals, where relative short additional *lane-km* have relatively strong effect on traffic flows. In contrast, additional *lane-km* in rural areas are pure accessibility improvements, offering faster or more direct routes than previously.

However, most if not all of these studies do not consider re-routing, i.e., how much *vkm* on the lower level networks have decreased at the same time. van der Loop et al. (2016) suggest that about half of the *vkm* increase on the trunk road network is re-routing.

An alternative approach might be based on travel time savings. German BVWP takes travel time gains as a consequence of (road) infrastructure investments as a major source of benefit. While we do not question that this may be counted as economic benefit, we nevertheless find it plausible to assume that these gains will be "exchanged" into something else later, e.g., a larger dwelling further outside the city, or more frequent weekend visits to other places, or visits to locations that are farther away. Within this mechanism, it is quite plausible that the travel time gains are exchanged again into travel time. Studies show that, if anything, the daily share of time spent travelling is increasing – a consequence of more agreeable traveling in planes, trains or automobiles, lowering the generalized cost of travel. For the purpose of this paper – to estimate downstream additional CO_2 emissions based on (road) infrastructure emissions – it thus seems plausible to investigate that the original travel time saving is fully re-invested into time spent travelling. We will assume that half of that time is invested into travel by car, and that these car trips have a travel speed of 29 km/h.

3 Results and discussion

Illustration: project A20

To gain some intuition, we will first look at the project "A20–G10-NI-SH".[1] The project adds 644 lane-km, which is an increase of 1.07% over the 61,000 lane km mentioned earlier. Assuming an elasticity of 0.6 (see above) this leads to additional

$$221'000 \; mio \; vkm/a \cdot 1.07\% \cdot 0.6 = 1'418 \; mio \; vkm/a \; . \tag{1}$$

This is comparable to the result of Heyl (2023), but far above the value of 131 mio vkm taken from the BVWP 2030.

However, this is not the end of the story. If we instead use the reduced 'new infrastructure' elasticity of 0.3, and additionally assume that half of the vkm on the motorway network are due to re-routing, then we end up with

$$221'000 \; mio \; vkm/a \cdot 1.07\% \cdot 0.3 \cdot 0.5 = 354.5 \; mio \; vkm/a \; , \tag{2}$$

which is already much closer to the 131 mio vkm/a of BVWP.

As stated earlier, one could alternatively assume that travel time gains are re-invested into travel. Assuming that half of the travel time gains of 12.96 mio Vehicle Hours (vhr) are reinvested into car travel, at a speed of 29 km/h, then this results in

$$12.96 \; mio \; vhr/a \cdot 0.5 \cdot 29 km/h = 187.92 \; mio \; vkm/a \; . \tag{3}$$

Note that this now is *in addition* to the 131 mio vkm/a already in BVWP 2030, resulting in

$$(131 + 187.92) \; mio \; vkm/a = 318.92 \; mio \; vkm/a \; , \tag{4}$$

which is indeed somewhat close to Equation (2).

All motorway projects of the BVWP

Implementing the previous calculation approaches on all 213 motorway projects results in the values presented in Figure 1. These are:

1. elasticity of 0.6 for all projects (blue)
2. elasticity of 0.6 or 0.3 depending on the project type: extending existing motorways (0.6) and building of new motorways (0.3); at the same time, only half of vkm are due to re-routing (red)
3. re-investment of travel-time gains in additional car travels as explained above (orange)

Approach 1) leads to a very significant increase of additional vkm compared to the values in BVWP 2030. Approaches 2) and 3) are at least for the large projects close to each other and much closer to the current values in BVWP 2030 than approach 1).

Resulting BCR

Figure 2 shows the changes of the BCR for the different approaches. On the x-axis are the original values of the BVWP 2030. Table 1 shows for how many of the 221 projects the BCR becomes less than 1. This analysis is done analogously to the one presented in Martins-Turner et al. (2024). As expected, due to the increased vkm, the negative effects of additional CO_2 emissions increases. This results in a lower benefit, so that the BCR decreases.

Similar to the results in Martins-Turner et al. (2024), we see, that the relative change in investment cots saved, is roughly as high as the CO_2 emissions saved, when withdrawing these projects. As a tendency, the results from updating only the additional vkm is, in most cases significant lower than, the effects of either updating the investment costs *or* the CO_2-costs.

[1] `https://www.bvwp-projekte.de/strasse/A20-G10-NI-SH/A20-G10-NI-SH.html`

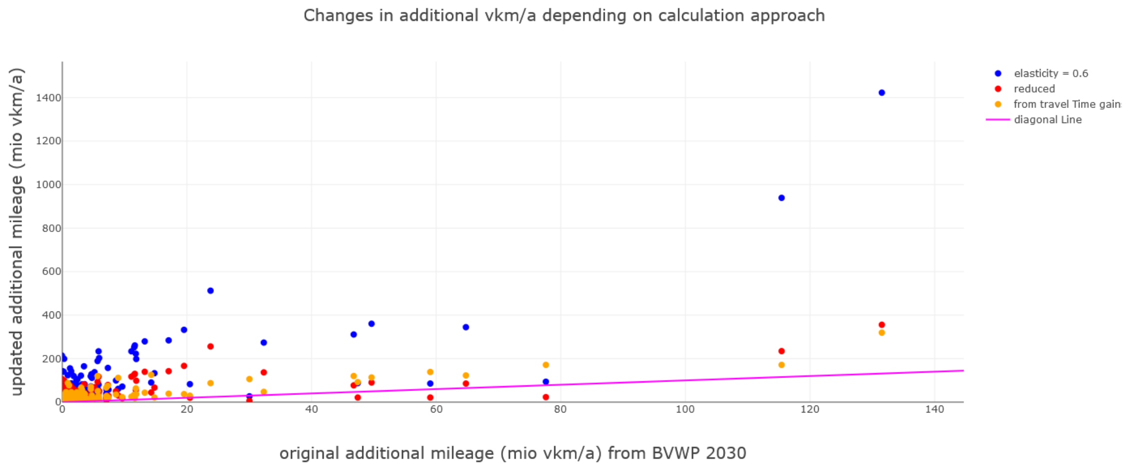

Figure 1: Additional vkm per year, depending on different calculation approaches. All 213 motorway projects of the BVWP 2030 are included. On the x-axis is the original value BVWP 2030. Blue: elasticity of 0.6; red: "reduced" elasticity of 0.3 for new project, and 0.6 for extensions of existing motorways, only half of additional vkm are due to re-routing; orange: reinvest half of travel time gains in additional car travel.

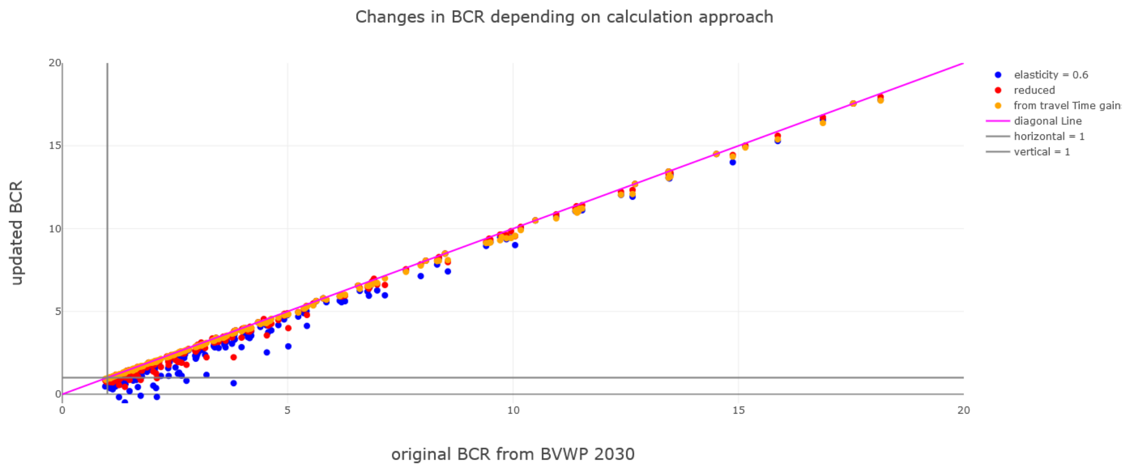

Figure 2: Changes of the BCR for all 213 motorway projects of the BVWP 2030 when including additional vkm. On the x-axis is the original value BVWP 2030. Blue: elasticity of 0.6; red: "reduced" elasticity of 0.3 for new project, and 0.6 for extensions of existing motorways, only half of additional vkm are due to re-routing; orange: reinvest half of travel time gains in addition car travel.

Increased vkm added to increased CO2-costs and increased investment costs

In this subsection, we will investigate the consequences of the previous subsection, i.e., of more vkm, when combined with other modifications of BVWP 2030.

Table 2 shows the same analysis as before, but now in combination with an increased price of 700 EUR/t CO_2, as well as increased investment costs for the projects (BMDV, 2023). As one can see already from increased CO_2 costs and revised investment costs (i.e. without the increased vkm investigated in the present paper), 56 from 221 projects 'drop out' by obtaining an BCR<1. However, even with the relatively modest vkm increases of the "reduced" approach or the approach based on travel time savings, this number increases to 103 or 86 projects, respectively. This would save approx. 0.7 mtons of CO_2 per year, and about 11 mEUR of investment costs, the latter number being significant since the amount of funding for new motorway construction is only about 1 mEUR per year (Die Autobahn, 2020).

Case	# of projects		Inv. costs (mEUR)		CO2 emissions (t/a)	
	change abs.	change rel.	change abs.	change rel.	change abs.	change rel.
elasticity = 0.6	−37	−17.4%	−3'194	−13.2%	−221'416	−14.2%
"reduced" elasticity	−20	−9.4%	−1'542	−6.4%	−103'350	−6.6%
el from travel time gains	−6	−2.8%	−640	−2.6%	−35'455	−2.3%

Table 1: Key values of motofway projects which move to BCR <1: number of projects, sum of investment costs and CO_2-Emissions. The relative share is compared to all projects included in this analysis.. Elasticity of 0.6; "reduced" elasticity of 0.3 for new project, and 0.6 for extensions of existing motorways, only half of additional vkm are due to re-routing; reinvest half of travel time gains in addition car travel.

Case	# of projects		Inv. costs (mEUR)		CO2 emissions (t/a)	
	change abs.	change rel.	change abs.	change rel.	change abs.	change rel.
base (incr. CO2-price, inv.costs)	−56	−25.3%	−5'200	−19.5%	−313'634	−19.6%
elasticity = 0.6	−126	−59.2%	−14'777	−60.9%	−1'023'508	−65.8%
"reduced" elasticity	−103	−48.4%	−11'887	−49.0%	−769'628	−49.5%
el from travel time gains	−86	−40.4%	−11'178	−46.1%	−706'493	−45.5%

Table 2: Key values of motofway projects which move to BCR <1: number of projects, sum of investment costs and CO_2-Emissions. The relative share is compared to all projects included in this analysis.. An increased price of 700 EUR/t CO_2 is assumed, as well as increased investment costs for the projects based on BMDV (2023). Elasticity of 0.6; "reduced" elasticity of 0.3 for new project, and 0.6 for extensions of existing motorways, only half of additional vkm are due to re-routing; reinvest half of travel time gains in addition car travel; BVWP with updated costs: no change of additional vkm (original values from BVWP 2030) – see (Martins-Turner et al., 2024, Table 2)

4 Conclusions

The BCA is the main driver for project evaluation in the BVWP. Based on the publicly available project data from the BVWP, we have recalculated the BCA of the highway projects. An isolated reassessment of additional road traffic has only a relatively weak impact on the BCAs. Other factors, such as an increased CO_2 price or updating the investment costs for the projects, have a greater impact. The values for the last two points in particular have increased significantly since the 2016 plan was published. However, adding the increased elasticity, even if much smaller than suggested by Heyl (2023), to increased CO_2 prices and increased construction costs increases the number of projects for which BCR <1 quite noticeably.

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