International Transport Forum

Assessing the Impacts of Vehicle Emissions and Safety Regulations

Discussion Paper

180 Roundtable

Bert van Wee
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The International Transport Forum

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Introduction

A well-functioning transport system is crucial for society. It allows people to reach their workplaces, schools, health services, other people and recreational facilities. In many countries people spend 10-15% of their income on transport (Schäfer et al., 2009), and ministries of transport generally have a substantial share in the overall budget for governmental expenditures. A large part of the budget is spent on infrastructure construction and maintenance, roads, railroads, harbours and airports being dominant categories of infrastructure. An extreme example: in 2009 in China the share of transport investments in GDP was 5.64% (Yu, 2016).*

However, public policies not only relate to infrastructure, but also include pricing (levies on vehicles and fuels, subsidies on public transport, etc.), regulations (such as standards for vehicles and fuels), and other policies. Limiting myself to environmental and safety effects of the transport system, it is important to realise that all these effects are realised via changes in five determinants:

- transport volume
- modal split
- technologies used (vehicles, fuels, etc.)
- the efficiency of using vehicles
- driving behaviour.

Table 1 gives an overview of policy instruments aiming to influence the environmental and safety effects of the transport system.

Table 1. Categories of policy instruments and effects on determinants for the environment and safety

	Transport volume	Modal split	Technology	Efficiency of using vehicles	Driving behaviour
Regulation	*	*	*		*
Prices	*	*	*	*	*
Land-use planning	*	*			*
Infrastructure	*	*			*
Marketing		*			
Information and communication	*	*		*	*

Source: Van Wee (2009).

This ITF Roundtable is on regulation. From that perspective, it is therefore important to realise that regulations are an important category of policy instruments, but as Table 1 shows, definitely not the only

* Author affiliation on the cover was provided at the time of drafting.

category. A second message from Table 1 is that regulations can be used to influence volumes, modal split, technologies, and driving behaviour, and therefore potentially can have many impacts.

Economists often prefer pricing measures, because of efficiency reasons, as often expressed in the saying "you can't beat the price mechanism". Indeed, in many cases pricing works best, at least from an economic efficiency perspective with road pricing to reduce congestion being an often discussed and studied example (Verhoef et al., 2008). However, pricing also has limitations, and in some cases, regulations are an easier way to make policy. It would be complicated to set price tags on emissions of pollutants or noise, because the effects depend on many factors. Take noise as an example. The noise "costs" of driving with a certain road vehicle over a road depend on its speed (which has an impact on noise production), the number of vehicles driving on the same road (in a non-linear way), the number of dwellings near the road and the distance between the dwellings and the road, and the characteristics of the area between the road and the dwellings) as well as the time of day. It would be complicated to set dynamic prices for the noise-related costs, and people very likely will not understand the price levels. Regulations for maximum noise production provide an easier and probably more acceptable alternative.

Which policies do policy makers and decision makers choose? Policy decisions are based on many inputs such as the political preferences and interests of the decision maker, the opinions of important actor groups, and insights into the pros and cons of the options under debate. Limiting the discussion to the latter category, ex-ante evaluations, an important question would be how to ex-ante evaluate the effects of candidate policy options. In many countries proposals for new infrastructure are ex-ante evaluated by a Societal Cost Benefit Analysis (SCBA, often abbreviated as CBA) (Hayashi and Morisugi, 2000; Bristow and Nellthorp, 2000; Grant-Muller et al., 2001). A CBA is an overview of the pros and cons of policy options. These pros and cons are expressed in monetary terms and then integrated into indicators. The most important indicators are benefits minus costs, benefit-cost ratio and return on investment (see Van Wee and Rietveld, 2013a).

The pros and cons of SCBA in general or specifically for transport infrastructure options are frequently discussed in academic literature. However, the academic debate on the pros and cons of CBA for regulations is much less mature. This paper therefore aims to reduce this gap in knowledge by providing such a discussion on the pros and cons of regulations.

The discussion is limited to regulations for standards for road vehicles aiming to improve the environmental and safety performance of these vehicles. The focus is on costs, although a brief discussion on benefits is added as well. The perspective of the paper is one of policy relevance and policy relevant research, not so much a theoretical academic one.

The methodology is one of learning by doing, based on experience gained in estimating costs and benefits of candidate policy options (regulations based or not), either in a more policy oriented or an academic discourse.

Is a high-level CBA the only input a policy maker needs if they are interested in an ex-ante assessment of candidate policy options? The answer is no, at least not in all cases. In the policy analysis community, it is common sense to assume that a sound policy would meet three criteria:

- effectiveness
- efficiency
- fairness/equity.

See for example Young and Tilley (2006). It is important to realise that a CBA primarily evaluates the efficiency of projects, often in terms of benefits minus costs, or the benefit-cost ratio. Implicitly or

explicitly it also evaluates the effectiveness. If, for example, an infrastructure project aims to reduce travel times, the CBA also makes clear if the project is effective, i.e. if it really reduces travel times. However, a policy does not only need to be effective and efficient, but also fair, and in some cases fairness is a very important criterion. Section 6 discusses this topic in more detail.

What a policy maker needs is often more than insights into effectiveness, efficiency and fairness. In an earlier paper (Van Wee, 2009) it is argued that these three criteria are important, but not sufficient. What also matters are three more criteria:

- ease of implementation
- flexibility
- long-term robustness.

The ease of implementation can depend on legal and institutional barriers, and social resistance and public support. Flexibility relates to "the ease to adapt the policy, because of the easy or difficulty to foresee changes" (Van Wee, 2009). Long-term robustness relates "to the question of whether a policy is 'no regret' under uncertain long term developments that could have a major impact on society" (Van Wee, 2009).

The message of this discussion on criteria relevant for policy makers is that the selection of policy instruments depends on many criteria, and not all criteria are well addressed in a CBA. Although a CBA is often a very useful tool to ex-ante evaluate candidate policy options, it does not mean that the outcome of the CBA is sufficient for real world policy decisions. The remaining part of this paper should be seen in the perspective of the broader set of criteria for policy decisions, even though the primary focus is on CBA and next costs and benefits.

The remaining part of this paper is organised as follows. The next section introduces regulations for safety and the environment, followed by a discussion on the relationships between regulations and direct and indirect costs, and between regulations and benefits. It then elaborates on the implications of the previous two sections. Finally, because a CBA evaluates welfare effects, but ignores equity issues, this paper looks at the importance of ethical issues for regulations, finishing with some concluding remarks.

Regulations for safety and the environment and the use of cost-benefit analysis

Regulations in transport are manifold, and include amongst others regulations for markets, infrastructure, vehicles and fuels, speeds, access of vehicles to roads and areas, drivers licence holding, helmet wearing, drinking and driving, etc. The focus of this paper is on regulations for safety and the environment, and it is limited to vehicle and speed regulations. Regulations for fuels have a lot in common with regulations for vehicles, and therefore this paper does not explicitly discuss these regulations. Some of the lessons drawn can be relevant for other regulations.

Regulations for environmental and safety standards for vehicles and regulations for fuels are common throughout the world, leading (groups of) countries being the United States, the European Union (EU28), Australia and Japan. In the EU28, the first safety and environmental regulations for road vehicles were introduced in the 1970s. Having the same standards for vehicles is more efficient than if each member state set its own standards, firstly for car manufacturers and importing companies, and secondly for public bodies. For car manufacturers it avoids vehicles needing to meet different requirements in different countries, leading to production and distribution inefficiencies. For public bodies it saves on costs related to policy making.

Speed regulations are also common across the world, and mainly aim to improve road safety, but also environmental impacts (noise, CO_2, polluting emissions) are relevant (e.g. Rietveld and Shefer, 1998).

Regulations for exhaust-related emissions are generally the combination of quantitative values (e.g. maximum emissions of a pollutant in grams per kilometre) and test conditions. In addition, noise emissions combine maximum noise production and test conditions, and regulations for crashworthiness combine impacts and test conditions. This is unavoidable, but the consequence is that manufacturers strongly focus on the test itself, ignoring other aspects, in particular the main goal of such tests. The tests aim for lower emissions of pollutants and CO_2, noise reduction and improvement in safety levels in real world conditions. The regulations are a means to reach these aims. But manufacturers generally focus much less on environmental and safety aspects of their vehicles, which are not the focus of the specific regulations and test conditions, the “dieselgate” scandal being a recent, though (probably) quite extreme example.

Suppose a country or group of countries considers (new) regulations for safety or the environment, and these regulations imply that new (or “better”) technologies are needed. Past examples include regulations leading to new cars having three-way catalytic converters, or Antilock Brake Systems (ABS). At first glance a CBA is a logical and relatively easy framework for the ex-ante evaluation of the pros and cons. The effects are (seemingly) quite clear: lower emissions and safer vehicles, and the cost of the technology. Nevertheless, this is theory – practice can be much more complicated. The next two sections explain why.

The challenges of direct cost estimates for certain technologies

This section discusses challenges related to direct cost estimates. Direct costs are defined in this paper as those related to the unit cost of certain technologies (the environment, safety). Note that speed limits do not have, or have very few, direct costs, the main costs being the (re)placement of road signs showing the maximum speeds and maybe enforcement costs. The section is organised by several propositions.

Unit costs change over time, mainly due to scale and learning effects

The unit costs of any new technology generally become lower in the first years or even decades of production, mainly due to so-called scale and learning effects. Scale effects imply that unit costs decrease if larger volumes are produced. An important reason is that larger volumes imply that the production process can be automated more. Learning effects imply that producers learn by experience, as a result of which the unit costs of production may decrease. The replacement of expensive platinum for cheaper alternatives in three-way catalytic converters provides an example.

If new regulations make manufacturers apply new technologies, it is very likely that both scale and learning effects will follow, reducing initial unit costs. The costs of such new regulations therefore heavily depend on the change of unit costs over time. Radical (technological) innovations in particular are relatively expensive in the early stages of diffusion, because they do not benefit yet from the potential of scale and learning effects (see Kemp, 1994).

Scale effects depend on regulations in other (groups of) countries

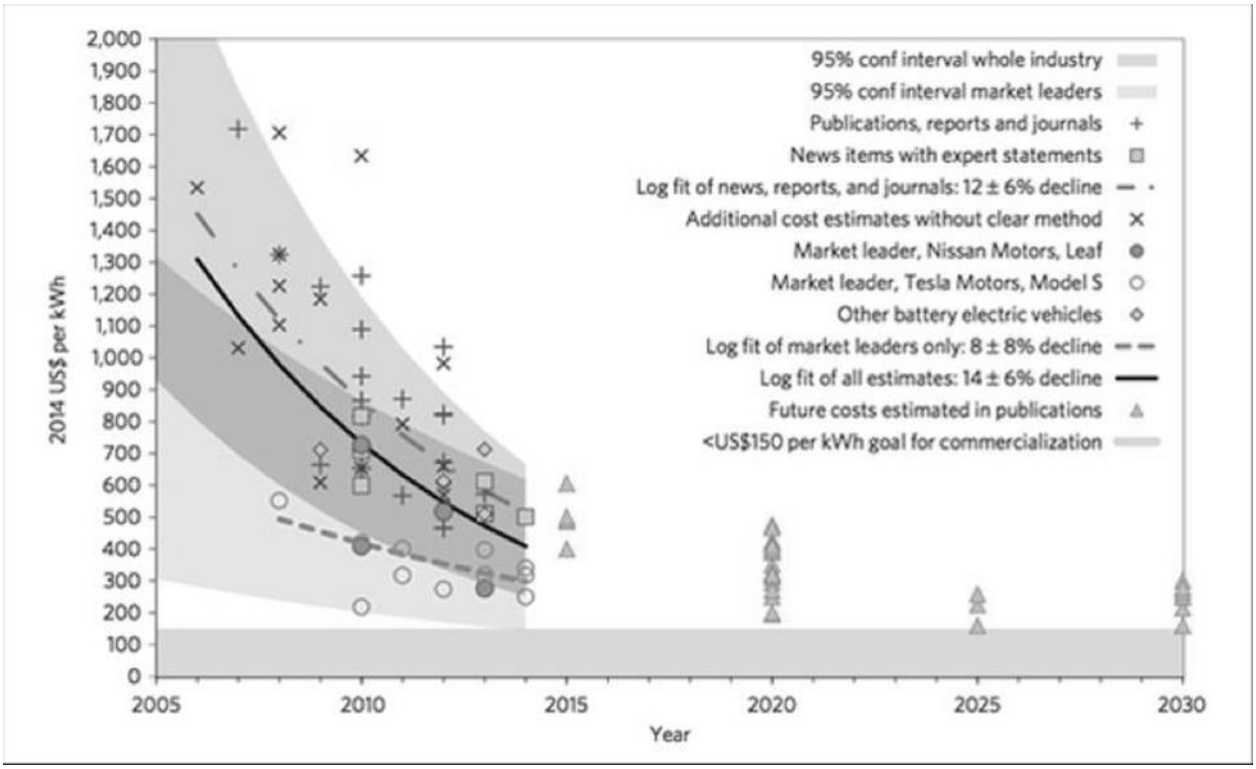
But to what extent? Scale effects depend on production volumes. A rule of thumb is that unit costs of technologies that result from regulations become lower the more a technology is produced. Therefore it matters how many (groups of) countries (or in the states in the United States) apply the same or comparable regulations (or other policies) resulting in the diffusion of the same technology. However, at the time of preparing new regulations and deciding upon these regulations, it is often unknown where and when future regulations will be implemented. This results in uncertainty with respect to future scale effects.

Not only are regulation-induced sales relevant for production volumes and next scale effects, but so are "autonomous" developments. For example, people might buy electric vehicles, regardless of regulations or other policies, resulting in higher sale volumes and lower unit prices.

There are no general values for the decrease in the effects of scale and learning effects

Estimating unit costs is further complicated by the fact that there are no generally applicable estimates for changes in unit costs. The change, for example, for computers does not have to apply to the change for airbags, ABS or electric vehicles. At the time of writing this paper an important discussion is the question of what the future costs will be per kWh of electric vehicles (EVs) (e.g. Wolfram and Lutsey, 2016). If these costs reduce strongly, EVs might become a competitive alternative for Internal Combustion Engine Vehicles. Then much tighter emission regulations might become politically acceptable. The uncertainty of future unit costs is visualised in Figure 1.

Figure 1. Unit cost of batteries for electric vehicles, 2005-2014, and estimates up to 2030



Source: Steinbuch (2016).

For EVs it is very important to understand whether this will be the only radical technology in the area of road vehicles and propulsion. An alternative could be hydrogen vehicles. The uncertainty about future developments in hydrogen is an important source of uncertainty, both for policy makers and industry, and can affect policy making and research and development (R&D) investments related to EVs.

The assumption of constant costs is almost per definition wrong

Because it is very likely that unit costs will decrease over time, the assumption of "constant unit costs" is almost by definition too conservative. It will result in an overestimation of costs. The extent to which this is the case is uncertain. Yet, due to a lack of insight into changes in unit costs, an assumption of constant costs is not unusual in policy-related ex-ante research.

We need to know the alternative, the reference case

Estimating costs of candidate regulations is further complicated by the fact that it is sometimes difficult to know what the alternative would be. The alternative is sometimes referred to as the reference case. For example the EU emissions regulations for cars introduced in 1993. These regulations resulted in petrol cars having three-way catalytic converters – this technology was the only technology available to meet the new standards. Before these were introduced, less strict standards were also considered an option, and in that case, the so-called lean burn engine would have been an option. That engine is more

fuel efficient. An estimation of the costs of the new regulations therefore should not be based on a "stand still" assumption, but on the "most likely alternative" assumption, in this case probably the lean burn engine, with higher emissions but lower energy costs and CO_2 emissions as a result. Nevertheless, it is often difficult to be able to specify the reference case.

Marginal costs should be considered, not total costs

Next, it is important to realise that not the total cost of technologies to reduce environmental pressure or to improve safety, should be considered, but the additional (in economic terms marginal) costs, compared to not changing regulations. Take the example of tighter emission standards of road vehicles. Then the additional costs of the technologies should be considered (and the extra reductions in emissions).

Indirect costs of regulation

Regulations normally have a direct effect on costs (and benefits) but can also have an indirect effect. It is generally harder to reliably estimate the indirect costs of regulations than it is to estimate the direct costs. Some examples are considered below. The message is that regulations can have many indirect effects, and that the effects can be substantial. Therefore, they should be included in ex-ante evaluations of possible future (new) regulations.

Safety regulations for road vehicles have several indirect effects

A first indirect effect is that stricter standards for the crashworthiness of cars and other road vehicles could increase a vehicle's weight, and so its energy use and CO_2 emissions. Secondly, stricter standards might lead to higher vehicle costs and, therefore, vehicles might become more expensive and more expensive vehicles can reduce vehicle sales and use. Such changes in sales and use have many indirect effects, ranging from economic costs to lower emissions and loss of welfare of potential users. The economic costs are very difficult to assess, because people will spend the money they would have spent on a car without the new regulations, on other goods and services. The related effects should be included in an ex-ante evaluation. Note that in that case the cost increase for the person or company changing behaviour by definition is below the unit cost increase. If not, the person or company would simply have accepted the higher vehicle costs. Thirdly, if safety regulations lead to larger cars, not only will these cars be safer, probably they are also more comfortable, resulting in an increase in the cars' utility. Fourth, if road vehicles get heavier due to safety regulations, the impact on other vehicles in the case of a crash becomes larger. Such regulations could benefit the safety of the people in the vehicle, but at the cost of the safety of other vehicles. This effect is not only limited to motorised vehicles, but also to pedestrians and cyclists. Fifth, if road vehicles become safer due to regulations this could be an incentive to raise speed limits, assuming the choice of speed limit is based on balancing pros and cons. However,

higher speed limits reduce the effect of these regulations, increase noise production, CO_2 and pollution emissions.

Speed limits have welfare costs

Changing speed limits hardly has any direct costs, but certainly can have indirect costs. A first cost category includes the changes in travel time. Higher speed limits could persuade people to drive faster, and this would, in normal circumstances, result in shorter travel times. Shorter travel times are generally evaluated positively (as expressed by the concept the Value of Time (VOT) or Marginal Value of Travel Time Savings (MVTTS). See, for example Wardman (2001). Nevertheless, higher speed limits could also result in more congestion, certainly on motorways, because the maximum capacity of a lane of a motorway occurs at a speed of around 90 km/h. If people drive faster, this can increase congestion levels and net travel times. If congestion occurs unexpectedly (from the perspective of the road user), this decreases the reliability/predictability of travel times. Lower levels of reliability are evaluated negatively by road users (Lam and Small, 2001). Speed limits can also affect the competitiveness of public transport and maybe even the bicycle, compared to driving. Therefore, changing speed limits can have indirect effects via mode choice.

In addition to changes in travel times and reliability being a bit speculative, the pleasure of driving faster is an incentive for some people to do so. However, there is hardly any literature available that discusses the quantitative magnitude of this effect.

A very difficult question is if and how travel timesaving resulting from speeding (or violating other legal rules such as driving and driving) should be evaluated. It is beyond the aim of this paper to summarise the debate and choose a position. However, the message is that changing speed limits can result in changing levels of speeding and there is debate about whether the gains of speeding should count at all.

Cars are positional goods, which reduces the welfare loss of a shift to smaller cars

Some regulations can have impacts on the composition of the car fleet. Above, a potential shift towards heavier cars was mentioned. In CO_2 related policy debates, a potential shift towards more fuel efficient cars is often an important topic. Such a shift could result in cars becoming smaller, having less powerful engines, and maybe being less comfortable. The potentially related welfare losses are an important indirect effect. However, how large are these loses? The mainstream position is that these losses can be derived from the willingness to pay of consumers for larger, more powerful and more comfortable cars. However, it is not certain if this method is reliable as cars to some extent are positional goods. The utility of a positional good depends on the consumption of the same good by others (Vatiero; Carlsson et al., 2007).

Verhoef and Van Wee (2000) argue that the utility of a car can indeed depend on the composition of the car fleet, and that utility losses of a shift towards more fuel-efficient cars can be lower than assumed if this positional effect is ignored. Hoen and Geurs (2011) empirically found cars to be positional goods to some extent. This potentially is a very important finding from the perspective of estimating the costs of such a shift – these costs would significantly be overestimated if no correction for positionality were made.

Regulations can have advantages in the area of transaction costs

Policy making costs money. This addresses the importance of the so-called transaction costs (in this case policy making), a fundamental concept from the area of institutional economics, introduced in 1931 by Commons (1931). Although the concept was not primarily introduced to study the costs of policy making processes, it is important to realise that policy making is not for free: it takes the time (and therefore cost) of several policy makers at several levels, of industry, interest groups and probably more actors.

The first time regulations are introduced the transaction costs are probably much higher than any follow-up regulations. Very relevant for regulations, at least for the very popular regulations for the environmental and safety performance of vehicles, and regulations for fuels, is that once introduced, it is relatively easy to introduce new standards. The legal barriers and most institutional barriers are solved, and the procedure is clear. Regulations can also be quite flexible, because the final decisions for changing standards can be made in a relatively late stage, at least in theory.

Benefits: challenges

Although the focus of this paper is on costs, this section briefly discusses some topics relevant for the benefits of regulations, again using the format of several propositions. The relevance for costs is made explicit.

Tests often poorly match real world conditions

Tests for emission and safety standards often poorly match real world conditions, the heavily debated EU tests for emissions of pollutants and CO_2 provide examples of this. Therefore, it is sometimes difficult to assess beforehand the real world effects of new regulations. Tests do not cover all real world conditions. E.g., EU tests for regulation of pollutants do not focus on speeds over 120 km/h, whereas higher speeds than 120 km/h are allowed in many EU28 countries. Especially cars with downsized small engines often have much higher emissions at higher speeds than 120 km/h because of bypassing the catalytic converter (based on communication with employees from a test institute).

If tests poorly match real world conditions, this primarily influences the benefits of regulations. If car manufacturers do not need to do as much as intended by the policy makers, this will also have an impact on their costs which will be lower.

Manipulation undermines effects

The discrepancy between tests and real world conditions is further complicated by deliberate manipulations of vehicle manufacturers, “dieselgate” providing a recent example. Such manipulations can hugely undermine the effects of regulations, as shown by Transport and the Environment (T&E) in their publications on the “dirty thirty”, a list of 30 highly polluting diesel cars (T&E, 2016). Again, such

manipulations not only have an impact on benefits but also on costs – note that avoiding additional costs of regulations is the main incentive for such manipulations.

Unit prices of emissions and safety improvements change over time, preferences for the environment and safety are not constant

In several countries, the Netherlands being an example, it is common to change the future valuations of travel time savings in CBAs because if people get richer (which is often assumed in scenarios) they value travel time savings higher. Indeed, academic literature shows that income levels have an impact on the marginal value of time (Mackie et al., 2001; Wardman, 2001).

In wealthy countries, environmental protection and safety generally get more attention than in poor countries. Tighter regulations generally are introduced in richer countries. This probably reflects a non-constant preference for safety and the environment. This effect can probably partly be explained by an income effect (Israel and Levinson, 2004) – a clearer environment is more important in higher income countries as opposed to low-income countries (who likely prioritise basic goods, such as food and housing). Another reason for this effect can be a time effect, regardless of income changes, e.g. because of the growing awareness of environmental impacts, and an increasing body of knowledge on the severity of environmental impacts.

Such preference changes have an impact on future valuations of the environment and should preferably be included in a CBA to avoid undervaluing the effects of environmental and safety regulations.

The performance of technologies may change over time

This is a very general phenomenon, which applies to many technologies. Well-known examples are solar panels (reduced yield over time) and three-way catalytic converters (see box below). Changing performance has an impact on the benefits and therefore should be included in a CBA for regulations and other policies.

Implications for cost-benefit analysis

Difficulties with respect to costs and benefits as discussed in the sections above have several implications for the ex-ante evaluations of potential new regulations, CBA and others. A first and very fundamental notion is that not evaluating the regulations using a CBA but a Multi-Criteria Analysis (MCA) does not solve the problem. Cost and effect will be relevant in all cases and uncertainty in cost and effect estimates is not irrelevant in case of an MCA.

Secondly, and related to the first point, it is important to realise that uncertainty in costs and benefits is not a reason to negatively value the methodology of CBA in general. A CBA only integrates estimations of relevant costs and benefits – the estimations of costs and estimates strictly speaking are external inputs for a CBA.

A poor estimate of costs and benefits certainly has an impact on the outcome of a CBA, and might even undermine its use. Assuming that regulatory policies are evaluated using a CBA framework, then the recommendations below might be useful.

Thirdly, this paper does not discuss the pros and cons of CBA and MCA in general or for specific cases.

1. Estimate unit costs based on literature of comparable technologies and expert judgments

It is recommended to estimate future changes in unit costs. Literature, often so called "grey literature" (not published in academic journals or peer reviewed book chapters) provides several case studies. For electric vehicles see, for example, TNO et al. (2012), for CO_2 reducing technologies for cars and vans in general see, for example, Hill (2014). Probably a categorisation of dynamic cost curves and technologies might prove helpful, as can be expert judgments. Experts, for example, could advise on which cost curve is most likely for a specific technology. Industry R&D investments can be used as an indicator for possible future changes in unit costs.

2. Include a margin for possible future unit costs and estimate the impact on CBA outcomes

It is wise to do sensitivity analyses for cost curves: What impact would another cost curve have on the outcomes of a CBA? What would be the policy implications of different cost curves (assuming that the policy choice would be based on the results of a CBA only)? What effect would postponing regulations, lowering standards, not implementing any of these have?

3. Make an estimation of the "break-even" points of unit costs: how low should they be in which year to have positive results?

For policy decisions, the precise welfare effects of candidate policies are not necessarily very important in all cases. What is sometimes more important is the notion of the balance: do costs exceed benefits or not? And, are there more cost-effective alternatives? Therefore, it is sometimes relevant to answer such questions. Researchers can show break-even points: at which point in time, or at which unit cost levels would the benefits exceed costs, or would regulations be competitive over alternative policies?

4. Make a decent analysis of the reference case, which is often not "do nothing", or "no change".

Very important for many CBAs, including those for infrastructure options, is the question of what the reference case is, as explained above. The reference case does not receive a lot of attention in many cases, but could significantly influence the outcomes of CBA (Mouter et al., 2013). Therefore, it is recommended to think through the reference case carefully in case of regulations, especially if it is unlikely that "do nothing" or "stand still" is the most likely reference case.

5. Consider indirect effects if applicable

Following the text above on indirect effects, and because these have proven to be very important for policy debates, it is highly recommendable to consider important indirect effects, if applicable. One could argue that these are certainly very important in the case of policies aimed at reducing CO_2 emissions from cars, if these policies have an impact on the composition of the car fleet. They can potentially also be important for safety regulations for vehicles, and speed limits, as discussed above.

6. Consider increases in future preferences for the environment and safety

In line with the discussion above on changing preferences, it is recommended to include those in ex-ante evaluations. In case of the environment, it is probably relevant to distinguish a stand-alone time component, from an income (economy) dependent component. Values for future years can probably be obtained from analyses of changes in past decades. It is probably a good idea to use economic developments for the estimation of future trends and maybe scenario specific assumptions on preferences for the environment and safety.

For policy makers, the next recommendations apply, but these are not directly related to CBAs. Nevertheless, they can have an impact on CBA outcomes:

7. Improve tests, so that these match real world conditions as well as possible, and cover all regular driving conditions.

As argued above, a lack of an adequate test undermines the effects, and costs, of regulations. Even if no ex-ante evaluations would be carried out, this is relevant. But, also for the ex-ante evaluation of effects, tests that replicate real world conditions are very important because real world effects can strongly depend on having an adequate test available.

8. Reduce options for manipulations as much as possible

The arguments provided for the previous proposition also apply to this proposition.

9. Environmental regulations: increase the focus on inspections and maintenance

This proposition does not follow from the previous sections, but can be relevant for the wider debate on environmental regulations. Emissions reducing technologies generally become less effective the older (age, kilometres) these get (Sergeant et al., 2007). Especially if standards for new vehicles are very tight, the impact of ageing and defects of technologies becomes more important, increasing the importance of inspections and maintenance.

Box 1. Case study: The introduction of the catalytic converter for petrol cars

An example of a CBA carried out in the past that in several aspects can be seen as a good example is the CBA of the EU regulations leading to the introduction of the three-way catalytic converter for petrol cars in 1993, and earlier versions of converters following regulations introduced in 1988. The CBA was carried out for the Netherlands (CPB, 2000) and is part of a broader study into the efficiency of environmental policies. Interesting aspects of the CBA are:

- It included decreasing unit costs for the three-way catalytic. These were estimated to be NLG 1 700 in 1990 (approximately EUR 765) to NLG 700 in 1997 (approximately EUR 315).
- It recognises that in theory pricing policies (levies) could be more efficient than regulations, but in this specific case pricing policies are difficult to implement, because of the fact that there is not a clear basis for regulations, and because inspections are relatively easy in case of regulations.
- It did recognise that converters' performance decline due to aging.
- It did include the additional costs of unleaded petrol compared to leaded petrol.

- It makes explicit at which (shadow) price of NO_x the break-even points (equal benefits and costs) occurs. This is a specific case of a sensitivity analysis. Results reveal that assuming the default price the three-way catalytic converter is a cost-effective technology, but the previous versions are not.
- The reference case is described clearly.

Weak points of the study include

- It only includes monetised benefits of lower NO_x-emissions.
- It did not monetise the benefits of lower lead emissions (but it does present quantitative impacts on lead emission, and it does discuss these effects).
- It did not include additional fuel use compared to a potential reference case assuming lean burn engines (see above).
- It did not included changes in unit prices for NO_x.

Ethical issues for regulations

As explained above, sound policies meet at least three criteria: effectiveness, efficiency and fairness/equity (Young and Tilley, 2006). A CBA does not include fairness considerations, and it is not meant to do this – it evaluates welfare effects. However, fairness implications are sometimes very relevant for society and policy making. The history of road pricing provides an example. Economists have argued for almost one century that in case of a shortage of road capacity introducing road pricing increases welfare (Pigou, 1920). However, the number of real world implementations is quite limited, partly due to assumed fairness considerations (Vonk Noordegraaf et al., 2014; Verhoef et al., 2008). The often heard assumption is that rich people benefit whereas the poor are affected.

Because fairness is not included in a CBA, it is not a sufficient basis for policy decisions if fairness issues are at stake (Van Wee, 2011; Martens, 2016). What additional relevant fairness considerations could be included? Below are some examples:

Distribution effects

Generally, the pros and cons of policies are not distributed equally over all groups of the population. In general, the vehicle user and owner pay for the additional costs of regulations. In the case of safety improvements, the user/owner generally benefits. But in some cases it is also others that benefit. This is the case for regulations to better protect pedestrians and cyclists in the case of a motor vehicle accident. Similarly, environmental regulations benefit people living near roads facing lower concentrations or noise levels.

Especially in the area of environmental economics several studies and debates exist on the importance of distribution effects (Johansson-Stenman and Konow, 2010), illustrating the importance of distributions in that area. Yet, in CBA, distribution effects are at best reported to some extent, but often ignored. In turn, these do not have an impact on the outcomes. Again, this is not necessarily criticism on the CBA, but a CBA is incomplete if important distribution effects occur, which are important for policy makers.

Some of the topics discussed below are specific cases of distribution effects.

Long-term effects hardly count in a CBA but can be very relevant

In case of long-term effects, such as the benefits of reductions in CO_2 emissions it is mainly future generations that benefit, fuelling debates on intergenerational justice (Tremmel, 2006). A problem with long-term effects is that these hardly have an impact on the outcomes of a CBA, due to the common practice of discounting (Van Wee, 2011). Nevertheless, these can be very relevant. There are fierce debates on discounting long term environmental effects, partly fuelled by the Stern report on climate change (Anonymous, 2006) – see for example Nordhaus (2007) or Weizman (2007). An overview of the debates is also available at Wikipedia (https://en.wikipedia.org/wiki/Stern_Review, accessed 16-8-2016). It is beyond the scope of this paper to summarise the discussion. The message is that the choice of discount rates has a big impact on CBA outcomes, and especially high discount rates raise serious concerns in the area of intergenerational justice.

Safety: impact on other road users

As explained above, a vehicle that is safer for the user may be less safe for others, especially if it is heavier. In that case its energy content is higher ($E=MV^2$), resulting in a greater effect on other road users. This means that safety regulations that improve the safety of vehicle occupants at the cost of others raise ethical concerns.

Poor versus rich

A specific case of distribution effects relates to income groups: some policies have higher income groups as the main winners, whereas lower income groups are the losers. A first example is that it is generally the low-income groups who live closer to motorways and other heavily-trafficked roads. This is because equal houses are cheaper in case of high noise exposure (Nijland and Van Wee, 2008). Therefore, policies favouring (some) road users, such as in case of higher speed limits (that are mainly attractive for people with faster cars and probably more than average higher income groups) come at the cost of people living near those roads who in general have lower incomes. Secondly, regulations for the crashworthiness of cars can improve the safety of newer cars (that are on average owned by higher income groups). However, if they become heavier, this can come at the cost of people owning smaller and older cars (lower income families).

I think what is extremely important, is the *perception* of these, and other, distribution effects. If they are not made explicit, people, including decision makers, cannot do anything else than base their thinking on these perceptions. Especially if perceptions differ from real world effects, decision makers could come to other decisions compared to a situation of being well-informed.

How to value safety effects?

In a CBA safety effects are generally expressed in monetary terms using the concept of the Value of a Statistical Life (VOSL), and values are generally based on the willingness to pay for higher safety levels. This tradition raises several ethical considerations, which are discussed in Van Wee and Rietveld (2013b). Here we summarise some of the discussions:

This willingness to pay (WTP) based valuation is in line with the broader notion that no one knows better what is good for a person, than the person itself. The related concept of consumer sovereignty is a fundamental concept underpinning CBAs. However, that does not mean it is the best underpinning from a policy perspective. People in middle age have the highest WTP for risk reductions, young and old people have a lower WTP. Nevertheless, is the life of a person, for example, a 40-year-old more valuable than the life of a 15 or 80-year-old? Answering this question is very relevant from an ethical perspective. I will not answer the question here, but it is important to realise that the method differs from the one followed in health economics, where the concept of Quality Adjusted Life Years (QALY) is leading. The QALY concept implies that all else being equal it is better to save the life of a 15 year old than of a 50 year-old person, which contradicts the concept of the VOSL.

Not only consequences are relevant

A popular ethical theory is utilitarianism, a theory in the wider theory of consequentialism. According to consequentialism, it is consequences of actions that matter: the “end justifies the means”. What matters is the maximisation of outcomes. The theory is strongly related to CBA because of the focus on outcomes (benefits minus costs, or related indicators). But is it only the consequences that matter? In that case, it does not matter which mode someone used in case of a fatal accident. However, people’s ethical preferences suggest it does matter. Johansson-Stenman and Martinsson (2008) studied people’s ethical preferences and the Value of Life (or, as many economists have argued: the value of risk reductions), and found that people think a pedestrian should be valued higher than a driver of the same age and other similar characteristics. This is probably because the pedestrian is a vulnerable victim. For a discussion on the use of some ethical theories for evaluations of environmental, safety and accessibility effects of transport policies we refer to Van Wee and Roeser (2013) and we refer to Martens (2016) for a discussion of ethical theories for the evaluation of accessibility effects of transport policies.

To conclude, ethical aspects, at least fairness, could be relevant for the broader evaluation of regulatory (and other) policies, but are not included in a CBA. The overall message is that because ethical considerations can be very important for decision makers and the wider public, it is recommended to at least check if these do exist, and if so which ones. Preferably, these should be reported in ex-ante evaluations in one way or another. Unfortunately, the scientific state of the art in this respect is not mature yet. Much research is needed on how to evaluate distribution effects and other ethically relevant effects, especially if policies have a range of different ethically relevant effects – most literature focuses on evaluation the distribution of only one effect (Johansson-Stenman and Konov, 2010).

Conclusions

The most important conclusions from this paper are:

- Regulations can have an impact on determinants for the environmental and safety impacts of the transport system in several ways. These determinants include volume, modal split, technology, and the way vehicles are used.
- A CBA is a potentially useful instrument for an ex-ante evaluation of the effects of regulations in the area of road safety and the environment.
- Estimating direct costs of regulations can be difficult, and especially estimating changes in unit costs over time can be problematic. Changing preferences for the environment and safety can also be very relevant.
- Regulations can have indirect effects, and these can both be very important in policy debates, as well as be substantial from a welfare perspective.
- Ethical considerations are not included in CBA, but can be relevant for policy making and the wider public.

Table 2 summarises the core of this paper.

Table 2. Challenges related to costs, benefits and ethical considerations of some environmental and safety regulations

		Costs - direct	Costs - indirect	Benefits	Ethical considerations
Environment	Emissions regulations	Dynamic unit costs Importance of policies other countries Reference case Marginal costs	Broader welfare effects Cars as positional goods	Poor tests, manipulation Dynamic preferences for environmental impacts	Distribution effects – general Effects for different income groups
Safety	Regulations for vehicles		Several indirect effects		Distribution effects – general How to value safety: VOSL versus QALY Consequences only, or not?
	Speed limits		Welfare effects		

It is important to realise that Table 2 does not aim to give a complete overview of all relevant topics related to environmental and safety regulations, and CBA. However, the discussions touch upon some key issues that raise concerns for regulatory policies in transport.

Secondly, it is important to realise that policies can interact, as already made explicit in the case of safety regulations and speed limits. It is very difficult to deal with such interactions in CBA, unless these interactions are made explicit beforehand and included in policy packages to be evaluated.

Thirdly, a lot of research needs to be done to support better ex-ante evaluations of environmental and safety regulations in the area of transport. Research challenges, amongst others, include:

- determinants for changes in unit costs
- indirect effects
- dynamics in preferences for the environment and safety
- the extent to which the utility of cars depends on the composition of the car fleet
- ethically relevant effects of transport: which effects are most important, for whom, how they are valued, and how to include them in ex-ante evaluations.

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International Transport Forum

Assessing the Impacts of Vehicle Emissions and Safety Regulations

This paper discusses how regulations can determine environmental and safety outcomes in transport systems. It explores the relationships between regulations and direct and indirect costs, and between regulations and benefits. It also discusses the ethical issues, such as the fact that cost-benefit analysis evaluates welfare effects but tends to ignore equity issues.

Resources from the Roundtable on Assessing Regulatory Changes in the Transport Sector are available at:
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