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Safe Efficient Vehicle Solutions
-On Driving Forces for Future Road Transportations

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Abstract

The primary objective of this paper is to present the most relevant factors and driving forces that influence future sustainable road transportations and exemplify how they may influence the development. The research methodology used is explorative scenarios where data collected from workshops, expert panels and surveys lay the foundations for the explanatory models [1]. Several driving forces are identified. However, two of them are found to be more important for the study as they have a strong influence on the development of the road transport system; yet it is uncertain how these driving forces will develop. The first of these driving forces is the ability of the authorities to take an active role when developing a sustainable transport system and the second how actively people will demand and support changes in the vehicles and the transport system. Four different future road transportation scenarios have been created to explore how changes in these two driving forces will influence the development of vehicles and road transport system; these scenarios are explained together with characteristics of future road transportation solutions. It is concluded that plans for technology development need to consider the uncertainties of these driving forces in order to enable creation of robust development roadmaps.

Keywords: environment, infrastructure, energy consumption, safety, modelling

1 Introduction

Society is accelerating toward a second billion vehicles on the earth. Climate changes [2] and limited oil resources [3] are strong driving forces against using fossil fuels [4], [5]. Eventually, a shift away from fossil fuel propulsion is inevitable. However, how are the road transportations in for example 15-20 years? This topic is a major concern for instance for the vehicle industry and their suppliers to be able to plan for future products, the politicians and society planners to build up suitable infrastructure, the research community to provide the industry and society with knowledge, and the users of the transportations [6], [7], [8], [9], [10]. Consequently, it is of concern for most people in one way or another.

There are several studies that give estimates of the number of different vehicles in the future, see e.g. [11], [12]. Since the outcome depends on multiple factors or driving forces, the estimation relies on more or less clear assumptions. If an assumption becomes invalid, the estimated outcome may differ a lot resulting in a different scenario. The study in [11] emphasizes the market in United States but also including some western European countries; the results are based on reasonable technology development, and implicitly assume that the change from fossil fuel to other renewable alternatives is driven by the market power where people transportation preferences remain similar as today. This incremental path is one possibility, but what happens if the politicians decides to be more proactive and e.g. radically change the market rules, or if the transportation preferences of the people are changed?

In Sweden, the SEVS (Safe Efficient Vehicle Solutions) project [13] has been carried out with the aim to point out research areas needed for the future sustainable road transportations. A large number of partners have participated in the project: the vehicle manufacturers SAAB, Volvo Car Corporation and AB Volvo (Volvo Technology Corporation) and their supplier Autoliv Research; the consultant companies Etteplantech, Semcon and Epsilon; the research institutes SP, Swerea SICOMP, Viktoria Institute and the authority VTI. The project has been conducted by the centers SAFER (Vehicle and Traffic Safety Centre) and SHC (Swedish Hybrid Vehicle Centre) which are related to Chalmers University of Technology and other universities in Sweden. In this paper, some of the findings will be presented.

The primary objective of this paper is to present the most important driving forces that will affect the future road transportation, and present scenarios based on variation of the two most uncertain factors. Scenarios are useful both in descriptions of possible future states and descriptions of developments [1], [14]. The research methodology used is explorative scenarios [1] where the intention is to describe possible courses of events and not to predict the most likely path. Theoretically, it is possible to alter all uncertain driving forces resulting in 2^n different scenarios in case of n driving forces. However, this paper focuses on the two most uncertain factors that have impact on the formulated question on which the scenario analysis is based on. Implicitly, it is assumed that the remaining factors are fixed even though the specific values can be discussed. One advantage of scenario planning is that the underlying assumptions are made explicit and therefore it is possible to study the effects when one or more of these assumptions are altered.

The data collected from workshops, expert panels and surveys lay the foundations for the explanatory model used in the scenarios. In the explanatory model, the main target is to find the factors or driving forces affecting the stated overall key question. There is always room for discussions and different assessments may occur when it comes to valuing if one driving force is more uncertain than another and which one that affects the outcome most. In this project, we have tried to gather different people from the Swedish vehicle industry to try to come to consensus in our choices. It is beyond the scope of this article to give all arguments; merely we try to give the result of the exercise. The effort has been to in a structural way combine a technological, economical, political, ecological/environmental and societal perspective and to be as general as possible regarding the market where the results are adopted. However, we cannot ignore the fact that most of us are engineers and that we live in a Western country and we are of course influenced by that. Nevertheless, since the scenario method in itself is clear, it is always possible to introduce new driving forces (if forgotten) and revaluing them in relation to the others regarding how they will affect the outcome, and make new scenarios.

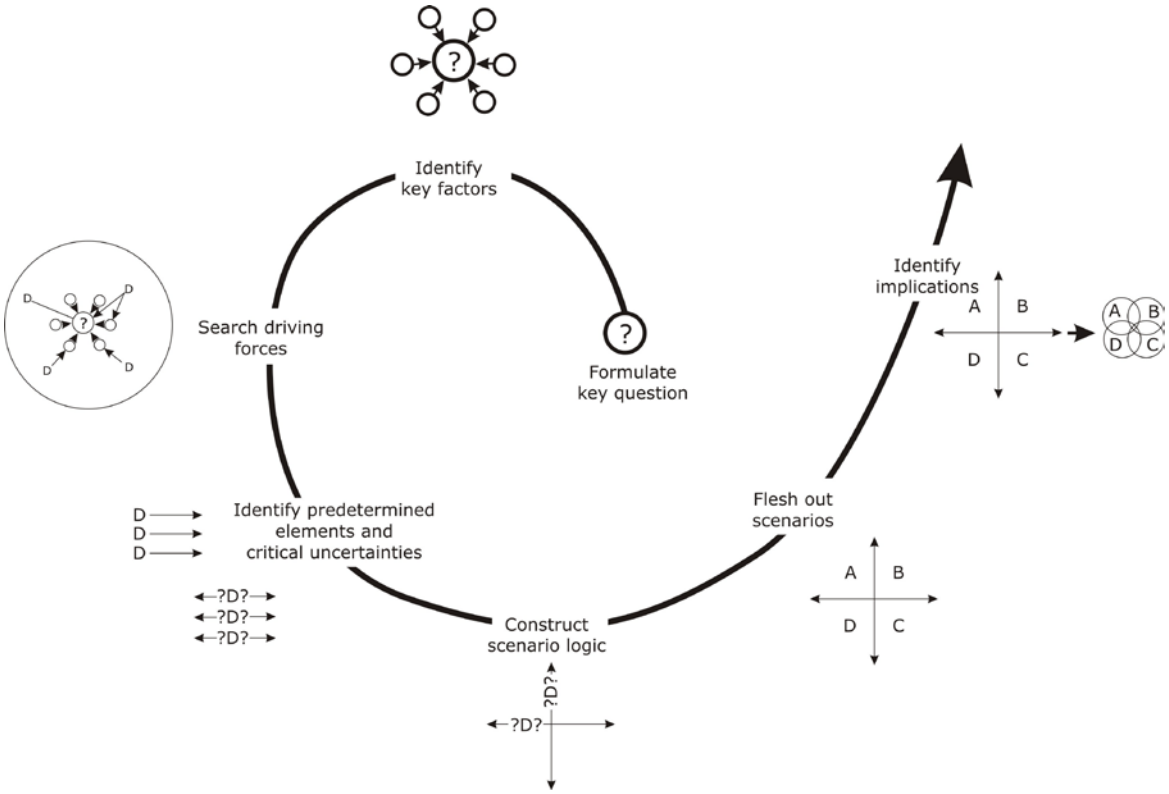

Figure 1: Scenario planning process, www.futuramb.se.

The outline of the paper follows the scenario planning process sketched in Figure 1. First, there will be a formulation of the key question, followed by a search of the driving forces and an identification of the most uncertain ones that has most impact on the key question (Section 3). The result of the scenario process is described in Section 4 followed by some discussion about sustainable solutions and the different scenarios in Section 5.

2 Key Question

A scenario planning process begins with a key question that pushes the work in the right direction. Sustainable transportation will be in focus. Even though there is no single definition, the phrase "meeting our present mobility needs without compromising the needs of future generations" [15] is one possibility that captures the essence of the meaning. Today's transports are not sustainable [16], [17], and therefore need to be changed. To be useful in the scenario planning process, the sustainable transportation meaning is phrased as a question according to: "Will we have a reduction of energy consumption by 80%, without use of fossil fuel and at the same time 80% reduced numbers of killed or injured, by 2030+?" This question relates to sustainable transports, involving both long-termed and short-termed aspects, and is quite clear and measurable, and is the base entering the scenario planning process.

3 Driving Forces and their Relationship to Each Other

From workshops and discussions, and verified by expert panels, sixteen overall factors that affects the key question have been identified: *vehicle techniques, vehicle industry conversion of inertia, consequences of population increase, raw material reserves, energy supply, new business models/actors, life style, infrastructure, politics, transport need, standardisation, security, alternative transport solutions, habituation /normalization, environmental impact, global financial position*. The underlying driving forces have been identified based on causal-loop-diagrams, which is a diagram that aids in visualizing how interrelated variables affect one another. Of all these driving forces, around 40 different have been identified affecting the key question most.

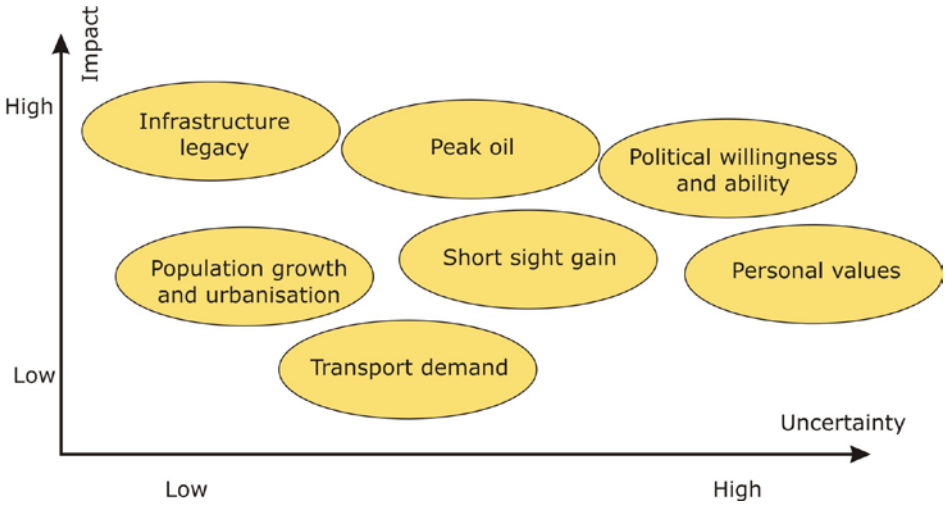

Figure 2: Uncertainty-impact chart.

The 40 driving forces have been rated against each other based on the uncertainty of each driving force and their impact on the key question; even though this assessment involves some level of subjectivity, it is important to remember that no absolute value is necessary, merely the relative relationship. The outcome resulted in different groups of driving forces which are shown in the chart of Figure 2.

4 The Result of the Scenario Process

According to Figure 2, two groups of driving forces have been identified as the ones with largest uncertainty and highest impact of the key question. First a group with different kinds of legislation and incentives and second a group of driving forces concerning values and attitudes towards consumption and travelling. The first group was summarized politically controlled actions and the second as personal values affecting our consumption and transportation. The scenarios will be built upon these two groups forming four different scenarios; further uncertain driving forces are possible that has an impact on the key question but that analysis is beyond the scope of this paper.

A fair question is why technical issues are not judged as important as the chosen driving forces, and the answer is that it is most likely no hinder for achieving sustainable transports. Light weight constructions and better batteries are probably present on the mass-market in a future not too far away.

As can be seen from Figure 2, there are several driving forces which are considered to have a large impact on the key question and are very likely to occur. These driving forces will have a large impact in developing and shaping all four scenarios but will not separate them from each other. The most important certain driving forces are:

- Infrastructure legacy and inertia. Transport infrastructure has large investment in facilities and knowledge in conventional technologies which will oppose a shift in technology.

- Peak oil. The oil reserves of the world will not be sufficient to cover the increasing demand for oil [3].

- Short sight gains, political and economical. Get re-elected or have a good second quarter financial report will not support necessary long term investment.

- Population growth and urbanization. The population growth especially in Asia and Africa is an undisputed fact and already today there are as many people living in the cities as outside the cities [18].

- Increasing transportation demand. The increasing population will have a need for food and products in the cities far away from where it is manufactured and needs for personal transportation for commuting, work or leisure is obvious.

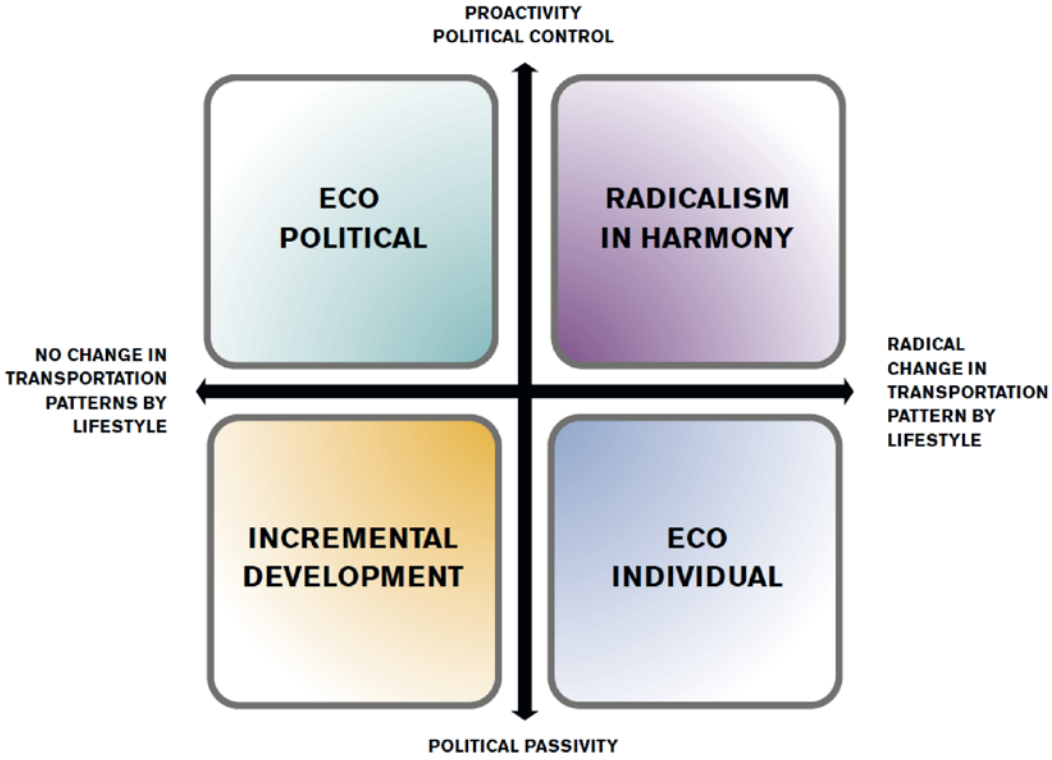

Figure 3: Scenario diagram.

The construction of the scenarios can be seen in Figure 3. The different values of the uncertainties span the possible outcome in four different scenarios. The x-axis corresponds to people values and attitudes towards consumption and travelling and the outcome of this driving force is *no change* (left) respectively *radical change in transportation pattern by lifestyle* (right). The y-axis corresponds to different kinds of legislation and incentives made by politicians taking the values *political passivity* (down) and *proactive political control* (up).

4.1 Incremental development

This scenario is based on *only minor changes in transportation pattern by lifestyle* and *political passivity*. Drivers for developing greener and safer transports are weak, the main driver is economy. High fuel prices and high battery prices are increasing the demand for public solutions but not at a rate that would initiate quick changes. Vehicle manufacturing will continue to be rationalized. New Asian actors will emerge on the world market.

The road to incremental development is spelled anxiety. The top issues for politics and people are finances, jobs and welfare. Anxiety is nourishing protectionism and distrust which are effectively blocking all attempts to the necessary global environment actions. Effects of global warming as well as the lack of energy are widely seen in the world. But instead of finding a preventative solution the global warming catastrophes are solved by fund raises on Facebook. The recurring lack of energy becomes the firewood increasing the gap between region and countries of the world. No one wants to give up anything for anyone else and every politician wants to get re-elected.

On the roads the top issue of the day is congestions. Private roads are commonly seen and cars are developed to queuing with automatic driving and all kind of integrated communication and amusement gimmicks. Road tolls are commonly used to reduce the effects of the congestions. Coal without carbon capture devices are used more and more both as energy source and liquefied as fuel in our growing transport sector. Without effective political control the variety of fuels is flourishing.

4.2 Eco political

This scenario is based on *only minor changes in transportation pattern by lifestyle* and *proactive political control*, and is a scenario based on mass transportation using green commercial vehicles. The society is driven by mass transportation solutions where personal mobility is constrained by road customs/taxes and city centres free from personal vehicles. The commercial transportation is subsidized. Freight transport is controlled in time and type in the city centre. Personal mobility is controlled to commuter parking's around the cities.

A future based on the idea of an eco political control can be the result of a number of possible future happenings e.g. the chaotic environmental situation, politicians that advocate environmental questions, people have traditional values based on safe affordable vehicles in front of mass-transport solutions, politicians introduce rewards and incentives paid by high taxes. This engagement could be seen in all countries using financially support to up comers offering new green technologies. This also leads to the establishment of new IT-related solutions for convenient travelling using mass-transportation solutions opening up for new business models and actors.

Transport solution is highly based on public transportation with adapted infrastructure and toll stations. Only "clean" vehicles can be seen in the city centres. The city traffic is less intense due to more public transportation. New IT-solutions for co-modality have to be introduced. Commuter parking can be seen near cities. Combined logistic for people and freight transport is introduced. New road infrastructure solutions for safe transportation have been built.

4.3 Eco individual

This scenario is based on *radical changes in transportation pattern by lifestyle* and *political passivity*. The society is characterized by inhabitants with a different set of values, from a fairly free travelling/transporting to a more restricted way. Thinking green and safe for every kind of transport/travel is always in focus. People are even willing to spend more on green/safe transports, even if the incitements or regulation does not require that. More consumer value measure will be developed (NCAP, etc.).

The path to this scenario is a new green wave that is formed by consumers and organizations. Hard lobbying makes companies compete for green and safe products. New companies open green transport alternatives and influence each other; eventually they outrun the traditional transport providers. The upcoming climate meeting fails again but there is a demand for more and more green cities around the world and eventually public transport sector are outrun by private initiatives.

Transport in this society is very much like today, there are no specific changes to infrastructure and toll stations are not very common. All types of vehicles can be seen all the way from rural areas to city centres. The traffic is less intense since people tend to use less transport and uses car pooling "more". The energy market/production is also diversified, with local, smaller, sources, e.g. wind/water etc. The city is also a greener place to live in since people care for the environment, they use the roof tops and terraces to grow plants and the solar cell panels are a common sight.

4.4 Radicalism in harmony

This scenario is based on *radical changes in transportation pattern by lifestyle* and *proactive political control*. The society is characterized by a common and mutual agreement that the world needs to strongly react against pollution and emissions in general. People make an effort in reducing waste, living green and consuming with "thought". Safety is of major concern, and the acceptance for road injuries and killed is really reduced to zero. Hence, the Zero-Vision (zero fatalities or critically injured in traffic) is not a vision, but an achievable and realistic goal.

In this society, people are prepared for the inevitable additional costs and reduction of freedom or flexibility, in order to really achieve a green and safe society. It is realized that one has to sacrifice something in order to gain something else. The politicians ride on the green wave and strengthen peoples will with rewards and incentives paid by high taxes. Mass transportation and car commuting are widely adopted.

As the will and drive for changes is high, both vehicular and infrastructural solutions will have a high rate of change for safety and energy efficiency. Smart logistical solutions, combined with strong (economical) incentives and efficient

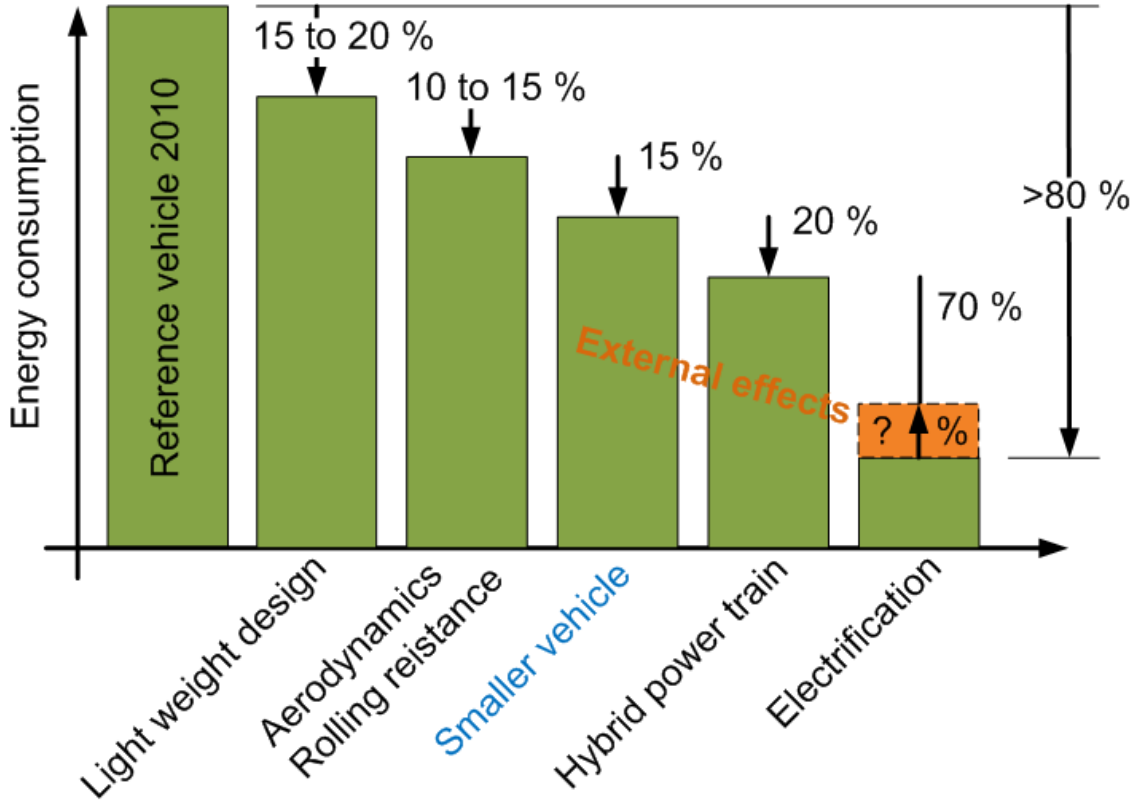

Figure 4: Energy consumption reduction.

infrastructure allows for significant improvement. The technological shift is fast. Legislation and safety thinking go hand in hand. Low adaptable speed limits, separate lanes and an acceptance for more expensive infrastructure are in general expected. Investments in green electricity, such as wind and solar energy, are easily funded and wide spread. Vehicle-to-vehicle and infrastructure-to-vehicle systems are implemented effectively.

5 Scenarios and Sustainable Transportations

To be able to answer the question which of the scenarios will lead to a society including sustainable transportations, it is necessary to find vehicle solutions of the different transportation needs in the different scenarios. This has been done within the SEVS project, coming up with different possible vehicle solutions; however, the analysis is beyond the scope of this paper but can be found in [13]. Implicitly, it is assumed that there still is need for transportation of people and goods in the future with use of buses, trucks and smaller vehicles (it is however possible to combine transportation of passengers and goods in the same vehicle). In the following, some conclusions are made showing how to reduce the energy consumption and improve safety indicating what is possible in the future.

Energy consumption reduction and new fuels

There are several ways to reduce the energy consumption of a vehicle, for instance: reduced transport need, change in transport mode, changes in the specification for the vehicle, energy efficient vehicle design, and more efficient transmissions and energy converters (engine). The three latter of these together can reduce energy consumption by more than 80%, cf. Figure 4. The energy reduction potential originates from the six expert teams in the SEVS-project: light weight design; safety; energy storage; sensor, control and communication; infrastructure and driveline. The presented savings are not the theoretical limits instead they indicate what is judged to be technical reasonable for a commercial product with ambitious energy consumption targets year 2030. To reach these high savings, the customer must be prepared to pay extra for reduced energy

consumption both by higher price of the vehicle and by reduced performance and functionality (in the different scenarios the effect of different preferences of the customer to accept this has been explored).

Safety improvements

The connection between safety and energy reduction lies mainly in the effects of a reduced vehicle weight and a possible reduction of size [9]. The lower weight is not in itself negative for safety, but collisions between vehicles of different weight leads to the lighter vehicle being subject to much more severe deceleration due to a larger change in speed. Smaller vehicles also reduce the crash zones, especially for side impacts (to reduce frontal area, rather than vehicle length).

As it is very unlikely that future energy efficient vehicles will not become both significantly lighter and also smaller, the safety improvements must not only improve today's solutions, but also compensate for the risk increase for smaller and lighter vehicles.

Discussion

Returning to the key question, which of the scenarios will lead to a society including sustainable transportations? Incremental development will for sure not since this scenario implies similar vehicles as today with large range capabilities. Furthermore, the eco political and eco individual scenarios will most likely not lead to sustainable transportations, since either the willingness of the people to change is limited or the politicians are passive. This conclusions requires however some further analysis. With ambitious targets, it is possible to reach 80% reduction in energy consumption and traffic casualties. The solution involves not only changes to the vehicle, but also changes in driver behavior and attitudes as well as road infrastructure and information- and communication technologies.

6 Conclusions

Instead of predictions of the most likely path of future transportations, a scenario planning process has been adopted in this paper. Several conclusions can be drawn from this exercise, and some of these have been given in this paper. The transportations of tomorrow strongly depend on driving forces related to people values and attitudes towards consumption and travelling and different kinds of legislation and incentives made by politicians. Based on the extreme values of these driving forces, scenarios have been built with conclusions that it is possible to achieve sustainable transports if people and politicians both strive for a sustainable transportation society. Sustainable transports are only possible if a change of people lifestyle occur together with a society that takes an active role in transforming the transport system.

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