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Sustainable Transport –

Knowledge and Innovations at RWTH Aachen University for Europe's Systems of Tomorrow

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***Abstract*— The transport of freight and people is a basic condition for the competitiveness of industry and services in Europe. This economic sector solitary has a turnover of approx. 1,000 billion EUR (approx. 7% of the gross domestic product of the EU), employs more than 10 million people and contributes substantially to the functioning of the European economy [1]. The general context of transport has strongly changed in Europe during the last years. Carbon dioxide emissions, noise pollution, rising oil prices and the strain of road traffic constitute important challenges and impulses for energy efficient, ecological and sustainable transport at the same time. In the following document the topical situation in the European transport sector is highlighted and the future challenges to the European transport system are pointed out. In this connection three approaches by RWTH Aachen University (Rheinisch-Westfaelische Technische Hochschule Aachen) are introduced which contribute to the aims of energy efficient, ecological and sustainable transport in Europe.**

***Keywords*— Sustainable Transport, European Transport System, semitrailer, intermodal, container, Swap Box, Truck Platoons, Advanced Driver Assistance Systems**

I. PROBLEM DEFINITION

The problem of transport overload in conurbations as well as on the main traffic arteries of Europe has appeared in the 90s for the first time and still threatens the competitiveness of the European Union (EU). The reason for this is especially the suboptimal organized European traffic system caused by a constant increase of the traffic amount in all transport sectors, irregular growth in different areas and the resulting charges for economy, environment and society hence.

NON-UNIFORM GROWTH OF DIFFERENT TRAFFIC CARRIERS

The biggest portion of freight haulage within the EU is 44% of freight haulage to the traffic carrier road (Fig. 1). It is followed by the short distance maritime transport with a portion of 41%, rail with 8% and the inland transportation with 4%. Even more striking is the meaning of road traffic in the area of passenger transportation with a market portion of 79%, whereas rail only holds on a portion of 5%. It becomes clear that some traffic carriers have adapted much better to the demands of modern economy. According to the European Commission [2] these are results of a missing consideration of external costs in traffic prices and lacking attention of certain social and security regulations, particularly in road traffic.

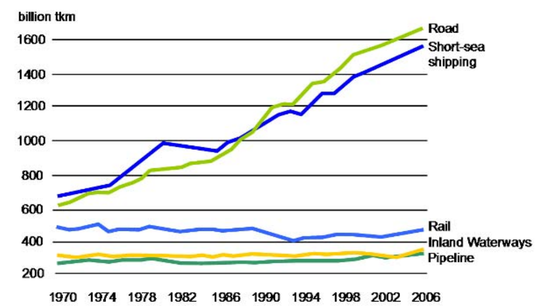

Figure 1. Transport amount in the European Union from 1970 to 2006 [1]

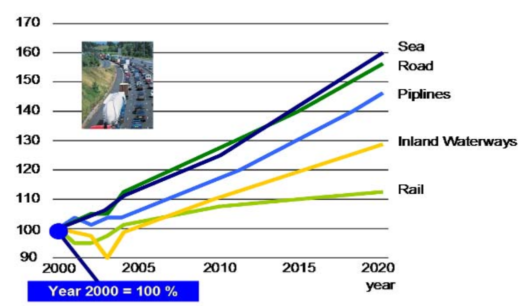

Figure 2. Expected transport growth in the EU from 2000 to 2020 [1]

This is a critical situation because further growth in all transport sectors is estimated (Fig. 2): For the period between 2000 and 2020 a growth of the freight haulage of approx. 2% per year is anticipated (50% for the whole period). The most important structural trends are:

- The traffic carrier road still bears the biggest portion of the traffic within the EU.
- Freight traffic on rail regains a stronger impact in some EU member states, though reaches a small contribution in percentage to the transport volume in the medium term and in the long term only.

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Therefore one should be aware that the European economy is seriously endangered by overload of the trans-European traffic network. The chronic overload is attributed to the intransparent prize structure of infrastructure costs, overload costs, environmental impact costs and accident costs. Among other things the suboptimal organized European traffic system and use of the traffic carriers as well as new technologies are mentioned as reasons.

EFFECTS OF THE EUROPEAN TRANSPORT POLICY

A sustainable transport policy of the European Union needs adjusted, state of the art transport systems for the economic, social and ecological requirements of today's society. After a cumbersome beginning the transport policy of the European Union obtained dynamics more rapidly in recent years. The most important aims of the EU transport policy can be summarized as follows [1]:

- High degree of mobility for citizens and enterprises in the whole European Union.
- Protection of the environment, guarantee of the energy supply security, support of current norms for the employment in the sector as well as protection of passengers and citizens.
- Contribution to energy supply security.
- Improvements of the occupation quality and better qualifications of employees in the European transport sector.
- Support of innovations with regard to the aims mentioned above through an increase of efficiency and sustainability of the expanding transport sector.

Based on the problem of increasing traffic growth (see chapter 1) and the transport policy of the European Union shown above, the European Commission [2] identified future challenges to a sustainable transport (extract):

1. Revival of rail traffic
2. Realization of intermodality
3. Support of the maritime and inland water navigation
4. Extension of the trans-European traffic network
5. Increase of road safety
6. Increase of the air traffic and environment protection
7. Optimization of road traffic
8. Use of clean fuels and technologies
9. Extension of the trans-European traffic network
10. Research and technology in the service of ecologically friendly and efficient means of transportation

Concerning these challenges identified by the European Commission RWTH Aachen can deliver approaches to solve these problems. All of them share the aspect that they contribute significantly to the goals identified by the European Union and help to decrease the problems in the transport sector.

In the following chapters three "highlights" from the area of the university research of RWTH Aachen University are introduced to sustainable transport:

- Revival of rail traffic and realization of intermodality: “Semitrailers in Advanced Intermodal Logistics (SAIL)“
- Realization of intermodality and operational optimization: “Intelligent MegaSwapBoxes for Advanced Intermodal Freight Transport (TelliBox)”
- Increase of road safety and optimization of road traffic: “Development and analysis of electronically coupled truck platoons (KONVOI)“

The projects SAIL and TelliBox share the aspect of intermodality. KONVOI can contribute to the identified challenges by an increase of road safety and optimization of road traffic.

II. RESEARCH PROJECTS OF RWTH AACHEN UNIVERSITY (EXTRACT)

A. Semitrailers in Advanced Intermodal Logistics (SAIL)

1) Project description

The project “Semitrailers in Advanced Intermodal Logistics (SAIL)” funded by the European Union focused on the potential for intermodal transport as a whole by evaluating the trends and decisions taken by transport operators. It was demonstrated that the worked-out solutions could not only fulfill the ambitious goal of the European Commission of increasing the percentage of rail haulage from 10% to 15% until 2010, but outnumbered it [3]. Within this project 29 different shipping principles were identified from which six were transferred to the next level of development. Finally three solutions were selected through of a method called “Technical attractiveness” for realization and were built as a prototype.

The first SAIL-solution, corresponding completely to the other non-intermodal semitrailers, has interior headroom of three meters. (Fig. 5, left). The vehicle has a total length of 13.7 m. Thus results a load volume of 100 m³. The entire height of three meters interior can be used by raising the roof, in order to position the loading. Thus approx. 28 t loading mass can be carried. The rear underrun bumper with the rear lights is equipped in that way, that in the new railway loading gauge of the pocket-wagon, a turn-up of the bumper for shipping is not necessary any more. In the further rear part of the semitrailer a cylinder exists apart from the control unit of the pneumatic spring and the air parking brake, which can be driven out in the case of loading and of unloading for support of the vehicle. A navigation-tool, which is connected by a vehicle interface with the truck, enables constant information for the scheduler about the position and the status of the vehicle.

Adapted to the cranable semitrailer, a new pocket-wagon generation as a second solution was developed, which has also a new loading gauge (Fig. 5, middle). The rail-mounted vehicle has a length over buffers of 19.7 m and a pivot distance from

14.2 m. The bogie has an axle-base of 1.8 m as well as a wheel diameter of 840 mm.

Around this base position a pocket was built, which has a standing height of 270 mm. This pocket is arranged in such a way that semitrailers of different lengths and different axle-positions can be shipped. The innovation in this rail-mounted vehicle is, that no wheel-rugs are necessary and the protection of the semitrailer can be implemented over the king pin accommodation or over the locked compressed air brake of the axles. On these new pocket-wagons further containers of the classes 20 foot to 24 foot as well as container of the classes 30/31 and 40/42/44 and 45 foot can be shipped beside the semitrailer of the new generation.

As a third solution a roll-on-roll-off concept was developed with type of a rolling road wagon is used as a form of transport to make a particularly not adapted semitrailer shippable (Fig. 5, right). The roll-on-roll-off machine pulls the straddle carrier onward to the rolling-road wagon. The straddle carriers handle up to 40 t weight.

The prototype of the cranable semitrailer which is equipped for the Ro-Ro-Traffic was used commercially on a total distance of 47.757 kilometers (freight capacity of approximately 750.000 ton kilometers) [4].

Figure 3. The three products in the project SAIL: Cranable Semitrailer (left), new pocket-wagon generation (middle), roll-On-roll-off-system (right)

2) Recommendations on traffic policy level

The plan for traffic political infrastructure should include an area-wide arrangement of transshipment stations for intermodal transport. The arrangement is to be made in this way that there is no need for a longer approach more than 200 kilometers. Thus, the approach to a terminal and the use of other traffic routes also for shorter way are efficient.

3) Recommendations concerning rail infrastructure

The European railroad network is to be strengthened in this way that a net for rail nets with high- and top-speed trains (passenger traffic) and are split up from rail nets with middle and higher speed (freight haulage). By this these to nets may be run autonomous and diversity as basis for innovations can be reached.

RECOMMENDATIONS CONCERNING SEMITRAILERS AND EXCHANGABLE CONTAINERS

The external dimensions of the semitrailers must not exceed the actual valid extent. This is especially due to the total height of 4 000mm, a length of 13 600 mm and a width of 2 480 mm maximum, otherwise there would be no intermodal transport possible due to the coherence of enveloping space and structural clearance.

For the accreditation of swap bodies and semitrailers for the intermodal transport the requirements are set to a maximal force of 2g, the requirements of the tie-down of only 0,8g. In case of an accident the tie-down collapses at first. A uniform measurement which makes sense from the physical and technical side would be an adaption of the tie-down and the accreditation conditions to 1,2g. That would mean a significant increase of safety on the road and still 20% more than the maximum force of 1g.

All semitrailers should be equipped with reach angles for a vertical shipment as well as hooks for the tie-down in intermodal transport as a standard. Thus intermodal transport with all semitrailers would be possible.

RECOMMENDATIONS CONCERNING AGGREGATE WAGON

Changes of the norm presetting (e.g. UIC-Leaflets) should be reached at the licensing of rail vehicles away from the detailed presetting to interface definitions. Therefore the innovation ability of wagon builders may increase similar to the street vehicle builders.

Technical innovations such as automatic clutches, electronic and electro pneumatic brakes or train traffic systems (GSM-R/GPS) should be sponsored. The application of innovative techniques in test runs should be allowed as a block train or as the last wagon for test runs in every-day use.

The UIC-norm UIC 96/53 (dimensions, weights and axle loads) should be fixed in order to the intermodal transport. To guarantee this issue, the UIC-norm should be turned into an EU-norm [5].

B. Intelligent MegaSwapBoxes for Advanced Intermodal Freight Transport (TelliBox)

Faced with a trend towards increasing freight transport, a global market and the need for a resource-saving transport system, it is mandatory that European transport policy shifts the balance between all transport systems [6]. Especially in the automotive and white good sectors these challenges have appeared. A general tendency in the enhancement of loading units concerns the maximisation of the cargo area and the facilitation of loading and transhipment processes. These loading units differ amongst others in aspects like dimensions and stability as well as usability regarding handling, transport and loading processes.

By drawing together the ideas and contributions of freight forwarders, manufacturers and scientists, the scientific aim of the project 'Intelligent MegaSwapBoxes for Advanced Intermodal Freight Transport' (TelliBox) is to achieve an all-purpose, intermodal loading unit that is applicable to transport via road, rail, short sea and inland shipping.

The advantages of containers and semitrailers will be combined to an optimal loading unit – a MegaSwapBox – regarding cargo volume, usage of standard equipment for handling, transportation and loading processes than currently available intermodal loading units (Fig. 4).

Within six decisive project steps, the interdisciplinary European consortium will realise three optimised and certified prototypes which will be tested on an intermodal European corridor (PL-D-NL-UK). The project started in April 2008 with duration of three years and is funded by the European Union.

TelliBox will achieve its objectives by combining new materials with innovative and intelligent constructions. The project TelliBox seeks to successfully introduce the MegaSwapBox onto the market with a view to encouraging the standardisation of new loading units in the long run [7].

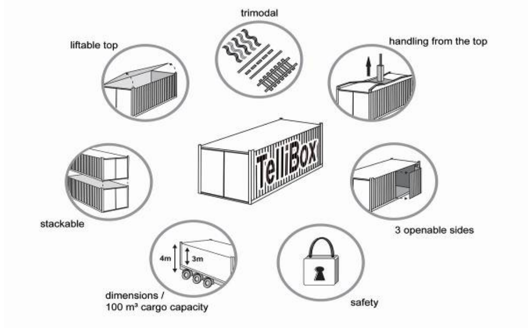

Figure 4. Challenges of the MegaSwapBox [6]

The analysis of the current situation, state-of-the-art situation in intermodal transport and expected impacts on the newly proposed intermodal loading unit - MegaSwapBox has been done in the As-is analysis report found out by a consortium of freight forwarders, manufacturers and scientists who are actively taking part in the European intermodal market.

From the analysis of intermodal loading units it is clarified that there is a space for a new high-volume loading unit that would satisfy conditions of trimodal usage and its design would enable loading from the rear and side. The result of this part is a comparison matrix that reveals advantages and disadvantages of the individual intermodal loading units and they are compared with the proposed MegaSwapBox. From the comparison matrix it is evident that the only competitor in this segment of intermodal transport could be the 45'HC container. Its advantage is in compatibility with the existing technical base (means of transport, handling equipment), but its disadvantage is less advanced design (lower cargo volume, absence of side doors and not liftable roof). Taking the needs of automotive and white goods industry as an example, those customers are using pallet cages with 1 and 1, 5 metres in height and will therefore profit particularly from loading units with 3m internal height. These dimensions must be achieved whilst adhering to the vehicle limits of Directive 96/53 which states that the external height of the loading unit plus chassis may not exceed 4 m on road and 2,55m in width. Furthermore the top needs to be liftable to one side to ease the loading process and reduce risks of damages of the cargo. Finally, the loading unit needs to be certified by CSC "International Convention for Safe Containers" and UIC "Union Internationale des Chemins de Fer".

Taking these facts into consideration, requirements of the TelliBox can be categorized in "must" and "should" requirements. "Must" requirements are fundamental for the new system, while "should" are the requirements fulfilling of which would enhance the properties of the new TelliBox system. It was identified that the most interesting "Must" requirements are an internal space for 33 pallets, internal height of 3000mm, external length of 13716 mm, external width 2550mm, 3200 mm, weight of 44 t, openable on three lockable sides (no topline) and a liftable roof for loading cargo of 3m height, an enabled maximum speed of 120 km/h, minimized costs and build of recyclable materials. Should requirements are an internal length of 13620 mm, internal width of 2480 mm, grooves at the bottom frame for handling, an enabled maximum speed of 140 km/h and a good maintainability.

Within the second work package, the technical attractiveness of possible combinations in the solution space was analysed. Therefore, analysing methodologies like technical feasibility, sensitivity analysis and cost-benefit-analysis were applied. In this decision phase there was identified a list of requirements effort for achieving the maximum possible utilisation of space that is available during transportation on roads, railways and inland and short sea shipping. Naturally, effective handling in terminals and during transloading has to be considered as well. At the same time the requirements have to obey physical (technical) laws, maximum dimensions acceptable on the three modes of transport, considering safety, economy and in maximum possible extent the existing standards so that the new system would be as much as possible compatible with other intermodal systems. The final result of this phase is a fixation of three solution variants which were chosen in cooperation with the Advisory Board of TelliBox. On the basis of these solutions further development of the future TelliBox will be done.

These first results show that the developed TelliBox will face the identified future challenges in transport better than topical loading units. As the project still is in progress, further results of TelliBox can be presented at the IEEE conference in October 2009.

As a conclusion, TelliBox actively promotes the EU's objectives by means of achieving intermodal integration because the aim is toshifting transports from road to intermodal. That means an operational optimisation of transport and by this can strengthen the competitiveness of the European Union.

C. Development and analysis of electronically coupled truck platoons (KONVOI)

The development and evaluation of the practical use of truck platoons is the objective of the BMWi[1]-funded project KONVOI[2]. With the assistance of virtual and practical driving tests, by using experimental vehicles and a truck driving simulator, the consequences and effects on the traffic will be analyzed [8].

[1] BMWi: Bundesministerium für Wirtschaft und Technologie, respectively Federal Ministry of Economics and Technology

[2] Project consortium KONVOI: RWTH Aachen (Zentrum für Lern- und Wissensmanagement und Lehrstuhl für Informationsmanagement im Maschinenbau - Projektkoordination, Institut für Kraftfahrwesen, Institut für Regelungstechnik, Institut für Psychologie, Institut für Straßenwesen Aachen, Lehr – und Forschungsgebiet Berg- und Umweltrecht), MAN Nutzfahrzeuge, WABCO Development, Ewals Cargo Care, Hammer GmbH, Offergeld Zentralverwaltung, Bundesanstalt für Straßenwesen, Berufskolleg Simmerath/Stolberg.

Within the project KONVOI, four experimental vehicles are equipped with the required automation-, information- and automotive-technology to build truck platoons. The main system components of the platoon system are the Advanced Driver Assistance System (ADAS) and the Driver Information System (DIS) (Fig. 7).

The longitudinal guidance of the ADAS is based on a LIDAR distance sensor. The distance sensor is used to determine the distance in longitudinal direction and the transversal offset to the leading vehicle. The vehicle-vehicle-communication transfers necessary vehicle data from all platoon members, which is required for the ACC to realize the target distance of 10 meters. In all trucks a target acceleration interface is implemented, which automatically calculates the drive-train and the management of the different brakes in the vehicles. The transversal guidance of the ADAS is based on the transversal offset to the leading vehicle and the recording of the own track position with a CMOS image processing system as well as the analysis of the data flow from the vehicle-vehicle-communication. A steering actuator on the base of an electric motor delivers the necessary steering moment for the automated guidance of the trucks [9].

After sufficient testing of the Advanced Driver Assistance System (ADAS) as well as the Driver Information System (DIS) for the proof of the system security as well as clarifying insurance-legal aspects, the experimental vehicles are subsequently tested on motorways with traffic. During the test runs on motorways, all the data streams are recorded to analyze the automation control, traffic flow, road safety, economic efficiency and environmental effects as well as the acceptance and stress of the truck drivers.

During the analysis and evaluation of truck platoons in different automation scenarios it became obvious that the scenario "platoons organized by the driver", with possible necessary modifications offers the best possibilities for a medium-term implementation [10] [11].

In this scenario, the driver has the permanent control of the autonomous driving procedures. The creation of a platoon depends on the initiating driver who delivers the necessary data about time and place of meeting, the destination, as well as the required truck telemetric data (loading weight, engine power etc.) with the help of a driver information system (DIS). Because no schedules have to be generated as they have to be in rail traffic, the high flexibility of truck transportation is preserved. After activating the ADAS it automatically shows a selection of the best matching platoons, informs the driver and prepares the participation to the selected platoon. It then helps the truck driver to plan the route and guides the driver to the meeting point. The driver has to initialize and respectively confirm all of the platoon maneuvers in order to build and to dissolve the platoon. Accordingly, the DIS is the human machine interface (HMI) of the platoon system [9].

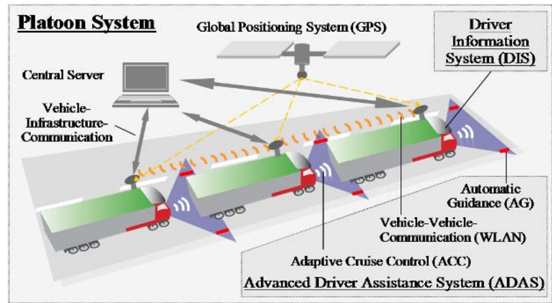

Figure 5. The Platoon System [7]

The presented software architecture fulfills all the fundamental demands for the development of interactive software systems in the automotive sector. Hereby the architecture ensures the user interaction between the driver and the technical systems as well as the data processing between the different system components in the vehicle. This architecture guarantees a modern, flexible, extensible and easily configurable system, especially for HMI of driver information and assistance systems. Due to its interactive and adaptive characteristics, the presented architecture could be moreover seen as a generic software architecture framework.

In the first instance, the Driver Information System was implemented into the RWTH Aachen University Truck Driving Simulator (Fig. 8) which was used as a test environment for the module, integration and system tests [9].

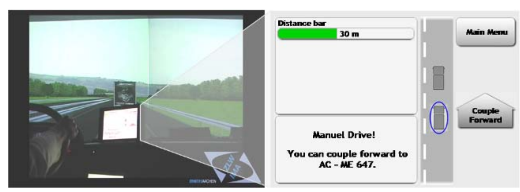

Figure 6. Truck platoons in a truck driving simulator and the graphical user interface of the DIS to organize and operate truck platoons [8]

For the platoon system's success, the acceptance of the truck drivers, freight forwarders and all other traffic participants plays an important role. Therefore their attitude towards the platoon system is surveyed throughout the whole system development. These surveys allow a forecast of the success or failure of a possible market introduction of the system. Furthermore they allow adopting the platoon system to the specific needs of its possible users [12]

The concept of creating "trains on road" (truck platoons) supported by Advanced Driver Assistance Systems is one possibility to manage the permanent increase of freight transportation and the utilisation of its capacities. An electronic coupling of trucks will relieve the truck driver and therefore will increase safety. Consequently, the capacity of the roads will be used more efficiently due to the short gaps between the trucks. An optimization of traffic flow up to 9 % and a reduction of fuel consumption up to 10 % caused of slip stream driving can be expected [11].

In the project KONVOI a trial implementation in virtual and real test runs is realized which shows the benefits of the ADAS in freight transportation. Furthermore, the project includes an impact analysis of vehicle platoons which considers all aspects with respect to the human, the organization and the technology [8] [13].

Furthermore the attitude of the truck drivers towards the platoon system was collected by the means of acceptance tests, following a test in the driving simulator with standardized interviews. In this test run the truck drivers had the chance to try all possible convoy manoeuvres and to experience the platoon system as the driver of the leading or a following truck. The reasons for the increase of the acceptance of the truck drivers and freight forwarders are the adaptation of the platoon system to the needs of the groups considered (truck drivers, freight forwarders and other motorway users) as well as the possibility for the subjects to get a deeper insight into the platoon system through the implementation of the system into the driving simulator.

The unique features in comparison to similar projects the developed system was successfully tested in real traffic without blocking the usual traffic volume on German highways. There are other projects in which vehicle platooning is developed but none with test runs with four trucks in real traffic [14].

During this test phase in real traffic over a period of several days, trucks were allowed to go by 80 km/h. Restrictions for the KONVOI-System are the facts that KONVOI can be used on highways only at the moment. More detailed facts will be published in the future in the final report.

Therefore KONVOI-System contributes to the EU's objectives by means of an increase of road safety and optimization of road traffic through a more efficient road-side traffic flow by harmonizing traffic on the highways. Thus can disburden transport overload in conurbations in the European Union.

III. Summary and Future Perspectives

Within the course of this paper the topical situation in the transport sector of Europe was highlighted. Furthermore, the topical problems of the European transport system are shown which are caused by the constant increase of the traffic amount in all transport sectors, irregular growth in different areas (see chapter 1). Solutions need to be developed which contribute to a sustainable transport concerning economy, society and environment (see chapter 2).

Three selected solution attempts of the RWTH Aachen were introduced which can give an important contribution to handling of the future challenges (see chapter 3). With the developed solutions in the projects SAIL and TelliBox the intermodal transport can be strengthened with sustainable effect and the rail traffic can be revived [4].

This would contribute to a better capacity utilisation of transport modes and counteract against the non-uniform growth the traffic carriers. The project KONVOI shows the application of driver assistance systems in freight traffic and their advantages concerning the economic efficiency, the environment (saving of fuel and reduction of the emissions) as well as the traffic flow and road safety [9] [10].

These solution attempts lie completely in the sense of a research and technology in the service of non-polluting and efficient transportation carrier as the European traffic politics demands [1], but only show a small facet of the whole range of innovations in industry and research. Beside the technological innovations in industry and research there are also other important aspects for a sustainable transport. According to EU office of RWTH Aachen University, it is essential that the attitude towards traffic issues and the behaviour of the society must be changed.

On the one hand incentives for the people must be created so that they change their behaviour concerning transport and mobility. On the other hand one need to show people that they can decisively contribute to a sustainable transport by using new technologies and thereby influence the effects on society, economy and environment positively as well as negatively [15].

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