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Factors influencing the integration process of the eHighway system by transport companies

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Abstract. To reduce greenhouse gas emissions from road freight transport, new drive concepts for heavy duty traffic such as the eHighway system are crucial. For a successful dissemination of the eHighway technology the user perspective needs to be considered. This paper identifies profiles with relevant characteristics of road freight transport companies and derives a catalogue of factors influencing the integration process of the eHighway system by transport companies. The company profiles and the catalogue of influencing factors form the basis for future analysis on the evaluation of the eHighway system from a transport company's point of view.

1 Introduction

Climate change and the impact of traffic on CO_2 emissions has been getting a lot of attention in the last decades. After the "Paris Agreement" opened for signature in April 2016 at UN Headquarters in New York, 189 nations committed to this agreement. The main objective of the "Paris Agreement" is to fight against climate change to limit the increase in world temperature to 2°C, from the pre-industrial era until the end of the century [1].

With the Climate Action Plan 2050, Germany shows how it intends to implement the Paris Agreement. The plan is based on Germany's extensive greenhouse gas (GHG) neutrality by the year 2050. It provides a clear orientation for all sectors: Energy, buildings, transport, industry and agriculture. For the transport sector, the need was defined to reduce CO_2 emissions between 95 and 98 million tonnes of CO_2 equivalents until 2030 [2].

Considering the different modes of freight transport, road freight transport has the largest share [3] and is responsible for 35.1 % of transport-related GHG emissions [4]. Moreover, when looking at the traffic forecasts for road freight transport, it is expected that until 2050 the volume will increase by almost half of today's volume due to its central role in a modern and manufacturing society [5].

Regarding solutions to achieve the objectives set by the German government for the road freight transport sector, traffic management solutions to avoid, shift or control traffic come to mind. But according to a study by the Wuppertal Institute [6], such traffic management strategies will not fully solve the problem. There is also a need as well as a high potential for introducing sustainable drive systems in road freight transport. Light commercial vehicles could switch to battery electric propulsion, road trains to hydrogen propulsion in particular, while for semitrailer trucks an eHighway system could be built [6].

In order to allow the transition to alternative drive systems, a well-founded analysis of the systems and the corresponding contributions to climate protection as well as studies on the integration with future users are required.

This paper aims to contribute to the evaluation of one of the systems mentioned above: the eHighway system. The eHighway system is a combination of an "Overhead Line" (OL) and "Overhead Line Hybrid trucks" (OH trucks). An OH truck receives the energy through a pantograph mounted on top which is connected to the OL as well as through an on-board energy supply unit for electric drives on non-equipped sections [7-8]. The functionality of the eHighway system has been evaluated in multiple projects such as ENUBA[1], ENUBA 2 and first field tests in Sweden and the US [9-10]. Currently, the system is tested in multiple pilot projects on German highways. ELISA[2] is the first German field tests and located in the Federal State of Hessen. A 5 km section in North and South direction between Frankfurt am Main and Darmstadt is equipped with an OL and has been in operation since 2019 [11-12]. An extension of the South direction to a total length of 12 km is currently prepared [13].

2 Research questions

Various studies have analysed the structure and developments in road freight transport going along with the future of alternative drive systems. However, most studies consider a holistic view on alternative systems rather than focusing on specific aspects of the eHighway system [14-21].

From the perspective of a transport company, a systematic analysis of the eHighway system is required. Particularly, the extensions of governmental restrictions concerning conventional trucks (e.g. truck bans or diesel bans in urban areas or CO_2 pricing) are urging the need for cost-efficient and reliable alternative drive systems. Therefore, this paper focuses on the following research questions:

- How can road freight transport companies be characterized regarding their ability to integrate the eHighway system?
- Which factors are influencing the integration process of the eHighway system by road freight transport companies?

3 Methodology

To answer the research questions, at first a **profile for transport companies** has been developed by conducting a literature review on the transport company structures, vehicle fleet composition and transport profiles [22-30]. Moreover, all ELISA transport companies have been consulted through expert interviews to provide input regarding the characteristics of transport companies which are relevant for the eHighway integration.

With the profile for transport companies in mind, a **catalogue of factors influencing the integration process of the eHighway system by transport companies** has been developed in a second step. The catalogue is based on the evaluation of insights obtained from the field test through surveys, additional expert interviews with transport companies and the vehicle manufacturer.

Besides the gained knowledge within the field test, previous research on OH trucks has been examined and core features have been integrated into the catalogue [17-20].

4 Results

4.1 Profile for transport companies

For the profile for transport companies, five categories have been identified: Company structure, transport scope, vehicle fleet, testing experience with alternative drive systems and field test participation.

Table 1. Profile for transport companies

Category	ID	Feature
Company structure	1	Legal form
	2	Company size
	3	Annual sales
	4	Number of employees
Transport scope	5	Operation area
	6	Number of branches
	7	Transport purpose
	8	Structure of the transport chain
	9	Group of goods
	10	Classification of goods
	11	Typical route length
	12	Share of toll routes
	13	Degree of digitalisation in the transport chain
Vehicle fleet	14	Fleet size in Germany
	15	Fleet age
	16	Dominant vehicle manufacturer in the fleet
	17	Dominant vehicle classes in the vehicle fleet
	18	Dominant emission class in the fleet
	19	Used vehicle types
	20	Average operating life of vehicles
	21	Dominant vehicle transfer type in the fleet
Testing experience with alternative drive systems	22	Years of testing experience with alternative drive systems
	23	Alternative drive systems tested
	24	Number of vehicles with alternative drive systems
Field test	25	Distance of the main location to the field test side
	26	Number of OH trucks in operation

The category *company structure* addresses the differentiation in general, based on features such as legal form or annual sales. The category *transport*

[1] Elektromobilität bei schweren Nutzfahrzeugen zur Umweltentlastung von Ballungsräumen (ENUBA), engl.: Electric mobility for heavy-duty vehicle to limit environmental impact in conurbations.
[2] Elektrifizierter, innovativer Schwerverkehr auf Autobahnen (ELISA), engl.: Electrified, innovative road freight transport on highways.

scope gives insights into the transport company's main business areas as well as the used transport network. The category *vehicle fleet* will enable a more detailed insight into the type of vehicles used. As a basis for future research, the fourth and the fifth category distinguish between the *experience with alternative drive systems*, e.g. based on years of testing the trucks and on the linkage to the ELISA *field test*. Further information can be taken from Table 1.

Based on the results of surveys and expert interviews, for each category in Table 1, feature characteristics of the ELISA transport companies have been identified. Due to some limitations in the course of the surveys, only 12 of the 26 features could be determined so far. Gaps within the features will be closed soon by conducting further surveys with the involved transport companies.

4.2 Factors influencing the integration process of the eHighway system by transport companies

The result from the second step is a catalogue of factors influencing the integration of the eHighway system by transport companies. The compiled factors can be divided into six categories, each consisting of influencing factors on two levels. The first level represents superordinate factors. The second level goes into more detail. For example, from a transport company's perspective, the technical requirements on an OH truck, e.g. vehicle type, range, average speed or energy consumption, play an important role.

Moreover, all factors on the second level can be an input or a consequence of other factors from different categories. For example, the OH truck range is affected by the spatial availability of the OL, the battery capacity and the energy consumption of the OH truck, and has an impact on the route planning and transport time.

Further details on the factors influencing the integration process of the eHighway system by transport companies are provided in Table 2.

5 Conclusion

The results of this research form the basis for further analyses in the ELISA field tests concerning the integration of the eHighway system by transport companies. The developed profile for transport companies (Table 1) is the basis for the differentiation between transport companies in the ELISA project. In combination with the catalogue of influencing factors (Table 2), it offers the possibility for future research to analyse correlations between findings from the field test and characteristics of transport companies on a very detailed level. These findings will help other transport companies to evaluate the potential for integrating the eHighway system within their company.

Table 1 Catalogue of factors influencing the integration of the eHighway system by transport companies

Category	Factor - Level 1	Factor - Level 2
Economic	Total cost	Acquisition costs
		Operating costs
		Maintenance costs
		Repair costs
		Personnel costs
		Insurance costs
		Government support
		Taxes
Operational	Billing system	Reliability
		Billing complexity
		Fairness
		Data collection system
		Pricing system
	Information system	Reliability
		Handling
		Usability
		Safety
	Transport process	Route planning
		Transportable goods
		Transport time
		Transport costs
		Timeliness
		Restricted areas
		Flexibility
		OL network density
		Customer satisfaction
	Overhead line	Spatial availability
		Temporal availability
		Reliability
		OL safety
		Terms of use
Technical		Vehicle compatibility
		Capacity
		Transportable goods
	OH truck configuration	Vehicle type
		Euro class
		Dangerous goods classification
		Gross vehicle weight
		Cargo capacity
		Toll classification
		Vehicle safety
		Energy consumption
		Average speed
		Battery capacity
		Range
		Driver power
		Charging rate
		Fuelling time
		Downtimes
		Operation life
		Driver assistance systems
		Operability by driver
		Cabin equipment
Ecological		Noise emissions
		GHG emissions
Traffic-specific	Operation restrictions	Restrictions in cities
		Restrictions on highways
Actor-specific	Acceptance	Driver
		Management
		Transport planner

6 Outlook on the presentation

To demonstrate the practical relevance of the concept developed in this paper, the presentation will include a report on the five transport companies contributing to the ELISA project. Their experiences, so far, with integrating the OH trucks in their fleet and consideration of the eHighway infrastructure in their route planning will be reported.

Moreover, the catalogue of factors influencing the integration process is not limited to the eHighway system and can be used to evaluate other alternative drive concepts from a transport company's point of view.

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