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Mobile Multi-functional Urban Logistics-Platforms with Electric Drive Train

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Abstract

Unconsolidated freight transport creates increasing problems in cities due to the use of public space and its negative environmental impact. The research project MULE analyzes if mobile multi-functional urban logistics platforms with electric propulsion in combination with a flexible two-stage city logistics concept can lift urban freight transport to a new level by using electric, (partially) autonomous utility vehicles that increase the efficiency of goods transport. To investigate its feasibility, the concept is modelled on vehicle level to investigate the electric drive-train as well as on logistics level. The feasibility of the holistic implementation of the MULE concept is realistic with regard to the concept's cost economy and simultaneously has a high ecological potential. The cost saving potential is the result of combining automated loading concepts, a two-stage (multi-stage) city logistics system as well as vehicles with tailored electric drive trains using intermediate charging.

Keywords: Environmental Impact of Transport; Decarbonization; Mobility in Smart Cities; Transport Hubs; Transport Modelling and Management; Electromobility.

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Nomenclature

F_A driving force
F_S grading resistance force
F_L air drag
F_S acceleration resistance force
$F_{Ttrans,Trot}$ translational and rotational acceleration resistance force
m_{ges} total weight of vehicle
β grading angle
a vehicle acceleration
v vehicle velocity
a_R tire resistance factor
ρ_L air density
c_W air drag factor
A_F frontal flow area of vehicle
λ factor rational mass ratio
C_{tot} total cost of ownership
C_{f1} fixed costs (drive train)
C_{f2} fixed costs (vehicle without drive train)
C_v variable costs

1. Introduction

1.1. Background

An increasing number of people are living in cities. Urbanization has the advantage of efficient use of the available space and its infrastructure but also implies to take care of these people with needed goods. Due to this and the fact of increasing e-commerce, changing consumer behaviour, and smaller volume transports, freight transport in Germany has increased between 1995 and 2010 by 55%, see UBA (2012). Unconsolidated freight transport creates increasing problems in cities due to the use of public space and its negative environmental impact. Especially Courier, Express and Parcel (CEP) services grow rapidly. Esser and Kurte (2013) reported a doubling of CEP transports between 2000 and 2013. This leads to growing environmental impact in urban regions, higher accident risk by commercial vehicles transporting heavy goods and loss of quality of life.
According to Aichinger (2014) about 30% of the CO2 emissions of road traffic in Europe are caused by freight transport, Gebhart-Graf et al. (2012) report a share of 53% for NOx and 41% for particulates. On the other hand, European road policies aim at 60% reduction of CO2 until 2050 and CO_2 free city logistics in bigger cities until 2030, see European Commission (2011).

1.2. Objectives

The presented project is carried out within the framework *Mobility of the Future*, funded by the Austrian Research Promotion Agency FFG. It analyses if mobile multi-functional urban logistics platforms with electric propulsion (MULEs) can lift urban freight transport to a new level by using electric, (partially) autonomous utility vehicles that increase the efficiency of goods transport. The particular aim is to increase cost, environmental, energy and spatial efficiency and thus lead to an increase in the urban quality of stay.

2. MULE concept

The MULE concept as described below is derived based on an evaluation of the state-of-the-art in (a) *automated driving* with focus on freight transport and (b) *city logistics* with focus on the definition of the needed vehicle lay-out and the sites of operation. In a multidisciplinary team work using different innovation techniques, a concept for a new urban freight transport concept is developed.

2.1. Two-stage city logistic

The MULE concept is based on a flexible two-stage logistics concept, initially described by Crainic et al. (2004), see Fig. 1.

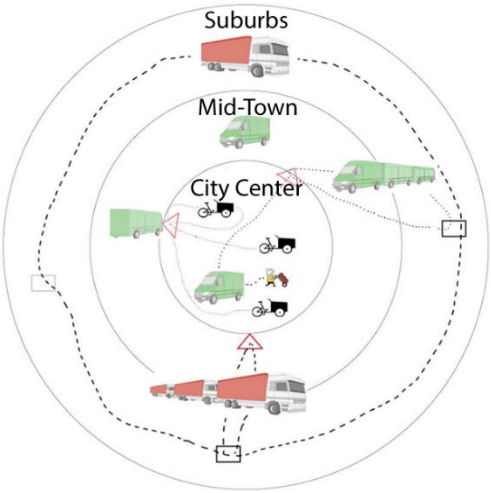

Fig. 1: MULE logistics concept (TU Graz – ITL, cp. Crainic et al. (2016

The main idea is to apply the ideas of the Physical Internet to the urban environment. This conceptual framework was also termed Hyperconnected City Logistics and is meant to revolutionize urban logistics and transportation. A Hyperconnected City Logistics system is strongly interlinked with others throughout the world and represents a node of larger regional, national and international transportation networks. The interconnection with other cities is also a fundamental key to the inner city's logistics and transportation performance. (cp. Crainic et al. (2016)). The services needed to run a Hyperconnected City Logistics system (vehicle fleets, hubs, freight terminals, etc.) enforce the involved participants to collaborate on a large scale. This is in total contrast to city logistic systems that have implemented in use so far also it uses familiar elements.

In detail, the logistics concept includes intermodal freight terminals (distribution centres) in suburban regions (zone 3) and central located city-hubs (zone 2) where the freight is loaded and unloaded.

Suburban distribution centres have been established in many cities enabling a worldwide freight logistics. These terminals are preferably located near the main road network and/or to railway, ship and airplane connections. A large number of goods can be sorted, stored and prepared for further distribution. Due to its location these terminals are not well suited for inner-city freight flow.

Therefore the concept considers a flexible step-by-step integration of several MULE vehicles (section 2.2.) into a comprehensive urban logistics solution. The freight is unloaded from heavy goods vehicles (HGV), depicted red in Fig. 1, loaded on smaller commercial vehicles, depicted green in Fig. 1 and after transportation unloaded in central located city hubs. City hubs are a small freight terminals offering simple loading and unloading capabilities (trans-dock, transhipment) as well as flexible specific B2C and B2B functions. The storage capacity and infrastructure is limited to communication, coordination and weather protection. Typical locations are: underground garages, (previous) coach terminals, parking lots, containers with flexible location, direct loading-unloading. From city hubs further goods transportation in the urban centres (zone 1) could be done by people, cargo bikes or other small (automated) devices.

2.2. MULE vehicles

In the MULE concept two vehicle categories are investigated, depending on the cargo load:

The MULE truck with a gross vehicle weight rating GMVR of 18 tons and the MULE CEP with a gross vehicle weight rating GMVR of 3.5 tons. The MULE vehicles can be driven manually, automated or unmanned, depending on the field of operation and readiness/availability of the (automated driving) technology.

2.2.1. MULE CEP

MULE CEPs are light commercial vehicles for inner-city operation which can operate together with unmanned transport platforms of the same category (active trailers) via an *electronic draw-bar*. They operate from the suburban distribution center or from the city hub mainly in zone 2. When parked, they can also operate as a micro-distribution center where the micro distribution is carried with cargo bikes, people or other (automated) transport devices. After reaching the destination within the vehicle platoon, the last mile can be operated at low speeds unmanned in designated areas in pedestrian areas or modern *smart cities*.

2.2.2. MULE trucks

This vehicle can be operated as a single vehicle or within a vehicle platoon where only the leading vehicles is driven by a human driver and the following vehicle are unmanned. The technologic feasibility of vehicle platooning was already demonstrated in many research projects and an introduction of the MULE concept is feasible within some years, whereas unmanned operation in complex urban areas (level 5) including unmanned loading and unloaded is not foreseen in the next few years. MULE trucks transport goods form the suburban distribution centers to the city hubs. They should not operate primarily in zone 1 but on dedicated roads such as ring roads and others eventually on future roads dedicated for automated transport. These MULE trucks can feature an automated decoupling from the automated vehicle platoon and automated loading and unloading at the city hub depending on the planning of the complete transport and the needed time for loading and unloading.

2.2.3. MULE logistics processes

The MULE logistics concept is designed to grow in complexity with time. In the beginning the MULE logistics concept is designed to operate parallel to conventional distribution logistics, aiming at a future replacement of these. The central idea is automated loading and unloading using the following three stage approach:

- Stage 1: Loading/unloading of complete transport container

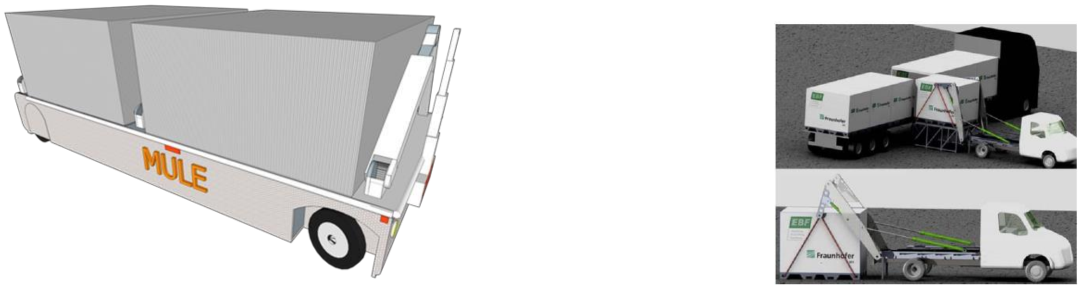

Fig. 2: Mobile loading/unloading devices for the MULE logistics concept
(G. Cebrat (left) http://mule.energie-umwelt.at;
Richter, Poenicke (2015), (right))

This approach requires mobile loading/unloading devices with low invest, see Fig. 2, left picture. The containers should respect standardized dimensions of devices such as ISO-containers. Also loading/unloading from the MULE truck to the MULE CEP vehicle is possible, see Fig. 2 right picture. This concept can operate also as a mobile city-hub. Loading/unloading can be operated manually, semi or fully automated.

- Stage 2: Loading/Unloading of the full content of a container

Fig. 3 Devices loading unloading the full content of a container (TU Graz – ITL/Lindenthal (left); Fritz et al. 2015 (right))

Stage 2 can be realized in mid-term due to higher invest for the automated loading/unloading device, Fig. 3 shows some already presented concepts and prototypes. The level of automation as well as the complexity in logistics is higher compared to stage 1.

- Stage 3: Automated separation during loading/unloading of the container

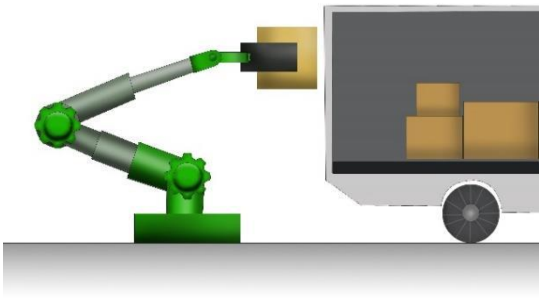

Fig. 4: Device for automated separation during loading and unloading (TU Graz – ITL/Lindenthal)

Separation of goods during fully automated loading/unloading is the long-term variant for the MULE concept due its high complexity, first results of research projects are available, see Fig. 4. In case of automated vehicle operation, personnel is not needed anymore in the complete logistics flow.

2.3. Electric Drive Train Layout of the MULE vehicles

A key factor in electrification of the vehicle drive train is the dimensioning of machine size and battery capacity. The technical challenge is the trade-off between range of operation and costs. In freight transport, the total costs are essential due to the high competition. Over-sized electric drive trains would lead to increased costs compared to standard drive trains with combustion engines. On the other hand in freight transport a detailed planning of the traffic route is possible, thus enabling a much more tailored drive train layout compared to vehicles for individual mobility. Also personnel costs for vehicle operation and loading/unloading are an important factor, both calling for automated solutions. The next section investigates the drive train layout based on a longitudinal dynamics model with measured velocity profiles of two vehicle types, the MULE CEP and the MULE truck. All parameters of the vehicle model are taken from data sheets of component suppliers for electric drive trains including costs, for details see Eichberger et al. (2016).

2.3.1. Vehicle model

A classical longitudinal vehicle dynamics model is used based on the equilibrium of driving force F_A and the driving resistances including the climbing resistance F_S, the air drag F_L, the tyre rolling force F_R, and the acceleration resistance F_T, comprised of the translational and the rotational share, see equations (1).

$$
\begin{aligned}
F_A &= F_S + F_L + F_R + F_T \\
F_T &= F_{Ttrans} + F_{Trot} \\
F_\mathrm{R} &= m_{ges} \cdot \mathrm{g} \cdot a_\mathrm{R} \\
F_\mathrm{L} &= \frac{1}{2} \cdot v^2 \cdot \rho_\mathrm{L} \cdot c_\mathrm{w} \cdot A_\mathrm{F} \\
F_\mathrm{S} &= m_{ges} \cdot \mathrm{g} \cdot \sin(\beta) \\
F_{Ttrans} &= m_{ges} \cdot a \\
F_T &= F_{Ttrans} \cdot \lambda
\end{aligned}
\qquad (1)
$$

Parameters for the total vehicle mass m_{ges}, the tyre rolling resistance factor a_R, the air drag c_W, the face area A_F, air density ρ_L are chosen for two types of vehicles, see Eichberger et al. (2016). The vehicle velocity v is derived from measurements with both vehicle types, see section 2.3.2.

The vehicle is modelled in Matlab Simulink, see Fig. 5, and included models of the

- *Driving cycle*: Velocity profile of the driving cycle. The velocity profile is taken from measurement with commercial vehicles of the MULE CEP and MULE truck size;
- *Driver*: A driver model controlling the pre-defined velocity profile based on a simple P controller with velocity feed forward. The main output of this model is the required machine torque. A detailed description of the vehicle model can be found in Eichberger et al (2016).
- *EMotor*: A model of the electric machine. Inputting the needed torque from the *Driver* block, the battery voltage from the *Battery* block and the rotational speed of the rotor from the *Gearbox* block, it calculates the electrical current and the machine torque. The motor model was adapted from Kraus (2015) for further reference.
- *Gearbox*: A model of the gearbox including gear ratios and factors describing the efficiency of the gearbox;
- *Battery*: A scalable battery model calculating the state of charge of the battery. Needed inputs are the electric current from the *EMotor* model and the driven distance from the *Vehicle* block. It respects the number of the used parallel and serial battery cells. The cell is modelled according to data sheets of a battery supplier. The model outputs the energy consumption E_v, the state of charge *SOC* as well as the battery voltage. The battery model was adapted from Kraus (2015) where a more detailed description is provided.
- *Differential drive*: A model of the differential drive simulating its efficiency;
- *Vehicle*: A model of the vehicle according to equation (1). The second order ordinary differential equation is integrated twice and outputs vehicle velocity and driven distance. The rotational resistance of the gearbox is calculated using an artificial brake force. A detailed description of the vehicle model can be found in Eichberger et al (2016).

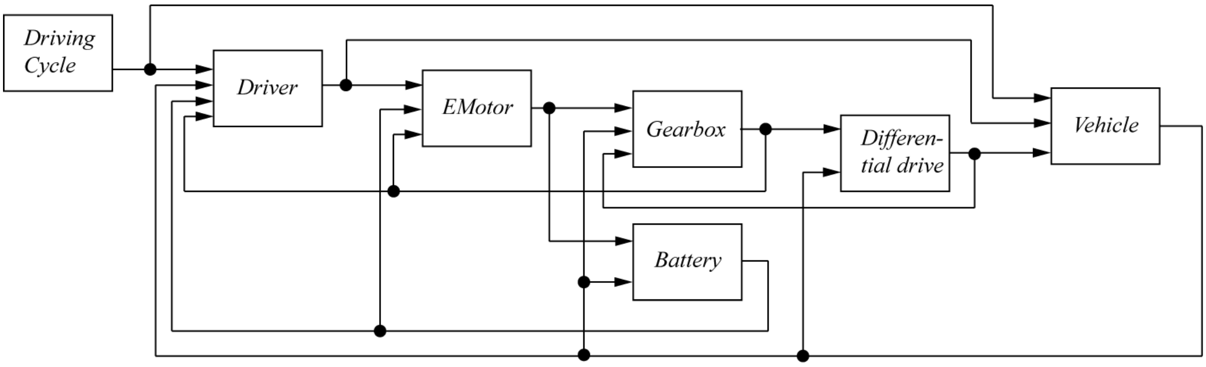

Fig. 5: Main structure of the Simulink vehicle model

2.3.2. Velocity profile

Measurements of commercial vehicles equipped with GPS logging devices during standard operation have been carried out and the velocity profile and the grade of the road is analysed. Data loggers have been installed in commercial vehicles of 3.5 ton class for CEP and 18 ton class for distribution transport. Measurements have been carried out during transports lasting one shift. The different routes is analysed and for each vehicle class a typical route is selected from the available measurements to represent the driving cycle of a real freight transport for each vehicle class. Velocity and height profile have beeen logged at 1Hz sample frequency. Further details can be found in Eichberger et al. (2016). Fig. 6 shows the velocity profile for the two vehicle classes.

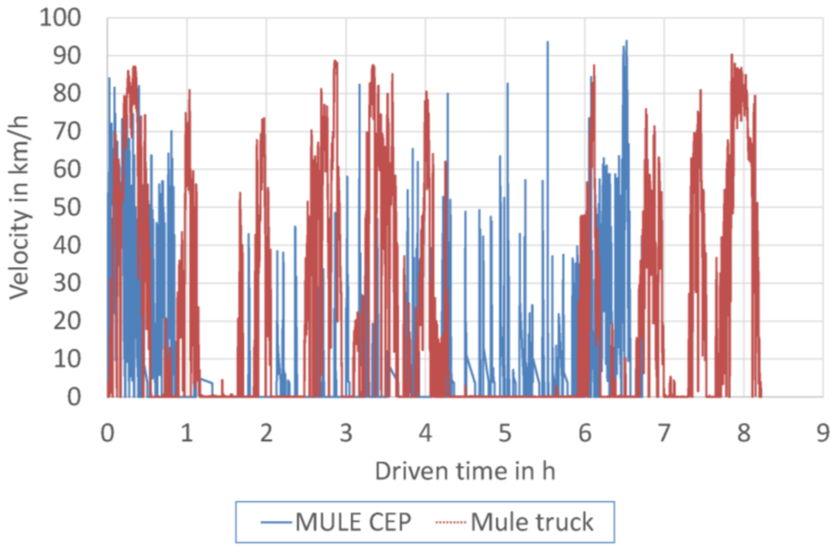

Fig. 6: Velocity profiles of two selected freight transport in the 3.5 and 18 ton vehicle class

3. Results

Using the vehicle model described in section 2.3.1 and the velocity profile in section 2.3.2 the machine and battery size is calculated. Criteria for the machine and battery dimensioning were:

- Battery: After reaching the end of the driving cycle minimum 20% of battery SOC has to be reached;
- Motor performance: the measured velocities have to be reached in a way that there is no significant elongation of the total driving time due to lower acceleration of the tailored power of the electrical motor;

Therefore different dimensions of battery and machines is chosen and compared for the

a) 3.5 ton vehicle class to the reference vehicles Mercedes Sprinter 313 CDI, see Mercedes (2106) and Kreisel Electric, see Kreisel (2016), which is a commercial electric variant of the Mercedes Sprinter.
b) 18 ton vehicle class to the reference vehicles Iveco Stralis, and E Force, see E Force (2016).

3.1.1. Total cost of ownership

For investigation of the costs of the MULE vehicle solution with respect to the electrical drive train, a calculation of the total cost of ownership is done and calculated according to equation (2),

$$C_{\mathrm{tot}} = C_{\mathrm{f1}} + C_{\mathrm{f2}} + C_{\mathrm{v}} \quad , \tag{2}$$

where C_{tot} is the total cost of ownership, C_{f1} is the cost of the electric drive train comprised of battery and the electric machine including further electrical components such as inverters in case of the MULE vehicles. Fixed costs C_{f1} of the reference vehicle is comprised of the combustion engine and gearbox as well as the tank system. Fixed costs C_{f2} is the price of the reference vehicle minus the cost of the conventional drive train. Therefor the price of the “base” vehicle is the same for the MULE and the conventional vehicle. For the electrical reference vehicle C_{f1} plus C_{f2} represents the purchase price.
Variable costs C_V include energy costs (electrical energy or diesel), costs for maintenance and repair as well as taxes related to the motor size and are calculated for each vehicle per driven kilometre using data sheets and literature, for details see Eichberger et al. (2016).

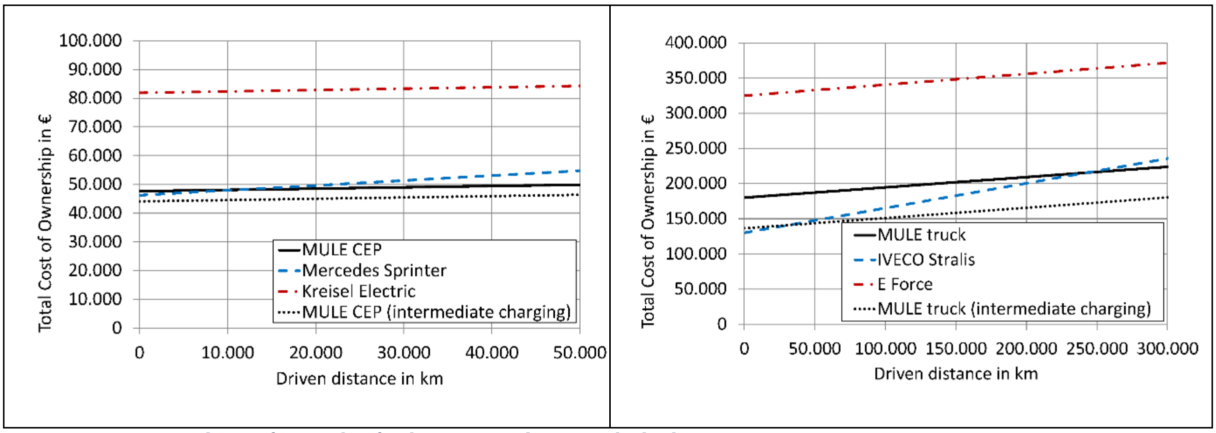

Fig. 7: Comparison total cost of ownership for the 3.5 ton and 18 ton vehicle class

The left picture in Fig. 7 depicts the results for the 3.5 ton vehicle class and the right one the 18 ton vehicle class. It shows that the dimensioning of the available electrical reference vehicle (Kreisel Electric) leads to increased total cost of ownership compared to the “tailored to operation” electric drive train of the MULE concept and conventional commercial vehicles. The MULE CEP is comparable to the reference vehicle with a combustion engine (Mercedes Sprinter) for the 3.5 ton vehicle class. During vehicle life-time the MULE CEP is more cost efficient due to its the lower variable cost of the electrical energy. For the 18 ton vehicle class the MULE truck solution is more expensive compared to the conventional vehicle (IVECO Stralis) but reaches a break even within the lifetime of the vehicle. Another side effect of smaller batteries is the increase in cargo load which is an important argument for the purchase of a commercial vehicle.

Analysing the velocity profile depicted in Fig. 6, it is seen that, due to loading/unloading, many stops of the cargo vehicle are observed. Fig. 8 shows the stop time for each consecutive stop lasting longer than 3 minutes of the vehicles in operation. Each stop is labelled with an increasing number and the total stop time is in sum 37 minutes for the 3.5 ton class in 5 stops and 4 hours for the 18 ton vehicle in total 14 stops.

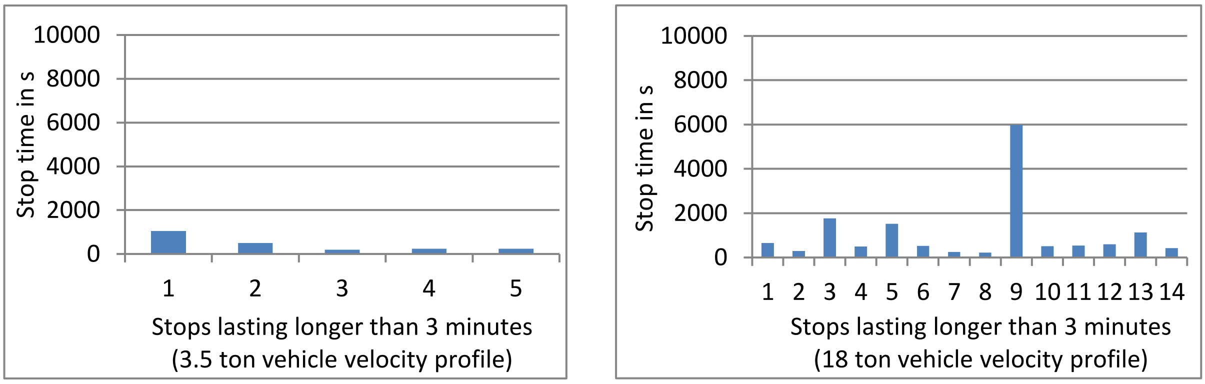

Fig. 8: Stop time analysis for the velocity profiles of the 3.5 and the 18 ton vehicle class

Assuming that stops lasting longer than three minutes can be used for intermediate charging using available charging technologies such as the *Supercharger* concept of Tesla, see Tesla (2016), the dimensioning of the battery size is repeated as well as the TCO calculation with the related smaller batteries. For both vehicle classes the TCO for the MULE CEP with intermediate charging is always lower than for the conventional reference vehicle, see dotted lines for MULE (intermediate charging) in Fig. 7. Especially in the 18 ton class longer stops during loading/unloading and rest periods of the driver were observed which underlines the positive effect of intermediate charging. For the 18 ton class the implementation of the charging infrastructure at distribution centres, city hubs and parking lots for rest periods is also easier.

3.1.2. Environmental impact

Using the vehicle model, the CO_2 emission of both vehicle classes are calculated. The CO_2 emission of electric vehicles depend on electric power generation which is different for each country. For the present project the electricity mix of Austria is used for the calculation of CO_2 emission for electric vehicles, see Österreichs E-Wirtschaft (2016). Fig. 9 depicts the results for both vehicle classes. For the 3.5 ton class the CO_2 emission is reduced from approximately 200 g/km to 22 g/km, for the 18 ton class from 275 g/km to 105 g/km, quantifying the positive effect in the driven routes.

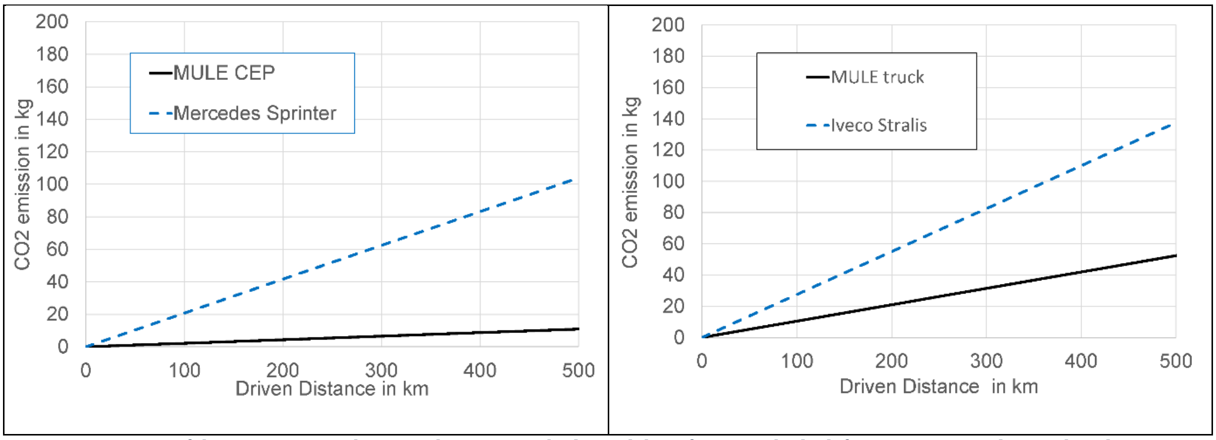

Fig. 9: Comparison of the CO2 emission between the MULE vehicles and the reference vehicle, left picture 3.5 ton class, right side picture 18 ton class.

4. Conclusions

The feasibility of the holistic implementation of the MULE concept is realistic with regard to the concept's cost economy of the electric drive train and simultaneously has a high ecological potential. The overall cost saving potential is the result of combining automated loading concepts and a two-stage (multi-stage) city logistics system. The MULE Concept can form the basis for a two- to multistage city logistics of the future as part of a Hyperconnected City Logistics Concept (in combination with the Physical Internet).

The present article focusses on the layout of the electrical drive train. Based on measurements of freight transports in the vehicle class of 3.5 and 18 tons the electric drive train is designed according to the actual transport performance based on the measured velocity profile of real freight transports. It is shown that state-of-the art electrified vehicles cannot compete against conventional powered vehicles without side-effects such as banning conventional vehicles from inner cities or city toll solutions. However, dimensioning the electric drive train according to the needed driving performance and operation range leads to smaller sized electric machines and batteries which have a comparable total cost of ownership to conventional vehicles. The operation for commercial vehicles is better known compared to individual mobility, because the driven routes can be planned in advance taking into account the available driving range. Using stops for intermediate charging of even smaller sized batteries offers the potential to operate electric driven commercial vehicles at lower costs compared to conventional vehicles. The needed supercharging infrastructure can be realistically provided for the 18 ton class, where the effect is higher than for the CEP transport due to a longer total stop time. In addition the potential of CO_2 reduction is quantified in the present study with approximately 90% for the 3.5 ton vehicle class and 62% for the 18 ton vehicle class. In addition harmful emissions (particles and nitrogen oxides) and noise are drastically reduced by the electric drive train, enhancing inner city quality of life.

The implementation of the MULE vehicles and logistics system can be expected to happen in three stages:

- Short-term (until 2020): electrification of the powertrain and needs-based electric energy storage systems, partially autonomous (autonomous manoeuvring, electric tow-bar, parking pilot and highway chauffeur), utilisation of electric trucks/vans as mobile transhipment units.
- Mid-term (until 2030): novel vehicles as MULE vehicles. Additional creation of stationary and mobile city-hubs with rapid-charging facilities (saving potential with regard to the vehicle and high ecological impact), automated platooning, self-driving and specific infrastructure on defined routes (level 3-4

automated driving), partial integration in transport concepts of the Physical Internet, reserved public parking areas for logistics purposes.
- Long-term (after 2030): additional automation of loading and unloading processes of the vehicles and platooning of vehicles (high ecological impact), self-driving in special modes to full automation (level 4-5 in automated driving), complete integration in Physical Internet solutions.

5. Outlook

Social acceptance as well as the impact of automated driving and automated loading/unloading were also part of the research project and will be presented in subsequent publications.

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The opinions expressed in this paper are those of the authors and are not necessarily those of their affiliated organizations.

6. References

Aichinger, W. (2014). Elektromobilität im Städtischen Wirtschaftsverkehr (Chancen und Handlungsspielräume in den Kommunen) Berlin, August 2014

E-Force Technische Spezifikationen (2105). http://eforce.ch/wp/wp-content/uploads/2013/06/E_FORCE_Fact_Sheet_D_2015.pdf, Datenblatt, 2015, accessed on 12.9.2016.

Crainic, T.G., Montreuil, B.: Physical Internet Enabled Hyperconnected City Logistics. In: Transportation Research Procedia 12 (2016), S. 383–398

Crainic, T.G., Ricciardi, N. ; Storchi, G.: Advanced freight transportation systems for congested urban areas. In: Transportation Research Part C: Emerging Technologies 12 (2004), Nr. 2, S. 119–137

Esser und Kurte (2013). Die Kurier-, Express- und Paketbranche in Deutschland – KEP Studie 2013, Köln

Eichberger A., Tiefengruber, R., Kraus, H., Ackerl, M. Hofstetter, M. Bucher, A., Schadler, M., Hafner, N., 2016. Mobile multifunktionale urbane Logistik-Plattformen mit elektrischem Antrieb. Technical report of work package 300, research project MULE (FFG 850323). Graz University of Technology.

Europäische Kommission (2011). Weißbuch. Fahrplan zu einem einheitlichen europäischen Verkehrsraum – Hin zu einem wettbewerbsorientierten und ressourcenschonenden Verkehrssystem. Brüssel

Fritz, M., Wolfschluckner, A., Landschützer, C. & Jodin, D. 2015 International Conference on Material Handling, Constructions and Logistics. Belgrad: Faculty of Mechanical Engineering, p. 151-156

Gebhart-Graf, Claus, et al (2012). Luftschadstoff-Emissionskataster Baden-Württemberg 2010, Karlsruhe

Iveco Stralis Hi Street Datenblatt (2016). http://www.iveco.com/Germany/collections/technical_sheets/Documents/2015/STRALIS/TOB_HRoad_EuroVI_AEBS/Stralis%20EURO-VI%20-%20AD%20AT%20HI-ROAD%20HI-STREET%20-%204x2%20Fahrgestelle/ADT_HISR_190S31-33-36-40FPD_E6_AEBS.pdf, accessed on 14.9.2016.

Kraus, H., 2016. Development of an Operation Strategy for Plug-in Hybrid Electric Vehicles - Long-term Prediction and Adaptation based on Past Vehicle and Driver Data. Dissertation thesis. Graz University of Technology.

Kreisel Electric Transporter (2016). http://www.kreiselelectric.com/projekte/electric-transporter/, accessed on 12.9.2016.

Mercedes Benz Sprinter, Technische Daten (2016). http://www.mercedes-benz.at/content/austria/mpc/mpc_austria_website/de/home_mpc/van/home/new_vans/models/sprinter_906/panel_van_/data/engines.html, accessed on 29.5.2016.

Richter, K., Poenicke, O.: Wechselbehälter als kombinierter Frachtraum und Energiespeicher für kleinvolumige Wirtschaftsverkehre (IZT-Workshop mit Energieeffizienz-Dienstleistungen). Berlin, 29.04.2015. URL http://docplayer.org/8805840-Dienstleistungen-fuer-die-city-logistik.html – Überprüfungsdatum 2016-11-03

Tesla Supercharger (2016). https://www.tesla.com/supercharger, accessed on 29.8.2016

Österreichs E-Wirtschaft (2016). Österreichischer Strommix, http://oesterreichsenergie.at/daten-fakten/statistik/stromerzeugung.html, accessed on 15.6.2016

UBA – Umweltbundesamt (2012). Daten zum Verkehr, Ausgabe 2012, Dessau