# Virtual Combination of Commercial Vehicle Modules (Virtual Truck) for characterization of future Concepts


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*Abstract*— **The commercial vehicle industry faces new challenges like an upcoming carbon-dioxide legislation, increasing cost pressure and a globally rising transport volume. Evolutionary developed vehicle concepts are reaching their technical borders. The potential of a holistic concept optimization stays unutilized because of largely separated developing processes in the domain of the vehicle, trailer and tire manufacturers. Focusing on concrete transportation tasks of the customer further optimization potential can be utilized. The total cost of ownership (TCO) is the key value for a comprehensive vehicle concept based on these potentials.**

**A tool was developd with the purpose of a generic approach to generate more efficient vehicle concepts for specified customer needs. The user combines virtual commercial vehicle modules, like different tractor and trailer combinations. Each module can be configured individually regarding its dimensions, number of axles, payload, power, etc. to adapt the concept for the transportation task. The virtual vehicle concept is tested via a digital homologation process and the fuel consumption and the TCO are calculated to evaluate the vehicle characteristics.**



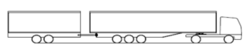
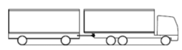
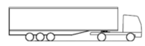
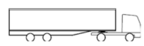
***Keywords—commercial vehicle development; vehicle concept; customer demand; TCO (Total Cost of Ownership); freight transport scenario,***


## I. INTRODUCTION

Because of the design for a variety of applications the optimum commercial vehicle concept for individual transportation tasks stays unrivalled until now. This hypothesis can be answered with the virtual combination of commercial vehicle modules. The method gives the user the possibility to find the optimum solution for his freight transport application and evaluate his vehicle concept regarding legislation and TCO. The method was programmed with Matlab to simplify the computing. To simplify the data input a graphical user interface (GUI) was integrated.

Presently the commercial vehicle market offers a variety of different commercial vehicle concepts. The four most relevant concepts for the German market are the European semi-Trailer (5 axles), the European semi-Trailer (4 axles), the European 'swap body' and the German 'long truck' trail vehicle, cf. [1]. Table 1 displays the maximum permitted weight, the maximum payload mass and the total length of these four vehicles.

Table I: The four most relevant commercial vehicle concepts for the German market according to [1]

| Name | Silhouette | Gross combined mass in t | Payload in t | Overall length in m |
|---|---|---|---|---|
| German 'long truck' trail vehicle |  | 40,0 | 22,5 | 25,25 |
| EU Gliederzug ‚swap-body' |  | 40,0 | 26,3 | 18,75 |
| EU semi-trailer (5 axles) |  | 40,0 | 26,3 | 16,50 |
| EU semi-trailer (4 axles) |  | 38,0 | 24,8 | 16,50 |

The vehicles displayed above are specified for a wide range of transportation tasks or for special volume transportations e.g. the 'long truck' trail vehicle. To achieve a significant decrease of costs, the potentials of weight savings need to be taken into account consequently.

The object of the Virtual Truck method is to find an optimum vehicle concept for freight transportation scenarios, adjusting the dimensions and the dry operational mass to its optimum. Furthermore the tool verifies the computed concept by a digital homologation process. Digital homologation includes verification of the allowed axle load, the legal dimensions and the gross combined mass, according to the legislation [2], [9]. For a holistic approach the low speed swept path of the vehicle is calculated as well as the optimal trailer loading pattern for EUR-pallets, the load distribution plans and the road wear factor [3], [4].

To compare the impact of weight reduction the Virtual Truck-Tool uses the TCO as key figure, focusing on the transport managers needs [5].

The operation of a commercial vehicle is cost intensive. Nearly 2/3 of the TCO can be calculated for variable costs, e.g. road charge, driver costs and operating resources, cf. [6].

With an optimized vehicle concept for certain amount of freight transportation scenarios the costs can be decreased.

## II. MODEL OVERVIEW

The workflow of the Virtual Truck starts with the calculation of the vehicle weight using a parametric weight model. In the next step the fuel consumption is simulated. The results are checked via a digital homologation and a calculation of the TCO, (Figure I).

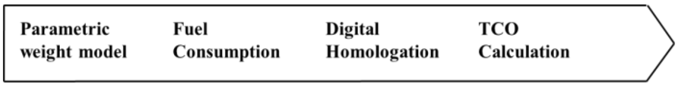



Figure I: Workflow of the characterization method

The programming behind the Tool is object oriented, because every module of a commercial vehicle, e.g. Truck and trailer, can be represented easily in an object class. The user can chose from 17 different modules for building a vehicle concept. It is not necessary to create an object class for every module. A semi-trailer with 1 axle and a semi-trailer with 2 axles belongs to the same object class. But they differ at least in one property, the difference in this example is the number of axles. The 17 modules displayed in the starting GUI are divided in 7 object classes:

- Trailer truck
- Articulated truck
- Semi-trailer
- B-double
- Draw bar trailer
- Rigid bar trailer
- Dolly

All classes are modelled with properties like mass, number of axles, dimensions, etc. Some of the properties are setup with initial values and some of them are calculated during the program run time. After finishing the configuration of the object's properties the program uses the created object to continue with the workflow. The object orientation allows the Virtual Truck to create as many objects as wanted during the program run time.
With the described object classes and the setup of the properties it is possible to rebuild all the vehicles shown in Table I.

## III. PARAMETRIC WEIGHT MODEL

The Virtual Truck method uses a top down approach to configure a parametric vehicle weight model. In Level 1 the user combines the vehicle modules, after selecting a tractive unit and trailer combination, each module of the combination can be configured in Level 2. Based on growth functions of the main components in Level 3 the tool calculates the weight of the setup vehicle concept in the background, (Figure II). The configuration of each module allows a fine adjustment of the vehicles combined gross mass and is the basis for a weight optimization derived from payload and loading volume.

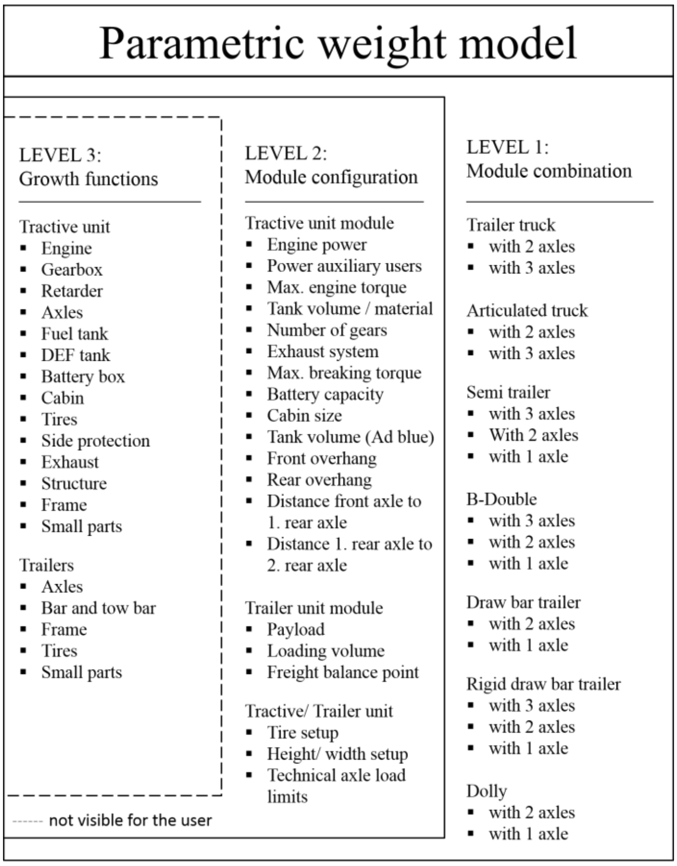



Figure II: Setup of parametric weight model

### A. Growth functions

The Level 3 layer is not visible for the user. The growth functions behind Level 3 are derived from a database of component weights using regression analysis. Figure III shows the weight curve of the trailer truck rear axle for heavy duty vehicles.

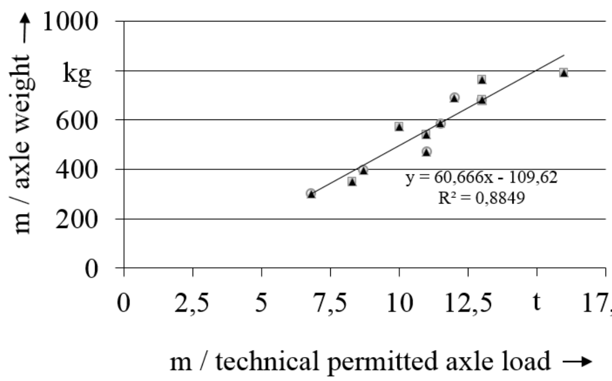



Figure III: Growth function for the mass of the driven rear axle of heavy duty trucks

The analysed vehicle classes are in the range from 12 t to 40 t gross combined mass. Rear axles from two different german OEMs were researched from data sheets, spare parts distributions and [11] to setup a database. In Figure III the results of the rear axle research were put together with axle weight in kilograms [kg] over technical permitted axle load in metric tons [t]. The Mathematical operation of linear regression gives a solution for the trailer truck rear axle growth function. The function shows a linear growth trend because the axles from the different weight classes are designed for linear increase of the payload, including linear dimensioning of the brakes and the drivetrain components, e.g. the differential.

An example for a nonlinear growth function is the weight curve of the gearbox. Figure IV shows the weight [m] of the gearbox in kg over the number of gears times the maximum input torque [Z*Nm].

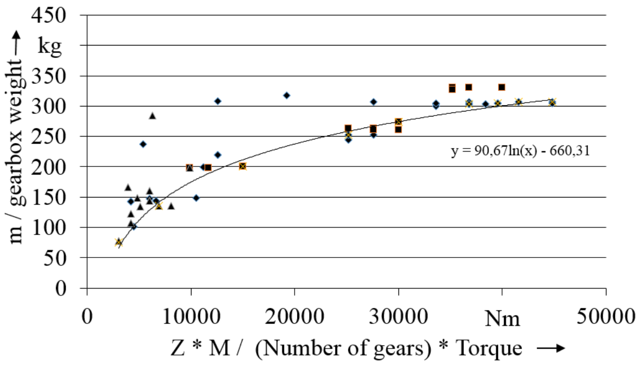



Figure IV: Growth function for the mass of the gearbox of heavy duty trucks

The collected data of the gearboxes were not explicit. One North American gearbox manufacturer was in average 100 kg heavier than the other OEMs. This is because of the usage of cast iron housings and heavier dual disc clutches instead of aluminium alloy housings and a single disc clutch, which are standard in European designs. Because of that the data were not taken into account for the growth function.

Two OEMs are using the gearboxes from the same supplier, that for, the weighting criteria for this data was adapted.

Another difficulty to get the original growth function was the labelling of the gearboxes from one OEM. The gearboxes were provided in the different vehicle classes with different labels, but the weight of the gearboxes was often the same. For not distorting the growth function the gearboxes of this OEM were clustered in three weight groups. The gearbox with the highest available torque of each cluster was taken to derivate the growth function.

The function displayed in Figure 4 shows a logarithmic growth trend because of the arrangement of the gear wheels and the layshafts depending on the design for the transmission forces in the gearboxes, as well as the target weighting of the OEMs. The Result of the OEM gearbox design is a limiting weight curve that is equal to the growth function.

Growth functions were built up for all LEVEL 3 components, and implemented in the programing. Consequently the dimensioning of the vehicle modules gives an exact weight value.

### *B. Validation of the parametric weight model*

Within the borders of interpolation the Virtual Truck method can be taken to calculate the optimum vehicle weight. The approach of adapting the vehicle to a given freight transportation scenario leads to a vehicle downsizing within the interpolation borders.

To validate the parametric weight model, available trucks from the heavy duty market were rebuilt using Virtual Truck to compare the result and calculate the deviation of the model to real vehicles. Figure V shows the validation of the trailer truck weight model.

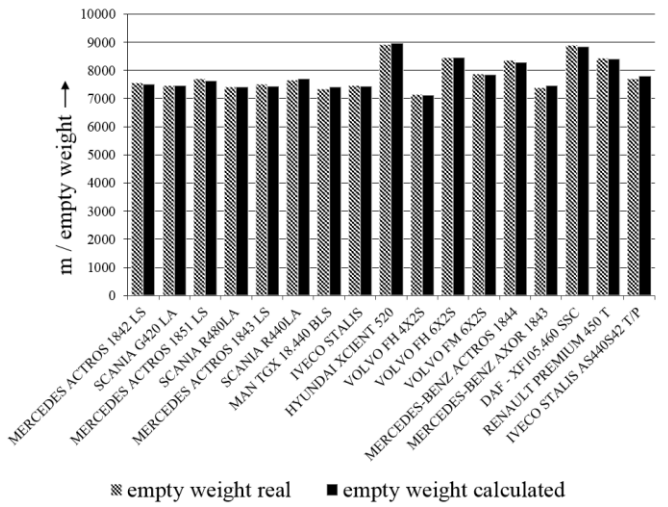



Figure V: Validation of the parametric weight model, e.g. tractor weight

To measure the forecasting quality of the Virtual Truck two basic methods of the error analysis were used. The Mean Absolute Error (MAE) gives the mean absolute deviation of the forecasted value. MAE = 0 can be interpreted as the perfect forecast, i.e. the real weight value is equal to the calculated weight for every sample. The second measure of quality is the Mean Percentage Error (MPE). The MPE gives the mean relative Deviation of the forecasted to the actual value. It is also known as mean percentage deviation. Both indicators are a measure of quality.

The analysis method of MPA and MPE is according to [15].

$\hat{x}_t$: forcasted value, t = 1,...,T

$x_t$: *actual value*, t = 1,...,T

$T$: *total number of samples*

MEAN ABSOLUTE ERROR (MAE):

$$MAE = \frac{1}{T}\sum_{t=1}^{T} |\widehat{x_t} - x_t| \tag{1}$$

MEAN PERCENTAGE ERROR (MPE):

$$MPE = \frac{1}{T}\sum_{t=1}^{T} \frac{(\widehat{x_t} - x_t)}{x_t} \tag{2}$$

The statistical Analysis of the weight models for all object classes used in the Virtual Truck tool are displayed in table II.

Table II: Statistical analysis: empty weight real data – empty weight calculated

| Object Class | Sample Size | MAE [kg] | MPE [%] |
|---|---|---|---|
| Trailer Truck | 12 | 34.67 | 0.1451323 |
| Articulated Truck | 13 | 65.54 | -0.0984497 |
| Semi trailer | 8 | 105.5 | -0.8551483 |
| B-Double | n < 5 | (* | (* |
| Draw bar trailer | 8 | 123.89 | -0.1194815 |
| Rigid draw bar trailer | 8 | 206.88 | 2.2701999 |
| Dolly | n < 5 | (* | (* |

(* Sample Size is to little for a valid Analysis

The modules for B-Double and Dolly are not validated yet, because of the little sample size (n < 5). The other Modules have a Mean Absolute Error between 34.67 kg and 206.88 kg. That corresponds with a Mean Percentage Error between 2.27% and -0.86%.

## IV. FUEL CONSUMPTION

After the digital selection and adjustment of the vehicle modules the combined gross mass and the selected engine settings are put together in a longitudinal dynamics simulation to compute the average fuel consumption of the vehicle concept.
The simulation model uses the driving cycle 'Trucker Runde' which is used for the popular 'VerkehrRundschau' truck tests, [12]. This course combines typical German federal roads and Autobahn parts for representative and comparable fuel consumption data (Figure VI). The track data were measured with GPS, gyroscope and CAN-Bus data logging in 2013 by the Institute of Automotive Technology.

Figure VI shows the 'Trucker Runde' divided in 5 Stages.

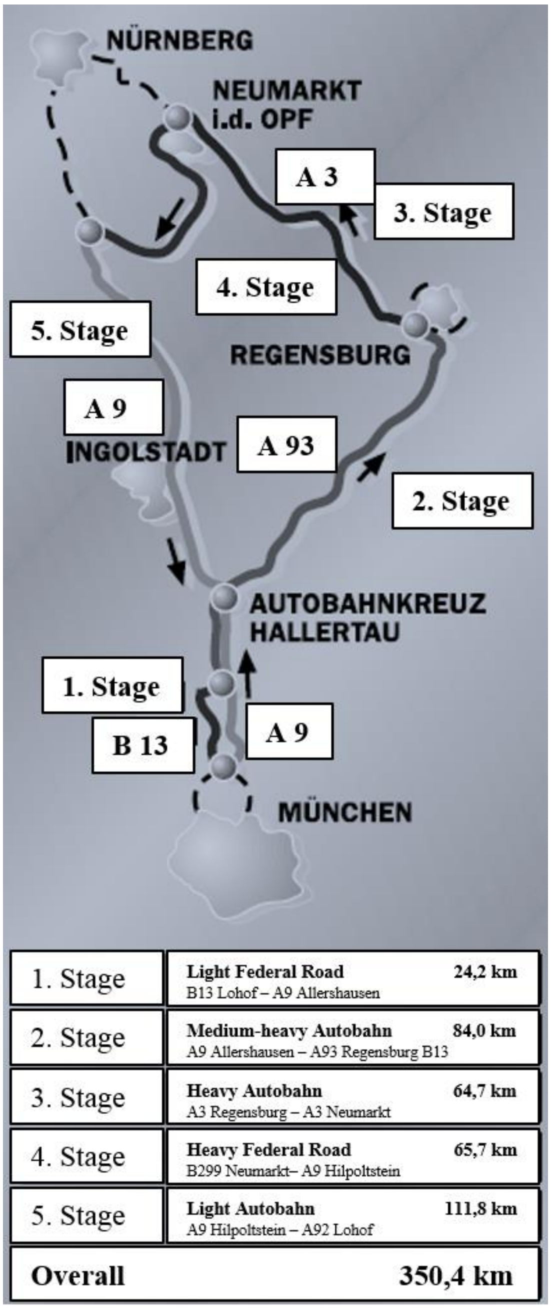



Figure VI: Driving cycle used for fuel consumption simulation, cf. [12]

The fuel consumption simulation model was setup up and validated according to [13].

## V. DIGITAL HOMOLOGATION

The dimensions, axle loads, road wear factor, and the low-speed swept path of the created vehicle concept are verified via a digital homologation process. The legislation in [2], [9] and [10] is giving the requirements to pass the homologation.

### *A. Legal Conformity*

One central part of the concept-tool in display is the verification of compliance with concept-sensing laws stated in EU and German regulations [2], [9] and [10]. These are the vehicle dimensions and weights, including axle mass, gross vehicle and gross combination mass as well as external and internal dimensions. Dimensions with legal relevance are: length (overall combination and single vehicle length as well as the loading area), width, height, coupling lengths and the swivel radius on trailers. Compliance with axle mass limits depending on axle spacing for driven and non-driven axles is also checked. Another aspect is the minimum engine power per gross combination weight where the fulfilment of minimum legal requirements is assured. Within the concept development tool the accomplishment of legal requirements is shown to the user via a traffic-light-like overview.

### *B. Low-speed swept analysis*

Another important legal aspect regarding new vehicle combinations and configurations is the compliance with low speed swept path regulations. German law [10], and European law as well [2], has some quite strict regulations for the manoeuvring performance of vehicle combinations in tight corners. This is important for trouble free operation in all junctions and turning points. For on-line testing of developed vehicle combinations the concept tool has an incorporated sub-program where low speed swept paths can be calculated for all practical combinations. This sub-program has been custom built especially for the evaluation of new longer vehicle concepts with the application of force- or self-steered axles or self- or forced steering dolly trailers cf. Figure VII.

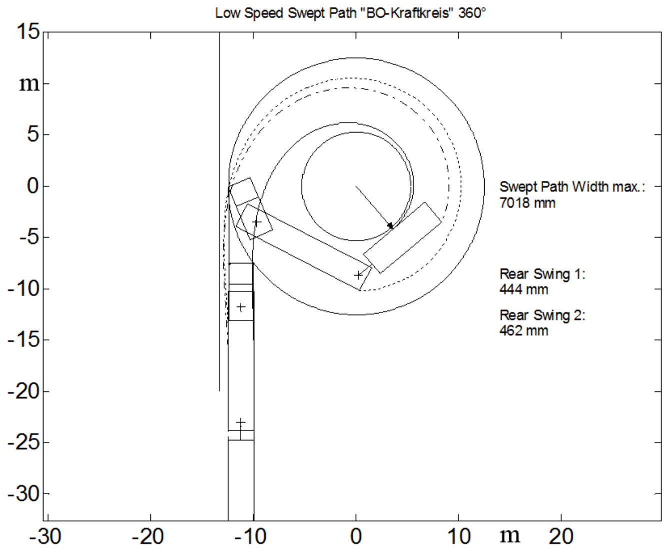



Figure VII: Simulation of low speed swept path for longer vehicle combination (e.g. German long truck type 2)

### *C. Load distribution plan and loading pattern for standard pallets*

To assure the usability of the designed concept the load distribution plan is calculated for all parts of the vehicle combination. This is important to eliminate 'impossible' concepts, where the loading capability cannot be used legally because of overloading of axles or compromised driving safety because of unstable driving characteristics.

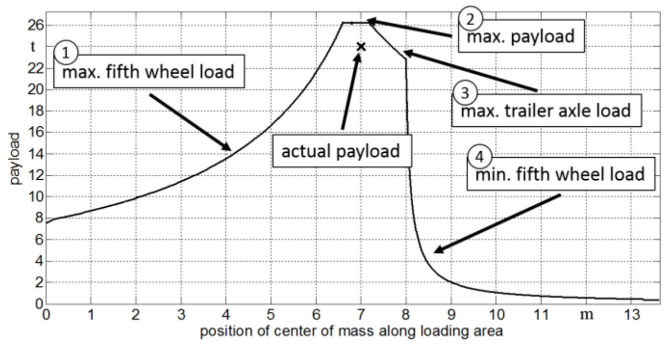



Figure VIII: Load distribution plan for standard European semi-trailer

Figure VIII shows a load distribution plan for a standard European 40 t semi-trailer. The limiting curves are (from left to right): the maximum vertical load on the tractors fifth wheel (1), the maximum payload (2), the maximum permitted load on the trailer axles (3) and the minimum vertical load on the tractors fifth wheel coupling (4). For combinations with more than one trailer these curves are calculated for each module and possible load transfer from vertical loads on coupling devices is taken into account.

Another crucial point for the usability of a commercial vehicle concept is the compatibility with standard load carriers like EUR-pallets or lattice boxes. To check this compatibility for newly designed concepts a calculation tool for loading patterns is incorporated into the Virtual Truck method. The result for the loading pattern with EUR-pallets on a standard European 13.60 m semi-trailer is shown in Figure IX:

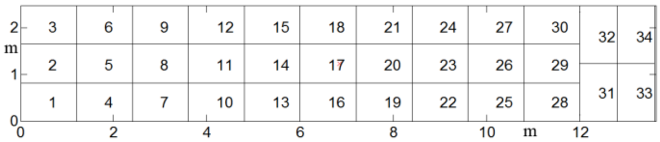



Figure IX: Loading pattern for EUR-pallets on standard European semi-trailer

### *D. Road wear factor*

For objective comparison of vehicle concepts in terms of road wear the ‘road wear factor’ is calculated for every combination in accordance to [14]. The ‘road wear factor’ is a non-dimensional, relative number which quantifies the expected impact on paved infrastructure of a vehicle combination by a calculated multiplier of a reference axle of 10 tons axle load and a known tyre set. This reference axle is a dual-wheeled, 10 t rigid trailer axle with air suspension. For the concept analysis, the ‘axle wear factor’ is calculated for every axle of the combination from the ‘tyre configuration factor’ and the ‘load equivalency factor’. The Load Equivalency Factor takes the actual axle load into account whereas the Tyre Configuration Factor focuses on the contact area width and the overall diameter of the tyres on the axle.

TYRE CONFIGURATION FACTOR (TCF):

$$TCF = \left(\frac{width}{470}\right)^{-1,65} \text{ x } \left(\frac{diameter}{1059}\right)^{-1,12} \quad (4)$$

LOAD EQUIVALENCY FACTOR (LEF):

$$LEF = \left(\frac{axle\ load}{10}\right)^{2} \quad (5)$$

AXLE LOAD FACTOR (ALF):

$$AWF = TCF \ x \ \ LWF \quad (6)$$

VEHICLE WEAR FACTOR (VWF):

$$VWF = \sum_{i=1}^{n} AWF_i \quad , \ n = number\ axles \quad (7)$$

For the vehicle combination the axle wear factors of all axles are summed up to form the vehicle wear factor which can be compared for different combinations. For example a European standard 40 t 5-axle semi-trailer combination with typical tyre equipment has a vehicle wear factor of 6.28 [16]

## VI. TCO

A TCO approach is used to get a general overview of all costs, the fleet manger has to pay for during the vehicle’s lifetime. They are the key figure to compare vehicle concepts including all efficiency influences.
The TCO are calculated via a separation in variable and fix costs using the methods described in [6]. Table III and IV show the most relevant of the assumed figures used for the TCO calculation and the general boundary conditions according to [6]. For calculating the toll, the new fees as from October 2015 for German federal roads have been used.

Table III: Fixed cost items according to [6]

| **Post** | **Characteristics** |
|---|---|
| Average distance per year | 130.000 km |
| Usage | Tractor: 6 years<br>Trailer: 12 years |
| Taxes | Tractor: 556 € / year<br>Trailer: 373 € / year |
| Insurances | 5500 € / year |
| Interest | 5,5 % |
| Driver costs overall | 51.115 € / year, including wages, expenses, social benefits |

Table IV: Variable cost items according to [6]

| Post | Characteristics |
|---|---|
| Fuel | 1,13 € / l (german average 2014) |
| Diesel Exhaust Fluid | 0,35 € / l<br>5 % on Fuel consumption |
| Lubricants | 1 % on fuel costs |
| Tyres | Tractor: 400 € per unit, 160.000 km longevity<br>Trailer: 350 € per unit, 200.000 km longevity |
| Toll<br>(future fees fom october 2015) | 0,113 € / km 3 axles, Euro 6<br>0,117 € / km 4 axles, Euro 6<br>0,135 € / km 4+ axles, Euro 6 |
| Maintenance and repair | 0,06 € / km |
| Management | 10 % on overall TCO |

## VII. RESULTS (USE CASES)

The efficiency of commercial vehicle concepts depends strongly on the transported freight. To build up a realistic scenario the observations according to [7], Annex A were analysed and put together in Figure X.

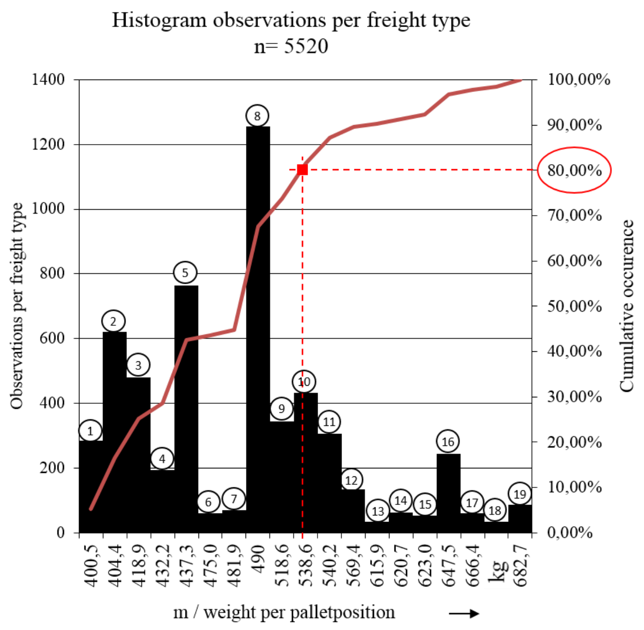
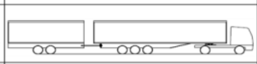
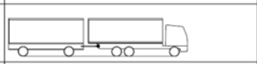
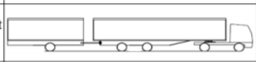



Figure X: Observations per freight type according to [7]

Figure X shows that nearly 80 % of all observed transported freights are below 540 kg per pallet position. Therefore 540 kg per pallet position is the mean payload value assumed in the use case. The maximum value for one pallet position assumed is 700 kg per pallet position, because all-round vehicles like the semi trailer (5 axles) and the EU Gliederzug are designed for a wide range of transportation tasks including 700 kg per pallet position. The area of application for the german 'long truck' as presented in Table I and V is around 400 kg per pallet position, for example moulding injection parts used in the automotive industry are typical transportation goods in this weight class. The three identified weights are used to analyse the vehicle concepts available on the german market, as shown in Table I. Furthermore three extra concepts have been developed with the Virtual Truck to show the potential of optimally designed commercial vehicles. Table V shows all concepts that were built up and simulated with the Virtual Truck Method.

Table V: Properties of the simulated vehicle concepts

| Name | Silhouette | Gross Combined Mass in t | Payload in t | Max. Capacity of EUR-Pallets | Overall Length in m |
|---|---|---|---|---|---|
| German 'long truck' trail vehicle |  | 40,0 | 22,5 | 53 | 25,25 |
| EU Gliederzug ‚swap-body' |  | 40,0 | 26,3 | 38 | 18,75 |
| EU semi-trailer (5 axles) |  | 40,0 | 26,3 | 34 | 16,50 |
| EU semi-trailer (4 axles) |  | 38,0 | 24,8 | 34 | 16,50 |
| Optimized Concept 'long truck' |  | 40,0 | 24,0 | 45 | 21,0 |
| optimized 'Euro-Trailer' 14,90 m (4 axles) |  | 38,0 | 24,5 | 37 | 17,80 |
| 12,80 m ultra-light trailer (3 axles) |  | 28,0 | 17,0 | 32 | 15,70 |

With the Virtual Truck method an optimized 'long truck' concept was identified with less capacity but designed for a bigger range of transport applications than the german 'long truck' trial vehicle. The second optimized concept is a Euro Trailer. It longer than the regular semi-trailer and using less axles with a trailer length of 14,9m instead of 13,6m. The third optimized vehicle concept is an ultra-light trailer with 3 axles and 32 pallet positions (Table V).

The simulated vehicle concepts from table V were analysed in two categories. The first category is transport efficiency calculated in [l / (100t*km)] and [l / (100m³*km)]. The second category is from a fleet manager's point of view, to compare the costs of the vehicle concepts.

### A. Transport efficiency results

Transport efficiency is a performance characteristic in the logistics to indicate the ratio of energy consumption to the capacity of transportation systems.

The 7 vehicle concepts from Table V were simulated with varying weights per pallet position to identify energy saving potential. Figure XI displays the energy consumption in litres per 100 tonne-kilometres.

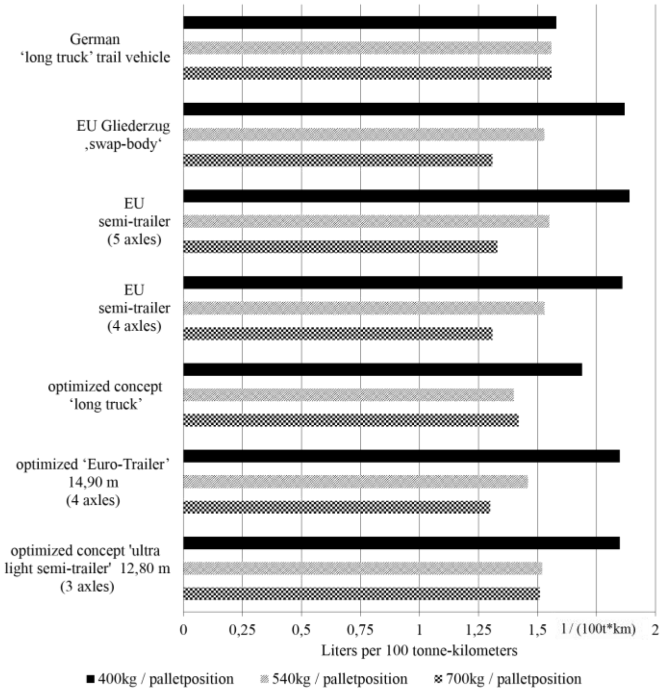



Figure XI: TRANSPORT EFFICIENCY IN LITRES PER 100 TONNE-KILOMETRES

The optimized vehicle concepts are between 2 to 10 % [l/100t*km] more efficient in comparison to the common german vehicle concepts, regarding 540 kg per pallet position. Figure XII shows the results in litres per 100 $m^3$-kilometres.

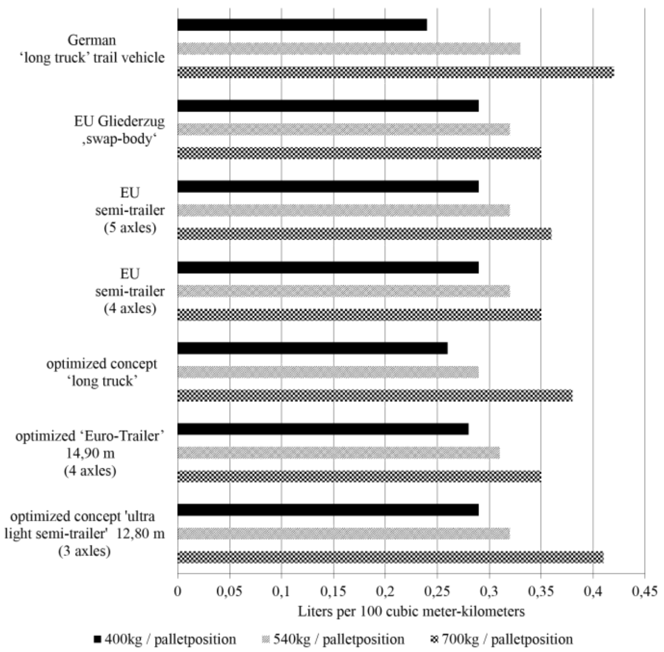


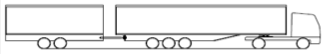
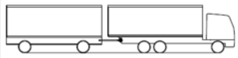
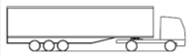
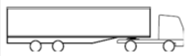
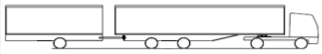
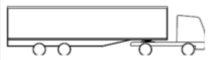
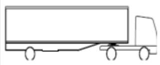

Figure XII: TRANSPORT EFFICIENCY IN LITRES PER 100 CUBIC METRE-KILOMETRES

The savings of the optimized concepts regarding the transported volume are not as significant as the savings regarding the payload.
The results from Figure XII show fuel consumption savings from 0 % to 9 % of the optimized vehicles, in the 540 kg per pallets position weight class.

### *B. TCO results*

For the calculation of the TCO in the presented use case the purchasing prices had been estimated using data from [6]. According to the TCO calculation in [6] the depreciation of fixed assets contributes to the TCO with 9 % and therefore small deviations in the estimation of the purchase prices are acceptable. Table VI shows the results for the concepts.

Table VI: Estimated purchase prices for evaluated concepts

| **Name** | **Silhouette** | **Purchasing Price in €** |
|---|---|---|
| German 'long truck' trail vehicle |  | 150.000 € |
| EU Gliederzug ‚swap-body' |  | 125.000 € |
| EU semi-trailer (5 axles) |  | 120.000 € |
| EU semi-trailer (4 axles) |  | 115.000 € |
| Optimized Concept 'long truck' |  | 145.000 € |
| optimized 'Euro-Trailer' 14,90 m (4 axles) |  | 120.000 € |
| 12,80 m ultra-light trailer (3 axles) |  | 115.000 € |

The results in Euro per 100tonne-kilometres and Euro per $100m^3$-kilometres are calculated with the TCO assumptions from tables III and IV according to [6]. Figure XIII shows the TCO in [€/100t*km].

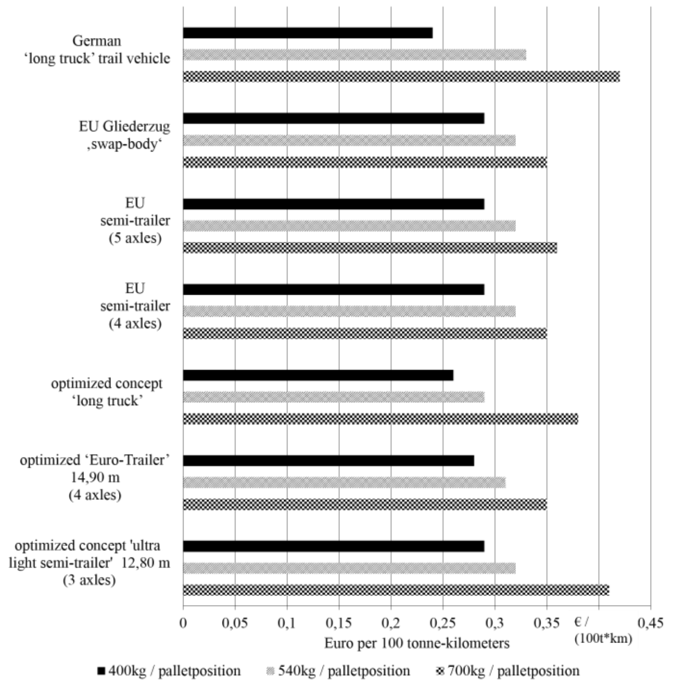



Figure XIII TCO IN
EURO PER 100 TONNE-KILOMETRES

The biggest cost saving potential, carrying goods of 540 kg per pallet position, is between operating an optimized 'long truck' (5 axles) instead of an EU semi-trailer (5 axles). The cost saving potential is around 13%. Comparing the optimized Euro Trailer (4 axles) with the regular semi-trailer (5 axles) the saving potential is still around 9% with carrying 540kg per pallet position.

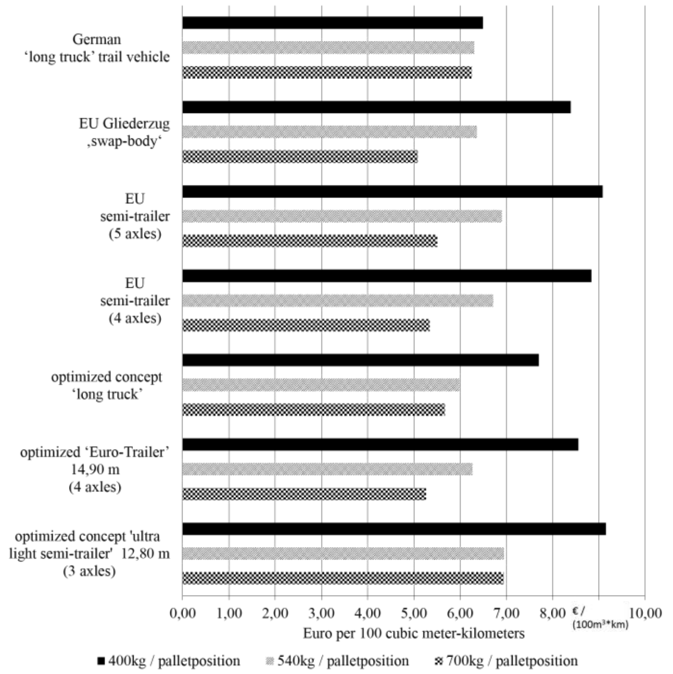



Figure XIV: TCO IN
EURO PER 100 CUBIC METRE-KILOMETRES

In Figure XIV the saving potential in [€/100m$^3$*km] is displayed.

All following comparison are in the weight class of 540 kg per pallet position.

The optimized 'long truck' saves 13% in comparison to the semi-trailer (5 axles). The Euro-Trailer (4 axles) saves 7% compared with the semi-trailer (5 axles).

## VIII. SUMMARY AND DISCUSSION

The hypothesis from the beginning "because of the design for a variety of applications the optimum commercial vehicle concept for individual transportation tasks stays unrivalled until now" could be proofed in the use case. The assumed individual transport scenario is derived from the statistics according to [7]. Therefore the vehicle concepts were optimized for transported goods with a maximum weight of 540 kg per pallet position.

To find a better vehicle concept the Virtual Truck method was used. The integrated weight model gives the user the opportunity to adapt the vehicle concept to its optimum payload. The gross combined mass is used to simulate the fuel consumption.

The digital homologation makes sure that the vehicle concepts are within the requirements of the legislation

The results of the use case show that savings of 5 % to 13 % in Euro per 100 tonne-kilometres and Euro per 100 cubic metre-kilometres can be achieved with new vehicle concepts, regarding a transportation scenario with 540kg per pallet position.

One point that needs to be discussed is the manually configuration of the truck modules. For a fully automated optimisation the adapting of the dimension can be done by an algorithm.

The cost estimation can be done more precisely. Therefore it is necessary to have more information about the OEM cost structure to build up a precise purchase price.

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Annex A: Observation of transported goods on german roads according to [7], number of observations = 5520

| lfd. Nr. | Gutart | Gewicht pro Palettenstellplatz [kg] | Anzahl Beobachtung |
|---|---|---|---|
| 1 | Kartoffeln, Frische Früchte, frisches und gefrorenes Gemüse | 400,5 | 285 |
| 2 | Fahrzeuge, Landwirtschaftliche Maschinen, Elektrotechnische Erzeugnisse, andere Maschinen | 404,4 | 622 |
| 3 | Besondere Transportgüter (einschl. Sammel- und Stückgut) | 418,9 | 480 |
| 4 | Baukonstruktionen aus Metall,EBM-Waren | 432,2 | 193 |
| 5 | Leder, Lederwaren, Textilien, Bekleidung, Sonstige Halb- und Fertigwaren | 437,3 | 765 |
| 6 | Spinnstoffe und textile Abfälle, Sonstige pflanzliche, tierische und verwandte Rohstoffe | 475,0 | 61 |
| 7 | Glas, Glaswaren, feinkeramische u.ä. mineralische Erzeugnisse | 481,9 | 69 |
| 8 | Zucker, Genussmittel und Nahrungsmittelzubereitungen a.n.g., Getränke, Fleisch, Fische, Fleisch- und Fisch- und Fischwaren, Getreide-, Obst- und Gemüseerzeugnisse, Hopfen, Futtermittel | 490 | 1255 |
| 9 | Chemische Grundstoffe (ausgenommen Aluminiumoxyd und -hydroxyd), Aluminiumoxyd und -hydroxyd, Sonstige chemische Erzeugnisse (einschl. Stärke) | 518,6 | 345 |
| 10 | Roheisen, Ferrolegierungen, Rohstahl, Stahlhalbzeug, Stahlbleche, Bandstahl, Weißblech und -band, Stab- und Formstahl, Draht, Eisenbahnoberbaumaterial, NE-Metalle und NE-Metallhalbzeug, Rohre u.ä. aus Stahl, rohe Gießereierzeugnisse und Schmiedestücke | 538,6 | 432 |
| 11 | Zement und Kalk, Sonstige mineralische Baustoffe u.ä. (ausgenommen Glas) | 540,2 | 306 |
| 12 | Holz und Kork | 569,4 | 134 |
| 13 | Ölsaaten, Ölfrüchte, pflanzliche und tierische Öle | 615,9 | 34 |
| 14 | Zellstoff und Altpapier | 620,7 | 62 |
| 15 | Eisenerze (ausgenommen Schwefelkiesabbrände), Eisen- und Stahlabfälle und -schrott, Schwefelkiesabbrände | 623,0 | 52 |
| 16 | Sand, Kies, Bims, Ton, Schlacken, Sonstige Steine, Erden und verwandte Rohmineralien, Gips | 647,5 | 245 |
| 17 | Getreide | 666,4 | 60 |
| 18 | Natürliche Düngemittel, Chemische Düngemittel | 678,2 | 33 |
| 19 | Kraftstoffe und Heizöl, Mineralölerzeugnisse, a.n.g. | 682,7 | 87 |