

Constant Speed Evaluation Tool VECTO-CSE V2.01

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User Manual

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Constant Speed Evaluation Tool
VECTO-CSE V2.01
Technical Documentation

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1. Introduction

A first version of a tool for evaluation of constant speed tests has already been developed in 2012 by TUG in a project sponsored by DG JRC. This software was named “VECTO Constant Speed Evaluation tool” Version 1.0 or short “CSE 1.0” and was distributed to all members of the HDV CO₂ advisory group. CSE V1.0 was applied during the Proof of Concept phase of the LOT3 project in 2012 and 2013.

Caused by the further development of the aerodynamic drag test procedure a major update of the evaluation tool was required. This update is released with VECTO-CSE V2.01. This software tool is compatible with the latest version of the technical annex.

The main changes of VECTO-CSE 2.01 compared to VECTO-CSE 1.0 are:

- All kinds of test track layouts with any configuration of measurement sections¹ and driving directions are supported.
- As methods for identification whether the vehicle is inside a measurement section either:
 - a combination of opto-electronic barriers with a GPS device or
 - a high precision DGPS systemcan be used.
- The foreseen calibration procedures for signals from the mobile anemometer and for vehicle speed are performed by the tool automatically.
- The algorithms are adapted to automatically evaluate the combination a “high speed test” and two “low speed tests” (one before and one after the high speed test) for each combination of measurement section and driving direction.
- All validity checks as specified in the technical annex which have to be passed to get approved results (e.g. for ambient conditions, stability criteria during constant speed phases) are considered in the test evaluation.

The tool as released in May 2014 is designed as an “engineering version”, where still some parameters or settings used in the evaluation can be modified by the user. This software shall be used in the ongoing process of elaborating the final details of the constant speed test procedure in 2014. Once all details of the official test procedure have been defined, a VECTO-CSE “declaration version” shall be generated, where all evaluation parameters are fixed to the exactly as specified in the regulations.

VECTO CSE V2.01 will be further tested based on the data from the Evobus and DAF measurements during April 2014. An updated version V2.1 is expected for summer 2014.

¹ Measurement sections (abbrev.: MS) define the part of the test track where the recorded signals are analysed in the evaluations.

2. Structure of the software

The CSE-Tool is written in VB.Net and delivered as executable file and Visual Studio 2010 project with commented source code. The CSE-Tool is a portable application, i.e. it is not necessary to run a setup procedure for installation. The executive file can be run from any place on a computer or in a network. More details on how to operate VECTO-CSE can be found in section 6.

3. Input data and file structures

This section gives a detailed description of the input data and the file structure required for VECTO-CSE.

3.1. General conventions

All files read or written by VECTO-CSE follow the *.csv format with

- the dot „. “ as decimal separator and
- the comma „, “ as the list separator.

Lines starting with „c_“ or „C_“(= c or C, not case sensitive, followed by a space character) are interpreted as comment lines and ignored in the input routines. Such comments can be placed at any line of the CSE input files.

The VECTO-CSE software uses certain extensions for certain file-types. This approach allows for quick browsing for specific data. However, any kinds of extensions can be used for input files as long as they are correctly specified in the Job file.

3.2. Overview input files

Table 1 gives an overview on all input files handled by VECTO-CSE.

Table 1: Overview input files

File type	Default extension	Explanation
vehicle	*.csveh	contains relevant information on the tested vehicle configuration (e.g. vehicle test mass, anemometer height)
ambient conditions	*.csamb	contains ambient conditions as measured by the stationary weather station
configuration file for measurement sections (“ms config”)	*.csms	contains the configuration of the measurement sections (coordinates, driving directions etc.) on the test track. The measurement sections can be configured for the calibration run and the measurement runs separately.

File type	Default extension	Explanation
measurement data	*.csdat	contains the measurement data recorded at the vehicle consolidated in 100Hz. Separate input files are required by CSE for: i.) the calibration run (during warm up of the vehicle) ii.) the first low speed run iii.) the high speed run iv.) the second low speed run Similar file formats are used for i.) to iv.)
altitude profile (optional)	*.csalt	contains the altitude profile on the measurement sections. This data is used for the correction of traction force for gradient influence in the evaluation if the related feature is activated in the VECTO-CSE GUI
job	*.csjob	contains all information for a test evaluation (evaluation settings, paths to input data). The job file is automatically created if VECTO-CSE is operated via the user interface but can also be generated or edited e.g. by means of a text editor.

3.3. Vehicle file (*.csveh)

The vehicle file contains the relevant information on the vehicle configuration. Figure 1 shows the structure of the vehicle file.

row nr.	c VECTO-CSE vehicle file
	c vehicle class code (1-17; 21-23)
1	4
	c vehicle configuration (0=rigid; 1=truck/tractor&trailer)
2	1
	c vehicle test mass [kg]
3	15000
	c wheels inertia [kgm ²]
4	100
	c axle ratio [-]
5	4
	c gear ratio high speed [-]
6	1
	c gear ratio low speed [-]
7	5
	c anemometer height [m]
8	4.96
	c vehicle height [m]
9	3.72
	c vehicle width [m]
10	2.55

Figure 1: Structure of the vehicle file

The data to be specified is:

- Row 1: Vehicle class code according to the HDV CO₂ segmentation matrix (1-17 for trucks and 21-23 for busses); (no unit)
- Row 2: If the vehicle was measured with (1) or without trailer (0) (no unit)

The combination of values in row 1 and 2 is the criteria for allocation of generic data for C_dxA dependency on beta.

- Row 3: Vehicle test mass during measurements (unit: [kg]). Please fill in the average value valid for the test sequence from low speed run 1, high speed run and low speed run 2. In VECTO-CSE the vehicle mass is used for correction of traction forces from road gradient and from acceleration (if these features are activated) and for determination of the vehicle average RRC (rolling resistance coefficient).
- Row 4: Rotational inertia of all wheels (unit: [kgm²]). Please determine this value based on the tire dimensions with the help of VECTO (the CO₂ simulation tool) or use the tables from the ACEA White book. In VECTO-CSE this inertia is used for correction of traction forces for acceleration (if this feature is activated)
- Row 5: Axle transmission ratio (no unit)
- Row 6: Transmission ratio of the gear engaged during the high speed tests (no unit)
- Row 7: Transmission ratio of the gear engaged during the low speed tests (no unit)

- Row 8: Height of the measuring point of the anemometer installed at the vehicle (unit: [m]).
- Row 9: Maximum vehicle height (unit: [m]). This value is applied in CSE for boundary layer correction of the air speed measured with the anemometer.
- Row 10: Vehicle width (unit: [m]). Value without side mirror. (Remark: this value is not used in CSE so far, a potential use is to calculate the frontal area).

3.4. File with ambient conditions measured by the stationary weather station (*.csamb)

Figure 2 shows an example for the structure of the file containing the ambient conditions measured by the stationary weather station.

row nr.	c VECTO-CSE file with data from stationary weather station			
1	<t>	<t_amb_stat>	<p_amb_stat>	<rh_stat>
2	[s] since daystart	[°C]	[mbar]	[%]
3	25200	18.1	1015.8	69.2
4	25210	18.0	1015.8	69.3
5	25220	18.1	1015.8	69.3
6	25230	18.0	1015.8	69
7	25240	18.0	1015.8	68.9
8	25250	18.0	1015.8	68.9
..	25260	18.1	1015.8	68.9

Figure 2: Structure of the ambient conditions file

In row 1 the column identifiers have to be specified. In the *.csamb file the order of columns is arbitrary. In row 2 the units are specified (in V2.01 the information in row 2 is not processed, a unit converter could be implemented in a later version). Row 3 and the following contain the measured values. Table 2 gives the specifications of the data signals to be provided in the ambient conditions file.

Table 2: Signal specifications for the ambient conditions file

signal	column identifier	unit(s)	remarks
time	<t>	[s] since day start	The time signal is used for consolidation with data measured at the vehicle; any frequency can be specified, minimum requirement from the technical annex is 1 signal per 5 minutes
ambient temperature	<t_amb_stat>	[°C]	
ambient pressure	<p_amb_stat>	[mbar]	
relative air humidity	<rh_stat>	[%]	e.g. 50% humidity is specified in the file by a value of "50"

3.5. Files with configuration of measurement sections (*.csms)

The measurement section files contain the configuration to allocate the recorded data to certain combinations of measurement sections (MS) and driving directions. In VECTO-CSE the MS have to be configured separately for the calibration test and for the measurement runs. Figure 3 shows the structure of a measurement section file.

column nr.									
	1	2	3	4	5	6	7	8	9
row nr.	c trigger used (1=yes, 0=no)								
1	0								
	c meas. section ID	direction ID	length	heading	latitude start	longitude start	latitude end	longitude end	<i>optional: path and/or filename altitude file</i>
	c [id]	[id]	[m]	[°]	[mm.mm]	[mm.mm]	[mm.mm]	[mm.mm]	[...]
2	1	1	250	236	..P1..	..P1..	..P2..	..P2..	TestTrack_1_1.csalt
3	2	1	250	236	..P2..	..P2..	..P3..	..P3..	TestTrack_2_1.csalt
4	3	1	250	56	..P4..	..P4..	..P5..	..P5..	TestTrack_3_1.csalt
5	4	1	250	56	..P5..	..P5..	..P6..	..P6..	TestTrack_4_1.csalt
... open nr. of entries ...									

Figure 3: Structure of the measurement section file

The data to be specified is explained below:

Row 1, column 1: specification whether a trigger signal is used to identify the exact moment when the vehicle enters a measurement section ("1" = trigger signal used; "0" = no trigger signal is used). The methods how CSE evaluates the measurement data for these two options are described in section 4.2.

From row 2 on: Specification of the measurement sections according to Table 3. The order of columns in the measurement section file is fixed. If headers are used (as shown in Figure 3) they have to be labelled beginning with "c" as comment lines. The number of measurement sections to be used in the VECTO-CSE evaluations is free.

Table 3 gives the specifications for the data to be provided in the measurement section files. For further explanation on the following pages two examples for test track layout and related configuration in the *.csms-file are given.

Table 3: Data specifications for the measurement section files

column number	data	unit	remarks
1	measurement section ID	[-]	user defined identification number
2	driving direction ID	[-]	<p>user defined identification number</p> <p>If on a circular test track only a single sense of rotation is driven, the MS on both straights can be labelled with driving direction “1” (VECTO-CSE internally validates the criteria for driving directions based on the heading signal).</p> <p>Measurement sections evaluated for the calibration run have to be configured in two driving directions.</p>
3	heading	[°]	heading of the measurement section
4	length of the measurement section	[m]	<p>to be determined by distance measuring wheel (or by DPGS). Distance is used for:</p> <ul style="list-style-type: none"> • calibration run: calibration of vehicle speed • measurement runs: verification of valid distance driven inside the measurement sections
5	latitude start point of section	[mm.mm]	<p>The coordinates also have to be provided in case a trigger signal is used for identification of MS (for the purpose of plausibility checks). For <u>standard GPS devices please provide minimum 4 digits after the decimal separator</u> (refers to an accuracy of better than 1.8 meter). For the <u>DGPS option please provide minimum 5 digits after the decimal separator</u> (refers to an accuracy of better than 0.18 meter)</p>
6	longitude start point of section	[mm.mm]	
7	latitude end point of section	[mm.mm]	
8	longitude end point of section	[mm.mm]	
5	path and/or filename of altitude file	[-]	only required for the constant speed tests (not the calibration test) and if the altitude correction is enabled. If only the filename is specified here, VECTO-CSE searches in the folder of the *.csm-file.

Examples:

Figure 4 shows the MS file configuration for a circular test track with two measurement sections on both straights and which is driven in a singular sense of rotation.

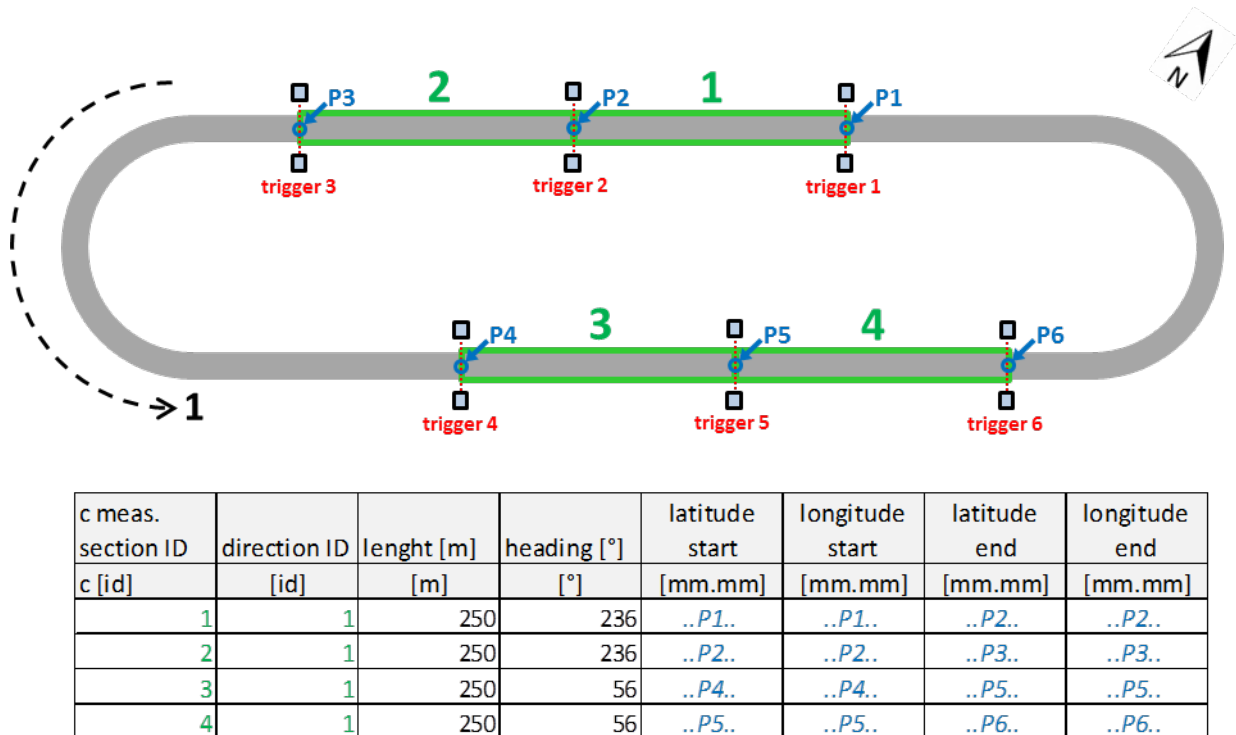
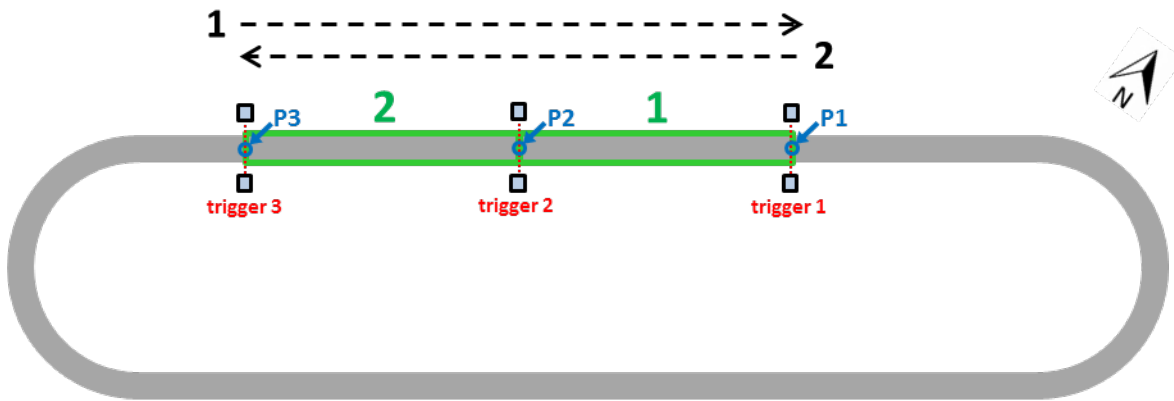


Figure 4: Example 1 for test track layout and MS configuration file (circular test track driven in single sense of rotation)

In Figure 5 the MS file configuration for measurements recorded on a single straight in two driving directions is given. Such a configuration could be used e.g. for the calibration run² on a test track as shown above or also for a test track which consists of a single straight with turning points at both ends.

² In CSE more than a single section can be configured in the calibration run (details see 4.2.3.3).



c meas. section ID	direction ID	length [m]	heading [°]	latitude start	longitude start	latitude end	longitude end
c [id]	[id]	[m]	[°]	[mm.mm]	[mm.mm]	[mm.mm]	[mm.mm]
1	1	250	236	..P1..	..P1..	..P2..	..P2..
2	1	250	236	..P2..	..P2..	..P3..	..P3..
1	2	250	56	..P3..	..P3..	..P2..	..P2..
2	2	250	56	..P2..	..P2..	..P1..	..P1..

Figure 5: Example 2 for test track layout and MS configuration file (measurement data recorded on two measurement sections on a single straight driven in two driving directions)

3.6. Files with measurement data recorded at the vehicle (*.csdat)

Figure 6 shows an example for the structure of the file containing the measurement data recorded at the vehicle. VECTO-CSE requires each a *.csdat-file for

- the calibration test (during warm up of the vehicle)
- the first low speed test
- the high speed test
- the second low speed test

row nr.	c VECTO-CSE file c Klettwitz, 2012-06-24, calibration run											
1	<t>	<lat>	<long>	<hdg>	<v_veh_GPS>	<v_veh_CAN>	<v_air>	<beta>	<n_eng>	<tq_l>	<tq_r>	...
2	[s]	[mm.mm]	[mm.mm]	[°]	[km/h]	[km/h]	[m/s]	[°]	[rpm]	[Nm]	[Nm]	...
3	37080.01	3091.3309332	834.6905802	38.3	87.26	89.01	23.05	-0.82	1310	1352.3	1094.0	...
4	37080.02	3091.3319202	834.6919578	38.3	87.30	89.05	23.05	-0.81	1309	1378.7	1180.2	...
5	37080.03	3091.3329192	834.6933138	39.1	87.28	89.02	24.03	-0.80	1309	1359.9	1033.2	...
6	37080.04	3091.3339326	834.6946482	39.9	87.23	88.97	24.03	-0.81	1310	1439.6	1165.3	...
7	37080.05	3091.3349532	834.6959658	40.5	87.32	89.06	23.97	-0.80	1311	1404.9	1037.3	...
8	37080.06	3091.3359816	834.6972654	41.1	87.26	89.01	23.97	-0.82	1312	1465.6	1102.0	...
..	37080.07	3091.3370232	834.6985458	41.9	87.34	89.08	23.97	-0.81	1311	1457.1	1124.7	...

Figure 6: Example structure of the *.csdat file

The order of columns is arbitrary. The program identifies the signals based on the column identifier to be specified in row 1. In row 2 the units are specified (in V2.01 the information in row 2 is not processed, a unit converter shall be implemented in a later version). Row 3 and the following contain the measured values. **The temporal resolution of the *.csdat files is defined with 100Hz.** This frequency is checked by VECTO-CSE during read-in. The files

containing measurement data as specified in i.) to iv.) must contain continuous data. It is not allowed to cut out driving phases e.g. recorded outside the measurement sections. Exceptional case is the *.csdat-file for the calibration run, where a single discontinuity is accepted by the program.³

The recordings in the *.csdat-file have to start early enough that the meaningful moving averages can be calculated at the point in time when the vehicle enters the measurement section (i.e. >0.5s for the high speed test, >4.5s for the low speed test).

Table 4 gives the specifications of the data signals to be provided in the measurement data files.

³ This feature can be used for cut out of not relevant recorded data (e.g. for the change of driving directions)

Table 4: Signal specifications for the measurement data file

signal	column identifier	unit	remarks
time	<t>	[s] since day start	rate fixed to 100Hz; time signal used for correlation with ambient conditions data and for check of frequency
(D)GPS latitude	<lat>	[mm.m m]	for <u>standard GPS devices please provide minimum 4 digits</u> after the decimal separator (refers to an accuracy of better than 1.8 meter). For the <u>DGPS option please provide minimum 5 digits after the decimal separator</u> (refers to an accuracy of better than 0.18 meter)
(D)GPS longitude	<long>	[mm.m m]	
(D)GPS heading	<hdg>	[°]	
(D)GPS velocity	<v_veh_GPS>	[km/h]	not used in analysis if opto-electronic barriers are used
vehicle velocity	<v_veh_CAN>	[km/h]	raw CAN bus front axle signal
air speed	<v_air>	[m/s]	raw data (instrument reading)
inflow angle (beta)	<beta>	[°]	
engine speed	<n_eng>	[rpm]	
torque meter (left wheel)	<tq_l>	[Nm]	primary torque calibration ($y=kx+d$) to be done in data capturing system (i.e. before import into VECTO-CSE!)
torque meter (right wheel)	<tq_r>	[Nm]	
ambient temperature on vehicle	<t_amb_veh>	[°C]	to be measured according to the specifications in the technical annex
trigger signal	<trigger>	[-]	optional signal; required if measurement sections are identified by opto electronic barriers (option "trigger_used=1"). This signal is defined to be an arbitrary integer value which changes at a "trigger event".
tyre temperature	<t_tire>	[°C]	average value of relevant tires
tyre pressure	<p_tire>	[bar]	average value of relevant tires; optional signal
fuel mass flow	<fc>	[kg/h]	optional signal
validity	<valid>	[-]	optional signal (1=valid; 0=invalid); This feature shall be used to label invalid data (e.g. due to close passing of another vehicle, technical or driving errors). Invalid data will be excluded by VECTO-CSE from further analysis.

Any other provided signal in the measurement data file will be also processed by VECTO-CSE. For these signals the averages for the driving phases within measurement sections are calculated. Any column identifier (except the predefined ones) can be used. These identifiers are then also used by VECTO-CSE in the result files. Additional signals to be processed by VECTO-CSE have to be existent in ALL measurement data files.

3.7. File with altitude profile (*.csalt)

Figure 7 gives an example for an altitude file. If the correction of gradient forces is enabled VECTO-CSE requires each a *.csamb-file for each combination of measurement section and driving direction as specified in the *.csms-file for the low speed – high speed – low speed sequence.

row nr.	c distance from start point	
	c [m]	altitude [m]
1	0.0	260.02
2	50.0	260.18
3	100.0	260.31
4	150.0	260.49
...	200.0	260.37
...	250.0	260.22

open nr. of entries ..

Figure 7: Example structure of the *.csalt file

The data to be specified is explained below:

Column 1: distance from start point of the measurement section (unit: [m])

Column 2: altitude

The first row has to start with the distance “0”, the distance specified in the last line has to match with the length of the measurement section as specified in the *.csms file. Any number of rows greater than or equal to two can be specified. VECTO-CSE applies linear interpolation for altitudes from the *.csalt file.

3.8. Job-File

The Job file contains all information for a VECTO-CSE test evaluation (settings, paths to input data and a small set of input parameters). **The Job file is automatically created by the VECTO-CSE user interface.**

4. Evaluation algorithms

This section gives a documentation of the algorithms which are used to evaluate the input data.

4.1. Processing of data for vehicle position

In a first step VECTO-CSE converts the (D)GPS coordinates to UTM coordinates. The according results for UTM coordinates can be found in the results files (values: "Lat (UTM)" and "Long (UTM)"). For data inside of measurement sections also the theoretical position of the vehicle projected to the line defined by the start- and end-coordinates of the measurement section (result file values "Lat (root)" and "Long (root)") is calculated. This coordinate is the reference for the identification of the vehicle position inside the measurement sections and for the allocation of the altitude if the altitude correction is applied.

4.2. Assignment of measurement data to measurement sections

For assignment of recorded data to the measurement sections as specified in the *.csms-file two options can be chosen how the point in time is determined when the vehicle enters and exits the predefined measurement sections.

Option 1: Trigger signal

CSE identifies the entry or the exit of the vehicle if the criteria 1. to 3. are met:

1. The trigger signal shows a change in integer value
2. The position of the vehicle is inside a square around a start point or an end-point of a MS as defined in the *.csms-file. The square is defined by the (+/-)-range from the parameters "delta_x_max" and "delta_y_max" (unit: [m]).
3. The heading of the vehicle is in a (+/-)-range as defined by the parameter "delta_head_max" (unit: [°])

Option 2: DGPS signal

CSE identifies the entry or the exit of the vehicle if both criteria 1. and 2. are met:

1. An imaginary line perpendicular to a measurement section going through the start point or the end-point is crossed within the (+/-)-range of the parameter "delta_y_max" (unit: [m]) to the start point or to the end-point
2. The heading of the vehicle is in a (+/-)-range as defined by the parameter "delta_head_max" (unit: [°])

Important remarks:

- If a measurement section is specified in the *.csms-file only in a single driving direction, the data recorded on this section during driving in the opposite direction is not evaluated in VECTO-CSE.
- If the end point of a MS is identical with the start point of the next MS the events for “exit” of the first MS and “entry” into the next MS happen at the same point in time.
- The validity of the allocated data is furthermore checked by comparison of driven distance (determined via the calibrated vehicle speed) inside the measurement section with the distance as specified as in the *.csms-file. If the absolute difference is greater than the parameter “leng_crit” (pre-set to 3m)⁴, the particular data is not considered valid.
- DGPS use: According to the technical annex it is only valid to use “option 2” as explained above in connection with use of high accuracy DGPS systems. This factum cannot be verified within VECTO-CSE.
- For all above mentioned parameters default values are pre-set in VECTO-CSE 2.01 as determined based on the experience with the available test data. An adaption of these parameters might be necessary for some cases in order to gain an appropriate assignment of measurement data to measurement sections.

4.3. Evaluation of the calibration test

According to the technical annex the signals for:

- vehicle speed
- air speed and
- yaw angle (beta)

shall be calibrated based on measurement data recorded at high speed driving during the warm-up phase. This evaluation is done in VECTO-CSE automatically in a pre-processing step.

Step 1: Calibration of vehicle speed

In VECTO-CSE the vehicle speed “v_veh” is determined based on the CAN (front axle) vehicle speed signal “v_veh_can” multiplied by the calibration factor “fv_veh”.

The calibration factor “fv_veh” is determined by the average ratio of a reference vehicle speed (“v_ref”) to the CAN (front axle) vehicle speed signal “v_veh_can” for all “datasets”⁵ recorded during the calibration run. The reference vehicle speed is determined depending on the method of assignment of measurement sections as described below:

⁴ Final value of parameter to be decided

⁵ A „dataset“ refers to the data recorded within a measurement section.

Option 1: Trigger signal

The reference vehicle speed is calculated by division of the length of the measurement section as specified in the *.csms-file by the driving time in the measurement section as determined based on the trigger signal.

Option 2: DGPS signal

For the DGPS option the vehicle reference speed is determined by two methods:

- by directly using the DGPS vehicle speed
- by division of the length of the measurement section as specified in the *.csms-file by the driving time in the measurement section as determined based on the DGPS coordinates.

Position and velocity are determined by (D)GPS devices by different physical principles. Currently it is not known which of the two methods a) and b) result in higher accuracy. Test data as available during VECTO-CSE development showed only very small deviations of the vehicle speed as determined by methods a) and b). A general selection of the method to be used shall be made after further use of VECTO-CSE in 2014. In the current VECTO-CSE version method a) is used for further processing. Calibration factors determined by both methods are shown in the result file.

Step 2: Calibration of air speed and yaw angle

For calibration of air speed and yaw angle CSE determines the calibration factors " f_{vpe} " (position error of measured air speed) and " β_{ame} " (misalignment factor for measured yaw angle) as specified in the technical annex. The evaluation steps are done as specified below:

1. The signals for air speed and yaw angle as recorded by the mobile anemometer are corrected for the instrument error ($y=fx+d$; where: x = original signal; y =corrected signal; f,d instrument correction factors). f and d have to be determined by an external procedure (anemometer laboratory calibration) and can be specified in VECTO-CSE in the user interface or via the job file.
2. In a first evaluation step it is assumed that all datasets have been recorded in valid wind conditions assigning the label "valid=1".
3. VECTO-CSE checks if a minimum of five valid datasets per measurement section and driving direction are available.⁶ If uneven numbers of datasets for the two driving directions are available, VECTO discards the last dataset from the driving direction with the higher number of available valid datasets. Such datasets and invalid datasets (according to the wind criteria) are labelled with "used=0". The labels "valid" and "used" assigned to each dataset are also shown in the VECTO-CSE output file.
4. Based on all "used=1" datasets the calibration factors " f_{vpe} " and " β_{ame} " are determined using the formulas as specified in the technical annex in section 5.1.2.8. For the yaw angle the correction factor f_{ape} (position error) is taken from generic data.

⁶ The number of required valid datasets can be modified in the „options“ tab, see 4.2.5.4.

5. With these correction factors the undisturbed air flow (air speed, yaw angle and wind at the anemometer position) and the boundary layer correction as specified in the technical annex in section 5.1.2.8 is calculated resulting in the reference values for air speed, wind speed and yaw angle.
6. Based on the values calculated in 5. the validity of the wind criteria for the single datasets as specified in the technical annex in section 5.1.2.2.3 is checked. If the validity of single datasets has been modified, the evaluation process is started again with point 3. If not, the calibration factors " f_{vpe} " and " β_{ame} " determined in point 3. are considered final.

Important remarks related to the evaluation of the calibration test:

- In the evaluation of the calibration test data recorded in both driving directions on a particular measurement section has to be available. This is checked by the software during read in.
- In VECTO-CSE more than one measurement section can be configured to be evaluated in the calibration test. The overall calibration factors are determined by averaging the results determined in a first step for each specified measurement section. If for a particular measurement section not enough valid datasets are available, the data for this section are completely discarded in the evaluations.
- In "step 1: calibration of vehicle speed" datasets are included in the analysis independent of the wind conditions.

4.4. Evaluation of the constant speed tests

This section describes the evaluation steps performed for the measurement data recorded in the first low speed – high speed – second low speed test sequence.

Step 1: Calculation of air speed, yaw angle and wind speed

VECTO-CSE calculates the values for air speed, yaw angle and wind speed as laid down in the technical annex. This is done in the 100Hz time basis.

Step 2: Calculation of forces from driving resistances

VECTO-CSE determines the forces which apply to the vehicle from the driving resistances in the 100Hz time resolution according to the steps i. to iv.:

i. Calculation of total traction force:

The total traction force is calculated as specified below:

$$F_{trac} = \frac{(T_L + T_R) \cdot \frac{n_{eng} \cdot \pi}{30 \cdot i_{gear} \cdot i_{axle}}}{v_{veh}}$$

where:

F_{trac}	=	total traction force [N]
T_L, T_R	=	corrected torque for left and right wheel [Nm]
n_{eng}	=	engine speed [rpm]
i_{gear}	=	transmission ratio of engaged gear [-]
i_{axle}	=	axle transmission ratio [-]
v_{veh}	=	vehicle speed [m/s]

ii. Correction for forces from road gradient and accelerations

From the total traction force the forces from road gradient and accelerations are subtracted gaining the driving resistance force caused by air drag and rolling resistance. This is correction is only done if enabled in the VECTO-CSE evaluation settings:

$$F_{res} = F_{trac} - F_{grd} \cdot s_{grd} - F_{acc} \cdot s_{acc}$$

where:

F_{trac}	=	driving resistances force (air drag and rolling resistance) [N]
F_{res}	=	total traction force [N]
F_{grd}	=	gradient force [N]
s_{grd}	=	parameter for gradient correction (1=enabled, 0 =disabled) [-]
F_{acc}	=	acceleration force [N]
s_{acc}	=	parameter for acceleration correction (1=enabled, 0 =disabled) [-]

The gradient force is calculated from:

$$F_{grd} = m_{veh} \cdot g \cdot \sin\left(\frac{\Delta alt}{\Delta dist}\right)$$

where:

m_{veh}	=	vehicle mass as specified in *.csveh-file [kg]
g	=	earth gravitational acceleration (9.81) [m/s ²]
Δalt	=	altitude difference from next to previous timestep
$\Delta dist$	=	difference of driven distance from next to previous timestep

The acceleration force is calculated from:

$$F_{acc} = m_{veh} \cdot a_{avg} + \frac{I_{wh} \cdot \dot{\omega} \cdot \omega}{v_{veh}}$$

where:

m_{veh}	=	vehicle mass as specified in *.csv-veh-file [kg]
a_{avg}	=	vehicle acceleration calculated from the moving averaged vehicle speed signal [m/s ²]
I_{wh}	=	wheels rotational inertia [kgm ²]
$\dot{\omega}$	=	wheels angular acceleration [rad/s ²]
ω	=	wheels angular speed [rad/s]
v_{veh}	=	vehicle speed [m/s]

The averaging period for the signals of vehicle speed and engine speed as used for calculation of vehicle acceleration and wheel speed acceleration is defined by the parameter *acc_corr_avg* (unit: [s]).

In VECTO-CSE V2.01 in the default evaluation settings both corrections are disabled. The reasons are:

Gradient correction:

The influence of road gradient does not affect the $C_d \times A$ test result due to the general VECTO-CSE evaluation principle. So no precise altitude profile is required for baseline air drag evaluations. However, the determined values for rolling resistance on single combinations of measurement sections and driving directions are biased by road gradient forces. If a precise altitude profile is available, this influence can be eliminated.

Acceleration correction:

During the constant speed phases the vehicle speed cannot be kept totally constant due to small oscillations resulting from vehicle control. To limit these oscillations strict boundary conditions for the stability of vehicle speed have been defined based on industry experience (+/- 0.15km/h for the low speed test, +/-0.3 km/h for the high speed test). However, due to the high vehicle masses even within these tight limits a variation of the vehicle speed can significantly influence the measured traction force.⁷

A correction of the measured traction force for acceleration effects has to take the quality of the vehicle speed signal into consideration. E.g. background noise or even small inaccuracies in the vehicle speed signal can significantly falsify the calculated accelerations and driving resistance forces. Based on the very few measurement data available to TUG in LOT3 (comprising no CAN vehicle speed signal) no setting for averaging of vehicle speed signal were identified which lead to improvement of calculated forces by the acceleration correction. This issue shall be further investigated in 2014.

⁷ E.g. a worst case calculation (assuming the maximum allowable drop of vehicle speed between the beginning and the end of a measurement section) for a standard loaded class 5 tractor semitrailer combination results in an average acceleration force of 550 [N], which is about 25% of the related air drag force. If the truck is tested in empty loading conditions, the acceleration force is reduced in this worst case example to about 250 [N].

iii. Normalisation of driving resistance forces to reference air density

$$F_{res,ref} = F_{res} \cdot \frac{\rho_{air,ref}}{\rho_{air}}$$

where:

$F_{res,ref}$	=	driving resistance force at reference air density [N]
F_{res}	=	driving resistance force at measurement conditions [N]
$\rho_{air,ref}$	=	air density at reference conditions 1.188 [kg/m ³]
ρ_{air}	=	air density at measurement conditions [kg/m ³]

ρ_{air} is calculated from the air temperature measured on the vehicle and the air pressure and relative humidity as measured at the stationary weather station based on the following equations:

$$p_{v,H_2O} = 611 \cdot \frac{RH_{stat}}{100} \cdot 10^{\frac{7.5 \cdot t_{amb,stat}}{237 + t_{amb,stat}}}$$

$$\rho_{air} = \frac{p_{amb,stat} - p_{v,H_2O}}{287.1 \cdot (t_{amb,veh} + 273.15)} + \frac{p_{v,H_2O}}{461.9 \cdot (t_{amb,veh} + 273.15)}$$

where:

p_{v,H_2O}	=	H ₂ O vapour pressure [Pa]
RH_{stat}	=	relative humidity measured by stationary weather station [%]
$t_{amb,stat}$	=	ambient temperature measured by stationary weather station [°C]
$t_{amb,veh}$	=	ambient temperature measured on the vehicle [°C]
$p_{amb,stat}$	=	ambient pressure measured by stationary weather station [Pa]

iv. Correction of driving resistance force for the low speed tests

The driving resistance forces for the low speed tests are furthermore corrected by the factor $f_{roll,corr}$ as read in from the main VECTO-CSE GUI.

$$F_{res,ref} = F_{res,ref} \cdot f_{roll,corr}$$

This feature aims for correction of a systematic change of rolling resistance in the low speed tests compared to the high speed tests as driven in the test sequence.

Example: If the rolling resistance in the low speed tests is known to be at 85% from the rolling resistance in the high speed tests a correction factor of $1/0.85 = 1.176$ has to be specified in VECTO-CSE.

Default setting for $f_{roll,corr}$ is 1 (i.e. no correction).

Step 2: Check of validity criteria for datasets to be included in the analysis

VECTO-CSE identifies the data recorded inside the measurement sections (“datasets”) with the methods as described in 4.2. Datasets will be automatically excluded by VECTO-CSE from further evaluations in case of:

- invalid wind speed conditions (calibration test, low speed test, high speed test)
- invalid yaw angle conditions (calibration test, high speed test)
- stability criteria for vehicle speed not met (low speed test, high speed test)
- stability criteria for vehicle torque not met (low speed test, high speed test)
- unequal number of datasets per vehicle heading direction (high speed test)
- unequal number of datasets for a particular combination of measurement section and driving direction for the first and the second low speed test

For the pilot phase VECTO-CSE executes the evaluations but gives warnings in case of:

- valid range of ambient conditions exceeded
- maximum deviation of average tire pressure in low speed and high speed exceeded
- maximum deviation of RRC between first and second low speed test exceeded

VECTO-CSE aborts evaluations in case of

- test track requirements not met (max. 20° direction deviations (from +/-180°) between measurement sections)
- not sufficient number of datasets available (calibration test, low speed test, high speed test)

All validity criteria can be edited in the VECTO-CSE GUI in the “options”-tab. The default settings for parameters as laid down in the technical annex can be restored via the “Set to standard”-button. The compliance of the single datasets with the single validity criteria is documented in the VECTO-CSE “ms-file”. This file can be used to identify which criteria was not met by the data. Datasets which fulfil all validity criteria are labelled in VECTO CSE with “valid = 1” (invalid datasets: “valid = 0”). In cases where unequal numbers of valid datasets e.g. for the two driving directions are available, VECTO-CSE excludes also the last dataset surplus dataset of the other driving direction from further evaluations by setting the parameters “used” to 0. In the further evaluation steps only the “used=1” datasets are considered.

Step 4: Calculation of $C_d \cdot A_{fr}$ values for all combination of measurement sections and driving directions

For all applicable combinations of measurement sections and driving directions the following analysis is performed:

- Setup of a linear regression for all used=1 datasets from the high speed tests and the two low speed tests for $F_{res,ref}$ as a function of squared air speed (v_{air}^2) achieving an regression coefficient F_2 (unit: [Ns²/m²]) and a constant term F_0 (unit [N]). In the regression weighting factors are applied so that the cumulative weighting of all high speed datasets is 50%.
- The average absolute yaw angle β_{avg} is calculated from all high speed datasets
- The value for $C_d(\beta_{avg}) \cdot A_{fr}$ [m²] is calculated from

$$C_d(\beta_{avg}) \cdot A_{fr} = 2 \cdot F_2 / \rho_{air,ref}$$

- The rolling resistance coefficient (RRC, unit [kg/t]) is calculated from

$$RRC = \frac{1000 \cdot F_0}{m_{veh} \cdot g}$$

Step 5: Determination of overall test result

The result for overall “ $C_d(\beta_{avg}) \cdot A_{fr}$ ” and overall “ β_{avg} ” is calculated from the results for all applicable combinations of measurement sections and driving directions by arithmetical averaging.

The final result for $C_d \cdot A_{fr}$ [m²] for zero cross-wind conditions is then achieved performing the yaw angle correction as specified below:

$$C_d \cdot A_{fr} = C_d(\beta_{avg}) \cdot A_{fr} - \Delta C_d \cdot A_{fr}(\beta_{avg})$$

where:

- | | | |
|--|---|--|
| $C_d(\beta_{avg}) \cdot A_{fr}$ | = | average result for product of air drag coefficient and frontal area from constant speed tests comprising an average absolute yaw angle of β_{avg} |
| $\Delta C_d \cdot A_{fr}(\beta_{avg})$ | = | yaw angle correction applying the generic curve for $\Delta C_d \cdot A_{fr}$ as a function yaw angle for the value of β_{avg} . In this correction the applicable generic curve for the particular vehicle class and vehicle configuration (rigid or with trailer) is used. |

During the pilot phase also an alternative method for yaw angle correction will be calculated by VECTO-CSE (yaw angle correction performed for each combination of measurement section and driving direction before averaging of final result). The according results can be identified in the result files labelled with “Option 2”.

5. Output files

VECTO-CSE produces three kinds of output files:

1. The “CSE main result file” comprising overall results
2. The “MS files” with the results for all single recorded measurement sections differentiated by driving direction if applicable
3. Each a “Hz file” (either in 1Hz or in 100Hz, depending on the settings) for the calibration run, the two low speed runs and the high speed test with all input data as well as all calculated values averaged to the specified frequency

The sections below give detailed explanations on the result files. All result files are written to the subfolder “\Results” of the folder of the job-file.

5.1. The CSE main result file

Filename = filename of the job-file + "CSE.csv"

Table 5 and Table 6 show the results as provided by the CSE main result file. Only data from "used" datasets are included in the analysis and provided in the CSE main result file

Table 5: Overall results provided in the CSE main result file

quantity	unit	description
fv_veh	[-]	calibration factor for CAN vehicle speed (if DGPS option is used in the calibration run: determined based on DGPS velocity signal) ⁸
fv_veh_opt2	[-]	only if DGPS option is used in the calibration run: calibration factor for CAN vehicle speed based on DGPS position signal. This value is not used in the further analysis
fv_pe	[-]	position error correction factor for measured air speed
fa_pe	[-]	position error correction factor for measured air inflow angle (beta)
beta_ame	[°]	misalignment correction for measured air inflow angle (beta)
CdxA	[m ²]	average Cd*A (β) of all combinations of MS ID and direction ID (before yaw angle correction)
beta	[°]	average absolute β of all combinations of MS ID and direction ID
delta_CdxA	[m ²]	β -influence on CdxA calculated with beta_ave_Opt1 and the generic drag curve
CdxA(0)	[m ²]	CdxA value for zero cross-wind conditions (= CdxA_ave_Opt1 - delta_CdxA_Opt1) FINAL RESULT
CdxA(0)_Opt2	[m ²]	CdxA value for zero cross-wind conditions (average of CdxA(0) for all combinations of MS ID and direction ID) FINAL RESULT
Validity criteria	[-]	particular error messages on single validity criteria (ambient conditions, tire temperature conditions)

⁸ In further investigations it shall be clarified which of the two calibration methods for vehicle speed based on DGPS data gives more reliable results, see also 4.2.3.3.

Table 6: Results provided per combination of measurement section and driving directions

quantity	unit	description
SecID	[-]	measurement section ID as specified in the *.csms-file
DirID	[-]	driving direction ID as specified in the *.csms-file
F2_ref	[N/(m2/s2)]	result for F2 from linear regression
F2_LS1_ref	[N/(m2/s2)]	result for F2 from linear regression (low speed data only from first test)
F2_LS2_ref	[N/(m2/s2)]	result for F2 from linear regression (low speed data only from second test)
F0_ref	[N]	result for F0 from linear regression
F0	[N]	result for F0 from linear regression for measurement conditions
F0_LS1_ref	[N]	result for F0 from linear regression (low speed data only from first test)
F0_LS1	[N]	result for F0 from linear regression for measurement conditions (low speed data only from first test)
F0_LS2_ref	[N]	result for F0 from linear regression (low speed data only from second test)
F0_LS2	[N]	result for F0 from linear regression for measurement conditions (low speed data only from second test)
CdxA	[m2]	$CdxA (\beta) (= 2 * F2_ref / \rho_air_ref)$
CdxA0	[m2]	CdxA converted to zero cross-wind
delta_CdxA	[m2]	cross-wind correction
be-ta_abs_HS	[°]	average absolute beta from high speed dataset
rho_air_LS	[kg/m3]	average air density during low speed tests
RRC	[kg/t]	rolling resistance coefficient
RRC_LS1	[kg/t]	rolling resistance coefficient (low speed data only from first test)
RRC_LS2	[kg/t]	rolling resistance coefficient (low speed data only from second test)
RRC_valid	[-]	Validity criteria for maximum difference of RRC from the two low speed runs passed (=1) or failed (=0)
t_tire_LS_min	[°]	minimum tire temperature during low speed tests

quantity	unit	description
t_tire_LS_max	[°]	maximum tire temperature during low speed tests
t_tire_HS_min	[°]	minimum tire temperature during high speed tests
t_tire_HS_max	[°]	maximum tire temperature during high speed tests

5.2. The “measurement section” (ms-)files

VECTO-CSE writes two MS-files (each one for the calibration test and one for the measurement runs). These files contain all results for the driving phases inside the measurement sections (the “datasets”).

For the calibration test: Filename = filename job-file + “MS_CAL.csv”

For the constant speed test: Filename = filename job-file + “MS_MEAS.csv”

Table 7 gives explanations to the results as provided in the ms-file for the constant speed test sequence. The ms-file for the calibration test contains fewer columns as fewer values are calculated CSE-internally.

Table 7: Results provided in the ms-file for the constant speed test sequence

quantity	unit	description
SecID	[-]	measurement section ID as specified in the *.csms-file
DirID	[-]	driving direction ID as specified in the *.csms-file
RunID	[-]	Run ID: "0" = high speed test; "1" = first low speed test; "2" = second low speed test
HeadID	[-]	Heading ID (internal quantity)
delta t	[s]	driving time inside the measurement section
length	[m]	section length as specified in the *.csms-file
delta s	[m]	driven distance inside the measurement section derived from vehicle speed signal
v (s)	[km/h]	=delta_t/delta_s
v (GPS)	[km/h]	average vehicle speed (GPS signal)
v_veh_CAN	[km/h]	average vehicle speed (CAN signal)
v_veh	[km/h]	average vehicle speed (after calibration)
vair_ar	[m/s]	average air speed (raw anemometer reading)
vair_ic	[m/s]	average air speed (after instrument error correction)
vair_uf	[m/s]	average air speed (undisturbed flow at anemometer height)
beta_ar	[°]	average yaw angle (raw anemometer reading)
beta_ic	[°]	average yaw angle (after instrument error correction)
beta_uf	[°]	average yaw angle (undisturbed flow at anemometer height)
valid	[-]	overall validity of dataset
used	[-]	dataset used in final evaluations ("1"=yes, "0"=no)

quantity	unit	description
val_User	[-]	validity as specified by user input
val_vVeh_ave	[-]	validity: vehicle speed range
val_vVeh_f	[-]	validity: vehicle speed stability (low speed tests)
val_vVeh_1s	[-]	validity: vehicle speed stability (high speed test)
val_vWind	[-]	validity: maximum wind speed
val_vWind_1s	[-]	validity: maximum gust wind speed
val_tq_f	[-]	validity: stability of torque signal (low speed tests)
val_tq_1s	[-]	validity: stability of torque signal (high speed test)
val_beta	[-]	validity: average absolute beta below limit (only for high speed test)
val_dist	[-]	validity: difference of distance from vehicle speed signal with length of section as specified in *.csms file
vair	[m/s]	average air speed
v_wind_ave	[m/s]	average wind speed
v_wind_1s	[m/s]	average 1s moving average of wind speed
v_wind_1s_max	[m/s]	maximum of 1s moving average of wind speed (=gust)
beta_ave	[°]	average yaw angle
beta_abs	[°]	average absolute yaw angle
v_air_sq	[m ² /s ²]	squared average air speed (squared in 100Hz, then averaged!)
n_eng	[rpm]	average engine speed
omega_wh	[rad/s]	average wheel rotational speed
omega_p_wh	[rad/s ²]	average wheel rotational acceleration
tq_sum	[Nm]	average torque (sum l+r)
tq_sum_1s	[Nm]	average 1s moving average of torque sum
tq_sum_1s_max	[Nm]	maximum 1s moving average of torque sum
tq_sum_1s_min	[Nm]	minimum 1s moving average of torque sum
tq_sum_float	[Nm]	average floating average of torque sum
tq_sum_float_max	[Nm]	maximum floating average of torque sum
tq_sum_float_min	[Nm]	minimum floating average of torque sum
t_float	[s]	averaging floating period ("floating" refers to averaging as de-

quantity	unit	description
		finned for stability for low speed tests)
F_trac	[N]	average total traction force
F_acc	[N]	average acceleration force
F_grd	[N]	average gradient force
F_res	[N]	average force from driving resistances
F_res_ref	[N]	average force from driving resistances at reference conditions
v_veh_1s	[km/h]	average 1s moving average of vehicle speed
v_veh_1s_max	[km/h]	maximum 1s moving average of vehicle speed
v_veh_1s_min	[km/h]	minimum 1s moving average of vehicle speed
v_veh_avg	[km/h]	average "averaged" vehicle speed (as calculated for acceleration correction)
a_veh_avg	[m/s ²]	average acceleration calculated from "averaged" vehicle speed
v_veh_float	[km/h]	average floating average of vehicle speed ("floating" refers to averaging as defined for stability for low speed tests)
v_veh_float_max	[km/h]	maximum floating average of vehicle speed
v_veh_float_min	[km/h]	minimum floating average of vehicle speed
t_amb_veh	[°C]	average ambient temperature measured on the vehicle
t_amb_stat	[°C]	average ambient temperature from stationary measurement
p_amb_stat	[mbar]	average ambient pressure from stationary measurement
rh_stat	[%]	average relative humidity from stationary measurement
vp_H2O	[Pa]	average H2O vapor pressure
rho_air	[kg/m ³]	average air density
t_tire	[°C]	average tire temperature
p_tire	[bar]	average tire pressure
F0_ref_singleDS	[N]	result for F0 from linear regression for single high speed dataset with all low speed datasets from similar MS and Dir ID (reference conditions)
F2_ref_singleDS	[Ns ² /m ²]	result for F2 from linear regression for single high speed dataset with all low speed datasets from similar MS and Dir ID (reference conditions)
F0_singleDS	[N]	result for F0 from linear regression for single high speed dataset with all low speed datasets from similar MS and Dir ID (measurement conditions)

quantity	unit	description
CdxA_singleDS	[m2]	CdxA value for single high speed dataset with all low speed datasets from similar MS and Dir ID
RRC_singleDS	[kg/t]	RRC value for single high speed dataset with all low speed datasets from similar MS and Dir ID (measurement conditions)

Additionally average values for all additional signals included in the *.csdat-files are written in the ms-file.

5.3. The Hz-files

VECTO-CSE writes each a “Hz”-File (either in 1Hz or in 100Hz, depending on the settings) for each provided measurement data file (i.e. for the calibration run, the two low speed runs and the high speed run). The Hz files comprise all input data and all quantities calculated by VECTO-CSE in 100Hz time resolution arithmetically averaged to the specified frequency.

Filename = filenames csdat-file + “1Hz.csv”

Table 8 gives explanations to the results as provided in the Hz-file for the constant speed test sequence. The Hz-file for the calibration test contains fewer columns as fewer values are calculated CSE-internally.

Table 8: Results provided in the Hz-file for the constant speed test sequence

quantity	unit	description
<i>First columns</i>		<i>all quantities as read from *.csdat-file</i>
Zone (UTM)	[-]	UTM zone ID
Lat (UTM)	[m]	UTM Y-value (refers to latitude) of the actual vehicle position
Long (UTM)	[m]	UTM X-value (refers to longitude) of the actual vehicle position
Sec_ID	[-]	measurement section ID as specified in the *.csms-file
Dir_ID	[-]	driving direction ID as specified in the *.csms-file
Lat (root)	[m]	UTM Y-value (refers to latitude) of the reference point on the line defining the measurement section
Long (root)	[m]	UTM X-value (refers to longitude) of the reference point on the line defining the measurement section
dist_root	[m]	distance driven inside the measurement section (length on the reference line)
slope_deg	[°]	slope angle (=0 if altitude corrections is disabled)
alt	[m]	altitude (=0 outside the measurement sections and if altitude corrections is disabled)
v_veh	[km/h]	vehicle speed (after calibration)

quantity	unit	description
dist	[m]	cumulative value of driven distance
vair_ic	[m/s]	air speed (after instrument error correction)
vair_uf	[m/s]	air speed (undisturbed flow at anemometer height)
vair	[m/s]	air speed (after boundary layer correction)
beta_ic	[°]	yaw angle (after instrument error correction)
beta_uf	[°]	yaw angle (undisturbed flow at anemometer height)
beta	[°]	yaw angle (after boundary layer correction)
vwind_ha	[m/s]	wind speed at anemometer height
vwind	[m/s]	wind speed (after boundary layer correction)
vwind 1s	[m/s]	1s moving average of wind speed
omega_wh	[rad/s]	wheel rotational speed
ome- ga_p_wh	[rad/s ²]]	wheel rotational acceleration
tq_sum	[Nm]	torque sum (left+right)
tq_sum_1s	[Nm]	1s moving average of torque sum
tq_sum_float	[Nm]	"floating" average of torque sum ("floating" refers to averaging as defined for stability for low speed tests)
t_float	[s]	floating period ("floating" refers to averaging as defined for stability for low speed tests)
F_trac	[N]	total traction force
F_acc	[N]	acceleration force
F_grd	[N]	gradient force
F_res	[N]	force from driving resistances
v_veh_1s	[km/h]	1s moving average of vehicle speed
v_veh_ave	[km/h]	averaged vehicle speed (as calculated for acceleration correction)
a_veh_ave	[m/s ²]	acceleration calculated from "averaged" vehicle speed
v_veh_float	[km/h]	floating average of vehicle speed ("floating" refers to averaging as defined for stability for low speed tests)
t_amp_stat	[°C]	ambient temperature from stationary measurement
p_amp_stat	[mbar]	ambient pressure from stationary measurement
rh_stat	[%]	relative humidity from stationary measurement
vair_sq	[m/s]	squared average air speed

6. User Manual

6.1. General

The CSE-Tool is written in VB.Net and delivered as executable file and Visual Studio 2010 project with commented source code. The CSE-Tool is a portable application, i.e. it is not necessary to run a setup procedure for installation. The executive file can be run from any place on a computer or in a network.

6.2. Required system settings

The regional and language options of Windows must be set in the system configurations to the following values:

- a) Decimal separator: <.> (Dot)
- b) Symbol for digit grouping: < > (Space)

List separator: <,> (Comma)

6.3. First program start

Copy the folder "VECTO-CSE_V2.01" as delivered to the computer or the network place. When the program is started for the first time, the folders "FileHistory" is generated in the application folder. Then the user interface of the VECTO-CSE-Tool is shown. If no license file (license.dat) is available in the folder of the executable, VECTO-CSE generates an "activation file". This file then has to be sent to the JRC user support in order to gain the license file.

After the first start it is recommended to adjust the settings for standard working directory and to check the path to the executable file of a text editor (e.g. notepad.exe). These settings can be adjusted in the menu item "Tools\Options".

6.4. Graphic User Interface

Figure 8 shows the VECTO-CSE main user interface. The main elements are:

- Input fields for file specifications ("..."-button to the right opens the file-browser, button to the left opens selected file in Excel or in the text editor)
- Input fields for correction factors:
 - Manual input of correction factors from anemometer instrument calibration
 - Manual input of correction factor for rolling resistance from the low speed test
- Button to start the evaluation of the calibration test
- Result field for calibration factors from the calibration test

- Button to start the evaluation of the low speed – high speed – low speed test sequence (this button is disabled if no valid results from calibration test are available)
- Output window for messages, warning and errors. During the calculations the main evaluation steps are stated. Main evaluation results are also shown in the message window.
- Menu bar:
 - Item “Job” for handling of job-file (“new”, “open”, “save”, “save as”)
 - Item “Tools” for opening of log-file and minor settings of CSE operation including the path to the standard working directory
 - Item “Info” for creating of “activation file” (required once if license is only distributed with hardware lock) and for opening of user manual.

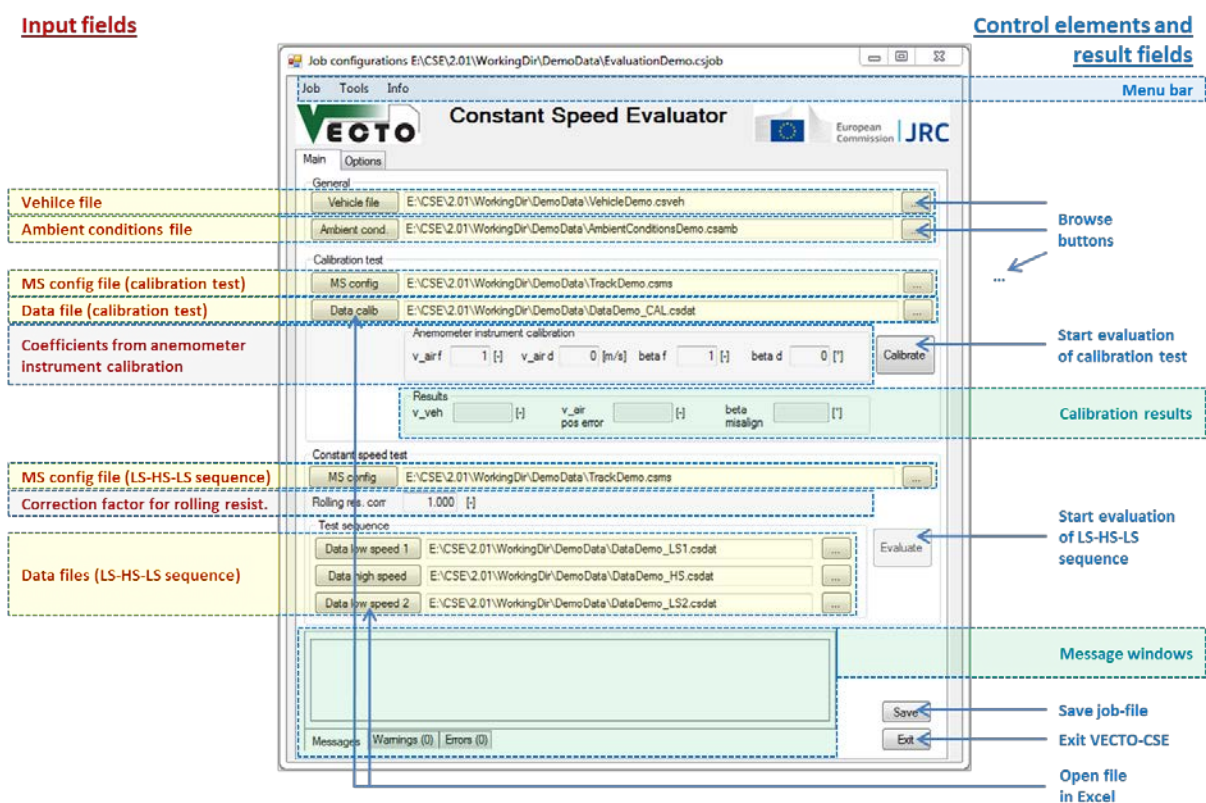


Figure 8: VECTO-CSE main user interface

Figure 9 shows the VECTO-CSE options tab. The elements are described below:

Left and middle column:

There the main relevant evaluation parameters can be modified by the user. An explanation to each parameter is provided if the cursor is moved to the related input field. The default settings for evaluation parameters as defined in the technical annex can be restored pressing the “set to standard” button.

Right column:

- “Evaluation”: Enables/disables the correction of traction forces for acceleration and for gradient effects (default: both disabled)

- “Output”: Specification of frequency of “Hz-files” in CSE-output.

Job configurations E:\CSE\2.01\WorkingDir\DemoData\EvaluationDemo.csjob

Job Tools Info

VECTO **Constant Speed Evaluator** European Commission JRC

Main Options

Dataset validity criteria

dist_float 25 [m]

Calibration run

v_wind_ave_CAL_max 5 [m/s]

v_wind_1s_CAL_max 8 [m/s]

beta_ave_CAL_max 5 [°]

Low and high speed test

leng_crit 10 [m]

Low speed test

v_wind_ave_LS_max 5 [m/s]

v_wind_1s_LS_max 8 [m/s]

v_veh_ave_LS_max 16 [km/h]

v_veh_ave_LS_min 9 [km/h]

v_veh_float_delta 0.15 [km/h]

tq_sum_float_delta 0.1 [-]

High speed test

v_wind_ave_HS_max 5 [m/s]

v_wind_1s_HS_max 8 [m/s]

v_veh_ave_HS_min 80 [km/h]

beta_ave_HS_max 3 [°]

v_veh_1s_delta 0.3 [km/h]

tq_sum_1s_delta 0.1 [-]

General validity criteria

delta_t_tire_max 5 [°C]

delta_RRC_max 0.3 [kg/t]

t_amb_var 3 [°C]

t_amb_tamac 25 [°C]

t_amb_max 35 [°C]

t_amb_min 0 [°C]

General

delta_Hz_max 1 [%]

rho_air_ref 1.1884 [kg/m3]

acc_corr_ave 1 [s]

delta_parallel_max 20 [°]

Identification of measurement section

delta_x_max 10 [m]

delta_y_max 100 [m]

delta_head_max 10 [°]

Requirements on number of valid datasets

ds_min_CAL 5 [#]

ds_min_LS 1 [#]

ds_min_HS 2 [#]

ds_min_head_HS 10 [#]

Evaluation

☐ Acc correction

☐ Grd correction

Output

☒ 1Hz

☐ 100Hz

Set to Standard

Maximum gust wind speed during calibration test

Figure 9: VECTO-CSE options tab

6.5. How to evaluate a constant speed test in VECTO-CSE

Below the single steps for the evaluation of a test series comprising a calibration test and the low speed – high speed – low speed test sequence are explained.

Step 1

Specify all input files using the browse-button (“...”).

Step 2

Check or modify correction parameters in the main tab.

- Correction factors from anemometer instrument calibration:
The default values: $v_{air\ f}$: 1.0 [-], $v_{air\ d}$ 0.0 [m/s], $\beta\ f$: 1.0 [-], $\beta\ d$ 0.0 [°] represent no change of raw anemometer readings by the instrument calibration.
- correction factor for rolling resistance from the low speed test:
The default value of 1.000 [-] refers to no correction.

Step 3

Check or modify evaluation parameters in the option tab. The default settings for evaluation parameters as defined in the technical annex can be restored pressing the “set to standard” button.

Step 4:

Save the job-file via the “save”-button.

Step 5:

Press the “Calibrate” button to start the evaluation of the calibration test. The progress of the evaluations and potential warnings or errors are shown in the message windows. When the evaluation of the calibration test is finished successfully, the resulting calibration factors are shown in the GUI. The output files are written into the subfolder “\Results” of the folder where the job-file is located.

Step 6:

Press the “Evaluate” button start the evaluation of the low speed – high speed – low speed test sequence. The progress of the evaluations and potential warnings or errors are shown in the message windows. When the evaluation of the calibration test is finished successfully,

the main results are shown in the message window. The output files are also written into the “\Results” subfolder.

Further important remarks

- A full set of evaluation settings (file-paths and options) can be reloaded by opening an existing job-file.
- Before start of evaluations (either of a calibration test or of a LS-HS-HS sequence) VECTO CSE always saves the current settings into the job-file (name and path as specified the last time). If the user does not want to overwrite the existing job-file the job-file has to be saved under a different name using the menu bar “Job\Save as”.
- A calibration test can also be evaluated without data specified for the LS-HS-HS sequence.

6.6. Generic data

The data for the generic correction of yaw angle influence of the $C_d \times A$ test result is stored in the file “GenShape.shp” (subfolder “\config”, file format “csv”). The generic correction is defined per vehicle class ID and whether the vehicle is operated with or without trailer (see also enclosed Excel for further information).

6.7. Demo data

VECTO-CSE V2.01 is delivered with a set of demo-data. This demo data has been compiled based on original data recorded on a straight line test track with 2 measurement sections driven in both directions. Data have been modified manually extensively in order to pass all validity criteria and for confidentiality reasons.

7. Support

Support can be obtained via

vecto@jrc.ec.europa.eu

or

rexeis@ivt.tugraz.at