



Assisted WIM Datalogger Calibration

**WIM Data Logger
Type 5204A...**

September 2017

Based on Data Logger
Firmware Version:
wim-rel-V1.3.x swu

Foreword

Thank you for choosing a Kistler quality product characterized by technical innovation, precision and long life.

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Purpose of Use

Assisted calibration is a sophisticated method to further improve WIM system measurement accuracy. The assisted calibration can only be performed by trained Kistler personnel. Please contact your local Kistler Sales or Service Center to organize and support your assisted calibration.

Content

Foreword.....	2
Purpose of Use	2
Content	3
1. Theory – System Optimization Factors Explained	4
1.1. Example Optimizations	6
1.1.1. Example Run 1 (Simple)	6
1.1.2. Example Run 2 (Interpolation).....	6
1.1.3. Example Run 2 (Out of Weight Range):	6
1.1.4. Example Run 3 (Out of Speed Range):.....	7
1.2. Example Factor Calculation	7
2. Calibration Procedure	8
2.1. Define Operating Range	8
2.1.1. Vehicle Selection.....	8
2.1.2. Speed Range	8
2.2. Day 1: Standard Calibration.....	8
2.3. Day 1: Measurement of dependencies (Speed&Weight)	9
2.3.1. Speed dependency	9
2.3.2. Weight dependency	9
2.4. Day 1: Analysis	10
2.5. Days 2-N: Verification (Trucks)	10
2.6. Days 2-N: Analysis	10
3. Factor calculation using Excel	11
3.1. Export data from Kistler Data Logger.....	11
3.2. Import CSV file.....	12
3.3. Results.....	15

1. Theory – System Optimization Factors Explained

Accuracy of WIM system depends on many aspects such as quality of road, number of sensors, etc...

To achieve best results calibration of WIM system has to be performed according Instruction Manual WIM Data Logger – chapter calibration.

Next step of improving results of WIM system is to find dependency of different types of vehicles (number of axles) based on speed and weight. For this reason WIM Data Logger provide feature: System Optimization Factors.

This document describes how to increase accuracy of WIM Data Logger based on System Optimization Factors.

Current version of WIM DL supports 6 speed bins. Ranges could be adjusted according customer needs.

Is also good keep one bin for speed > defined maximum.

VehicleType	At Weight		At Speed					
			0 km/h	10 km/h	20 km/h	40 km/h	60 km/h	120 km/h
2AxleVehicleEmpty	5000	kg	10 %	10 %	10 %	10 %	10 %	10 %
2AxleVehicleFull	30000	kg	10 %	10 %	10 %	10 %	10 %	10 %
3AxleVehicleEmpty	0	kg	0 %	0 %	0 %	0 %	0 %	0 %

Figure 1: System Optimization Factors Lookup Table

For each **Lane** and Vehicle Type (Number of **Axles**), there exists a Lookup table of Weight Correction Factors. The **Weight** dependent factor can be chosen to be **Speed** independent, or Speed dependent.

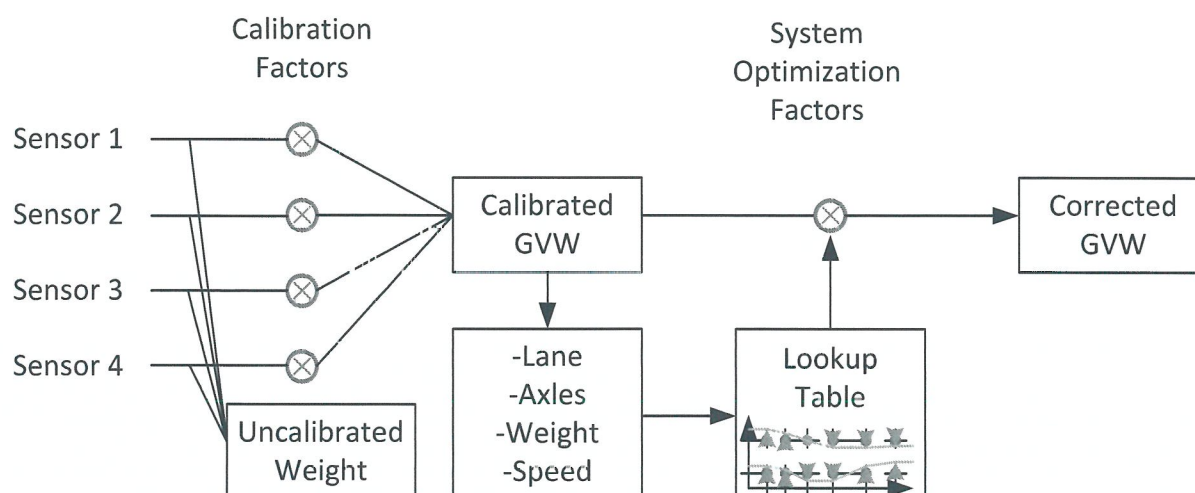


Figure 2: Calibration & Optimization Functionality Map

The application of the System Optimization Factors is a 2D Linear Interpolation
When a Vehicle is measured, the following decisions and calculations are done:

1. **Lane:** Based on the driving Lane, the Lookup Table is chosen
2. **Axes:** Based on the number of axes, the two corresponding rows (empty&full) are chosen
3. **Speed (if enabled):** For both weight columns (empty&full), the factors are calculated by linear interpolation for the actual speed value (See Figure 4)
4. **Weight:** Between the weight columns, the factor is calculated by linear interpolation for the actual weight value (See Figure 3)

If the measurement lies out of the Lookup Table, the closest Value is applied (static extrapolation)

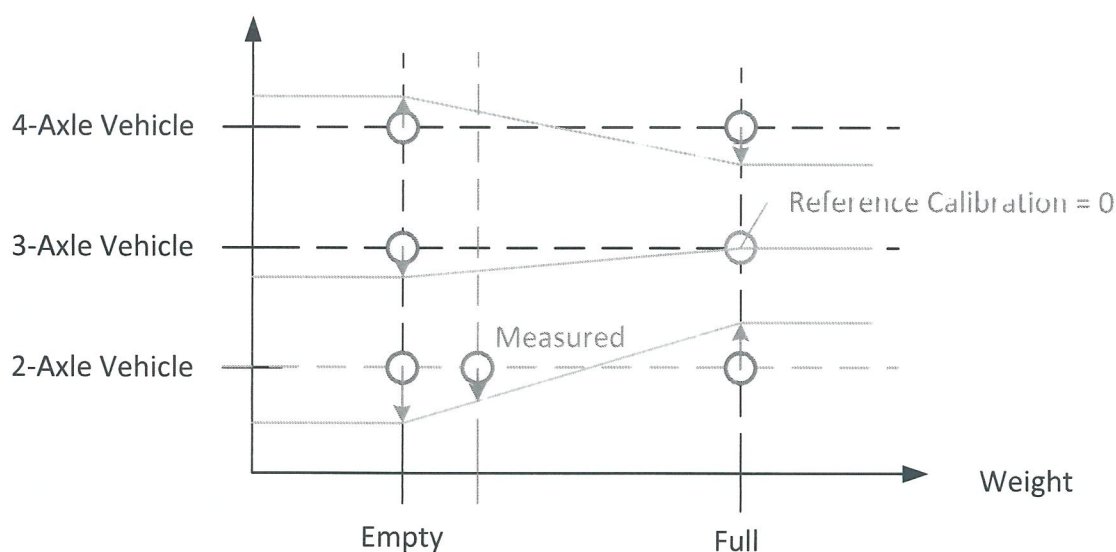


Figure 3: Weight dependent Interpolation

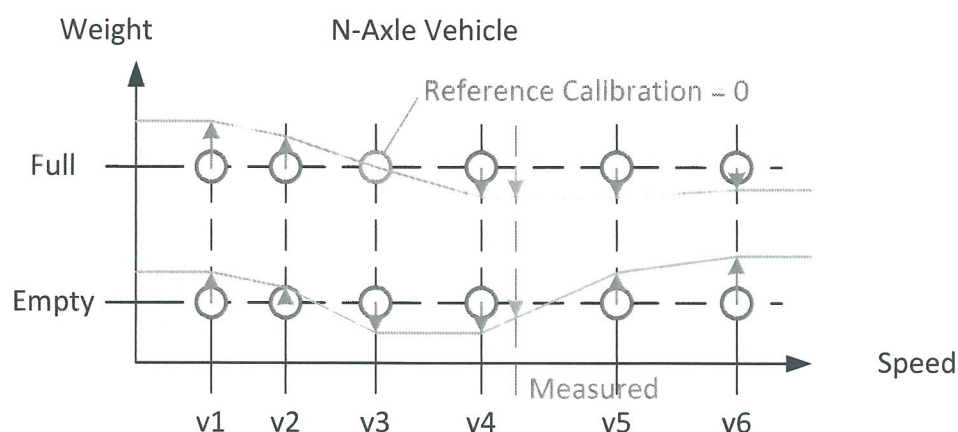


Figure 4: Weight & Speed dependent Interpolation

1.1. Example Optimizations

The following Picture shows the Optimization Factors Table, after these factors have been found by the calibration procedure.

Vehicle Type	At Weight	At Speed	20 km/h	30 km/h	40 km/h	50 km/h	60 km/h	80+ km/h
2 Axle Vehicle Empty	8'000 kg	2 %	2 %	3 %	4 %	4 %	3 %	
2 Axle Vehicle Full	30'000 kg	1 %	0 %	0 %	1 %	2 %	2 %	

1.1.1. Example Run 1 (Simple)

Axles = 2

Measured Weight = 8'000kg

Speed = 20km/h

Optimization Factors according table is **3%**

Corrected Weight = 8'240kg

1.1.2. Example Run 2 (Interpolation)

Axles = 2

Measured Weight = 10'000kg

Speed = 25km/h

Speed Correction Empty (8'000kg) = 3.25% (Interpolation between 20-40km/h)

Speed Correction Full (30'000kg) = 0.75% (Interpolation between 20-40km/h)

Speed Correction At 10'000 Kg = **3.02%** (Interpolation between 8'000-30'000kg)

Corrected Weight = 10'302kg

1.1.3. Example Run 2 (Out of Weight Range):

Axles = 2

Measured Weight = 40'000kg

Speed = 25km/h

Speed Correction Empty (8'000kg) = 3.25% (Interpolation between 20-40km/h)

Speed Correction Full (30'000kg) = 0.75% (Interpolation between 20-40km/h)

Speed Correction At 40'000 Kg = **0.75%** (Static Extrapolation from 30'000kg)

Corrected Weight = 40'300kg

1.1.4. Example Run 3 (Out of Speed Range):

Axles = 2

Measured Weight = 10'000kg

Speed = 90km/h

Speed Correction Empty (8'000kg) = 3% (Static Extrapolation from 80km/h)

Speed Correction Full (30'000kg) = 2% (Static Extrapolation from 80km/h)

Speed Correction At 10'000 Kg = **2.91%** (Interpolation between 8'000-30'000kg)

Corrected Weight = 10'291kg

1.2. Example Factor Calculation

Formula:

Correction Factor = $100 * (\text{ReferenceWeight} / \text{MeanMeasuredWeight} - 1)$

OR

CorrectionFactor% = $(1 / (1 + [\text{Error}\%] / 100) - 1) * 100$

Example1:

Reference Weight = 10'000kg

Measured Weight = 9'500kg (-5% Error)

Optimization Factor = $100 * (\text{ReferenceWeight} / \text{MeasuredWeight} - 1) = 5.26\%$

Optimization Factor = $100 * (10'000 / 9'500 - 1) = 5.26\%$

Example2:

Reference Weight = 9'200kg

Measured Weight1 = 9'500kg (3.25% Error)

Measured Weight2 = 9'220kg (0.22% Error)

Measured Weight3 = 9'100kg (-1.09% Error)

Measured Weight4 = 9'530kg (3.59% Error)

Measured Weight5 = 9'800kg (6.52% Error)

Mean Measured Weight = 9'430kg (2.50% Error)

Optimization Factor = $100 * (\text{ReferenceWeight} / \text{MeanMeasuredWeight} - 1) = -2.44\%$

Optimization Factor = $100 * (9'200 / 9'430 - 1) = -2.44\%$

2. Calibration Procedure

2.1. Define Operating Range

2.1.1. Vehicle Selection

Select Vehicles according to the targeted WIM Traffic

Typical Vehicle Description	Percentage of Traffic	Number of axles	Minimum Weight	Maximum Weight

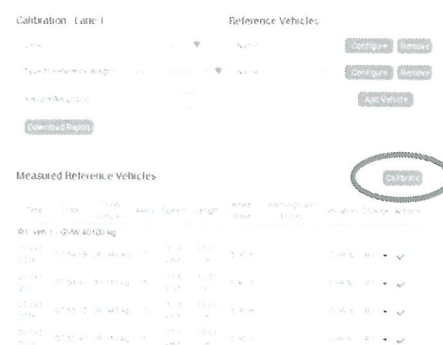
2.1.2. Speed Range

Define the minimum, typical and maximum speed:

Minimum Speed	
Typical Speed	
Maximum Speed	

2.2. Day 1: Standard Calibration

- Choose a Reference Calibration Point
 - Lane 1-N
 - Vehicle (Most typical)
 - Weight (Maximum Weight)
 - Speed (Typical Speed)
- Measure the static reference Weight
- Perform a standard, automated sensor calibration
 - UI => "Site Setup" => "Calibration"
 - A minimum of 10 runs is suggested
- This procedure will determine and set the "Calibration Factors". There is one fixed calibration factor for each sensor channel. And this set of calibration factors will not change anymore with the following procedure to find the "System Optimization Factors".



2.3. Day 1: Measurement of dependencies (Speed&Weight)

2.3.1. Speed dependency

1. Measure the speed dependency with the following Vehicle
 - Lane 1-N
 - Vehicle (Most typical)
 - Weight (Maximum Weight)
 - Speed **Select 4-5 Speed Values**
2. Measure the static reference Weight
3. Perform 3-5 Runs at each Speed Value and “Mark” these runs:

Speed bins example	Speed (3-5 Runs)
1 Minimum Speed (0-20)	
2 Speed (20-40)	
3 Typical Speed (40-60)	
4 Speed (60-80)	
5 Maximum Speed (80<)	

4. Export “Marked” Runs to “SpeedVerification_Full_TruckX_Date.csv”
(See chapter 3.1 “Export...”)

2.3.2. Weight dependency

1. Measure the weight dependency with the following Vehicle
 - Lane 1-N
 - Vehicle (Most typical)
 - Weight Unload the Vehicle to minimum Weight
 - Speed (Typical Speed)
2. Measure the static reference Weight
3. Perform 3-5 Runs at each Speed Value and “Mark” these runs:

Speed bins example	Speed (3-5 Runs)
1 Minimum Speed (0-20)	
2 Speed (20-40)	
3 Typical Speed (40-60)	
4 Speed (60-80)	
5 Maximum Speed (80<)	

4. Export “Marked” Runs to “SpeedVerification_Empty_TruckX_Date.csv”
(See chapter 3.1 “Export...”)

2.4. Day 1: Analysis

Analyze the Verification Export files according to chapter 3. “Factor calculation using Excel”

Set the “System Optimization Factors” according to the Results

Vehicle Type	At Weight	At Speed							
		0 km/h	10 km/h	20 km/h	40 km/h	60 km/h	80 km/h	100 km/h	120 km/h
2-Axle Vehicle Empty	5000 kg	0 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
2-Axle Vehicle Full	10000 kg	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
3-Axle Vehicle Empty	0 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
3-Axle Vehicle Full	10000 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
4-Axle Vehicle Empty	0 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
4-Axle Vehicle Full	10000 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
5-Axle Vehicle Empty	0 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
5-Axle Vehicle Full	10000 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
6-Axle Vehicle Empty	0 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
6-Axle Vehicle Full	10000 kg	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %

2.5. Days 2-N: Verification (Trucks)

- Choose other typical Vehicles and Weights (Full/Empty)
 - Lane 1-N
 - Vehicle Choose other typical Vehicles
 - Weight Load/Unload the Vehicle to Full/Empty
 - Speed (Typical Speed)
- Measure the static reference Weight
- Perform 3-5 Runs at each Speed Value and “Mark” these runs:

Speed bins example	Speed (3-5 Runs)
1 Minimum Speed (0-20)	
2 Speed (20-40)	
3 Typical Speed (40-60)	
4 Speed (60-80)	
5 Maximum Speed (80<)	

- Export “Marked” Runs to “SpeedVerification_Full/Empty_TruckX_Date.csv”
(See chapter 3.1 “Export...”)

2.6. Days 2-N: Analysis

Analyze the Verification Export files according to chapter 3. “Factor calculation using Excel”

Set the “System Optimization Factors” according to the Results

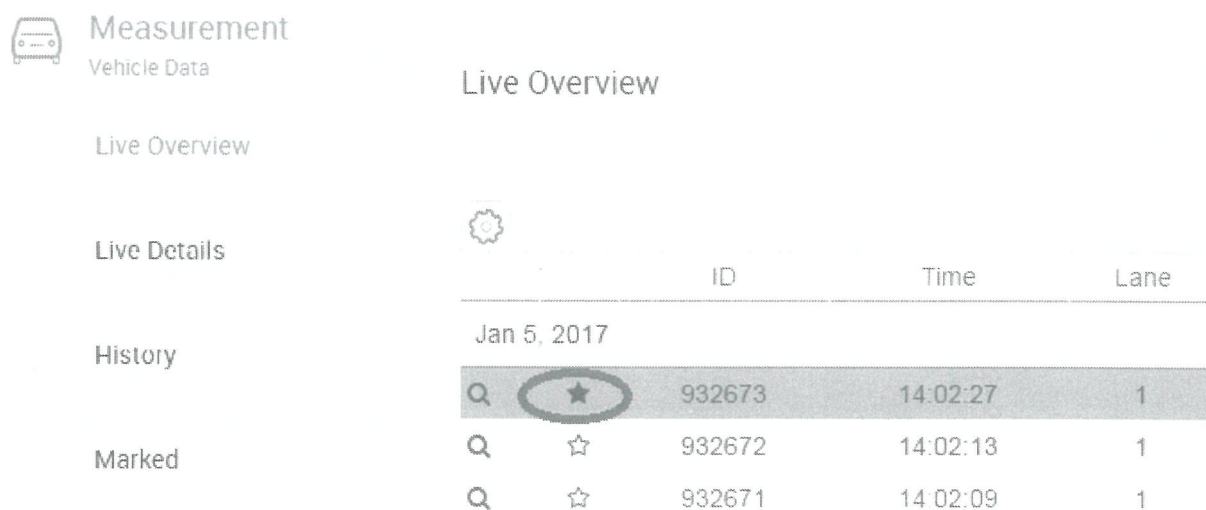
3. Factor calculation using Excel

For easy calculation of factors is available file
5204A_AssistedCalibrationCalcSheet_e_20170713.xlsm.
Below are described steps how to do that.

3.1. Export data from Kistler Data Logger

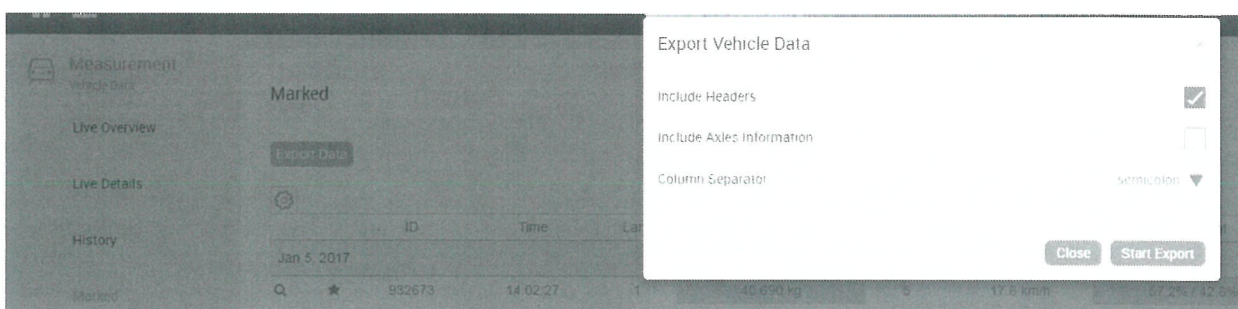
File has two sheets first is for importing data based on export from Kistler Data Logger and calculation sheet where are all calculated factors.

3.1.1. Mark all interested vehicles (just one type of vehicle and one weight load, different speeds are possible) in **Live Overview**



		ID	Time	Lane
Jan 5, 2017				
Q	★	932673	14:02:27	1
Q	☆	932672	14:02:13	1
Q	☆	932671	14:02:09	1

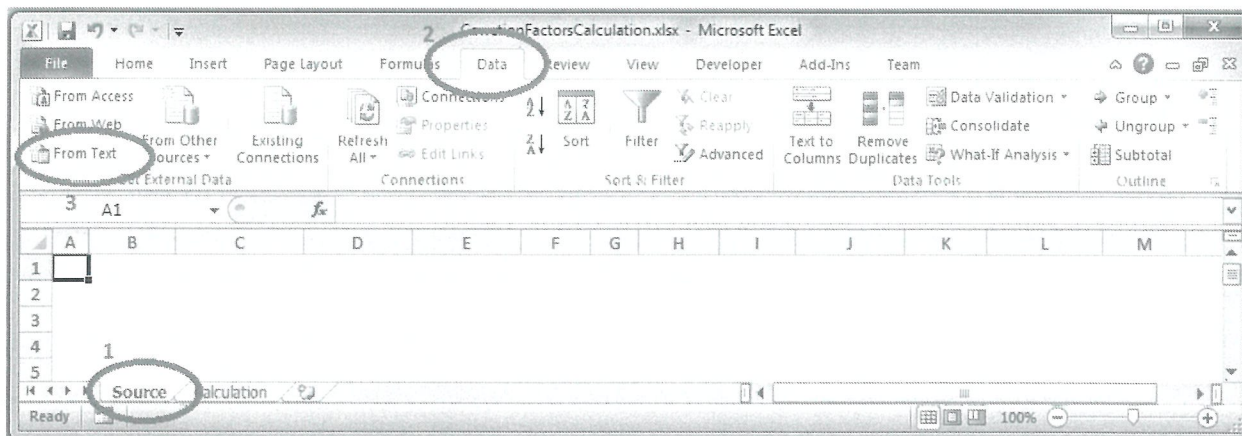
3.1.2. Go to the **Marked** and export all vehicles to the CSV file as a column separator choose **semicolon**. Save exported file.



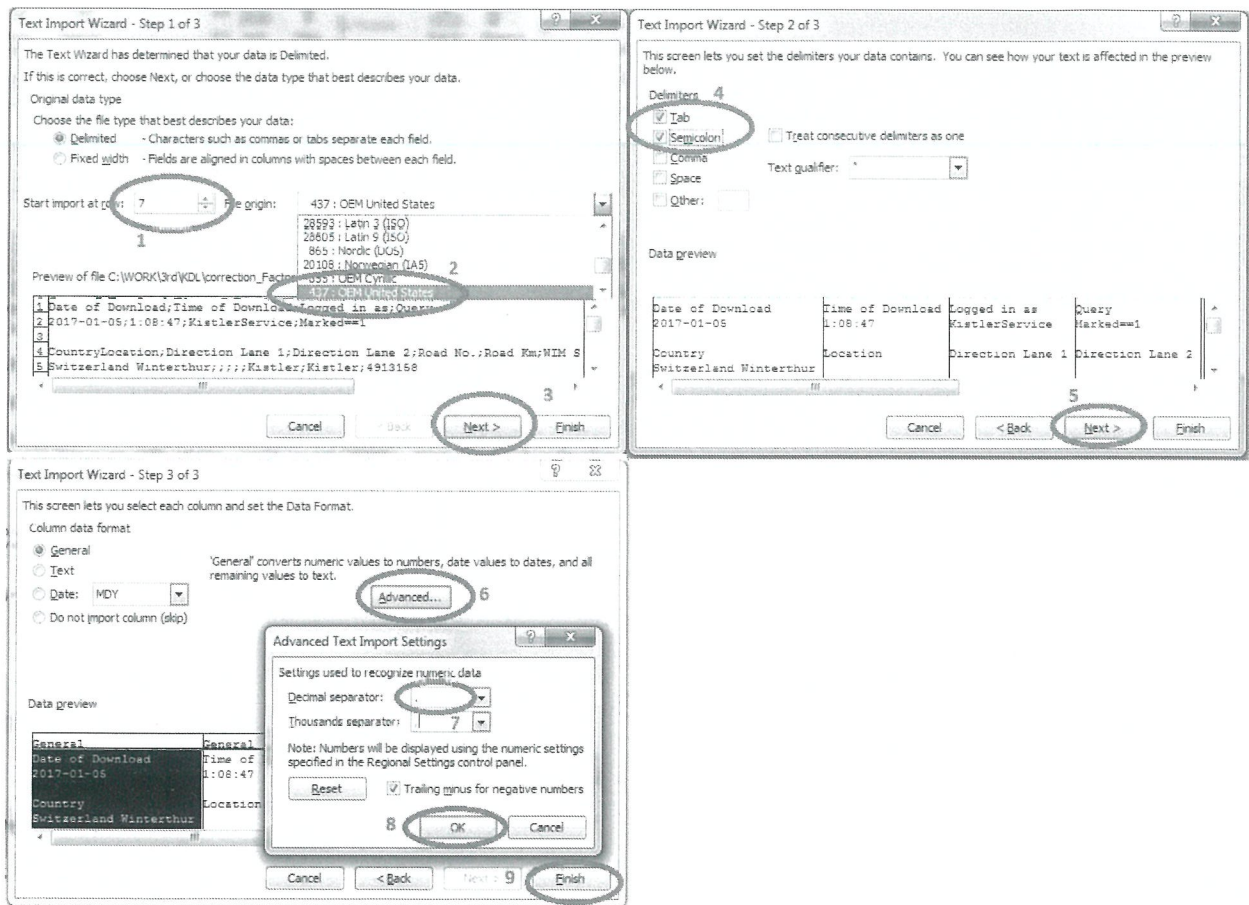
3.2. Import CSV file

Imported data to the **5204A_AssistedCalibrationCalcSheet_e_20170713.xlsm** has to be in followed format.

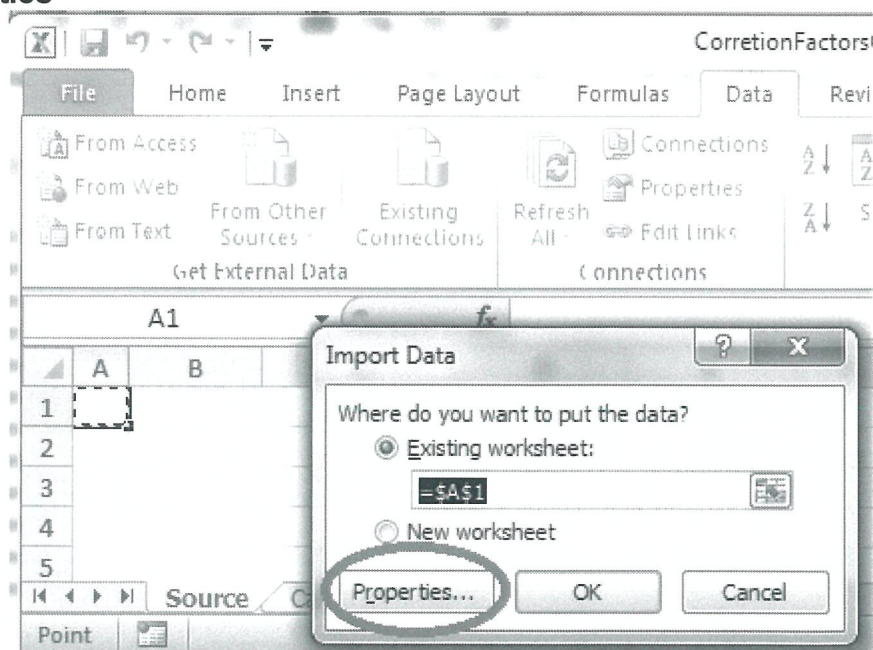
- a) Open file on **Source** sheet, than go to the bookmark **Data** and click on **From Text** from the Get External Data field.



- b) Choose downloaded export from **DataLogger**.
In Import wizard follow these steps:
 1. Setup Start Import at row: **7**
 2. Select file origin **437:OEM United States**
 3. Than **Next**
 4. Delimiters has to be set as **Tab** and **Semicolon**
 5. Than **Next**
 6. Click on **Advance**
 7. Decimal Separator has to be: **.** (**dot**)
 8. Click **OK**
 9. Click **Finish**



c) On **Import Data** window select cell A1 from **Source** sheet and click on **Properties**



- d) Uncheck box **Save query definition** and check box **Overwrite existing cells with new data, clear unused cells**. Then confirm two times by **OK** button.

External Data Range Properties

Name: 4979318-15_t

Query definition

☐ Save query definition

☐ Save password

Refresh control

☒ Prompt for file name on refresh

☐ Refresh every 60 minutes

☐ Refresh data when opening the file

☐ Remove external data from worksheet before closing

Data formatting and layout

☒ Include field names ☐ Preserve column sort/filter/layout

☐ Include row numbers ☒ Preserve cell formatting

☒ Adjust column width

If the number of rows in the data range changes upon refresh:

☐ Insert cells for new data, delete unused cells

☐ Insert entire rows for new data, clear unused cells

☒ Overwrite existing cells with new data, clear unused cells

☐ Fill down formulas in columns adjacent to data

OK Cancel

3.3. Results

In **5204A_AssistedCalibrationCalcSheet_e_20170713.xlsm** switch to the sheet **calculation**.

Some cells are inputs for calculation. Inputs cells have orange background.

Input Values							
True Weight [Kg]	38000						
		From	Speed BIN1		Speed BIN2	Speed BIN3	Speed BIN4
		To	5		8	10	15
			5		8	10	15
							25
							30

True Weight is weight measured on precise scales. If there was several runs with one type of vehicle but with different speeds, there is possibility setup speed bins – vehicles with speed in range **from** – **to**. From These selected vehicles will be calculated system optimization factors for the selected speed bin.

After selecting whole data factors are calculated.

Below is example of source of data and calculated results.

Example:

Source data is set of 22 vehicles, weight around 42000Kg. Various speed from 5km/h to 97km/h.

J	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	ID	VehicleID	Metrological	Starttime	StarttimeStr	LaneNo	Error	ErrorFlag	W	WarningFlag	Violation	Kistler Base Class ID	Vehicle	Class ID	ViolationFlag	Direction	Movement	FrontTire	BackTire	Duration	VehicleLength	GrossWeight	LeftWeight	RightWeight	Velocity
2	474	28E00677	1.48E+12	13.31.6	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	59.847	40.387	8.64	15.78	42560	20450	22110	6.10
3	475	28E00677	1.48E+12	10.11.1	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	58.579	38.83	10.405	15.7	42230	20110	22020	5.50
4	472	28E00677	1.48E+12	08.51.5	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	58.843	36.777	10.277	15.66	42390	20300	22090	6.60
5	471	28E00677	1.48E+12	07.34.5	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	53.406	34.984	10.481	15.71	42180	20260	21920	6.80
6	470	28E00677	1.48E+12	06.23.3	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	50.623	33.859	8.785	15.65	42440	20340	22100	14.00
7	469	28E00677	1.48E+12	05.14.0	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	58.674	40.124	10.453	15.71	42370	20380	21990	18.00
8	468	28E00677	1.48E+12	03.55.1	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	60.352	40.621	10.558	15.71	42430	20360	22070	15.00
9	467	28E00677	1.48E+12	02.33.9	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	52.291	35.607	9.529	15.68	42530	20410	22120	14.00
10	466	28E00677	1.48E+12	01.22.3	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	59.551	40.191	10.132	15.68	42430	20370	22050	17.00
11	465	28E00677	1.48E+12	00.01.8	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	53.229	38.64	11.342	15.77	42270	20300	21970	22.00
12	464	28E00677	1.48E+12	58.46.5	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	60.94	41.129	13.086	15.65	42320	20380	21940	22.00
13	463	28E00677	1.48E+12	57.24.9	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	52.64	36.509	11.53	15.74	42220	20240	21980	24.00
14	462	28E00677	1.48E+12	56.11.3	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	55.008	36.408	9.27	15.74	42230	20220	22010	30.00
15	461	28E00677	1.48E+12	54.57.3	1	0	0	0	0	0	0	1	FHWA	15	0	0	1	59.791	39.834	11.239	15.72	42290	20250	22080	31.00
16	460	28E00677	1.48E+12	53.35.8	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	47.049	31.899	11.070	15.71	42300	20200	22100	74.00
17	459	28E00677	1.48E+12	52.31.4	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	48.156	31.362	8.785	15.68	42630	20380	22250	52.00
18	458	28E00677	1.48E+12	51.24.7	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	47.296	32.812	9.534	15.78	42540	20420	22130	67.00
19	457	28E00677	1.48E+12	50.18.4	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	50.338	32.748	10.2	15.64	42440	20470	21970	59.00
20	456	28E00677	1.48E+12	49.07.5	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	51.489	36.101	11.193	15.75	42300	20350	21950	87.00
21	455	28E00677	1.48E+12	47.56.6	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	56.764	38.291	10.17	15.69	42270	20330	21940	89.00
22	454	28E00677	1.48E+12	46.39.2	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	57.762	39.246	11.256	15.68	42180	20300	21880	86.00
23	453	28E00677	1.48E+12	45.21.1	1	0	0	0	0	0	0	1	FHWA	15	0	0	0	49.451	31.85	10.41	15.79	42300	20120	21960	97.00

For the selected speed bin from 0 -10 km/h was calculated optimization factor: -0.48%. This factor will be applied to the into system optimization factors table in Data Logger.

Storing different system optimization factors based on speed is possible when **Speed correction** in Data Logger has to be **enabled**.

Figure 10 is a line graph showing the correction factor versus speed. The Y-axis is labeled "Correction factor" and ranges from -3.00% to 4.00% in increments of 1.00%. The X-axis is labeled "Speed" and ranges from 0 to 30 in increments of 10. There are two data series: "Measured Vehicle Runs" (represented by diamond markers) and "Correction Factors (for the Speed Bins)" (represented by square markers). The "Measured Vehicle Runs" series starts at 0% for speed 0, drops sharply to approximately -2.5% at speed 10, and then rises to about -0.5% at speed 20. The "Correction Factors (for the Speed Bins)" series starts at 2.3% for speed 0, drops sharply to approximately -1.2% at speed 10, and then rises to about 0% at speed 20.

Speed	Measured Vehicle Runs (%)	Correction Factors (for the Speed Bins) (%)
0	0.00	2.30
5	2.00	2.30
10	-2.50	-1.20
20	-0.50	0.00
25	-0.50	0.00

File **5204A_AssistedCalibrationCalcSheet_e_20170713.xlsm** is designed for calculation one type of loaded truck (one weight load). For calculation another weight loads of truck (half loaded, empty) all these steps has to be proceed again.

5204A AssistedCalibration 20170918.docx