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This deliverable consists of several documents. They are described in the following table:

Name of Document	Description of Content
FESTA D2_1_PI_Matrix_Final.xls	Main body of Deliverable 2.1
FESTA_D2_1_Annex1_HowToUse.doc	First annex of the deliverable, manual for excel-table.
FESTA_D2_1_Annex2_BackgroundInformation_Final.doc	Second annex of the deliverable, additional information on topics not covered sufficiently by the information in the excel-table.

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Field Operational Test Performance Indicators

Main table containing the performance indicators.
Measures linked with each indicator are specified in the "Measures" table.

KEY_PI	Performance indicator	Description	Unit	Subjective/Objective	Qualitative/Quantitative	Equation	Need for synchronisation	Comments	Required measures	References	Reliability	Validity	Safety	Environment	Efficiency	Acceptance	Ethical Issues	Special Requirements	Required frequency	Required resolution	Required accuracy			
Unique key identifying the performance indicator	*Basic name of the performance indicator*	*Illustrative description of the indicator*				*Euation used to calculate indicator.*	*Describes which of the involved sensors have to be time synchronised*	*Comments on the indicator*		*References of studies that used the PI.*		*e. g. frequency of use, well validated through studies, construct validity …*	*tick if relevant indicator for safety aspect*	*tick if relevant indicator for environment aspect*	*tick if relevant indicator for efficiency aspect*	*tick if relevant indicator for acceptance aspect*	*Criticality of measuring, logging, storing, publishing this PI, and what has to be considered for doing so*	*Anything out of the ordinary for this Performance Indicator, e. g. very fast startup-time, very high frequency or resolution, etc.*	*What is the frequency requirement for this measure? Guidelines?*	*What is the resolution requirement for this measure? Guidelines?*	*What is the precision requirement for this measure? Guidelines?*			
P01	Mean speed	Mean speed of the vehicle	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor	Can be calculated over time or distance, discrete value for a certain distance/time, but can be treated as continuous measure if calculated as rolling average.	Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	Dependent on scenario, high speed associated with high risk (). U.S.DOT and UMTRI plan to conduct FOT trials in 2008. They use GPS sensors to record speed and vehicle position	good	strong	x	x	x		may highlight illegal behaviour (speeding)	N/A	chosen speed sensor ideally > 10Hz	chosen speed sensor ideally > 0.1kph	typical signal to noise ratio 50:1 for higher bandwidth speed sensor			
P02	SD speed	Standard deviation of vehicle speed	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor	Should be used over equivalent time or distance epochs, discrete value for a certain distance/time, but can be treated as continuous measure if calculated as rolling average	Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	In constant traffic flow scenarios, high variation considered an indicator of poor speed control, associated with development of shock waves in traffic flows and rear-end shunts	good	strong	x	x	x		none	N/A	as above	as above	as above			
P03	Maximum speed	Max speed recorded over event/scenario	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor		Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	In some scenarios, unsuitable (or high max speed) is associated with high risk	good	debateable	x	x	x		may highlight illegal behaviour (speeding)	N/A	as above	as above	as above			
P04	Minimum speed	Mix speed recorded over event/scenario	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor		Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	Rarely used, but maybe of interest in aging research as an indicator of hazardous behaviour to other road users	good	debateable	x	x	x		none	N/A	as above	as above	as above			
P05	85th %ile speed	85th percentile speed	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor	Assumes a normal distribution of speed profile	Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	Commonly used percentile to describe design speeds in road design. Used in assessment of speed reduction measures.	good	standard	x	x	x		may highlight illegal behaviour (speeding)	N/A	as above	as above	as above			
P06	Median speed	median speed	m/s (kph or mph)	objective	quantitative	standard statistical definition	speed sensor		Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	Alternative to above	good	standard	x	x	x		may highlight illegal behaviour (speeding)	N/A	as above	as above	as above			
P07	Spot speed	measured speed in a certain spot (defined location)	m/s (kph or mph)	objective	quantitative		speed sensor and position	if to be measured in-car then a position sensor is necessary, if measured from outside a laser or equal measuring device necessary	Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance AND GPS_Longitude AND GPS_Latitude															
P08	Percentage speed limit violation	time and/or distance (or proportion of) spend exceeding posted speed limit	s or m (%) (count)	objective	quantitative	dependent on chosen dimension	speed sensor	Assumes posted speed limit is suitable for safety case	(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) (AND SpeedLimit_ISA OR SpeedLimit_RoadDatabase OR SpeedLimit_SignRecognition)	Unsuitable speed associated with high risk	good	strong	x				none	N/A	as above	as above	as above			
P09	number of speed limit violations	the number of times the speed limit was exceeded (count transitions from below speed limit to above speed limit)		objective	quantitative	count	speed sensor and speed limit (possibly position)		(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) (AND SpeedLimit_ISA OR SpeedLimit_RoadDatabase OR SpeedLimit_SignRecognition)															
P10	approach speed to events	speed at xxx seconds or xxx meters before an event	m/s	objective	quantitative		speed sensor and time of event	the event of interest must be well defined in terms of time or location	(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) AND [event time or location]															
P11	maximum acceleration	peak level of longitudinal or lateral acceleration achieved during a scenario	m/s^2	objective	quantitative	SI unit	accelerometer or speed sensor (for differentiation of speed wrt time)	Wide variety in sensor quality. Potential signal noise if using speed differentiation (SD)	Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance OR Acc_Long OR AccLat	Dependent on scenario, high vehicle deceleration associated with either appropriate response to extreme event or as consequence of delayed response (e.g. inattention)	good	strong	x		x		none	If using speed differentiation (SD), output requires low pass filtering (cut off frequency ~ 5Hz;)	accelerometer bandwidth ideally > 500Hz; if using SD chosen speed sensor ideally > 100Hz	If using SD, resolution will be orders of magnitude worse than using accelerometer	Sensor noise described in terms of mg/sqrt(Hz), ideally < 0.3			
P12	maximum jerk	peak level of rate of change of longitudinal or lateral acceleration	m/s^3	objective	quantitative	rate of change of accelerometer output low pass noise filtered ~ 25Hz	accelerometer	Certain signal noise from differentiation of acceleration sensor data	Jerk_Long OR Jerk_Lat	Research suggests that jerk overrides acceleration in human perception of motion strength (Grant et al, 2007). High jerk associated with rapid onset of acceleration, e.g from sudden avoidance manouevre	relatively untested	strong	x			x		Filtered output (estimated low pass cut off ~ 25Hz)	accelerometer bandwidth ideally > 500Hz	Resolution orders of magnitude worse than raw accelerometer output	Sensor noise ideally < 0.2 mg/sqrt(Hz)			
P13	max brake force								Brake_Force															
P14	number of times brake force > xxx	the number of times the brake force exceeds xxx per time or distance or another apropriate variable		objective	quantitative	count			Brake_Force															
P15	Mean time headway (THW)	* The mean value of the time gap to a object, e.g., a lead vehicle (bumper to bumper) or pedestrian, which is travelling in the vehicle's path of travel.	s	objective	quantitative	$\overline{THW} = \text{mean}(THW)$ $\forall\, 0 \le THW \le THW^*$ where THW^* is often taken as 3s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform duration less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data. * The THW samples are measured at a fixed time interval	THW	* Östlund et al. (2004)		H	x		x				* velocity: 10Hz * distance to lead car: 10Hz * THW: 10Hz * mean THW: timing on task					
P16	Mean of time headway (THW) local minima	* Defined as the mean of the local THW minima. * A local THW minima is determined within a THW waveform * Reflects a safety margin to a lead vehicle, pedestrian or other object	s	objective	quantitative	$\overline{THW} = \text{mean}(THW_{min})$ where THW_{min} = the minimum THW $\forall\, 0 < THW < THW^*$ [s] THW^* is often taken as 3s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform duration less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data. * The THW samples are measured at a fixed time interval	THW	* Östlund et al. (2004)		L	x						* velocity: 10Hz * distance to lead car: 10Hz * THW: 10Hz * Mean of THW minima: timing on task					
P17	Standard deviation of time headway (THW)	* Defined as the standard deviation of the THW	s	objective	quantitative	$\sigma = \text{std}(THW)$ $\forall\, 0 < THW < THW^*$ [s] where THW^* is often taken as 3s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform duration less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data. * The THW samples are measured at a fixed time interval	THW				?		?				* velocity: 10Hz * distance to lead car: 10Hz * THW: 10Hz * Std of THW: timing on task					
P18	Standard deviation of the local time headway (THW) minima	* Defined as the standard deviation of the local THW minima.	s	objective	quantitative	$\sigma = \text{std}(THW_{min})$ where THW_{min} = the minimum THW $\forall\, 0 < THW < THW^*$ [s] THW^* is often taken as 3s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform durationa less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data. * The THW samples are measured at a fixed time interval	THW				?		?				* velocity: 10Hz * distance to lead car: 10Hz * THW: 10Hz * Std of THW minima: timing on task					

P19	The proportion of time headway (THW) local minima less than 1s	* The proportion of THW local minima less than 1 seconds * Reflects a percentage of extremities in the longitudinal control task	-	objective	quantitative	$THW_{prop} = \frac{size\{THW_{min} < 1 \mid THW_{min}\}}{size\{THW_{min}\}} \cdot 100\%$ where THW_{min} = the minimum THW $\forall\, 0 < THW < THW^*$ [s] THW^* is often take n as 3s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform durationa less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data.	THW	* Östlund et al. (2004)			x						* velocity: 10Hz * distance headway: 10Hz * THW: 10Hz * Proportion of THW local minima: timing on task					
P20	The probability of time headway (THW) less than 1s during following	* The probabiltiy that the THW is less than a 1s during following. * Reflects a percentage of extremities in the longitudinal control task	-	objective	quantitative	$THW\ P = \frac{\text{duration that } THW \le 1}{\text{duration that } THW \le THW^*} \cdot 100\%$ THW^* = the threshold value for car following often take n 3 s	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* THW values >3 are ignored because than there is no car-following * waveform durationa less than 1s are ignored? * Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * Any transient effects in the beginning at ending of the situation should be excluded form the data. * The THW samples are measured at a fixed time interval	THW				x						* velocity: 10Hz * distance headway: 10Hz * THW: 10Hz * PI: timing on task					
P21	The probability of following	* The probability of following * Reflects the traffic density	-	objective	1	$P_{following} = \frac{\text{duration that } THW \le THW^*}{T_{total}} \cdot 100\%$ THW^* = the threshold value for car following often taken 3 s T_{total} = total duration of measurement [s]	* THW * (Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.)	* Sensor locking on vehicles and objects other than in the travel path needs to be advoided. * The THW samples are measured at a fixed time interval	THW						x				* velocity: 10Hz * distance headway: 10Hz * THW: 10Hz * PI: timing on task					
P22	Mean of time-to-collision (TTC) local minima	* The mean time required for two vehicles (or a vehicle and a object) to collide if they continue at their present speed and on the same path. * Measures a longitudinal margin to lead vehicles or objects.	s	objective	quantitative	$\overline{TTC}$ = mean $\{TTC_{min}\}$ where TTC_{min} = TTC minima within a TTC waveform [s] A waveform starts and ends when the TTC values crosses the 15s value	* TTC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* TTC values >15s are ingnored. * wave durations less than 1s are ignored. * Only minima are analysed. Resulting in less statical power than mean time headway. * The TTC samples are measured at a fixed time interval	TTC	* Östlund et al. (2004)			x						* distance to lead car: 50Hz (to determine time derivative) * TTC: 10Hz * PI: depends on task	* velocity: 2/3.6=0.56 m/s * distance headway: 0.1 m * PI: <0.1s	<0.1s			
P23	The proportion of time-to-collision (TTC) local minima less than 4 seconds	* The proportion of TTC local minima less than 4 seconds * Reflects the proportion of safety critical values of the longitudinal control task	-	objective	quantitative	$TTC_{prop} = \frac{size\{TTC_{min} < 4 \mid TTC_{min}\}}{size\{TTC_{min}\}} \cdot 100\%$ where TTC_{min} = the minimum TTC $\forall\, 0 < TTC < TTC^*$ [s] TTC^* is often taken as 15s	* TTC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* TTC values >15s are ingnored. * wave durations less than 1s are ignored. * Only minima are analysed. Resulting in less statical power than mean time headway. * The TTC samples are measured at a fixed time interval	TTC	* Östlund et al. (2004)			x						* distance to lead car: 50Hz (to determine time derivative) * TTC: 10Hz * PI: depends on task	* velocity: 2/3.6=0.56 m/s * distance headway: 0.1 m * PI: <0.1s	<0.1s			
P24	Time exposed time-to-collision (TET) probability	* Proportion of time of which the TTC is less than 4s * The duration of expostion to safety-critical time-to-collision values over a specified time duration	-	objective	quantitative	TET = duration that $TTC \le TTC^*$ TTC^* = the threshold values often taken 4 s $TET\ P = \frac{\text{duration that } TTC \le TTC^*}{T_{total}} \cdot 100\%$ TTC^* = the threshold value often taken 4 s T_{total} = total duration of measurement [s]	* TTC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* TTC values >15s are ingnored. * wave durations less than 1s are ignored. * Only minima are analysed. Resulting in less statical power than mean time headway. * The TTC samples are measured at a fixed time interval	TTC	Minderhoud et al 2001			x						* distance to lead car: 50Hz (to determine time derivative) * TTC: 10Hz * PI: <0.1s	* velocity: 2/3.6=0.56 m/s * distance headway: 0.1 m * PI: <0.1s	<0.1s			
P25	Time integrated time-to-collision (TIT) probability indicator	* Time-to-collision (TIT) performance indicator weighted by the duration and amplitude of safety critcial TTC values. * Reflects the exposition time to duration-weighted unsafe TTC-values, which is negative for road safety.	-	objective	quantitative	$TIT = \int_0^T (TTC^* - TTC(t))\,dt$ $\forall\, 0 \le TTC(t) \le TTC^*$ where TTC^* = the threshold value often taken as 4 s $TIT\ P = \frac{TIT}{TTC^* \cdot T_{total}}$ where TTC^* = the threshold value often take n as 4 s T_{total} = total duration of measuremen t [s]	* TTC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* Wave durations less than 1s are ignored. * The TTC samples are measured at a fixed time interval	TTC	Minderhoud et al 2001			x						* distance to lead car: 50Hz (to determine time derivative) * TTC: 10Hz * PI: depends on task	* velocity: 2/3.6=0.56 m/s * distance headway: 0.1 m * PI: <0.1s	<0.1s			
P26	Mean (Median) value of the minima time-line-crossing (TLC) values (sometimes called the mean TLC)	* TLC is defined as the time to reach the lane marking assuming a fixed heading angle and a constant speed. * Mean (Median) TLC is defined as the mean (median) of the local minima. * Reflects the percentage of extremities in the lateral control task	s	objective	quantitative	$\overline{TLC} = \text{mean}\{TLC_{min}\}$ where TLC_{min} = the minimum $\lvert TLC \rvert\ \forall\, 0 \le \lvert TLC \rvert < TLC^*$ [s] TLC^* is often taken as 20s	TLC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* TLC values >20s are ignored * wave form duration <1s are ignored * For task lengths shorter than 10s, there may be a risk that no minima are found due to the fact that there are too few TLC-minima. * A problem with TLC occurs if the lane markings do not represent the safe travel path. * The TLC samples are measured at a fixed time interval	TLC	* Winsum et al. (1998) * Östlund et al. (2004)			x						* PI: depends on task	* PI: <0.1 s	* PI: <0.1 s			
P27	The proportion of time-to-line-crossing (TLC) min values < 1 s	* Time to reach the lane marking assuming a fixed heading angle and a constant speed. * The ratio # local minima smaller than one second divided by total # local minima. * Reflects the percentage of extremities in the lateral control task	-	objective	quantitative	$TLC_{prop} = \frac{size\{TLC_{min} < 1 \mid TLC_{min}\}}{size\{TLC_{min}\}} \cdot 100\%$ where TLC_{min} = the minimum $\lvert TLC \rvert\ \forall\, 0 \le \lvert TLC \rvert < TLC^*$ [s] TLC^* is often taken as 20s	TLC * Own_Distance OR Own_Time OR GPS_Longitude, GPS_Latitude OR Time_OfDay, LOS etc. is used to determine the PI per distance, time duration, type of road etc.	* TLC values >20s are ignored * wave form duration <1s are ignored * For task lengths shorter than 10s, there may be a risk that no minima are found due to the fact that there are too few TLC-minima. * A problem with TLC occurs if the lane markings do not represent the safe travel path. * The TLC samples are measured at a fixed time interval	TLC	* Östlund et al. (2004)			x						* PI: depends on task	* PI: <0.1 s	* PI: <0.1 s			
P28	PET (Post Encroachment Time)		s					to measure in situations where two road-users, not on a collision course, pass over a common spatial point or area with a temporal difference that is below a predetermined threshold GPS position not accurate enough for PET. Video for vehicle type and positioning identification desirable. 360 deg-radar might help.	Own_Position AND (Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) AND Route_Actual				x											
P29	Frequency of performed left and right lane changes	Time frequency of performed lane changes, either time or distance based	Number of lane changes made per hour or per kilometre	Objective	Quantitative				LaneChange				x		x									

Measures

	Measure group	Vehicle independent measure name (KEY)	Description	Comments	Generalisability	Unit	Other limitations	Special needs	Storage requirement	Comment storage requirement	Potential problems regarding privacy
Comments	*The general class of measure, such as Speed. Position, Acceleration etc.*	*The name of the measure. It also works at key for this table, therefore no duplicates can occur.*	*Description of this measure.*	*Additional comments to the measure.*	*Describes how easily the measure can be generalised from one vehicle type/brand/model etc to the next. If this is a 5 then doing analysis on the "vehicle*	*Standard unit that applies to the measure. Use preferably SI units.*	*General limitations of the measure, which can be important to consider in FOT. Nature of the limitation can be technical, ethical, legislative, etc.*	*Important needs to be considered for the measure They can be technical, practical, legislative, etc.*	*Space requirement to store the data with the typical frequency.*	*Comment on the data format for the memory requirement (for example binary or ASCII data, text format, etc.)*	*Explanation of how this sensing system contributes to the privacy issues for FOTs*
Unit					*Scalar*	*SI-units*			*Kbyte/sec*		
Range min					*1*				*0*		
Range max					*5*				*1.00E+09*		
	Speed	Speed_CAN	Vehicle speed obtained from the CAN bus	Need speed profile of the vehicle							May arise if max speed exceeds speed limit
		Speed_GPS	Vehicle speed obtained from a GPS-based sensor			m/s	In tunnels the GPS signal is usually lost, and no speed reading is possible. When starting the sensors a time up to 5 minutes may be necessary to acquire precise GPS data.	Sensor must have sky-visibility, thus not be mounted under metallic roofing.	0.149	Memory requirement is calculated for raw NMEA data in ASCII format, storing only $GPGGA and $GPRMC sentences at 1 Hz sampling frequency.	May arise if max speed exceeds speed limit
		Speed_WheelUnitDistance	A pulse sensor on a free rolling wheel	In order to get better accuracy in V and dV/dT compared to using ABS		accumulated number of pulses		The tire rolling radius. Number of pulses/rotation			
	acceleration	Acc_Long	Measurement of vehicle longitudinal translational acceleration using analogue or digital accelerometer(s)	Most easy and cheap applications are digital, typically lower bandwidth problem to isolate vehicle acceleration from gravity	5	m/s2	None significant, but output needs to be noise filtered	Rigid fixing required for sensor. Difficulty in siting along vehicle longitudinal and lateral axes.	2 bytes at rate of speed sensor (typically 500Hz +)	User definable	none significant
		Acc_Lat	Measurement of vehicle lateral translational acceleration using analogue or digital accelerometer(s)	Most easy and cheap applications are digital, typically lower bandwidth problem to isolate vehicle acceleration from gravity	5	m/s2	None significant, but output needs to be noise filtered	Rigid fixing required for sensor. Difficulty in siting along vehicle longitudinal and lateral axes.	2 bytes at rate of speed sensor (typically 500Hz +)	User definable	none significant
		Acc_Vertical	acceleration of the vehicle in z-direction (vertical): for detection of road bumps location etc.			m/s2			2 bytes at rate of speed sensor (typically 500Hz +)	User definable	none significant
		Brake_Force	force with which the brake pedal is pressed			N	brake signal on CAN can trigger for vibrations in the road (potholes etc.)				
		Accelerator_Operation	distance how far the accelerator is pressed			m					
		KickDown_Activation	kick down function activation in vehicles with automatic transmission								

		Clutch_Operation	distance how far the clutch pedal is pressed			m					
		Gear_Selected	active gear, either selected by the driver or by the automatic transmission system								
		Direction_Indicator	activity of direction indicators (left or right turn indicated)								
	jerk	Jerk_Long	Post-processed rate of change of accleration	Susceptible to noise from sensor and differentiation	5	m/s3	None significant, but output needs to be noise filtered	Signal processing	2 bytes at rate of speed sensor (typically 100Hz +)	User definable	none significant
		Jerk_Lat	Post-processed rate of change of accleration	Susceptible to noise from sensor and differentiation	5	m/s3	None significant, but output needs to be noise filtered	Signal processing	2 bytes at rate of speed sensor (typically 100Hz +)	User definable	none significant
	Lateral position	Position_Lat	Lateral position of the vehicle to the center line	Need the center line on the road as refernece		m			small, some bytes per second	User definable	none significant
	Steering wheel position	Stw_Angle	Sterring wheel position obtained from the CAN bus	CAN bus must provide the streenig wheel position information		°			small, some bytes per second	User definable	none significant
	GPS position	GPS_Longitude	Longitudinal vehicle position	Position profile needed for each trip							Absolute positioning systems is probably the sensor type that reveals the most about personal habits as well as home/work address etc - if not constrained
		GPS_Latitude	Latitudinal vehicle position	Position profile needed for each trip							
		GPS_Altitude	Road and traffic conditions	Estimation of road gradient							
	Environment Sensor	Time_DistanceOtherVehicles	Time distance to the vehicle ahead in the own lane, adjacent lane and oncoming lanes	* Information on traffic in oncoming lanes (on roads without barriers between the directions) is important for systems that give overtaking or passing assistance on single carriageway roads * Distance to vehicles in the own lane is often critical information and distance to vehicles in adjacent lanes is highly desirable		seconds					
	Environment Sensor	Space_DistanceLeadVehicle	Space distance to the vehicle ahead in the own lane	* Information on traffic in oncoming lanes (on roads without barriers between the directions) is important for systems that give overtaking or passing assistance on single carriageway roads * Distance to vehicles in the own lane is often critical information and distance to vehicles in adjacent lanes is highly desirable		metres					
	Environment Sensor	Space_DistanceOtherVehicles	Space distance between FOT vehicle and the vehicle behind in the own lane and vehicles in adjacent and oncoming lanes	* It is important for traffic modelling to also measure distance to adjacent lanes. However, it may sometimes be difficult and/or expensive do conduct these measurements. * Information on traffic in oncoming lanes (on roads without barriers between the directions) is important for systems that give overtaking or passing assistance on single carriageway roads * Distance to vehicles in the own lane is critical and distance to vehicles in adjacent lanes is highly desirable. * Information on oncoming vehicles is critical for systems that give overtaking or passing assistance on single carriageway roads.		metres					

Pre-processed (derived from sensor, other pre-processed)

Countermeasures for ensuring privacy				Signal processing based data dropout	Synchronisation	Pre-processing methodology	Equation for pre-processing
How can the data be handled/processed to minimize the privacy intrusion				*Typical conditions at which the measure drops data directly related to the signal processing*	*How is the data synchronized with the other measures if it is an aggregation of more than one measure.*	*Methodology for signal processing. Short description on how the data is processed to achieve the wanted results*	*How the pre-processing is made. Pre-processing should be relatively simple operations.. There is a need to have cross references to other KEY_measures. All KEY_measures used must be defined to be used.*
					Data is synchronized with the CAN bus synch timer when stored in files (one column is the CAN synch).		
none significant				Failure of system	Synchronisation via common data logger	Sensor noise reduction	Low pass filter cut-off frequency ~ 5Hz (noise reduction) Sensor noise reduction, standard signal processing technique
none significant				Failure of system	Synchronisation via common data logger	Sensor noise reduction	Low pass filter cut-off frequency ~ 5Hz (noise reduction) Sensor noise reduction, standard signal processing technique
none significant				Failure of system	Synchronisation via common data logger	Sensor noise reduction	Low pass filter cut-off frequency ~ 5Hz (noise reduction) Sensor noise reduction, standard signal processing technique

none significant				Failure of system	Synchronisation via common data logger	Sensor noise reduction	Low pass filter cut-off frequency ~ 25Hz (noise reduction) based on Acc_Long Sensor noise reduction, standard signal processing technique
none significant				Failure of system	Synchronisation via common data logger	Sensor noise reduction	Low pass filter cut-off frequency ~ 25Hz (noise reduction) based on Acc_Lat Sensor noise reduction, standard signal processing technique
Discarding data x kilometres around the start/stop point of the vehicle is one option.							

Raw (from sensor)

Pre-processing limitations	Sensor source	Data source - sensor	Raw Unit	Synchronization - hardware	Sensor based data dropout	Methodology	In-car data	Frequency	Frequency comment
General limitations of the pre-processing, which can be important to consider in FOT. Nature of the limitation can be technical, ethical, legislative, etc.	*Reference to the specific sensor this measure is based on.*	*Source data on which the data is based. This can be of importance for the limitations and requirements of the indicator.*	*What is the unit of the data that comes from the sensor (then converted to Unit)*	*How is the data synchronized with the other collected data.*	*Typical conditions at which the sensor drops data directly related to the measure measurement (from a sensor).*	*Methodology for signal (sensor) to measure implementation. Short description on how the data is usually obtained and used.*	*Is the data available without additional sensors in a standard car (from the CAN bus for example).*	*What range the frequency for this type of sensor usually is in*	*Explanation in text about issues with frequencies for this sensor*
	S00								
In tunnels the GPS signal is usually lost, and no speed reading is possible. When starting the sensors a time up to 5 minutes may be necessary to acquire precise GPS data.	S02, S01	GPS satellite position (triangulation calculation on phase difference between L1 and L2 signal and C/A + P-code) with data from at least 3 satellites.		Data is synchronized with the CAN bus synch timer when stored in files (one column is the CAN synch).		GPS sensor is installed in vehicle (where metal roofing does not weaken signal). Data is send via USB or RS232 to computer, where the NMEA data is logged for off-line evaluation.	NO		
	S75								
Processed signals suffer from attenuation	S03, S08	Sensor output corresponds to acceleration being experienced (typically piezoelectric - containing microscopic crystal structures that get stressed by accelerative forces, causing small voltages to be generated. System requires regular calibration.	mV converted to g	Synchronisation via common external data logger using CAN bus timer	Sensor failure	Sensitivity of sensor critical to accuracy of recorded data. Consideration of natural frequency of sensor mounting required.	No	Dependent on quality of sensor. Typically between 100-500Hz	Dependent on quality and type of system
Processed signals suffer from attenuation	S03, S07	Sensor output corresponds to acceleration being experienced (typically piezoelectric - containing microscopic crystal structures that get stressed by accelerative forces, causing small voltages to be generated. System requires regular calibration.	mV converted to g	Synchronisation via common external data logger using CAN bus timer	Sensor failure	Sensitivity of sensor critical to accuracy of recorded data. Consideration of natural frequency of sensor mounting required.	No	Dependent on quality of sensor. Typically between 100-500Hz	Dependent on quality and type of system
Processed signals suffer from attenuation	S03, S09	Sensor output corresponds to acceleration being experienced (typically piezoelectric - containing microscopic crystal structures that get stressed by accelerative forces, causing small voltages to be generated. System requires regular calibration.	mV converted to g	Synchronisation via common external data logger using CAN bus timer	Sensor failure	Sensitivity of sensor critical to accuracy of recorded data. Consideration of natural frequency of sensor mounting required.	No	Dependent on quality of sensor. Typically between 100-500Hz	Dependent on quality and type of system
	S87								
	S10, S00								
	S00								

				S11, S00								
				S00								
				S00, S92								
Processed signals suffer from attenuation				S03	as S03	mV converted to g and processed to g/s	Synchronisation via common external data logger using CAN bus timer	Sensor failure	As S03	No	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer
Processed signals suffer from attenuation				S03	as S03	mV converted to g and processed to g/s	Synchronisation via common external data logger using CAN bus timer	Sensor failure	As S03	No	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer
				S22	A camera captures the enviroment and out of this informations software calculate in the background the lateral position to the center line?	pictures converted and processed to m	Data is synchronized with the CAN bus synch timer when stored in files (one column is the CAN synch).			NO		
				S13, S00		°	Data storing with the CAN bus time			YES		
				S01, S02								
				S01, S02								
				S01, S02								
				S14, S18, S35								
				S14, S18, S35								
				S14-S22, S35								

Note that the specifications will give the general specifications of this measure from the specific sensor type, as well as a typical values for reference state-of-the-art FOTs

Specification range					Typical specification for state-of-the-art FOT			
Resolution	**Resolution comment**	**Precision/ accuracy**	**Precision/ accuracy comment**	**Storage needs**	**Frequency**	**Resolution**	**Precision/ accuracy**	**Storage needs**
What resolution range is available for this sensor	*Explanation in text about issues with resolution for this sensor*	*What precision/accuracy is available for this sensor*	*Explanation in text about issues with precision/accuracy for this sensor*	*How much data (kb/mb) is required per hour recording - range*	*Explanation in text what frequency is required and why.*	*Explanation in text what resolution is required and why.*	*Scale 1-5 of how important good precision/accuracy is for Performance Indicators*	*How much data (kb/mb) is required per hour recording*
			Estimated position error when full sky coverage and good satellite position: ??-??m					
			Estimated position error when full sky coverage and good satellite position: ??-??m					
The maximum output typically 5V. Typical accelerometer sensitivity 1000mV/g	Typical dynamic range +/- 5g	between ~0.1% - 1%	Proportional to sensor noise	~2Mbyte per hour	Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable
The maximum output typically 5V. Typical accelerometer sensitivity 1000mV/g	Typical dynamic range +/- 5g	between ~0.1% - 1%	Proportional to sensor noise	~2Mbyte per hour	Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable
The maximum output typically 5V. Typical accelerometer sensitivity 1000mV/g	Typical dynamic range +/- 5g	between ~0.1% - 1%	Proportional to sensor noise	~2Mbyte per hour	Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable

Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	~2Mbyte per hour	Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable			
Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	Order of magnitude worse than accelerometer	~2Mbyte per hour	Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable			
			Estimated position error when poor visibility on the street		Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable			
Full steering range(typical -780° to +780°), typical resolution 0.1°	Typical dynamic range +/- 2.5°				Current standards more than acceptable	Current standards more than acceptable	3	Current sensor standard acceptable			

Sensor group	Sensor class	Sensor type	Sensor Key	Description	Technology used	Typical hardware interface	Secondary hardware interface	Communi-cation protocol	Need of ECU, connector box or other extra control unit
Grouping of sensors to indicate what the main type of information this sensor primarily measures	Sensor class.	The specific type of sensor.		Description of the sensor.	What is the underlaying technology used for this sensor?	The typical source of the data.	Alternative source of data if usual source is not used.	Typically, what communication protocol is the raw data source using?	Does the sensing system need other units (than the sensor) to be integrated in the vehicle? Should be marked even if unit could be shared between sensors.
Vehicle	Vehicle bus	CAN (or LIN/MOST/FlexRay)	S00	The vehicle bus is considered a sensor with many possible outputs. For each FOT, the capabilities of the intended vehicle must be investigated.	Several different built-in sources.	Available vehicle bus		The particular protocol version for the bus. Details may be proprietary and not available.	The logger must be equipped with a CAN capable device, like a CAN bridge or CAN gateway.
Positioning system	GPS	GPS	S01	"Standard" consumer global satellite positioning system.	GPS	Internal	CAN or USB	NMEA	Antenna always needed
	DGPS	DGPS	S02	Enhanced GPS, using reference stations on the ground, improving accuracy.	GPS, radio, DGPS service	Internal	RS232	NMEA	Antenna always needed. Some implementations require separate GPS and Differential reciever boxes, of which one or both may be integrated in the DAS
	Inertial Navigation System (INS)	Inertial Navigation System (INS)	S03	Acceleration and gyro based system often used in combination with GPS to "fill in the blanks" at GPS dropouts	Usually accelerometers and gyros.	Device CAN	RS232		Usually one unit connected to the DAS
Vehicle dynamics	Rate sensors	Yaw rate	S04		Angular rate sensor	Vehicle bus	Analog		(ADC if secondary interface)
		Pitch rate	S05		Angular rate sensor	Analog			ADC
		Roll rate	S06		Angular rate sensor	Vehicle bus	Analog		(ADC if secondary interface)
	Acceleration sensors	Lateral acceleration	S07		Accelerometer	Vehicle bus	"		"
		Longitudinal acceleration	S08		"	Vehicle bus	"		"
		Vertical acceleration	S09		"	Analog			ADC
		Speed sensor	S75	Sensor on free running wheel for increased accuracy.	Pulse sensor/counter	Analog			"
Driver/vehicle interaction control	Driver vehicle interaction control	Throttle pedal position	S10			Vehicle bus	Analog		interface)
		Clutch pedal position	S11			Vehicle bus	"		"
		Brake pedal position	S12			Vehicle bus	"		"
		Brake force	S87			Analog			ADC
		Windscreen wipers position	S69			Analog			"
		Turn indicator status	S92			Analog			"
		Steering wheel angle	S13			Vehicle bus	"		(ADC if secondary interface)
		Forward looking video	S14	Low Light - High Res B&W/colour video camera	CCD/(CMOS)	Analog=>digitizer (grabber card)	Digital: Ethernet, USB, Firewire	(depending on grabber)	Frame grabber/grabber card, camera lens
		Rearward looking video	S15	Low Light - High Res B&W video camera	CCD/(CMOS)	Analog=>digitizer (grabber card)	Digital: Ethernet, USB, Firewire	(depending on grabber)	"

Environment sensors	Environment Video	Side looking video - left	S16	Low Light - High Res B&W video camera	CCD/(CMOS)	Analog=>digitizer (grabber card)	Digital: Ethernet, USB, Firewire	(depending on grabber)	"
		Side looking video - right	S17	Low Light - High Res B&W video camera	CCD/(CMOS)	Analog=>digitizer (grabber card)	Digital: Ethernet, USB, Firewire	(depending on grabber)	"
	RADAR/LIDAR	Forward looking RADAR	S18	Multi target radar	24 GHz AAC radar	Device CAN	RS232		Yes
		Side looking RADAR - left	S19	Multi target radar	24 GHz AAC radar	Device CAN	"		"
		Side looking RADAR - right	S20	Multi target radar	24 GHz AAC radar	Device CAN	"		"
		Rearward looking RADAR	S21	Multi target radar	24 GHz AAC radar	Device CAN	"		"
		Forward looking LIDAR - scanning	S35	Laser scanner	laser class 1	Device CAN	Ethernet		No
	Machine vision	Lane tracker	S22	System to recognise road lanes and warn for lane drift, LDW	Forward-looking video camera	Vehicle bus	Device CAN		Yes
		Blind spot-side	S23	Detection of objects in blind spot	Cameras/radar, process	Device CAN			"
		Blind spot-front	S24	Detection of objects in blind spot	"	"			"
		Sign detection	S25	Automatic detection of road signs	Cameras, processing	"			"
		Pedestrain detection	S26	Automatic pedestrian detection	"	Device CAN	Ethernet, Firewire		"
	Situational (environment)	Ambient air temperature	S72			Vehicle bus	Analog		(ADC if secondary interface)
		Air flow	S80			Vehicle bus	"		"
		Air pressure	S71			Vehicle bus	"		"
		Humidity	S73			Vehicle bus	"		"
		Clock	S99	Date/time		Internal logger			
Driver behavior monitoring	Driver video	Face video	S27	Video of driver's face	CCD/CMOS camera with IR light	Analog=>digitizer (grabber card)	Ethernet	(depending on grabber)	"
		Interior view (from driver rear)	S28	Interior view for further driver behaviour analysis	CCD/CMOS camera with IR light	Analog=>digitizer (grabber card)	Ethernet	(depending on grabber)	"
	Head/eye-tracker	Eye-Tracker	S29	Video-based eye, gaze and eye-lid tracking	Video, image processin	Internal	Ethernet, CAN, serial		Yes
		Head-Tracker	S30	Head and gaze tracking system with post-processing	Video, image processin	Device CAN	Ethernet, other vehicle buses		"
Qualitative data collection	Driver demographics	Age	S39						
		Gender	S40						
	Self-reported data		S41						
	Rater based annotation		S45						
	Driver annotation		S46						
	Closed questions	Driver background data	S83			Pen and paper	Web		
		Vehicle background data	S42						
	Structured closed answer questionnaire - rating		S82	Example: Questionnaire measuring driver acceptance of new in vehicle technology		Pen and paper	Web		Yes - need for input in database
	Open question		S84	Self generated and self reported questionnaire. Included in a battery of questions used in study?		Pen and paper	Web		

	Fully open question		S85	Example: "What is your opinion on ISA in cars?" Fully open question to driver for feedback on acceptance/opinion of specific system (ISA).		Pen and paper	Web		
Vehicle status	Engine data	Fuel flow meter	S47			Vehicle bus			
		Fuel temperature	S81			Vehicle bus (?)	Analog		
		HC	S48			Analog			ADC
		NMHC	S49			"			"
		CH4	S50			"			"
		NOx	S51			"			"
		NO	S52			"			"
		NO2	S53			"			"
		PM	S54			"			"
		CO	S55			"			"
		Electricity from the net	S74			Vehicle bus	Analog		(ADC if secondary interface)
		Lambda	S79			Analog			ADC
		Engine pressure	S78			Analog			"
External information	Databases	Road information database	S96	Off-line road information					
		Goods Tracking Information Sys	S100	Off-line information					
		Map database	S94	Off-line geographical info					
	Real-time services	Real-time traffic information	S95	Information on traffic situations (density, flow, etc.)					
		Real-time weather information	S97						
		Real-time road condition	S93	Information on road conditions (ice, wet, etc.)					
		Real-time road information (for I	S98	Real-time feedback on speed limits, etc.					
Modelling	Simulation models	Macro simulation model	S91						
		Micro simulation model	S89						
i									

Sensor position	Mounting tolerance and sturdiness needs	Electromagnetic noise specification	General latency (real world event to time stamp)	Specification range			Typical specification of State-Of-The-Art FOT				Calibration needs	Sensing drift	Sensing noise	Power requirements
				Physical size	Weight	Cost	Physical size	Weight	Cost	Examples/ references				
Definition of typical sensor position and how important the position is.	Explanation on how important the mounting tolerances are.	In text, what is the sensing system's usual contribution to EMC noise?	Examples of latency (possibly with different interfaces).	What is the size range for this sensor?	What is the weight range for this sensor?	Typical cost or cost range for sensing system?	What is the size range for this sensor?	What is the weight range for this sensor?	Typical cost or cost range for sensing system?	References to example sensors.	Definition of typical calibration needs.	Typical problems with drift (temperature/time etc)?	Typical problems with noise ?	Estimates of power consumption and other power requirements.
			Timing of CAN signals is generally non-deterministic.								Individual signals must be evaluated.			
Antenna needs to be placed so that satellite signals can be received. The receiver itself can be placed anywhere within the vehicle?				*90 x 70 x 20*	*100-200 g*	*~ €200*								*12 VDC, 65 mA*
As GPS but with addition that the Differential receiver should be positioned some distance away from known sources of electromagnetic noise.	Preferred to be in a relatively central vehicle location if to be used as part of vehicle dynamics modeling.			(as above)	(as above)	(as above)								
Fixed in vehicle.	(as above)			125-1250 cm^3	100-1500 g	$ 1800-20000					Yes, need calibration with GPS.	Drifts with time		9 VDC, 90 mA
At wheel														
rear-view mirror			Grabber: 200-500	35 x 40 x 50	~100-200 g	$90-$350	30 x 33 x 37		$350	Sensata ACM100	Need to calibrate logger for latency.			5 VDC, ? mA
rear-view mirror			"	"	"	"					"			"

			"	"	"	"	35 x 35 x 30	46 g	$100	Monacor TVCCD-30	"			12 VDC, 110 mA
			"	"	"	"					"			"
Behind car front centre panel			40-110 ms (cycle time)	105 x 94 x 34	~300 g					Smartmicro				9-35 VDC, 3.6 W (ECU<900 mA)
Behind car front left panel			40-110 ms (cycle time)	105 x 94 x 34	~300 g									"
Behind car front right panel			40-110 ms (cycle time)	105 x 94 x 34	~300 g									"
Behind left/right car rear panel			40-110 ms (cycle time)	105 x 94 x 34	~300 g									"
Front grill				85 x 128 x 83	900 g				EUR (2008)	Ibeo LUX				
Windshield, headliner, or rear-view mirror										Mobileye, Assistware	Self-calibrating			12/24 V
										Smartmicro				
										"				
Windshield, headliner, or rear-view mirror										Mobileye				
"				233 x 183 x 65						"				12 V
Headliner or rear-view mirror			Grabber: ??? ms	50 x 35 x 35	~100 g				$ 219	Marshall V1214-I	Need to calibrate logger for latency.			12 V, 110 mA
			Grabber: ??? ms	"	"				"		"			"
driver on or in the dashboard										Smarteye	Yes			
"										Seeingmachines	Yes			
Before and/or after test									No	Reference to standards.	Interviews do not need to be calibrated between each other, but language translation calibrations needed for cross country comparison	Interviewer bias	Interviewer bias	
										Ref to contact person that derived the measure				

Before and/or after test										Ref to contact person that derived the measure		Interviewer bias	Interviewer bias	
As close as possible before and in front of the fuel flow meter														

Environmental constraints	Sensor based data dropout	Typical sensor startup time	Time required	Training requirement for interviewer/ observer	Crashworthiness
How does weather and environmental factors affect the data quality?	Typical problems with data dropout?	Typically, time from power on until data is being logged properly?	For example, time for follow-up interviews.	For subjective measures.	
Antenna needs free access to the sky and satellites. Bridges, trees or buildings decrease quality or completely cancels out function	If satellite coverage is missing.				
(see above)	As above, and covered area must have reference stations.				
-40 -- +85 deg C					
"					

-40 -- +70 deg C						
"						
"						
"						
0 -- 55 deg C						
In several languages - not validated in all languages where available	Subject refuses to answer single questions or entire questionaire		X min			
			X min			

	Drivers refuse to answer or answer a completely different questions.		X min	Maybe	

Notes FESTA VTI

MATRIX STRUCTURE

The matrix is built up of three tables, which in a later stage can be utilised to create a relational database.
The first table is **"PerformanceIndicators"**.
"Measures" is a second table, which contains measures used as input to the performance indicators.
To obtain these measures a number of tools or sensors will be needed.
The sensors at which the measures point can be found in the **"Sensors"** table. This has to be seen as a supplement to the document delivered as annex in the FESTA handbook.
Each table contains a key-variable in the first column, which is used to identify the variable. A database will need this information to define relations and associations between the tables.
Therefore it is important to make sure that the appropriate keys are entered when new performance indicators are listed. The key list must be complete, and the logical operators must be correct.

Example with the performance indicator "average speed":

The performance indicator "mean speed" is associated with three measures:
Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance.
Speed_CAN is the speed as obtained by the CAN bus, Speed_GPS is speed from a GPS sensor, for example. To collect these measures the sensors S01 (CAN bus speed) and/or S02 (GPS speed) can be used.
S01 is simply the CAN bus output filtered for vehicle speed, and S02 is a specified GPS sensor.

A selection of ***situational variables*** can be found in the measures table.
They provide information on the surrounding environment, weather, infrastructure, traffic, etc.

A few examples for ***events*** can also be found in the measures table.
They are to be treated as suggestions; definitions and trigger values have to be decided upon within each FOT, depending on the hypotheses, geographical particularities and other issues.

User interface

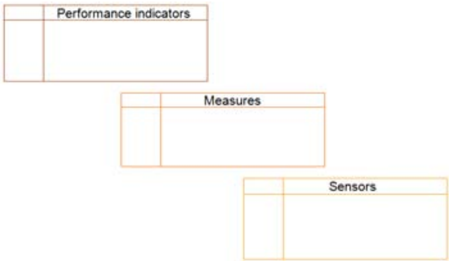
The Excel database with several tables is not optimal in terms of usability, since a user has to navigate between different worksheets to collect the information in the example above. A simple user interface should be implemented where the user can for example select a number of performance indicators, and then get a list with the measures and sensors associated with them. There are several possibilities to design such a user interface.
Certain modifications are still required before the information can be entered into a relational database or a similar tool.

PI MATRIX Guideline

This worksheet contains a description on how to use the PI matrix.

The matrix is two-dimensional and contains three tables.

"Performance indicators" table: here all the performance indicators can be found.
The associated measures (linked clear text name) are listed for each performance indicator.
"Measures" table: in this table the measures are specified.
The associated sensors are listed for each measure.
"Sensors" table: here all the sensors are specified.



The tables are linked by keys, which uniquely identify each performance indicator, measure and sensor.
Each single performance indicator has one row in the PI matrix (first table), and descriptions in the columns.
Each single measure has one row in the measures matrix (second table), and descriptions in the columns.
If one measure can be read from more than one sensor, each of these instances is considered to be a different measure.
Each single sensor has one row in the sensors matrix (third table), and descriptions in the columns.

Performance indicators belong to one or several of the four main groups:
SAFETY, ENVIRONMENTAL ISSUES, EFFICIENCY, and ACCEPTABILITY.

For more detailed information and descriptions please refer to "How to use the FESTA PI Matrix".

How to Use the PI Matrix
FESTA WP2.1

2008-05-12

Table of Contents

European Commission
Information Society and Media

1 The FESTA PI Matrix

The FESTA PI Matrix is a document containing Performance Indicators that can be used to assess safety, efficiency, environmental and acceptance aspects in a Field Operational Test (FOT). The list was compiled by a number of experts who used their own experience and the literature as basis.

The list is meant to be used as a tool both during the planning phase and during the analysis phase of an FOT. It should also be of help for budget decisions, as it can aid the user in estimating sensor costs, for example, but also in estimating how intricate and time intensive certain analyses are.

The list is meant to be used by people with background knowledge in the field, it does not substitute a solid education in traffic research. Even though the list is quite comprehensive, it is by no means exhaustive, which means that existing and established Performance Indicators might not be included, even though some effort has been made to cover all aspects that nowadays can be measured in a reasonable way in an FOT. The list can be extended and new Performance Indicators can be added.

2 Contents of the Matrix

The FESTA matrix contains three main tables. One is called “PerformanceIndicators”, one is called “Measures”, and one is called “Sensors”. Here mainly the first two will be described.

2.1 Performance Indicators

The Performance Indicators table contains more than 150 PI which can be based on log data from the car, from external sensors or from questionnaires, interviews and the like. Many of the mentioned PI are established in the traffic research world and have been used in many studies, both in the field and in simulators, others are relatively new and directly related to FOTs. The PI in the table are not sorted, but loosely grouped according to categories like speed related, lateral position related, acceptance related, eye movement related, and so on. For each PI different variables are described, like whether the PI is objective or subjective, whether it is qualitative or quantitative, how it is computed and so on. Not all variables are meaningful for all PI. One very important variable, however, is the one named “required measures”. Here, the measures that are necessary to compute the PI are named. They are connected via the logical operators AND or OR, and parantheses can be used to indicate grouping or facultative inclusion. If not the measure name but a measure group is mentioned, it is written in squared brackets [xxx]. Table 1 provides a short syntax guide.

Table 1. Syntax guide for the “required measures” variable in the Performance Indicator tab of the FESTA PI Matrix.

EXAMPLE	DESCRIPTION	COMMENTS
Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance	Either one of the measures is enough, but it is possible to	

	collect all three of them.	
(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) (AND SpeedLimit_ISA OR SpeedLimit_RoadDatabase OR SpeedLimit_SignRecognition)	At least one of the speed measures and one of the speed limit measures have to be collected.	
(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) AND [event time or location]	At least one of the speed measures and the event trigger of interest have to be collected.	In this case it is not defined which event has to be measured, but instead of listing all possible events the generic [event] is used. Here either the time of the event, synched to the vehicle time, or the location of the event can be of interest.
(Speed_CAN OR Speed_GPS OR Speed_WheelUnitDistance) AND Traffic_Flow AND Traffic_Density (AND Video_ForwardView)	At least one of the speed measures and traffic flow and traffic density have to be collected. Video forward view is a meaningful optional, depending on the hypotheses.	

All measures that are mentioned in the “required measures”-variable can be found in the Measures table, where they are described further (see below). The only group that is not included in the Measures table are the subjective measures like questionnaires, focus groups, interviews, etc. The reason is that they do not fit into the structure of the matrix very well. Therefore, a reference is made to either the name of a questionnaire or a rating scale, or to the qualitative method in general that would produce the PI in question.

2.2 Measures

The Measures table includes all measures except for almost all measures collected with qualitative methods. Five different measure types exist, and they are treated slightly differently. Here they are described briefly, a more detailed description with examples can be found in the FESTA Handbook Chapter 5.

Direct Measures are collected directly from either vehicle-internal or from external sensors. No pre-processing of the signal before logging is required. Direct Measures have different sub-groupings, which are entered into the “measure group” variable.

Derived Measures are pre-processed before logging, and they build on Direct Measures, other Derived Measures, Events or Self-Reported Measures.

Self-Reported Measures are not included in general, but only if they in combination with another Direct or Derived Measure are the basis for a PI.

Events are singularities based on a combination of Direct Measures and/or Derived Measures. Triggers have to be defined for them.

Situational Variables describe the setting of the trip. They are normally not necessary in order to compute PI, but they can be used for detailed comparisons.

Events and Situational Variables are listed as examples. Their number is unlimited, and the hypotheses in the current study decide both which are of interest and how they have to be defined in order to allow a meaningful analysis. It is out of scope for FESTA and not meaningful, either, to provide detailed definitions at this stage.

2.3 How to Use the Matrix

In most cases one or several research questions are the reason for why a study is conducted. These research questions can be translated to hypotheses, which in turn result in certain Performance Indicators, that have to be studied in order to be able to answer the hypotheses and research questions. For this type of scenario the matrix can be used in the following way:

It is assumed that the Performance Indicators are defined via hypotheses. Then the PIs are located in the PI table. The descriptions provide additional information about the PI, including for example whether collecting them entails ethical issues or not. The “required measures” variable tells the user which measures are necessary in order to be able to compute the PI. Due to budget and/or other limitations a certain way of measuring can be preferred over another. Comparisons between different ways of obtaining a certain measure can be made both in the measures table and in the sensors table. Once it is decided which measures are going to be obtained, it is also possible to cross-check, whether other PI can be obtained with the same already selected sensors, and whether they contribute any added value in order to answer the hypotheses.

The hypothesis steers the selection of Situational Variables, too. These variables are not pointed at from the PI table if they are not critical for a PI. Rather, if the hypothesis states that it is necessary to split the analysis into subgroups defined by Situational Variables, those have to be collected, too. Here, the user has to go into the Measures table directly and select the desired Situational Variables, respectively add own ones, in case that they are not present yet. Not only those variables marked as Situational Variables can be used as such, but any other kind of variable as well.

If the hypothesis is related to Events, the Events in question have to be described and defined. The matrix only provides a list with examples of Events, but those are not defined more than on a very rough level.

It can be of interest to investigate which other PI can be computed with the sensors available for a certain study. To this end, the names of the measures that can be obtained have to be searched for in the “required measures” column in the PI table of the matrix. All PI for which all measures are available can be computed with the currently available sensors.

Below an example of how to work with the matrix are provided.

Research Question A:	A low friction warning system will increase traffic safety in rural areas.
Hypothesis A:	A low friction warning increases the mean headway on icy rural roads while the warning is given.
Hypothesis B:	Mean speed will be increased during periods when no low friction warning is given, but low friction due to ice is possible.
PI:	Mean time headway (THW), mean speed.
Resulting Measures:	
Mean THW:	THW (which is a Derived Measure, combined of (*Speed_CAN* OR *Speed_GPS* OR *Speed_WheelUnitDistance*) AND *Space_DistanceLeadVehicle*)
Mean Speed:	*Speed_CAN* OR *Speed_GPS* OR *Speed_WheelUnitDistance*
Decision on Sensor:	The user in this example has no access to the vehicle CAN bus. As icy roads will most often occur out in the open, and not in tunnels, it is decided to use *Speed_GPS* for speed measurement. Signal loss in tunnels will not disturb data collection in relevant areas, and GPS receivers are comparatively cheap. For measurement of the *Space_DistanceLeadVehicle* a radar is bought, mounted and time synchronised with the GPS receiver.
Situational Variables:	The hypotheses are directed at rural areas, which means that it is necessary to keep track of where the vehicle is driven. The Situational Variable *Road_Type*, possibly in combination with *LOS* will provide this information. In order to obtain the data a GPS receiver in combination with access to a road database are necessary. The GPS sensor is already planned as speed logging device. If access to a road database is not feasible, a rough classification of road types can be made via Google Maps, for example. Hypothesis A focuses on icy rural roads, therefore it is necessary to know whether the road is icy or not (related measure: *Road_Friction*). As it is deemed of importance to know about road friction with some

	certainty, and because CAN information is not available to this user, it is decided to buy a friction sensor, and also to install a camera to catch the *Video_ForwardView* measure, where recording is triggered by a thermometer, which was bought additionally.
Further PI:	With the measures that were selected a number of other PI can be computed without additional logging costs. Those that appear relevant are noted, because they might help refine the answer to the research questions. In this example especially Speed Variance and the Standard Deviation of the local time headway minima were collected for the icy patches and for corresponding dry road segments.

2.4 Adding new PI and Measures

This tool is most useful if it is kept up to date. If new PI and new measures are developed, they should be added to the document. The following steps have to be taken when a new PI is added:

- Check that it is not already there.
- Fill in the PI and complete the row.
- Fill in the required measures. Check carefully which of them already exist and type the exact name of the existing measures. If measures that are not in the table yet are required, fill in those, too, and give them unique names.
- Make sure that the logical operators are correct.
- If new measures are needed, fill in those in new rows in the measures table and complete the rows.
- Continue in a similar manner with the sensors.

FESTA WP2.1
Annex to Deliverable 2.1
Final Version

2008-05-13

This annex contains further background to groups of PI that can be found in the matrix provided in excel-format, which is the main Deliverable 2.1. Specifically the indicators that pertain on environmental issues and traffic efficiency issues are treated here. Background information on the other Performance Indicator groups like driver behaviour or system performance are sufficiently covered in the FESTA handbook and in the PI matrix. A chapter on driver characteristics, which are not taken up in the matrix, is included as last part of this annex.

Table of Contents

1 List of abbreviations

BS	Boredom susceptibility
DBQ	Driver Behaviour Questionnaire
DE	Driving Internality
DI	Driving Externality
Dis	Disinhibition
ES	Experience seeking
FC	Fuel consumption
FESTA	Field opErational TeSt supporT Action
FFM	Five Factor Model
FOT	Field Operational Test
IQ	Intelligence Coefficient
LOC	Locus Of Control
PI	Performance Indicator
TAM	Technology Acceptance Model
T-LOC	Traffic Locus Of Control
TS	Traffic situations

Annex WP 2.1.3
Environmental Indicators

1 Possibilities to estimate performance indicators for road vehicle exhaust emissions

1.1 Overview

For evaluation of environmental aspects of FOTs there is need for exhaust emission Performance Indicators (PI).

An FOT is used in order to estimate effects of for example ICT-functions (Information and Communication Technologies). In many cases one cannot expect big effects of ICT functions on emissions. Still, small effects could represent big benefits compared to costs, which means that even small effects could be of interest. The evaluation of representative exhaust emission effects in an FOT could be a big problem. The reason for this is that exhaust emissions could be difficult to estimate with enough accuracy to prove possible small effects. There is one important exception, fuel consumption (FC) and carbon dioxide (CO_2) emissions. FC can be estimated without high costs and with good accuracy.

The best PI/measures for exhaust emissions would in principle be the exhaust emissions themselves. Exhaust emissions include many different substances. One then needs to decide what substances will be included. One proposal for such a gross list could be what is included in the ARTEMIS-program[1]. This program includes what is needed in most EU-countries: hydro carbons (HC); carbon monoxide (CO); nitrogen oxides (NO_x); FC; particulates (PM); CO_2; Methane (CH_4); non methane hydro carbons (NMHC); lead (Pb); sulphur dioxide (SO_2); laughing gas (N_2O) and ammonia (NH_3).

CO_2, SO_2 and Pb have in common they can easily be estimated based on FC.

There are two alternatives for quantifying exhaust emissions: measured exhaust emissions or calculated. For measurements there are still two alternatives: on board or in laboratory. The laboratory alternative demands use of logged driving patterns.

Because of the high complexity and costs for measurements of exhaust emissions, in practice, calculated emissions in most cases is the only alternative within reason. If a FOT represents extensive field measurements, of course there will be a big problem selecting a representative part for exhaust emission laboratory measurements.[2]

A range of conditions have to be measured in order to calculate exhaust emissions. If all these conditions are measured and there is a reliable emission model available exhaust

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[1] Keller, M. and Kljun, N. ARTEMIS Road Emission Model. Model description. (EU Commission – DG Tren – Contract 1999-RD.10429). Workpackage 1100 – Model version 04c. Deliverable 13. INFRAS. Bern. 2007.

[2] A rough estimation of exhaust emission measurements in laboratory should be 5000-10000 Euro per vehicle and day. The investment costs for on board equipment could be 100 000 euro.

emissions could be estimated, at least on a macro level. One problem with the macro level is that what is special with an ICT could perhaps not be expressed on a macro level. Still, there are available models also on the micro level.

Weather conditions are of considerable importance for exhaust emissions. Measured exhaust emissions at standardized test procedures usually are adjusted to reference conditions. In the standardized test procedures methods for such adjustments are documented and should be possible to use for evaluation of an FOT.

An advantage with a model is that the standard deviation should be smaller compared to measurements and because of this an indication should be easier to detect, with the drawback that there always will be a risk that the calculated effect is not representative.

If exhaust emissions cannot be estimated in absolute values one needs other measures correlated to these effects as PI. Such measures, correlated to emissions, should represent independent variables in emission models. When absolute values for emissions cannot be estimated, the corresponding PI should be independent variables with high correlation to exhaust emissions. One problem with such independent variables is that a relative change in such a variable could be different to the change in exhaust emissions.

Models for exhaust emissions in general include three parts:

- Cold start emissions
- Hot engine emissions
- Evaporative emissions.

Evaporative emissions are special since they appear both for parked vehicles and from vehicles with a running engine. Hot engine emissions is the part which is most depending on the driving pattern.

The following formula is a rough description of an exhaust emission model:

Σ(Traffic activity) x (Emission factor) = Total emissions

Of course, traffic activity data has a high correlation to total emissions. Traffic activity data includes at least:

- Exposure
- Engine starts.

Exposure is of importance in two ways, both the total value and the distribution on traffic situations.

In most cases total exhaust emissions per substance will increase when mileage and engine starts increase but not for sure. If the emission factors would decrease in parallel total emissions could decrease. An ICT can influence both traffic activity and emission factors. This structure of an emission model is of interest for exhaust emission measurements as well. When performing emission measurements the structure above is in general used in some way.

There are different types of calculation models for exhaust emission estimation:

- Macro level models
- Micro level models including engine simulation.

In macro models (aggregated level) input data is in a simplified form, for example average speed, compared to micro models with complete driving patterns. One important question is if the special characteristics of an ICT can be described in the input to such a model. If not, the ICT cannot be evaluated. In the EU area probably COPERT[3] is the most well known macro model besides ARTEMIS. The main difference between COPERT and ARTEMIS is that COPERT uses average speed as input and ARTEMIS uses the distribution of mileage on traffic situations (TS). A traffic situation includes: type of area; type of road; speed limit; level of service and road gradient. ARTEMIS also, as an alternative option; it can use average speed as input.

One simple method to estimate fuel consumption on an aggregated level with high accuracy is notes about fuel filled in the tank and odometer reading. One drawback is that there is no possibility for time or geographical resolution with exception for the time period between filling the tank.

Examples for micro scale models: PHEM[4]; VETO[5] ; VERSIT [6] etc. The first two models are based on mechanistical principles and the third on statistical. At least in principle there is a

[3] Gkatzofilas, D., Kouridis, C., Ntziachristos, L. and Samaras, Z. COPERT 4. Computer programme to calculate emissions from road transport. User manual (version 5.0). Laboratory of applied thermodynamics. Mechanical engineering department. Aristotle university Thessaloniki. December 2007.

[4] Rexeis, M. In-Use Fahrzeugtests an einem schweren Nutzfahrzeug und Erstellung der Eingabedaten zur Berechnung der Emissionsfaktoren mit dem Modell Phem. TUG, SECTION: Thermodynamics and Emissions Research - Emission. Graz. 2007.

[5] Hammarström, U. and Karlsson, B. VETO – a computer program for calculation of transport costs as a function of road standard. VTI meddelande 501. Swedish Road and Traffic Research Institute. Linköping. 1987.

[6] Smit, R., Smokers, R., Schoen, E. and Hensema, A. A New Modelling Approach for Road Traffic Emissions: VERSIT+LD – Background and Methodology. TNO report 06.OR.PT.016/RS. TNO Science and Industry. Delft. 2006.

difference in resolution, the mechanistal based models can estimate emissions "meter by meter" and the statistical model down to 100 m.

Models on a micro level should in general be able to describe most ICT functions. This is not the case for more aggregated level models. In the Swedish ISA project a micro level exhaust emission model, VETO, was used[7]. Micro models are often used for emission factor estimation and macro models for total emission estimations.

One important question is the expected accuracy of different types of models.

Micro level models based on VTI opinion:

- Fuel consumption or energy use for all types of engines: can be estimated with good accuracy
- Diesel engines and other substances than fuel/CO_2: HC and NOx can be estimated with acceptable accuracy
- Petrol engines and other substances than fuel/CO_2: For petrol engines without catalytic converters the accuracy is acceptable in general. With catalytic converters there are not that many models available with at least acceptable accuracy. VERSIT+ could be such a model.

When absolute emission values are not used as measures, PI could be classified after the structure in emission models, for example traffic activity and type of emission factor.

The hot emission factors for one vehicle are functions of a set of independent variables such as:

- Vehicle speed (V)
- Acceleration (dV/dT,+/-)
- Engine speed (which together with vehicle speed gives gear position)
- Meteorological conditions
- Road conditions etc.

Of course all vehicle parameters are of big importance for emission factors:

- Vehicle mass including load
- Cross section area
- Air resistance coefficient
- Rolling resistance
- Emission concept
- Engine power
- Type of engine
- Type of transmission
- Vehicle age etc.

[7] Results of the world's largest ISA trial. Vägverket. Publikation 2002:96E. Borlänge Sweden.2002.

The mix of fossil fuels with renewable fuels could result in different fuel quality from tanking to tanking. The mix of petrol with ethanol also changes in a systematic way from month to month during a year. The FC and other emission factors are influenced by the fuel mix. If there are values on the mix at least FC (and CO_2, SO_2 and Pb) should be possible to estimate. Other exhaust substances for mixed fuels could be more difficult to estimate with models. Since FC is depending on the fuel mix one needs to have full control of used fuel quality if FC is measured in a FOT. It is not enough to fill the tank just anywhere. For evaluation one needs to adjust measured FC and emissions to one reference fuel mix.

In order to estimate emission factors on a micro level a driving pattern for the engine is needed directly or indirectly. A driving pattern for the engine constitutes of:

- Engine speed
- Engine torque
- Time distribution.

An indirect description of the engine driving pattern constitutes of:

- Vehicle speed
- Gear position
- Traction force including the acceleration contribution.

There are also more simplified forms of driving patterns:

- A distribution matrix with speed and acceleration classes
- An average speed.

In order to estimate such a matrix there must be good accuracy for both V and dV/dT.

In order to estimate the drag force there is need for dV/dT with good accuracy. In Appendix A expressions for error estimation are described. In order to reduce the error in V and dV/dT there is need for filtering of the logged driving pattern, see Appendix A. The smaller true dV/dT value the bigger relative importance of an error in dV/dT. For example at constant speed the drag force could be 0,2 N/kg (vehicle). If the maximum accepted error would be 0,02 N/kg and logging frequency 10 Hz the accuracy of measured distance should be 0.00005 m. For 1 Hz the accuracy demand should be 0.005 m. The filtering method in the Appendix to this section should improve the situation.

One question is to what extent an observed PI should be possible to explain, that is what caused the observed value. This raises a special demand on data like traffic conditions, driver information etc. Such data will in most cases be registered by other means than sensors in the FOT vehicle. The demand for this purpose is the possibility to connect data from the FOT vehicle with other data registers and situational indicators. This is also necessary in order for global scaling of results. The proposal should be that PI always should be estimated per registered TS in order to make comparisons between with and without ICT meaningful.

When exhaust emissions are measured they need to be adjusted to one reference meteorological situation.

In order to make a cost/benefit analysis of an ICT one needs geographic information about the PI since the damage/costs caused by emissions is depending on the degree of human exposure to the emissions. This demand should be able to be fulfilled by combining in-vehicle registered indicators with other data registers based on GPS. If a PI is based on average speed there must be a connection of the estimated PI to local conditions like speed limit.

The conclusion about what to include as PI would then be: exhaust emissions or indicators with high correlation to exhaust emissions.

The drive train of motor vehicles is becoming more complex by time. Such a complex drive train is a hybrid system. In a hybrid system PI need to represent both engines in the system.

1.2 List of proposed potential PI

Measures for PI estimation can be of two types: fixed and varying. In order to estimate total emissions one needs both.

Motor vehicle static data:

- manufacturer
- model
- year of type approvement
- year of manufacturing
- emission concept
- registration number
- gross vehicle weight
- empty vehicle weight
- cross section area
- air resistance coefficient
- propulsion system:
    - type
    - power, max
- gear box, type. Number of gear positions
- gear box ratios
- final gear box ratio
- position of propulsion system
- drive wheels: front; rear; all
- number of axles
- wheels per axle

Trailer static data:

- model
- year of manufacturing
- registration number
- gross vehicle weight

- empty vehicle weight
- cross section area
- air resistance coefficient in relation to motor vehicle
- number of axles
- number of wheels per axle

There could be need for describing effects from hybrid vehicles taking part in a FOT. Because of this there could be need to use sensor data from more than one engine.

Engine 1, combustion:

- Measured fuel consumption
- Temperature of measured fuel consumption
- Measured content of exhaust emissions per substance
- Injection times
- Engine speed
- Engine pressure
- Lambda
- Air flow
- Fuel temp
- O_2 content in fuel
- Water temp
- Oil temp
- Temp of catalytic converter
- Use of engine heater
- Exhaust emissions directly.

Engine 2, electric:

- Engine speed
- Use of electricity from generator
- Use of electricity from battery

Auxiliaries:

- Air cond: use/not use
- Other auxiliaries: use/not use
- Cooling fan: operating/ not operating

Tires:

- manufacturer, model and dimension
- rolling radius
- rolling resistance coefficient
- tire pressure: cold tires; hot tires
- odometer reading at tire exchange.

One problem with tires is the influence of air pressure and ambient temperature on rolling resistance. Even if the tire pressure is correctly used from the handbook there might be other disturbing factors out on the road. To some extent data on ambient temperature and air pressure can be used afterwards for correction of the drag force.[8]

Vehicle load weight:

- driver + passengers
- load besides driver and passengers
- trailer connected or not
- amount of fuel in the tank.

The difference in total drag force between full and empty tank in a car could be some percent.

Driving pattern:

- time based 10 Hz (for example)
- time: date; time of the day
- road distance (a GPS will probably not have accuracy enough)
- accelerometer (x; y; z)
- gyro
- distance to vehicle in front
- distance to vehicle behind

If dV/dT is to be used for the PI the demand of accuracy on time and coordinate increases. If a driving pattern with a resolution of 10 Hz will be used the accuracy of coordinate and time must be in focus. The time resolution for 10 Hz should be < 1/1000 sec. If for example a sensor for coordinate is fixed to the wheel axle the oscillation of the vehicle sprung mass can cause problems. The problems with this oscillation can to some extent be solved by using a gyro. In Appendix 1 uncertainty in computed dV/dT is described.

Distance to the vehicle in front and to the vehicle behind influence air resistance.

GPS:

- Time
- Coordinate.

A GPS can be used for connecting measured data in the vehicle with data on conditions of importance outside the vehicle. If average speed is used to form the PI GPS can be used but not for describing a complete driving pattern.

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[8] Gent, A., N. and Walter, J., D. The Pneumatic Tire. Published by the National Highway Traffic Safety Administration. U. S. Department of Transportation, Washington DC 20590. DOT Contract DTNH22-02-P-07210.

Road and traffic conditions based on GPS and time:

- gradient; horizontal curve; road width; speed limit; junction; roughness; macrotexture
- traffic signal picture
- road surface conditions (in Sweden by use of the winter model)
- traffic flow.

In Sweden, for example, most of this data is available in a national road database.

Meteorological conditions:

- Air pressure (measured with vehicle sensor)
- Air temp (measured with vehicle sensor)
- Humidity (measured with vehicle sensor)
- Wind speed and wind direction could be measured with vehicle sensor but in most cases from sensors not in the FOT-vehicle.

Appendix to Annex 2.1.3

Uncertainties in computed acceleration

Suppose a vehicle is equipped with a measurement device (e. g. a wheel pulse instrument or a GPS) that produces data for a number of points in form of position and time. We assume here for simplicity that the spacing between subsequent points is constant in time. Let (t_i, s_i) denote the time and position when the vehicle passes the *i*:th point.

A very common way to estimate the velocity and acceleration at the *i*:th point is to compute the standard symmetric difference quotients:

$$v_i = \frac{s_{i+1} - s_{i-1}}{2h} \text{ for the velocity}$$

$$a_i = \frac{s_{i+1} - 2s_i + s_{i-1}}{h^2} \text{ for the acceleration,}$$

where h is the constant time difference between subsequent points: $h = t_{i+1} - t_i$.

An important property of these estimates is that any disturbance or random error in position or time tend to be amplified resulting in a typical “noisy” velocity or acceleration curve. This is particularly true for the acceleration, especially if *h* is small. Let as assume that we have errors in positions only and that they are bounded by, say, ε, i. e., $|\Delta s_i| \le \varepsilon$ for all *i*. It is easily verified that the correspondingly induced errors in estimated velocity and accelerations, Δv_i and Δa_i resp., will satisfy the following inequalities:

$$|\Delta v_i| \le \frac{\varepsilon}{h}$$

$$|\Delta a_i| \le \frac{4\varepsilon}{h^2}$$

Hence, on the right hand sides of the inequalities we have upper bounds for the sizes of the fluctuations in velocity and acceleration caused by the errors (fluctuations) in measured positions.

The fluctuations in velocity or acceleration can be reduced by filtering. One such filter that has been found very efficient for this purpose is to apply repeated averaging:

```
For j=0, N-1
```

```
        For i=j+1, M
                a_i^{j+1} = (a_i^j + a_{i-1}^j)/2 ,
        End
End
```

where *N* denotes the total number of iterations, a_i^0 , $i = 1, \ldots, M$ denotes the computed (by differentiation) acceleration values (= a_i), and a_i^N denotes the corresponding filtered accelerations to the *N*:th degree. (To avoid displacements of the acceleration signal, the averaging can be appropriately applied alternately backwards and forwards, i.e. replacing index *i-1* with *i+1* in every second iteration.) In experiments, the typical high frequency fluctuations that arise in the acceleration have been very efficiently reduced by this filter without seriously distorting the true curve. However, rather large values for *N* may be needed (*N* in the order of 20 to 30 has been found appropriate in our application).

By induction this filter can easily be shown to be equivalent to using a moving average with (normalized) binomial coefficients as weight coefficients. This means that:

$$a_i^N = \sum_{k=0}^{N} \frac{1}{2^N} \binom{N}{k} \cdot a_{i-k}$$

The degree of the binomial coefficients equals the total number of iterations for the repeated averaging.

E.g., for *N=20* the weight coefficients are as in Table 1:

Table 1 Binomial coefficients (not normalized) of degree 20 (only half of the distribution is shown here).

Term	0	1	2	3	4	5	6	7	8	9	10
Vikt	184756	167960	125970	77520	38760	15504	4845	1140	190	20	1
Procent	18%	16%	12%	7%	4%	1%	0%	0%	0%	0%	0%

Thus, approximately 75 % of the weight is located within two points from the middle point (Term=0). This simple analysis verifies that the dissipation is small when *N = 20*, i. e., that the original “true” curve is not seriously distorted by applying the filter. For increasing values of filtering degrees this dissipation is growing, but only very slowly.

Annex WP2.1.4
Traffic Efficiency Indicators

The aim of FESTA Task 2.1.4 is to identify and describe indicators of traffic efficiency and to provide guidance on the collection of traffic efficiency related data in Field Operational Tests (FOTs).

The efficiency of a traffic system can be measured as, for example, traffic flow, speed and density in relation to the optimum levels of these properties given the traffic demand and the physical properties of the road network.

A combination of Field Operational Tests (FOTs) and traffic modelling is required to allow estimation of traffic efficiency impacts of the tested technologies. A schematic picture of the proposed methodology is shown in Figure 1.

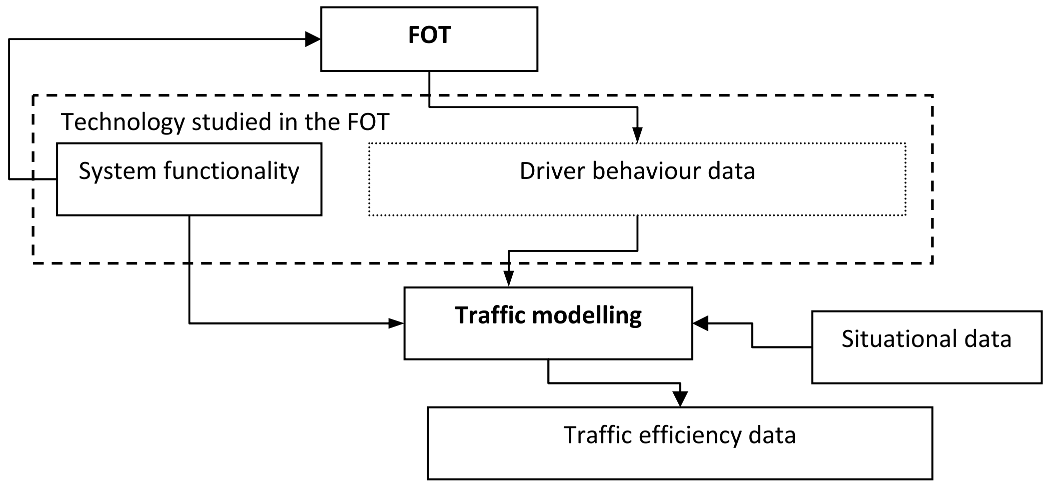

Figure 1 FESTA Traffic efficiency estimation based on FOT results

Driver behaviour data are based on the data collected in the FOT. These driver behaviour data will, together with the system functionality[9] of the tested technology, be used as input to traffic modelling in order to aggregate the individual driver/vehicle impact on traffic efficiency effects. This requires that both driver/vehicle data of equipped vehicles and properties of the traffic system that the vehicles have driven in are collected in the FOT. Properties of the traffic system will henceforth be referred to as situational data[10].

[9] System functionality refers to the way in which the tested FOT system works. Information on when and how the system operates can be used to create parameters for the models developed.

[10] Situational data are not necessarily directly relevant Performance Indicators or Measures, but must also be measured or recorded as they provide key background information that complements the driver behaviour data and is sometimes needed to derive the driver behaviour data. Examples include light conditions, system status (e.g. on or off) and road type. A list can be found in Table 3.

The appropriate traffic modelling approach will differ depending on which type of driving tasks the considered technology supports. Michon's (1985) hierarchical driving model can be applied to select a traffic modelling approach. To model systems that support tactical or operational driving tasks it is appropriate to apply a traffic microsimulation model. A microsimulation model considers individual vehicles in the traffic stream and models vehicle-vehicle interactions and vehicle-infrastructure interactions. To model systems that support strategic and some types of tactical driving tasks it is appropriate to apply a traffic simulation model. A mesoscopic model considers individual vehicles but model their movements and interactions with a lower level of detail than microscopic models.

It is advisable to study traffic efficiency for a series of scenarios with varying levels of traffic penetration of the tested systems. The systems should also be studied in representative traffic volumes. This is achieved straightforwardly by running the traffic simulation model with different inputs. The situational data will also contribute to the differences between the scenarios (both measured and modelled).

Outputs from the traffic models will be used to make comparisons of traffic efficiency for the studied scenarios. Example outputs of interest are traditional quality of service and traffic efficiency indicators such as speeds, travel times, and queue lengths.

In addition to modelling, the system functionality, driver behaviour data and situational data can also be examined quantitatively.

1.3 Driver behaviour data

As mentioned above, driver behaviour data will be used in order to write rules that define behavioural aspects in the Microsimulation models. This means that the Performance Indicators and Measures that comprise this driver behaviour data are an intermediate level of information required in order to assess traffic efficiency using a traffic model.

1.3.1 Performance Indicators and Measures

In order to assist the development of the accompanying matrix, driver behaviour data has been separated into Performance Indicators and Measures.

Performance Indicators are quantitative or qualitative measurements, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria.

A *Measure* can either be direct or pre-processed. A direct measure is logged directly from a sensor, while a pre-processed measure is a combination of different direct or other pre-processed measures. A measure does not have a 'denominator' which makes it comparable to other instances of the same measure or to external criteria.

So, for example, the Performance Indicator 'Deviation from desired lane' can be derived from:

- 'Video_ForwardView' AND
- 'Position_Lat'
- 'DriverIntention_Lane'.

To be able to derive many of the Performance Indicators needed for the traffic model, the equipped vehicle's driving course of events has to be recorded. This includes position, speed and acceleration in both longitudinal and lateral directions.

1.3.2 Sensors

An additional information layer in the matrix, 'Sensors', indicates how the Measures will be collected. Technical information on Sensors will be provided by partners in WP2.2.

It is difficult to identify all possible Performance Indicators and Measures that are needed for estimating traffic efficiency for any type of FOT system. However, Tables 1 and 2 contain those identified as generally useful for this purpose. The relationship between Performance Indicators and Measures is not shown in Tables 1 and 2, but is shown in the accompanying matrix.

Table 1 – Driver Behaviour Data: Performance Indicators
Frequency of performed left and right lane changes (number per kilometre and hour)
Frequency of active overtaking (number per kilometre and hour)
Frequency of passive overtaking (number per kilometre and hour)
Deviation from desired lane
Frequency of route changes (number per kilometre and hour)
Travel time uncertainty
Delay
Following/free state profile

Table 2 - Driver Behaviour Data: Measures
Acceleration profile
Position
Time headway
Space headway

Distance to other surrounding vehicles
Speed profile
Intended speed
Desired lane
Mental workload
Intended route
Actual route
Travel time (including stop time)
Travel distance (mileage)
Waiting time at intersections
Traffic density
Traffic flow
System interaction and driving behaviour related responses to alarm/warning
Reaction time to alarm/warning

These Performance Indicators and Measures should be ascertained for the baseline case (unequipped vehicle) FOT and equipped vehicle FOT, so that comparisons can be made between the two.

1.4 Situational data

In addition to the driver behaviour data, a series of additional 'situational data' have been identified. These are not necessarily directly relevant Performance Indicators or Measures, but must also be measured or recorded as they provide key background information that complements the driver behaviour data and is sometimes needed to derive the driver behaviour data.

For the situational data of a static nature, field observations or linkage of position and road databases are required. For the situational data of a more dynamic nature, e.g. traffic and driving conditions, road link measurements with loop detectors, video detectors, or other types of sensors are required. The situational data needed for Task 2.1.4, such as road type, weather conditions and light conditions are shown in Table 3.

Table 3 – Situational data	
Area of Interest	**Situational Data**
System status	• On or off (including at which points during the journey e. g. on for the first hour, then switched off at 15:32) • Selected settings
Time	• Daylight/dark conditions • Peak/off-peak/interpeak
Road environment	• Road type • Environment (Urban/interurban/rural) • Number of lanes • Width of lanes • Base capacity and saturation flows • Central barrier • Sight distance • Speed limit • Current traffic management: road markings, signs, etc • Bus stops or parked cars along the street • Hard shoulder • Intersections o frequencies o intersections types (signals/roundabouts/yield/stop) • Number of stops on route
Traffic conditions	• Density • Flow • Speed distribution, average speed and standard deviation • Traffic composition • Other (unrelated) incidents that may affect traffic flow
Driving conditions	• Weather conditions o wind speed o precipitation (i.e. snow or rain) • Road conditions o friction o snow/ice

1.5 Model requirements

As mentioned above the choice of traffic model and the requirements on the traffic model depend to a large extent on the studied system. However, it is possible to outline some general model requirements. The traffic model has to offer possibilities to deal with enough vehicles such that it represents a typical traffic flow associated with the use of the system and also to model:

- the observed driving behaviour changes due to the system;

- the functionality of the system, if the system affects the vehicle's performance; and
- the proportion of equipped vehicles in the modelled traffic flow..

1.6 Definitions

Where quantified definitions relating to traffic efficiency are required, for example, a standard definition of congestion, these should be taken from the Highway Capacity Manual (Ackerman et al., 2000).

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Annex WP2.1.6
Driver Characteristics

1 Executive Summary

Drivers differ on a large variety of characteristics, which may all have an influence on how they drive and use different systems and services. These differences may be important to take into account when planning a FOT. Four categories of driver characteristics may be distinguished:

- Demographic characteristics: gender, age, country, educational level, income, socio-cultural background, life and living situation, etc.
- Driving experience, and driving situation and motivation: experience in years and in mileage, professional, tourist, with or without passengers and children etc.
- Personality traits and physical characteristics: sensation seeking, locus of control, cognitive skills, physical impairments or weaknesses etc.
- Attitudes and intentions: attitudes towards safety, environment, technology etc.

Studies often focus on characteristics of individual drivers. However, drivers are not alone on the road. There are other road users and there may be passengers in the car, who may influence the driver`s behaviour.

There are several different reasons for considering driver characteristics:

- To make sure that the sample of drivers is representative of the target population.
- To explain the outcomes of the FOT.
- To improve systems and services, taking into account differences between drivers.

Driver characteristics may play different roles in FOTs:

- Characteristics of drivers possessed before the FOT may play a role in how they behave in traffic during the FOT.
- Although some characteristics are stable, other ones may change when using a system or service in the FOT. Attitudes may change radically before and after using a system for a longer period of time.

In general it is useful in a FOT to gather as many characteristics of drivers as practically possible. Even if no specific impacts are expected of certain characteristics, some outcomes may be explained better with more knowledge about the participants. A minimum set of data such as age, gender, income group and educational level is easy to gather from participants.

Next information is needed about driving experience. Usually this is measured by means of self-reports. The amount of practice, i.e. the mileage of an individual driver can be collected by asking the subject for an estimation of his/her overall mileage since licensing or the current mileage per year. However, beware that these self-reports are not very reliable.

For further understanding of driver behaviour one may consider to use questionnaires on attitudes, driving behaviour and personality traits. A well-known questionnaire about (self-reported) driving behaviour is the Driver Behaviour Questionnaire (DBQ). Some widely used personality tests are the Five Factor Model (FFM) test and the Traffic Locus of Control (T-LOC) test. Special attention may be given to the personality trait of sensation seeking, which is correlated with risky driving. The Sensation Seeking Scale (SSS) measures this trait. These questionnaires are available in many different languages, but they are not always standardized and cultural differences may play a role. Personality traits are very easy to measure, just by administering a short questionnaire. However, the concepts and interrelations of factors are very complex, and results should be treated with caution.

When evaluating the acceptance and use of new systems in the car, drivers' acceptability of technology is important. Both social and practical aspects play a role. Technology acceptance has different dimensions, such as diffusion of technology in the drivers' reference group, the intention of using the technology, and the context of use (both personal and interpersonal). Measuring acceptability can be realized via (existing) standardized questionnaires, in-depth interviews before and after "use" (driving), and focus groups.

2 Introduction

2.1 Driver characteristics in general

Drivers differ on a large variety of characteristics, which may all have an influence on how they drive and use different kinds of systems and services. These differences may be important to take into account when planning a FOT.

Four categories of driver characteristics may be distinguished:

- Demographic characteristics: gender, age, country, educational level, income, socio-cultural background, life and living situation, etc.
- Personality traits and physical characteristics: sensation seeking, locus of control, cognitive skills, physical impairments or weaknesses etc.
- Attitudes and intentions: attitudes towards speeding, safety, environment, technology etc.
- Driving experience, and driving situation and motivation: experience in years and in mileage, professional, tourist, with or without passengers and children etc.

These characteristics are not independent; some are even highly related and influence each other. Combinations of these different characteristics may influence driving behaviour quite differently. For example, an elderly driver with a sensation seeking personality may take much less risk when driving with his grandchildren than when he was young and driving alone.

Characteristics may be stable and unchangeable, such as gender, or more volatile, such as attitude. Some of the driver characteristics can be measured very easily, such as age, but others are more complex, such as personality traits. Even simple demographic characteristics are not always easy to use for classifying drivers into groups, for example drivers who lived in different countries.

In this document we focus on characteristics of individual drivers. However, drivers are not alone on the road. There are other road users and there may be passengers in the car, who may influence the driver`s behaviour. For example studies have shown that young male drivers behave differently depending on the presence of passengers and on whether those passengers are male or female. There are also other kinds of influence, such as the (perceived) opinion of important others, such as parents, and more general social influences. So there is an interaction between the characteristics of the individual driver and those of other people.

2.2 The role of driver characteristics in FOTs

There are several different reasons for considering driver characteristics:

- To make sure that the sample of drivers is representative of the target population. If, for example, the sample contains a high percentage of young male drivers because they were recruited from a university, the outcomes of the FOT will have less value for the whole population.

- To explain the outcomes of the FOT. If, for example, the FOT reveals that an anti-collision system causes a shorter headway for the group of sensation seekers, the cause may be that they increase their risk level by this behaviour.
- To improve systems and services. If, for example, the FOT reveals that elderly drivers did not benefit from a system while younger drivers did, improvement of the system may be focussed especially on this group.

Driver characteristics may play different roles in FOTs:

- Characteristics of drivers possessed before the FOT may play a role in how they behave in traffic during the FOT. For example young male drivers tend to be more prone to speeding.
- Although some characteristics are stable, other ones may change when using a system or service in the FOT, for example nervous drivers may become confident drivers because they feel that the new systems improve their safety. Attitudes may change radically before and after using a system for a longer period of time.

In general it is useful in a FOT to gather as many characteristics of drivers as practically possible. Even if no specific impacts are expected of certain characteristics, some outcomes may be explained better with more knowledge about the participants. A minimum of data such as age, gender, income group and educational level are easy to gather from participants. Next questions are needed about factual driving behaviour, such as mileage per year and reasons for driving (commuting, professional driving etc), and area of living and driving. For further understanding one may consider to provide questionnaires about attitudes, driving behaviour and personality traits.

If there is reason to believe that characteristics are not stable, and may change during the FOT, it is recommended to administer the same questionnaire before and after the FOT.

In this document we will further explain the background of these characteristics, explain why they may be of interest in a FOT and how they may be measured. We will focus on three main issues:

- Driver experience, in Chapter 3
- Personality traits, in Chapter 4
- Self-reported driver behaviour, in Chapter 5
- Attitudes on technology, in Chapter 6

3 Driving experience

3.1 Description

The role of the factor “driver experience” has been discussed in the literature in particular within the context of the explanation for the strikingly high crash risk of young novice drivers. However, there is clear evidence that driving experience has a significant impact on individual crash risk even if effects of age are controlled. Generally speaking, there seems to be a dramatic decrease of crash risk during the first months after licensing independently of driver age even if the starting level decreases with increasing driver age (Maycock et al., 1991). The variable “driving experience” describes the amount of practice a driver has gathered while performing the task of driving a vehicle which can be considered as the acquisition of a complex skill. This process can be described according to the well-known “Power-Law-of-Practice” which simply assumes that a skill or the proficiency of task performance increases as a function of practice (Groeger, 2000). There is also evidence that the “Power-Law-of-Practice” fairly nice describes skill acquisition when performing in-vehicle tasks like destination entry into a navigation system (Jahn et al., 2003).

There might be several mechanisms by which experience might influence driver behaviour. A very important finding in the context of FOTs has been reported by Lansdown (2002). The results of his driving simulator experiment suggest that novice drivers spend more time for looking away from the road when performing in-vehicle tasks than experienced drivers. As a whole Lansdown (2002, p.660) concludes that experienced drivers are *“less taxed by the driving activity”* which leaves them more spare-capacity from vehicle control for in-vehicle tasks. However, recent research provided no convincing evidence for the assumption that these additional capacities leads to a strong correlation between driving experience and hazard perception (Sagberg & Bjornskau, 2006). Moreover, the tendency to overestimate one’s own skill seems to be equally strong among novice and expert drivers (Waylen et al., 2004).

3.2 Measurement

Usually the variable “Driving Experience” is measured by means of self-reports. The amount of practice, i. e. the mileage of an individual driver can be collected by asking the subject for an estimation of his/her overall *mileage since licensing* or the current *mileage per year*.

We are not aware about much systematic research on the issue which question provides the better answers. At least with respect to reliability Tränkle (1981) found that the re-test reliability of self-reports of yearly mileage in a sample of young drivers (Median = 22 years of age) was surprisingly low (r=.80) whereas reports on lifetime-mileage seemed to be more stable (r=.97). However, as the subjects sample of this study was composed solely by students we cannot infer that the relationships found are also valid for the overall driver population.

3.3 Conclusions and recommendations for FOT

Without any doubt there is a need to have information on subjects’ individual driving experience when planning an FOT. As this variable can only be measured by means of self-reports and subjective estimations seem to be not very reliable we recommend to collect information about both aspects of driving experience (lifetime and yearly) and combine if needed.

4 Personality traits

4.1 Description

Personality is a complex concept. It consists of many different traits which are not always stable and may change over a lifetime. Personality may also be considered as a construct, derived from scores on research instruments. Just as intelligence is often operationalised by IQ (Intelligence Coefficient), where people have a high or a low score on an IQ test, personality traits are often determined by scores on a personality test, for example neuroticism. When determining personality of drivers, for using different driver groups in FOTs, we should not treat personality traits as discreet types like gender (one is either male or female). We cannot, for example, say that someone is neurotic or extrovert or not. However, we may say that someone is more neurotic if he/she scores higher on a neuroticism test or we may construct experimental groups with drivers who have passed a certain threshold in a test.

Personality traits may directly influence driving behaviour. However, different personalities may also have different attitudes and intentions, which are the determining factor for certain behaviour. For example a person with a high score on a sensation seeking test may drive more risky, but he/she may also have a different attitude about traffic rules and therefore not respect the speed limit, or he/she may take more risks in being late for meetings and therefore feels obliged to speed to arrive in time.

Using personality tests is a good way of making sure how certain personality types are represented in the study sample. If the percentage of drivers who score high on a sensation seeking scale is elevated in comparison with the normal driver population, or if these drivers are over represented in a certain condition, it will be harder to explain outcomes related to dangerous driving and to attribute them only to system characteristics.

Research on drivers` personality has especially been focused on the relation between personality and unsafe driving and accidents. Two personality traits in particular of interest in this area: sensation seeking and locus of control.

4.2 Sensation seeking

Sensation seeking (SS) “is a trait defined by the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take physical, social, legal, and financial risks for the sake of such experiences” (Zuckerman, 1994 p. 27). Zuckerman (1994) has written a book on a large number of issues related to sensation seeking in a wide range of domains, and discusses a large number of international studies being done in this area. Sensation seeking has been found to be higher in males than females, and it declines with age. There seems to be a positive relationship with the level of education and occupational status. A high sensation seeking score is positively related with a wide variety of risky behaviours, for example risky sexual activities, gambling and financial risk taking.

The relationship between sensation seeking and risky driving and its consequences (such as collisions and citations for traffic violations) has been widely documented. Examples of risky driving are drinking and driving, non-use of seat belts, speeding and following too closely.

Jonah (1997) gives a comprehensive overview of 40 studies. He reports that sensation seeking accounted for 10-15% of the variance in risky driving. Although this is a high number, it also shows that it is not the only variable that plays a role. Jonah et al (2001) report that sensation seeking drivers may adapt their behaviour when using new systems that reduce risky driving, such as ABS. They may change their behaviour in order to maintain the same level of risk, so they may, for example, driver faster.

4.3 Locus of control

Another well-known personality trait is the concept of Locus of Control (Rotter, 1966). Individuals with an internal locus of control (internals) tend to perceive events as a consequence of their own behaviour whereas individuals with an external locus of control (externals) tend to believe events are under the control of external factors or powers that cannot be influenced. Research has suggested therefore that externals are more likely to be involved in traffic accidents since they are less likely to take precautionary steps and engage in responsible driving. Internals may overestimate their skills and since they believe that accidents are a consequence of their own behaviour engage in risky behaviour, confident that they possess the skills to avoid an accident.

However, not all studies give conclusive evidence of the relationship between locus of control and risky driving and accident involvement.

4.4 Five Factor Model of Personality

While sensation seeking and locus of control are specific personality traits, one can also look at a wider range. The five factor model of personality (FFM: Digman, 1990; Goldberg, 1993; McCrae & Costa, 1997) may be regarded as the basic structure of personality, consisting of:

- Extraversion: marked by pronounced engagement with the external world, characterized by positive emotions and being social, active and dominant.
- Neuroticism: relates to a tendency to be anxious, pessimistic and worry about one's health.
- Conscientiousness: relates to the way individuals control, regulate and direct their impulses and is generally characterised by a tendency to be organised and persistent in pursuing goals.
- Agreeableness: refers to individuals concern with cooperation and social harmony and can be measured in terms of trust, compliance and altruism.
- Openness: characterised by a receptivity to new ideas and experiences.

Studies have been performed that link the factors of this model to aberrant driving behaviours, especially on the extraversion and neuroticism factors. A higher involvement in accidents is related to extraversion. High levels of neuroticism have been negatively related to driving confidence and positively related to driving stress. High levels of conscientiousness, agreeableness and openness are negatively related to risky driving, driving errors and involvement in accidents. However, the results are sometimes contradictory and there are interactions between the factors.

4.5 Other personality models

There is an extensive research on personality and many different models and tools exist. By no means have we intended to provide a complete list.

4.6 Measurements

4.6.1 Sensation Seeking

The Sensation Seeking Scale (SSS) operationalises this dimension and the SSS Form V is the most widely used measure of sensation seeking. The scale comprises of four sub-scales:

- Thrill and adventure seeking (TAS);
- Experience seeking (ES);
- Boredom susceptibility (BS);
- Disinhibition (Dis).

These subscales have been found to relate differently to various risky behaviours (Zuckerman, 1994) but Thrill and Adventure Seeking appears to have the strongest relationship to risky driving.

The scale contains 40 items. Respondents have to choose between alternatives, stating which one describes them best. An example of an item is:

A. I like “wild” uninhibited parties
B. I prefer quiet parties with good conversation

Zuckermann (1994) lists translations of the SSS into different languages.

An alternative scales is the Arnett Inventory of Sensation Seeking (AISS; 1994) which provides a short 20 item questionnaire which asks respondents to rate how likely each describes them. The scale is composed of two dimensions; novelty and intensity. An example item:

> “I would like to travel to places that are strange and far away.”
>
> (1 = describes me very well, 2 = describes me somewhat, 3 = does not describe me very well, 4 = does not describe me at all)

4.6.2 Locus of control

Montag and Comrey (1987) developed a test for locus of control consisting of two scales, a Driving Internality (DI) scale and a Driving Externality (DE) scale, designed to measure these constructs with specific reference to driving. Özkan and Lajunen (2005) have developed a driving targeted *multidimensional* locus of control scale. There are four scales within their Traffic Locus of Control Scale (T-LOC):

- “Other Drivers” (causes of accidents attributed to other drivers);
- “Self” (causes of accidents attributed to oneself);
- “Vehicle and Environment” (causes of accidents attributed to external factors);
- “Fate” (causes of accidents attributed to fate or bad luck).

In the T-LOC, participants are given a list of 16 possible causes of accidents. They are asked to indicate on a five-point scale how possible it is that those 16 reasons had caused or would cause an accident when they think about their own driving style and conditions. An example item:

> "Whether or not I get into car accident depends mostly on shortcomings in other drivers' driving skills" scale (1=not at all possible and 5=highly possible)

4.6.3 Five Factor Model of Personality

For the five factor scale of personality an international pool of items is available (see http://www.ipip.ori.org/). The test consists of 10 items per factor. Subjects are given a statement and they have to indicate on a five points scale how accurate it describes them. An example item (for extraversion) is

> "Am the life of the party" 1 very inaccurate – 5 very accurate

The tests for the Five Factor Model have also been translated in many languages; contacts are available on the International Personality Item Pool website: http://www.ipip.ori.org/.

4.7 Use of personality traits and driver behaviour in FOTs

An example of using personality tests is the Intelligent Cruise Control Field Operational Test of the University of Michigan for the US National Highway Traffic Safety Administration (Francher et al., 1998). They administered a personality test before the FOT and a driver style test before and after the FOT. This last test was constructed for this study. The tests were used to investigate the differences between participants and to see whether the driving style was changed by the use of the system.

4.8 Concerns

Different variations of tests discussed above are used in different studies. Sometimes fewer items are used in order to avoid giving drivers very long questionnaires to fill in. It is, however, questionable what happens to the reliability if only a few items are used.

All the tests discussed above are translated in many different languages. Questionnaires are not always translated literally, sometimes wording or even complete items have to be changed in order to be made more understandable for a certain group. It is often the researcher who takes care of a translation for a specific study. This means that for most countries there are no formalised or standardized tests.

Studies performed with subjects with different nationalities and cultural background found differences, sometimes in interaction with variable like gender and age. We may assume that are cultural differences in how people perceive, for example, risk and sensation, and thus value items in test.

Another problem with administering personality tests is that these kinds of concept become more and more known by the general public. For example at the BBC website you can fill in the SSS yourself http://www.bbc.co.uk/science/humanbody/mind/surveys/sensation/. In Australia, a shortened version of the SSS is given on the official site for the driver qualification test, so that drivers can test themselves in order to see whether they fall into the risk category:

http://www.rta.nsw.gov.au/licensing/tests/driverqualificationtest/sensationseekingscale/. You can even do a driver personality test on-line:

http://psychologytoday.tests.psychtests.com/take_test.php?idRegTest=1309.

If a large part of the population for a FOT is already familiar with a test, bias in completing it may occur.

In conclusion, personality traits are very easy to investigate, just by administering a short questionnaire. However, the concepts and interrelations of factors are very complex and even if there are strong correlations with dangerous driving, this relation is mainly statistical. We should not say things like that a certain driver is a sensation seeker and that that is the reason for speeding.

Given the mixed evidence especially regarding Locus of Control and the Five Personality Factors, their role in FOTs as a variable for driver characteristics should be treated with caution.

5 Self-reported driver behaviour

5.1 Description

Another way of looking at driver characteristics is look at their self-perceived and intended behaviour. There is a more direct link between intended and actual behaviour than between personality and behaviour. The theory of planned behaviour (Azjan, 1988) explains that human behaviour is guided by three kinds of considerations:

- Behavioural: beliefs about the likely outcomes of behaviour;
- Normative: beliefs about the normative expectations of others and motivation to comply with these expectations;
- Control: beliefs about the presence of factors that may facilitate or impede performance of the behaviour and the perceived power of these factors.

Together these beliefs lead to an intention to behave in a certain way. Of course the actual behaviour is also influenced by the actual control one has to execute the behaviour. For example, the intention to drive faster may be caused by the beliefs that it will bring you quicker at your destination (behavioural), that everyone speeds (normative) and that there are no dangerous bends in the road (control). If there is no speed limiting system in the car (actual control), a driver with this intention will probably speed. Asking drivers about their beliefs will thus predict, at least for some part, their behaviour.

Another way of distinguishing driver groups is to ask them directly about their behaviour. Of course one has to be aware that there is a clear distinction between asking a driver about past behaviour and measuring the behaviour directly with an objective method.

Drivers may be questioned about all different kinds of beliefs, intentions and behaviour. If we want to focus on risky behaviour a distinction may be made between (Reason et al., 1990):

- Errors: planned actions which fail to achieve their intended consequences, for example a misjudgement of distance to another car;
- Lapses: attention and memory failures, for example getting into the wrong lane when approaching a roundabout;
- Violations: deliberate deviations from safe and legal practices, for example running red traffic lights. Also aggressive acts fall under this category.

Again the determining factor is the intention, not the observable outcome of the behaviour. Driving too fast on a certain road may be caused by braking too late (error), forgetting the maximum speed for this road (lapse) and speeding (violation). Studies show that especially a high score on violations is positively related to accident involvement. A high frequency of lapses may be an indication for older drivers that they are not fit to drive.

5.2 Measures

The Driver Behaviour Questionnaire (DBQ) is widely used to measure driver behaviour (Reason et al. 1990). The questionnaire consists of items describing errors, lapses and violations. The subject has to indicate on a 6 point scale the frequency with which they committed each type of aberrant behaviour. There are different variations of this test, but the original test has 50 items. A 24 item test is also used often (Parker et al., 1995). An example item:

"Misjudge speed of oncoming vehicle" (0 = Never to 5 = nearly all the time)

For measuring beliefs and intentions one may also devise a dedicated questionnaire. A guideline from Azjen (2000) may be found on:

http://people.umass.edu/aizen/pdf/tpb.measurement.pdf. Especially for investigating the intentions and beliefs about a specific system for a FOT this may be a good option.

5.3 Other self-reported driver characteristics

There are also other self reported driver characteristics, such as driving style and driving competence. There are no standard methods for measuring this. Studies often construct their own method and test, sometimes based upon the tests described above.

5.4 Use of driver behaviour tests in FOTs

In the Road Departure Crash Warning System Field Operational Test of the University of Michigan for the US National Highway Traffic Safety Administration (LeBlanc, et al., 2006), the following tests were used in the pre-driving phase: DBQ, driver style, SSS, and locus of control to be used in analyses of driver acceptance. Four other measures were collected. They included the sensation seeking scale, the locus of control scale, a driving risk assessment questionnaire, and a driving dilemma scenarios questionnaire. These four measures were not directly used in any subsequent RDCW FOT analyses, but were administered to RDCW drivers to facilitate other research projects.

5.5 Concerns

The same concerns that were identified for the personality traits apply to tests of self-reported driver behaviour. Again there are many variations of the DBQ, both in terms of length, items and language.

6 Acceptability of Technology

6.1 What is Acceptability?

1. "Satisfactoriness by virtue of conforming to approved standards." "Worthy of being accepted."[11]
2. "Adequate to satisfy a need, requirement, or standard; satisfactory"[12]

Regarding the field of "technology acceptance", the term acceptability indicates the degree of approval of a technology by the users, which can be measured by the frequency of use. According to Nielsen (Nielsen, 1993), the general acceptability of an interactive system depends on, whether a system can satisfy the needs and expectations of its users and potential stakeholders.

6.2 Social Acceptability and Practical Acceptability of Technology

Acceptability in the framework of introducing new technologies (cf. Innovation), relates to social and individual aspects as well, another distinction of different levels of acceptability can be operated, regarding "social acceptability" and "practical acceptability" (cf. Nielsen, 1993).

- "Social acceptability" can be defined as an "ex-ante" acceptability, which refers to the social representations and socio-cultural disposition prior to the use of a specific technology.
- "Practical acceptability" refers to acceptability in the framework of the real confrontation with a given technology and the individual decision to use this technology or not.
- Further, the aspects of perceived utility and usability, as well as the aptitude to use the technology should be integrated in this framework.

The distinction of "social acceptability" to "practical acceptability" operates of two levels, an upstream level, which considers the societal dimension of acceptability and a downstream level, on which the individual acceptability is considered. Both levels are in a kind of hierarchical relationship, meaning that the social acceptability is prior to the practical acceptability on the individual level.

Social Acceptability relates to the socio-cultural predispositions towards a technology, which is socially constructed on behalf of social representations. In the framework of a constructivist approach (cf. Engel, Krishnakumar et. al., 2007) the following dimensions are addressed in Social Acceptability analysis:

- Degree of diffusion of a technology

[11] (http://wordnet.princeton.edu)

[12] (The American heritage dictionary of the English language; 2006; http://dictionary.reference.com)

- Technological culture in general
- Ethical predisposition for use
- Social expectations (expected benefits versus expected negative side effects)
- Risk perception
- Social representations for use precedents (reference cases via reference groups, peers)
- Social norm

Practical acceptability is also multidimensional – it includes perceived usefulness (which includes a distinction in utility and usability), and includes further the following dimensions:

- Perceived utility
- Individual technical culture
- Education level
- Experience with related technology
- Individual usability criteria
- Individual risk perception
- Subjective norm
- Satisfaction
- Cost
- Compatibility with existing systems

Usefulness = utility and usability

The usefulness of a system refers to the aspect, if the system can meet the needs of the user and help him to achieve his (expected) goals. According to Grudin (1992), usefulness should be split up in the dimensions of utility – which refers to the functional aspects of the system (the system is able to do what is needed) and usability – which concerns the aspects of the user's general capacity to interact with the system (including installation and maintenance issues).

6.3 Social Acceptability of Technology and the Dimension of Aptitude and Access to Technology

To understand Social acceptability better, the analysis should not only limit itself on a "voluntaristic" perspective on potential users' attitudes regarding their interest of using a technology. Another important dimension is the aptitude of using a technology in the sense of having (or having not) **technological culture** in the sense of first-hand user experience and access to new technologies (cf. Castells, 2002). For example, the notion of the **"digital divide"** applies perfectly to the domain of automotive technology, in the sense that the knowledge of how to use a computer is a condition to use most of the current on board navigation systems (knowledge of what is a "menu" or arborescence, for example).

Consequently, Social Acceptability includes the dimensions of the social conditions (cf. Bourdieu, 1979) and the cultural background, permitting access to new technologies' use, which leads to the question of if there are specific socio-cultural factors which facilitate access and use of new technologies.

6.3.1 Apprenticeship and factors facilitating access to new technologies

Acceptability and potential use of new technologies cannot be disconnected from the users' social roots, which means, the socio-cultural dispositions of the users has to be studied and user-profiles (ore merely, Acceptability profiles) should be developed. The identification of the apprenticeship process for specific social categories is a complementary dimension to investigate.

The linkage of the aptitude (social and technical) to use a technology, utility and usability has to be completed with the economic aspect for the user: is he willing and able to afford a new technology, dimension which not only relates to (sometimes overestimated) "willingness-to-pay" approaches, but to socio-economic conditions (budget and vital priorities) of the target users. Acceptability is multidimensional and its analysis requires multidisciplinary approaches; there are plenty of examples of technologies being perfectly usable but never socially accepted (cf. Shakel, 1991).

6.3.2 Social Acceptability Profiles

To improve Acceptability of Technology 'Analysis, a further profiling of potential users regarding their degree of acceptability towards technology in general appears as an interesting perspective. For example, Rogers (1995) points out the role of categories such as "early adopters" or "innovators" which in fact constitute examples for Social Acceptability Profiles, regarding their role as "leaders" in the acceptance of innovations. On the other hand, it can be expected that there exist at least one profile with a less privileged access (or "refuter"-patterns) to technology that has to be decrypted as well, to be sure to have a complete scope on Social Acceptability.

6.4 The role of Acceptability of technology in FOT's

Acceptability is the key issue for the diffusion of new technologies in the automotive sector and regarding the aspect of road safety improvement. In the framework of FOT, several arguments have to be considered regarding the aspect of Acceptability of technology:

- To integrate a maximum of useful criteria, which will help to analyze the conditions (and obstacles) that facilitate Acceptability of the technologies implemented through the FOT.
- To contribute, together with the analysis of Driver Characteristics, to a performing segmentation process, aiming to constitute a diversified target population for the FOT field phases.
- To determine, via the FOT research, what are Acceptability criteria for new technologies in the automotive sector and so contribute to improve public implementation strategies.

6.5 Concepts for measuring acceptability of technology

6.5.1 Diffusion of innovations (Rogers, 2003)

The basic concept of this model is to explain phenomena of adaptation and diffusion of innovations in general; five variables are supposed to have an influence regarding the individual adaptation of technologies:

- Relative advantage: on what extent a technology offers improvements over available technology.
- The compatibility with the value system of the reference group
- The level of complexity of the technology, ease of use and learning;
- The possibility to test the technology;
- The aspect of visibility / observability, on what extent the technology's advantages are clear to see.

These five variables form together a system of predictors for the intentions of using a technology.

6.5.2 Theory of planned behaviour (Ajzen & Fishbein, 1975)

Fishbein and Ajzen (1975) proposed this general model aiming to explain and predict individual behaviour (see also Chapter 5). According to this theory, the behaviour of an individual is directly determined by his intention to realize this behaviour. The intention hereby is a function of three variables, being:

1. The attitude, which is formed by all the faiths as for the consequences of the realization of the behaviour, balanced by the importance that the individual grants to each of these consequences;

2. The subjective norm that refers to the system of beliefs of an individual, as for the opinion of persons or reference groups with regard to the fact that they do behave or act in a specific way.

3. The perceived behavioural control corresponds to the degree of perceived ease or difficulty that represents the realization of a behaviour for the individual. This variable reflects the presence of external factors, which facilitate or hinder the realization of a given behaviour, as well as the perception of the individual of its personal efficiency to realize this behaviour. This variable can act, in the same way as the attitude and the subjective norm on the intention, or can contribute to predict the behaviour, when this one is not under the individuals' voluntary control.

6.5.3 Technology acceptance model (TAM) (Davis, 1989)

The model proposed by Davis (1989) is based on the theory of Fishbein and Ajzen (1975), but represents a variant which specifically applies to the behaviour of adoption of information technologies. According to the TAM, the intention to use a technology is the direct antecedent of the behaviour of use. However, contrary to the theory of the strategic behaviour, the TAM includes only the attitude in the forming process of the intention. Furthermore, according to the model of Davis (1989) the attitude is determined itself by two types of faiths: the perceived utility and the perceived ease of use.

6.5.4 The theory of interpersonal behaviour (Triandis, 1972)

Triandis' theory of interpersonal behaviour includes peer influences and situational characteristics in explaining behaviour; this psychosocial model is used to understand the behaviour of adoptions of the technologies. According to this theory, a behaviour is directly determined by three variables:

1. The intention to adopt a behaviour;
2. The custom to execute this behaviour or a close behaviour;
3. The conditions facilitating the adoption, which dismiss to variables outside the person, who can have an influence on the adoption or not technologies.

In this behavioural model, the intention is determined by four factors: the social factors, the received consequences, the affects and the personal convictions. Triandis introduces a research paradigm, the **"subjective culture",** which he defined as a social group's specific way to perceive its social environment; the subjective culture forms a system of beliefs and meanings, interpersonal relationships, norms and values as well as attitudes that guide interaction of persons in various social contexts.

To measure the different dimensions, which constitute Acceptability in FOT, tools such as standardized Questionnaires, Focus Groups and individual interviews can be applied. Also, a performing method for self-reporting will complete the data collection on acceptability.

6.5.5 Socio-demographic data

To complete the analysis of Acceptability of technology, socio-demographic variables should be constantly integrated. Age, gender, education level, the professional situation as well as information on the geographic situation and habitat do contribute to complete the knowledge of factors for technology' acceptability.

6.5.6 Context

Finally, an evaluation of Acceptability factors has to consider the context wherein the technology is supposed to be used. In the framework of driving, the context is constantly changing and the driver has to adapt, sometimes under emergency conditions. To fully understand if the users / drivers are willing and able to accept new technologies in their cars, the different dimensions of social and practical acceptability have to be examined in a variety of real world contexts.

6.5.7 Willingness to pay

A way of measuring acceptability is to look at willingness to pay. If the user accepts the technology and perceives the utility, he/she will be willing to buy a system. However, willingness to pay is also dependent on other factors, such as the financial situation of the user and the price of the system in comparison with other similar systems. Also the question whether other people, important for the user, are buying the system plays a role. Willingness to pay is an important indicator for acceptability, but it should be treated with caution. There are also systems that do not bring a clear individual benefit to the user, but provides social benefits, such as in the area of safety and environment. Willingness to pay may be much lower, but that does not mean that the technology is not acceptable or that users would not be ready to adopt the system.

6.6 Conclusion

Regarding Acceptability of Technology, there does not exist a unique model or theory today; there are several variables which altogether contribute to analyze, what are conditions that will enhance or hinder potential users' acceptability of new technological systems.

Acceptability hereby has to be explored on an upstream level, whereas the dimensions of social acceptability such as technical culture, norms and beliefs have to be analyzed, towards a downstream level of practical acceptability, which refers, among others, to the individual capacity, perceived utility and understanding of technology. The aspects of user experience and training also impact the different level of Acceptability of technology, as well as the analysis of the context of its potential use. One suggestion for further research on Acceptability is to focus on the identification of "Acceptability Profiles" by a segmentation approach through the diverse Acceptability approaches collected in this paper. Regarding the specific FOT context, measuring of acceptability can be realized via (existing) standardized questionnaires, based on a methodology mix of the presented theoretical approaches, in-depth interviews before and after "use" (driving), and Focus Groups.

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