Field testing of vehicles

Lecture 9

Schedule

Week nr.	Date	Lecture (Wednesday)			Lab (Wednesday)		Comment
1	09.04.	1	General information		1	Lab	
2	09.11.	2	Development methods		2	Lab	Online
3	09.18.	3	Design goals and requirements		3	Lab	
4	09.25.	4	Conceptualization I		4	Lab	
5	10.02.	5	Design guidelines		5	Lab	
6	10.09.	6	Prototype racecar investigation in workshop		6	Lab	
7	10.16.	T1	Midterm exam I.				
8	10.23.	B	National holiday				
9	10.30.	-	-		T1 R	Exam 1 - Retake	
10	11.06.	7	Testing strategies in the automotive industry		7	Lab	
11	11.13.	8	System level testing		8	Lab	
12	11.20.	9	Field testing of vehicles		9	Lab	
13	11.27.	T2	Midterm exam II.				
14	12.04.	T2R	Project presentation		T2 R	Exam 2 - Retake	

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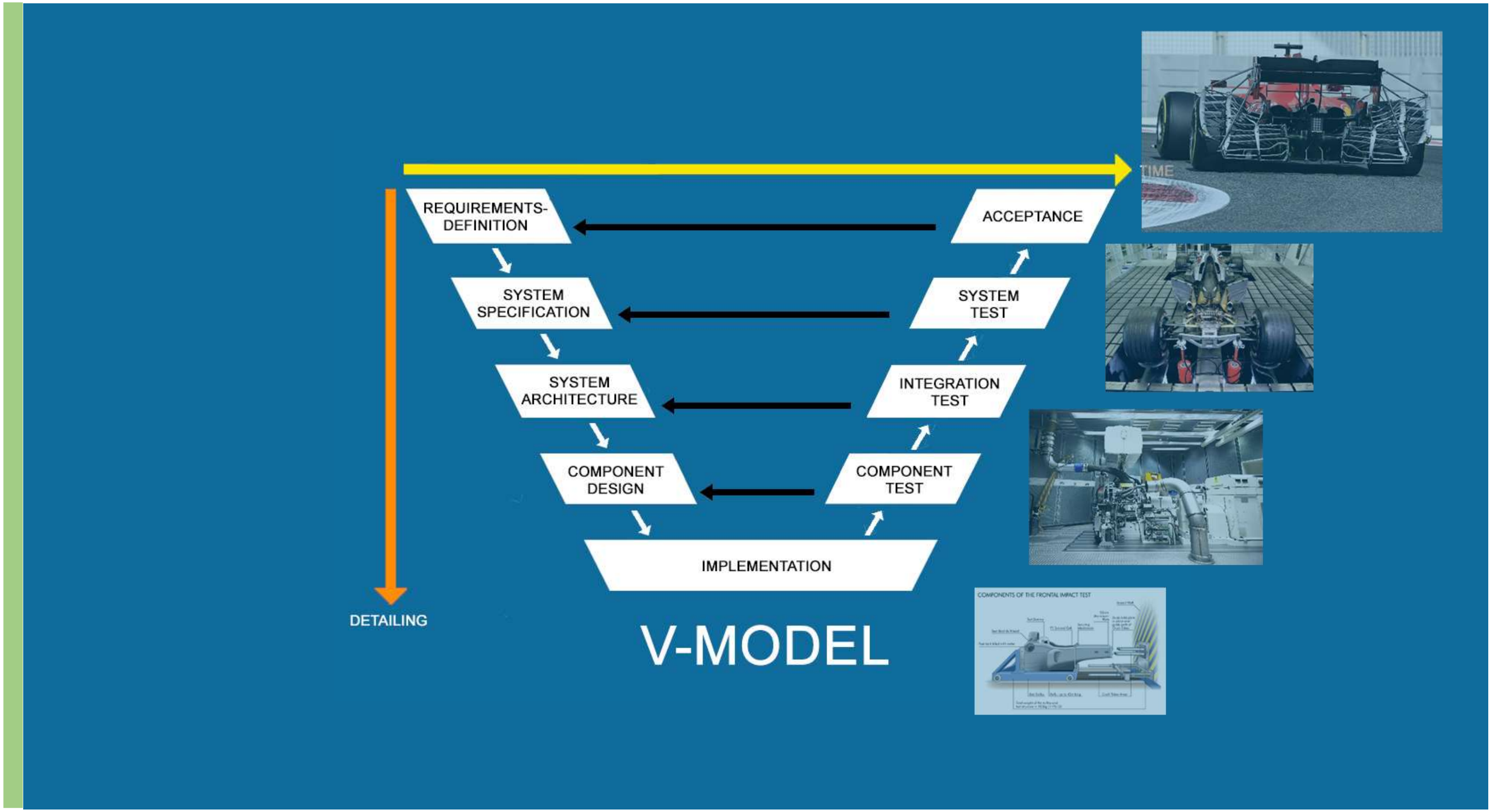
- Overview
- Field Testing in Vehicle Development
- Overview of Standard Vehicle Test Types
- Detailed Prototype Test Plan
- Data Collection and Analysis
- Case Study – ZalaZONE Test Track Elements
- Practical Demonstration
- Q & A

Overview

- Brief recap of previous lectures on vehicle design methodology.
- Importance of structured testing in the development cycle.
- Overview of today's focus:
  - track tests, data analysis, and practical applications

https://dewesoft.com/blog/list-of-automotive-proving-grounds ;

Field Testing in Vehicle Development



https://www.mdpi.com/1996-1073/14/1/171; https://www.racecar-engineering.com/articles/tech-explained-2022-f1-technical-regulations/ ; https://www.pmw-magazine.com/news/race-series-news/fia-reveals-details-of-2026-f1-regulations.html ;
https://formula1technical.weebly.com/articles/2014-f1-car-fia-safety-equipment-testing ; https://ehfcv.com/hardware-in-loop-hil-simulation-formula-1-racecar/

Field Testing in Vehicle Development

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- The Synergy Between Theory and Practice
  - In vehicle design, the connection between theoretical models and practical outcomes from testing is integral. Theory provides the foundation for initial design, and testing validates or challenges these predictions. The results from testing allow engineers to continuously improve and refine the design. This feedback loop between theory and practice ensures that the final vehicle meets both the design goals and the real-world performance expectations. It is this iterative process that allows for the development of high-performance, safe, and reliable vehicles.
  - Feedback from Field Testing: Engineers collect feedback from consumers or fleet operators using the vehicle in real-world conditions. This feedback might highlight issues such as poor fuel economy, uncomfortable ride quality, or vehicle handling issues that were not fully anticipated in initial simulations. Adjustments are then made in the design to improve overall performance.

Field Testing in Vehicle Development

Let's characterize field testing!

- High Costs
  - Expensive Track Time: Renting test tracks or using public roads incurs significant costs.
  - Operational Costs: Manufacture and maintaining test vehicles, equipment, and the test infrastructure adds to the expense. Measurement systems could increase costs heavily.
- Uncontrollable Factors
  - Environmental Variability: Weather, road conditions, and traffic introduce unpredictability into testing.
  - External Distractions: External variables such as nearby vehicles, pedestrians, or wildlife can interfere with testing.
- Changing Conditions
  - Dynamic Test Environments: Unlike controlled lab settings, the field environment changes constantly, impacting test consistency.
  - Real-World Complexity: Different surfaces, weather conditions, and real-world road irregularities make it hard to replicate tests precisely.

https://www.tiretechnologyinternational.com/news/testing-analysis/bridgestone-opens-wet-handling-track.html ;

Field Testing in Vehicle Development

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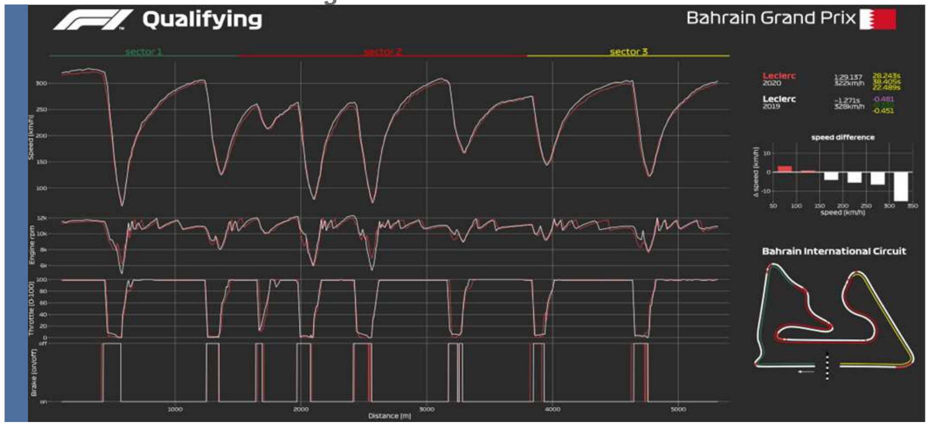
Let's characterize field testing!

- Need for Comprehensive Data Recording
  - Documenting Every Factor: Detailed data collection is essential to account for external variables.
  - Test Report Importance: Clear, structured reporting ensures all variables are considered and helps in analyzing results accurately.
- Data Collection and Efficiency
  - Real-Time Data Capture: Efficient data logging systems capture critical information, such as vehicle behavior, environmental data, and driver input.
  - Effectiveness and Time Management: Given the cost of track time, optimizing the testing procedure is vital to ensure maximum return on investment.
- Coordination of Multiple Factors
  - Car, Track, Driver Coordination: Success requires precise synchronization between the vehicle, the test track, and the driver's actions.
  - Test Team Coordination: From engineers to safety personnel, everyone must align for effective field testing.



Overview of Standard Vehicle Test Types

- **Acceleration Tests:**
  - Setup, key performance indicators (KPIs) measured, and the importance for evaluating drivetrain efficiency.
- **Skid Pad Test:**
  - Methodology, purpose (e.g., lateral grip and handling characteristics), and typical results interpretation.
- **Moose Test**
  - Emergency maneuver testing and stability assessment.
- **Braking Tests:**
  - Including full-stop braking, braking distance measurements, and deceleration rate analysis.
- **Cornering Tests:**
  - Vehicle behavior during high-speed cornering and steady-state cornering performance.
- **High-Speed Stability Tests:**
  - Assess vehicle behavior at high speeds to ensure safety and control.
- **Noise, Vibration, and Harshness (NVH) Testing:**
  - Evaluate the comfort level and the impact of vehicle noise and vibration.
- **Endurance Testing:**
  - Simulate long-term vehicle use to detect potential failures and durability issues.
- **ADAS Test Cases:**

Overview of Standard Vehicle Test Types

1. Acceleration Tests

- **Setup**: Conducted in a controlled environment on a straight track.
- **Purpose**: Evaluates drivetrain efficiency and power output.
- **KPIs Measured**: 0-100 km/h time, quarter-mile time, acceleration rate.

Implementation

Goal

Acceleration (FSC, FSE, DC)

The vehicle's acceleration from a standing start is measured over a 75 metre straight. In addition to trac-tion, the correct engine design is especially important, either in terms of greater power or for the highest possible torque. The fastest cars cross the line in less than four seconds and can reach speeds of over 100 km/h by the end of the stretch.

Maximum score: 50 points with driver & 75 points without driver

Regs

D5.1 Acceleration Track Layout

D5.1.1 The acceleration track is a straight line with a length of 75 m from starting line to finish line. The track is at least 3 m wide. Cones are placed along the track at intervals of about 5 m.

https://www.formulastudent.de/fileadmin/user_upload/all/2024/rules/FS-Rules_2024_v1.1.pdf ; https://www.formulastudent.de/about/disciplines/ ;

Overview of Standard Vehicle Test Types

1. **Acceleration Tests**
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2. **Skid Pad Test**
   - **Setup**: Vehicle driven in a circular path at increasing speeds.
   - **Purpose**: Assesses lateral grip and handling characteristics.
   - **Results Interpretation**: Higher lateral G-forces indicate better cornering capability.

Goal

Skid Pad (FSC, FSE, DC)

During the Skid Pad event, the cars must drive a figure of 8 circuit lined with track cones, performing two laps of each circle. In each case, the sec-ond lap will be measured. The lap time gives a comparative value for the maximum possible lateral acceleration of the car. Most of the cars use aerodynamics to raise the contact pressure and thus, increase lateral acceleration. As with all the dynamic events, knocking over any of the cones results in a time penalty.

Maximum score: 50 points with driver & 75 points without driver

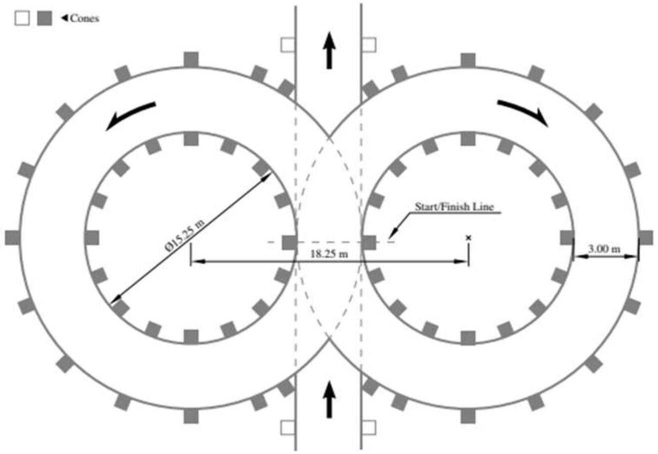

Figure 23: Skidpad Track Layout

Regs

D4.1	**Skidpad Track Layout**
D4.1.1	The skidpad track consists of two pairs of concentric circles in a figure of eight pattern.
D4.1.2	The centers of these circles are 18.25 m apart. The inner circles are 15.25 m in diameter and the outer circles are 21.25 m in diameter.
D4.1.3	16 cones are placed around the inside of each inner circle. 13 cones are positioned around the outside of each outer circle, in the pattern shown in the skidpad layout diagram.
D4.1.4	Each circle is marked with a line, outside the inner circle and inside the outer circle.
D4.1.5	The driving path is the 3 m wide path between the inner and outer circles. The vehicles enter and exit through gates on a 3 m wide path that is tangent to the circles where they meet.
D4.1.6	The line between the centers of the circles defines the start/finish line. A lap is defined as traveling around one of the circles, starting and ending at the start/finish line.

D4.2.5	The vehicle will enter perpendicular to the figure of eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap. The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track perpendicular to the figure of eight and moving in the same direction as entered.

https://www.formulastudent.de/fileadmin/user_upload/all/2024/rules/FS-Rules_2024_v1.1.pdf ; https://www.formulastudent.de/about/disciplines/ ;

Overview of Standard Vehicle Test Types

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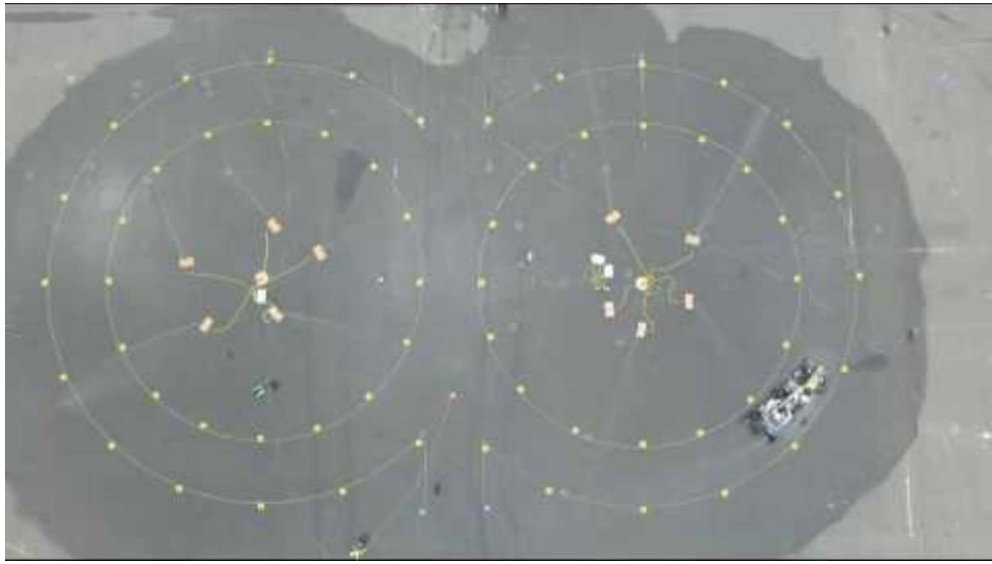
Implementation



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https://www.formulastudent.de/fileadmin/user_upload/all/2024/rules/FS-Rules_2024_v1.1.pdf ; https://www.formulastudent.de/about/disciplines/ ;

Overview of Standard Vehicle Test Types

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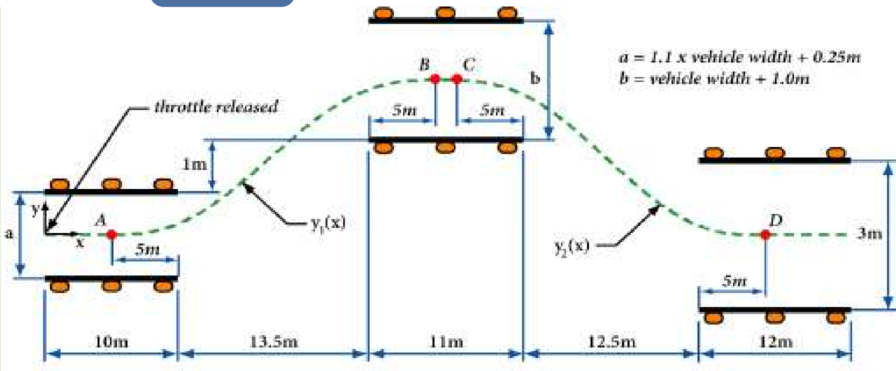
3. **Moose Test**
   - **Setup**: Sudden obstacle avoidance maneuver.
   - **Purpose**: Tests vehicle stability and control during emergency maneuvers.
   - **KPIs Measured**: Stability, agility, and electronic stability control effectiveness.



Double-lane-change maneuver test track ISO3888

Recommended: https://cdn.standards.iteh.ai/samples/57253/5e8cdcc7c2fe4c0c8fe6f1de8beb5dba/ISO-3888-2-2011.pdf

https://www.researchgate.net/figure/SO-3888-double-lane-change-maneuver-test-track-14_fig4_256422117 ;

Overview of Standard Vehicle Test Types

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   - **Purpose**: Tests vehicle stability and control during emergency maneuvers.
   - **KPIs Measured**: Stability, agility, and electronic stability control effectiveness.
4. **Braking Tests**
   - **Setup**: Full-stop braking scenarios and emergency braking.
   - **Purpose**: Assesses braking system performance and safety.
   - **KPIs Measured**: Braking distance, deceleration rate.

IN 11.1 Brake Test Procedure

IN 11.1.1 Lock all four wheels and stop the vehicle in a straight line at the end of an acceleration run specified by the officials without stalling the engine.

https://www.formulastudent.de/about/disciplines/ ; https://www.natrax.in/braking-track/ ;

Overview of Standard Vehicle Test Types

5. Cornering Tests

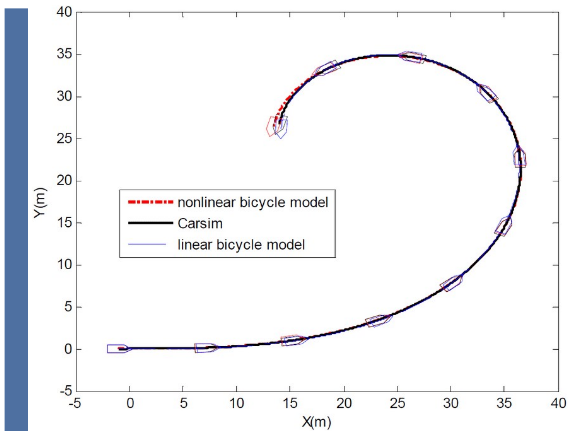
- **Setup**: High-speed and steady-state cornering exercises, ramp steer test.
- **Purpose**: Examines vehicle behavior during different cornering scenarios.
- **KPIs Measured**: Balance, tire grip, understeer/oversteer tendencies.

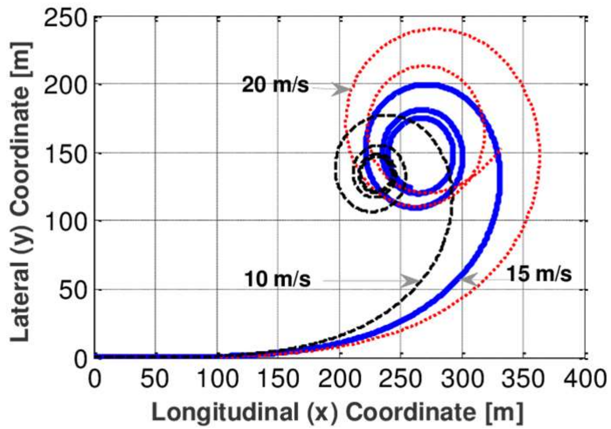
6. High-Speed Stability Tests

- **Setup**: Conducted on a high-speed track or highway simulation.
- **Purpose**: Assesses vehicle control and stability at high speeds.
- **KPIs Measured**: Safety, handling consistency.

7. NVH Testing

- **Setup**: Interior and exterior noise measurements during various conditions.
- **Purpose**: Evaluates the comfort level and the impact of vehicle noise and vibration.
- **KPIs Measured**: Noise levels, vibration frequencies, ride comfort.





https://www.ramseyethetrackguy.com/2020/02/understeer-vs-oversteer-which-is-quicker.html ; https://avlzalazone.com/testing-and-track/pass-by-noise-track-nvh/ ; https://www.bitauto.com/global/news/100193380845.html ; https://www.researchgate.net/figure/UGV-x-y-trajectory-during-ramp-steer-maneuver-and-different-driving-speed-10-15-and-20_fig5_319043884 ; https://www.researchgate.net/figure/ehicle-trajectory-comparison-for-the-ramp-steer-input-at-a-speed-of-30-km-h_fig5_271545759 ;

Overview of Standard Vehicle Test Types

8. **Endurance Testing**
   - **Setup**: Long-term driving simulation under varied conditions.
   - **Purpose**: Detects potential failures and assesses vehicle durability.
   - **KPIs Measured**: Component reliability, wear and tear analysis.

9. **ADAS Test Cases**
   - **Setup**: Simulations of real-world driving scenarios, including lane keeping and emergency braking.
   - **Purpose**: Verifies the effectiveness of ADAS.
   - **KPIs Measured**: System responsiveness, accuracy, and safety compliance.

https://www.abdynamics.com/solutions/adas-testing/ ;

Overview of Standard Vehicle Test Types

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8. **Endurance Testing – offer example**

- **Setup**: Long-term driving simulation under varied conditions.
- **Purpose**: Detects potential failures and assesses vehicle durability.
- **KPIs Measured**: Component reliability, wear and tear analysis.

Details:

- 4 km long cobblestone road (level and uneven cobblestones with different shirring factors).
- 900 m chippings section, ideal for corrosion development
- S-curve section followed by a large crest
- Bumps (long waves, short waves, potholes)
- Traction control test
- Mud bath (56 m long, 5 m wide, 5 cm deep)
- Water bath – can be filled up to 30 cm
- Salt splash track
- Salt spray chamber (15 m long, 3 m wide, 2.50 m high)
- Ramps at 13° and 16°

https://www.segulatechnologies.com/en/endurance-test/ ;

Detailed Prototype Test Plan

- Present the specific test plan written for the prototype race car.
    - Objectives and key metrics to be collected.
    - Breakdown of the tests planned (acceleration, handling, braking).
    - Procedures for conducting each test, including safety protocols.
- Highlights of importance of iteration based on test findings.

Detailed Prototype Test Plan

#	prio	Kategória	Mérés		leírás	időigény [ó]	nap	helyszín	eszköz
1.1.1.	1		Tömegmérés			0,5	1	SZE műhely	4 mérleg
1.1.2.	1		Súlypontmagasság-mérés			1	1	SZE műhely	4 mérleg + asztal/ emelvény + emelő/emeberek?
1.1.3.	1		Nyomtávmérés			0,5	1	Zalazone műhely	futómű-pad/pók és mérőeszközök
1.1.4.	1		Tengelytáv mérés			0,5	1	Zalazone műhely	futómű-pad/pók és mérőeszközök
1.1.5.	1		Futómű mozgástartomány átmozgatás		berugózás+ elkormányzás (rugóstag-kikötéssel)	1,5	1	Zalazone műhely	szerszámok futómű szereléshez
1.1.6.			Futómű paraméter változtatás-hatás vizsgálat		kerékdőlés, szét-össze, hasmagasság	3	1	Zalazone műhely	szerszámok futómű szereléshez
	3		További mérések						
1.1.7.	3			Váz torziós merevség (hub-to-hub, csak váz)					torziós merevség mérőpad / egyedileg gyártott készülék
1.1.8.	3			Ackermann geometria					
1.1.9.	3			Bumpsteer					
1.1.10.	3			Camber variation					
				Hajtáslánc rögzítés vizsgálata	Változó tapadású felületen (pl.macskakő) gyorsítások (~100% TP) több alkalommal (~10) rövid ideig (0.1-0.5s)				
	3			...					
1.1.11.	1		Pilóta kiugrás teszt		teljesen bekötött állapotból hány másodperc alatt ugrik ki?	0,5	2	MT műhely	

Detailed Prototype Test Plan

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#	prio	Kategória	Mérés		leírás	időigény [ó]	nap	helyszín	eszköz
1.2.			**Elektromos**						
1.2.1.			LV funkciók						
1.2.1.1.	1			CAN kommunikáció teszt		2	2	MT műhely	Can bus reader, rendszerterv
1.2.1.2.	1			Szenzorok tesztje		2	2	MT műhely	
1.2.1.3.				Adatgyűjtő rendszer teszt		1	2	MT műhely	
1.2.2.			Biztonsági funkciók						
1.2.2.1.	1			HVD mechanikai tesztje	Az autót üzemeltető összes személy képes oldani a HVD-t.	0,5	2	MT műhely	
1.2.2.2.	1			Shutdown circuit összes elemének tesztje	A SC összes eleme képes szakítani a kört.	1,5	3	MT műhely	
1.2.2.3.	1			Discharge circuit teszt	A megadott időn belül megtörténik a kisütés a megadott fesz szintre.	1	3	MT műhely	
1.2.2.4.	1			Safety light teszt	A lámpa minden állapotot megfelelően jelez vissza	0,5	3	MT műhely	
1.2.3.			HV funkciók						
1.2.3.1.	1			Teljes bekapcsolási folyamat teszt.	Az autó bekapcsolása teljesen OFF állapotból menetkész állapotig. Mindenhol az történik amit várunk.	1,5	3	MT műhely	
1.2.3.2.	1			Kerékforgatás emelve.	Az autó képes megforgatni a hajtott kerekeket bakon. Mindig az történik amit várunk.	2	3	MT műhely	
1.2.3.3.	1			Teljes kikapcsolási folyamat teszt.	Az autó kikapcsolása forgatott kerekektől a teljesen OFF állapotig. Mindig az történik amit várunk.	1	3	MT műhely	
1.2.3.4.	1			Töltés	Teljesen lemerített (amíg a rendszer engedi) akkumulátor feltöltése a maximumig normál töltőárammal.	2	4	MT műhely	

Detailed Prototype Test Plan

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Blokk	Run	Kategória	Mérés		pálya	pályatevékenység	box tevékenység	idő			akkumulátor kapacitás		
								kezdet	idősáv	vége	kezdet	fogyasztás	vége
		Pályatesztek						8:00			100%		
1			Alap járműfunkció										
	1			Ciklus 1 max 40 km/h;	DP	autó elindul, átmozgat (felgyorsít, lelassít, teljes kormányzási tartomány), visszajön, vészstoppal leáll;		8:00	0:15	8:15	100%	10%	90%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés) bármely szinten probléma.	8:15	0:05	8:20	90%	0%	90%
	2			Ciklus 2 - max 80 km/h	DP	autó elindul, átmozgat (felgyorsít, intenzíven lelassít, teljes kormányzási tartomány), visszajön, leáll;		8:20	0:15	8:35	90%	10%	80%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	8:35	0:05	8:40	80%	0%	80%
	3			Ciklus 3 - max 100 km/h	DP	autó elindul, átmozgat (felgyorsít, intenzíven lelassít, teljes kormányzási tartomány), visszajön, leáll;		8:40	0:15	8:55	80%	10%	70%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	8:55	0:05	9:00	70%	0%	70%
	4			Ciklus 4 - max 120 km/h	DP	autó elindul, átmozgat (felgyorsít, intenzíven lelassít, teljes kormányzási tartomány), visszajön, leáll;		9:00	0:15	9:15	70%	10%	60%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	9:15	0:05	9:20	60%	0%	60%
	5			Ciklus 5 - max 120 km/h	DP	autó elindul, átmozgat (felgyorsít, intenzíven lelassít, teljes kormányzási tartomány), visszajön, leáll; és így tovább eljutni a végsebességig		9:20	0:15	9:35	60%	10%	50%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	9:35	0:05	9:40	50%	0%	50%
	6			Vészstop, restart	DP	autó leállítás vészleállítóval menet közben, megáll, újraindítás		9:40	0:15	9:55	50%	10%	40%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	9:55	0:05	10:00	40%	0%	40%

Detailed Prototype Test Plan

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								idő			akkumulátor kapacitás		
Blokk	Run	Kategória	Mérés		pálya	pályatevékenység	box tevékenység	kezdet	idősáv	vége	kezdet	fogyasztás	vége
							visszajelzés)						
2	7			Transition test (Ramp steer test)		Straight-line path. The vehicle is driven at a nominally constant longitudinal velocity. The standard test velocity is 100 km/h. Other longitudinal velocities may be used; these should be decremented or incremented by 20 km/h from the standard velocity. The steering-wheel shall be subjected to a ramp input (that is one that increases in amplitude with a nominally constant angular velocity). The steering input shall be applied for a minimum duration of 3 seconds, and at an angular velocity not exceeding 5 degrees/second, until the lateral acceleration achieved by the vehicle reaches a minimum of 1,5 m/s2.		10:00	1:00	11:00	40%	15%	25%
							autó átvizsgál (lelazulás, kotyogás, pilóta visszajelzés)	11:00	0:10	11:10	25%	0%	25%
	8			Skid pad test				11:10	0:30	11:40	25%	20%	5%
							Töltés	11:40	1:30	13:10	5%	-95%	100%

Detailed Prototype Test Plan

BME Automotive Technologies

Blokk	Run	Kategória	Mérés		pálya	pályatevékenység	box tevékenység	idő kezdet	idő idősáv	idő vége	akkumulátor kapacitás kezdet	akkumulátor kapacitás fogyasztás	akkumulátor kapacitás vége
3			Hajtáslánc paraméterezés					13:10		13:10	100%	0	100%
	9			Inverter paraméterezés Ciklusok...	handling	??		13:10	6:00	19:10	100%		100%
4			Beállítás-vizsgálat					19:10		19:10			0%
	10			Járműdinamikai funkciók (modellvalidálás, paraméterek, setup-változtatások)	handling			19:10	8:00	3:10			
5			Hosszútávú viselkedés					3:10		3:10			
	11			Long runok (hőmérséklet, kopások, fogyasztás)	handling	25 km egyben, megállás nélkül a jármű aktuális maximális teljesítményével, handling pályán.		3:10		3:10			

Detailed Prototype Test Plan

Blokk	Run	Kategória	Mérés		pálya	pályatevékenység	box tevékenység
6	12			Ciklus 1.	handling	Jármű álló helyzetből (vagy nagyon lassú gurulásból), lehetőleg sík terepen felgyorsít legalább 100 km/h-ra (amennyiben a pálya erre lehetőséget nyújt lehet 150 km/h is, de mindenképp reprodukálható legyen), majd intenzíven fékez (amennyiben generátoros mód elérhető, úgy azt kihasználva). Az intenzív fékezést követően a tesztet további 8-10 alkalommal szükséges megismételni. A teszt célja az elektromos hajtás termikus védelmének (derating) vizsgálata. Az utolsó gyorsítási ciklusoknál várhatóan romlik a jármű gyorsulása a teljesítmény korlátozásoknak köszönhetően. A vizsgálatot követően a motor hűtése javasolt (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával) (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával)	
							A tesztet követően legalább 15 perc hűstési
	13			Ciklus 2. (Opcionális)	handling	A ciklus 100 km/h-val haladó járművel veszi kezdetét. A jármű maximális gyorsítással gyorsul konstans ideig, majd intenzíven lelassít 100 km/h-ra, és újra gyorsítani kezd. A ciklust 8-10 alkalommal szükséges megismételni A teszt célja az elektromos hajtás termikus védelmének (derating) vizsgálata. Az utolsó gyorsítási ciklusoknál várhatóan romlik a jármű gyorsulása a teljesítmény korlátozásoknak köszönhetően. A vizsgálatot követően a motor hűtése javasolt (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával) (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával)	
							A tesztet követően legalább 15 perc hűstési
	14			Ciklus 3. (Opcionális)	handling	(amennyiben kellő hely áll rendelkezésre) A jármű végsebesség közeli tempóval halad, 3 másodpercig gyorsítás nélkül kigurul, majd visszagyorsít végsebességre és 10 másodpercig tartja azt. A ciklus 8-10 alkalommal megismétlendő. A teszt célja az elekromos hajtás termikus védelmének (derating) vizsgálata. Az utolsó gyorsítási ciklusoknál várhatóan romlik a jármű gyorsulása a teljesítmény korlátozásoknak köszönhetően. A vizsgálatot követően a motor hűsése javasolt (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával) (hosszú kigurulással, alacsony terheléssel, hűtővíz áramlásának biztosításával)	

Detailed Prototype Test Plan

BME Automotive Technologies

Blokk	Run	Kategória	Mérés		pálya	pályatevékenység	box tevékenység
7	15			Áram szabályozás emelkedőn való elindulást követően (alacsony emelkedő)	handling	A jármű a kijelölt emelkedő első szakaszán megáll, majd állóhelyzetből elindul (vizsgálat különböző gázálások mellet)	
	16			Áram szabályozás emelkedőn való gyorsítás közben (alacsony emelkedő)	handling	A jármű a kijelölt emelkedőt megközelíti 15 km/h sebességgel, majd gyorsítást végez el az emelkedő tetejéig (vizsgálat különböző gázálások mellet)	
	17			Áram szabályozás emelkedőn való elindulást követően (közepes emelkedő)	handling	A jármű a kijelölt emelkedő első szakaszán megáll, majd állóhelyzetből elindul (vizsgálat különböző gázálások mellet)	
	18			Áram szabályozás emelkedőn való gyorsítás közben (közepes emelkedő)	handling	A jármű a kijelölt emelkedőt megközelíti 15 km/h sebességgel, majd gyorsítást végez el az emelkedő tetejéig (vizsgálat különböző gázálások mellet)	
	19			Áram szabályozás emelkedőn való elindulást követően (meredek emelkedő)	handling	A jármű a kijelölt emelkedő első szakaszán megáll, majd állóhelyzetből elindul (vizsgálat különböző gázálások mellet)	
	20			Áram szabályozás emelkedőn való gyorsítás közben (meredek emelkedő)	handling	A jármű a kijelölt emelkedőt megközelíti 15 km/h sebességgel, majd gyorsítást végez el az emelkedő tetejéig (vizsgálat különböző gázálások mellet) (Bálint: Lehetőleg 20% alatti akkumulátor szinten (is) tesztelve)	
	21			Hill-hold	handling	A járművet meredek emelkedőn csupán a motor nyomatékával megtartani többször ~20 másodpercig, legalább 1 perc szünetet két mérés közé iktatva	
	22			Generátor mód (amennyiben rendelkezésre áll)	handling	Legalább 99%-ra töltött akkumulátorral meredek emelkedőn generátoros fék üzem	
	23			Akadály a kerék elé	DP	Maximális gázpedál pozíció, ahol még nem kezd el forogni a kerék, legalább 10 másodpercig tartva	

Data Collection and Analysis

- Review techniques for gathering and analyzing data from vehicle tests.
- Demonstration how to use data from ramp steer test to refine vehicle dynamics.
  - Impact of real-world data on simulation models and subsequent design modifications.

Data Collection and Analysis

- Review techniques for gathering and analyzing data from vehicle tests.
- Data Gathering:
  - Sensors: GPS, accelerometers, wheel speed, pressure sensors
  - OBD Systems: Engine, transmission, and diagnostics data
  - Telematics: Remote data collection during testing
- Data Analysis:
  - Pre-processing: Noise reduction, smoothing, interpolation
  - Statistical Analysis: Regression, correlation
  - Vehicle Models: Simulate dynamics, estimate forces (e.g., two-track model)
  - Visualization: Graphs and charts (e.g., Slip angle vs Lateral force)
- Summary
  - Data Collection: Real-time, accurate vehicle performance data
  - Analysis: Statistical methods & simulations for deeper insights
  - Visualization: Clear insights into vehicle behavior

Data Collection and Analysis

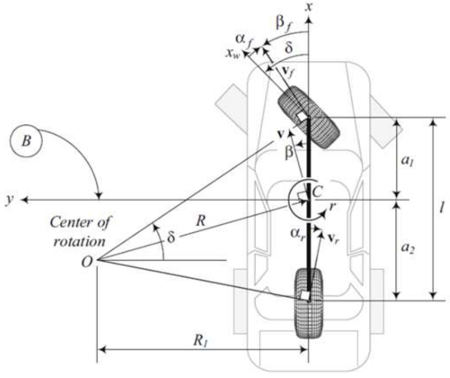
3. Tire characteristics identification

Transition test (ramp steer test) (ISO 13674-2)

This test method originally targets the quantification of vehicle on-centre handling. However, in this case the main goal of the test is the identification of the tire cornering stiffnesses and friction coefficients. For this purpose, varied road conditions (wet, dry) and different speeds are targeted.

1.1 Test procedure

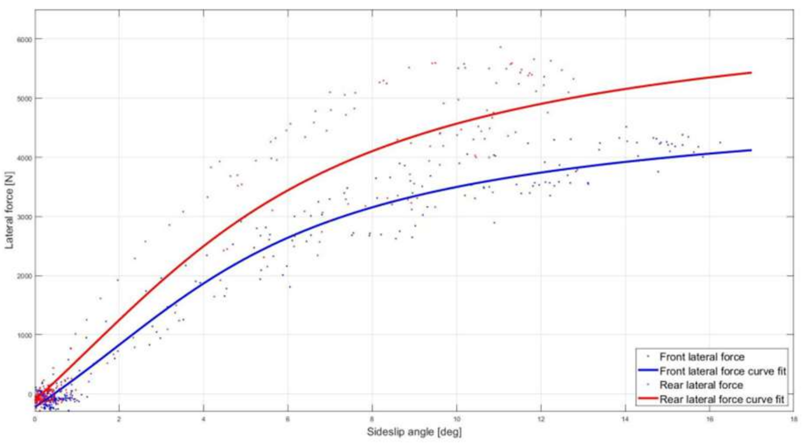
The transition test is an open-loop procedure and is conducted from an initial straight-line path. The vehicle is driven at a nominally constant longitudinal velocity. The standard test velocity is 100 km/h. Other longitudinal velocities may be used; these should be decremented or incremented by 20 km/h from the standard velocity.
The steering-wheel shall be subjected to a ramp input (that is one that increases in amplitude with a nominally constant angular velocity).
The steering input shall be applied for a minimum duration of 3 seconds, and at an angular velocity not exceeding 5 degrees/second, until the lateral acceleration achieved by the vehicle reaches a minimum of 1,5 m/s2.



Source of signals in the below evaluation (in order of appearance):

Nr.	Signal name	Source
1.	Vehicle position	KJIT dGPS via CAN
2.	Steering wheel angle	Steering angle sensor via CAN
3.	Steering wheel speed	Steering angle sensor via CAN
4.	Vehicle speed	KJIT dGPS wheel speed sensor via CAN
5.	Roadwheel angle	Calculated from steering angle sensor using measurement data
6.	Tire sideslip angle	calculated from KJIT dGPS signals and steering angle
7.	Tire forces	calculated from KJIT dGPS signals and steering angle

<u>Lateral force in the function of tire sideslip angle</u>



The identified cornering stiffness:
front wheel: 13125 [N/rad] / tire
rear wheel: 19130 [N/rad] / tire

Case Study – ZalaZONE Test Track Elements

- Overview of ZalaZONE and its unique test environments:
  - Dynamic platform: uses and data insights.
  - High-speed oval: benefits for testing top speed and endurance.
  - Various road surfaces for simulating diverse driving conditions.
  - Autonomous testing zone for ADAS and self-driving features.
- ZalaZONE's facilities with specific test cases relevant to prototype development.

Case Study – ZalaZONE Test Track Elements

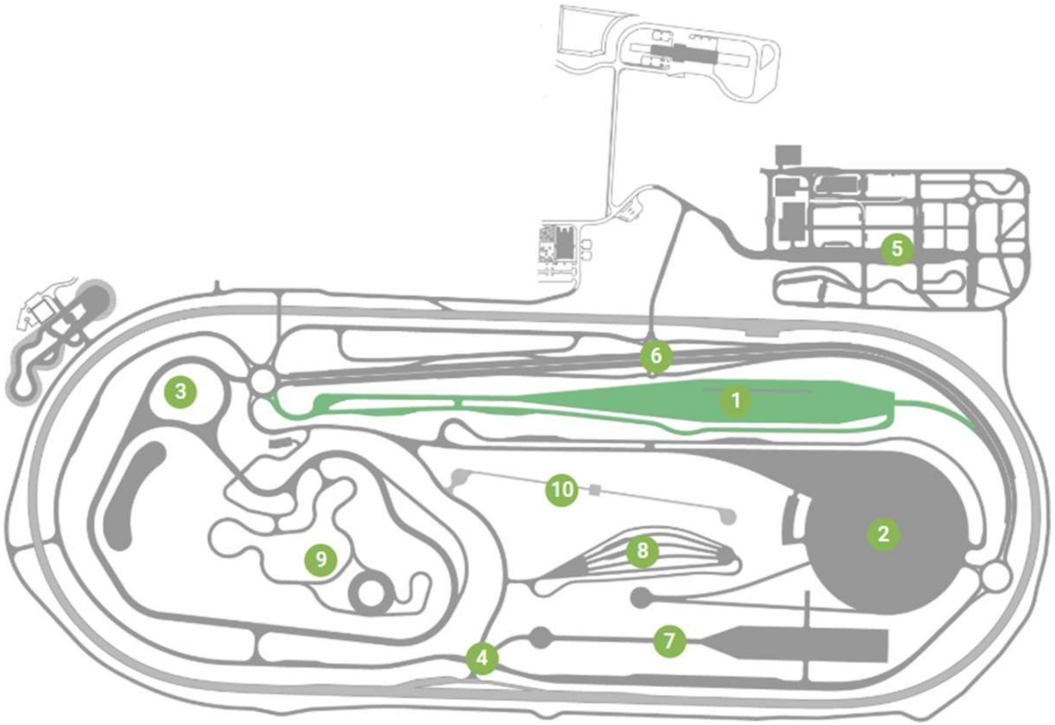
1

BRAKE MEASUREMENT SURFACES

Description

The braking surfaces are separated into **8 different lanes**: a **chess board** surface, **high friction**, **low friction**, **blue basalt**, **asphalt (mue=1)**, **polished concrete**, **asphalt (mue=0,8)**, and **an aquaplaning basin**.

READ MORE



Case Study – ZalaZONE Test Track Elements

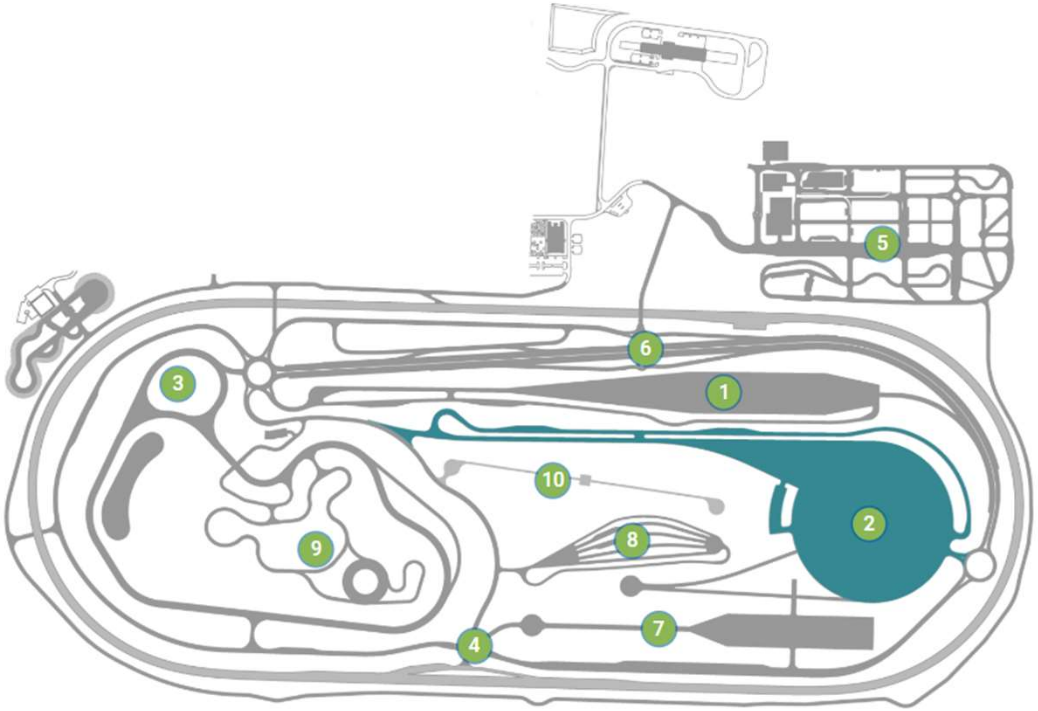
2

DYNAMICS PLATFORM

Description

The dynamic platform has a **300 m** diameter asphalt surface, an acceleration lane **760 m** long with a 0% inclination, and a **20 m** wide run-off-area surrounding the asphalt circle.

READ MORE



Case Study – ZalaZONE Test Track Elements

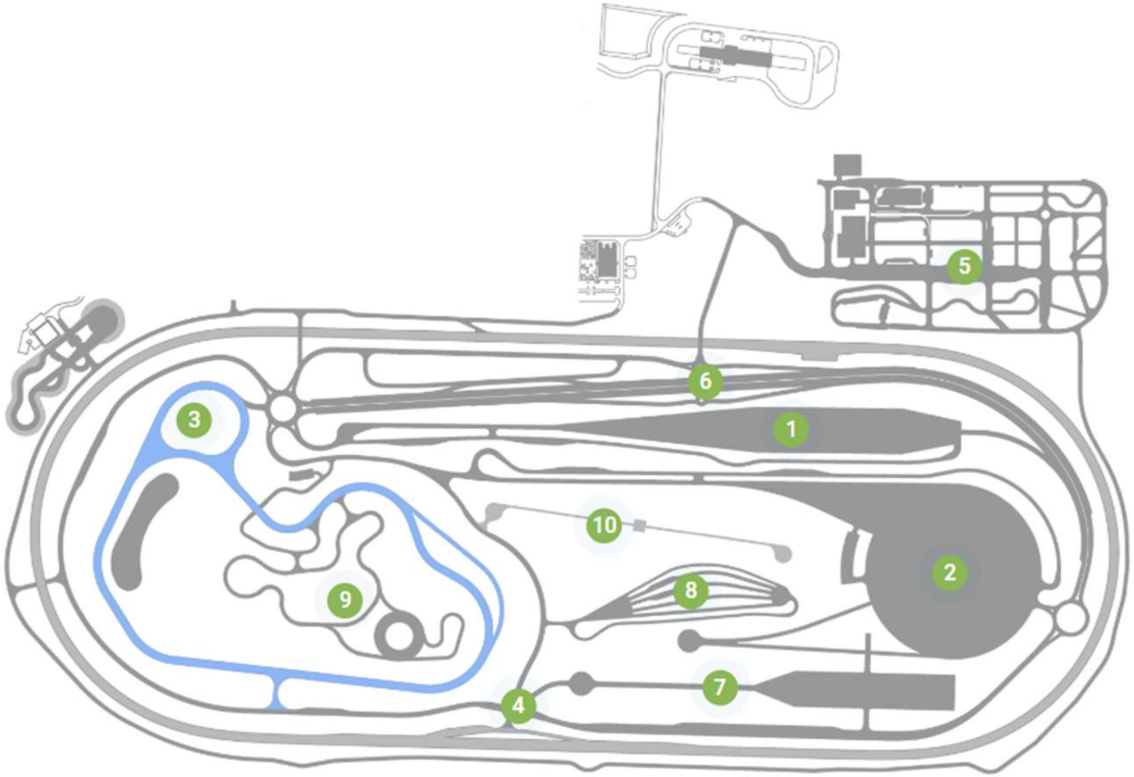
3

HANDLING COURSE

Description

The high-speed handling course is showing the following physical characteristics: a length of **2000 m**, a width of **12 m**, a soft gravel / asphalt run-off-area, and a **80 cm basalt** base/foundation allowing for vehicles up to 40t to be tested.

READ MORE



Case Study – ZalaZONE Test Track Elements

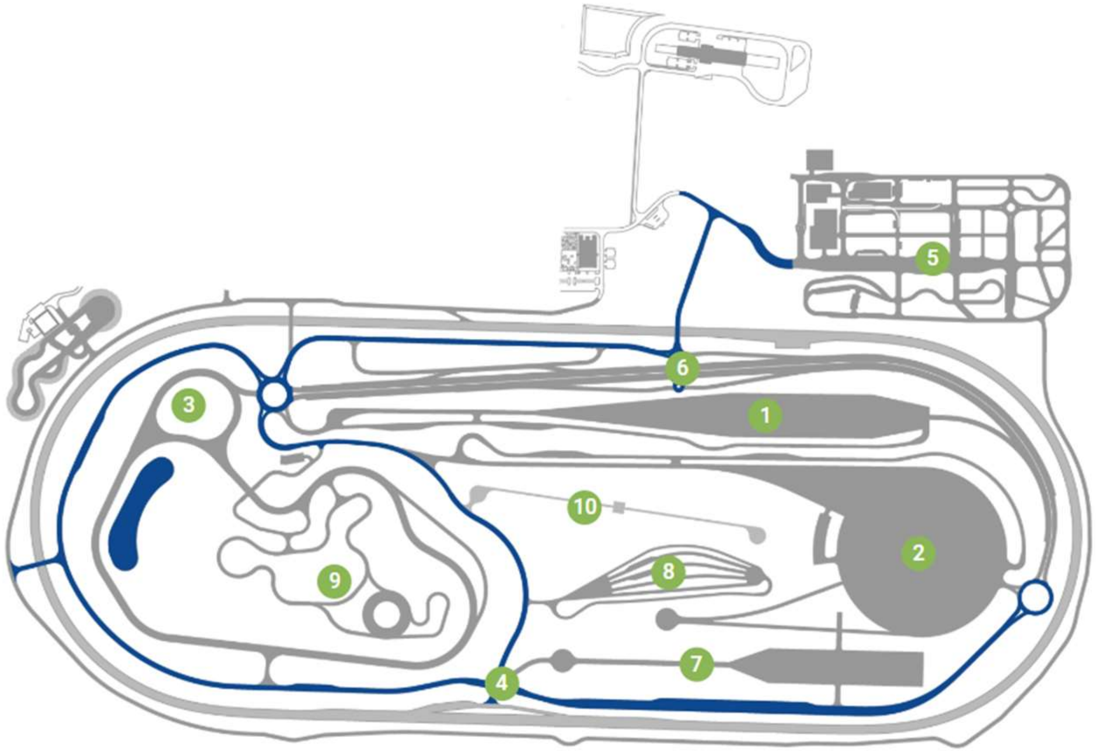
4

RURAL ROADS

Description

The rural road system is covering an internal road network with a total length of **2500 m**, including a **2x2 lane section** of 500 m and **130 m long 10% banked** road section.

READ MORE



Case Study – ZalaZONE Test Track Elements

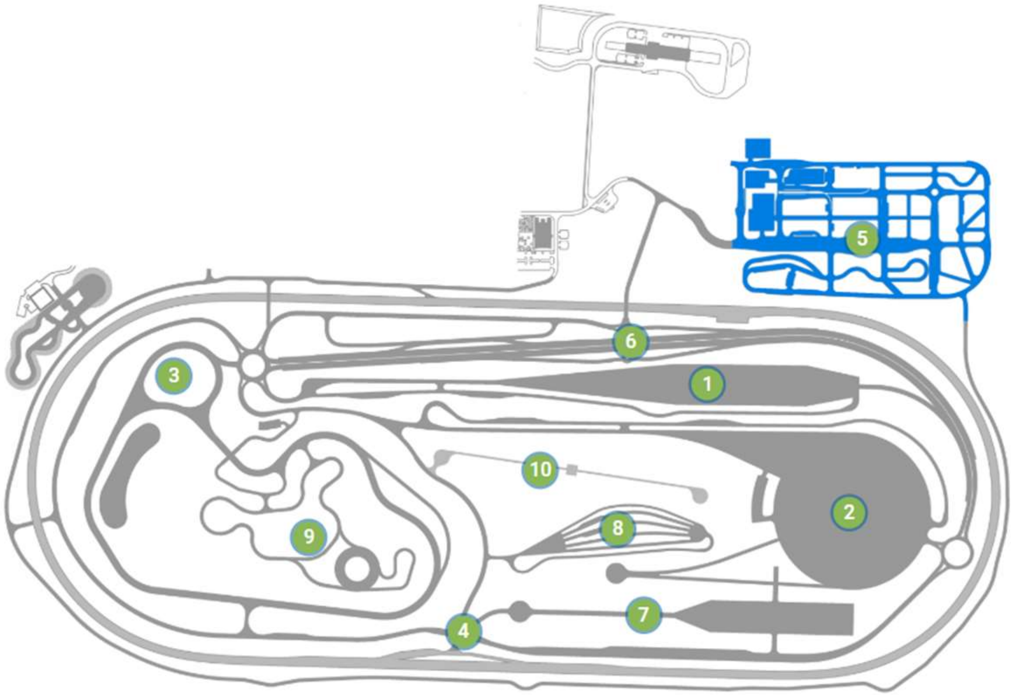
5

SMART CITY

Description

The smart city is a **state-of-the-art** module at AVL ZalaZONE Proving Ground and an European ADAS/AD test infrastructure **benchmark** providing 5 sub-modules or different urban testing environments.

READ MORE



Case Study – ZalaZONE Test Track Elements

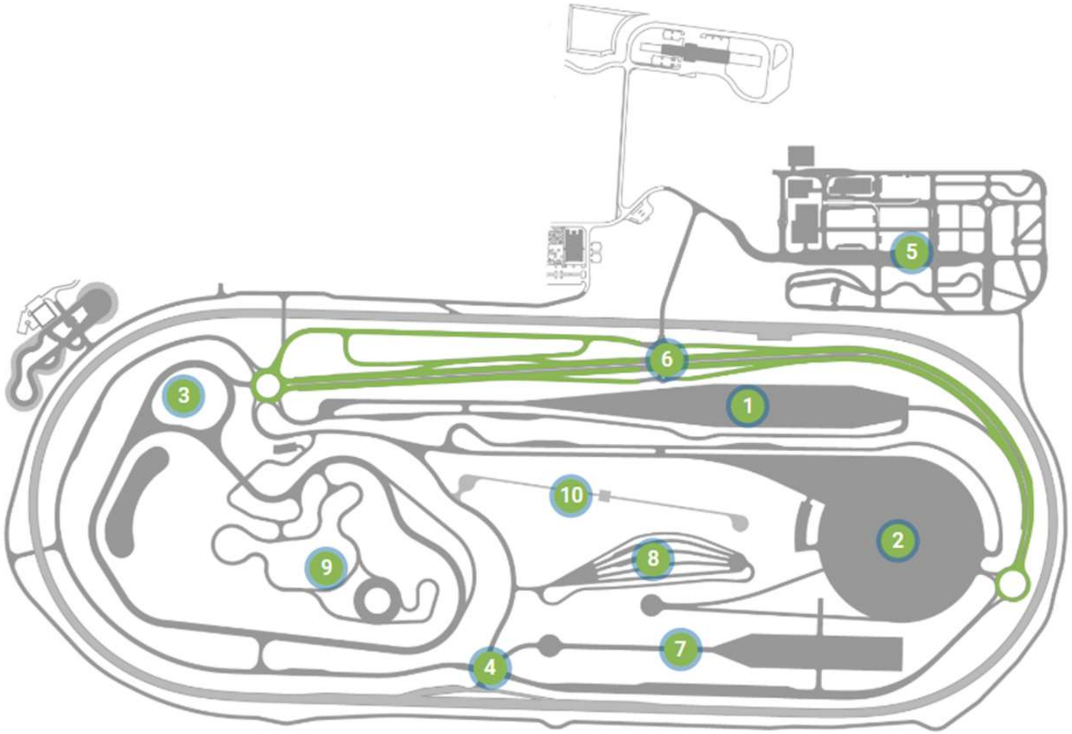
6

MOTORWAY

Description

The purpose of the Motorway is to provide a **realistic environment**, which is particularly important for **testing** and **validating** the **ADAS system**.

READ MORE



Case Study – ZalaZONE Test Track Elements

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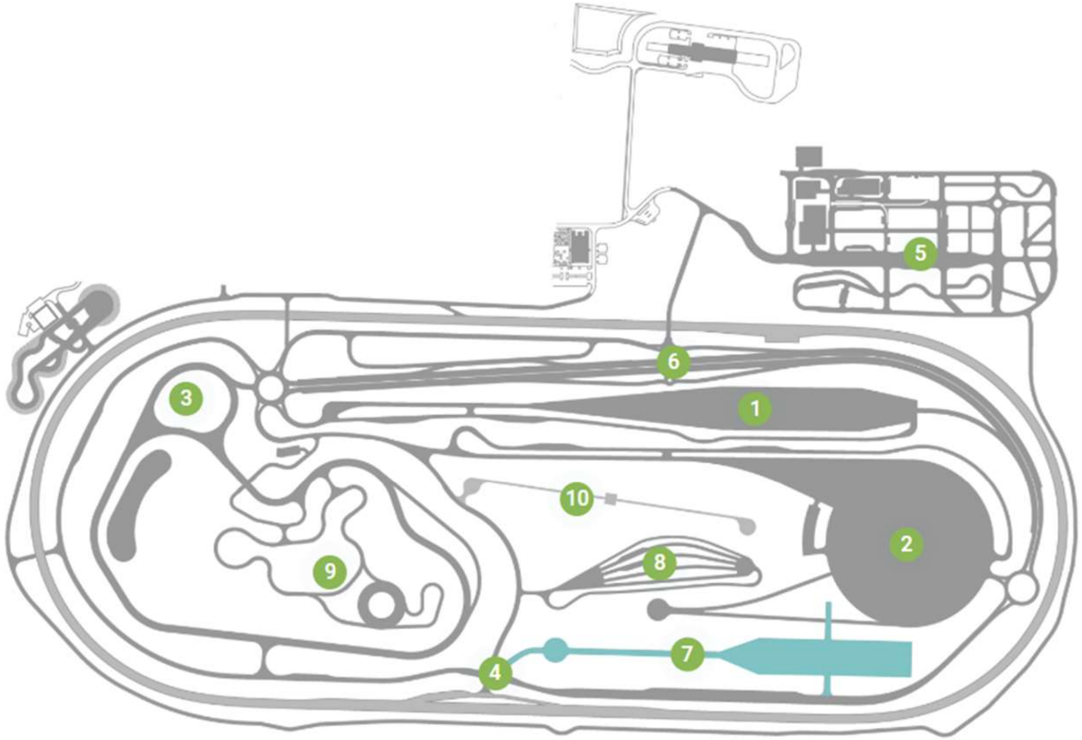
7

ADAS SURFACE

Description

All **AD** and **ADAS** related systems can be tested in compliance with **all existing standards and requirements** according to the most diverse **NCAP** scenarios. For all that we provide a completely equipped car and truck workshops indispensable during daily use, with a **complete** engineering and service background (**EuroNCAP** targets & carriers, actuators, localization and high-level control units).

READ MORE



Case Study – ZalaZONE Test Track Elements

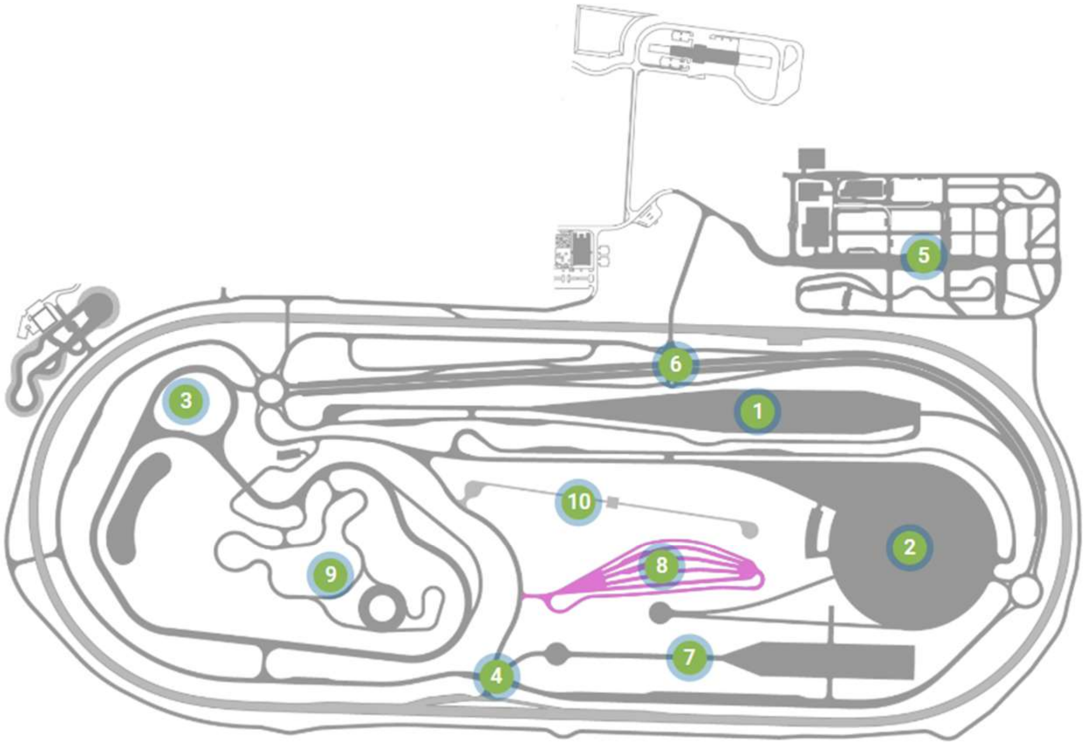
8

HILL TRACKS

Description

Conventional element for testing **traction control systems** like hill start assist function, hill holder systems, etc. The module can also be used for **robustness** and **reliability** tests of ADAS functions, like AEB system.

READ MORE



Case Study – ZalaZONE Test Track Elements

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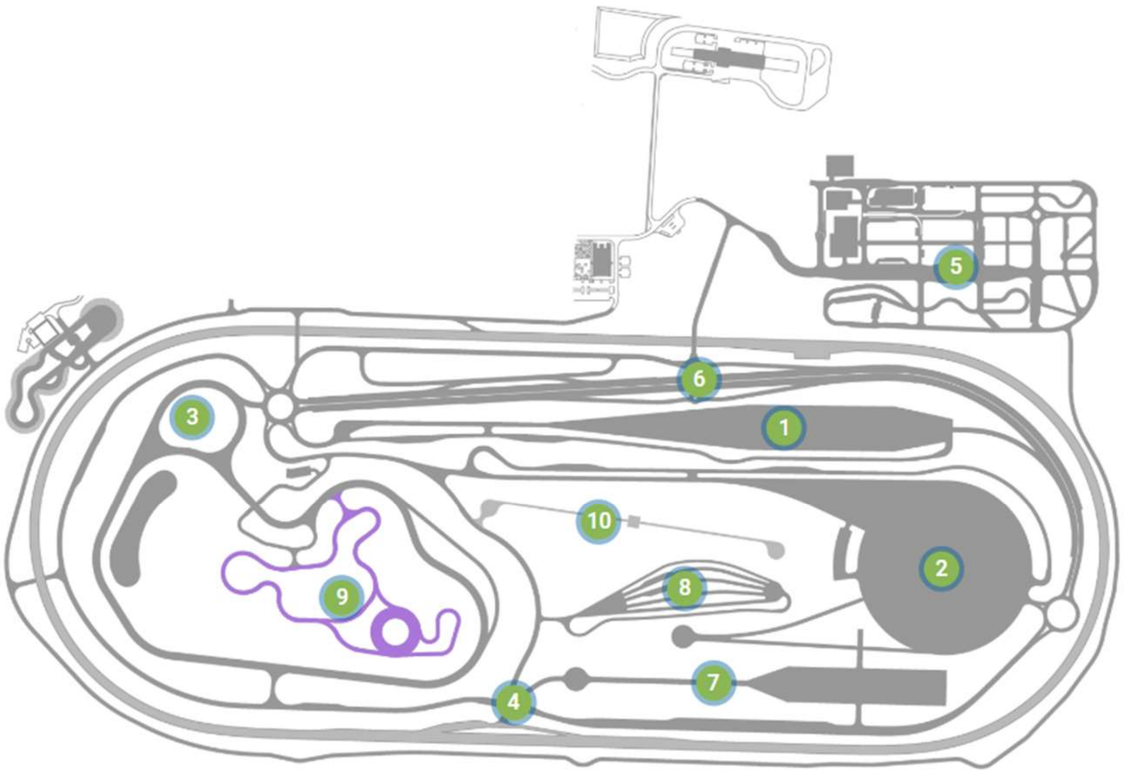
9

WET HANDLING COURSE

Description

The low-speed or wet handling course is primarily used for **testing tyres** and **electronic stability control systems**, but can also be used for driving technique trainings.

READ MORE



Case Study – ZalaZONE Test Track Elements

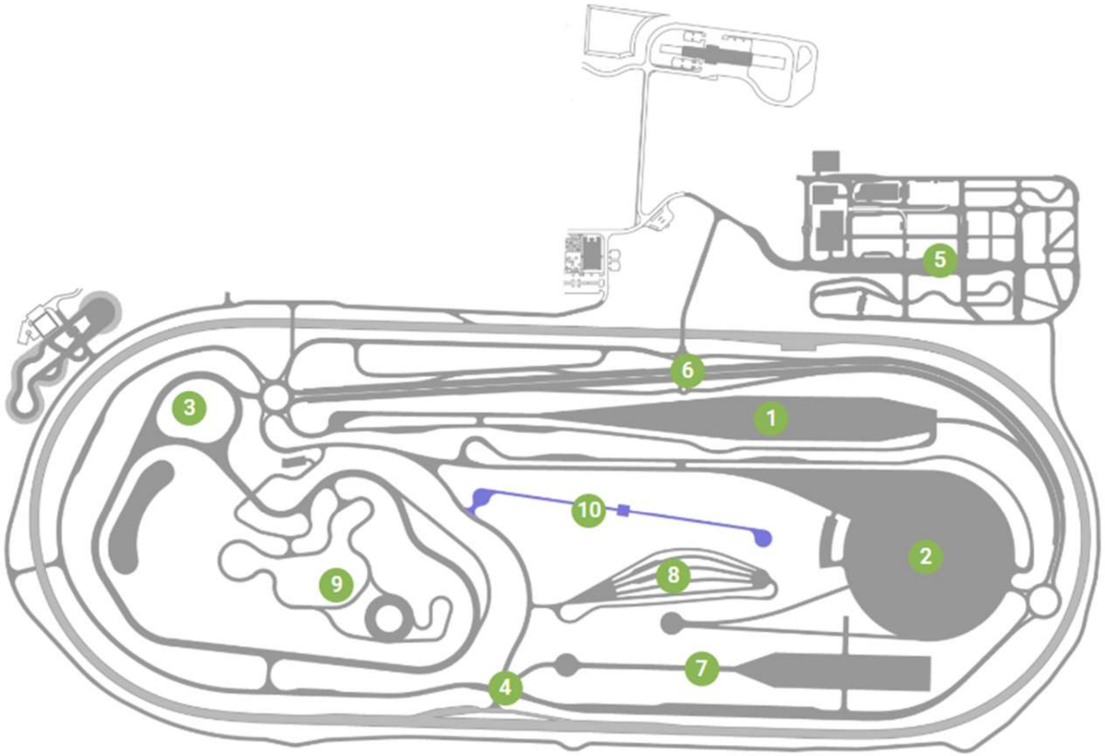
10

PASS-BY NOISE TRACK

Description

The ISO-certified Pass-By Noise Track module and the Class 1 measurement equipment fulfill all the requirements for **pass-by noise type approval, homologation**, and **COP measurements** for any vehicle, including heavy-duty commercials.

READ MORE



Practical Demonstration

- Showcase recorded data from prototype's previous test runs.
- Acceleration curves, lateral force graphs, etc.
- Identify potential design changes based on the data!

Q & A

- Main objective?
- Starting point-ending point?
- Complex parts?
- Less relevant part(s), could be omitted part(s)?
- Most useful part(s)?

Closing

- Bibliography
  - See bottom of slides
  - Tervezéselmélet és módszertan (BMEGEGE MGTM) Előadások Dr. Horák Péter BME GT3 Tanszék 2010
- Literature
  - W. Ernst Eder: Engineering Design: Role of Theory, Models, and Methods
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  - Markus Maurer, Hermann Winner - Automotive Systems Engineering
  - Christian Grönroos - The V-Model of Service Quality: An Application in Automotive Services
  - Gerhard Pahl, Wolfgang Beitz - Engineering Design: A Systematic Approach
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  - Dominic Haider - Automotive Functional Safety: A Complete Guide to ISO 26262
  - Bercsey Tibor - A terméktervezés módszertana.Jegyzet
  - Pahl-Beitz - A géptervezés elmélete és gyakorlata


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Thank you for your attention!