WEBINAR

AI-Powered Vehicle Concept Development

Mario Oswald

Today’s Presenter

View my LinkedIn® Profile

Mario Oswald

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Complete Vehicle Functions & Systems
AVL List GmbH, Graz/Austria

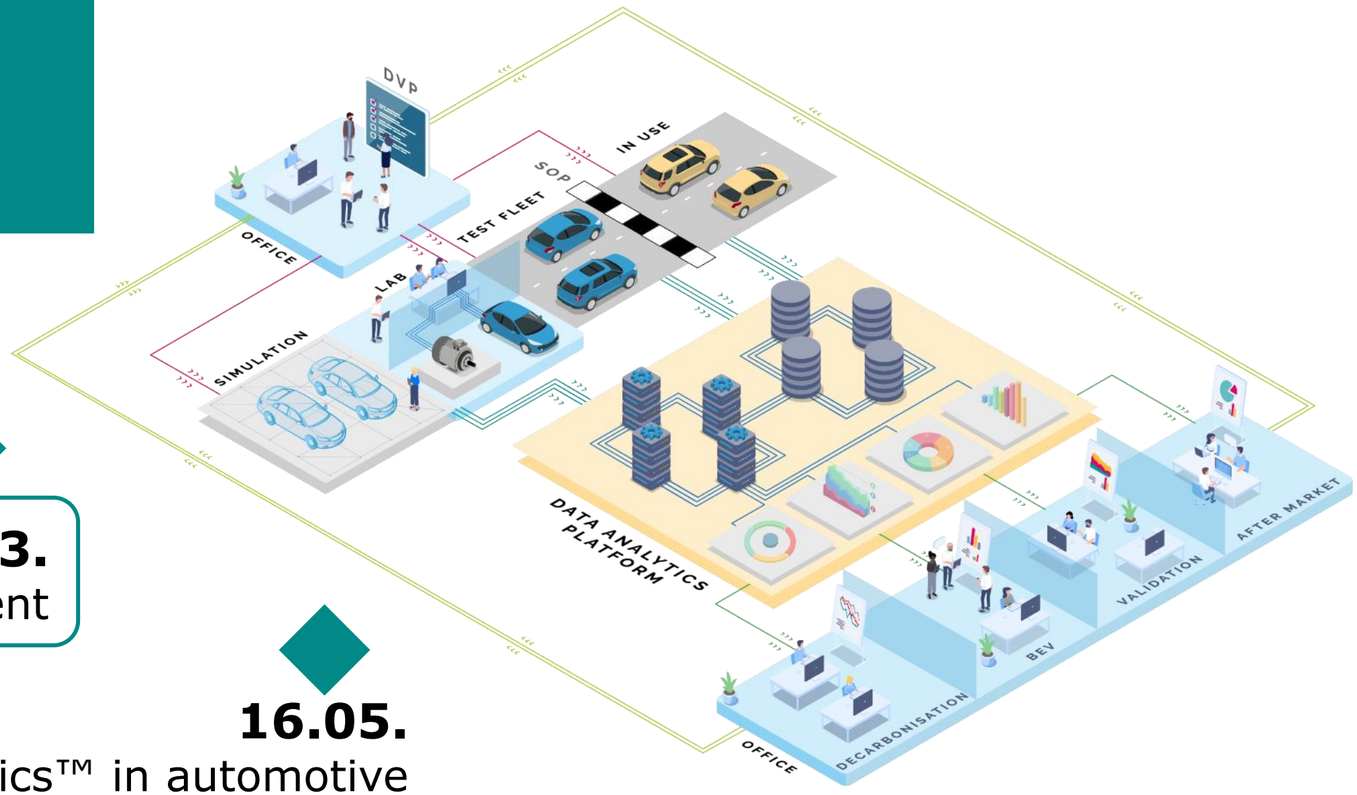
- AI @ Virtual Vehicle Development
- System Simulation
- Vehicle Development
- Simulation Software Development

15 years in automotive industry

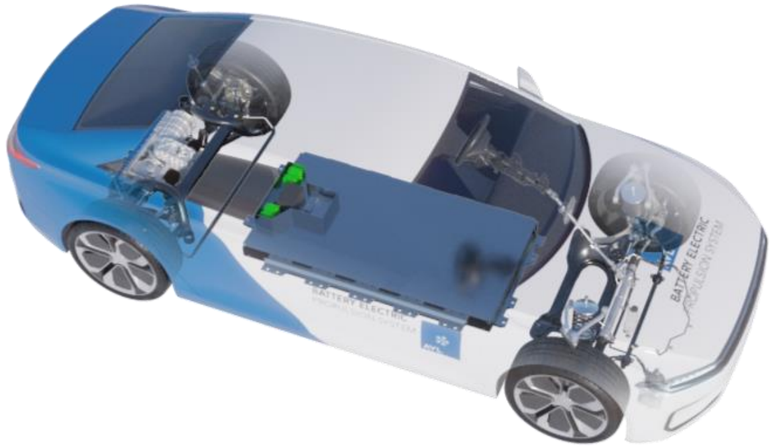
AVL Webinar Series
AI-powered product development

05.03.
Concept to after sales

07.03.
Concept Development



16.05.
AVL Data Analytics™ in automotive development process



11.06.
Extending lifetime and reducing warranty costs

24.09.
Scalable framework for efficient development and execution of data analytics

Today’s Agenda

1 **Motivation**

OEM | Tier1 | Supplier

2 **AI-powered Solution**

Predictive Models | Vehicle Composer™ | Demo Movies

3 **Customer Reference**

Hyundai

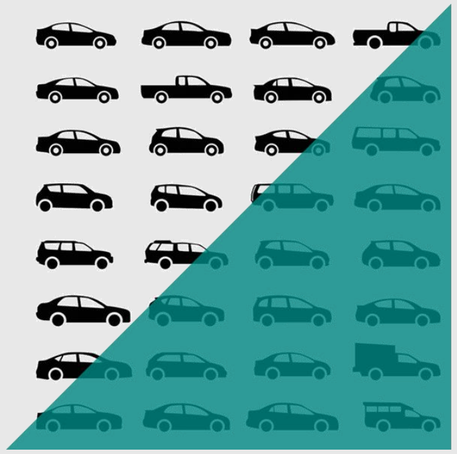
4 **Q & A**

Motivation

Challenge

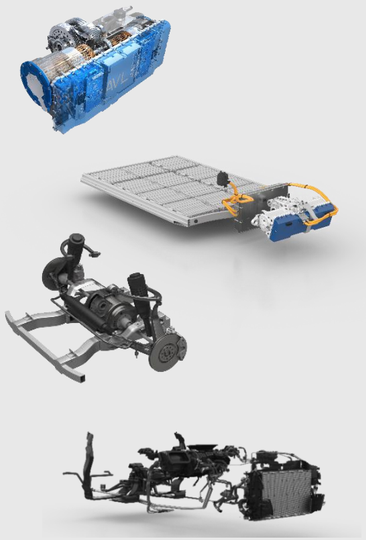
OEM

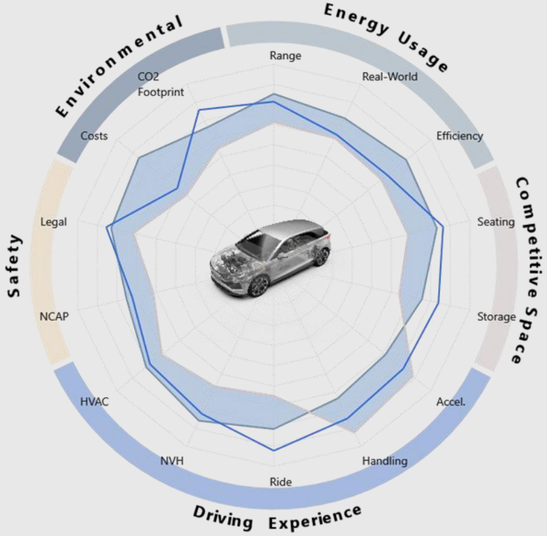
Reduce
Prototype Vehicle



Tier1 | Supplier

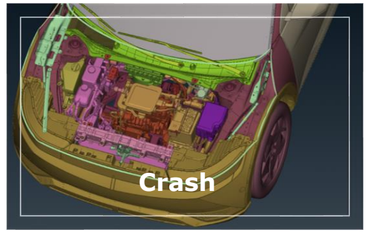
Evaluate **component specification** on vehicle-level targets

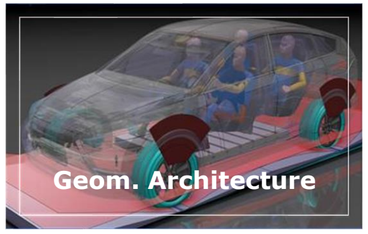


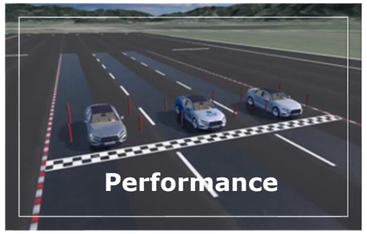


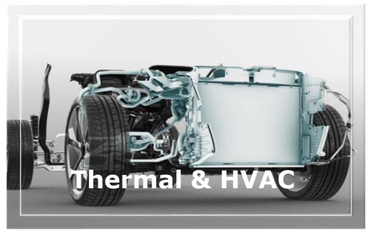
Derive **component specification** based on vehicle-level targets

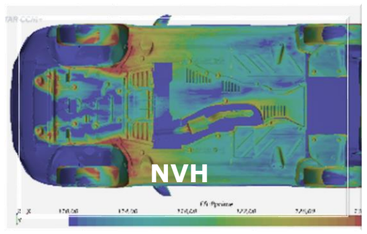
Digital Vehicle Prototype – The Solution ???

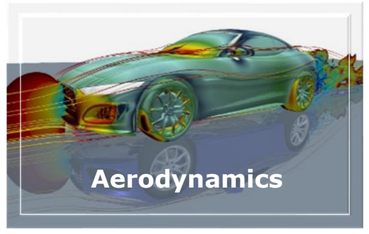


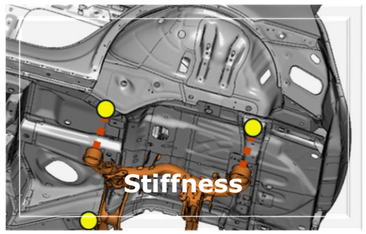












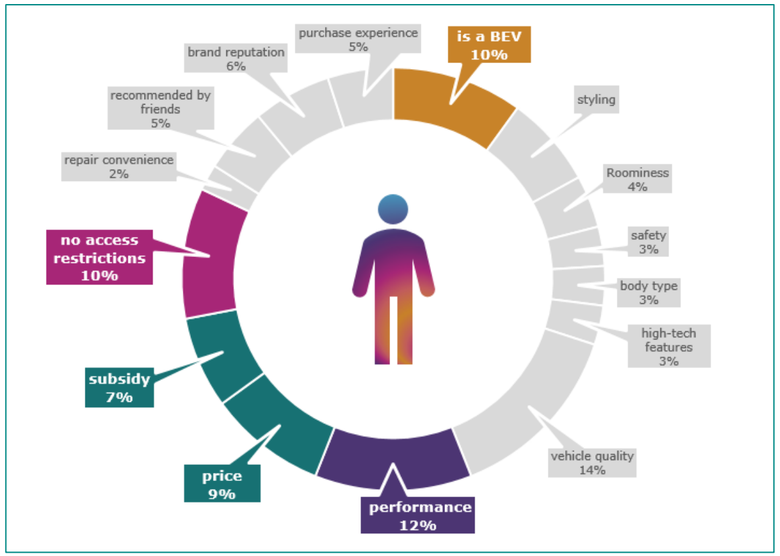
… and many more

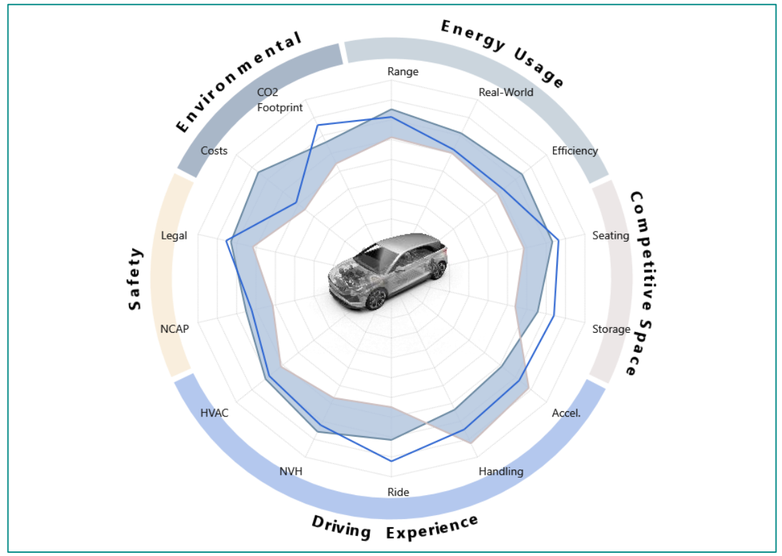
YES, but…

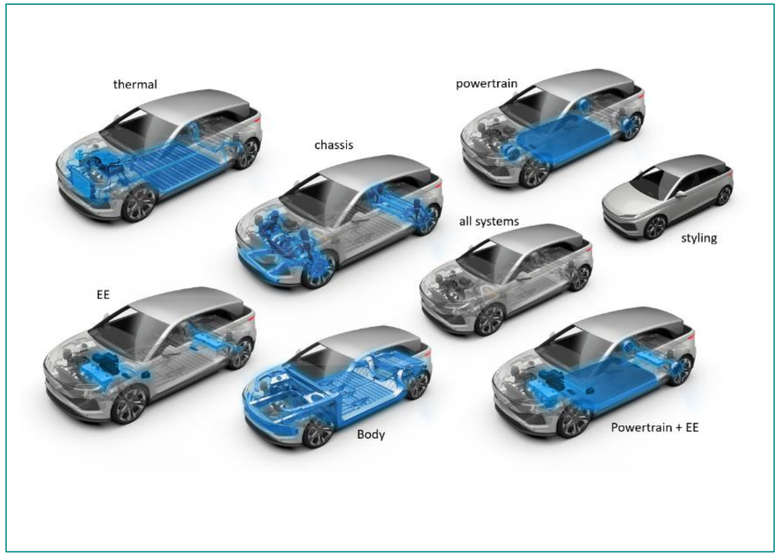
- Hardly available in early phases
- (Mostly) execution time too slow
- **Local optima** (not interconnected)

As Fast as Possible from **Customer Expectation** to **Targets & Architecture**

Customer Expectation	Vehicle Targets | Brand D.N.A.	Architecture & Technology



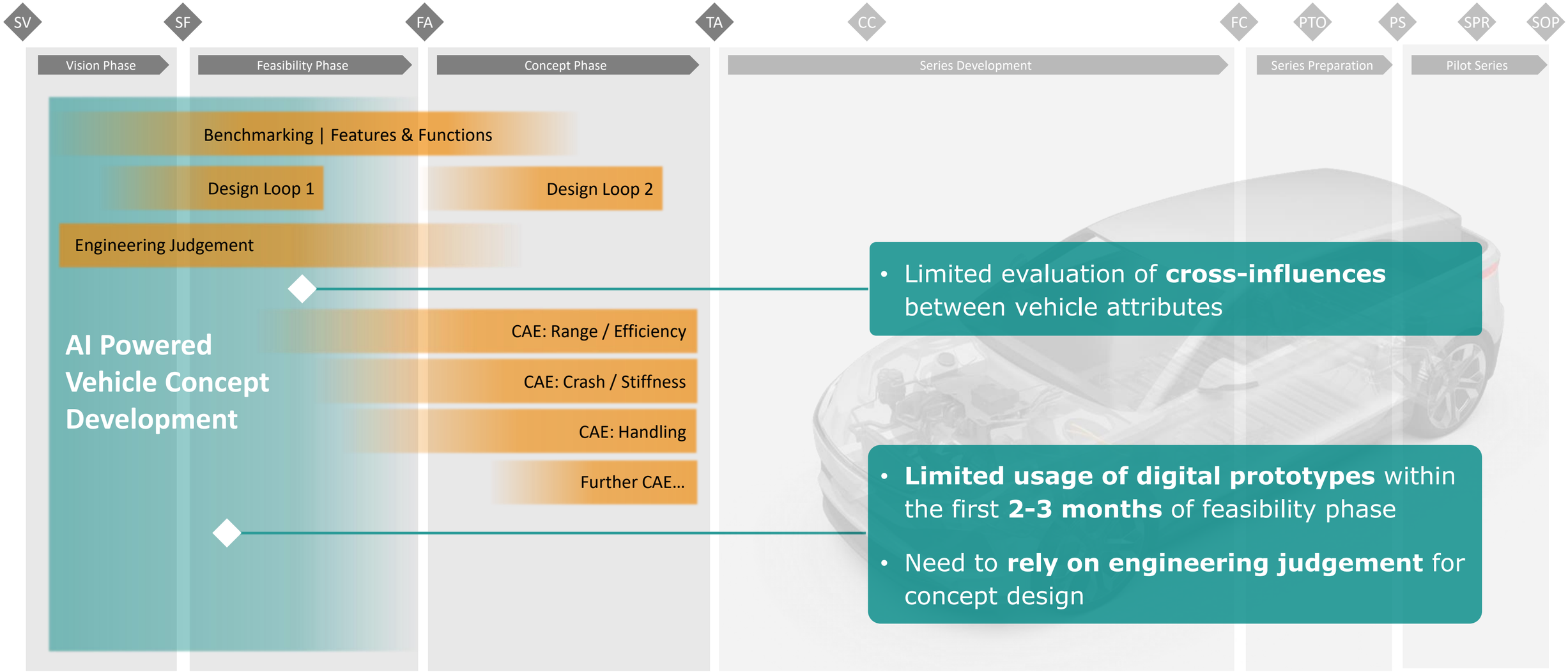




Typically **6-9 months** from Start of Feasibility to Target Agreement / Concept Agreement

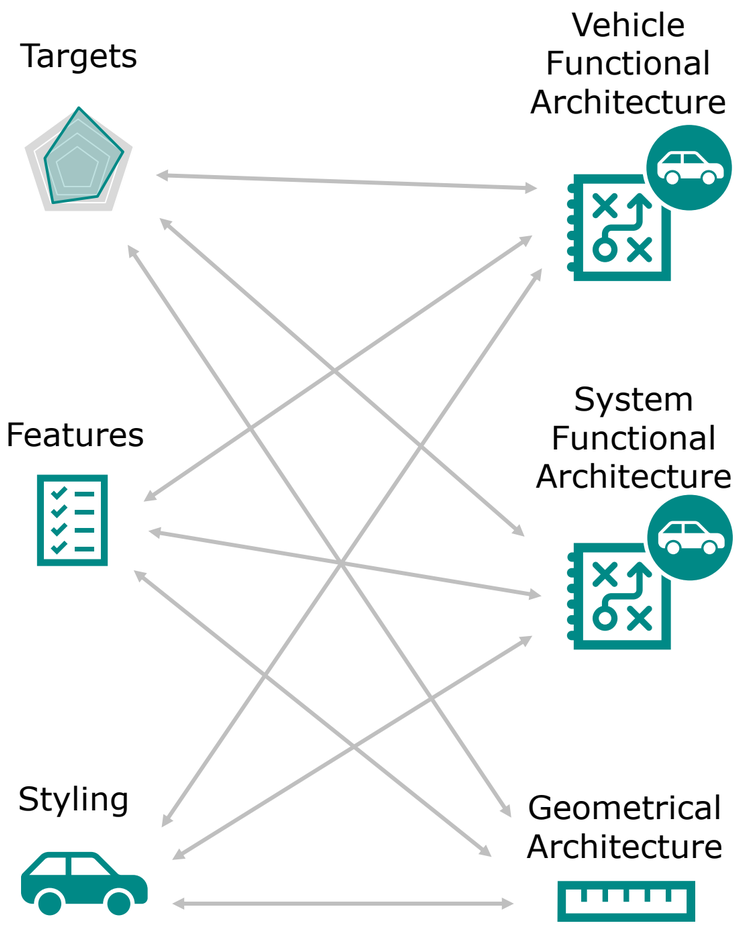
How to shorten it? How to manage complexity?

Challenge
Late Usage of Digital Prototypes to Define Vehicle Architecture

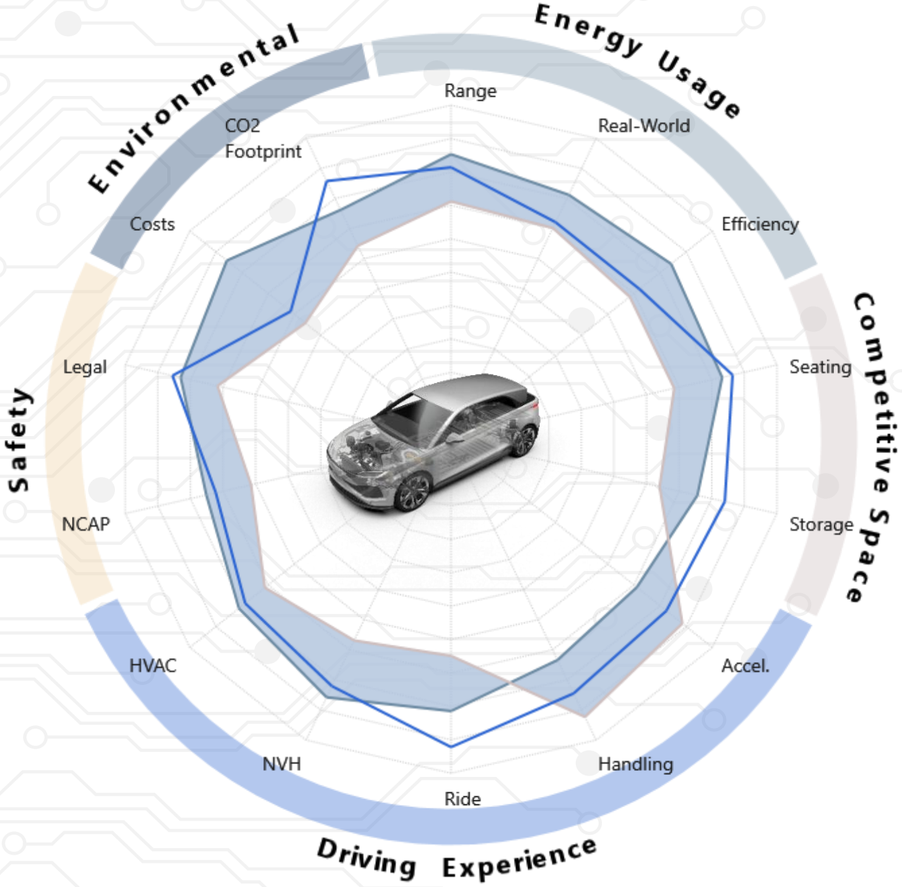


Solution

AI Powered Attribute Engineering

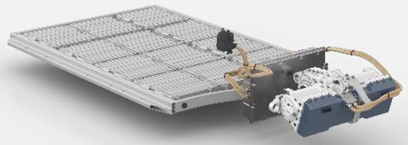


AI Powered Attribute Engineering

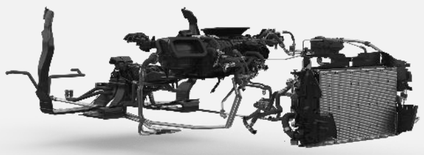


Technical Specification

Powertrain



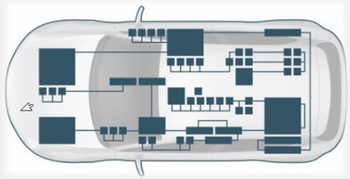
Thermal & HVAC



Chassis

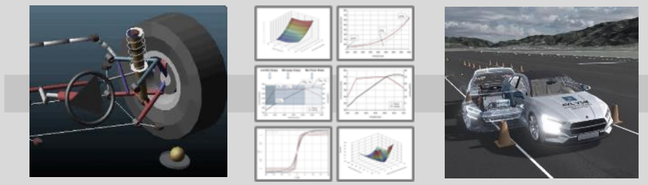
Body

E/E & ADAS/AD

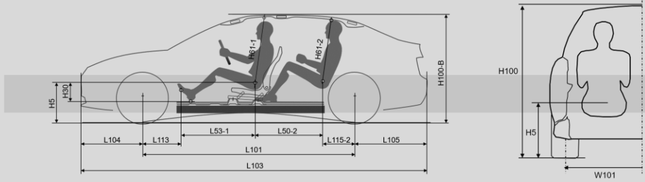


Generation of Predictive Models

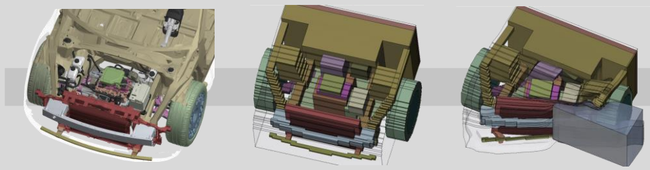
Energy Management
Thermal
Charging



Vehicle Dynamics
Performance
Driveability
Braking

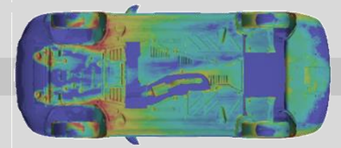


Geometric
Architecture
Dimensions



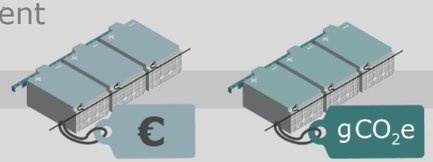
Crash
Durability

In development



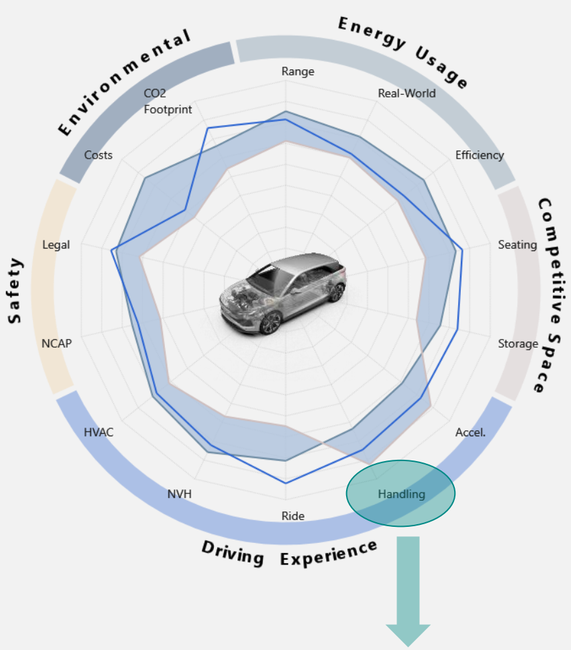
Ride Comfort
NVH

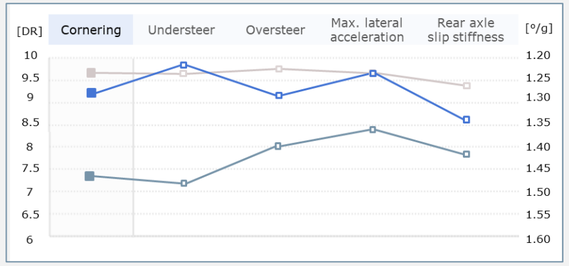
In development



Costs
CO_2 Footprint

Attribute Optimization





Generation of Predictive Models
Example: **Handling**

Key Parameters (Significance > 1%)

Body
- Weight
- Weight distribution
- Center of gravity
- Vehicle inertia
- Vehicle geometry

Tyre
- Dimension
- Type

Aerodynamics
- Downforce (front/rear)

Chassis
- Suspension
  - Spring & Damper
  - Anti-Roll bar
  - K & C
- Steering system
  - Ratio
- Controls
  - Torque vectoring
  - Rear wheel steering

Powertrain
- Layout

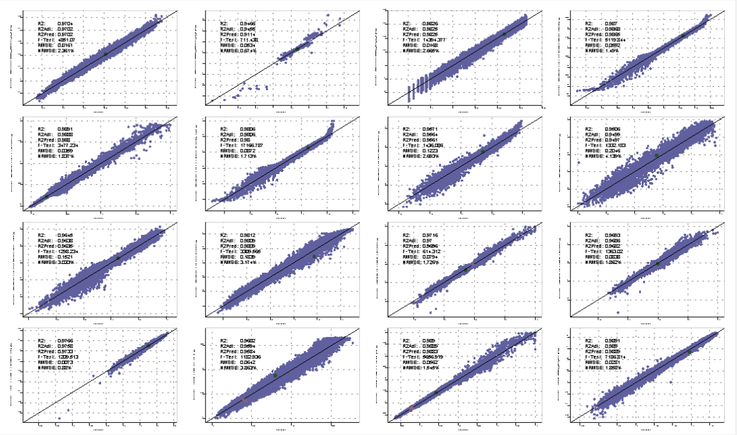
Maneuver | Driving Modi

Cornering
- Slowly increasing steering
- Constant radius cornering

Cornering transient
- Accelerated cornering
- Brake in turn

Agility
- Turn in
- Slalom
- Double lane change

Predictive Model (RNN Neural Network)



KPI | Attributes (> 25 single KPI's)

Physical
(ISO)
- Maximum Ay [g]
- Roll angle gradient [°/g]
- Rear axle slip stiff. [°/g]
- …

Objective
(AVL-DRIVE™)
- Cornering [DR]
- Cornering Transient [DR]
- Agility [DR]
- …

> 25 parameters
7 maneuvers

> 300.000 single simulations

ø Model Accuracy: **98%**
Execution Time **< 0.01s**

Generation of Predictive Models

Example: Energy Management & Charging

Key Parameters (Significance > 1%)

General
- Vehicle Weight

Tyre
- Dimensions
- Rolling Resistance

E/E
- AC Charging Power
- DC Charging Power
- OBC Efficiency

Controls
- AWD Torque Split
- Recup. Percentage

Powertrain
- AWD/RWD/FWD
- HV Battery Energy
- EM Torque & Power
- EM & Inv. Losses
- Gear Ratio
- Gear Losses
- LV Auxiliary Cons.
- HV Auxiliary Cons.

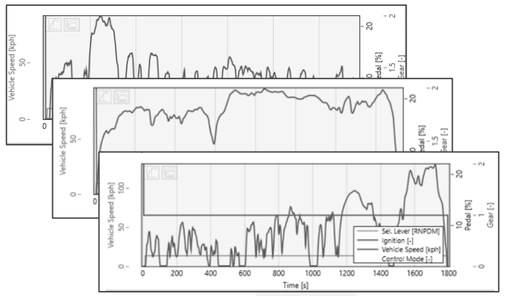
Body
- Weight
- Frontal Area
- Drag Coefficient

Test Procedures

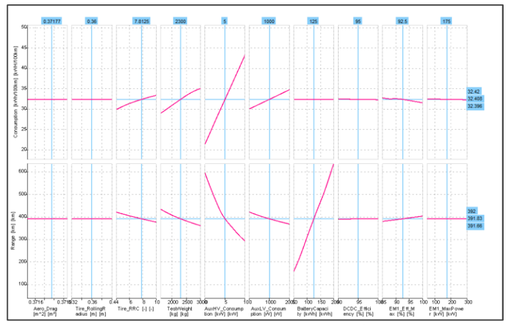
Legislative Procedures
- WLTP
- EPA 2-Cycle

Charging Experience
- AC Charging 0-100%
- DC Charging 10-80%

Use Case Definition



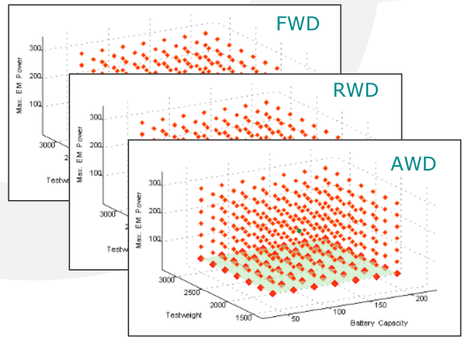
Sensitivity Analysis



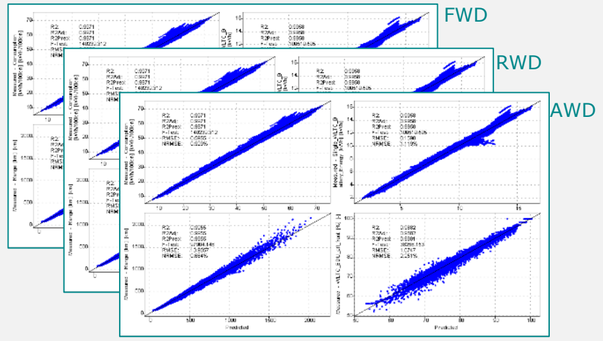
Dynamic Simulation Model Validation

WLTP	Meas.	Sim.
Range *(km)*	458	457.8
	Ref.	**99.8%**
Consumpt. *(kWh/100km)*	15.7	15.74
	Ref.	**99.7%**
DC Charge *(min)*	18.2	18.1
	Ref.	**99.4%**

DoE Plan Generation



Predictive Model *(e.g. RNN)*



KPI | Attributes

Physical
(ISO)
- WLTP Energy Consumption (kWh/100km)
- WLTP Range (km)
- EPA 2-Cycle Energy Cons. (kWh/100mi)
- EPA 2-Cycle Range (miles)
- Indiv. Cycle Battery Energy Depletion (kWh)
- AC & DC Charging Duration (min, h)
- AC & DC Charging Efficiency (%)
- Average E-Machine Efficiency (%)
- Average HV Battery Efficiency (%)

> 25 parameters

4 Maneuvers

>80.000 cycle simulations in **cloud**

Legislation-specific **automated KPI calculation**

Model Accuracy >98%

Evaluation in **Real Time**

Generation of Predictive Models
Example: **Crash**

Key Parameters

General
- Weight
- Weight distribution
- Center of gravity
- Vehicle inertia

Body
- Vehicle geometry (Part dimensions)
- Part stiffness characteristics categories

→ **Vehicle Geometry Sets**
Selection of consistent part dimension sets

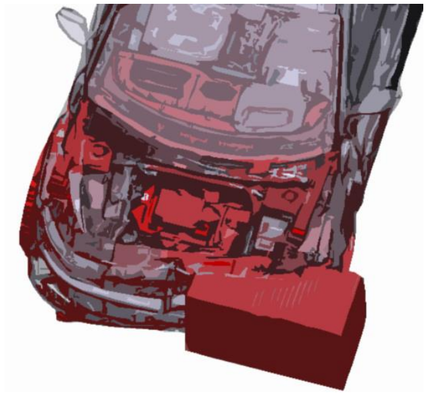
Package
- Component positions, size, weight
- Deformation characteristics categories

→ **Package Sets**
Selection of consistent sets of package-comp. configurations

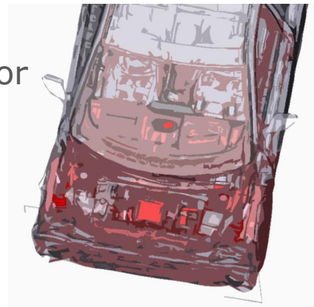
Load Cases
- **Full-width frontal crash**
- **Offset-deformable-barrier 40%**
- **Small-overlap-barrier 25%** (2024)
- **Pole side impact** (2024)

> 25 parameters
2+ load cases

FE-Model Variation & **Abstract Model Validation**

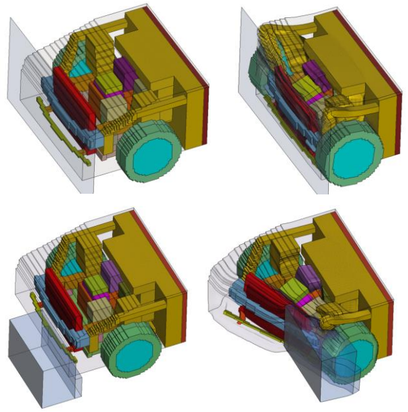


Validation for different levels of abstraction

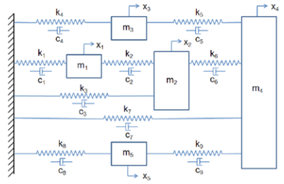


> 20 full-vehicle FE simulations for abstract model validation

DoE with **Abstract Models**



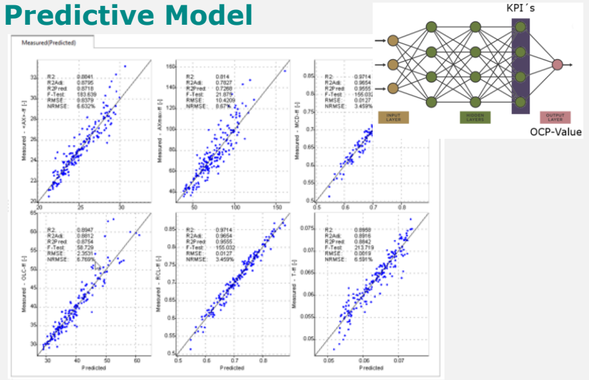
Abstract Model – Level 1
(Simulation time < 15 min)



Abstract Model – Level 2
(Simulation time < 1 min)

> 10.000
single simulations

Predictive Model



KPI | Attributes (> 15 single KPI's)

Full-width frontal
- Mean acc. [g]
- Mean intrusion [m]
- OLC [g]
- …

ODB-40%
- Mean acc. [g]
- Mean intrusion [m]
- OLC [g]
- …

Overall Crash Performance (OCP)-Value
- Combined criterium

Real-time crash performance evaluation

Generation of Predictive Models

Example: Vehicle Geometric Architecture

Key Vehicle Characteristics and Customer preferences

Vehicle segment
- City car
- Compact
- Medium Size
- …

Body type
- Sedan
- CUV
- SUV
- …

Roominess, usability
- Seating posture
- Head, knee and shoulder room
- Ingress/egress
- Trunk volume
- …

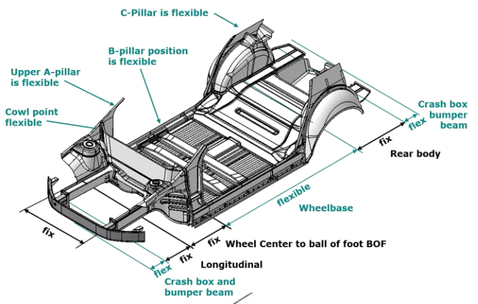
(Platform) Design parameters
- Chassis and powertrain
  (tire size, powertrain, pedal box and steering layout)
- Body structure (e.g., roof structure stack-up)
- Underfloor package (e.g., HV battery stack-up)

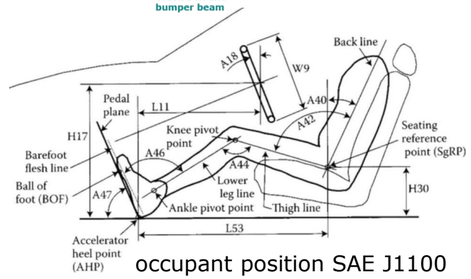
Legal (homologation) and industry standards
- Min. visibility and view angles
- Max. vehicle width
- Min. ground clearance

> 20 vehicle descriptive parameters

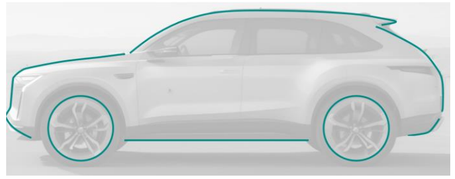
(reflecting the voice of the customer)

Geometric Composition





occupant position SAE J1100



technical package boundaries

front occupant

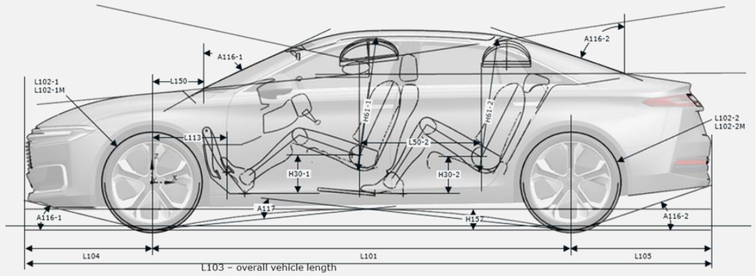
rear occupants

storage space

appearance, proportions

Combining and comparing the vehicle characteristics/customer preferences

Vehicle Layout



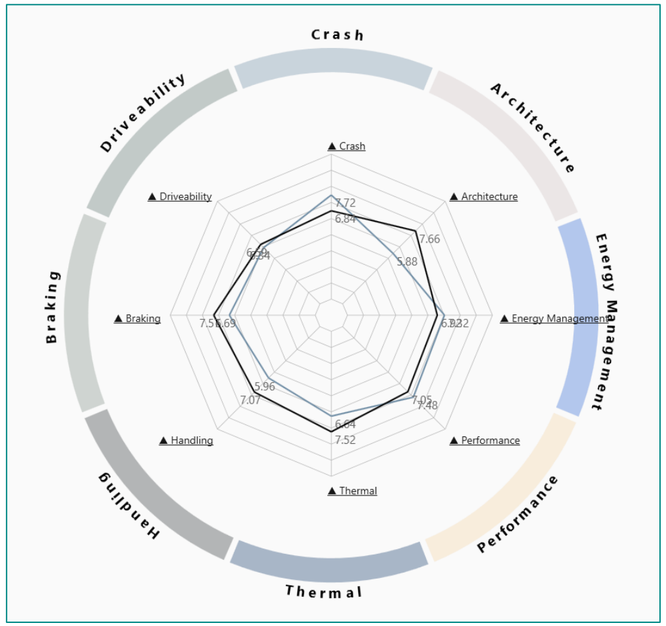
KPI | Benchmark

Harmonically composed Vehicle Architecture
- Interior dimensions
  - occupant position
  - occupant posture
  - space and roominess
- Exterior dimensions
  - overall vehicle dimensions (length/width/height)
  - proportions/proportional rations
  - ground clearance, approach/ramp/departure angle
- …

> 60 parameters related to the occupant package.
Derived vehicle layout plan

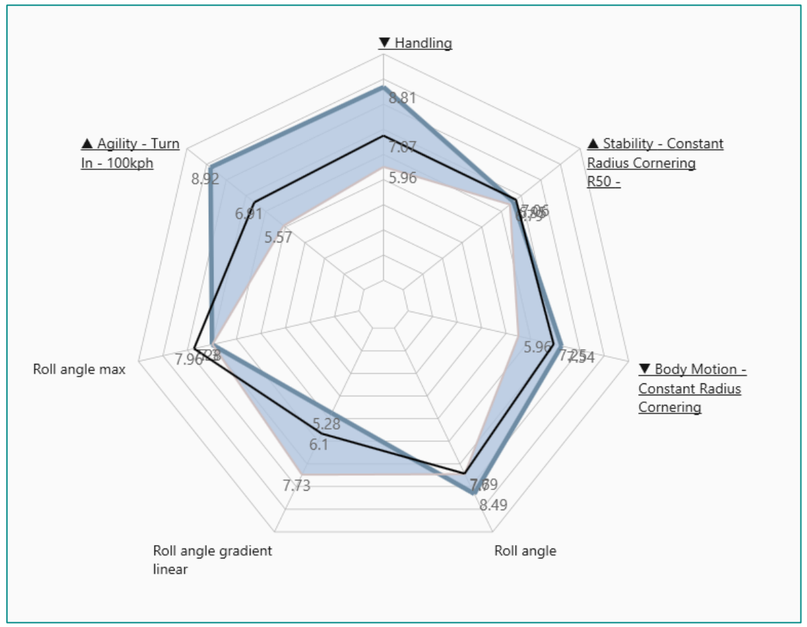
Vehicle Target Cascading

Top Level



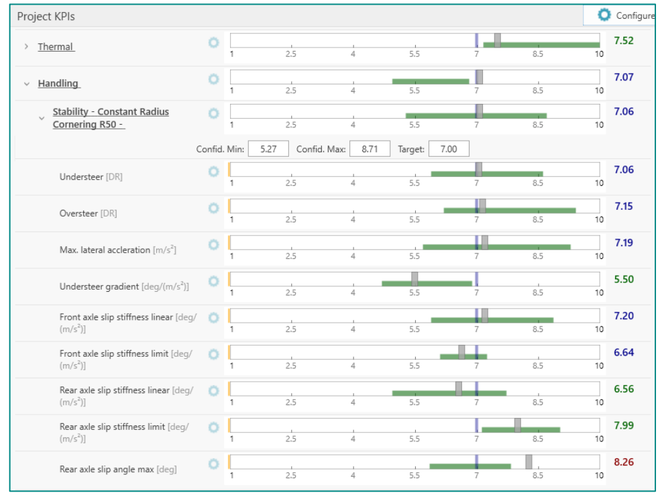
Target Cascading

Attribute „Handling“



Target Cascading

Physical Details



AVL Vehicle Composer

File Home Predictive Model View

New Project | Import Project | Save Project | Configure Project | Auto-Configure | Create View | Save View — Project
Manage | Show/Hide | Reset — Specifications
Manage | Show/Hide — KPIs
Export Scenarios — Scenarios
Sensitivity | Significance | Randomize — Analysis
Optimize — Reverse Optimization

Navigation

Projects
- Create a new Project
- Projects
  - Demo

Predictive Models
- Import a Predictive Model
- CALC_Aero_CDxA
- CALC_CombinedMass_Crash
- CALC_CombinedMass_Dynar
- CALC_CombinedMassModel_
- CALC_UnitConversion_TyreRa
- CALC_UnitConversion_TyreRo
- PRED_BrakeDiscTemperature
- PRED_BrakeDistance
- PRED_ConstantRadiusCorner
- PRED_Crash
- PRED_EPA2
- PRED_LongPerformance
- PRED_TurnIn
- PRED_WLTC

Vehicle Composer | Predictive Model

Specifications

Technical Specifications — Add | Edit | Delete | Import | Export

View Type: Hierarchical **Hierarchical-By-Significance** All-Specifications By-Significance Alphabetical

Aero	base
Brakes	base
Control	base
Drivetrain	base
Electric System	base
Geometry	base

Chassis

Curb vehicle weight (CVW) [kg]	1500 (1500 1650 1800 1950 2100 2250 2500)	1500	0.1906
Additional Mass [kg]	(0 75 150 225 300 375 500)	100	0.0689
Additional Energy Management Mass [kg]	(0 75 150 225 300 375 500)	100	0.0269
Wheelbase, L101 [m]	(2.7 2.775 2.85 2.925 3 3.075 3.2)	2.9	0.0105
CVW distribution front [%]	(46 47 48 49 50 51 52)	48	0.0074
COG height (CVW) [m]	(0.45 0.5 0.55 0.6 0.65)	0.544	0.0056
Additional Crash Mass [kg]	(0 75 150 225 300 375 500)	100	0.0002

Scenario Management

Variants — Configure | Add Variant | Remove Variant | Clear Table | Apply Variant

Use	Compare	Label	Curb vehicle weigh...	Brake Distribution	Useable Battery En...	Tyre rolling radius
☑	☐		1900	58	80	3

Radar Plot

☑ Labels ☑ Values ☑ Tips ☑ Intersection ☐ Groups — Min.: 0 — Max.: 1 — AutoSize | Reset Scale | Reset View

KPIs

Project KPIs — Configure

Crash	8.01
Geometric Architecture	7.54
Energy Management	7.04
WLTC	7.34
EPA 2-Cycle	6.75
Performance	8.28
Thermal	7.22
Handling	9.10

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Vehicle Composer | Predicitve Model

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Aero	base
Brakes	base
Control	base
Drivetrain	base
Electric System	base

HV

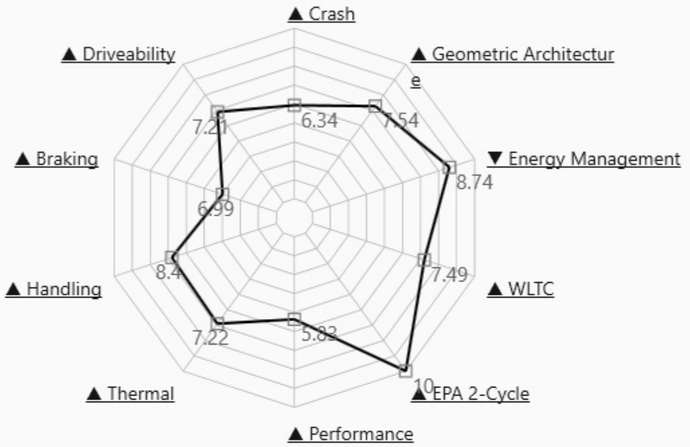
Useable Battery Energy [kWh]	50 75 100 125 150 175 200	196.79	0.2001
Max. Efficiency E-Motor+Inverter Rear [%]	85 87.5 90 92.5 95 97.5 100	94	0.0317
Gear Ratio (E-Motor to Wheel)	8 9.5 11 12.5 14 15.5 17	10.65	0.0269
Recuperation Percentage [%]	0 15 30 45 60 75 90 100	97	0.0195
HV Auxiliaries Consumption [kW]	0 1.5 3 4.5 6 7.5 9 10	0	0.0194
Average Gear Efficiency (E-Motor to Wheel) [%]	90 91.5 93 94.5 96 97.5 99 100	96	0.0087
Max. Efficiency E-Motor+Inverter Front [%]	85 87.5 90 92.5 95 97.5 100	94	0.0062
Peak E-Motor Power Rear [kW]	50 100 150 200 250 300	150	0.0029

Scenario Management

Variants — Configure | Add Variant | Remove Variant | Clear Table | Apply Variant

Radar Plot

Labels Values Tips Intersection Groups — Min.: 0 Max.: 1 AutoSize Reset Scale Reset View



KPIs

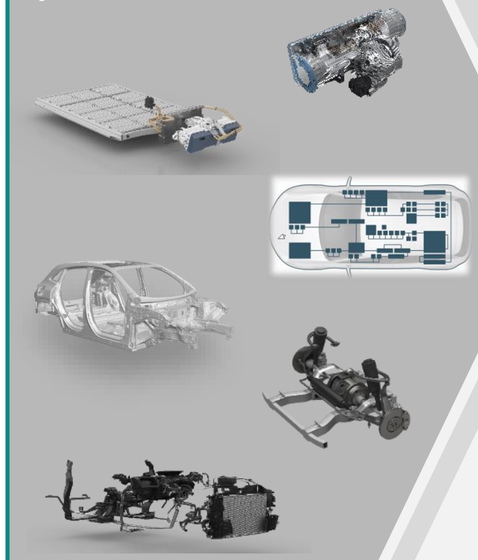
Project KPIs — Configure

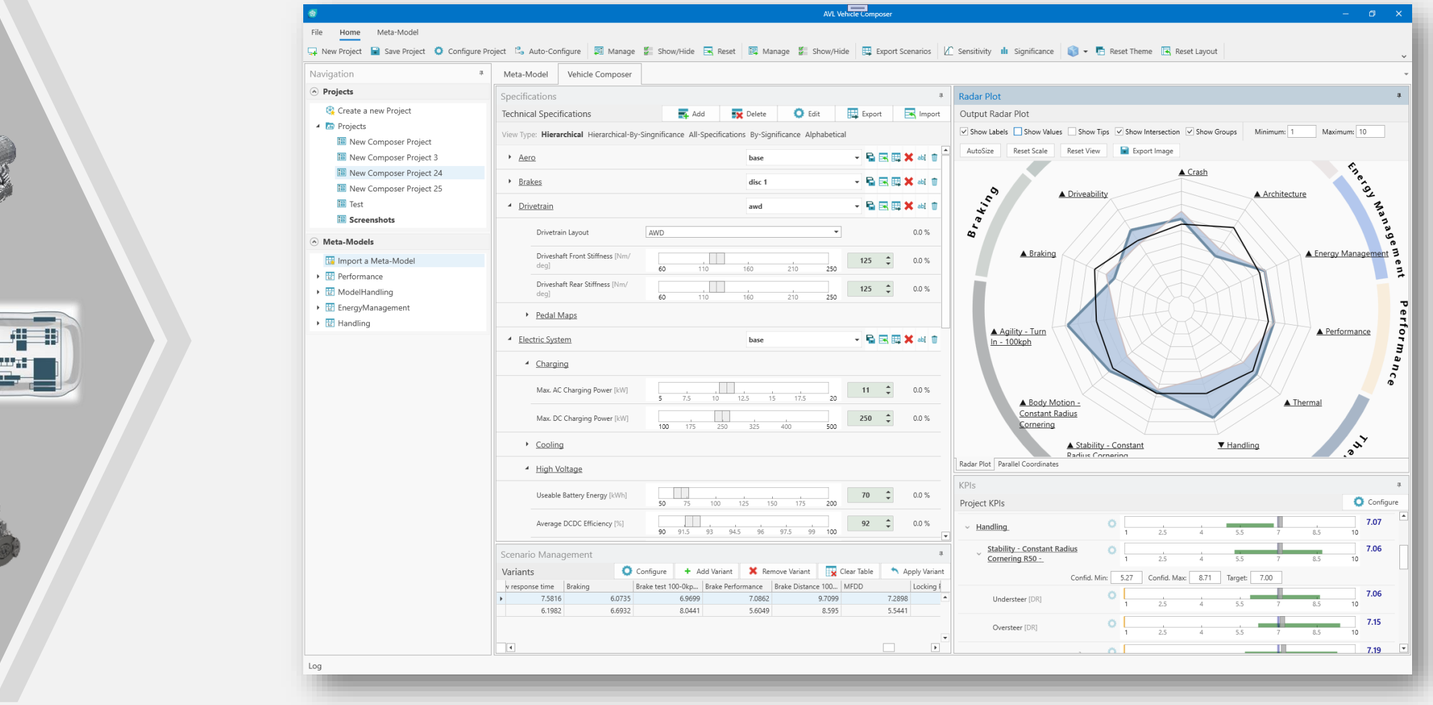
Geometric Architecture	7.54
Energy Management	8.74
Performance	5.83
Thermal	7.22
Handling	8.40
Braking	6.99
Driveability	7.21

Solution Architecture (OEM)

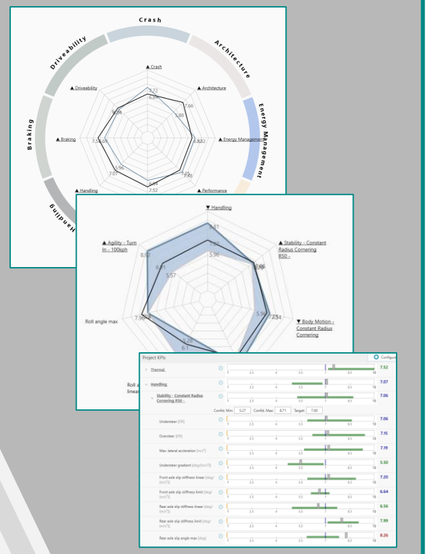
Vehicle Composer™

Technical Specifications
Technologies
Components
Platform
Systems

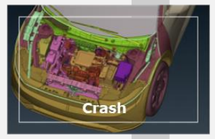




Vehicle Targets
Requirements
Attributes
D.N.A.
KPIs



Generic
AI Predictive
Models
(integrated in
Vehicle Composer)



...and more

Customer
Models
(FMU)

- Numerical
- Physical
- Empirical

Solution Architecture (Supplier / Tier1)

Vehicle Composer™

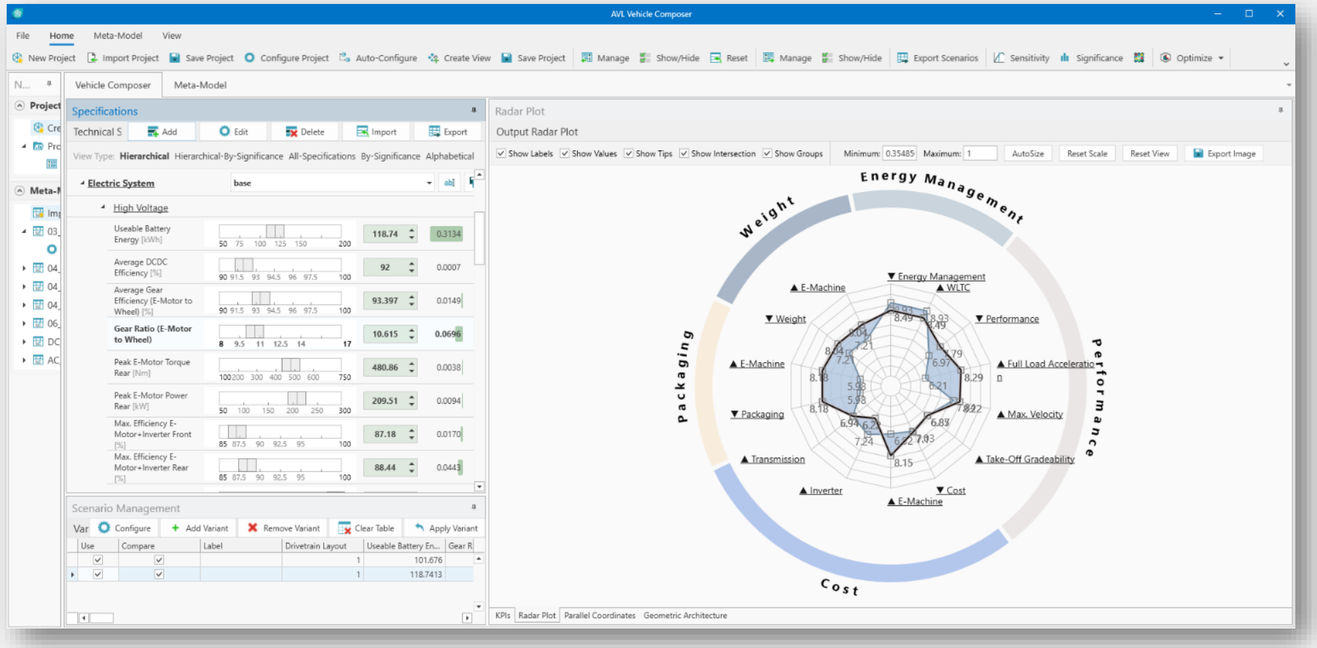
Techn. Specifications

PT Components:

- *Electric Drive Units (EDU)*
- *Inverters*
- *Thermal components*

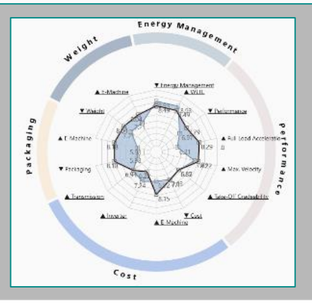
Specifications:

- *Peak torque / power*
- *Cooling technology*
- *EM Technology*
- *Inverter Technology*
- *# of power-card coolers*
- *…*



Vehicle Attributes

Consumption
Performance
Dimensions
Efficiency
Weight
Cost



Generic AI Predictive Models (integrated in Vehicle Composer)

…and more

AI Predictive Models from Benchmark Vehicles (Vehicle Model Factory)

Tesla Model Y Performance

Hyundai Ioniq 5

Lucid Air Dream

BMW iX

VW ID.4 GTX

Customer Models (FMU)

Customer Reference

Customer Reference Hyundai

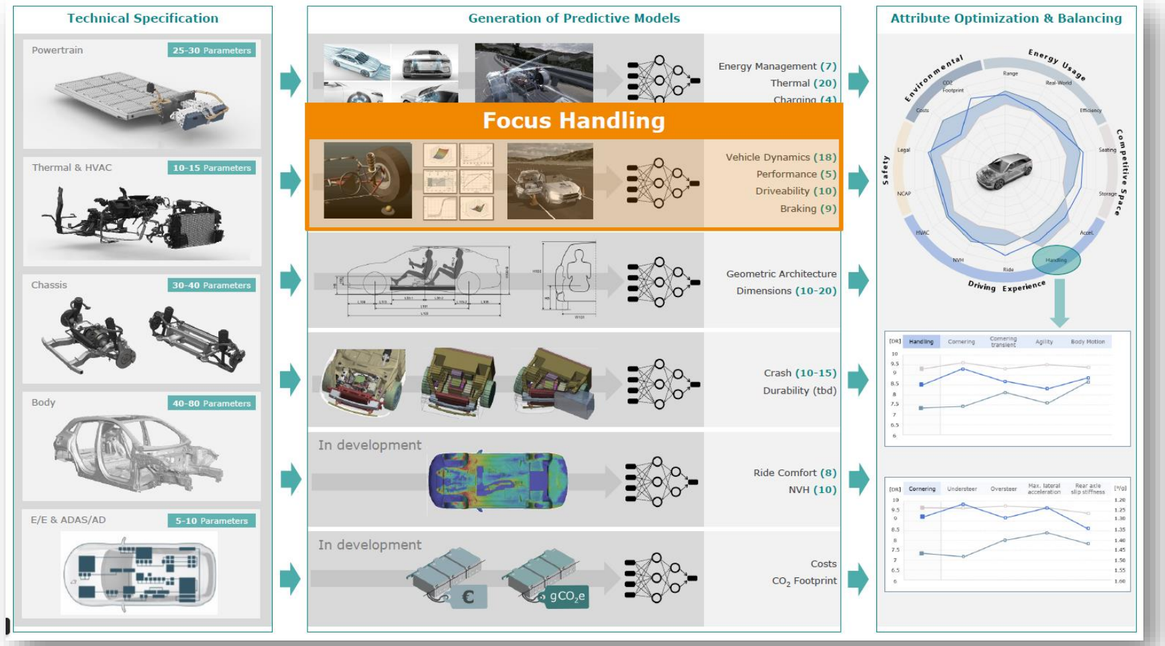
HYUNDAI AVL

AI-Based Decision-Making Tool for Concept Definition focusing on Vehicle Handling

10th International Symposium on Development Methodology
08.11.2023, Wiesbaden/Germany

Jeong Pilyoung, Ph.D Jaekil Lee, Dong Soo Kang - Hyundai Motor Company
Stefan Kellner, Jörg Schlager, Andreas Ramsauer, Mario Oswald, Francesco Duchi – AVL List GmbH

HYUNDAI



Customer Benefit

	Conventional Attribute Engineering	**AI Powered Attribute Engineering**	
Vehicle Concept Assessment Time	> 9min	< 10ms	Vehicle Handling
Easy to use	no	yes	
ø Accuracy	> 98%	> 96%	
Interactive Multi-Attribute Balancing Capabilities	no	yes	**Multi-Attribute**
Vehicle Concept Assessment Time	> 3 weeks	< 10ms	

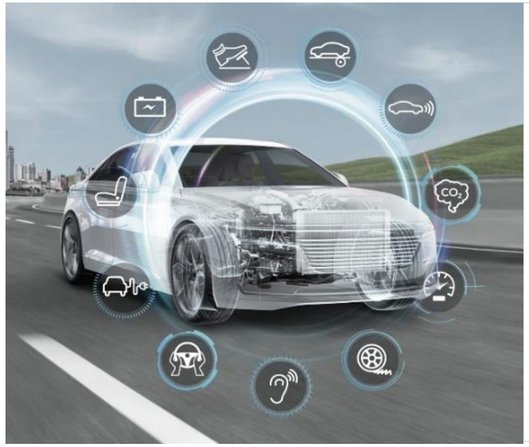
AI Powered Attribute Engineering enables **balancing of cross influences** in **real-time.**

Summary

Why **AVL Vehicle Composer**?

Real-Time Evaluation

Interactive vehicle concept assessment in real-time <u>without</u> CAD / FE models



10+ Vehicle Attributes

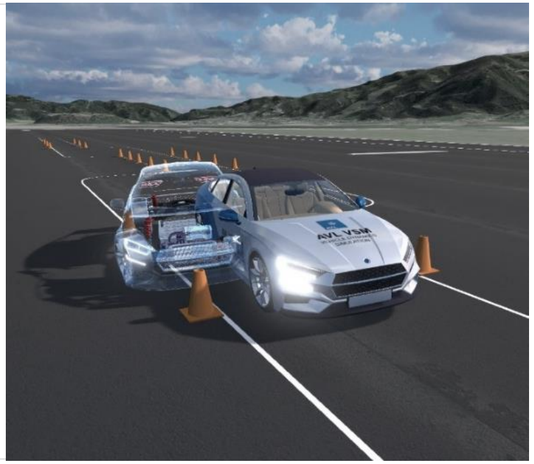
Multi-attribute evaluation enabling balancing of cross influences

6 Vehicle Systems

Covering the entire vehicle to achieve global optimum

ø Accuracy: **96-98%**

Predictive models based on > 1 Mio. single simulations



Q & A

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