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MATLAB/Simulink based modeling for industrial Electric Vehicle design

Thesis Project **:** *Development of autonomous vehicle simulator*
Application to tunneling

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ABOUT ME

Mouna SAMAALI received the engineer's degree in electronics « Automatic, Mechatronics, Automotive, Aeronautics and Space » from the University ENSEIRB-MATMECA of BORDEAUX –INP, France in 2021. She is currently a doctoral student in science engineering between the Labotory "DRIVE"and the campany "METALLIANCE".

His research interest focus on the modeling and simulation autonomous vehicles behaviors : Application to Tunneling

In September 2020 , she completed an engineering degree in embedded electronics systems (Electricity Sector) from The National School of Engineers of Sfax (ENIS), Tunisia.

In July 2017, SAMAALI obtained the bachelor's degree in biomedical engineering from the institute of biotechnology of Sfax, Tunisia (ISBS).

OUTLINE

- *INTRODUCTION AND OBJECTIVES*
- *LITERATURE OF ELECTRIC VEHICLE MODELS*
- *MODEL DEVELOPPEMENT STEPS*
- *INDUSTRIAL ENVIRONMENT AND MODEL DESCRIPTION*
- *SIMULATION, RESULTS AND VALIDATION ON A REAL ROAD PROFILE (Tunnel Rennes France)*
- *CONCULSION*
- *ACKNOWLEDGMENTS*
- *REFERENCES*


INTRODUCTION AND OBJECTIVES

Research Project SIMVA-2

- *Funded by the French « Plan de Relance », « France relaunch » plan - measures to preserve R&D jobs.*
- *Bipartite link between the DRIVE laboratory and the METALLIANCE company*
- *Develop a simulator for an autonomous vehicle with an application to the confined industrial environment in which the company's construction machinery operates*

Objectives

- *Provide solutions for partial or total driving delegation of a construction vehicle in a controlled indoor environment.*
- *Predict the physical behavior (electrical, thermal engine, etc.) of the various parts of the vehicle (engine, battery, perception/vision systems, etc.).*
- *Train driver of this new mode of material transport*

INTRODUCTION AND OBJECTIVES

Connected Autonomous Vehicle

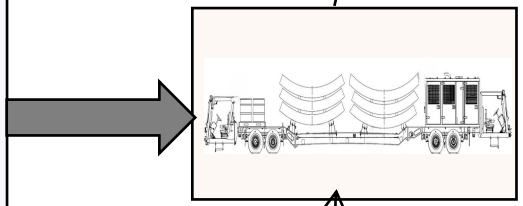
Autonomous

Driving tasks

Accidents

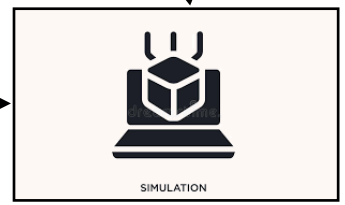
Safety

Connected



Prediction

Data



Real World (Metalliance's vehicles)

Simulation model

Experimentation

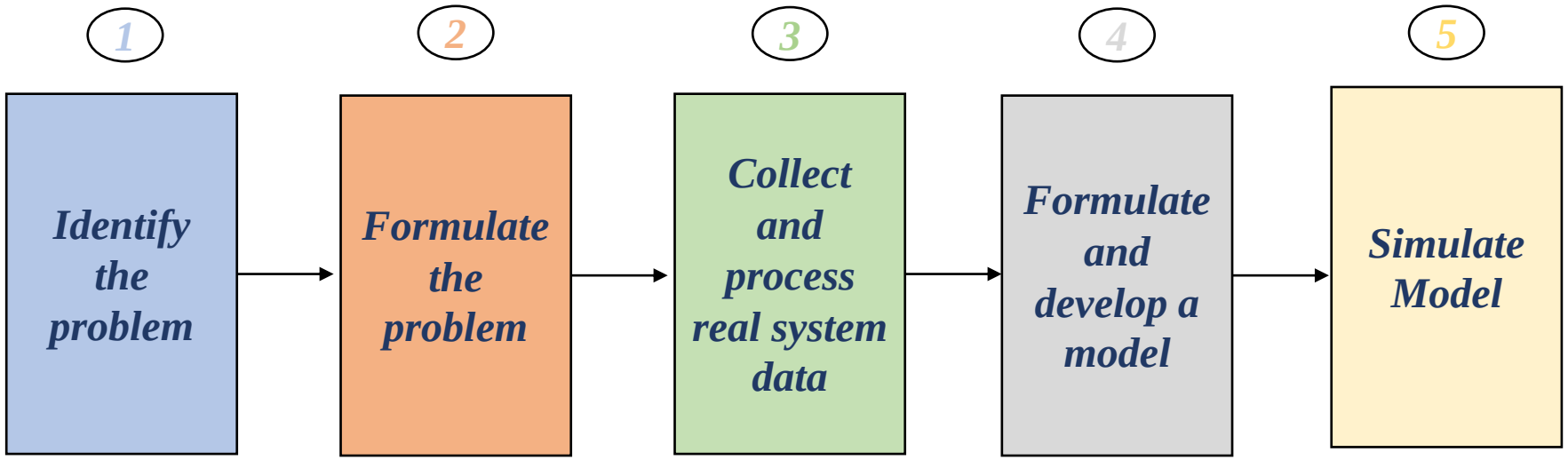
LITERATURE OF ELECTRIC VEHICLE MODELS

Electric vehicle models

Models	Benefits	Disadvantages
[1] : Optimization of control strategy for a low fuel consumption vehicle engine	• Model-based optimization of an electric vehicle was developed in Simulink (the vehicle, the electric motor, and the motor controller) • Simulation was compared to real measurements	• Prototype electric car that has been designed for the Shell Eco-marathon
[2] : Modeling and optimization of the consumption of a three-wheeled vehicle	• Model optimization of the powertrain three wheeled vehicle has been developed in AMESIM • Dynamic behavior was analyzed by the comparison of simulation results to results obtained on the track.	• Vehicles with three wheels use a carbon-fiber monocoque pushed by a hydrogen fuel cell with a DC electric motor
[4] : Multiphysics modeling and optimization of the driving strategy of a light duty fuel cell vehicle	• Numerical modelling of the vehicle powertrain was developed in MATLAB /Simulink • The model was validated using real measurements.	• The model includes the vehicle motion and the fuel consumption.
[3] : Model-Based Optimization of Velocity Strategy for Lightweight Electric Racing Cars	• Multiphysics dynamical model of a fuel cell vehicle has been developed (the losses and consumptions of the power several vehicle behavior : mechanical requirement, thermal behavior of fuel cell) • The simulation results are compared and validated with experimental measurements	• Power train : urban-concept vehicle used for energetic races

METALLIANCE designs industrial machines which are type of complex system (two or three vehicle module), no previous modeling of this type of industrial electric vehicles is done before.

MODEL DEVELOPPEMENT STEPS

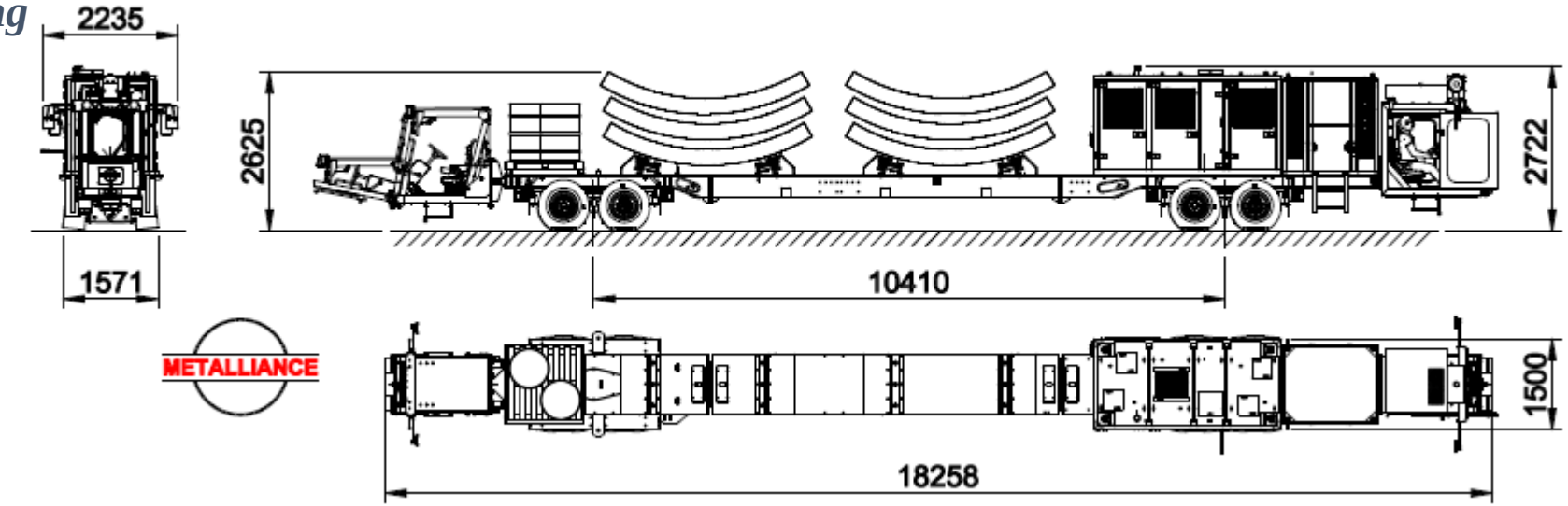


[5]

INDUSTRIAL ENVIRONMENT AND MODEL DESCRIPTION

Construction Site : Application to tunneling

Multi Service Vehicles (MSV)



https://www.metalliance-tsi.com/product/vehicules-multi-services/

Outdoor environment

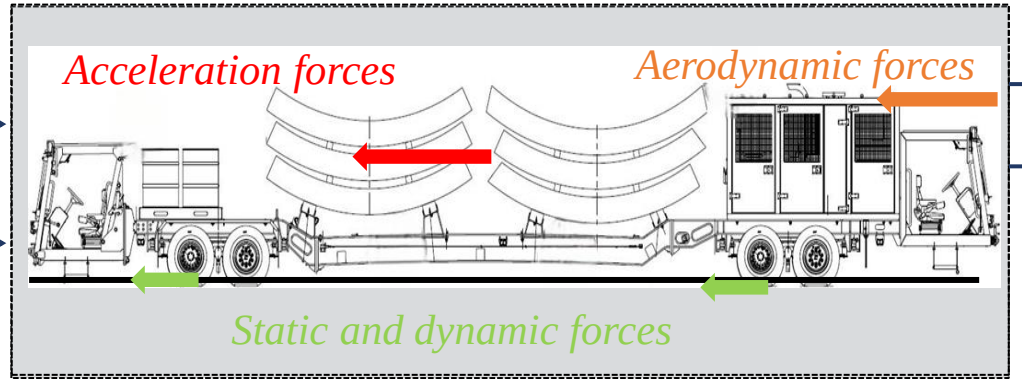
Indoor environment

INDUSTRIAL ENVIRONMENT AND MODEL DESCRIPTION

Physical Tools

Required vehicle Speed →

Road profile →



→ **Resistant wheel torque**

→ **Mechanical Power**

- *Rolling friction force :* $F_r = C_r * m * g$
- *Acceleration force :* $F_{acc} = m * a$
- *Aerodynamic force :* $F_{aero} = 0.5 * S_{vehicle} * C_x * \rho * [V^2]$
- *Downhill-slope force :* $F_{slope} = m * g * sin(\alpha)$
- *Motor Speed :* $S_{motor} = V * \frac{60}{2*\pi*R_r}$

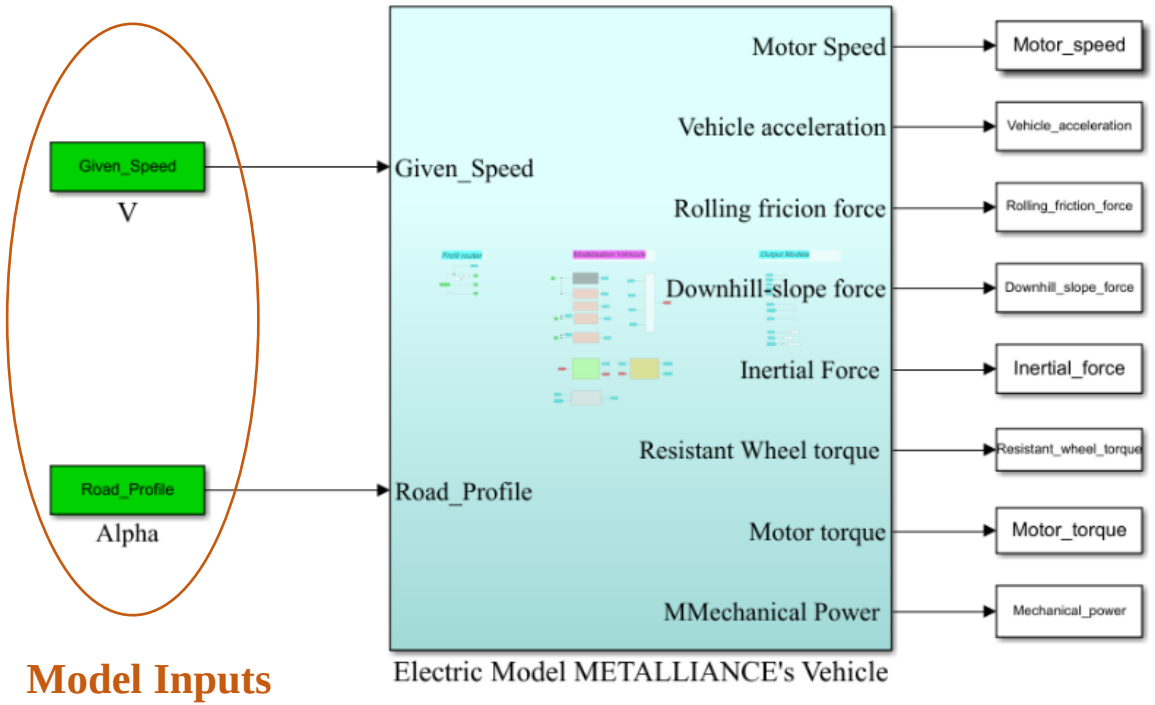
- ***Resistant wheel torque :*** $T_r = \sum Forces * R_r$
- ***Motor Torque :*** $T_{motor} = T_r * R_{ratio}$
- ***Mechanical power :*** $P = S_{motor} * T_{motor}$

Parameter	*Symbol*	*Value*
Maximum vehicle speed	V_{max}	*18 km/h*
Wheel radius	R_r	*599 mm*
Rolling resistance coefficient	C_r	*0,02*
Unlaoded vehicle mass	m	*15000 Kg*
Laoded vehicle mass	m	*40000 Kg*
Aerodynamic Coefficient	C_x	*1*
Air Density	ρ	*1.2 kg/m³*
Section area of the vehicle	$S_{vehicle}$	*6 m²*
Gravitational acceleration	g	*0.9419.81 m/s²*
Reduction wheel ratio	R_{ratio}	*53*

Reference vehicle data

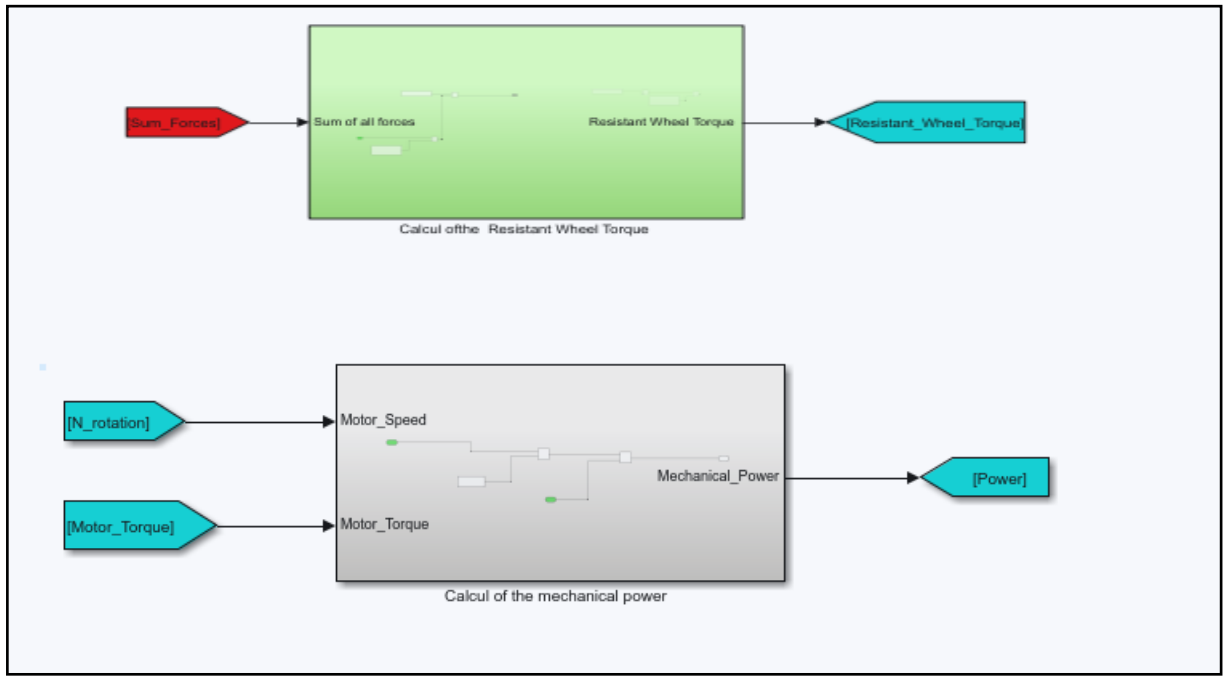
INDUSTRIAL ENVIRONMENT AND MODEL DESCRIPTION

Matlab/Simulink Model



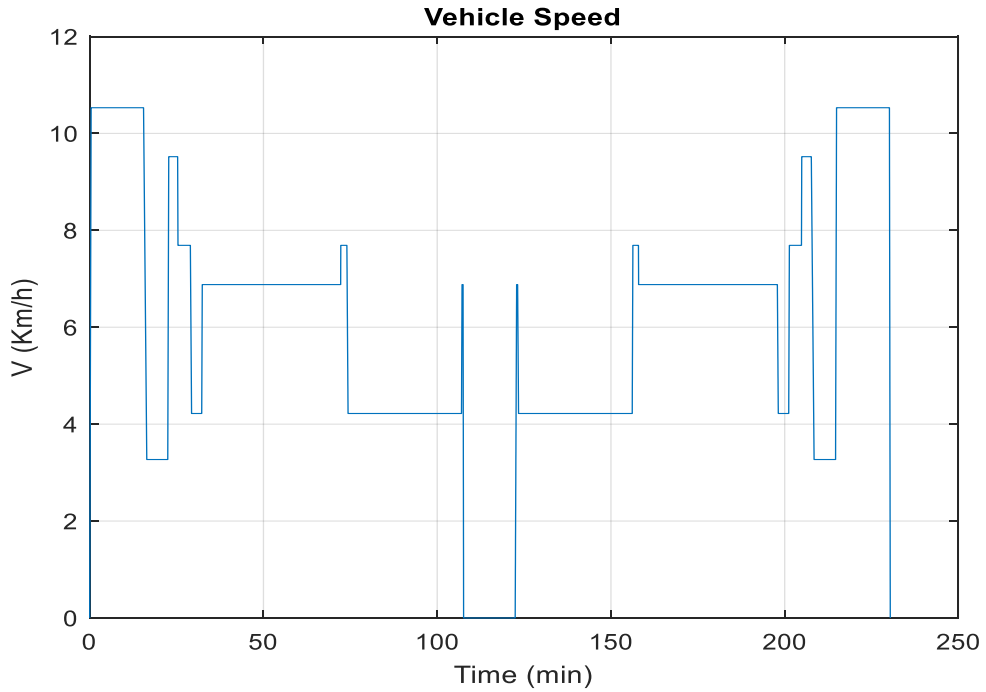
Model Inputs

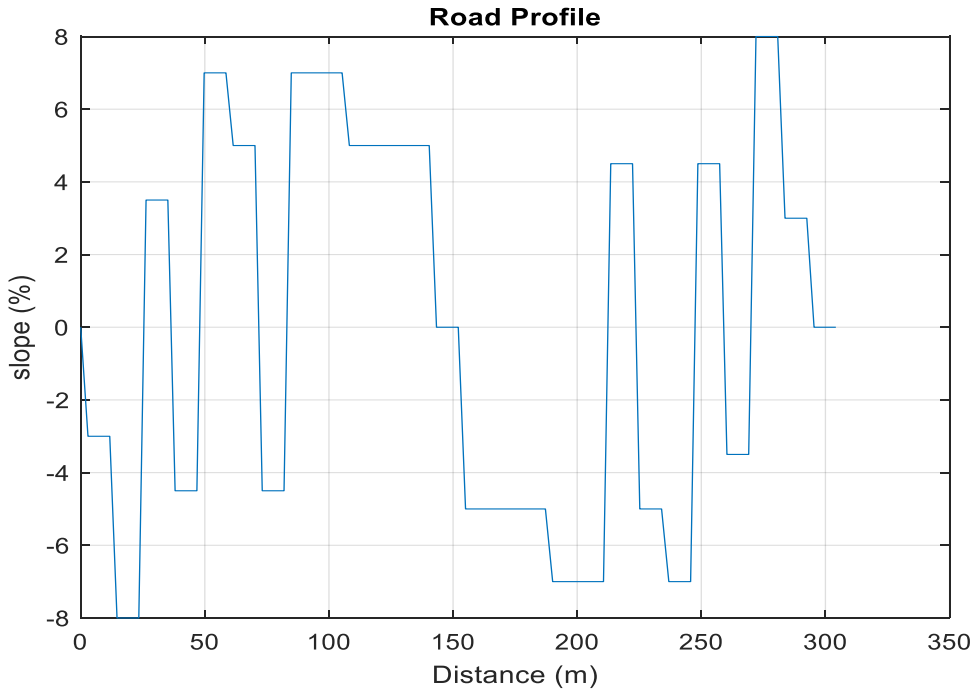
Model Outputs : Simulation results



Simulation ,results and validation on a real road profile (tunnel Rennes France)

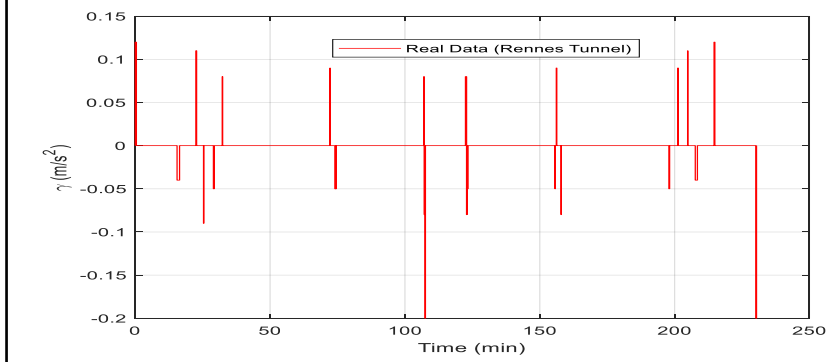
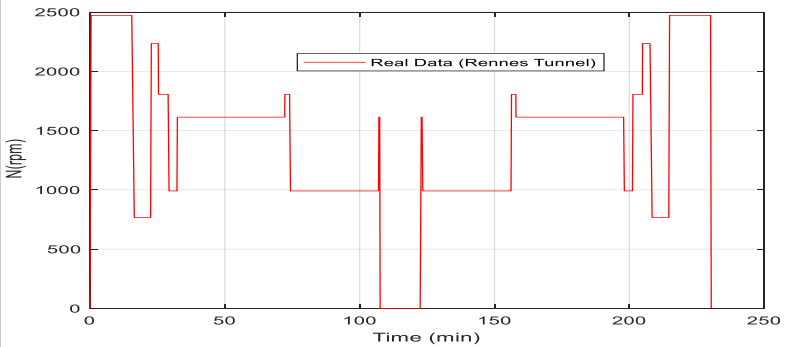
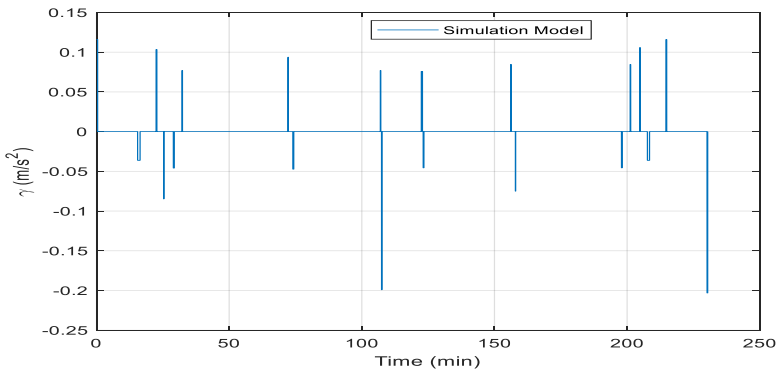
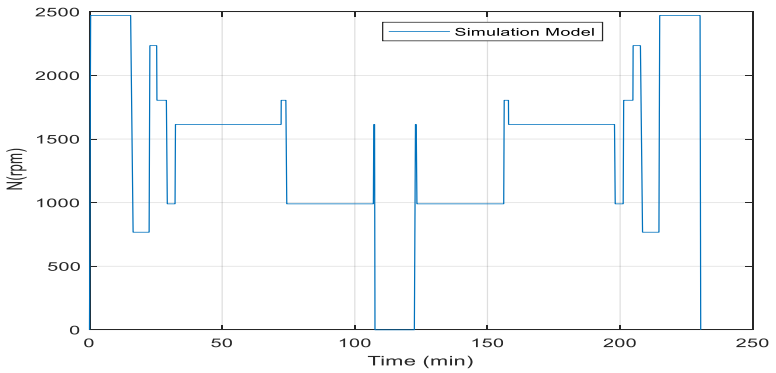
Inputs





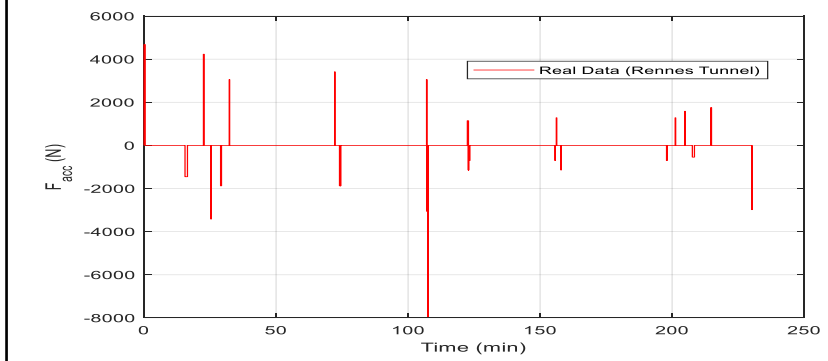
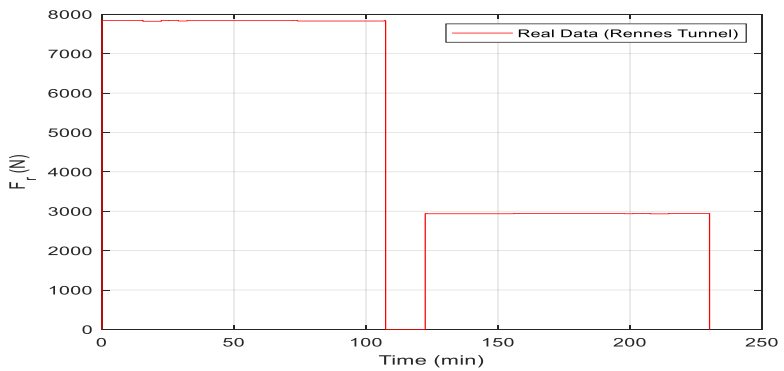
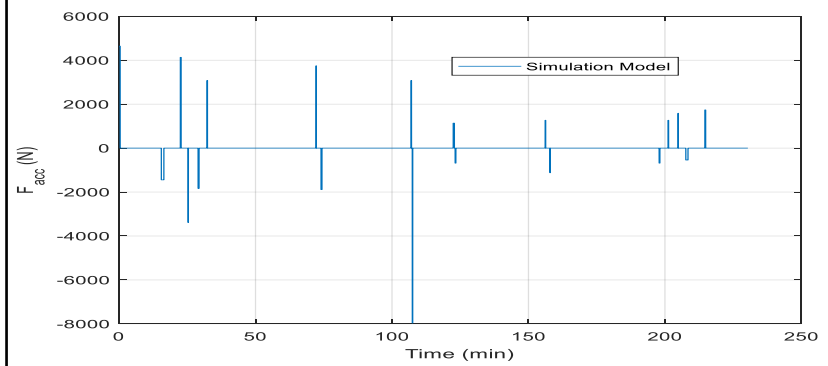
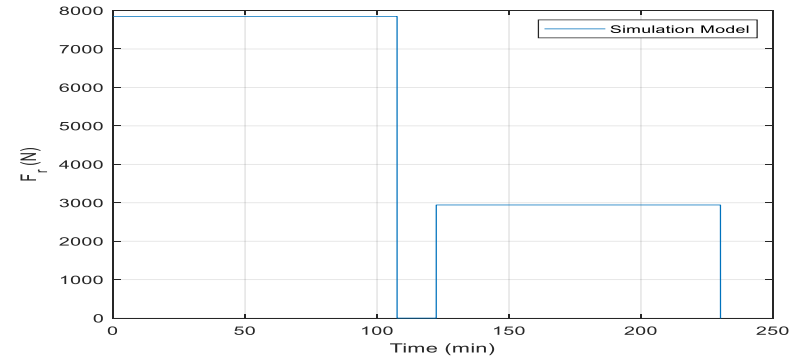
Simulation ,results and validation on a real road profile (tunnel Rennes France)

Outputs

	Acceleration Vehicle	*Motor Speed*
Real World		
Simulation Results		

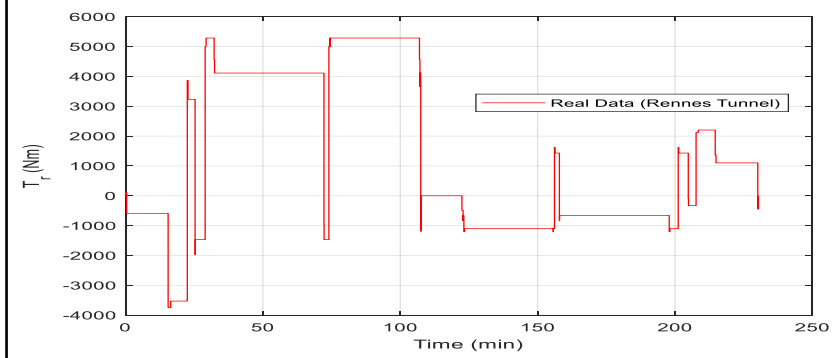
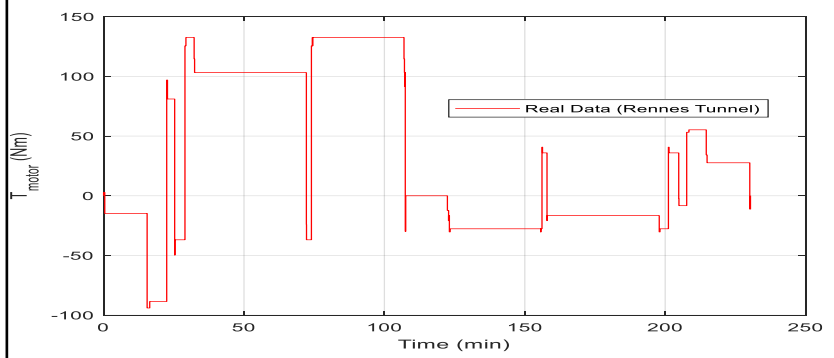
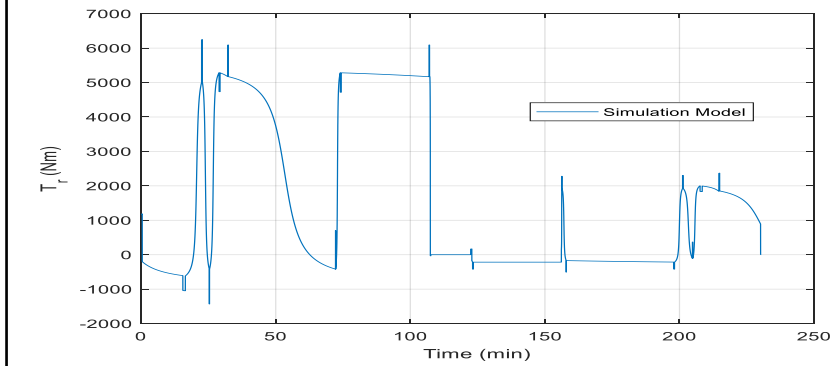
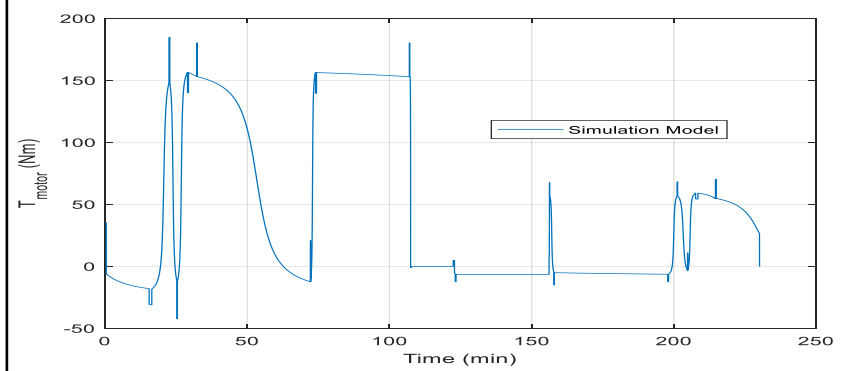
Simulation ,results and validation on a real road profile (tunnel Rennes France)

Outputs

	Acceleration Force	*Rolling Friction Force*
Real World		
Simulation Results		

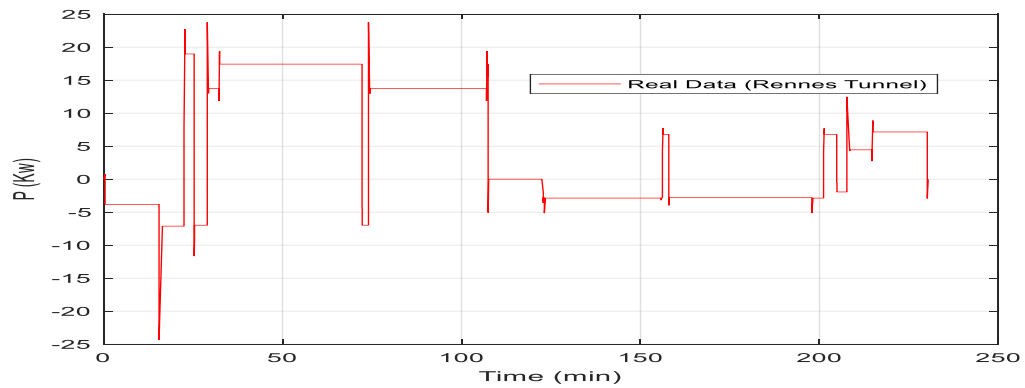
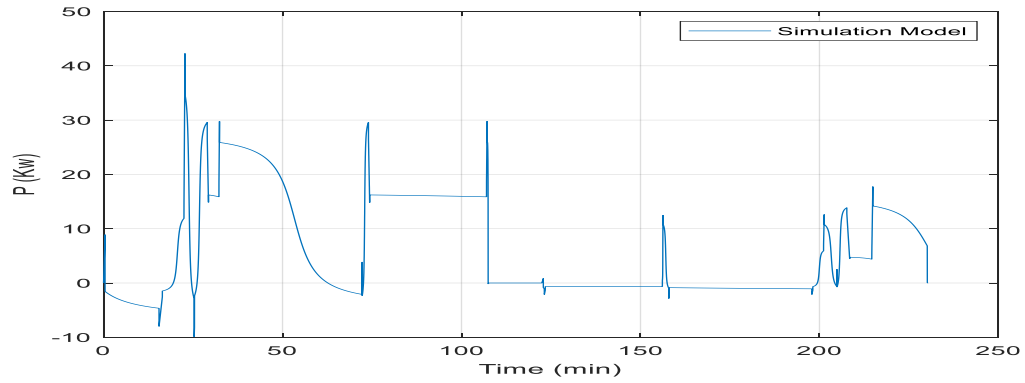

Simulation ,results and validation on a real road profile (tunnel Rennes France)

Outputs

	Resistant Wheel Torque	*Motor Torque*
Real World		
Simulation Results		


Simulation ,results and validation on a real road profile (tunnel Rennes France)

Outputs

	Mechanical Power
Real World	
Simulation Results	

CONCLUSION

- *Implementation of an electrical model of a METALLIANCE Multi-Service Vehicle (VMS) based on physical description*
- *Methods and steps for modeling systems*
- *Study of the operational design domain : vehicle system environmental ,characteristic and operation.*
- *Validation of the model with real recording data. The simulation shows that the model is highly close to the real world*

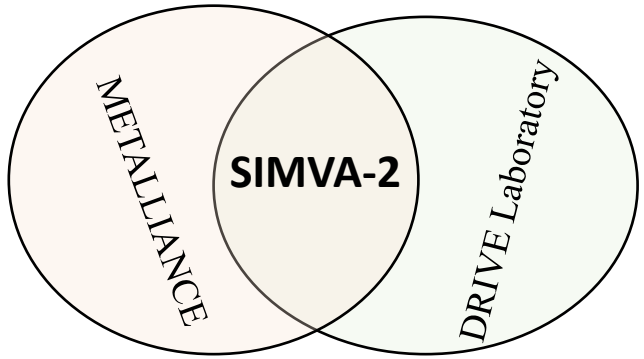
Future work :

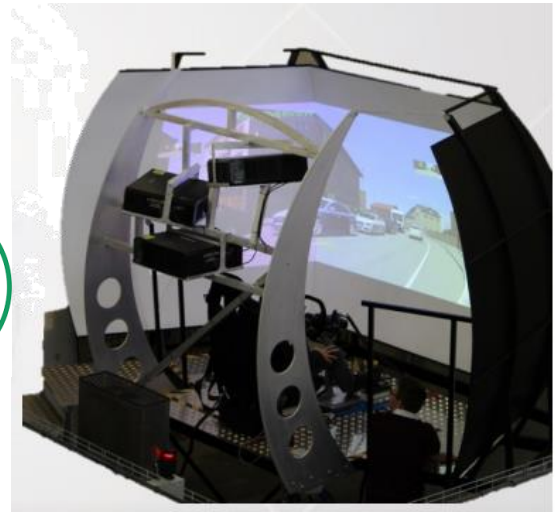
- *Development of the hydraulic and thermal vehicle model*
- *Combining these models to have a complete Metalliance's Vehicle model*
- *Use this full model to develop a METALLIANCE autonomous vehicle simulator*


ACKNOWLEDGMENTS

Research Project SIMVA-2

« France relaunch » Plan
AND « Measures to preserve R&D jobs »





Simulator for an autonomous vehicle with an application to the confined industrial environment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Thank you for your attention

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