emrails
MyRailS
EMPIR
EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Ecodriving: first results from the European Research Project MyRailS

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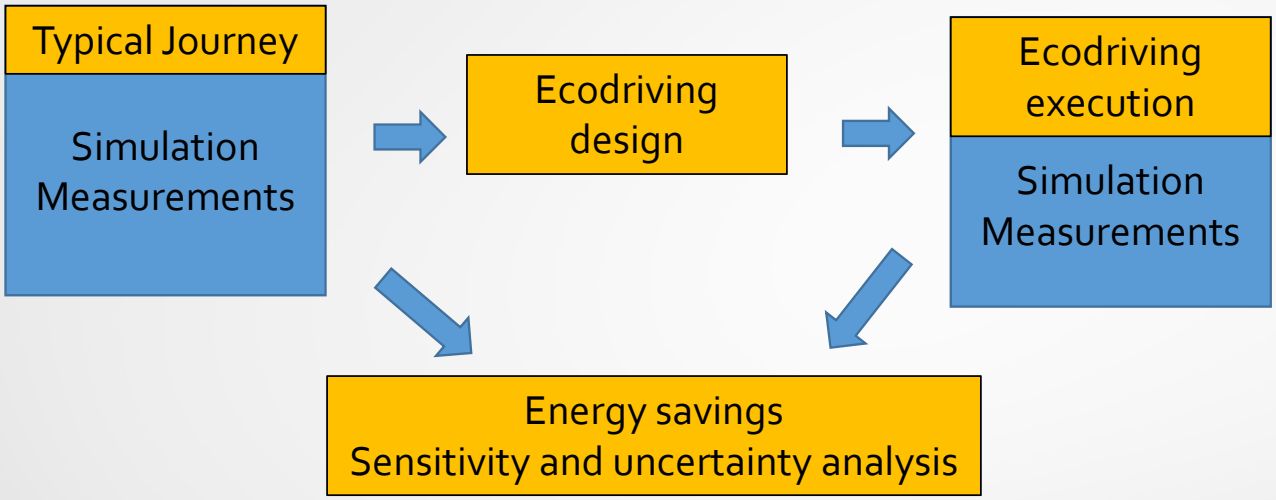
Institute for Research in Technology

ICAI-Universidad Pontificia Comillas

Madrid-Spain

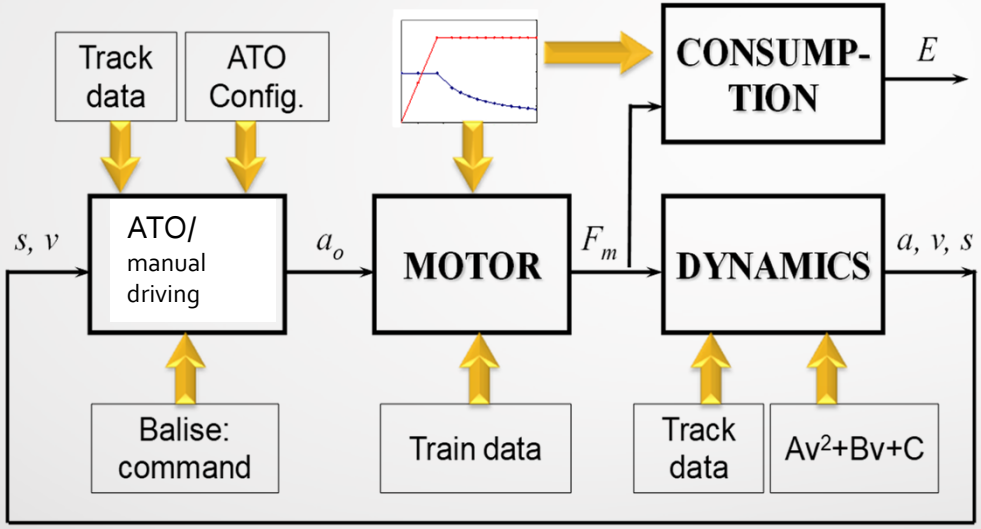
MyRailS project: Ecodriving



- Test cases:
  - Metro de Madrid
  - Italy railway network

Simulation

- Simulation of the train motion and energy consumption in a metro line (SN) and a railway network (RN)



- Selection of the scenarios for the ecodriving

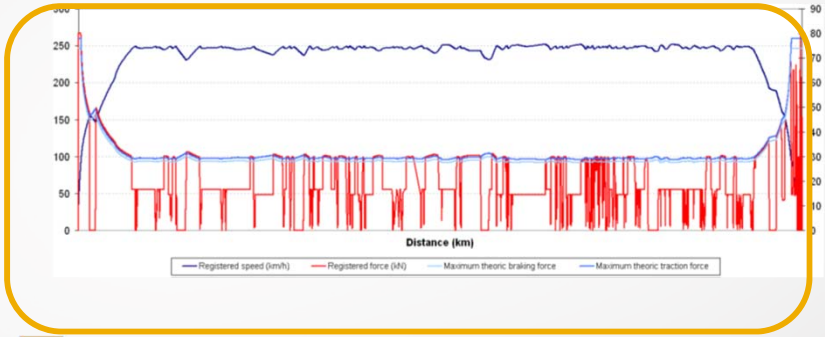
Adjustment and validation of the model with real measurements

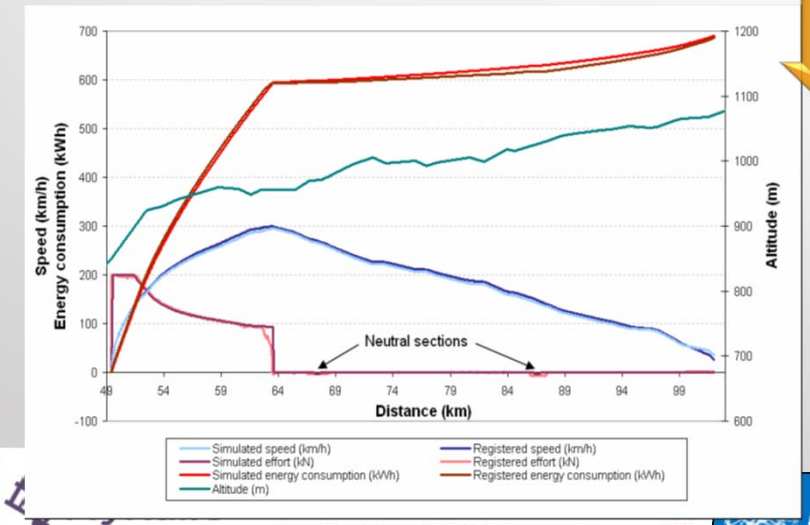
Measurements selection to register on board

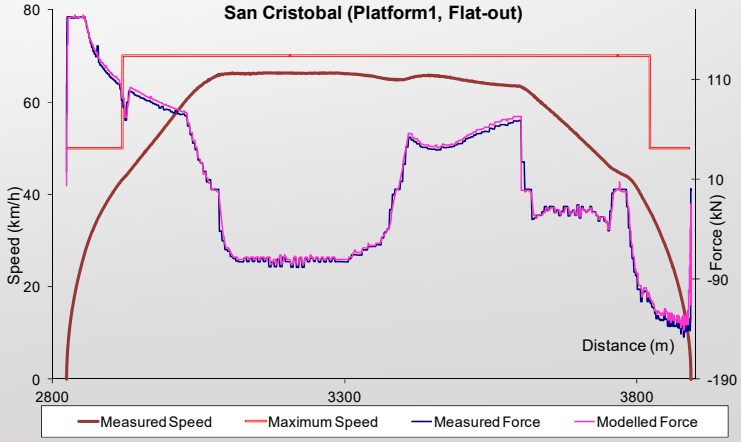
- Time, Distance, Traction & Braking forces, Voltage, Current…..

Model Validation/adjustments

- Traction/braking curves
- Consumption of auxiliary equipment
- Manual/ATO driving commands…







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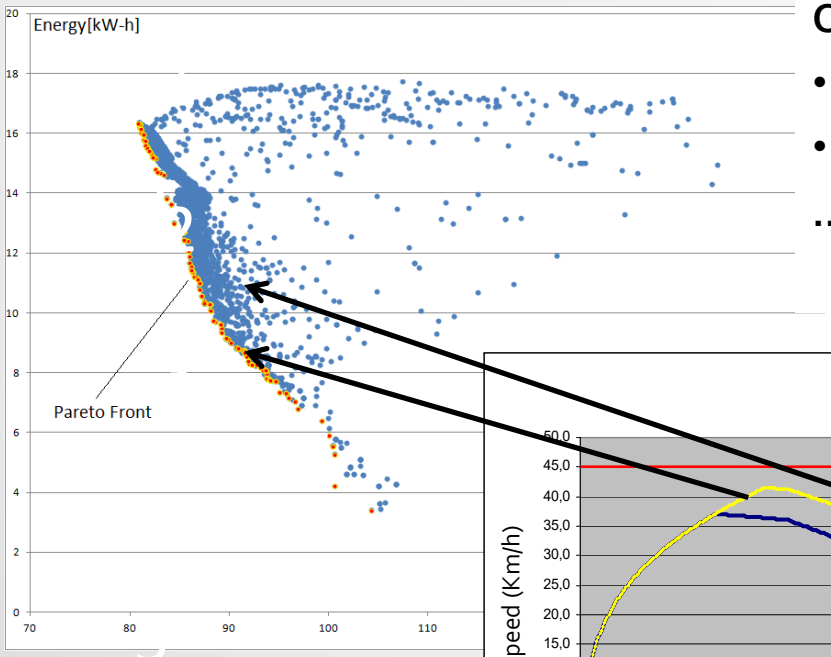
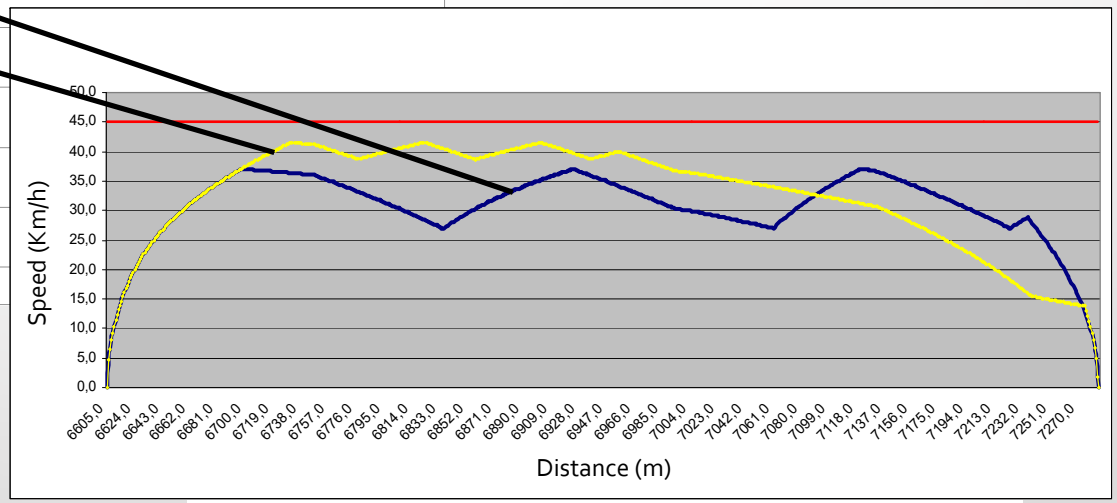
Ecodriving: speed profile optimisation



Optimisation algorithms:

- GA: genetic algorithms
- PSO: particle swarm optimisation

...



Example of Metro line intersatation equipped with ATO

Ecodriving test cases: Metro de Madrid

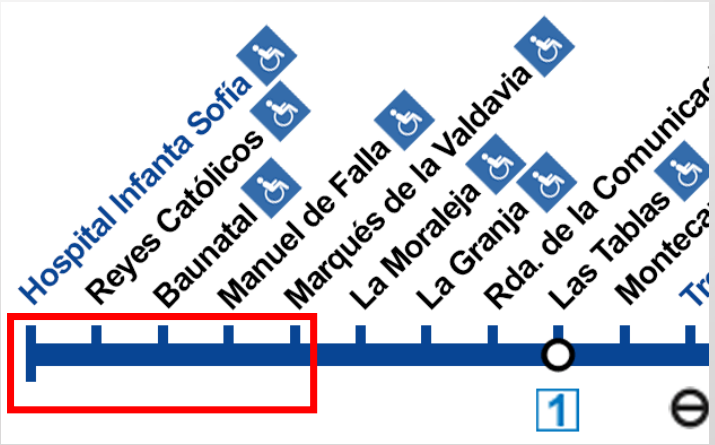
✓ Simulation of maximum journey speed profile in Metro Madrid

✓ Journey and Rolling Stock have been defined: 4 inter-station of Line 10B. Train: class 9000 1500 V

✓ Track, signalling and train (length 55m, mass: 126 Tm) data have been collected. ATO equipment: Siemens

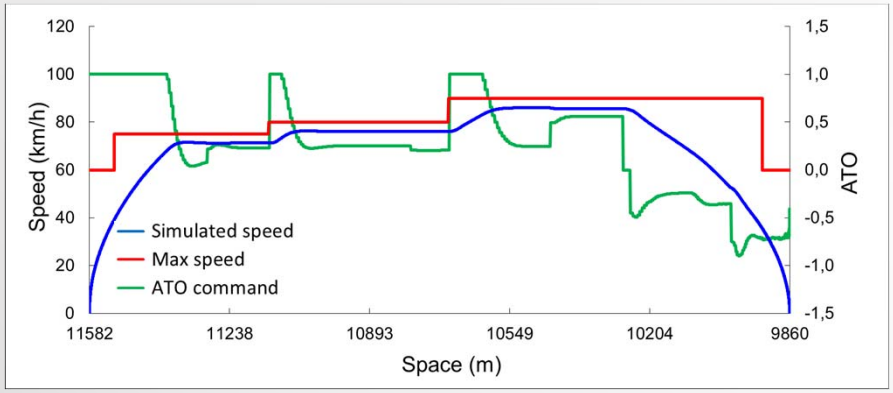
✓**Line 10(B).** Interstations:

- Marqués de la Valdavia – Manuel de Falla
- Manuel de Falla – Baunatal
- Baunatal – Reyes Católicos
- Reyes Católicos – Hospital Infanta Sofía



Ecodriving test cases: Metro de Madrid

Flat out Simulation Results Metro Madrid (I)

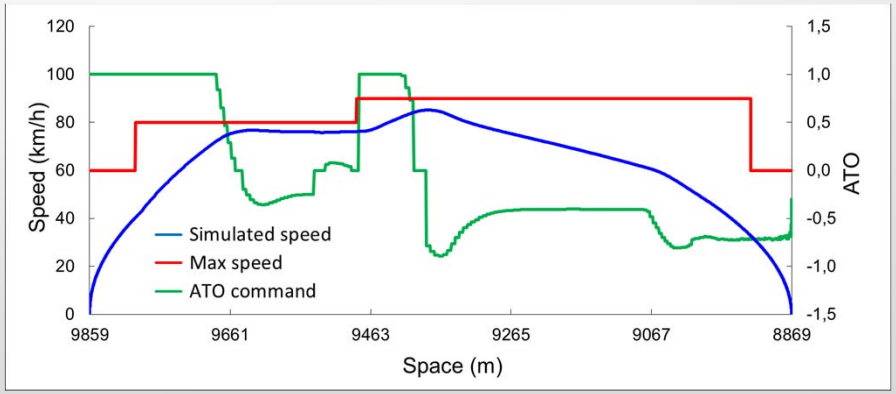


Marqués de la Valdavia – Manuel de Falla

Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)
0,75	0	0	0	106,8	20,45

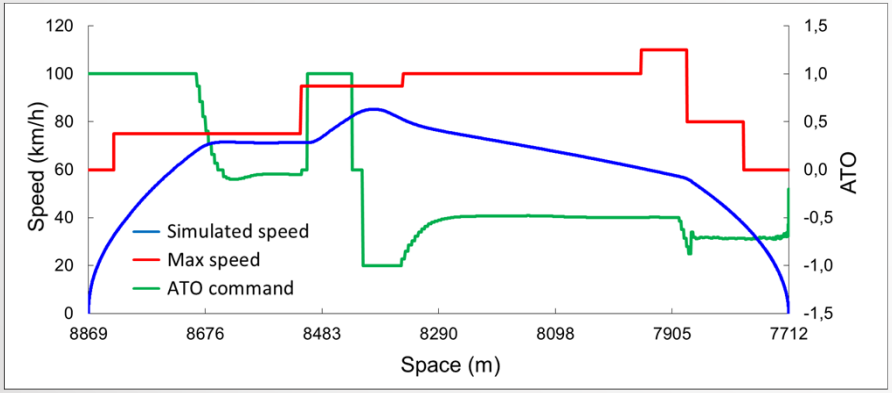
Manuel de Falla – Baunatal

Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)
0,75	0	0	0	73,1	9,31



Ecodriving test cases: Metro de Madrid

Flat out Simulation Results Metro Madrid (II)

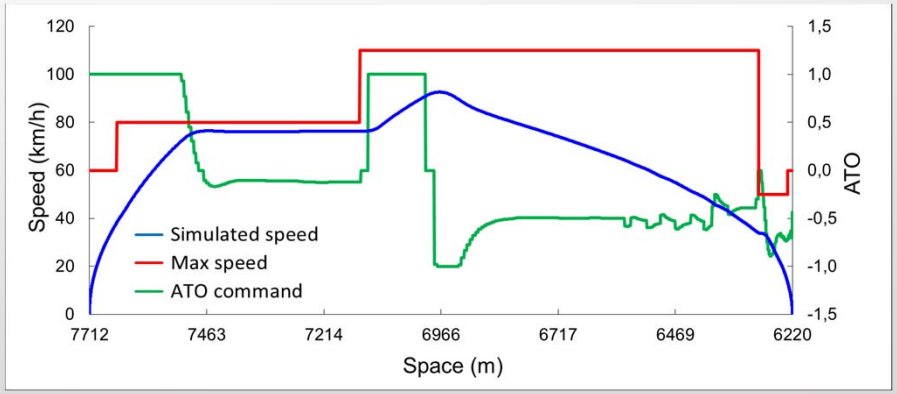


Baunatal – Reyes Católicos

Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)
0,75	0	0	0	83,2	9,60

Reyes Católicos – Hospital Infanta Sofía

Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)
0,75	0	0	0	99,5	11,25



Energy flows: characterization of a set of trains during a typical journey

Metro de Madrid measurements campaign execution

✓ METRO DE MADRID has recorded using the existing on-board measurement equipment (100 ms)

- Hospital Reina Sofía – Reyes Católicos
- Reyes Católicos – Baunatal
- Baunatal – Reyes Católicos
- Reyes Católicos – Hospital Reina Sofía

Energy flows: characterization of a set of trains during a typical journey

Definition of system information to be recorded during the on-site measurements

✓ Cinematic data: current speed, position, time

✓ Motor: traction/braking effort, driving command (driving handle / ATO command), current, voltage

✓ Auxiliary systems: power demanded

✓ ATO/ATP system: current speed and position, output command, speed limit, distance to go

Energy flows: characterization of a set of trains during a typical journey

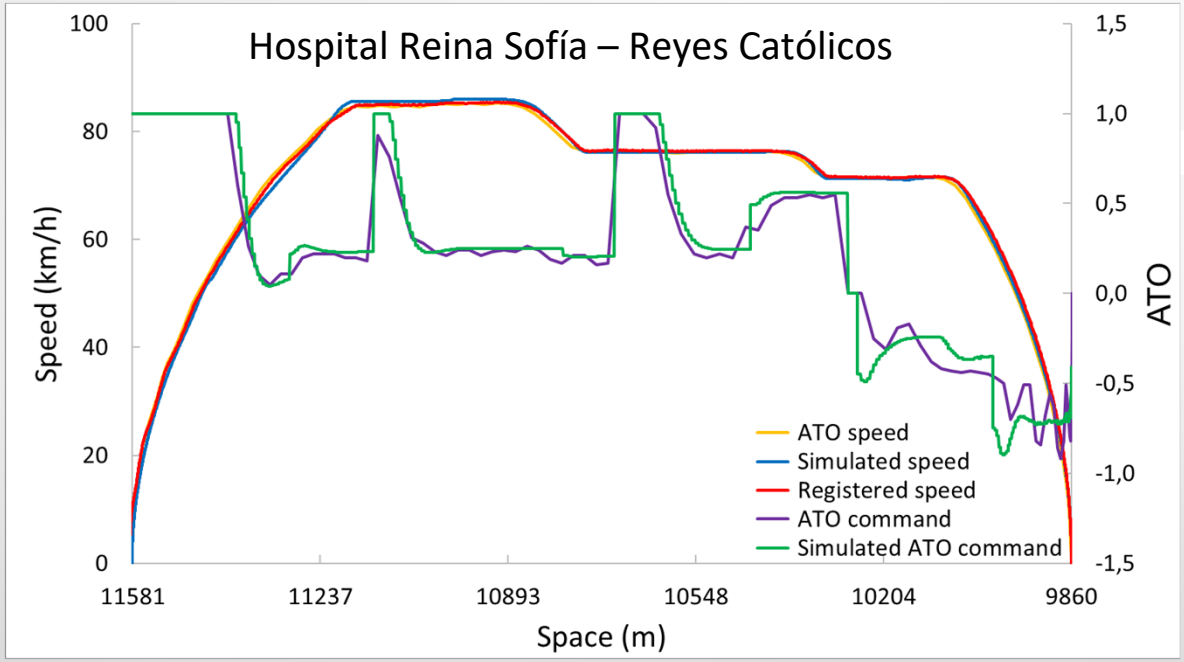
Metro de Madrid measurements campaign execution

Field measurements data analysis

Numerical and experimental results comparison (in progress)

METRO DE MADRID

1-2-2019



	Running time (s)	Time difference (s)	Electrical energy (kWh)	Error (%)
Registered	107,0		19,6	
Simulation	106,8	**-0,2**	18,9	**3,8**

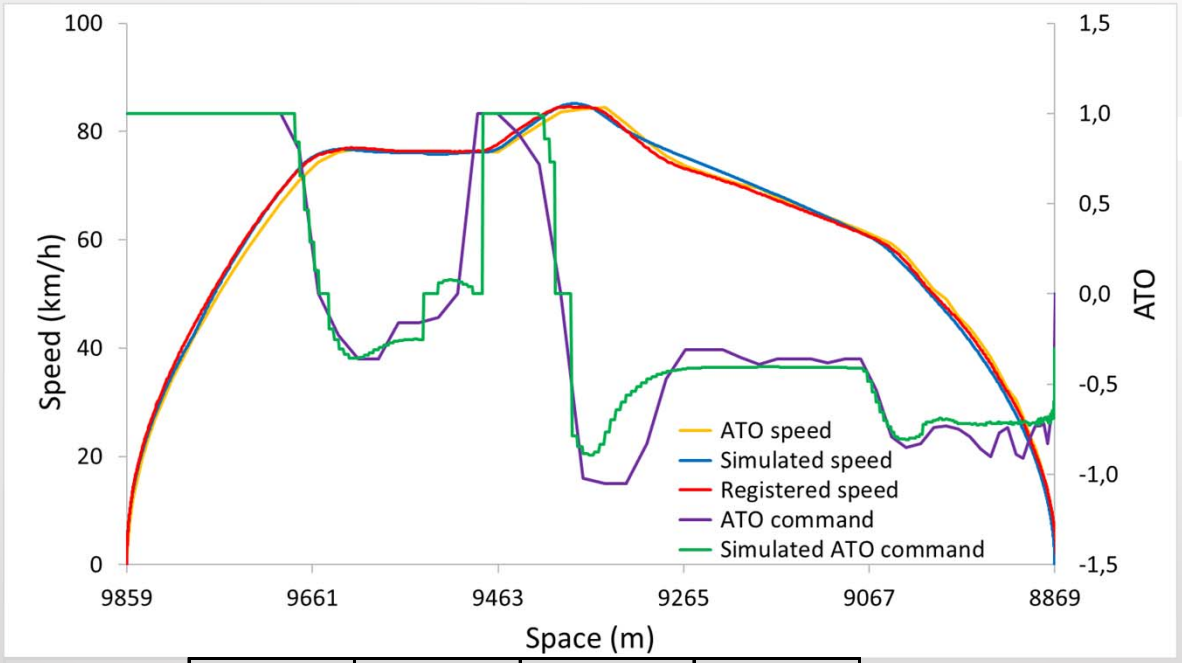
Using the already existing measurement equipment

Energy flows: characterization of a set of trains during a typical journey

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

METRO DE MADRID

Manuel de Falla – Baunatal



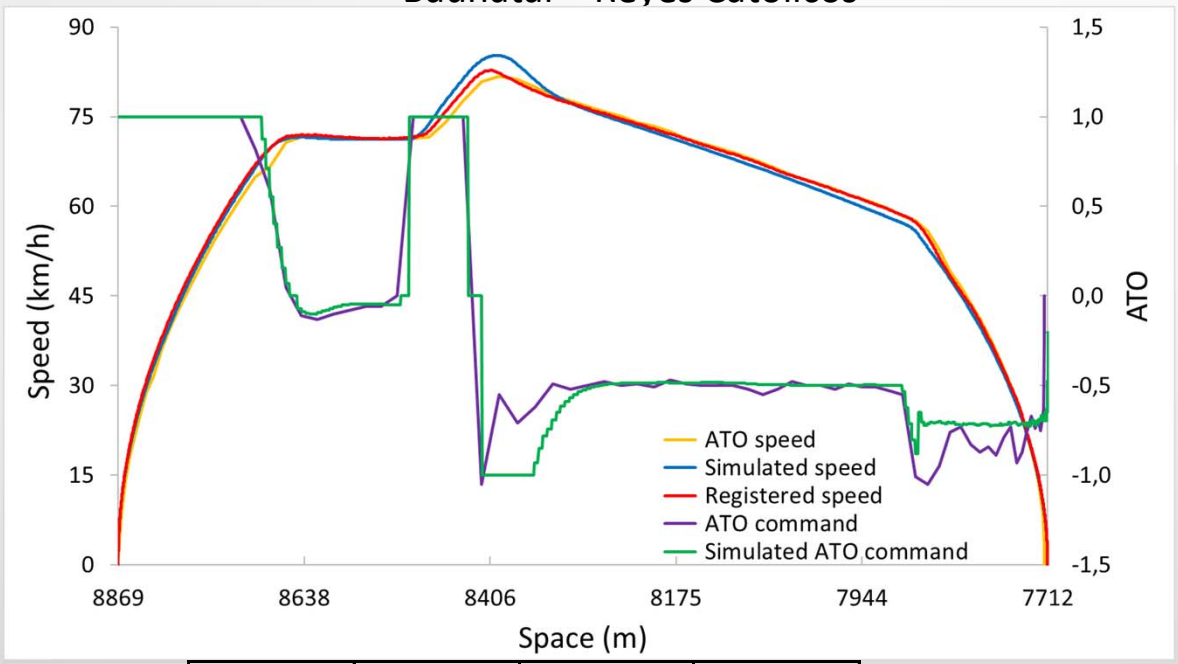
	Running time (s)	Time difference (s)	Electrical energy (kWh)	Error (%)
Registered	73,0		8,8	
Simulation	73,1	**0,1**	8,6	**2,3**

Energy flows: characterization of a set of trains during a typical journey

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

METRO DE MADRID

Baunatal – Reyes Católicos



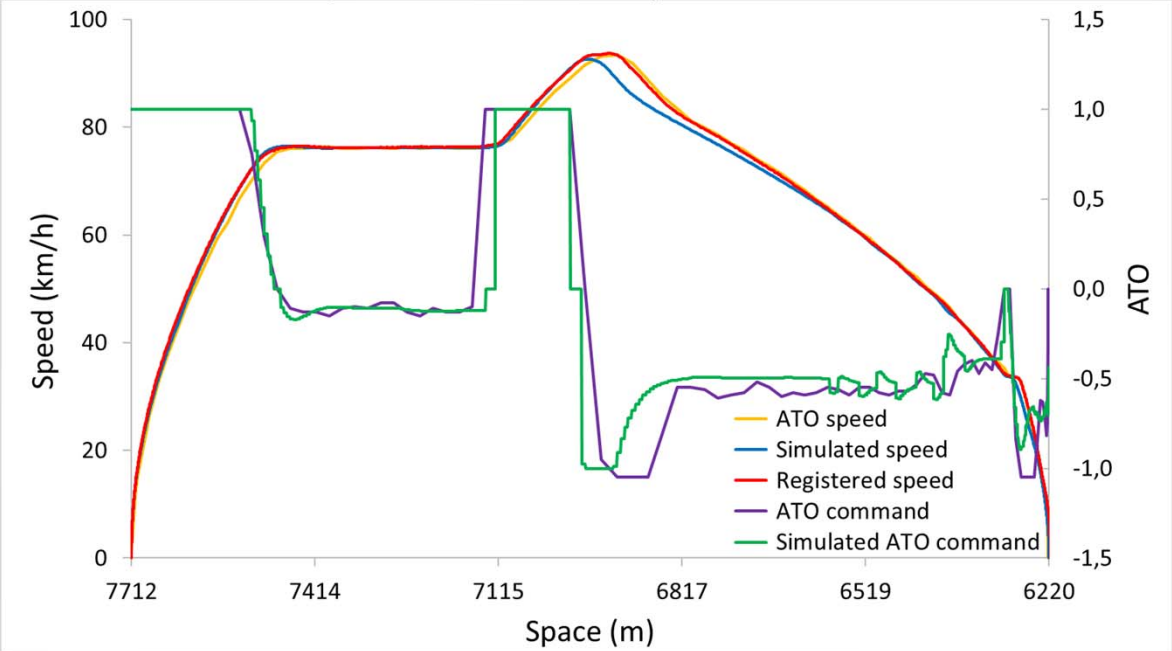
	Running time (s)	Time difference (s)	Electrical energy (kWh)	Error (%)
Registered	83,0		8,9	
Simulation	83,2	**0,2**	8,8	**0,6**

Energy flows: characterization of a set of trains during a typical journey

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

METRO DE MADRID

Reyes Católicos – Hospital Infanta Sofía



	Running time (s)	Time difference (s)	Electrical energy (kWh)	Error (%)
Registered	99,0		11,1	
Simulation	99,5	**0,5**	10,3	**6,8**

Ecodriving design in Metro de Madrid

Selection of constraints considered in the ecodriving optimization

✓Constraints considered for ecodriving in Metro de Madrid

- ATO parameters that can be configured in Siemens ATO equipment, Distance to Go signalling system
- Running time: the nominal (commercial) running time
- Comfort constraints: coast command cannot start at a ramp greater than 25mm. No more than 2 remotorings.
- Operational constraints: maximum speed limits, minimum speed limits at curves

✓**Line 10(B)**

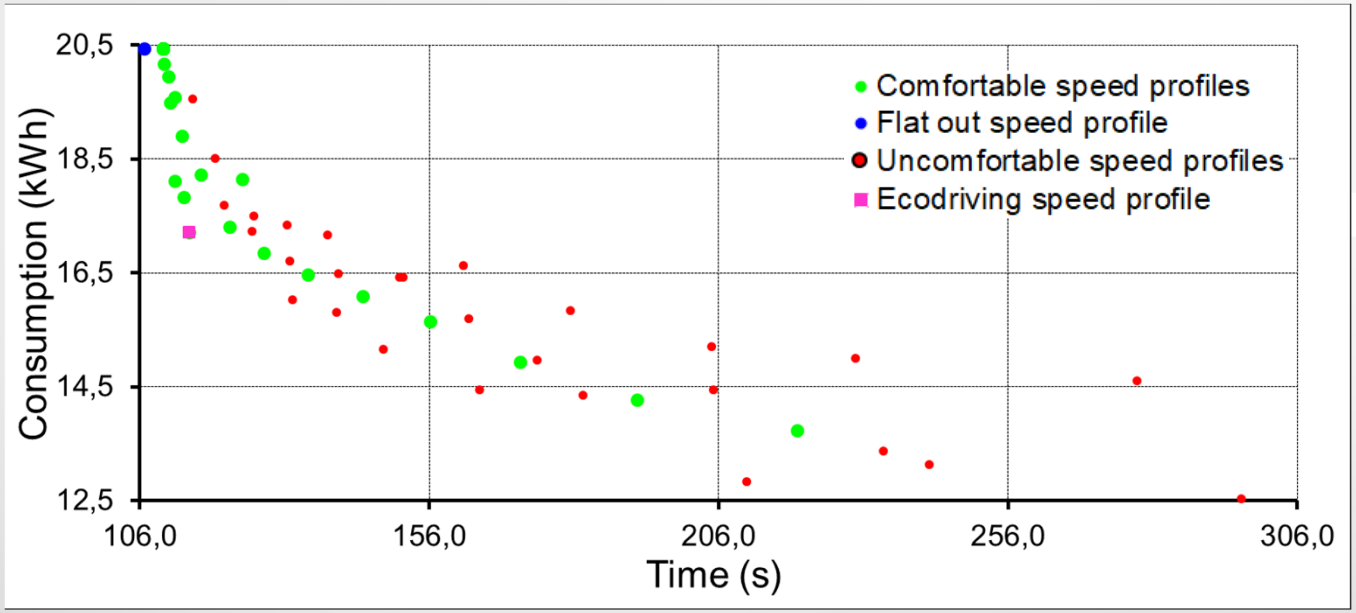
✓Interstations:

- Marqués de la Valdavia – Manuel de Falla
- Manuel de Falla – Baunatal
- Baunatal – Reyes Católicos
- Reyes Católicos – Hospital Infanta Sofía

Ecodriving design in Metro de Madrid

Speed profile optimization for minimizing the absorbed energy

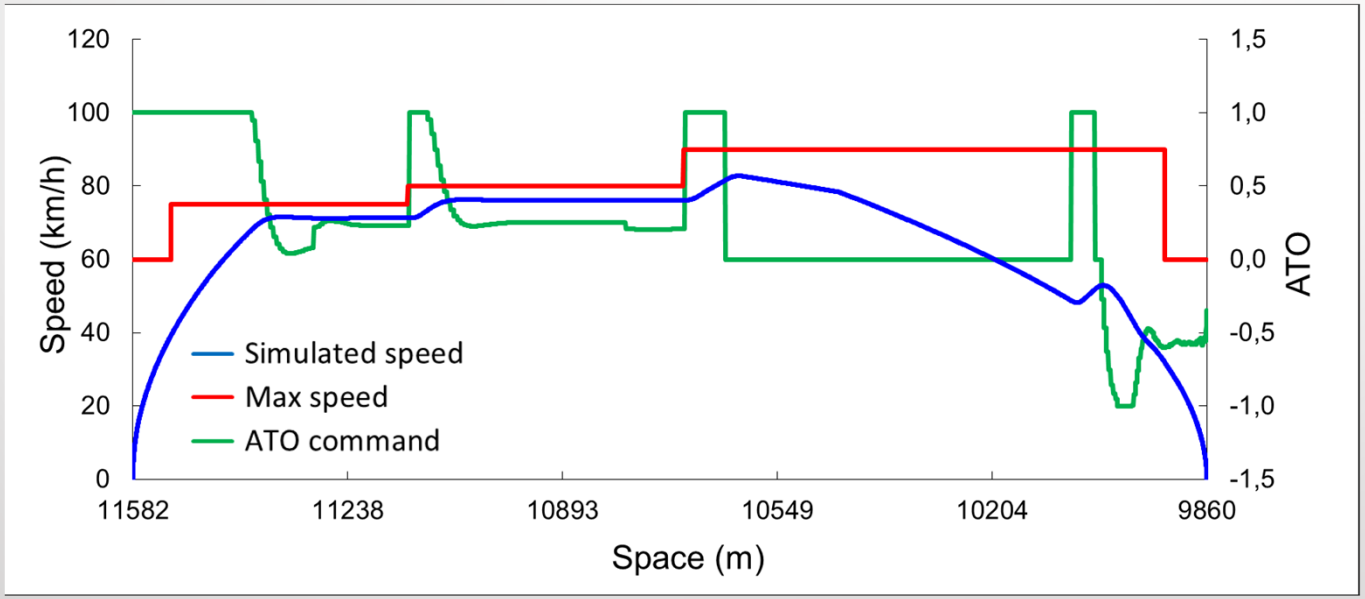
- Marqués de la Valdavia – Manuel de Falla



	Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)	Energy saving (%)
Flat out	0,75	0	0	0	106,8	20,45	
Ecodriving	0,6	0	80	30	114,4	17,22	**15,8**

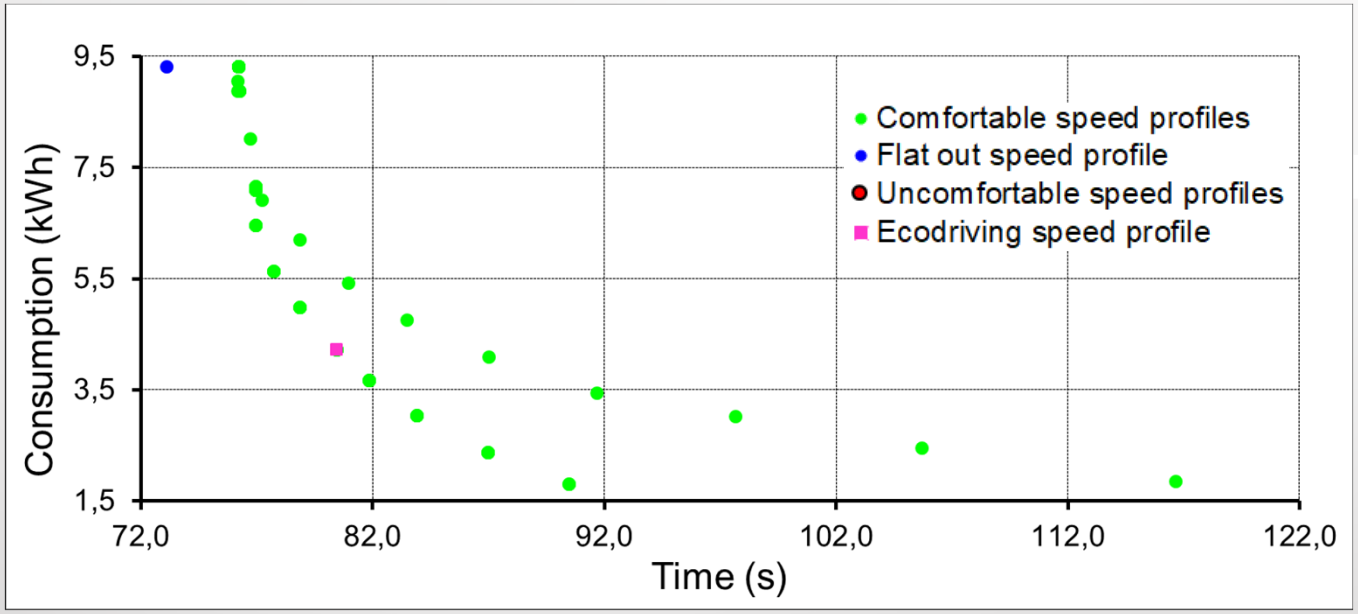
Ecodriving design in Metro de Madrid

- Marqués de la Valdavia – Manuel de Falla



Ecodriving design in Metro de Madrid

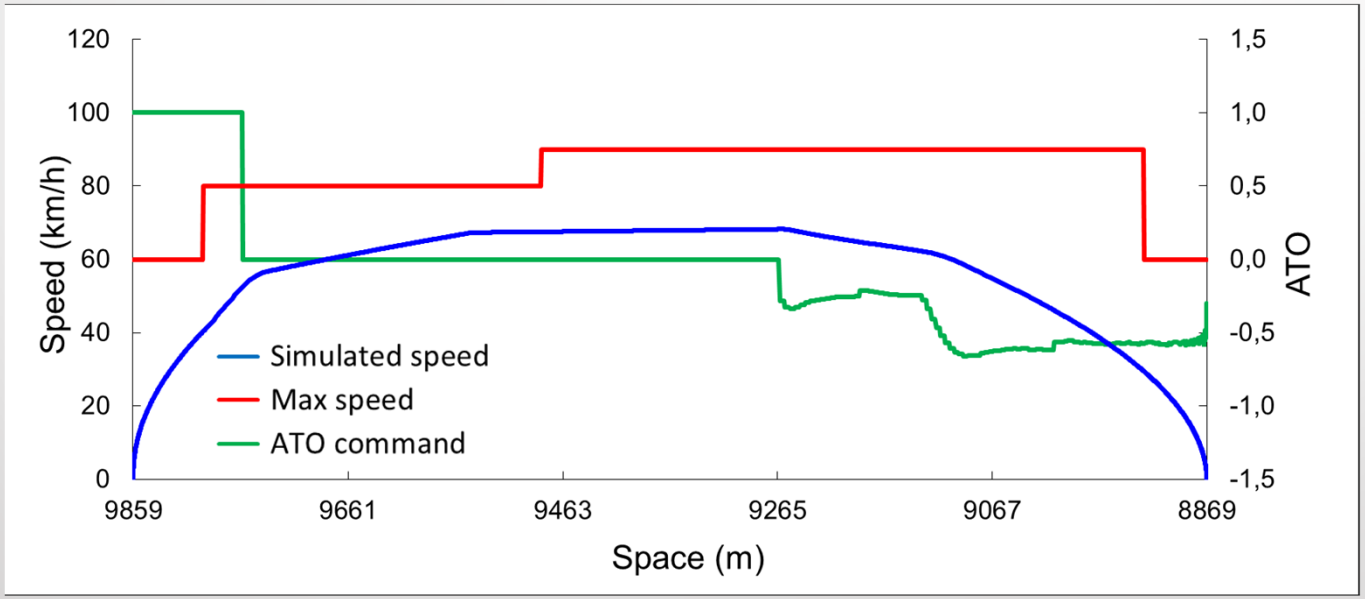
- Manuel de Falla – Baunatal



	Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)	Energy saving (%)
Flat out	0,75	0	0	0	73,1	9,31	
Ecodriving	0,6	0	50	10	80,4	4,23	**54,6**

Ecodriving design in Metro de Madrid

- Manuel de Falla – Baunatal



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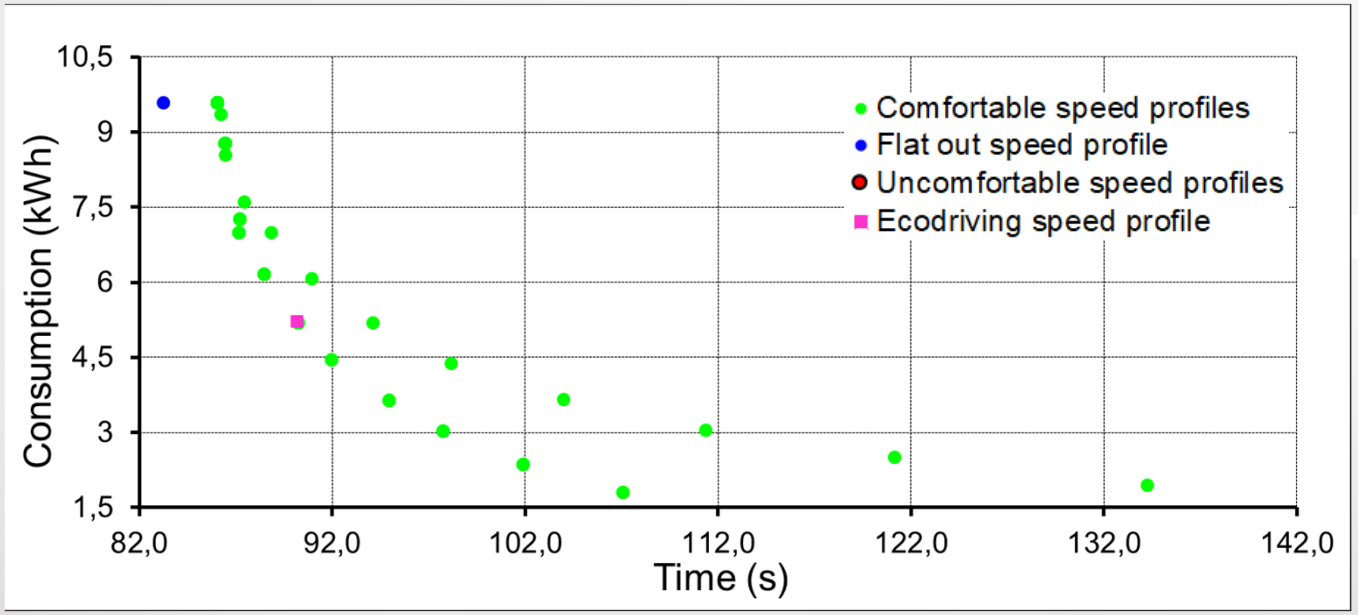
Ecodriving design in Metro de Madrid

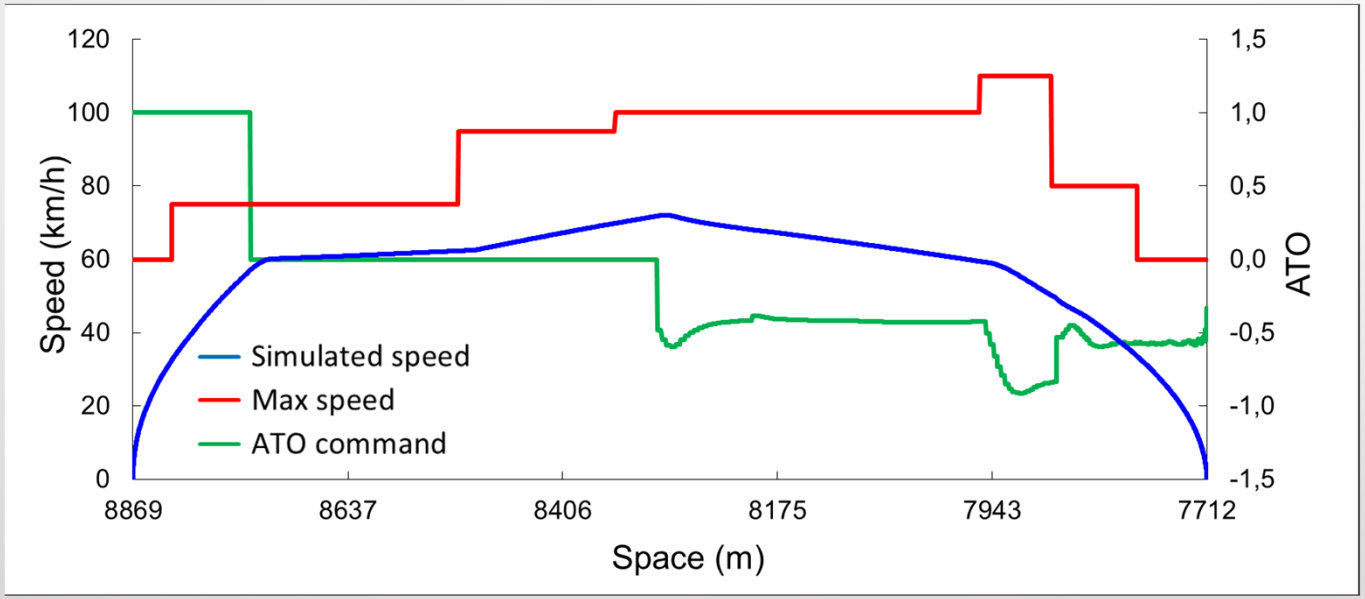
- Baunatal – Reyes Católicos



	Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)	Energy saving (%)
Flat out	0,75	0	0	0	83,2	9,60	
Ecodriving	0,6	0	55	10	90,2	5,21	**45,8**

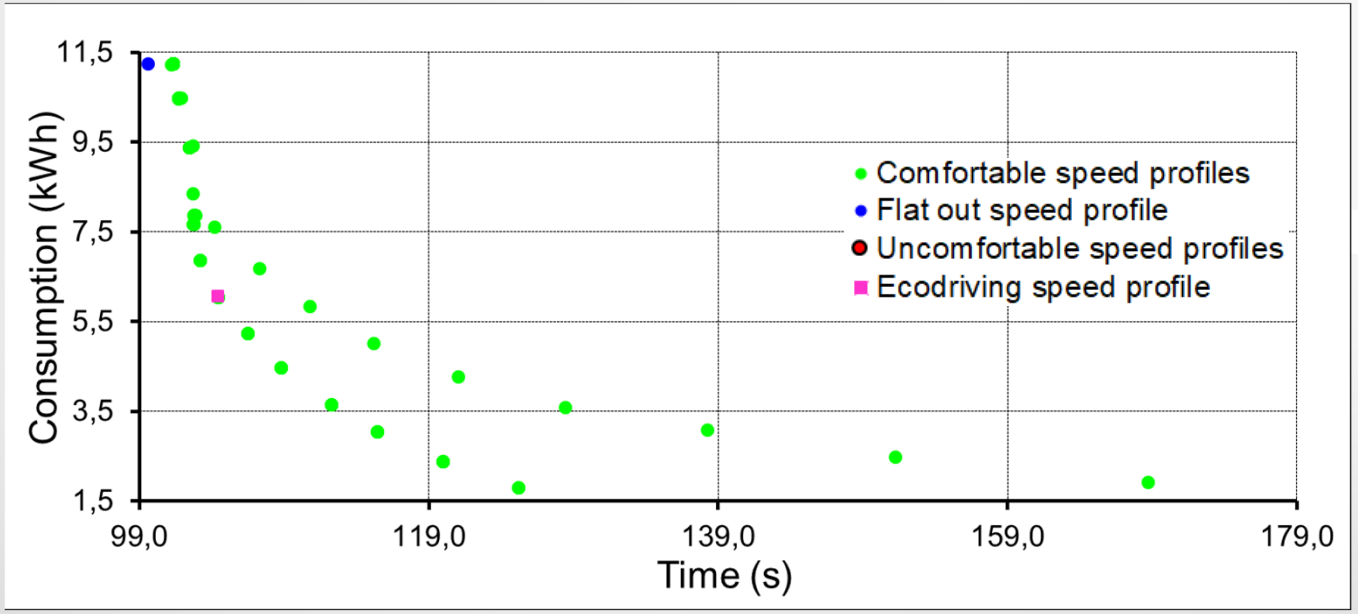
Ecodriving design in Metro de Madrid

- Baunatal – Reyes Católicos



Ecodriving design in Metro de Madrid

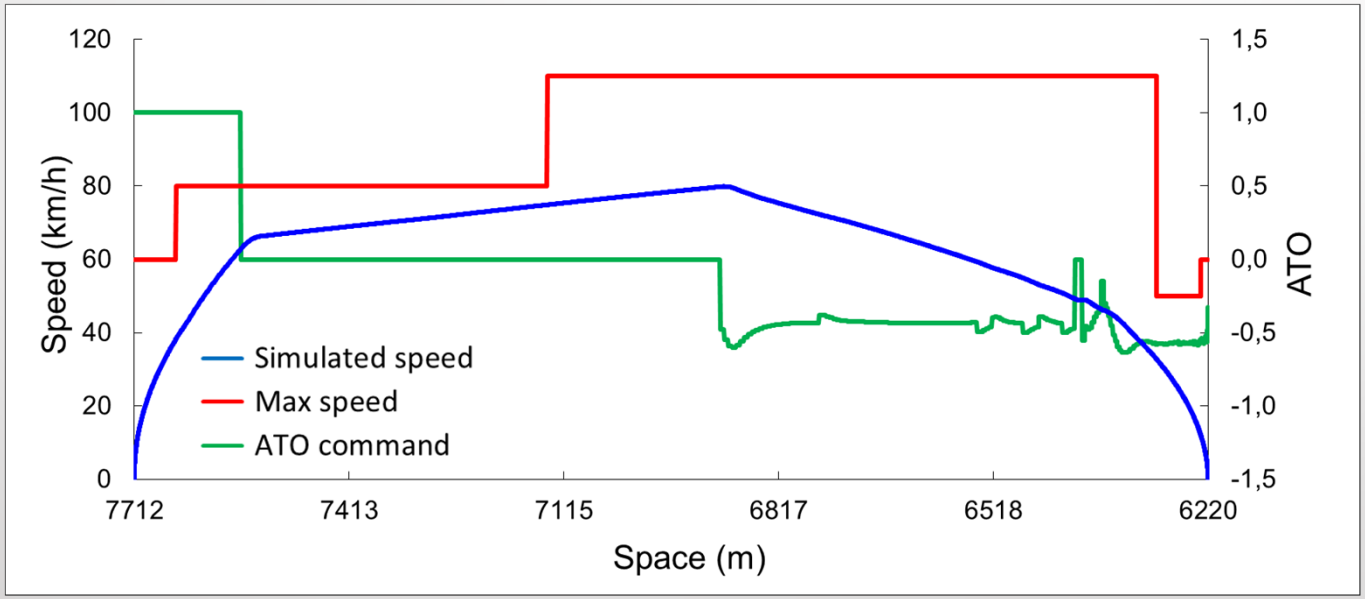
- Reyes Católicos – Hospital Reina Sofía



	Deceleration (m/s^2)	Regulation speed (km/h)	Coasting speed (km/h)	Remotoring speed (km/h)	Running time (s)	Consumption (kWh)	Energy saving (%)
Flat out	0,75	0	0	0	99,5	11,25	
Ecodriving	0,6	0	60	10	104,4	6,05	**46,2**

Ecodriving design in Metro de Madrid

- Reyes Católicos – Hospital Reina Sofía



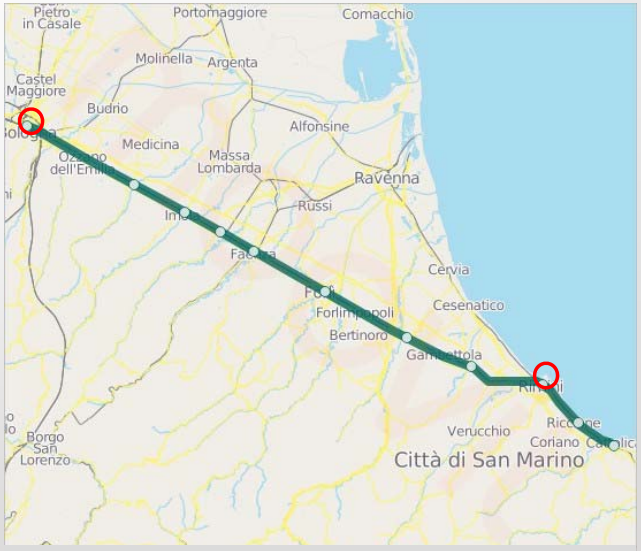
Ecodriving test cases in Italy: Bologna-Rimini

✓ Simulation of maximum journey speed profiles with Trenitalia train

✓ Selected line: **Bologna-Rimini**

✓ Track: slopes, curves, maximum speed limits (rango B)

✓ Train: locomotive E464 3000V, 5 coach Vivalto. Train Length (150 m), mass (350 Tm), running resistance, traction and brake curves have been considered.



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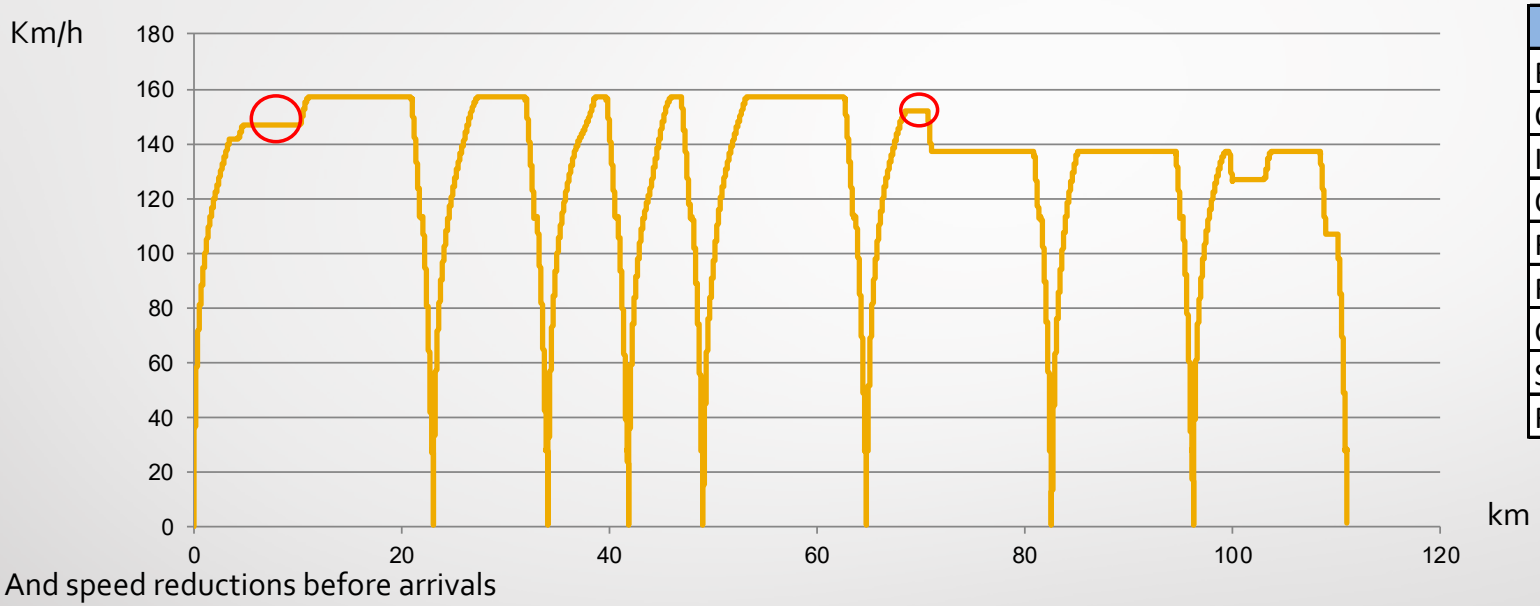
Ecodriving test cases in Italy: Bologna-Rimini

Flat out Comillas Simulation results Bologna-Rimini

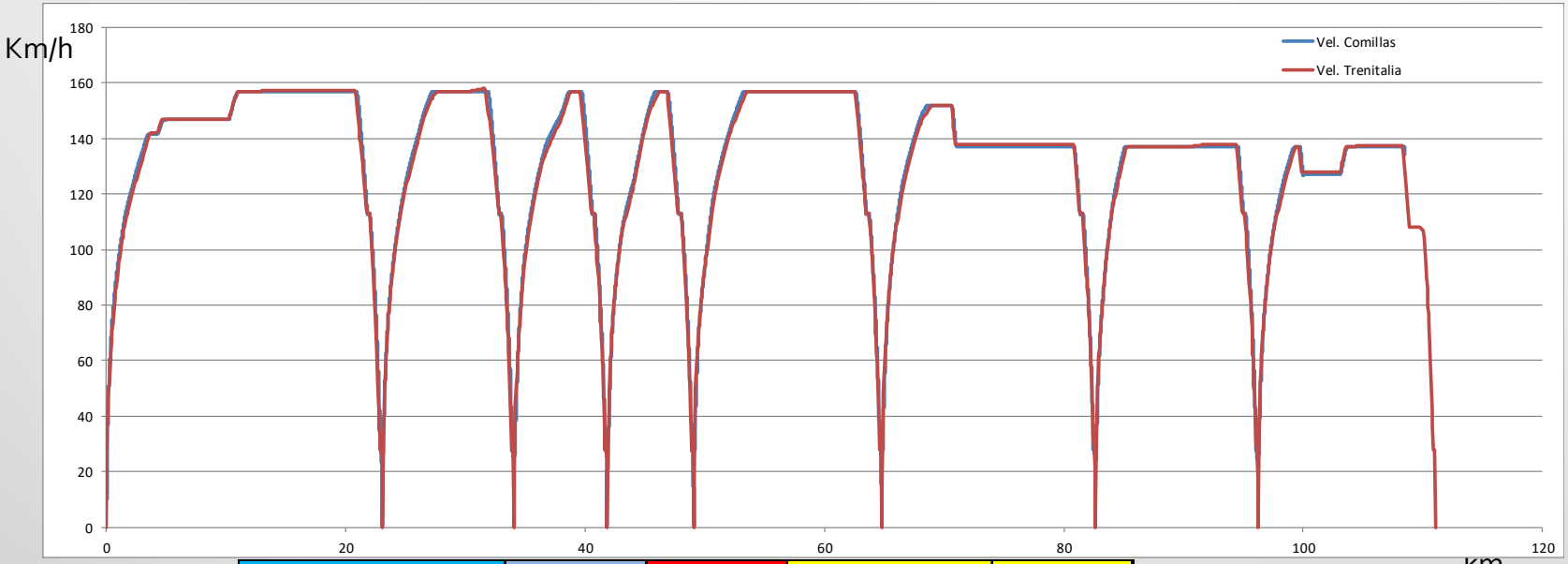


And speed reductions before arrivals

STOPS
Bologna
Cast.S.Pietro
Imola
Cast.Bolognese
Faenza
Forli
Cesena
Savignano
Rimini

Ecodriving test cases in Italy : Bologna-Rimini

Flat out Simulation Results Bologna-Rimini
Comparison Comillas - TRENITALIA simulations



SIMULATION COMPARISON	Comillas	Trenitalia	Difference	Diference %
running time (s)	3556,3	3612,0	55,7	1,5%
absorbed energy (KWh)	1498,2	1604,0	105,8	6,6%

Ecodriving test cases in Italy : Bologna-Rimini

Bologna-Rimini

17-4-2018

Trenitalia measurements campaign execution

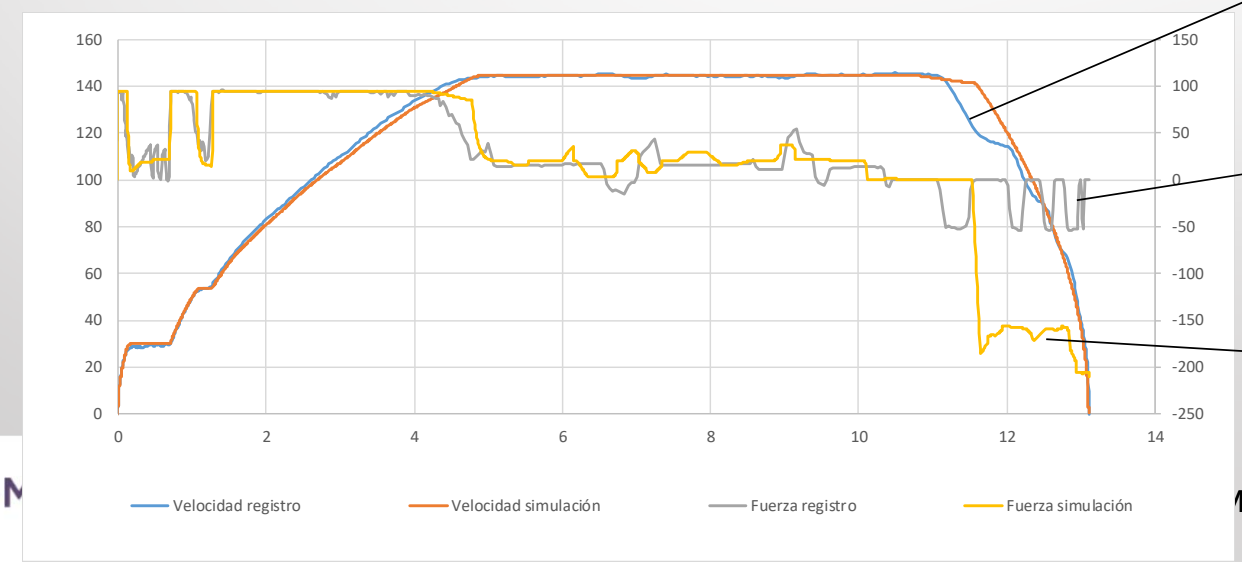
Field measurements data analysis

Numerical and experimental results comparison (in progress)

Trenitalia has recorded using the existing on-board measurement equipment (1s)

- A4.1.3 simulation was performed for flat-out driving, as well as Trenitalia simulation
- Field measurements are manual driving, some of them slower than flat-out
- Comillas simulation is modified to adapt the running time to the measurements
- Different STOPS than in A4.1.3. Between Bologna and Castel San Pietro: 2 more stops

Bolonia-Ozzano



Manual driving: speed reduction

Electrical braking effort

Total braking effort

Ecodriving test cases in Italy : Bologna-Rimini

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

Bologna-Rimini

Considerations:

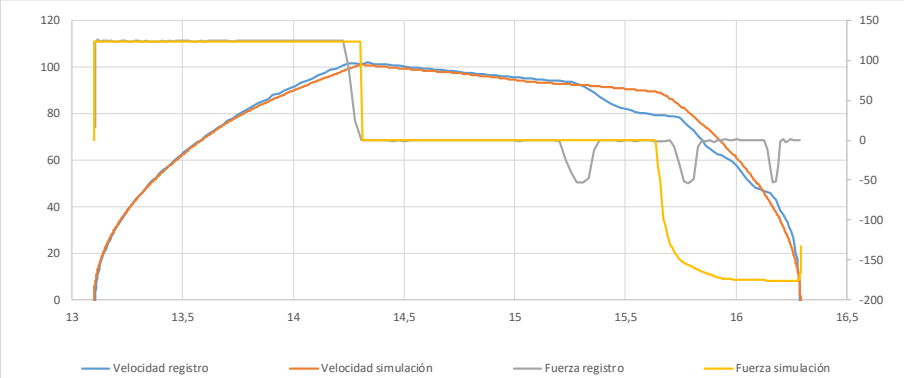
- There is no separate measurement for auxiliary systems consumption.
- Efficiency ratio of the motor. It is assumed to be constant (approach)
- Mass is assumed as constant. If measurements were recorded during commercial service, mass would be not constant
- Manual driving is not systematic (especially braking)

		Measurements		Simulation		Differences		
		Time(s)	Energy consumption. gross (kWh)	Time(s)	Energy consumption. gross (kWh)	Time (s)	Time (%)	Energy consumption. gross (%)
Bolonia	Ozzano	521	160,1349042	521	171,885	0	0,00%	7,34%
Ozzano	Varignana	185	52,17493334	183	51,18	2	-1,08%	-1,91%
Varignana	Castel S. Pietro	274	125,1284794	267,5	135,008	6,5	-2,37%	7,90%
Castel S. Pietro	Imola	INCORRECT						
Imola	Castel Bolognese	305	129,3766578	302,75	136,332	2,25	-0,74%	5,38%
Castel Bolognese	Faenza	342	120,4906977	331,75	114,965	10,25	-3,00%	-4,59%
Faenza	Forli	708	160,0291333	701,5	167,871	6,5	-0,92%	4,90%
Forli	Cesena	571	194,9232069	569,5	209,42	1,5	-0,26%	7,44%
Cesena	Savignano	444	132,5838878	441,25	154,236	2,75	-0,62%	16,33%
Savignano	Rimini	562	112,3913799	558,25	121,492	3,75	-0,67%	8,10%
Total		3912	1187,23328	3876,5	1262,389	35,5	-0,91%	6,33%

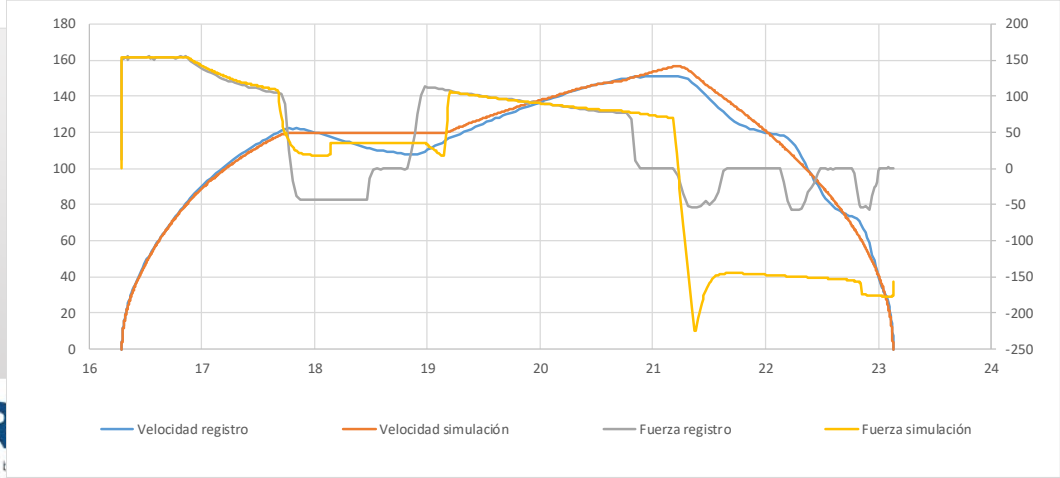
Ecodriving test cases: Bologna-Rimini

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

Ozzano-Varignana



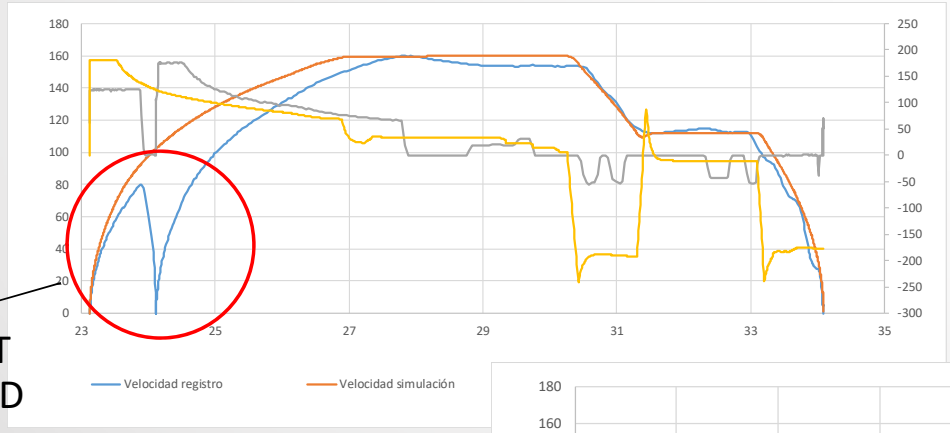
Varignana-Cast.S.Pietro



Ecodriving test cases: Bologna-Rimini

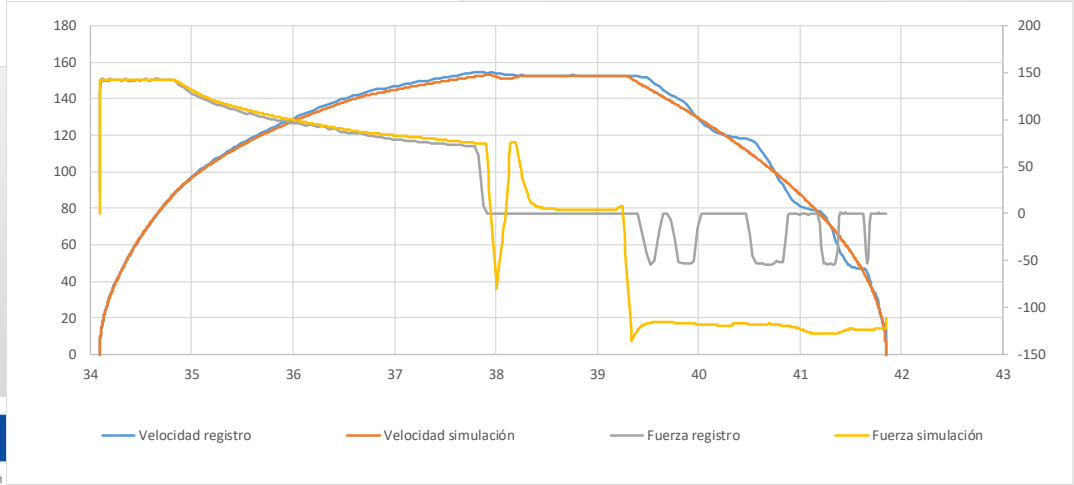
Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

Cast.S.Pietro-Imola



NOT VALID

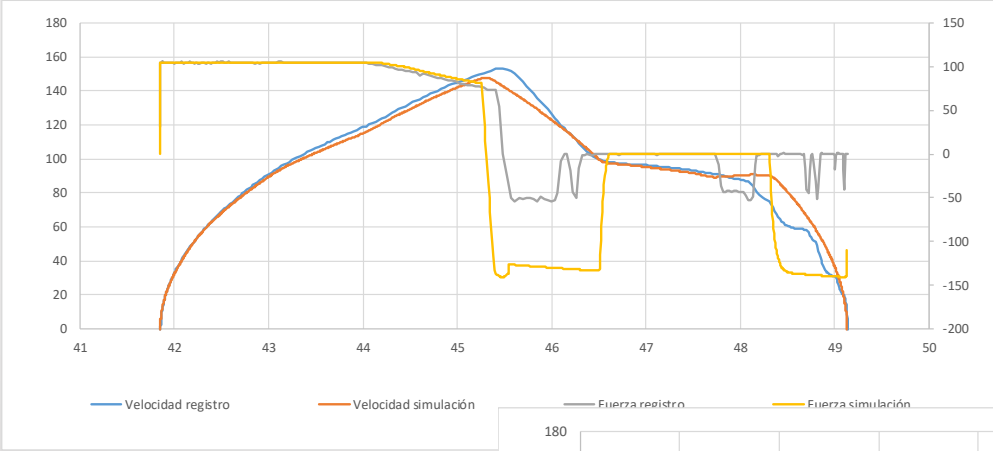
Imola-Cast.Bolognese



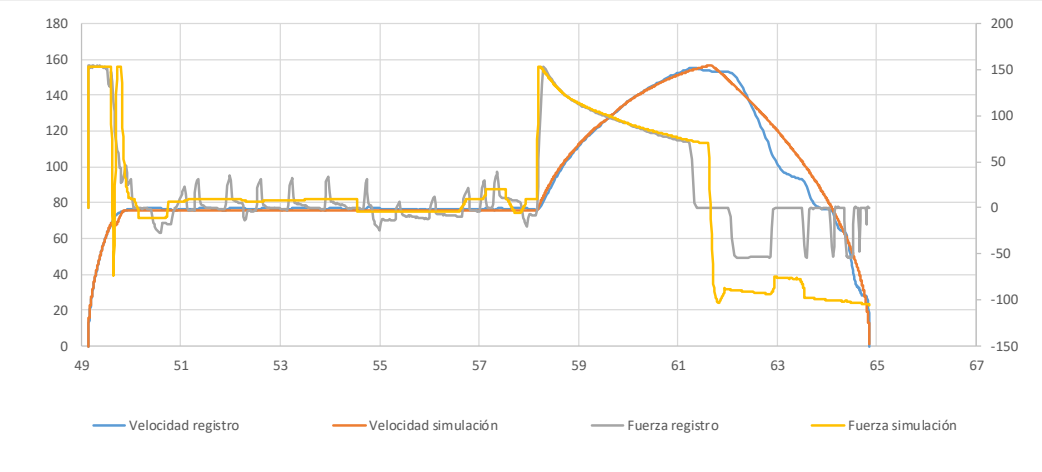
Ecodriving test cases: Bologna-Rimini

A4.2.3 Measurements campaign execution
A4.2.4 Field measurements data analysis
A4.2.6 Numerical and experimental results comparison (in progress)

Cast.Bolognese-Faenza



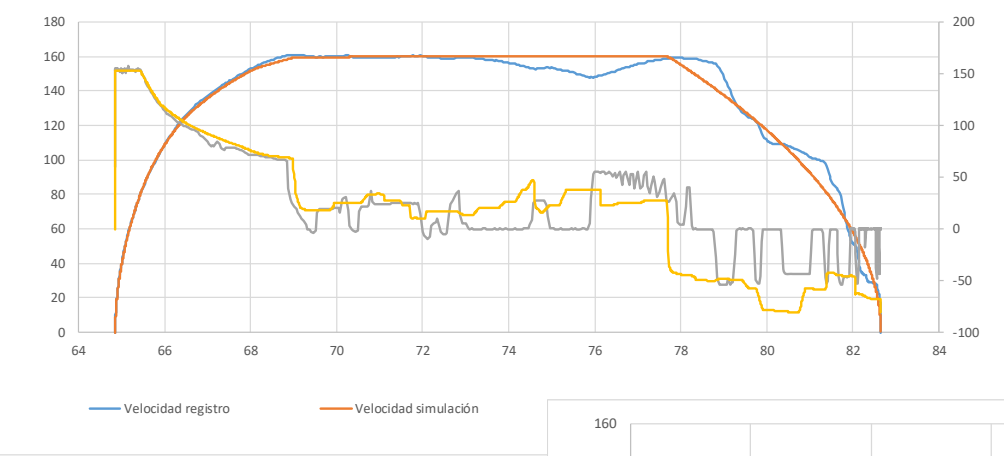
Faenza-Forli



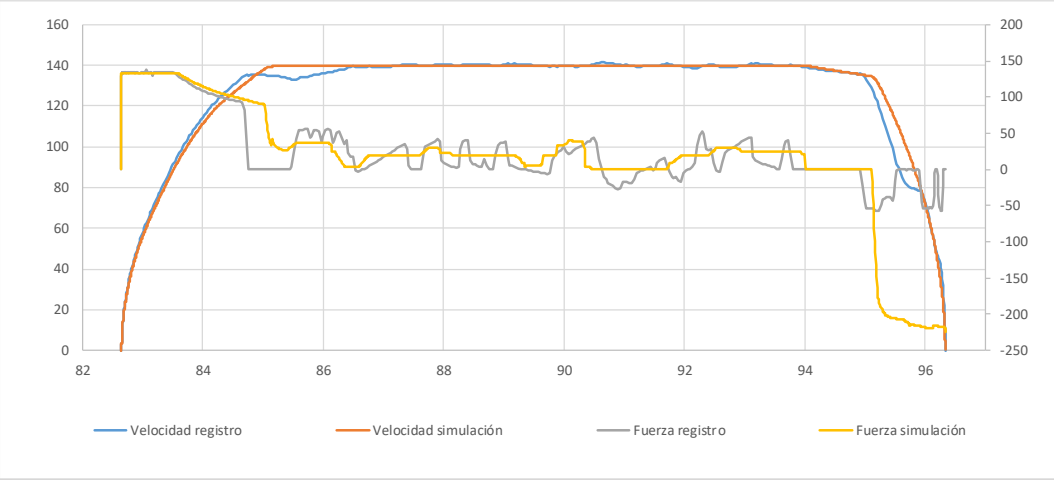
Ecodriving test cases: Bologna-Rimini

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

Forli-Cesena



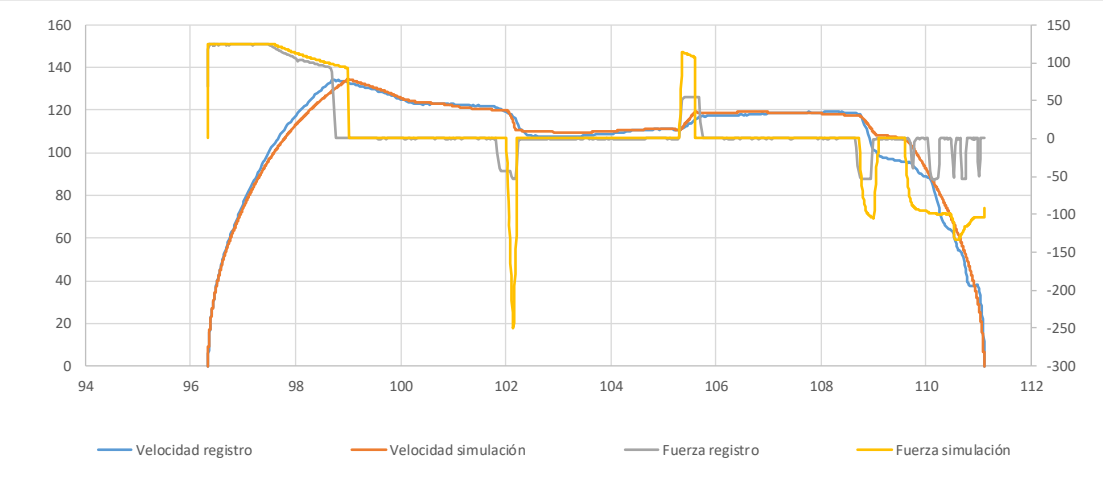
Cesena-Savignano



Ecodriving test cases: Bologna-Rimini

Measurements campaign execution
Field measurements data analysis
Numerical and experimental results comparison (in progress)

Savignano-Rimini

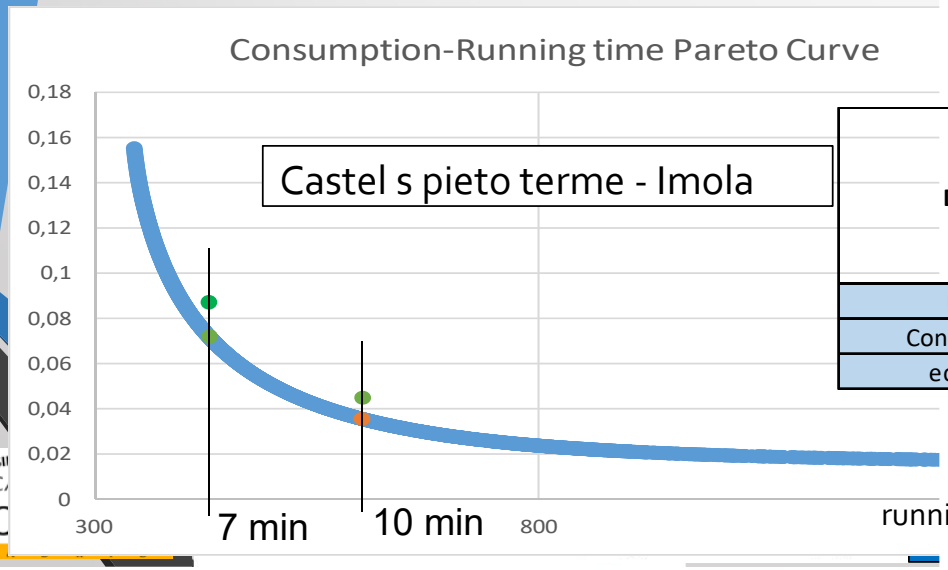


Ecodriving design in Italy : Bologna-Rimini

Selection of constraints considered in the ecodriving optimization

✓Proposal of Constraints for ecodriving in Bologna-Rimini

- Target running time: the reference one plus a margin time
- Commands: Speed regulation without braking, coast
- Operational constraints: maximum speed limits (green signals)
- Comfort constraints: jerk, acceleration and deceleration limits



Example to show the importance of ecodriving design
Comparison constant speed vs ecodriving

DESIGN 1	Running Time	Consumption (KWh)	Savings compared to flat-out	Savings compared ecodriving vs constant speed
Flat-out	0:05:45	155,7		
Constant speed	0:10:00	45,4	70,9%	
eco-driving	0:10:00	36,0	76,9%	20,6%

70 km/h

Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

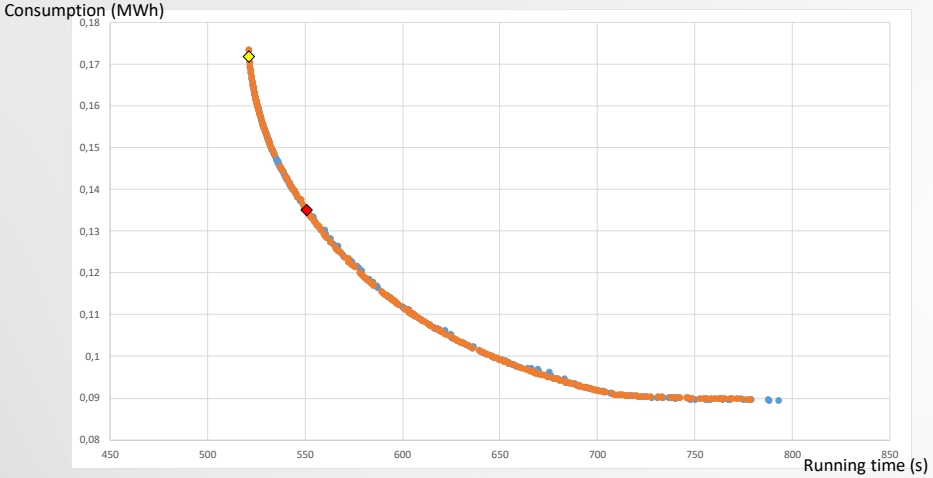
Having as a reference the Bologna-Rimini measurements

Bologna-Rimini

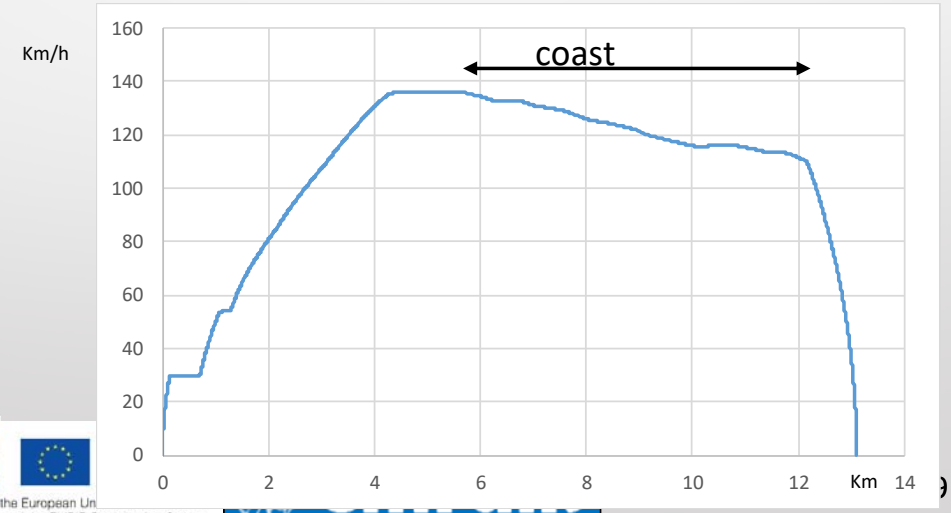
Departure station	Typical (measurements)		ECODRIVING (simulation)		SAVINGS	time difference (s)
	time (s)	consum. (KWh)	time (s)	consum. (KWh)		
Bologna	521	171,9	551	135,0	21%	30
Ozzano	183	51,2	194	41,0	20%	11
Varignana	267	135,0	278	92,0	32%	11
Castel S. Pietro	XX					
Imola	303	136,3	323	91,0	33%	21
Castel Bolognese	332	114,9	351	66,8	42%	19
Faenza	701	167,8	731	109,2	35%	30
Forlì	569	209,4	599	162,9	22%	30
Cesena	441	154,2	472	119,6	22%	31
Savignano	558	121,5	588	98,2	19%	30
	TOTAL	1262,2		915,8	27%	

Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

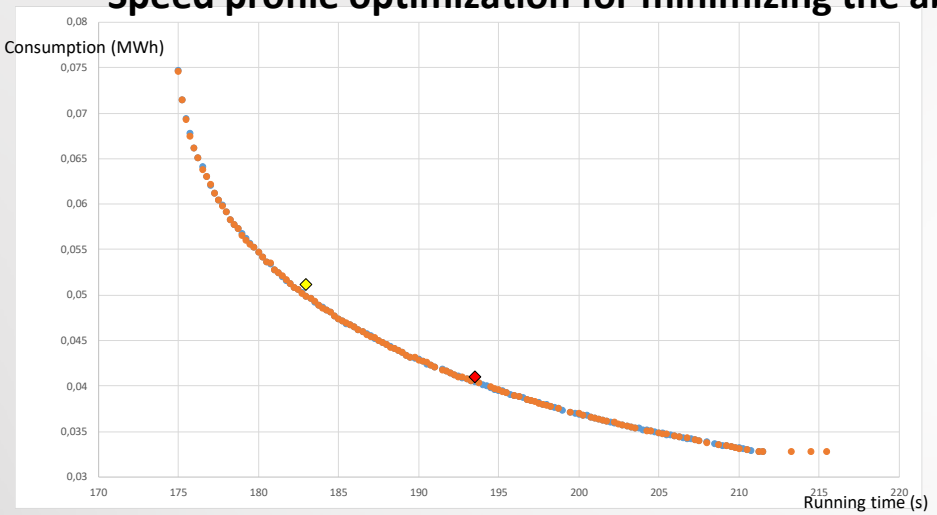


Bologna-Ozzano

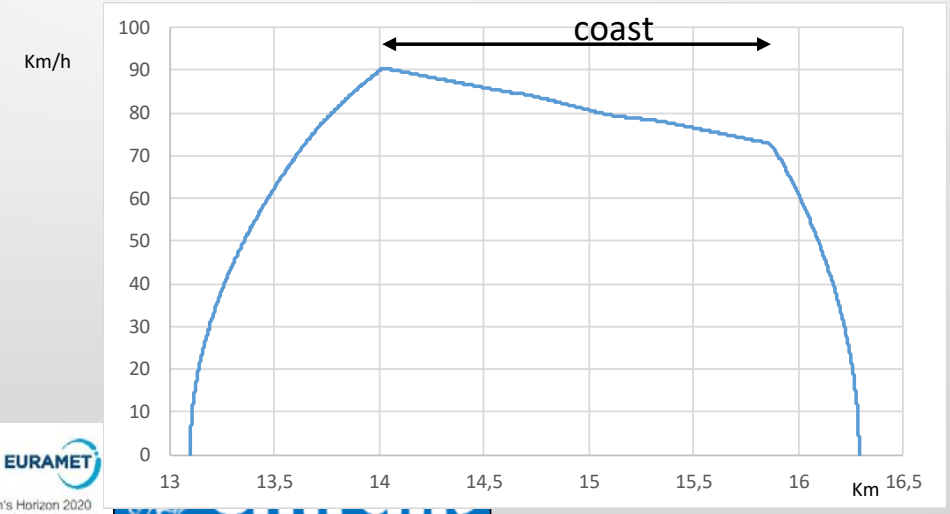


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

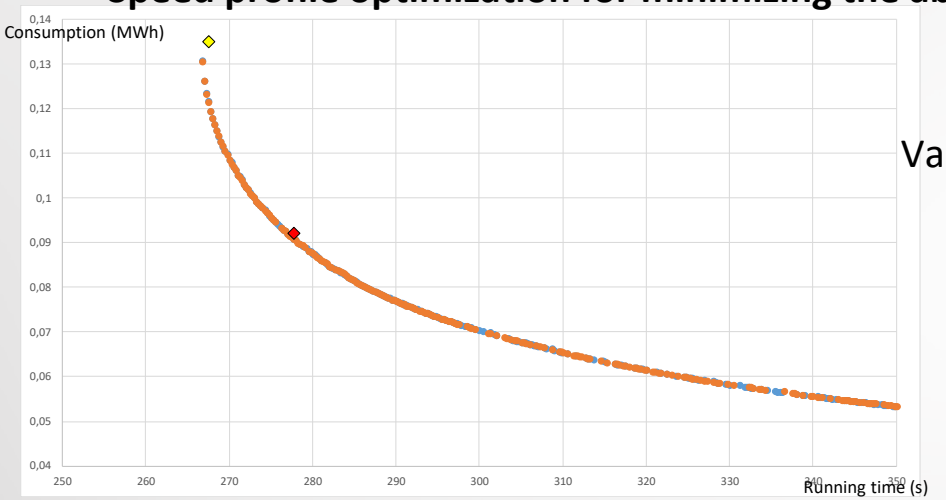


Ozzano-Varignana

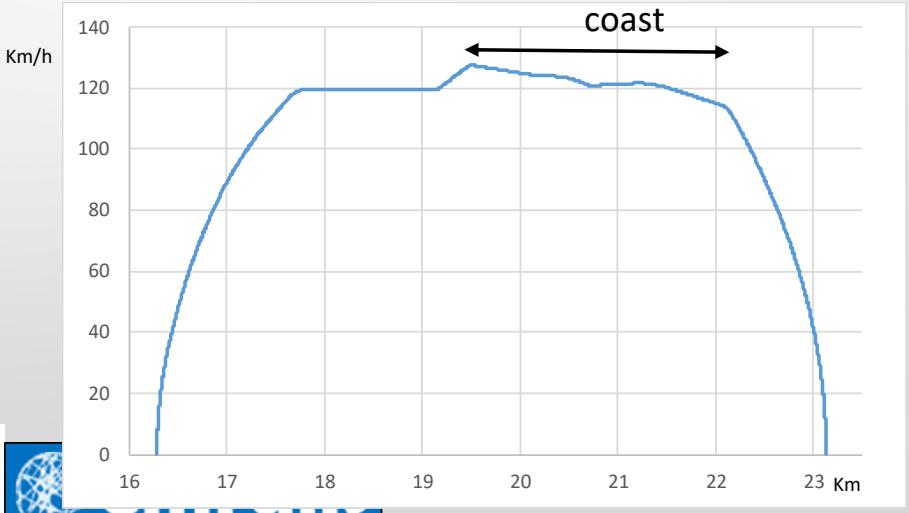


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

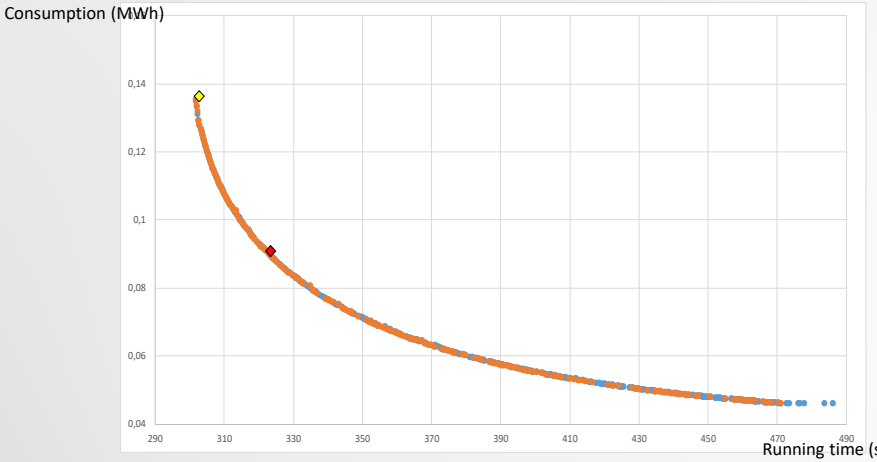


Varignana-Cast.S.Pietro

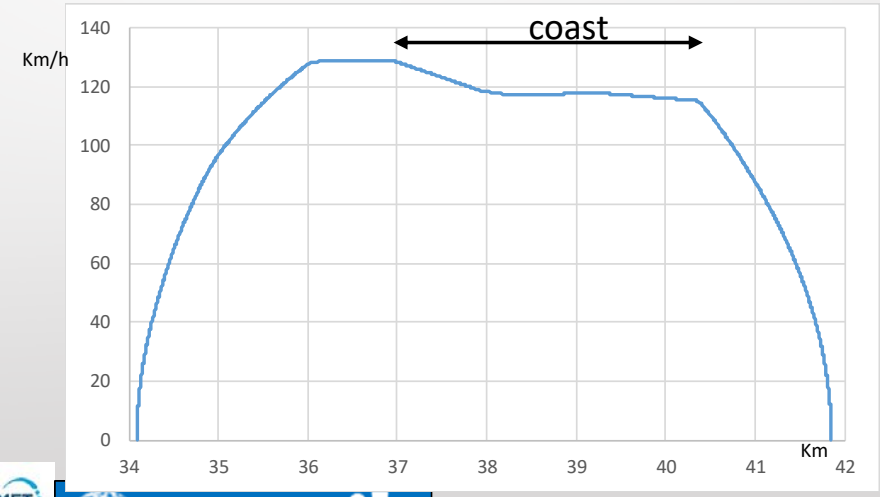


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

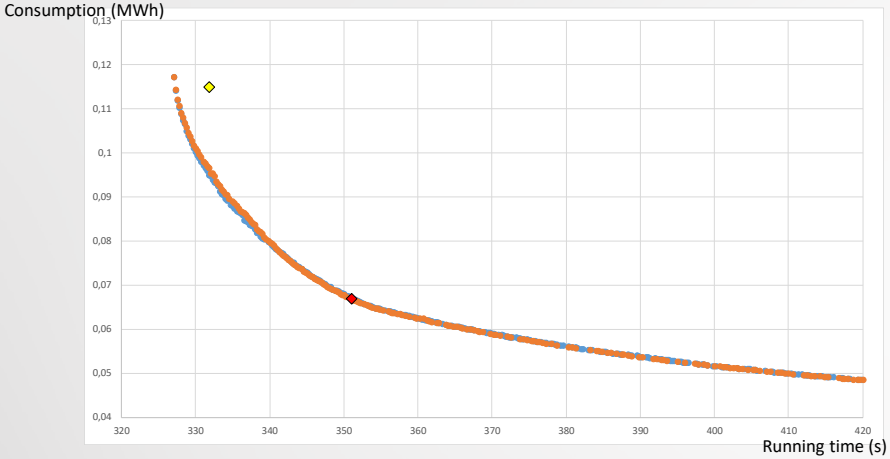


Imola-Cast.Bolognese

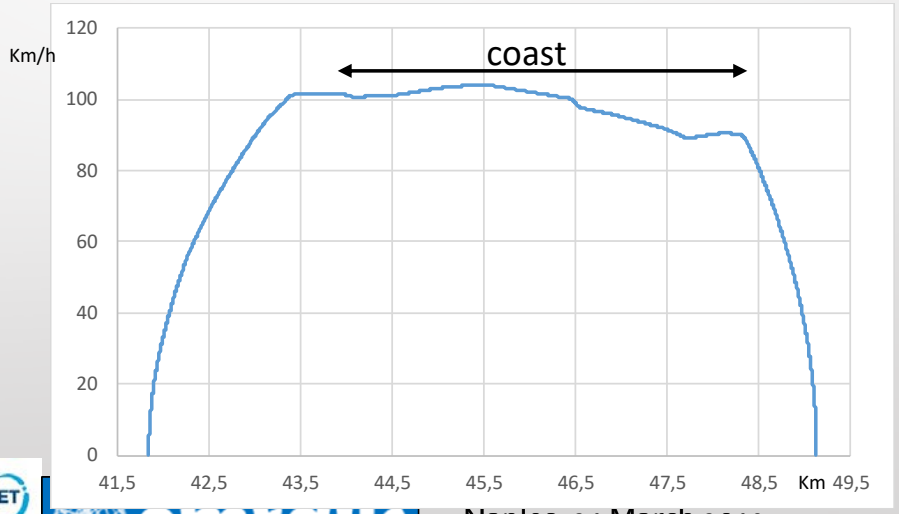


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

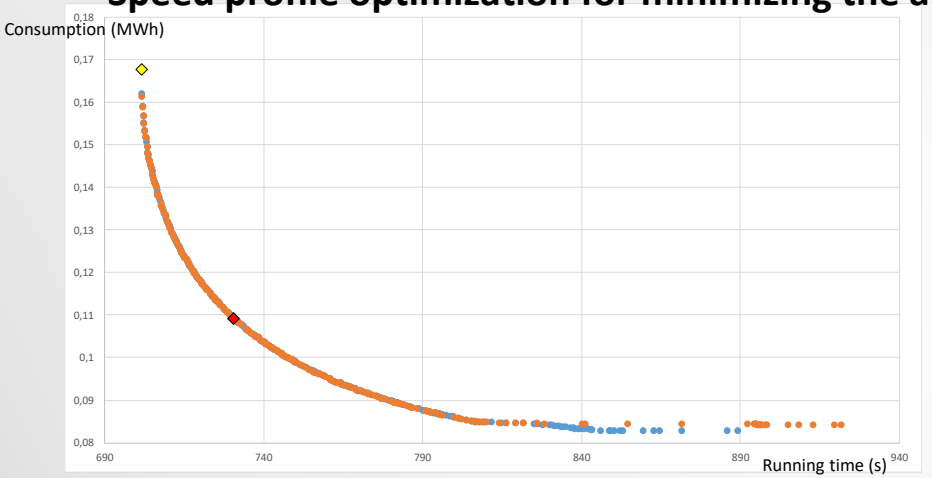


Cast.Bolognese-Faenza

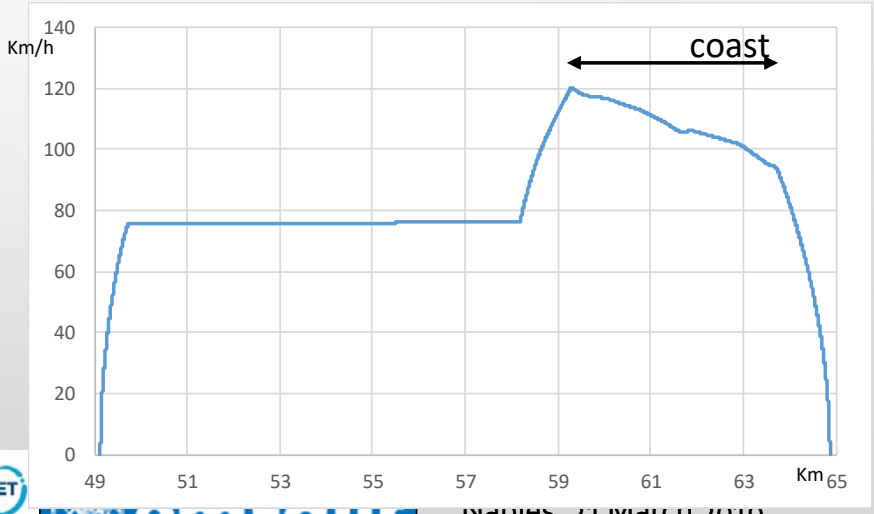


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

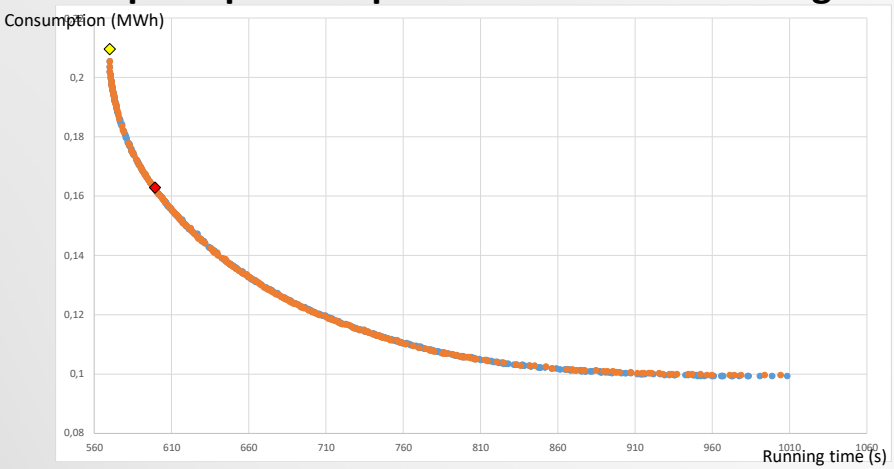


Faenza-Forli

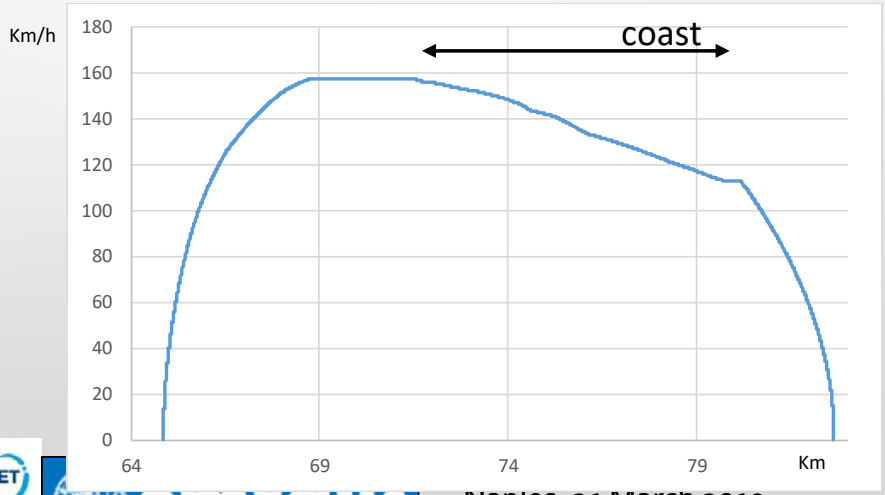


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

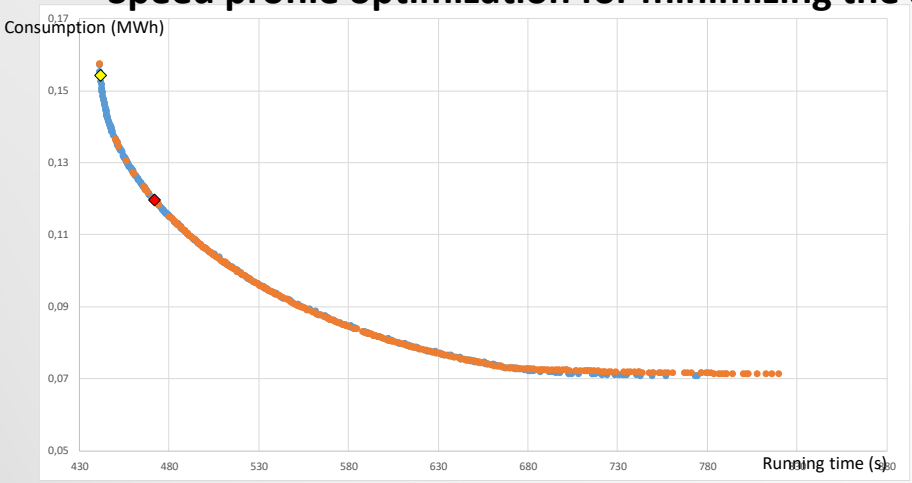


Forli-Cesena

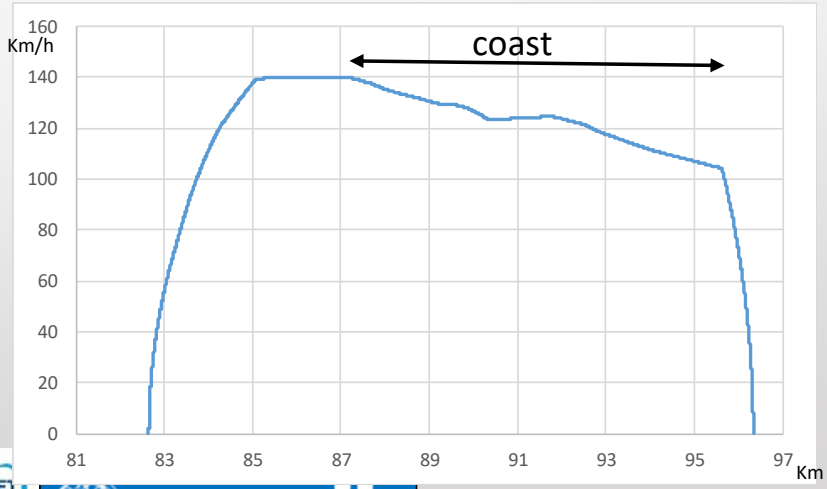


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy

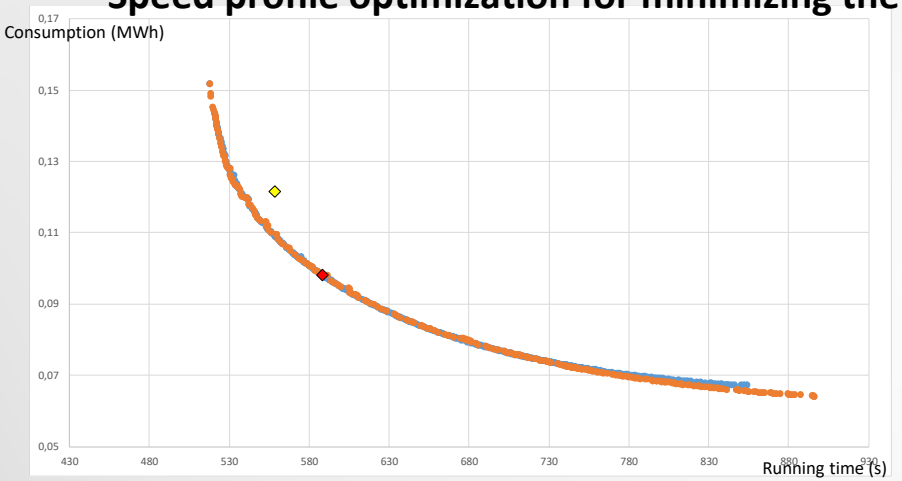


Cesena-Savignano

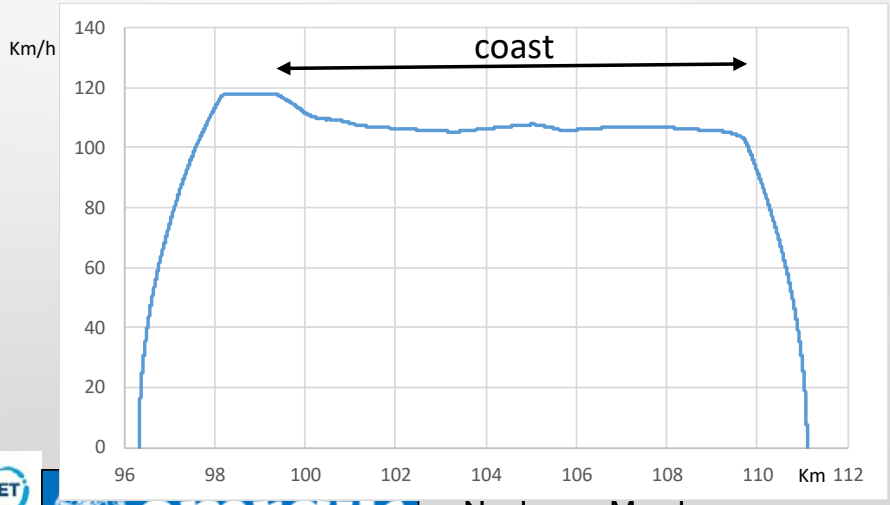


Ecodriving design: Bologna-Rimini

Speed profile optimization for minimizing the absorbed energy



Savignano-Rimini



Thank you
Questions?

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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States