# Driving style influence on car $CO_2$ emissions

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# Introduction

- Driving style is one of the most significant among factors in the environmental impact of a vehicle
- CTL measured differences up to 40% between drivers driving the same car on the same route
- In the past two decades a new driving style, called eco-driving, has been developed in some European countries to guarantee maximum driving efficiency
- The basic rules of eco-driving were summarized by European project ECODRIVEN (2006-08, from FP7) and are still on updating in current ECOWILL project

# Main concepts of eco-driving

1. Adopt an anticipatory driving style avoiding unnecessary accelerations and braking. These situations are the ones, into a driving cycle, consuming more fuel.
2. Use the engine as efficiently as possible. As the engine efficiency increases with the engine load and the internal friction loss decreases with decreasing the engine speed, the combination of high loads and low engine speeds allows to spend less fuel for the same power supplied by the engine.

# Basic rules of eco-driving from Ecodriven project

1. Shift up early, approximately between 2000 and 2500 RPM.
2. Maintain a steady speed.
3. Drive smoothly using the highest possible gear at low RPM, applying, if needed, high engine loads.
4. Anticipate traffic flow avoiding useless acceleration and braking.
5. Decelerate gradually releasing the throttle in time and leaving the gear engaged. Use of cut-off mode of the engine.

# Eco-driving and driving style evaluation: state of the art (1/2)

- Over the years some studies have been performed to evaluate Ecodriving effectiveness and driving style differences.
- They evaluated Ecodriving efficiency by analyzing driving behavior before and after Ecodriving training or else Ecodriving efficiency with fixed driving cycle on a chassis dynamometer or simply evaluated differences among different drivers in terms of fuel consumption.
- Literature studies show an average reduction in fuel consumption and $CO_2$ emissions of 10% to 15% when Ecodriving is adopted.

# Ecodriving and driving style evaluation: state of the art (2/2)

- All these studies stated the efficiency of eco-driving or which of the monitored drivers got the best results in terms of fuel economy but in general they were not able to state if such an efficiency or such a result in terms of fuel consumption only depended on the driving style.
- It is not a simple issue to state precisely the driver influence on fuel consumption independently from other factors as car, route (urban, extra urban, highway), traffic level and some others.

# CTL driving style evaluation methodology

- In this work has been developed a methodology to assess and quantify the influence of the driver on the vehicle's fuel consumption independently from other factors as car type, route ambit and traffic level.
- CTL has developed an algorithm to quantify the influence of the driving style on fuel consumption comparing the driver behaviour with that of an ideal driver following the Ecodriving rules.

# How the algorithm works

1. It takes a real driving cycle.
2. It modifies the real driving cycle according to the eco-driving rules utilizing a vehicle motion model.
3. It computes the fuel consumption (and therefore the CO2 emissions) of the modified cycle (that is the minimum ideal fuel consumption obtainable following the eco-driving rules).
4. It calculates the Ecoindex that is the ratio between the fuel consumption of the modified cycle and the fuel consumption of the real cycle.

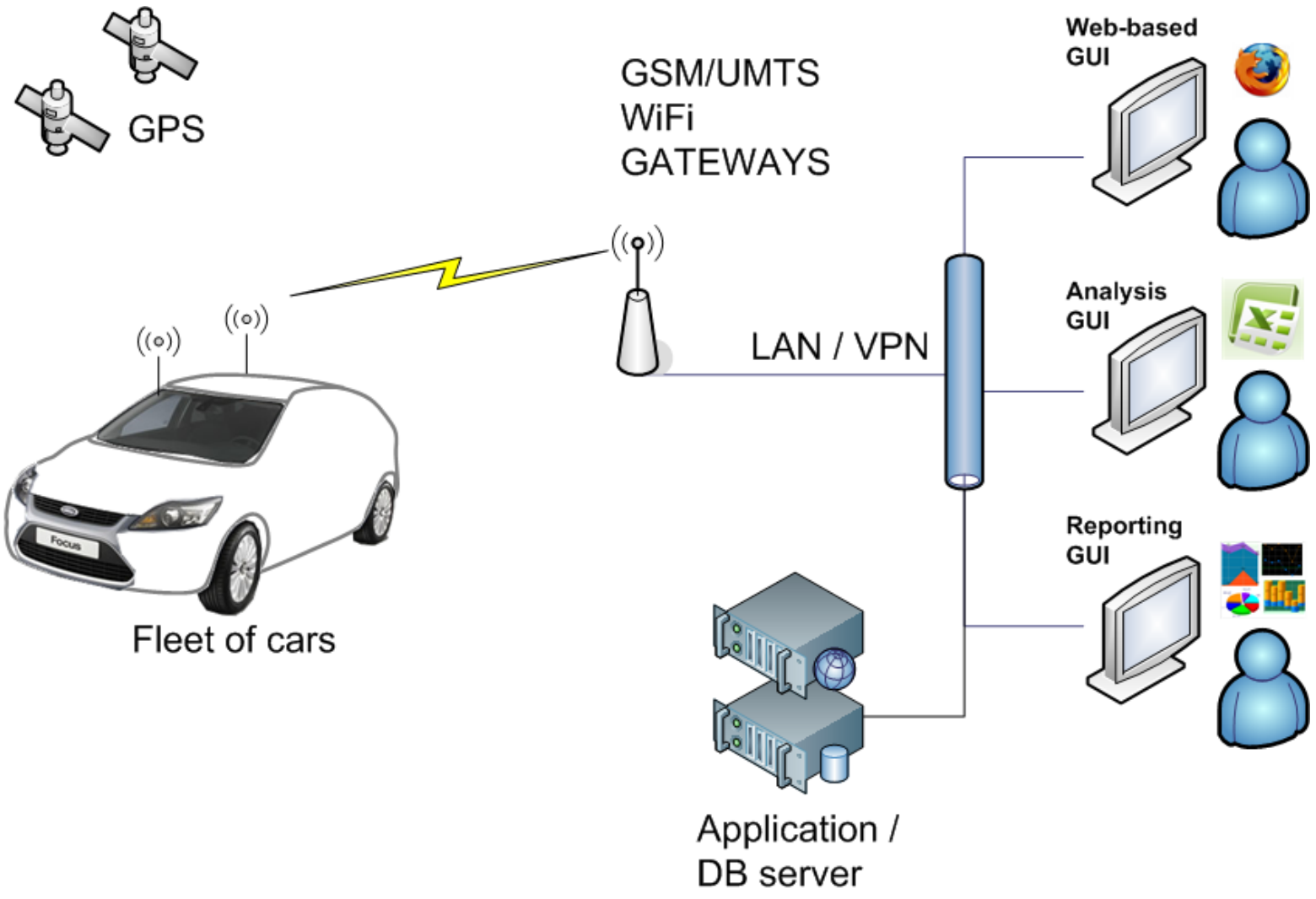
# The constraints for the modification process

- Same number of stops and local minima of the original speed diagram and same spatial position (respecting these constraints allows to generate a modified cycle theoretically coming from the same “environment” of the original).
- Every local minimum of the speed-distance plot has to be reached in the most efficient way (getting there leaving the accelerator in time and the gear engaged).
- Every instantaneous working condition of the engine has been recalculated in order to respect the suggested limits of engine speed (2000-2500 RPM).
- The total trip time has to be the same as the original.

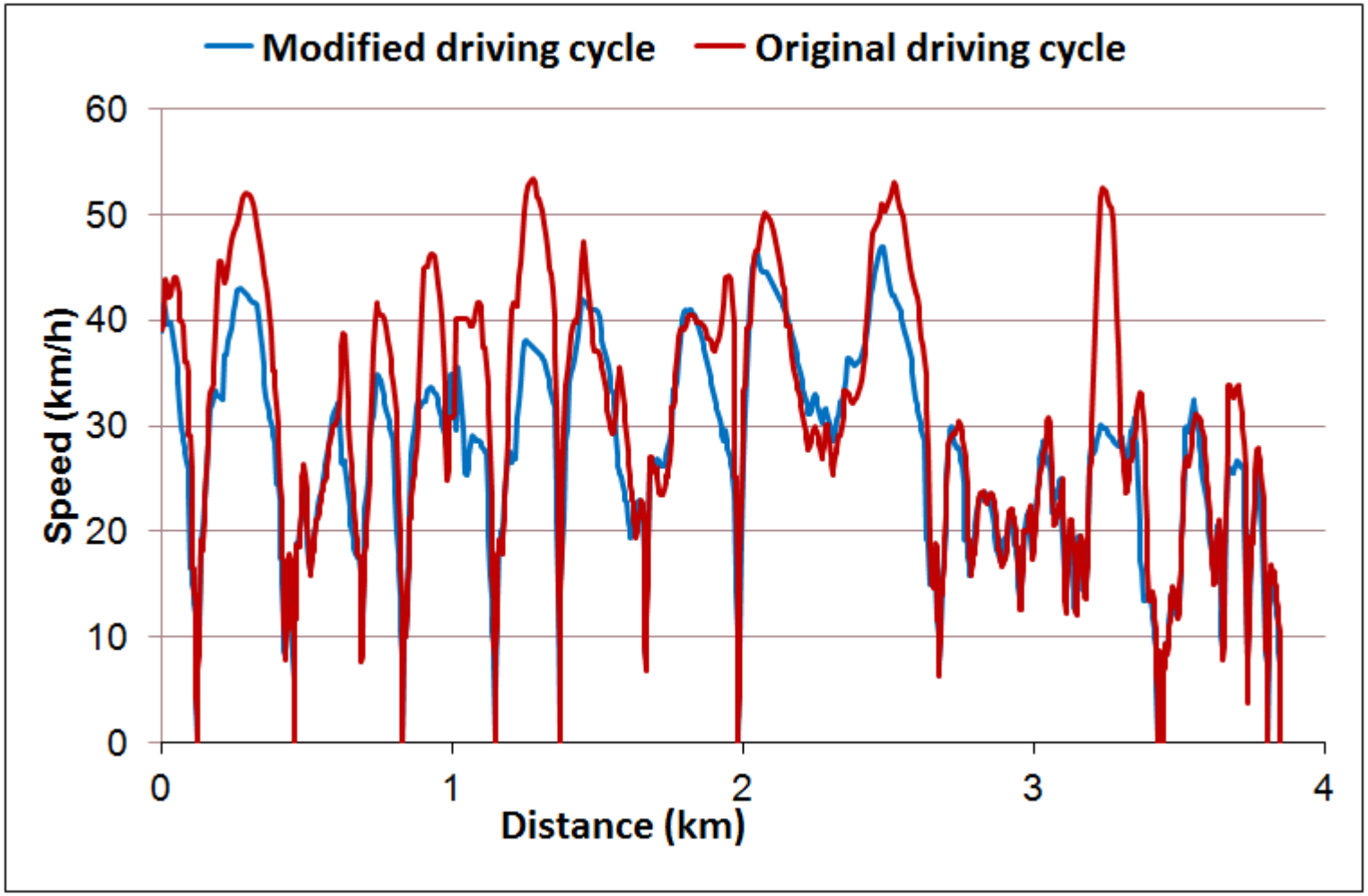
# The on-road acquisition campaign

- The algorithm has been applied on a large on-road campaign.
- It has been made within “PEGASUS” research Project.
- 10 rental vehicles monitored: 4 from Rome car-sharing and 6 from AVIS car-rental.
- 120.000 km collected (from April to December 2010).
- 278 different drivers monitored.
- Instantaneous vehicle and engine parameters, fuel consumption and emissions were collected and aggregated by route.

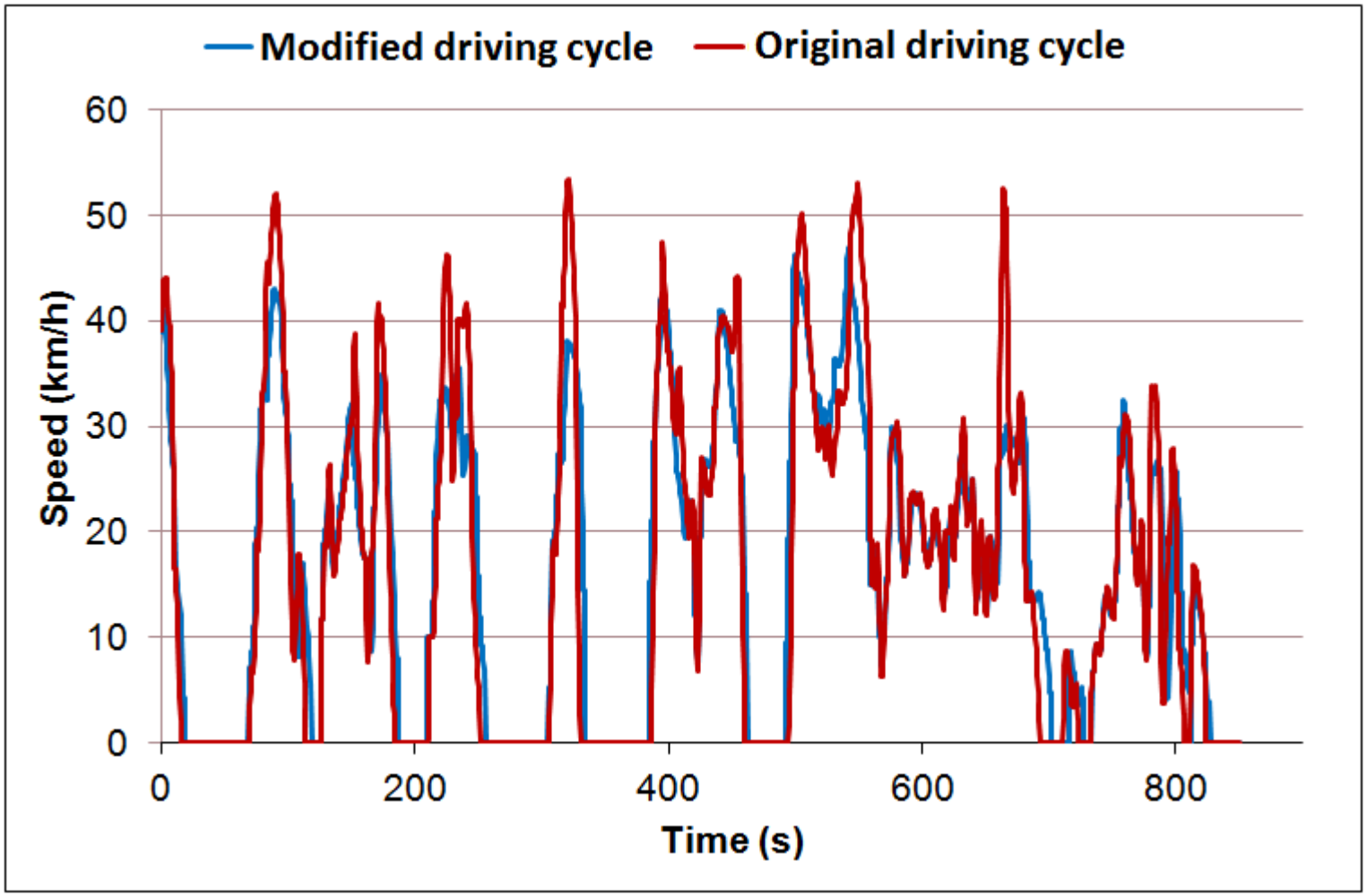
# The overall CTL monitoring system



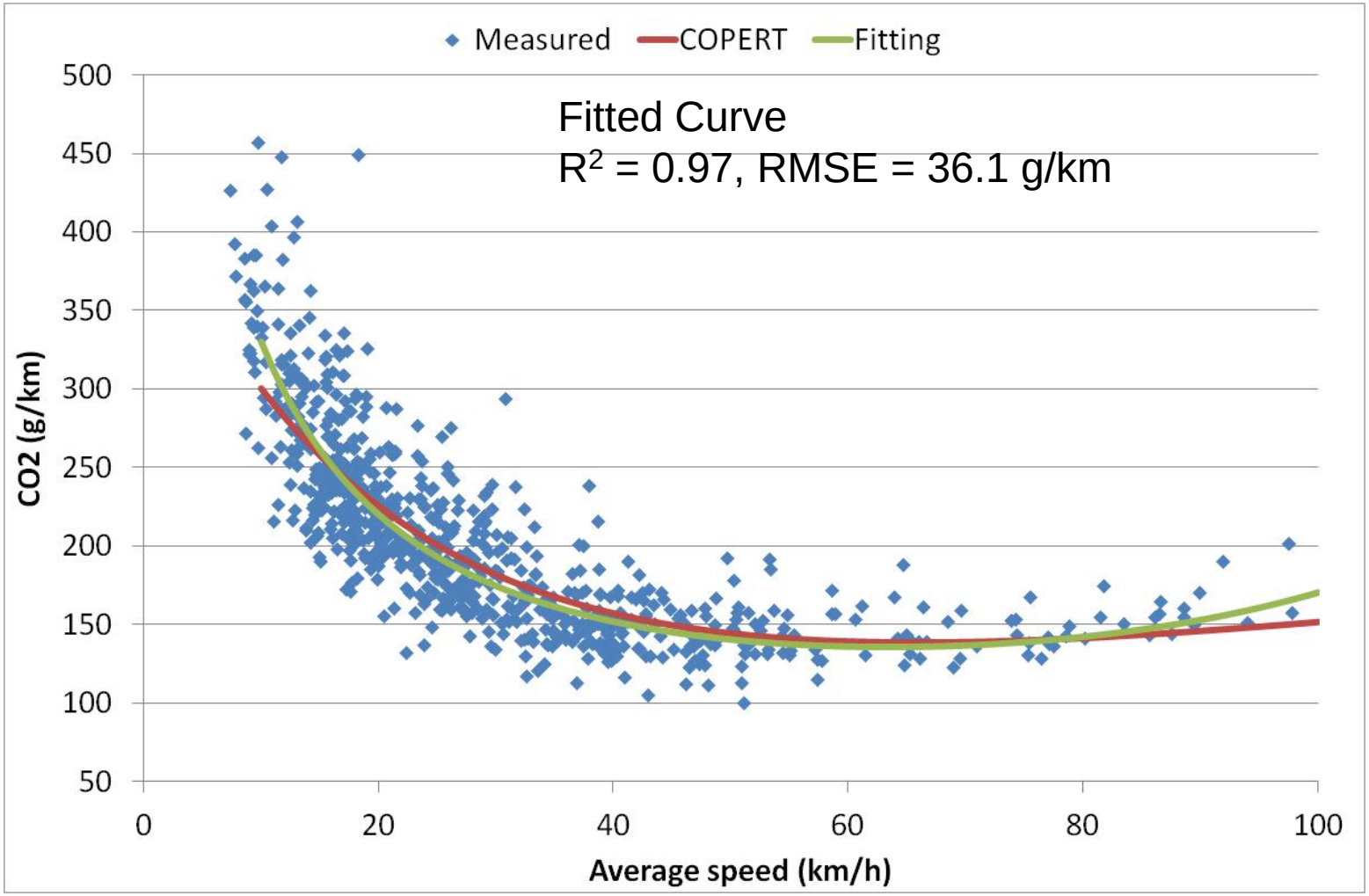
# Modification process results: speed-distance plot of a driving cycle



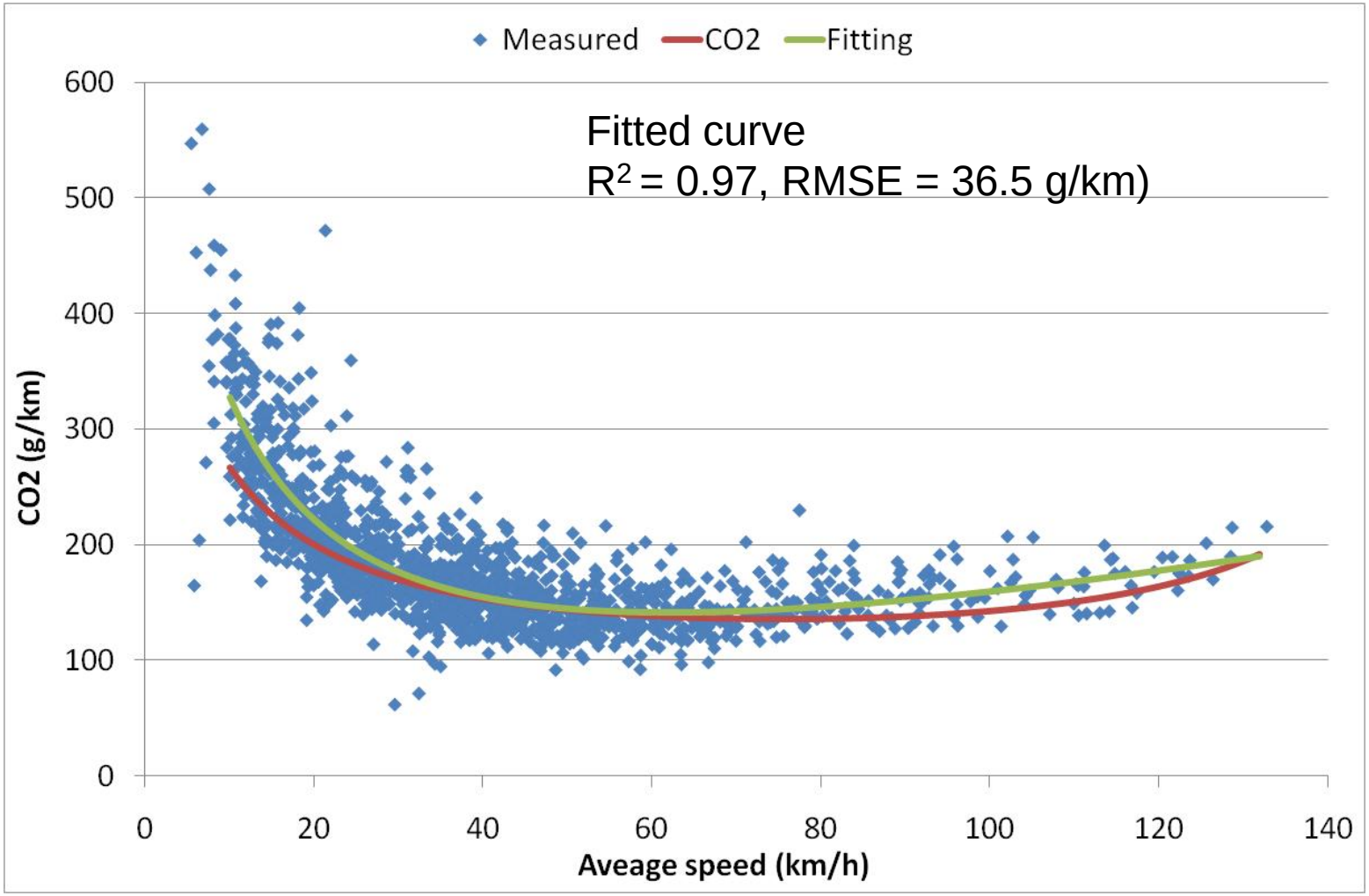
# Modification process results: speed-time plot of a driving cycle



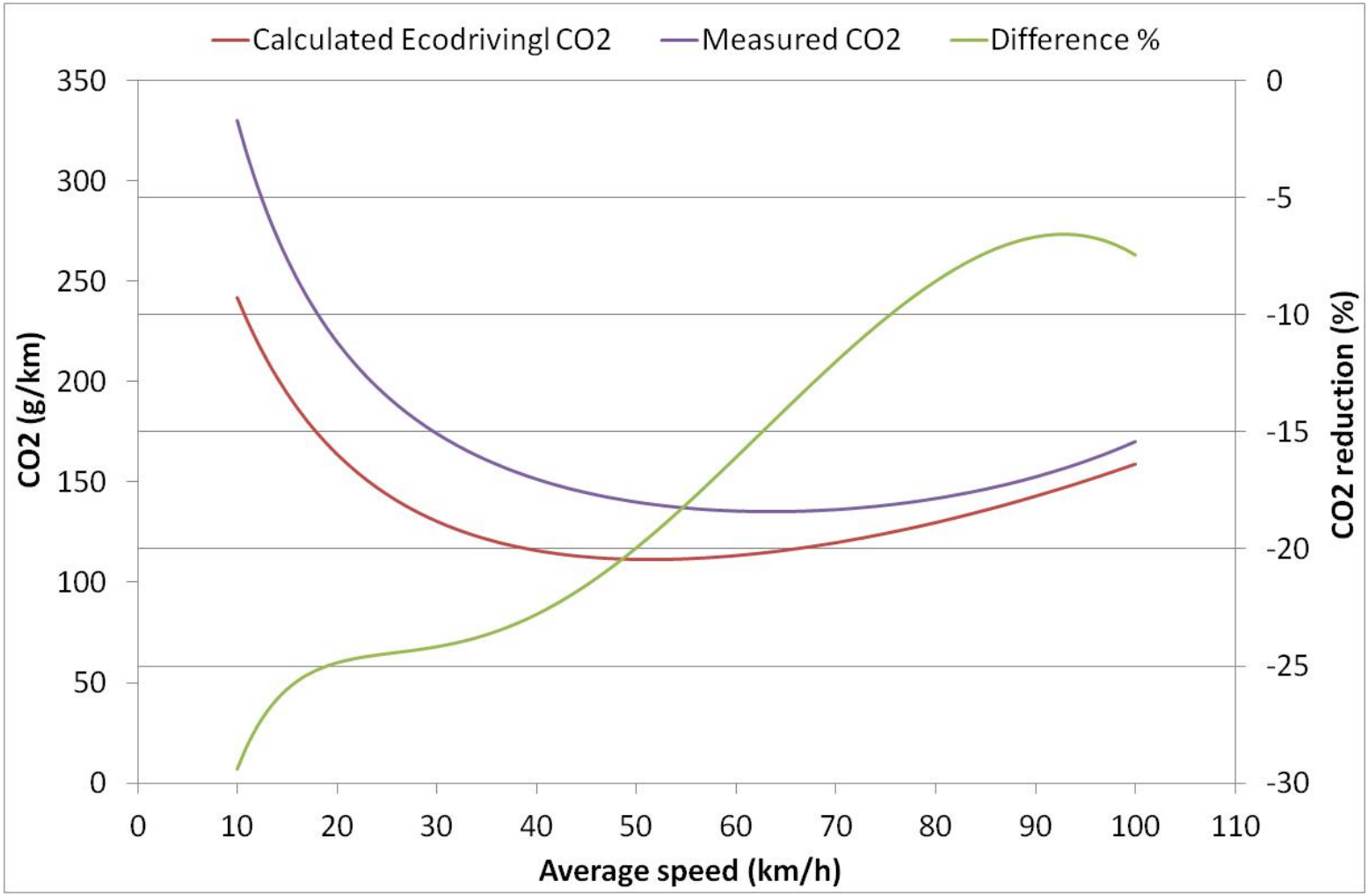
# $CO_2$ results (1/2): measured data, their fitted curve and EEA COPERT curve (Gasoline Euro 4 < 1.4 l)



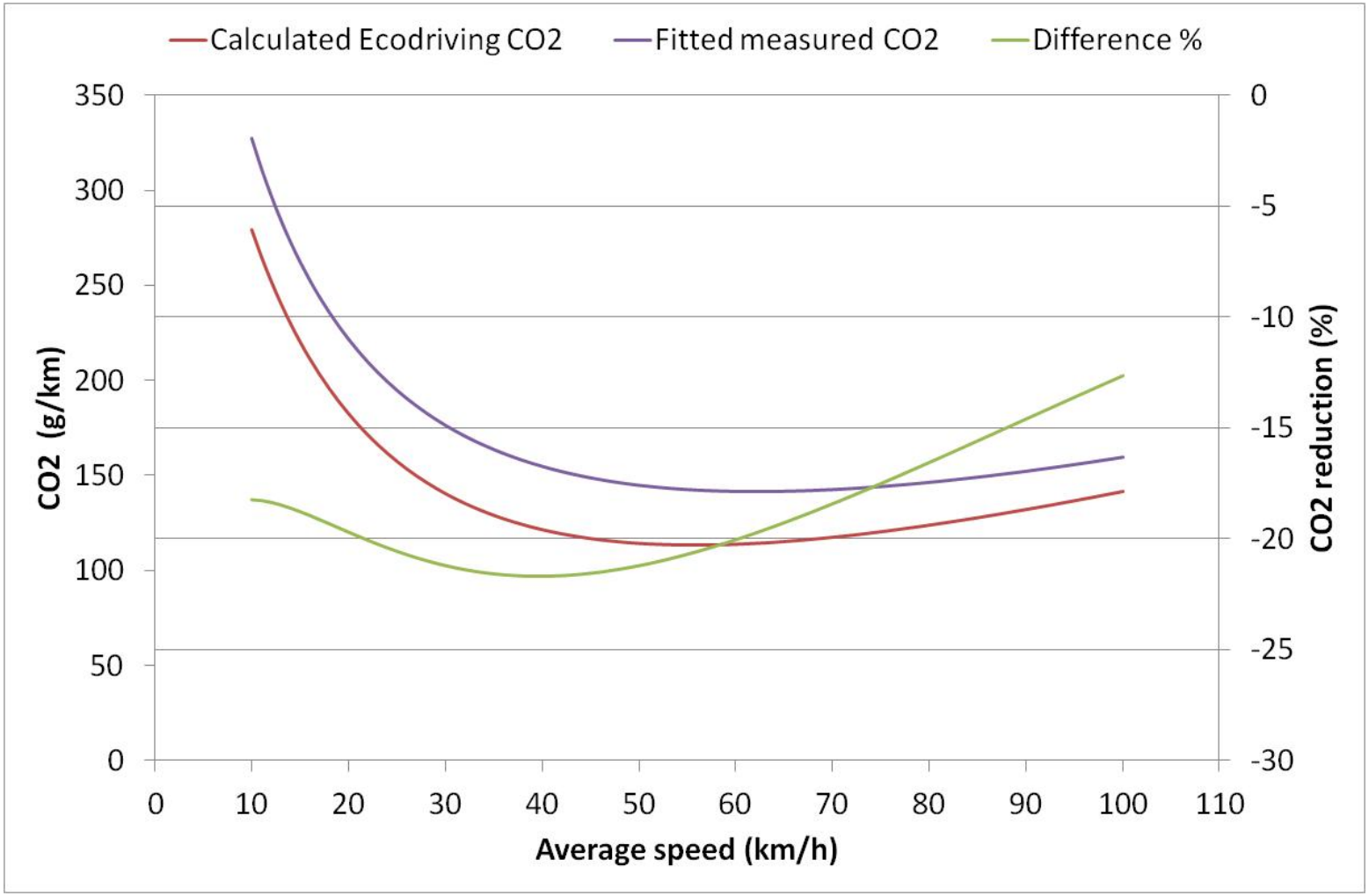
# $CO_2$ results (2/2): measured data, their fitted curve and EEA COPERT curve (Diesel Euro 4 < 2 l)



# Obtainable $CO_2$ reductions (1/2): fitted measured $CO_2$ and fitted calculated Ecodriving $CO_2$ (Gasoline)



# Obtainable $CO_2$ reductions (2/2): fitted measured $CO_2$ and fitted calculated Ecodriving $CO_2$ (Diesel)



# Conclusions

- A methodology to quantify the influence of the driving style on cars' fuel consumption has been developed.
- It modifies a real driving cycle like an ideal driver had adopted the Ecodriving rules. Then it recalculates the fuel consumption.
- It has been applied on a large on-road campaign.
- Obtainable average reduction in fuel consumption and $CO_2$ are greater at low average speeds (urban). At higher speeds driver influence diminishes.
- Obtainable reductions are higher with gasoline vehicles (up to 30%) rather than diesel ones (20%).
- Measured $CO_2$ emissions (average values) are in agreement with EEA COPERT mean curves.

# Thank you

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