CISIS-2012

The 6th International Conference on
Complex, Intelligent and Software Intensive Systems

ILRSH: Intelligent Lane Reservation System for Highway(s)

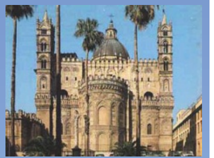
Ciprian Dobre, Valentin Cristea, Liviu Iftode

Emails: {ciprian.dobre, valentin.cristea}@cs.pub.ro, iftode@cs.rutgers.edu

06.07.2012

Outline

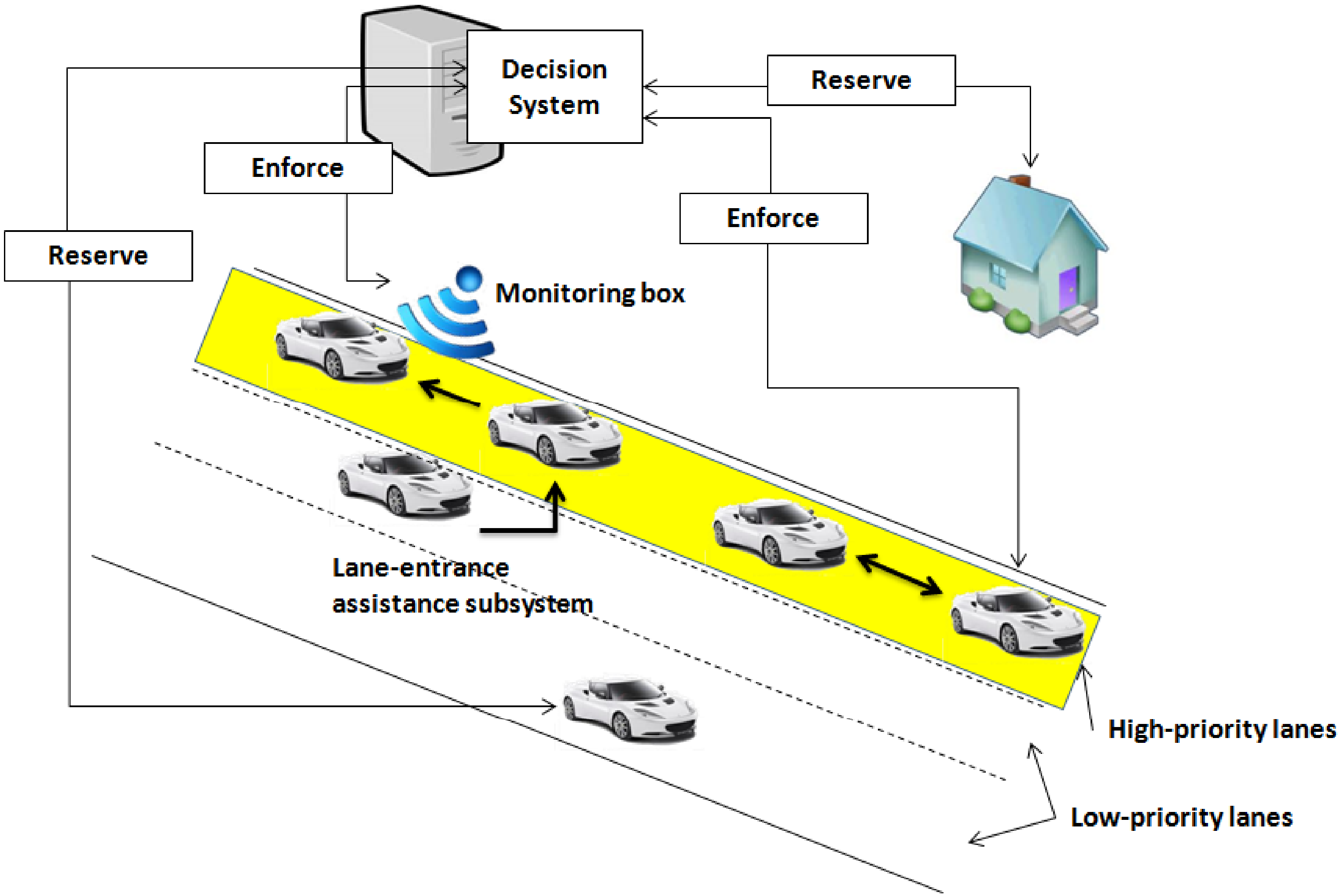
- Scope and motivation
- The proposed system
- Decision algorithms
- Experimental results
- Conclusions



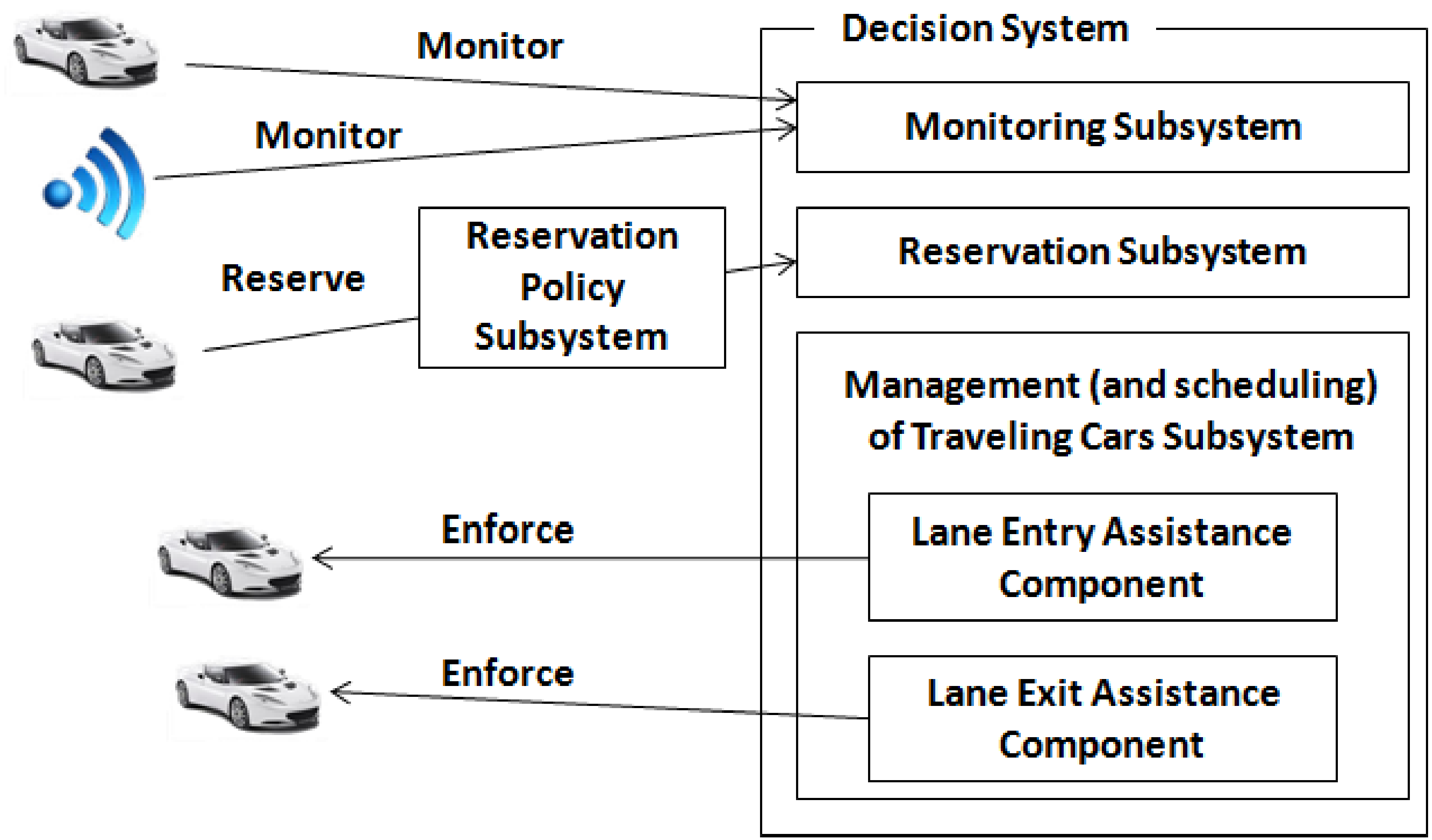
Introduction

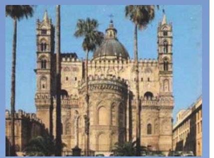
- Problem: congestin on highways
- Solutions:
  - Build new highways
  - ICT to the rescue …
- Idea: “lane reservation” to support priority traffic
  - Free/empty slot

System overview



Architecture



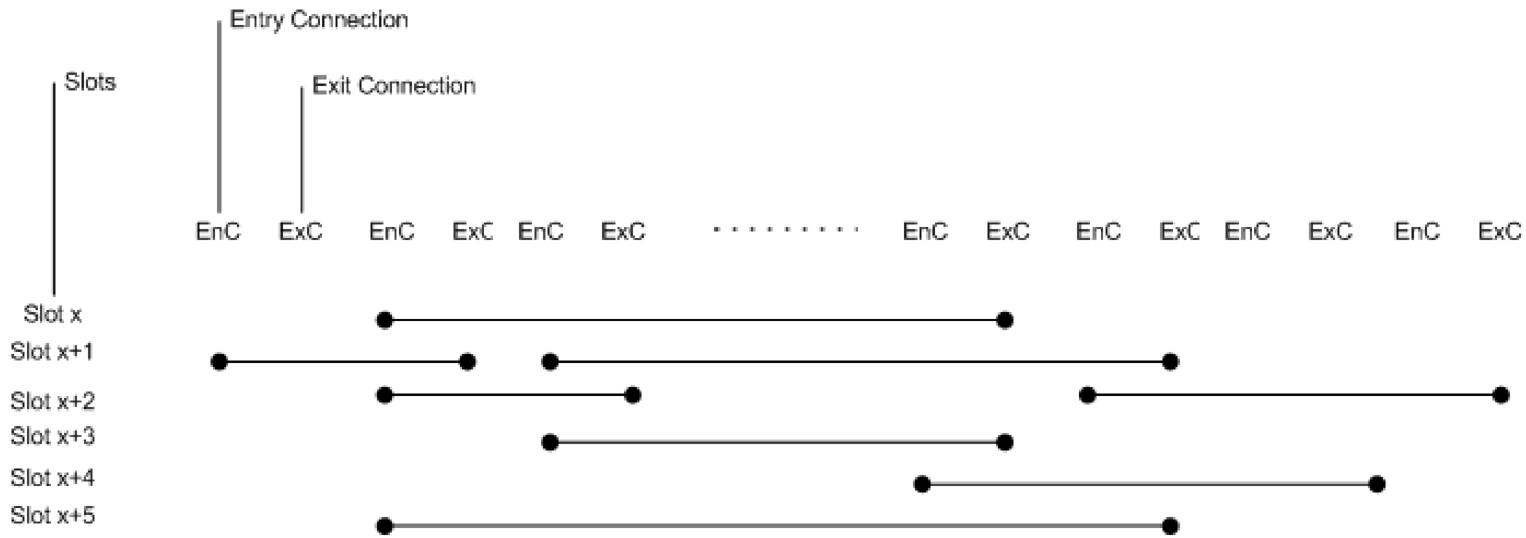



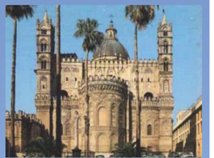

System parameters

- For the system
  - CruiseSpeed [m/s] ~ 150 km / h
  - Minimum safety distance $D_{min\ car\text{-}car}$[m] ~ 100 m
  - Recommended distance $D_{car\text{-}car}$ [m] ~ 125 m
  - $T_{car\text{-}car}$[s]
- For cars
  - $Car_{TopSpeed}$[m/s] ~ 16 km/h above Cruise Speed
  - Time to reach 100 km/h ~ 15 seconds
  - Car_a[m/s^2] ~ 1.85 m/s^2
  - Car_d [m/s^2]

Reservation Subsystem

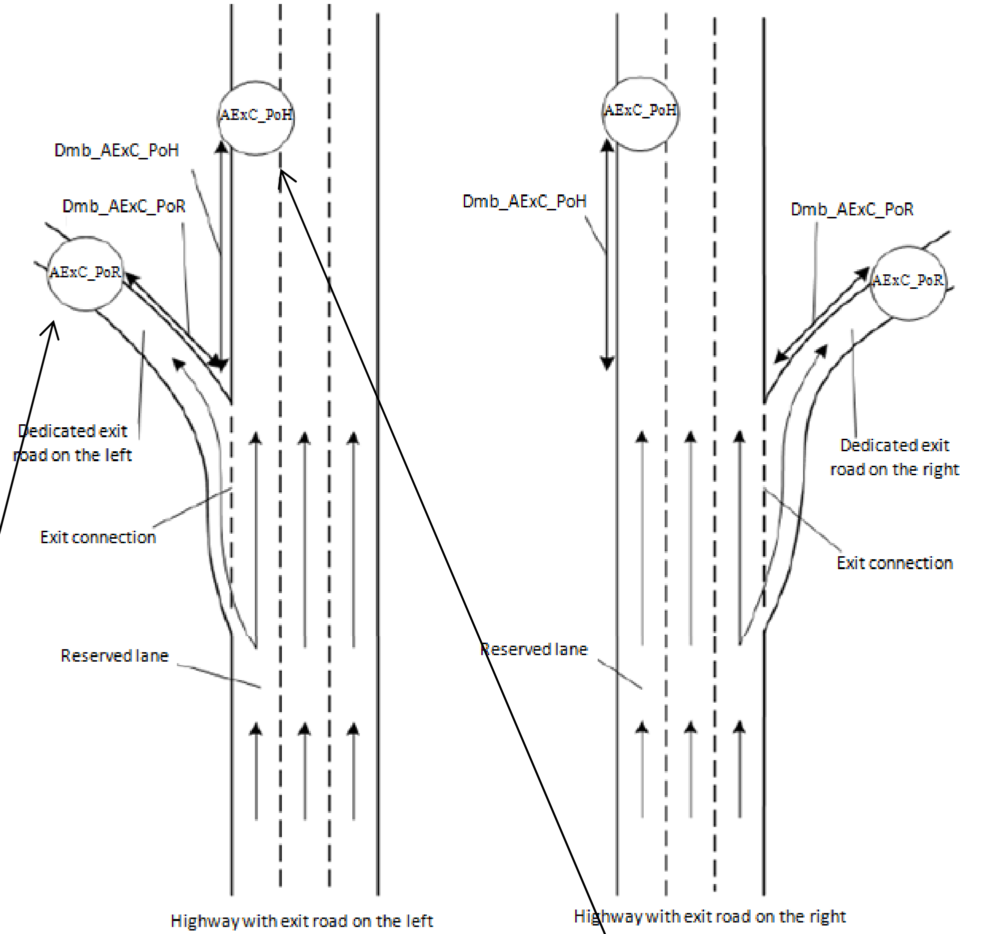
- Responsible for matching a free slot (empty space between two consecutive cars travelling on the reserved lane) with a reservation request, on a specific time interval
- A slot is valid from one entry point to another exit point (or connections on the highway, for a specific time window
  - The distance and time difference between slots follows safety regulations
  - For safety reason the system allows for a time interval of 15 minutes before that time and 15 minutes after the time for the driver to reach the lane next to the reserved lane and to request to enter the reserved lane...





Monitoring the Travelling Cars

- The Monitoring subsystem uses
  - *monitoring boxes* within the road infrastructure
  - mobile applications running on *cars*.
- A *monitoring box* is equipped with sensors (to identify a car) and communications capabilities (to send back the information)
  - Can be equipped, for example, with video cameras



After EXit Connection, Positioned On Road

After EXit Connection, Positioned On (the reserved lane of the) Highway

06.07.2012

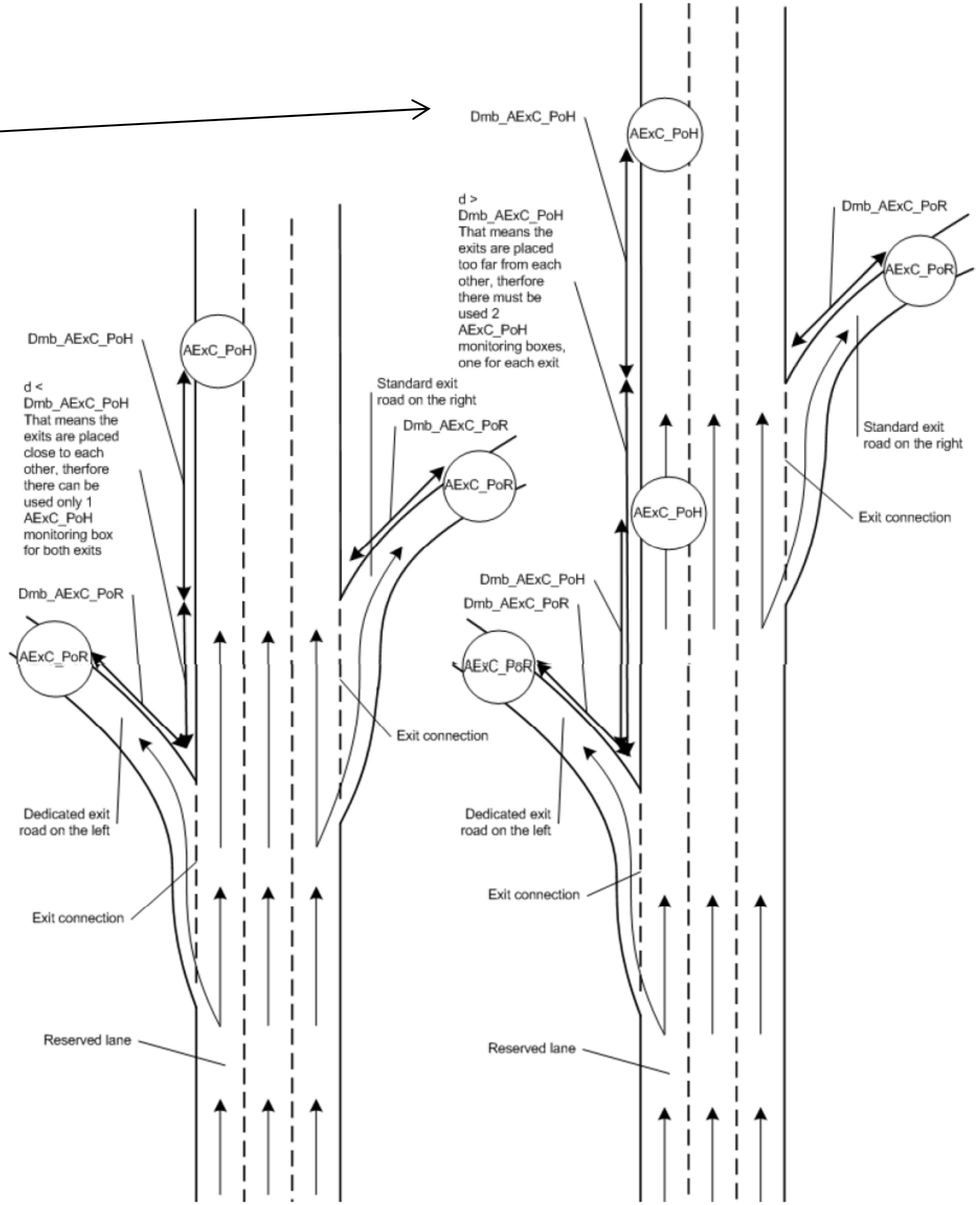


Monitoring

The case for highway with both types of exits, placed too far from each other

- Representation of positions of AExC_PoR and AExC_PoH monitoring boxes for close and not close exit connections

The case of a highway with both types of exists, placed close to each other



Decelerate / Accelerate

- Problem: how to slow-down (and re-accelerate) sets of cars traveling on the reserved lane?

  Advise the driver

  => Algorithms to support cars entering/exiting the reserved lane rely on solutions to this problem

- Solution: Decelerated Pluton

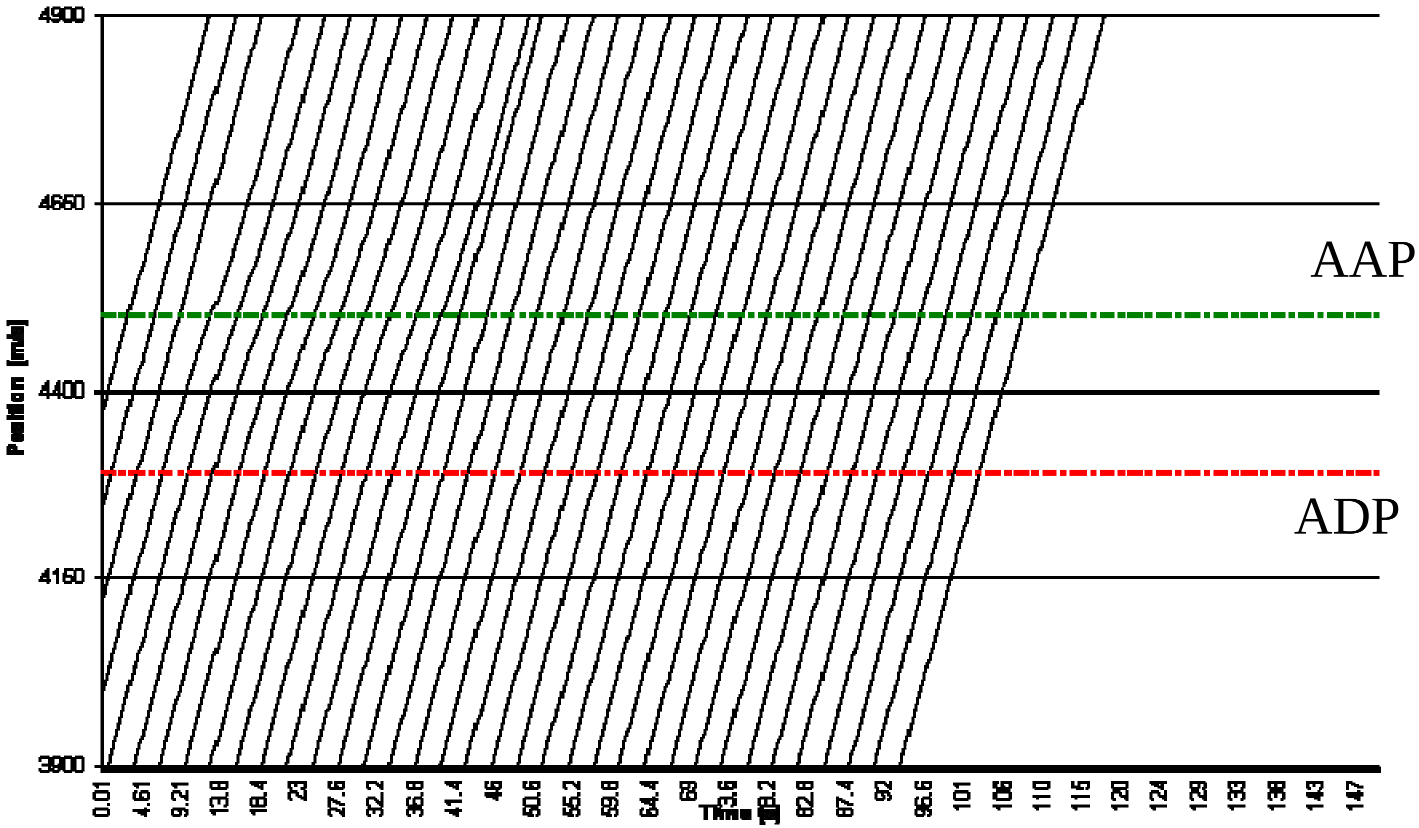


Decelerated Platoon

- *Absolute Deceleration Position* (*ADP*) = a point where the platoon of passing cars must start a deceleration process with a reference deceleration.
- *Absolute Acceleration Position* (*AAP*) = a point where cars should start accelerating with a reference acceleration.
- car_1 is the first car reaching the ADP
- car_n the last car that is affected by ADP
- Cars following/after car_n keep driving with *CruiseSpeed*
- *acc* and *dec* are values for the reference acceleration and reference deceleration (values are equal).
- Idea: slow down cars to create distance between cars to allow safe entering of the new comer
  - When car reaches ADP it decelerates
  - Accelerate at AAP again
- Advantage: distance between cars is preserved

Experimental results (1)

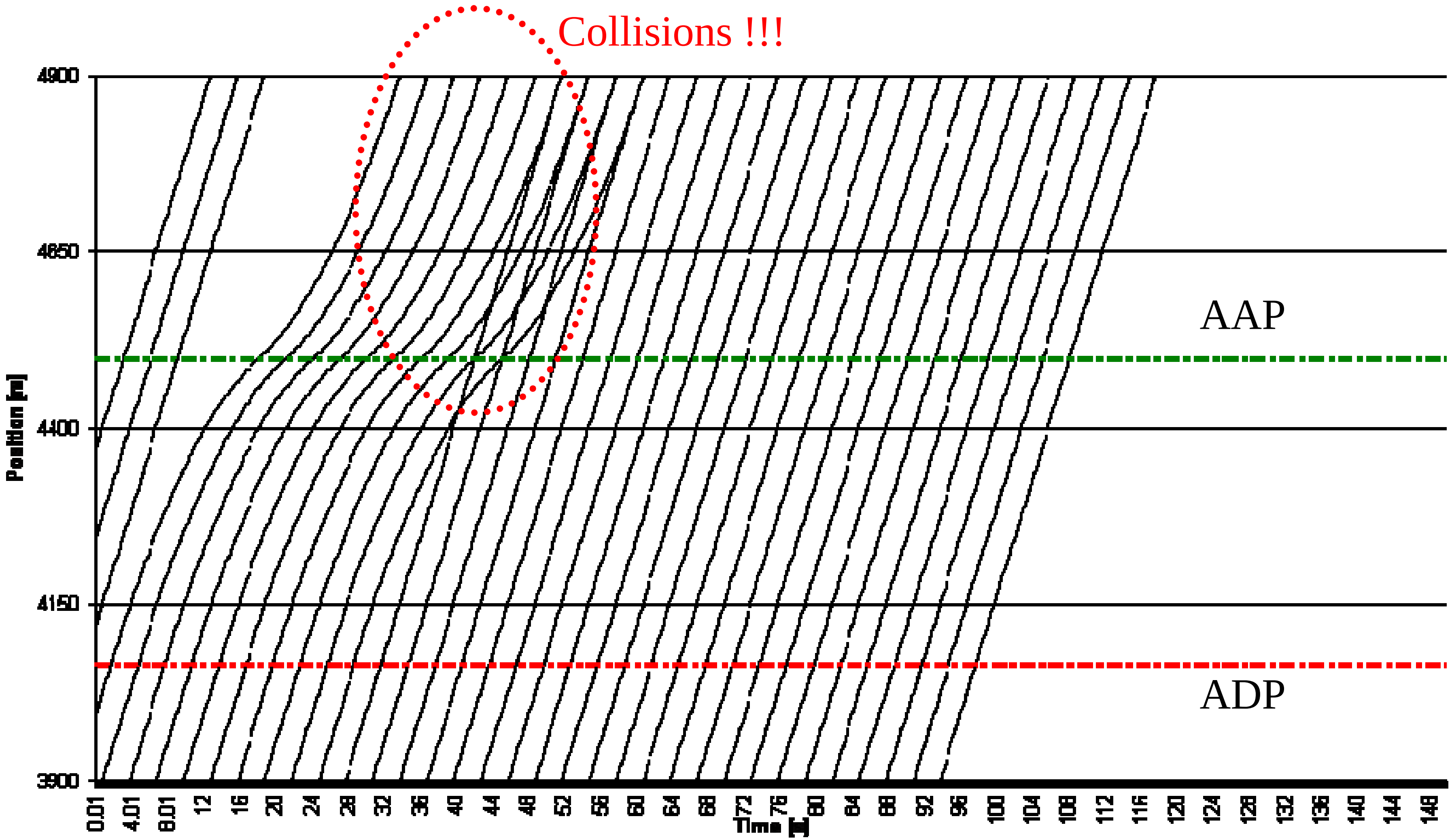
- Problem: could there be collisions?
- Simulation: decelerated platoon of 10 cars
  - V=31.00 m/s and V=11.15 m/s

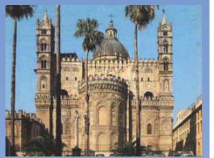




Experimental results (2)

- However, for V = 11.15 m/s

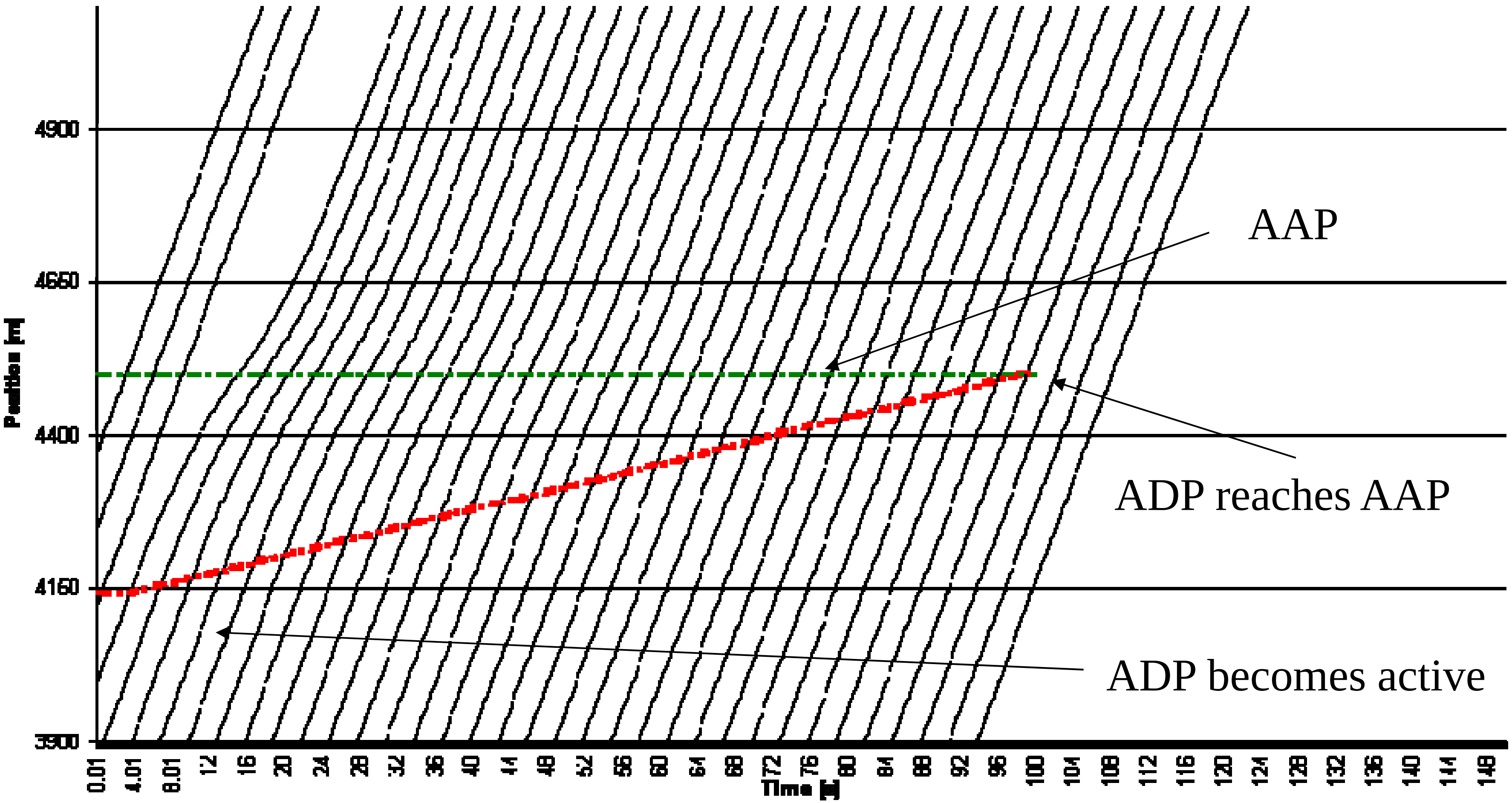




New approach

- A solution to collision avoidance would be to allow also ADP to travel with speed v_{ADP} towards AAP (instead of keeping fixed positions)
  - o When ADP reaches AAP, the platoon management approach stops
- So how to construct the platoon?
- First 2 cars decelerate to allow a distance of $D_{min\ car\text{-}car}$ between them when they reach again CruiseSpeed
  - o Because ADP travels, the distance between compressed platoon tends towarsd $D_{car\text{-}car}$ when ADP reaches AAP
- Is it enough? Simulation for deceleration towards V = 20.21 m/s

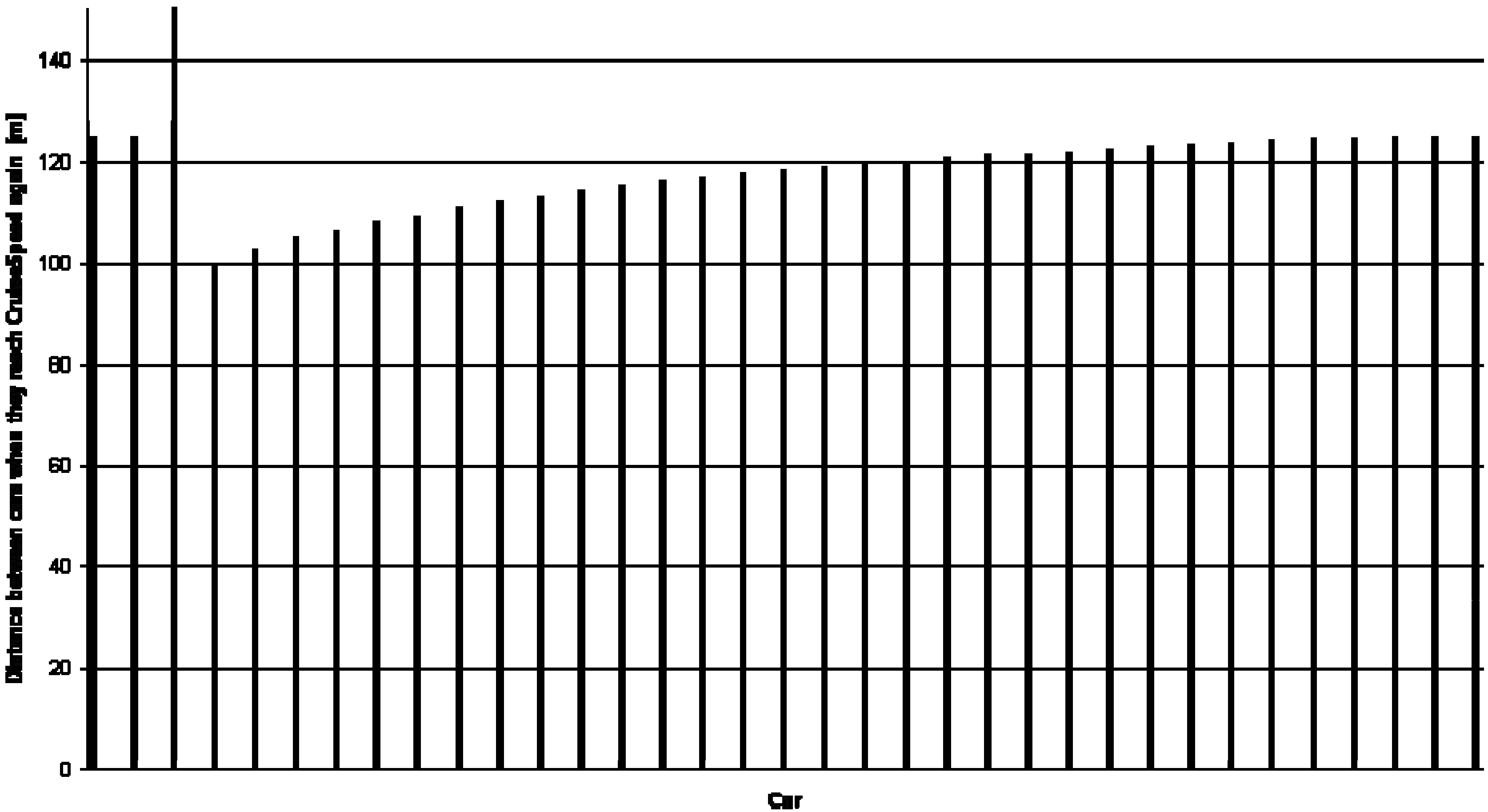
Experimental results





Further results

- V = 20.21 m/s – distances between cars when they reach again CruiseSpeed





Lane entry assistance component

- Responsible for determining if a car can be inserted between two consecutive cars traveling on the reserved lane…
  - car_{NC} ("new car"): the new car which enters the lane
  - car_{IF} ("in front" car): the on-lane car in front of car_{NC}
- Computation using car_{NC} car_{IF} => parameters to recommend driving conditions to car_{NC}

⇒ Algorithm to determine where to insert the car on the reserved lane

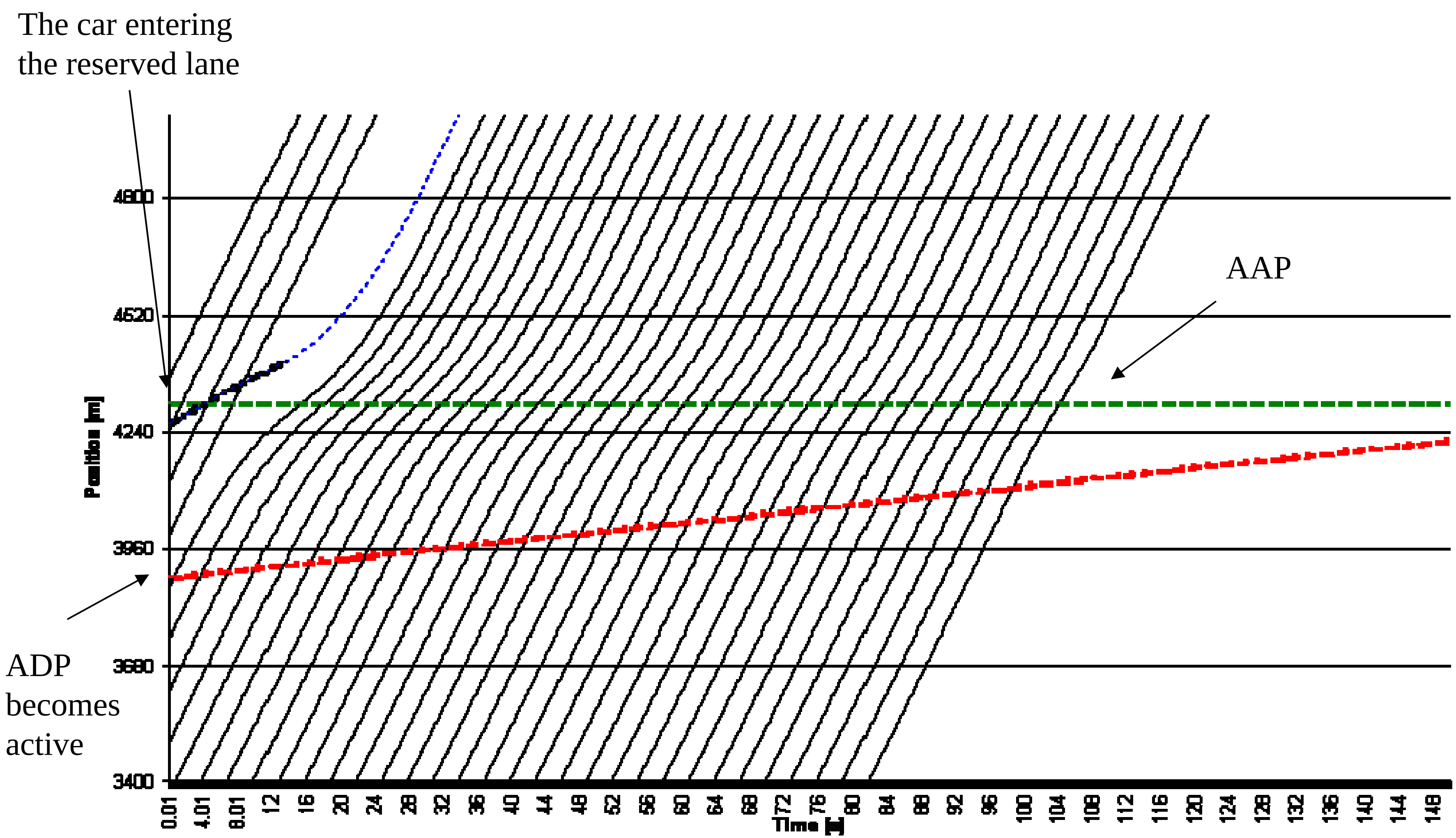
⇒ Algorithm for assisted entrance

  ⇒ Independent on the method used to decelerate cars after car_1

- Evaluation:
- Example of a simulation where a car is assisted to enter
- v_{NC}= 11.15 m/s
- Reserved lane is fully occupied, and we use the decelerated platoon solution

Experimental results

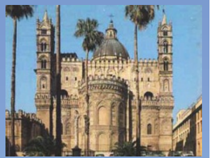




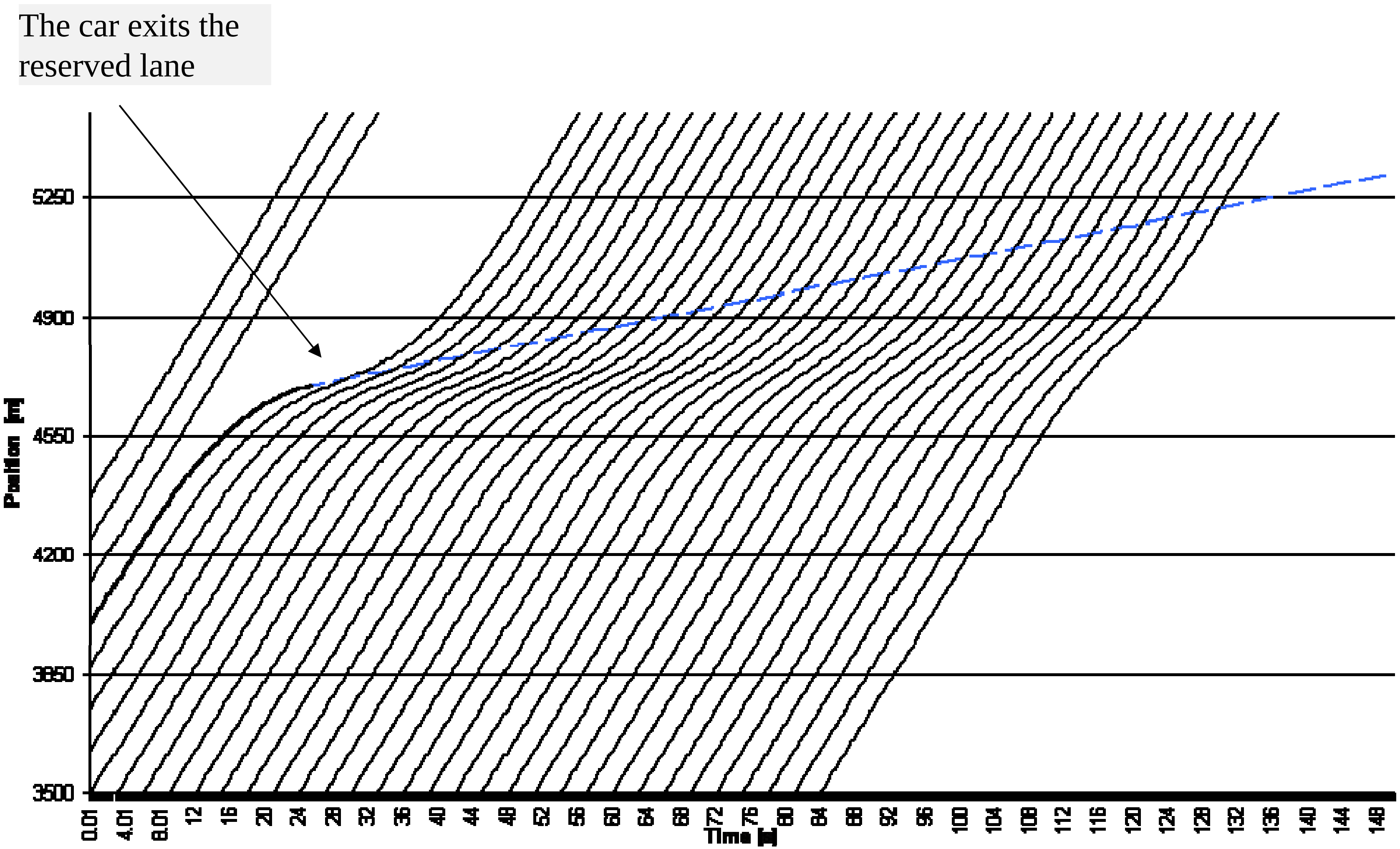
06.07.2012

Lane exit assistance component

- Necessary to assist the exit of car
  - Avoid accidents due to the speed difference; cars on the reserved lane travel at a much higher speed than the speed required when entering the dedicated exit or the speed that cars travel on the lane next to the reserved one
  - We also want to minimize the traffic disruption generated by the exiting car (which is slowing down)
- Algorithm for assisted exit
  - The system computes the required distance (*RD*) and required time (*RT*) for the car to reach v_{low} at the exit point, considering it decelerates with the reference deceleration
  - At *RD* before the exit point, the system defines a point where all cars receive the signal to slow down with the reference deceleration to form the "decelerated platoon".
- Experimental evaluation – decelerate to V = 5.00 m/s



Experimental results





Conclusions

- Prioritize lanes on highways in order to provide congestion free travel during periods of high volume:
    - Reserve a lane of the highway for cars traveling on high speeds
    - Drivers wanting to travel on this lane have to pay a small fee to reserve an empty slot for a specific portion on that lane
    - In exchange, they are guaranteed a congestion free travel on the highway
- Solutions to electronically manage the lane, using sideway sensors and mobile devices in cars communicating with a control server.
- Several components: Reservation Subsystem, Monitoring Subsystem, Lane Entry Assistance Component, Lane Exit Assistance Component
- The system is capable to increase the efficiency of the highway

Q&A

Thank you!

06.07.2012