

Sustainable Mobility in Smart Cities: Research Achievements and Challenges

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Prague, January 20th, 2016

Overview

- Introduction – Smart(er) Cities
- Smart(er) City Operations
- Innovative mobility concepts inside Smarter Cities (Telematics in transportation)
- Intelligent Transport Systems: basic concepts
- Case studies
 - 1. Dynamic ridesharing (car pooling)
 - 2. Global warning system
 - 3. Reconfigurable driving styles
 - 4. Autonomous parking management
- Conclusions and Future Challenges
- Indicative research projects and publications

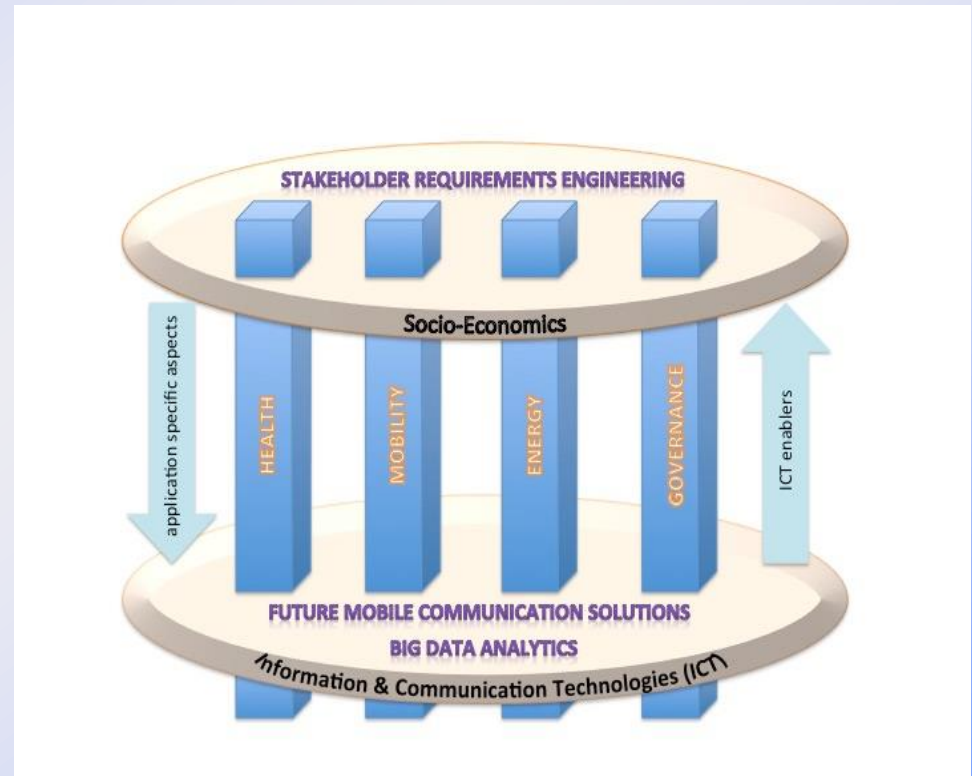
Introduction: smart and smarter cities

■ Smart Cities

- Cities that provide smart services to their citizens
- Numerous pillars - multidisciplinary interest fields
- Enablers: Utilization of Information and Communication Technologies (ICT)
- Concept coined by IBM

■ Smarter Cities

- City like natural living organism
- Continuous evolution
- What is smart today is not smart tomorrow
- Immense research



Smart(er) City Operations (1/3)

■ Smart(er) City Operations (SCOs)

- City operations based on ICT and offer solutions for better quality of life
- Indicative areas
 - Health, mobility, governance, energy, etc.
- Example1: Electronic patient record for public hospitals in a city, doctors booking, telemedicine, etc.
- Example2: Cooperative mobility, internet-connected vehicles, parking management, car pooling, etc.
- Example3: provision of compliant public documents to citizens oIP
- Example4: provision of motives for citizens to reform energy sources utilization.



Smart(er) City Operations (2/3)

■ SCO aspects

- 1. Level of intelligence (“smartness”) required
 - At short, medium and long time scale
 - Consider needs, plans and opinions of all stakeholders involved in its operations, such as (i) citizens, (ii) service providers, (iii) businesses, (iv) municipal authorities and (v) (inter)national standards.
- 2. Scalability with respect to the definition of objectives to be achieved
 - Smartness should be scalable enough, in that a city should appropriately design the objectives to be achieved at various scales.



Smart(er) City Operations (3/3)

■ SCO aspects (continued)

- 3. Formulation of city-specific objectives
 - A city sets at a local level some standards to be achieved at various time scales.
 - Then, some Key Performance Indicators (KPIs) are monitored (city-selected criteria / benchmarks).
 - KPIs should be adaptive enough to respond to new (external) requisitions.
- 4. Consideration of the economic growth of a smart city
 - Enable internally operating business groups to obtain income from outside its geographical region, and then enable the obtained revenues to circulate within its region.
 - Long term SWOT analysis will allow a city to continue attracting immense attention for businesses, whilst being comfortable and secure for its citizens.



Telematics in transportation as SCO

- **Telematics = Telecommunications and Informatics**

- Telematics refers to the combined utilization of telecommunications and informatics and involves all kinds of data transfer among systems and devices

- **Telematics applications**

- Internet of Things, m-health – emergency incidents management, Avionics, Shipping, Road transport
- Example (Fleet management)
 - Needs to effectively manage fleets of large or smaller companies
 - Mass transport media (Buses, trains, even taxis)
 - School buses

- **Telematics is intrinsically linked to transportation**

- Fundamental part of operation provided in the context of Smart Cities

Intelligent Transport Systems: overview

■ Overview of transportation inside cities

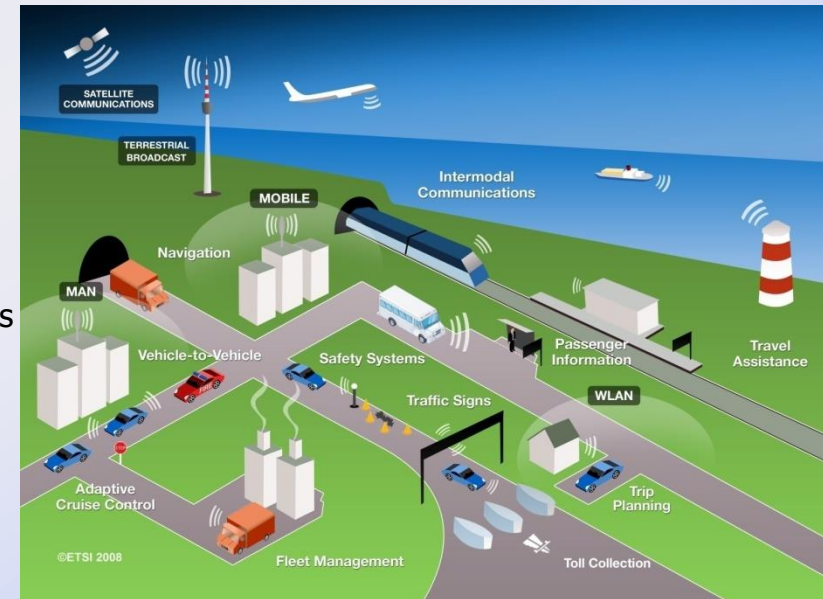
- Increased utilization of vehicles
 - Traffic congestions
 - Pollution
 - Degradation of life quality
 - Emergencies / accidents
- Inefficiencies related to transportation

■ Research in innovative mobility concepts

- Cooperative mobility and the use of telecommunications systems inside vehicles
 - Transportation is facilitated by means of newly introduced, revolutionary telecommunication techniques and gadgets
 - Improvement of the driver's safety
 - Improvement of the passengers' quality of life through entertainment

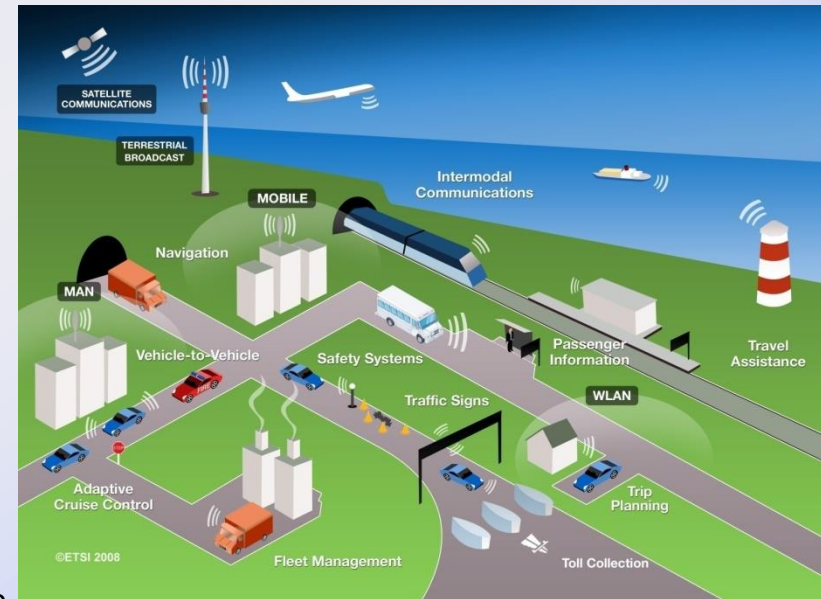
■ Intelligent Transport Systems (ITS)

- Expected benefits
 - Improvement of mobility quality in cities
 - Improvement of life quality in cities (less time losses)
 - Reduction of environmental pollution
 - Passengers' entertainment
 - Targeted marketing solutions



Intelligent Transport Systems: main technologies

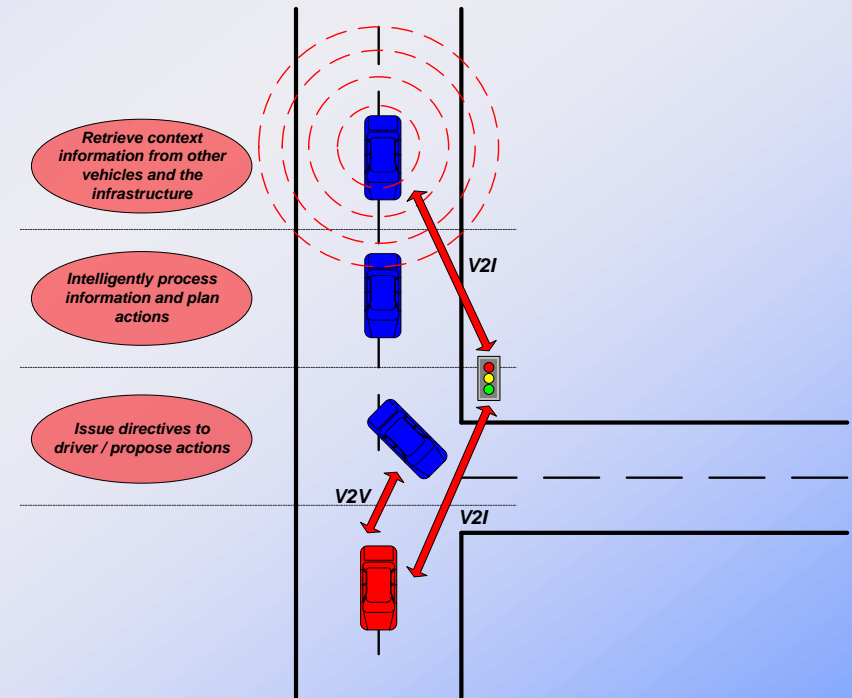
- Vehicle-to-Vehicle (V2V) communications
 - IEEE 802.11p (5.9GHz, 75MHz bandwidth)
 - It is at an early stage of adoption
 - It does meet the requirement for minimal infrastructure investment
 - It suffers from reliability, resilience to interference and stability problems
 - It faces the 'fax machine problem' – it's only any good if you can communicate with a second party that has similar equipment.
- Vehicle-to-Infrastructure (V2I) communications
 - IEEE 802.11p, Wide Area Networking (WAN) technologies such as 2G/GPRS/EDGE, 3G/UMTS/HSPA/HSPA+ and 4G/LTE
 - These suffer from location accuracy which could be improved by secondary mechanism such as GPS.
 - They require high infrastructure costs (e.g. sensors)



Intelligent Transport Systems: example areas

- Traffic assessment and management
- In-vehicle and on-road safety management
 - Active / passive
- Emergency management
- Driver modeling
- Parking management
- Infotainment
- Environmental effects of transportation
- Application of technologies like sensor networks or network entities' control techniques

- 2 directions
 - A) inform the driver/passenger
 - B) intervene in CAN-BUS and take over
 - **AUTONOMOUS DRIVING**



Intelligent Transport Systems: research challenges

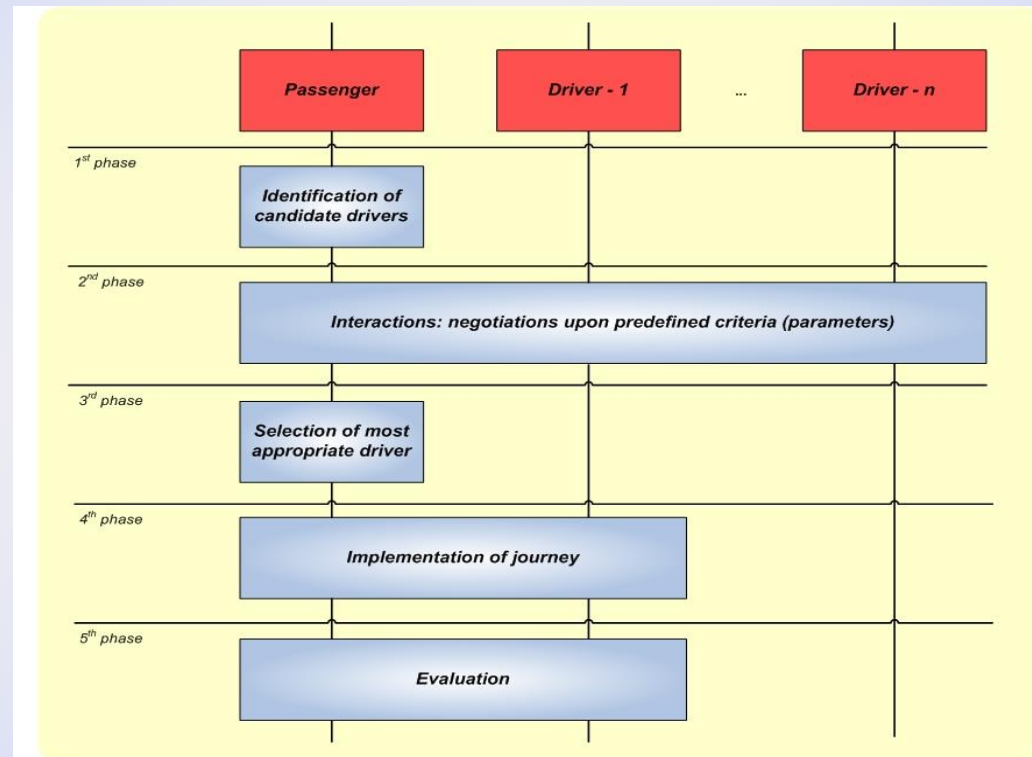
- **Traveler's information enhancement:** Real-time, accurate and tailored information provision to the driver, especially when information originates from multiple sources and is associated with large amounts of data.
- **Deployment cost reduction:** At this time, ITS are associated with high costs that are associated with the distributed infrastructure necessary for their deployment.
- **Communication availability improvement for ITS:** Availability of state-of-the-art communication infrastructure/technologies nation-wide.
- **Vehicle Co-operation improvement:** In-vehicle intelligence, connectivity and coordination among heterogeneous technologies.
- **Driving safety improvement:** Solutions that will assist the driver in effectively handling sudden or unforeseen situations (Advanced Driver Assistance Systems – ADAS).

Case study 1: car pooling - Introduction

- Intelligent Management Functionality for Improving Transportation Efficiency by means of the Car Pooling Concept
 - **Motivation**
 - The increasing level of utilization of vehicles, linked to the minimization of vehicle passengers, due to the increase in vehicle ownerships.
 - Creation of traffic volumes and therefore intensifies the difficulties mentioned above.
 - **Solution**
 - Car-independent life styles
 - The concept of car pooling
 - The establishment of agreements among a driver and one or more passengers to share a ride inside one vehicle, instead of making the same trip independently.
 - **Results**
 - (i) the reduction of the number of vehicles on the route
 - (ii) the reduction of expenses for gas
 - (iii) the reduction of energy consumption (CO2 emissions) and pollution
 - (iv) the provision of social connections in an increasingly disconnected society

Case study 1: car pooling - Business case

- A user (prospective passenger) desires to make a certain journey.
 - Logs on to the system (smartphone/laptop/tablet)
 - One time only the user is proposed to complete a form regarding specific preferences.
 - Makes request
 - The system has access to personal information, specific preferences and history.
 - This information on each user is kept in log files, in appropriately formed databases.
 - Several parameters that affect the selection of the appropriate matches among drivers and passengers, can be changing with time.
 - The functionality should increase the reliability of the decisions is required.



TM-CPS Detailed Analysis

- TM-CPS Detailed Analysis
 - User Profile Aspects
 - Service Aspects
 - Optimization Method
 - Feedback – Evaluation

User Profile Aspects

- Age
 - Gender
 - Educational Level
 - Family State
 - Work
 - Smoking
 - Language
 - Nationality
 - Source
 - Destination
 - Commuter Cost
 - Evaluation
 - Driving Skills, Social Behavior, Repeat Match
-

Service Aspects

■ Itinerary Characteristics

Driver Parameters	Matching Parameters	Passenger Parameters
Driver departure point	Itinerary	Passenger departure point
Driver departure time	Itinerary's cost	Passenger departure time
Driver destination point	Pick-up point	Passenger destination point

$$\sum cost = \frac{(0.25 \times km + 2 \times n)}{N}$$

where km is the itinerary's distance (expressed in km), N is the number of the passengers and n expresses the times that tolls shall be paid throughout the itinerary. The cost of the tolls is set to 2€, yet it may change and the equation may be formed accordingly

■ Cost calculation formula

Optimization Method

$$OF_{System} = Max \left\{ \sum_d K(x, d) \square \sum_{par} W(x, par) \square par(d) \right\}$$

$$OF_d = \sum_{par} W(x, par) \square par(d)$$

$$K(x, d) = \begin{cases} 0, & \text{if user } x \text{ does not choose driver } d \\ 1, & \text{if user } x \text{ chooses driver } d \end{cases}$$

Feedback – Evaluation

- When registering on the platform, the user provides the system with their personal data and preferences.
 - This might change
 - Of course, a user may update his profile by himself.
 - On the other hand, changes in user's profile or preferences may be inferred through the *evaluation procedure* within the system.
- Specifically, there are three categories of overall evaluation which a user can choose from: positive, neutral or negative.
- Also, the user may specify whether he is *willing to share a ride again with the same user* of the system.

System Update – Evaluation Parameters	Potential Values
Overall evaluation on user	positive, neutral, negative
Willingness to share a ride again	positive, neutral, negative
Driving style	calm, convulsive, environment friendly and gas saving
Driving competence	good, efficient, dangerous
Social behavior	pleasant, friendly, annoying, rude

Indicative simulation results – scenario 1 (regular service request) (1/4)

- We consider user Mary, who has already registered on the TM-CPS and therefore disposes a unique identity in the system.
- Her starting point is SP-A and her destination point is DP-A
 - 18 kilometers (km).
- 3 drivers make a car pooling system request, making the system aware that they are going to follow the itinerary SP-A to DP-A.

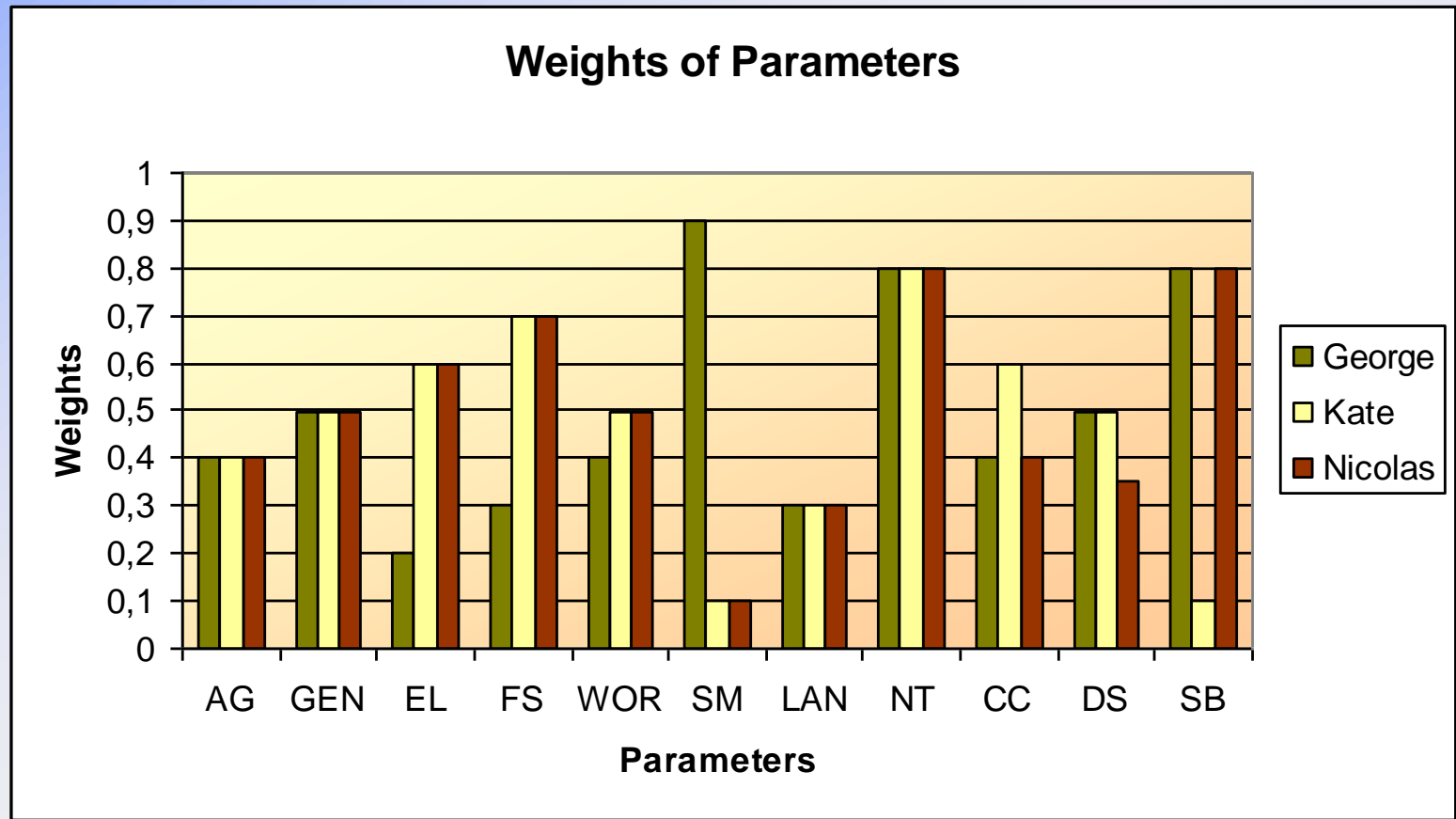
Parameter	Weight
<i>Age</i>	0,09
13 – 17	0,1
18 – 24	0,25
25 – 34	0,4
35 – 44	0,16
45 – 54	0,05
55 – 64	0,02
65 – 70	0,02
<i>Gender</i>	0,02
Male	0,5
Female	0,5
<i>Educational Level</i>	0,07
Higher	0,6
Medium	0,2
Low	0,2
<i>Marital Status</i>	0,05
Married	0,3
Single	0,7
<i>Occupation</i>	0,07
Employed	0,4
Unemployed	0,05
Housewife	0,05
Student/ Pupil	0,5
<i>Smoking</i>	0,25
Yes	0,1
No	0,9
<i>Language</i>	0,02
English	0,3
French	0,3
Greek	0,3
Other	0,1
<i>Nationality</i>	0,05
English	0,8
Other	0,2
<i>Evaluation</i>	
Driving Competence	0,25
Good	0,5
Medium	0,35
Low	0,15
Social Behavior	0,08
Good	0,8
Medium	0,1
Low	0,1
Itinerary Cost	0,05
Economic	0,6
Non-economic	0,4
<i>Repeat Match</i>	
(NMB) No Match Before	
Yes	
No	

Indicative simulation results – scenario 1 (regular service request) (2/4)

- 3 candidate drivers

Parameters	George	Kate	Nicolas
Age	29 yrs (0,4)	26 yrs (0,4)	34 yrs (0,4)
Gender	Male (0,5)	Female (0,5)	Male (0,5)
Educational Level	Medium (0,2)	Higher (0,6)	Higher (0,6)
Marital Status	Married (0,3)	Single (0,7)	Single (0,7)
Occupation	Employed (0,4)	Student (0,5)	Employed (0,5)
Smoker	No (0,9)	Yes (0,1)	Yes (0,1)
Language	English (0,3)	English (0,3)	English (0,3)
Nationality	English (0,8)	English (0,8)	English (0,8)
Departure	SP-A	SP-A	SP-A
Destination	DP-A	DP-A	DP-A
Itinerary Cost	Non - Economic (0,4)	Economic (0,6)	Non-Economic (0,4)
Evaluation			
1. Driving Competence	Good (0,5)	Good (0,5)	Medium (0,35)
2. Social Behavior	Good (0,8)	Medium (0,1)	Good (0,8)
3. Repeat Match	NMB	NMB	Yes

Indicative simulation results – scenario 1 (regular service request) (3/4)



Indicative simulation results – scenario 1 (regular service request) (4/4)

$$\begin{aligned}
 OF_{\text{George}} &= \sum_{par} W(x, par) \cdot par(d) = \\
 &0,09 \cdot 0,5 + 0,02 \cdot 0,5 + 0,07 \cdot 0,2 + 0,05 \cdot 0,3 + 0,07 \cdot 0,4 + \\
 &0,25 \cdot 0,9 + 0,02 \cdot 0,3 + 0,05 \cdot 0,8 + 0,05 \cdot 0,4 + 0,25 \cdot 0,5 + 0,08 \cdot 0,8 \\
 &= 0,583
 \end{aligned}$$

$$\begin{aligned}
 OF_{\text{Kate}} &= \sum_{par} W(x, par) \cdot par(d) = \\
 &0,09 \cdot 0,4 + 0,02 \cdot 0,5 + 0,07 \cdot 0,6 + 0,05 \cdot 0,7 + 0,07 \cdot 0,5 + \\
 &0,25 \cdot 0,1 + 0,02 \cdot 0,3 + 0,05 \cdot 0,8 + 0,05 \cdot 0,6 + 0,25 \cdot 0,5 + 0,08 \cdot 0,1 \\
 &= 0,392
 \end{aligned}$$

$$\begin{aligned}
 OF_{\text{Nicolas}} &= \sum_{par} W(x, par) \cdot par(d) = \\
 &0,09 \cdot 0,4 + 0,02 \cdot 0,5 + 0,07 \cdot 0,6 + 0,05 \cdot 0,7 + 0,07 \cdot 0,5 + \\
 &0,25 \cdot 0,1 + 0,02 \cdot 0,3 + 0,05 \cdot 0,8 + 0,05 \cdot 0,4 + 0,35 \cdot 0,5 + 0,08 \cdot 0,8 \\
 &= 0,4005
 \end{aligned}$$

$$\begin{aligned}
 OF &= \text{Max} \left\{ \sum_d K(x, d) \cdot \sum_{par} W(x, par) \cdot par(d) \right\} \\
 &= \text{Max} \{ 1 \cdot 0,583 + 0 \cdot 0,392 + 0 \cdot 0,4005 \} \\
 &= 0,583
 \end{aligned}$$

Indicative simulation results – scenario 2 (cost – driven scenario) (1/4)

- In this case, user Thomas (a driver now) wishes to drive an itinerary of 463km, having as starting point the SP-K and destination point the DP-L. This means that the itinerary is an interurban itinerary and it definitely involves tolls. Driver Thomas specifies the day and time of departure, the possible stops he is going to make during the itinerary and the number of tolls he is going to pay:
- Starting Point: SP-K
- Destination Point: DP-L
- Kilometers: 463 Km
- Number of tolls: 5

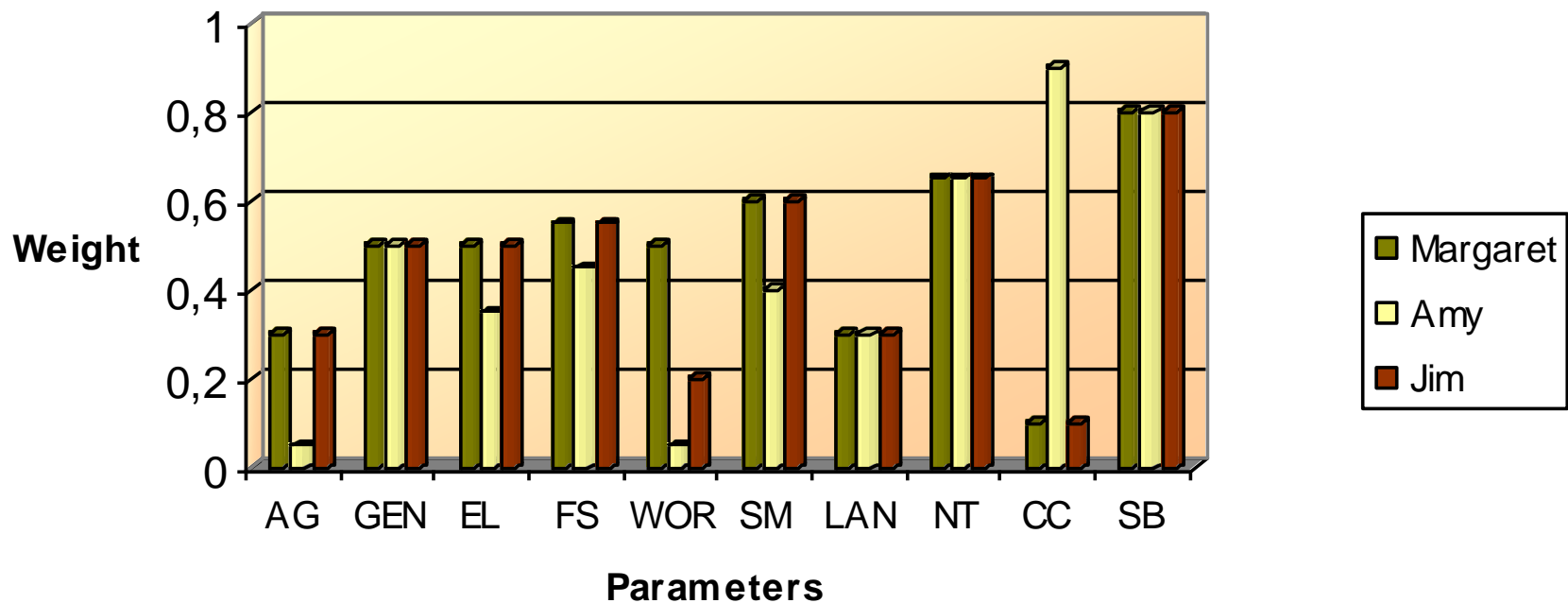
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55 – 64	0,05
65 – 70	0,05
<i>Gender</i>	0,02
Male	0,5
Female	0,5
<i>Educational Level</i>	0,09
Higher	0,5
Medium	0,35
Low	0,15
<i>Marital Status</i>	0,04
Married	0,45
Single	0,55
<i>Occupation</i>	0,08
Employed	0,2
Unemployed	0,25
Housewife	0,05
Student/ Pupil	0,5
<i>Smoking</i>	0,15
Yes	0,6
No	0,4
<i>Language</i>	0,02
English	0,3
French	0,3
Greek	0,3
Other	0,1
<i>Nationality</i>	0,05
English	0,65
Other	0,35
<i>Evaluation</i>	
Driving Competence	0,0
Good	0,0
Medium	0,0
Low	0,0
Social Behavior	0,1
Good	0,8
Medium	0,1
Low	0,1
Itinerary Cost	0,35
Economic	0,1
Non-economic	0,9
<i>Repeat Match</i>	
(NMB) No Match Before	
Yes	
No	

Indicative simulation results – scenario 2 (cost – driven scenario) (2/4)

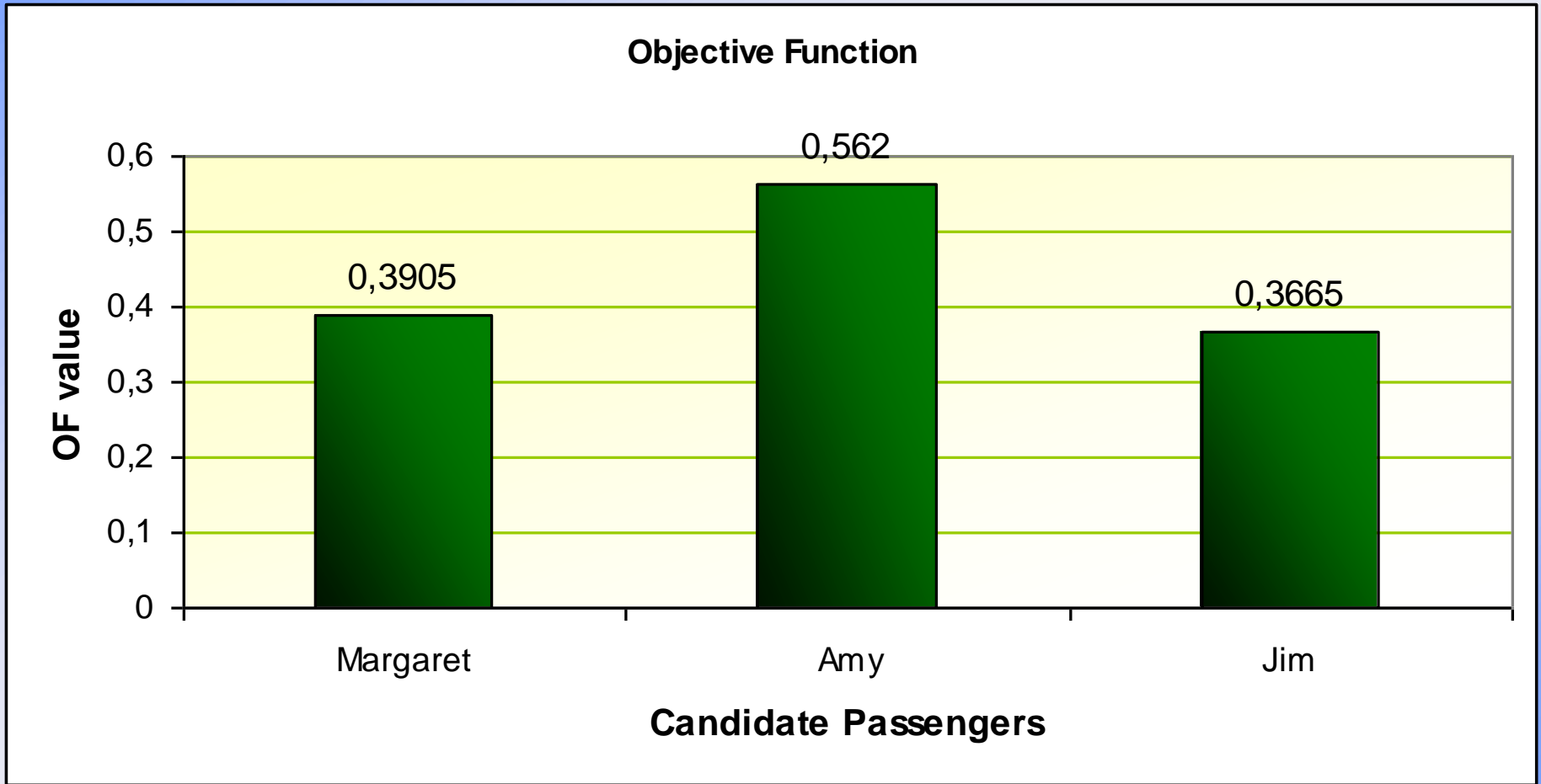
Parameters	Margaret	Amy	Jim
Age	23 yrs (0,3)	53 yrs (0,05)	31 yrs (0,3)
Gender	Female (0,5)	Female (0,5)	Male (0,5)
Educational Level	Higher (0,5)	Medium (0,35)	Higher (0,5)
Marital Status	Single (0,55)	Married (0,45)	Single (0,55)
Occupation	Student (0,5)	Housewife (0,05)	Employed (0,2)
Smoker	Yes (0,6)	No (0,4)	Yes (0,6)
Language	English (0,3)	English (0,3)	English (0,3)
Nationality	English (0,65)	English (0,65)	English (0,65)
Departure	SP-K	SP-K	SP-K
Destination	DP-L	DP-L	DP-L
Itinerary Cost	Economic (0,1)	Non – Economic (0,9)	Economic (0,1)
Evaluation			
1. Driving Competence	-	-	-
2. Social Behavior	Good (0,8)	Good (0,8)	Good (0,8)
3. Repeat Match	NMB	NMB	Yes

Indicative simulation results – scenario 2 (cost – driven scenario) (3/4)

Weight of parameters



Indicative simulation results – scenario 2 (cost – driven scenario) (4/4)



Case study 1: car pooling - potential extensions

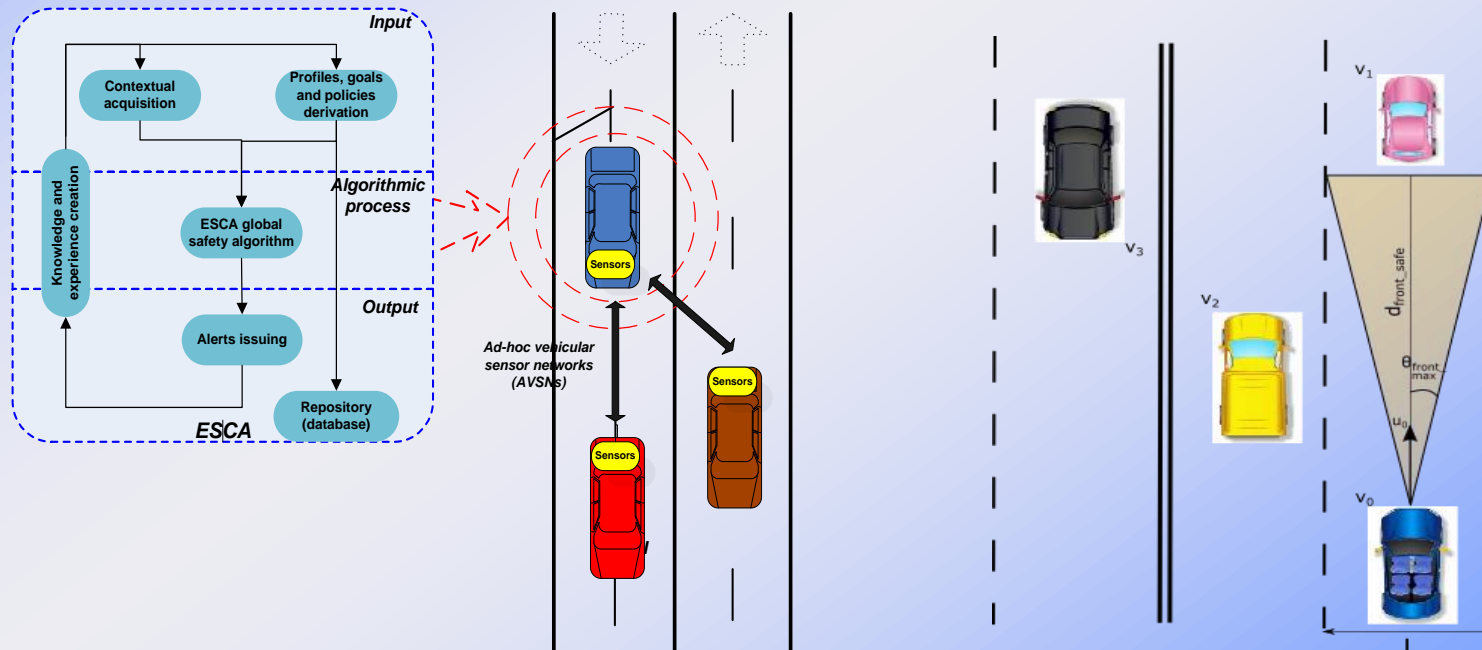
- Extensions

- **Further machine learning techniques** that could create collective knowledge that would be exploited by the systems more efficiently in reaching the appropriate decisions.
- **Possibility to change the importance (weights) attributed to the personal and service profile parameters** during the robust discovery phase and test the functionality's response. Integration of the concept of car pooling in larger management functionality for intelligent transportation systems based on knowledge and experience.

Case study 2: ADAS: global warning system

■ Vehicle sensors and vehicular ad hoc networks

- Inputs: vehicle condition, velocity, direction, data of vehicles nearby, infrastructure elements (traffic lights, signs, etc), congestion, driver profiles
- Outputs: notification of driver on forthcoming dangers (alert levels)
- Benefits: increase in driving efficiency, increase in safety, reliability and stability, cost reduction
- Algorithmic manner: optimization of objective function (heuristic)



Case study 3: Reconfigurable driving styles (1/3)

- **Driving style**

- Combination of parameters
 - Vehicle reactions, controls, gear changes, suspension

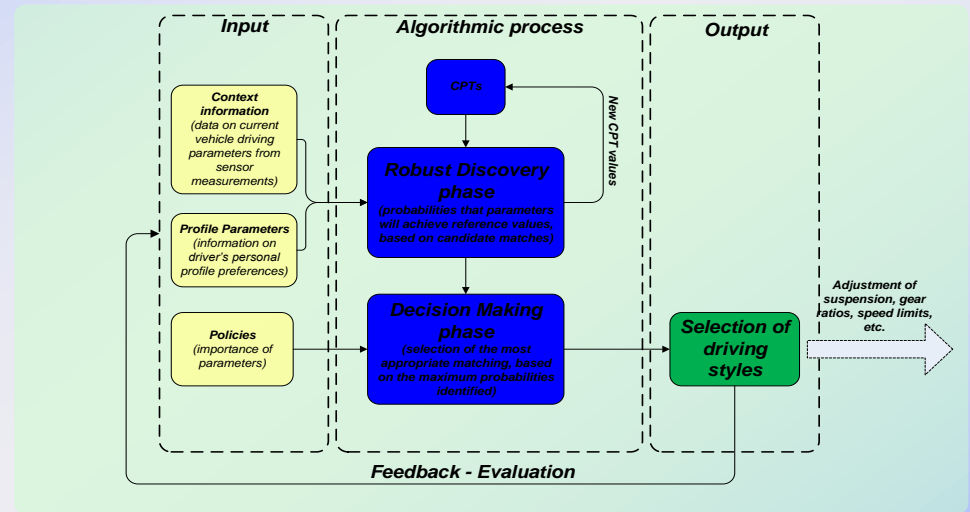
- **Adaptation of driving style**

- A) Manually
- B) Dynamically
 - Parameter-based (road condition, vehicle condition, driver condition / fatigue / profile, etc.)
- System that increases the reliability of decisions taken (Bayesian networks)
- Benefit: increase in in-vehicle intelligence

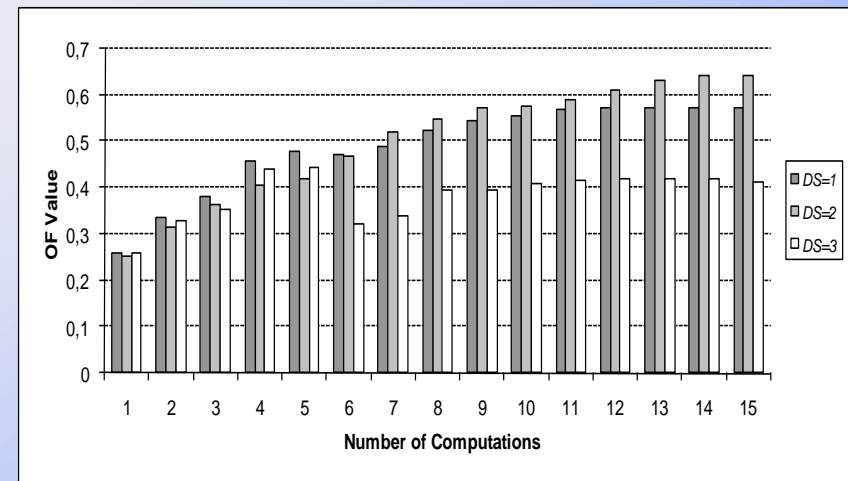
Case study 3: Reconfigurable driving styles (2/3)

- 1. A set of drivers that may drive a certain vehicle is assumed (one of them is also enough for the case), as well as a set of driving styles.
 - The drivers and the driving styles are associated with specific parameters
 - i.e. (a) context information deriving from measurements obtained from the vehicle's sensors
 - data on the driver's personal profile parameters
 - data associated with style related parameters
 - A set of overarching policies reflects driver/styles preferences, in the form of weights (importance) attributed to the aforementioned parameters.
- 2. The manner in which a driver operates the vehicle can change from time to time.
 - Change of the personal profile parameters.
 - Thus, a change in the driving style of the vehicle may be desirable (change of suspension adjustments, gear ratios, speed of vehicle reaction, etc.).
- 3. Goal of functionality
 - Interact, on behalf of the driver, with all candidate driving styles and find and propose an optimum match

Case study 3: Reconfigurable driving styles (3/3)



<table border="1"> <tr><th>Context information</th></tr> <tr><td>1. Mean driving speed</td></tr> <tr><td>2. Frequency of turns</td></tr> <tr><td>3. Mean level of revolutions / minute</td></tr> <tr><td>4. Frequency of gear changes</td></tr> </table>	Context information	1. Mean driving speed	2. Frequency of turns	3. Mean level of revolutions / minute	4. Frequency of gear changes	<table border="1"> <tr><th>Personal profile parameters</th></tr> <tr><td>1. Age / experience</td></tr> <tr><td>2. Gender</td></tr> <tr><td>3. Mental state/fatigue</td></tr> </table>	Personal profile parameters	1. Age / experience	2. Gender	3. Mental state/fatigue	
Context information											
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3. Mental state/fatigue											
(a)	(b)										
<table border="1"> <tr><th>Driving parameters</th></tr> <tr><td>1. Vehicle reaction</td></tr> <tr><td>2. Control</td></tr> <tr><td>3. Economy</td></tr> <tr><td>4. Comfort</td></tr> </table>	Driving parameters	1. Vehicle reaction	2. Control	3. Economy	4. Comfort	<table border="1"> <tr><th>style</th></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> </table>	style				
Driving parameters											
1. Vehicle reaction											
2. Control											
3. Economy											
4. Comfort											
style											



Case study 4: autonomous parking management

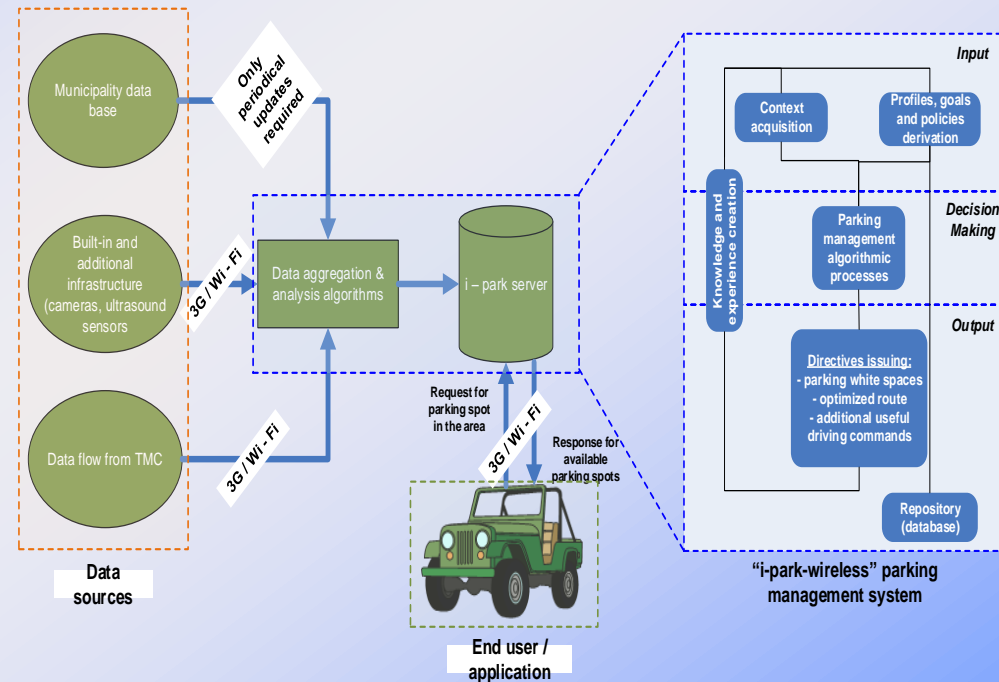
■ Data aggregation

- (i) the municipality data base with information about the number and location of all available parking spots within an area
- (ii) built – in as well as additional infrastructure to gather real – time information (cameras, ultrasound sensors)
- (iii) TMC data flow regarding current traffic.

■ Data analytics

- Evaluate all information gathered and extract accurate, real time results regarding the available parking spots within a specific geographical area.

- User – friendly, fast and accurate communication between the driver and the i-park server through a smartphone application



Conclusions and future challenges

■ **Conclusions**

- Smart Cities are getting more and more smart
- This requires capital expenditure
- Novel solutions are sought for in various areas
- Transportation is an area where SCO find prosper ground
- ITS can increase the quality of mobility in large cities

■ **Challenges: further exploitation of ITS principles in Smart City Operations**

- 100% real-time assessment of traffic congestions
- A priori identification of forthcoming dangers
- Directives for multimodal transport inside a city / region
- Directives for identification of white parking spaces / autonomous parking
- Inform drivers on city-specific events (cultural, etc.)
- Inform drivers on city-specific incidents (e.g. protests, works, etc.)
- Targeted/focused ads and infotainment
- Confront privacy issues
- Decrease of infrastructure costs
- Potential utilization of future mobile communication infrastructures (LTE, 5G D2D)

Indicative R&D projects and publications

■ R&D projects

- i-DOHA (Design Requirements: Capability-Driven Requirements Engineering with Application on i-Doha for the 2022 World Cup), funded by Qatar National Research Fund (QNRF) under the 7th National Priorities Research Programme (Collaborative Project). 01/03/2015 –28/02/2018.
- EMC2, Embedded Multi-Core Systems for Mixed Criticality Applications in Dynamic and Changeable Real-Time Environments, EU FP7 JTI-CP-ARTEMIS (Joint Technology Initiatives - Collaborative Project). 01/04/2014 – 31/03/2017

■ Publications

- G. Dimitrakopoulos, T. Zographos and G. Bravos, "A Holistic Framework for Embedded Safe and Connected Automation in Vehicles", in Proc. 13th IEEE International Conference on Industrial Informatics (INDIN) 2015, Cambridge, UK, July 2015.
- G. Dimitrakopoulos, G. Bravos, M. Nikolaidou and D. Anagnostopoulos, "A Proactive, Knowledge-Based Intelligent Transportation System based on Vehicular Sensor Networks", IET Intelligent Transport Systems journal, vol. 7, Issue:4, pp 454 - 463, December 2013.
- G. Dimitrakopoulos, P. Demestichas, V. Koutra, "Intelligent Management Functionality for Improving Transportation Efficiency by means of the Car Pooling Concept", IEEE Transactions on Intelligent Transportation Systems, vol 13, issue 2, June 2012, pp. 424-436.
- G. Dimitrakopoulos and J. Ghattas, "Autonomic Decision Making for Vehicles based on Visible Light Communications", in Proc. IEEE 14th Wireless Telecommunications Symposium (WTS) 2015, New York, USA, April 2015.
- G. Dimitrakopoulos, "Knowledge-based Reconfiguration of Driving Styles for IITS", International Journal of Artificial Intelligence and Neural Networks", vol. 4, issue 4, December 2014.
- G. Dimitrakopoulos, P. Demestichas, "Intelligent Transportation Systems based on Cognitive Networking Principles", IEEE Vehicular Technology Magazine (VTM), March 2010.

Thank you!

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