ITS & SMART CITIES
(SMART MOBILITY & SMART CITIES)
WHERE COME WE FROM, WHERE WE ARE, WHERE WE GO?

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WHERE COME WE FROM?

• **1989-1991 EU Program DRIVE-I**
  – A new concept is born: Advanced Transport Telematics (ATT) → Explore what the “new” technologies (Telecommunications + Informatics) can do for transportation
  – Along with an emerging idea “the instrumented city” (the embryo of the future “Smart City”?)

• **1992-1994 DRIVE-II**
  – ATT is “apparently” consolidated
  – First concerns about energy (fuel consumption, the echoes of the firsts oil crisis?) and emissions (QUARTETT defines the first emissions models)
  – The transportation world starts to speak about “sustainability”

• **1995 onwards**: a change in the terminology (only?) the start of the Framework Programs
  – ATT is quickly replaced by the most successful (from a market and commercial point of view) terminology ITS (Intelligent Transport Systems)
  – Sustainability concerns become more relevant
SMART CITY

• The concept of Smart City emerges from a reflection on how the development and pervasive application of the Information and Communication Technologies (ICT) can influence the urban development, the socioeconomic conditions and the quality of life

• Technology lays at the heart of the concept as if technology by itself could “solve” all our problems
SMART CITIES

• Are based on the instrumentation and interconnection of mobile devices, sensors and actuators

• Enabling the collection of urban data in unprecedented amounts and quality

• Whose analysis will substantially improve the capability for forecasting and managing the urban flows increasing significantly the ability of fostering the smart management of the city.
KEY APPLICATION AREAS (PILLARS) IN A SMART CITY
(SCHAFFERS ET AL. 2011)
Smart Diamond to define Smart city

Smart Governance

Smart Citizen

Smart Energy

Smart Healthcare

Smart Building

Smart Technology

Smart Mobility

Smart Infrastructure
Smart City: a System of Systems of Systems...

https://lancenl.wordpress.com/tag/smart-city/
However...

- The proposals of solutions for Smart Cities are predominantly dominated more by technology vendors than by initiatives of municipal authorities (Belisent 2010, Schaffers et al. 2011)

- Who claim that “smart city solutions must start with the city not the smart”

- A fact: independently of how much dense is the sensorization of a city, and from it, rich and varied the data collection:
  - Data by themselves, alone, do not mean information
  - Information is generated by a suitable data processing
TECHNOLOGY AND “SMARTNESS”

• From raw data to efficient information
• Where is the intelligence?
• Smartness as a suitable “blending” of
  – Efficient Data Collection (Technology)
  – Efficient Data Processing (Computer Models)
ITS & SMART MOBILITY
ICT TRAFFIC DATA COLLECTION SCENARIO

THE “SMART CITY”
MULTIPLE HETEROGENEOUS DATA SOURCES (SENSORS)

- Point detection with discrete time resolution
  - Inductive loop detectors:
    - Flows (veh/hour), occupancies (time %)
    - Spot Speeds (km/hour)
    - Traffic mix (% light, heavy vehicles)
- Point detection with continuous time resolution:
  - Magnetometers
    - Time in/Time out (flow counts, spot speeds, occupancies, traffic mix)
  - Bluetooth/Wi-Fi, LPR, TAGs
    - Time tag, vehicle/device identification and downstream re-identification (sample counts, travel time measurements)
- Continuous time-space detection
  - GPS, Connected Cars
    - Time tag, position (X, Y, Z coordinates) local speed, heading
  - Smartphone data (Open question)
TRAFFIC DATA ANALYTICS (I)

Dealing with heterogeneous traffic data:
- Data filtering, completion and fusion
- Processing huge amounts of data (Big Data)

Kernel Smoothing Methods & traffic flow based models to identify and remove outliers
Missing data supply

Network with Multisensor Technologies for Traffic Data Collection

Measures from Technology 1 (Loop Detectors, Radar, Magnetometers,...)
Measures from Technology 2 (GPS)
Measures from Technology k (Bluetooth, LPR, TAG)
Mobile Data from Smartphones

Data from Measurement Point 1.1
Data from Measurement Point 1.n
Data from Collection Point 2.1
Data from Collection Point 2.m
Data from Measurement Point k.1
Data from Measurement Point k.p

Data CollectionProtocols
Raw Data Filtering and Completion
Data Fusion Methods of Type II (Kalman, Bayesian...)
Fusion Results: state reconstruction, map of speeds and their time evolution,.....
FUSING DATA FROM INDUCTIVE LOOP DETECTORS WITH BLUETOOTH/WI-FI
BETTER DATA → BETTER MODELS → BETTER INFORMATION → BETTER SERVICES

ADVANCED (ACTIVE) TRAFFIC MANAGEMENT & INFORMATION SYSTEMS (INTEGRATED CORRIDOR MANAGEMENT)
4th EU Framework Program 1999, Project ENTERPRICE

- Scenarios
- Estimation
- Model
- Graphical User Interface
- Qualitative analysis
- Knowledge Bases
- Quantitative analysis
- Statistics

Real-time TIC data

- Interface to External Systems
- Historical traffic data
- Geographic data
- Planning data (control strategy)

Software Data Bus

- Geographic Database (Network Model)
- Evaluation Database (Scenarios, results, ...)

Long-/mid-term strategy update
CONCEPTUAL ARCHITECTURE FOR AN ADVANCED TRAFFIC MANAGEMENT AND INFORMATION SYSTEM

**Data Collection Protocols**

Sensored Urban Network & Data from Mobile Sensors

**Real-Time Raw Traffic Data**

Data Processing Level I (Data Cleansing, Missing Data Models, Profile Generation & Profile Identification)

**Traffic Data Processing & Management**

Other data
- Weather
- Calendar

**Real-Time Cleansed Traffic Data**

**Profile Pattern Recognition Process**

**Selected Profile**

**ONLINE DECISION SUPPORT SYSTEM**

- Impact Evaluation Process
- DYNAMIC TRAFFIC MODELS
- Management Strategies

**ACTUATORS TO IMPLEMENT STRATEGIES**
- Gate In/Gate Out
- Reroutings
- Speed Control
- Control Changes
- Other

**SELECTED STRATEGY**

**DISSEMINATION OF INFORMATION TO USERS**
- Variable Message Panels
- Internet/Smartphones
- Navigation Equipment
- Other

**Historical Database**
- Traffic profiles

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INTEGRATED CORRIDOR MANAGEMENT (ICM) AND ANALYSIS, SIMULATION MODELING (AMS) APPROACH

IN THE WAY TO CREATE “COMPREHENSIVE SITUATIONAL AWARENESS”
Identification of time-dependent mobility patterns in terms of Origin-Destination (OD) Matrices Exploiting ICT measurements

Factors determining the quality of the estimation:
1. % technology penetration
2. Detection layout
3. Input OD seed

Off-line estimation of a good input OD seed per time interval

Nonlinear bilevel nondifferentiable optimization problem solved using:
- A special version of Stochastic Perturbation Stochastic Approximation at the upper level
- A Dynamic User Equilibrium Assignment at the lower level

Online Ad Hoc Kalman Filter to estimate the time dependent OD

\[
\begin{align*}
g_{k+1} = Dg_k & \quad p_{k+1} = Dp_k D^T + W_k \\
G_{k+1} = P_{k+1} F_{k+1} (F_{k+1} P_{k+1} F_{k+1}^T + R_k)^{-1} & \\
p_{k+1} = (I - G_{k+1} F_{k+1}) p_{k+1} & \\
g^{k+1} = g^{k+1} + \alpha d_{k+1} \geq 0 & \\
d_{k+1} = G_{k+1} [z(k+1) - F_{k+1} g^{k+1}] & 
\end{align*}
\]
Traffic
Network
Space State
Estimation
and Short
Term
Forecasting
Based on a
Dynamic
Traffic Model
Mesoscopic Traffic Simulation
(Projects SIMETRIA, MITRA, In4Mo)

MAIN OUTPUTS
- Time dependent flows
- Time dependent travel times
- Queue dynamics
- Congestion dynamics

COMPLETE NETWORK INFORMATION
- Link Speed Map
- Link Travel Times
- Alternative paths and forecasted path travel times

Network Model
Time-dependent OD matrices
Traffic Control Data

Initial path calculation and selection

DUE Convergence criteria (Rgap) satisfied

YES

NO

Estimate path travel times at time t

calculate paths and paths flows at time t

Perform Dynamic Network Loading (meso traffic simulation)

Estimate the new path sets according to the computational algorithm for equilibrium (MSA, Projection…) adding new paths or removing existing ones for each OD pair and time interval

STOP

calculate paths and paths flows at time t
CONCEPTUAL ARCHITECTURE OF THE DECISION SUPPORT SYSTEM FOR ADVANCED TRAFFIC MANAGEMENT AND INFORMATION
A STEP FORWARD
Decision Support Systems based on the **Network Fundamental Diagram (NFD)** allow to identify in real time the current traffic state of a urban area and its evolution. This information is the used, in combination with traffic models, for the implementation of proactive traffic control strategies.
CONCEPTUAL APPROACH TO AN ADAPTIVE FLOW CONTROL STRATEGY BASED ON THE NFD

LARGE URBAN OR METROPOLITAN AREA

Origin r
Alternative recommended route
GATE-IN
Congestion
GATE-OUT
Queue
Destination s

Input flow rates $\beta(k)$

Critical Point in the managed area
Real-time Traffic Data Measurements from sensors
Output flows $n(k-1)$

Allow access
Restrict access
Estimation algorithm for $\hat{n}(k)$
ADAPTIVE FLOW CONTROL STRATEGY

SMART MOBILITY SHOULD NOT FORGET MULTIMODAL TRANSPORT
BUT, AN INTEGRAL MOBILITY SUPPORT SYSTEM MUST ALSO ACCOUNT FOR ALL AVAILABLE TRANSPORTATION MODES: Private vehicles, public transport, cycling, walking....

Real-time Journey Planners: Multimodal path search engines to find time-dependent hyperpaths with time-windows in multilayered modal networks with modal exchange nodes, optimizing user objectives.
REAL-TIME ADVANCED JOURNEY PLANNER

- Interactive, integrated, multimodal, real-time decision support system (pre-trip, in-trip)
- Data interoperability
Seamless Smooth Door-to-door mobility services offered to users by ‘mobility operators’, supported by digital solutions operating in the cloud. With open access to the **timetables, real-time location information, and payment systems** of existing transport service providers (e.g., railway operators, taxis, local transport operators, car sharing).
TOWARDS A EUROPEAN MULTI-MODAL JOURNEY PLANNER (Final Report, September 2011)

• One of the **key obstacles** for the development of high quality information services is the difficulty that service providers face to **get access to traffic and travel data**.

• Barriers for a **fair and transparent access and reuse of Traffic and Traveler information held by public authorities**, with harmonized conditions and standards of exchange (Directives on Open Data have not yet solved this issue)

• Need of facilitating a transparent market for reuse of Traffic and Traveller information held by commercial organisations, stimulating harmonised conditions and standards of exchange.
DOOR TO DOOR SEAMLESS MaaS
SHORTCUTS WITH SOCIAL NETWORKS AND MOBILE APPS

• Turning citizens into an active agent in the generation of mobility data using mobile devices: tracking subscribers, mining mobile messages from social networks

• Analysis of mobility and personal and urban behaviour to provide services (Waze, TripZoom, Sunset, Foursquare, UBER, Ca2Go....)


TRIPZOOM consists of a network of Core Services guarded by Proxy and Security Services

- Personal Mobility Store (PMS)
- Mobility Pattern Detector (MPD)
- Mobility Pattern Visualizer (MPV)
- Relation, Identity, and Privacy Manager (RIP)
- Social Network Connector (SNC)
- Incentives Market Place (IMP)
WHAT ABOUT SUSTAINABILITY?
ACHIEVING SUSTAINABLE URBAN TRANSPORT MOBILITY IN POST PEAK OIL ERA

Hubbert's "idealized" production model

\[ x = \frac{e^{-t}}{(1 + e^{-t})^2} = \frac{1}{2 + 2 \cosh t} \]

The actual curve of each oil region differs from this theoretical graph, but more-or-less follows this pattern. There are also differences between on-shore and off-shore profiles.

Before oil can be consumed, it first needs to be located

Transition Culture (transitionnetwork.org)
SMART CITIES WITH SMART MOBILITY MUST BE SUSTAINABLE

HOW WILL OUR FUTURE CITIES LOOK?

Will we use flying cars to avoid the rush-hour in the cities of the future?

Or will electrical, automated, connected vehicles be the panacea?
AFTER ALL “SUSTAINABLE” MOBILITY (Low consum and emissions) WAS ALREADY A PROPOSAL OF PROFESSOR FRANZ OF COPENHAGEN 60 YEARS AGO
TRENDS IN URBAN DEVELOPMENT

**Urban Growth**
- In 2008 more than 50% of world population was living in cities
- Today 75% of anthropogenic GHG from cities
- In 2050 70% of world population will live in cities

**Urban Sprawl**: combined effect of growing affluence, changing life-styles and vast advance in personal mobility

Separation of living and working areas ↔ Enabled by transport systems ↔ Congestion ↔ Impact on energy consumption ↔ emissions ↔ quality of life
TRANSPORT, MOBILITY, QUALITY OF LIFE AND SUSTAINABILITY

- 30% of total energy and 71% of all oil in EU is consumed by transportation (European Commission, 2007)
- The urban-density and transport-related energy consumption raises serious concerns on our “urban planning rationality”
TWO-WAY INTERACTION BETWEEN TRANSPORT AND URBAN FORM

SPATIAL INTERACTION PARADIGM: Interaction between individual mobility and location behavior
INVESTIGATE THE COMPLEXITY OF CITIES

• Urban transportation systems are complex dynamic subsystems of the city, a larger more complex system ⇒ The Smart City as a System of Systems

• To understand the complexity of these systems a suitable methodological modeling approach is System Dynamics, which has the ability to account for the multiple variables, feedback loops between components and the role of the influencing factors

Causal relationships of the urban transportation system with its environment, A. Moser
The strategic model MARS and its application, Pfaffenbichler et al. Systems Dynamics Review
THE SUSTAINABLE MOBILITY PARADIGM

• Alternative paradigm requiring
  ➢ To investigate the complexity of cities
  ➢ To strengthen the links between land-use and transport
• Implying mixed use developments
  ➢ Preference to public transport
  ➢ Accessible corridors near public transport interchanges
  ➢ Satisfy the requirements of service and information based economies

• Sustainable transport asks for
  ➢ Urban forms keeping average trip lengths below the thresholds required for maximum use of the walk and cycle modes
  Not to prohibit the car but to design cities of such quality and at a suitable scale that people would not need to have a car
• THE KEY POLICY BECOMES THAT OF REASONABLE TRAVEL TIME RATHER THAN TRAVEL TIME MINIMISATION
CONCLUDING REMARKS

• The reflection of the Smart City concept as a consequence of the development and pervasive application of the Information and Communication Technologies (ICT) has driven an analysis on the role of models to generate information of the required quality to support the envisaged applications.

• Mobility as a Service has been analyzed and discussed its drawbacks consequence due more to political and administrative hurdles than to technological barriers.

• Shortcuts to circumvent these drawbacks have been found resorting to social networks and mobile telecom services.

• Smart Mobility calls for sustainability, but sustainability is not only a technological question but an issue requiring a better understanding of the complex relationships in the city dynamic system and their combination with technological issues.
THANK YOU VERY MUCH FOR YOUR ATTENTION