

Global System Science and Smart Cities

Collegio Superiore, Novembre 2015

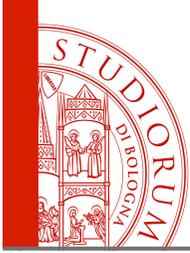
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DISI – Dipartimento di Informatica – Scienza e Ingegneria



Outline

- Introduction to Global System Science
 - Policy Challenges driving GSS
 - Smart cities and GSS
- Case studies:
 - Energy systems
 - Urban mobility
 - Disaster management
- Technological challenges for ICT
 - Emerging architectures for GSS
 - Big data science
 - Computational sustainability



Timing

- Introduction to Global System Science
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Nov. 3



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Nov. 4



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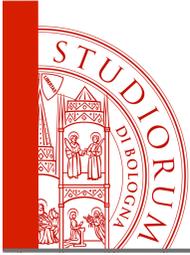
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Nov. 9



Global System Science

- Our society is organized around a number of interconnected global systems
 - Logistics and supply chain
 - Health services
 - Financial market
 - Energy systems
 - Water/heat networks
 - Computer networks
 - Mobility and transportation systems



Global System Science

- Global systems are socio-technical, and involve interactions among:
 - Complex infrastructures
 - Man-made processes
 - Economic systems
 - Environment
 - Natural phenomena
 - Multiple stakeholders
 - Human behaviour



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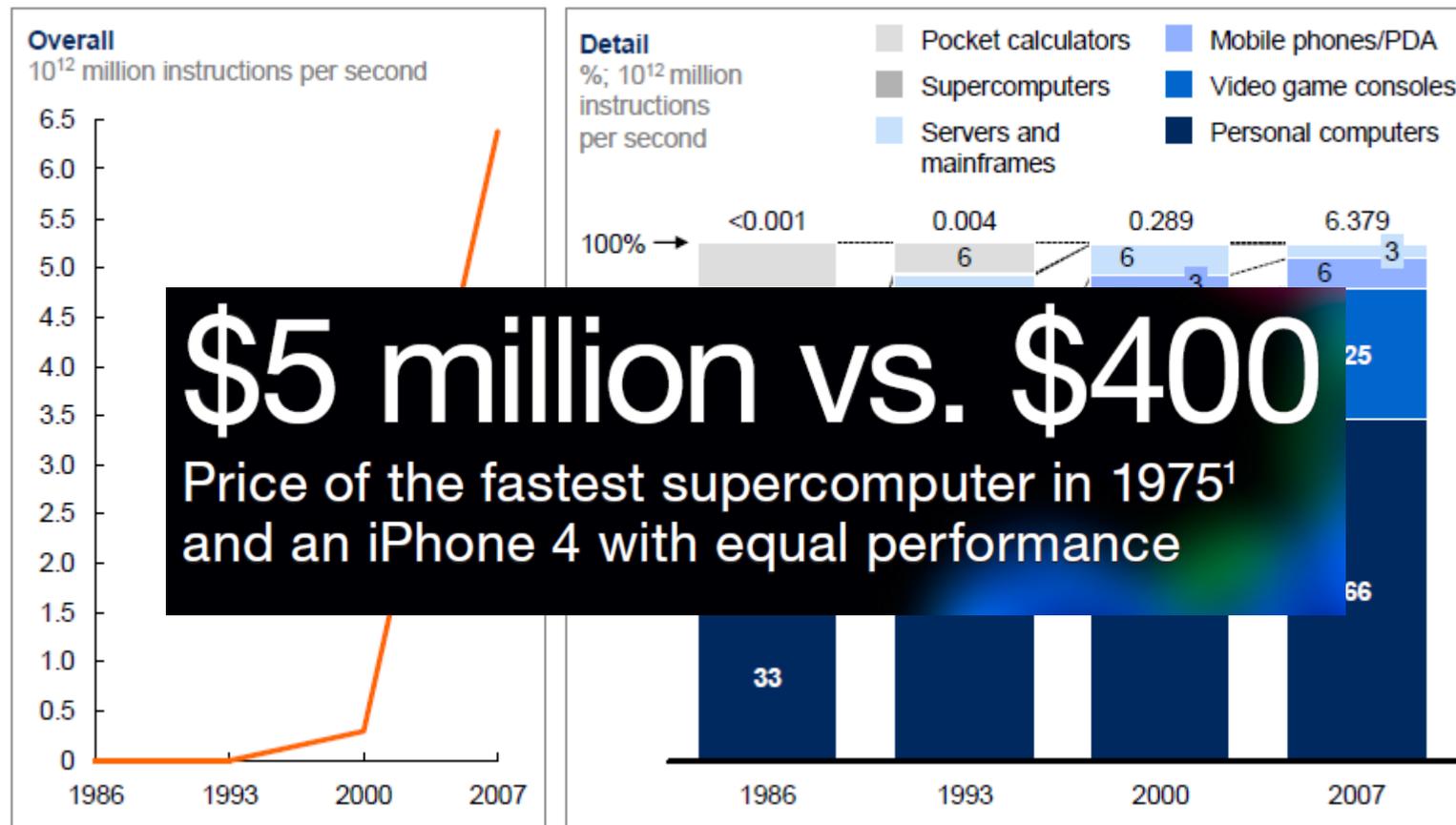
The progress in high-performance computing, data mining, machine learning and decision support opens new possibilities to look at the system more holistically



Enabler: computation capacity

Computation capacity has also risen sharply

Global installed computation to handle information



NOTE: Numbers may not sum due to rounding.

SOURCE: Hilbert and López, "The world's technological capacity to store, communicate, and compute information," *Science*, 2011

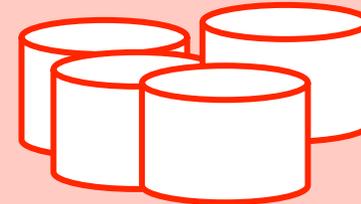


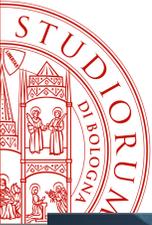
Global System Science

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For the first time in the history of mankind we have access to data-sets of unprecedented scale and accuracy





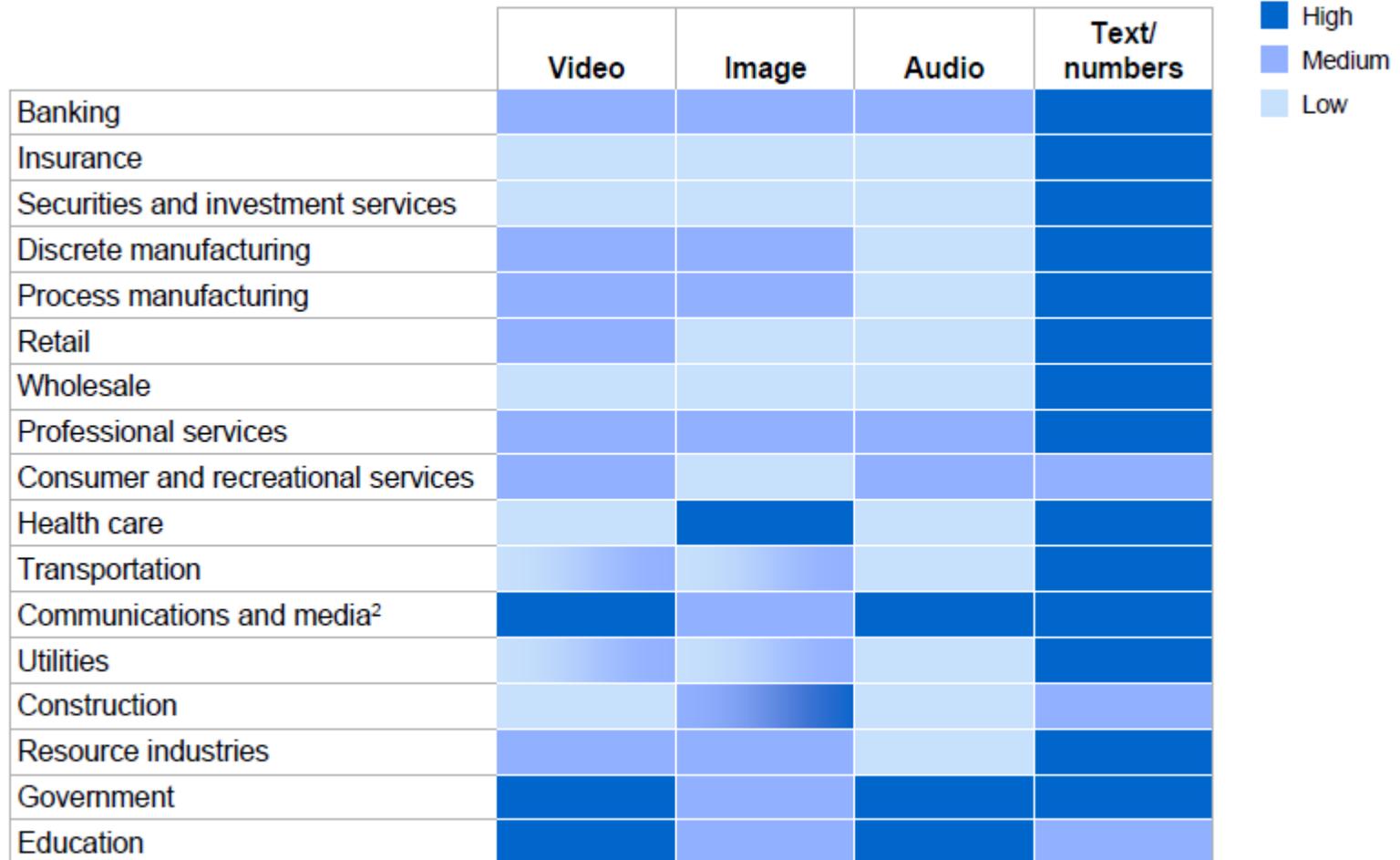
Big data in numbers





Big data: types

The type of data generated and stored varies by sector¹



1 We compiled this heat map using units of data (in files or minutes of video) rather than bytes.

2 Video and audio are high in some subsectors.

SOURCE: McKinsey Global Institute analysis



Global System Science

Global System Science (GSS) is the evidence-based study of socio-technical interconnected complex systems. Its goal is to identify fundamental concepts that help structure problems, identify phenomena, and organize actions.



Global System Science

- GSS looks at systems holistically, studying their main components and how they interact.
 - The complex underlying **infrastructure/organization**, including the physical laws/process governing it.
 - The **environment** influencing and being influenced by the system.
 - The **human factor** driving and perturbing its dynamics
 - The **conflicting interests** of a number of self-interested actors involved in the process.
 - The different **time/geographical scales** at which the systems components operate.

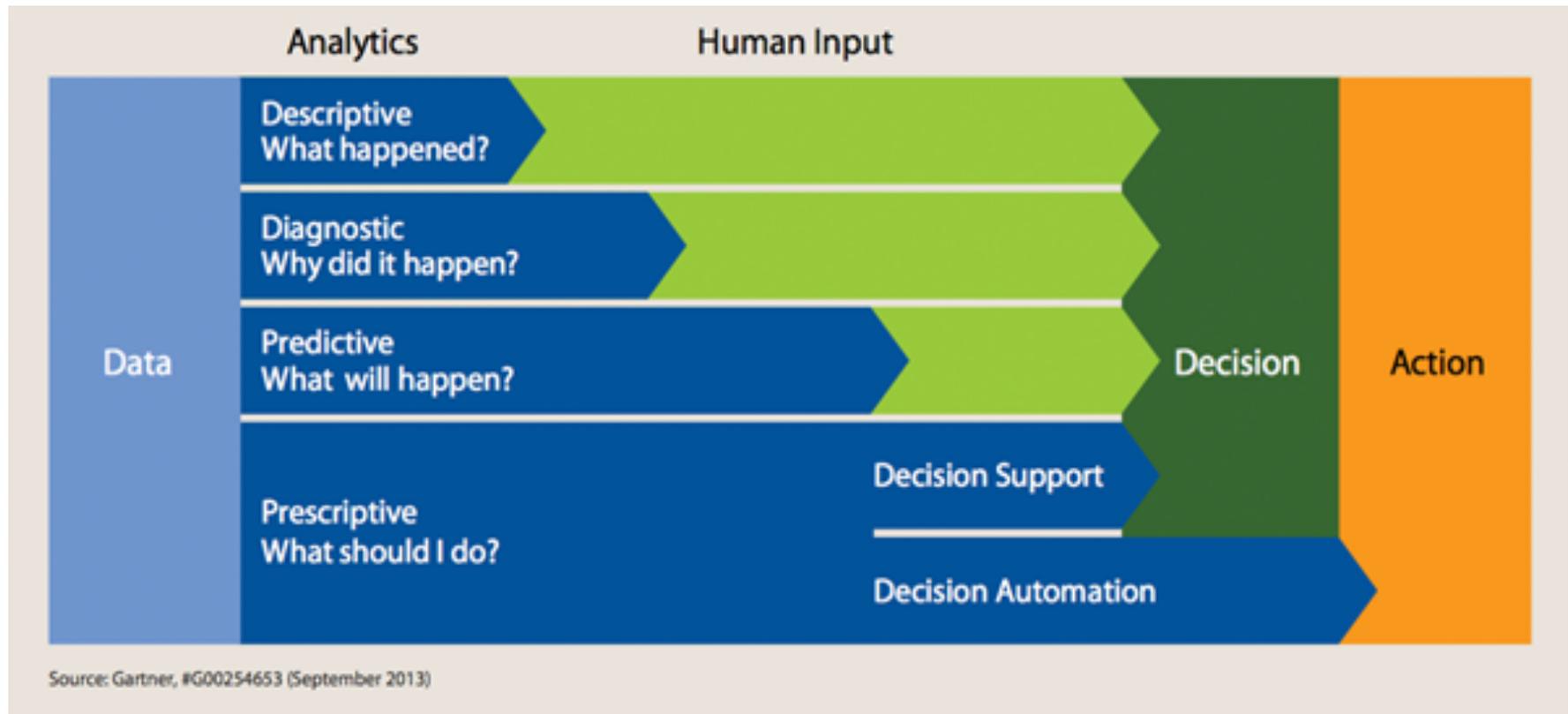


The role of analytics....

- GSS foresees a crucial role of analytics:
 - **Descriptive analytics**
 - Understanding the system behaviour, its components, and their relations.
 - **Predictive analytics**
 - Predicting how the system will behave over time.
 - **Prescriptive analytics**
 - Operational Control: Controlling and optimizing the dynamics of the system.
 - Strategic and Tactical Planning: how to influence/optimize the medium- and long-term behaviour of the system.



The role of analytics....





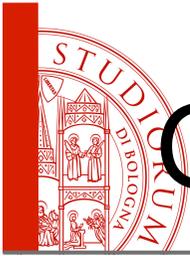
GSS challenge

- The real GSS challenge is to tightly integrate the operational behaviour of the infrastructure/ organization, human behaviour, and mechanisms to influence it, the social and environmental interaction and systemic effect that require the adaptation of the system and strategic and tactical planning.



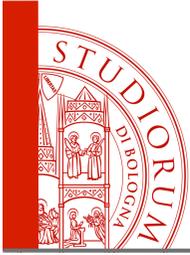
GSS target

- GSS is aimed at studying global systems for providing policy makers decision support tools for strategic planning
 - Cross cutting issues among policy domains
 - Policies cover different actors and sectors operating at different levels (local/global) connected through a variety of social-economic networks.
- GSS calls for evidence-based policy making



GSS and cities: some numbers

- Roughly 7 billion people on Earth
- 3,5 billion (50%) live in cities
- Expected to rise to 80% in this century
- The development and growth of urban systems is the most constant dynamic in human societies since about 6000 years
- Most innovation is born in cities
- High-risk systems: Cities innovate and change rapidly, but the trajectories they take are difficult to predict or to impact



Smart cities

A smart city is livable, resilient, sustainable urban environment, and designed through open and collaborative governance.

[DeSouza 2012]

Smart cities features

- **Resilient**, i.e. possesses the capacity, desire, and opportunity for sensing, responding to, recovering, and learning from natural and man made disasters.





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- **Resilient**, i.e. possesses the capacity, desire, and opportunity for sensing, responding to, recovering, and learning from natural and man made disasters.
- **Sustainable** approach to the management of its economic, social, and ecological resources



Smart cities features

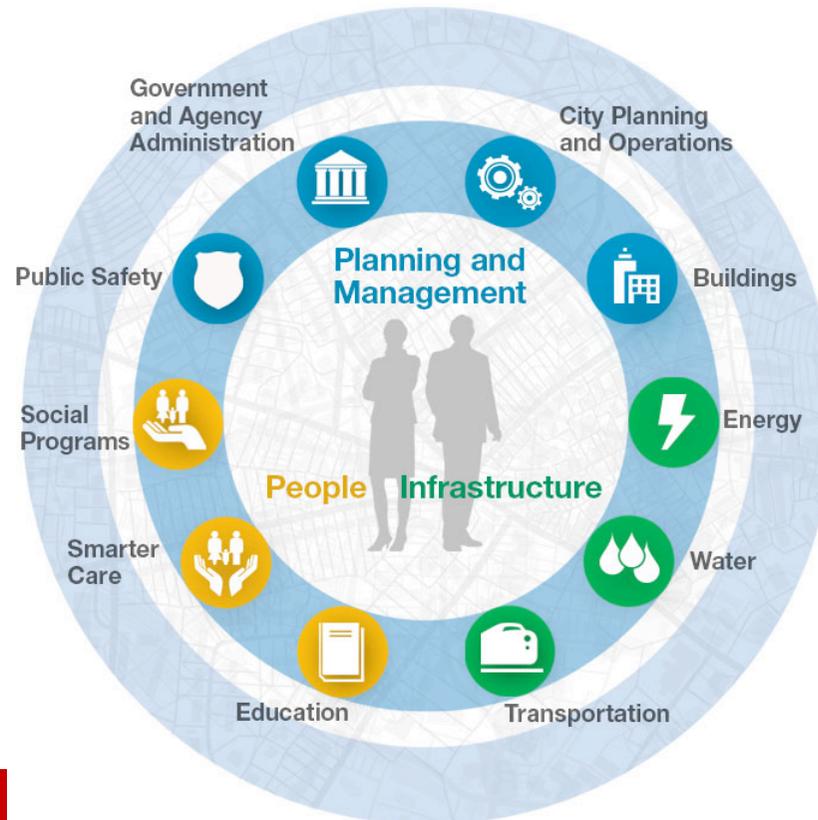
- **Data-driven:** fuses information for automated and human, individual and collective, decision making.





Smart cities

- operates as a **seamlessly integrated platform** where information links the various infrastructures, systems, organizations, and citizens' goals and values.



Smart cities

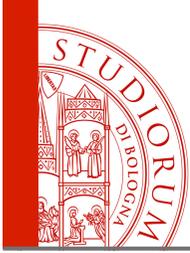
- **Engages citizens** in planning and design of public spaces and governs use of public resources through open and **collaborative governance platforms** supported by information technologies that generate, and leverage, the collective intelligence of its residents.





GSS and cities

- GSS explores how the interaction between the global urban system and the global ICT system are changing settlement structures and lifestyles, and how policy-makers can influence their future dynamics.
- It will do so by relying on
 - Case studies,
 - Crowd sourced data and sensed data
 - Simulation models
 - Prescriptive models



GSS and cities

- Urban systems are one of the major fields of application of global systems science
- Almost all problems in smart cities share:
 - They involve many different heterogeneous systems, (the transportation systems, the behaviour of citizens, - influenced by social networks, or the energy system)
 - They evolve at different time/space scale.
 - They are coupled (the dynamics of transportation systems is impacted and impacts the social behaviour of individuals) or belong to hierarchies (one system being a subsystem of another one)
 - They are regulated by laws and norms



GSS and cities

- Smart planning:
 - think at cities as ecosystems of infrastructure, citizens, and processes impacting environment, society and economy
- Collective smart:
 - Collective intelligence, crowd sourcing/funding, knowledge co-creation, co-production
- Smart infrastructure
 - Providing data on its usage and reacting to events
- Smart operation
 - Promoting sustainable behaviours
- Smart governance
 - Multi-objective goals, negotiation among conflicting interests, optimal collaboration between stakeholders



GSS and cities: where we are

- The final aim is to consider a city as a system of complex systems
- Current research still faces single systems by different angles and considering various influences
- In the course we will make some examples



Case studies

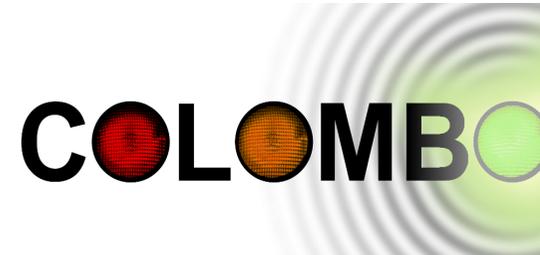


- **Energy policies and energy systems**
 - Planning tools for sustainable energy plans
 - Environmental and economic impact assessment
 - Prediction tools for understanding the impact of policy measures on society
 - Monitoring tools for data acquisition
 - Citizen awareness and engagement
 - Collective awareness platforms



Case studies

- **Traffic management**
 - Traffic control systems
 - Traffic monitoring through opportunistic harvesting
 - Impact of technology penetration rate
 - Emission monitoring and control



COLOMBO



Case studies

- **Disaster Management:**
 - Evacuation planning
 - Natural phenomena
 - Human factor
 - Traffic network
 - Complex infrastructure: ex. Electrical grid

Courtesy of
Prof. Van Hentenryck



Methodological challenges

- Provide integrated architectures, methodologies and tools for dealing with global systems
 - Simulation tools
 - Decision support tools
 - Social science models
 - Engineering
 - Big data science
 - IoT



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