I am speaking in the behalf of colleagues at ENEA

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ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

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Simulation of cascading outages in (inter)dependent services and estimate of their social consequence

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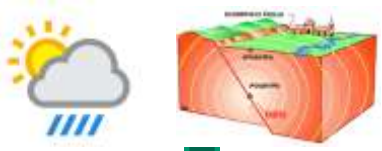
Rationale

CIPcast is a Decision Support System aimed at providing the operator with a more complete picture of the current and predicted status of its own infrastructure

It is composed by the following components and modules

- *A large and heterogeneuos DB*
- *A Natural Events forecast module (weather,…)*
- *A Natural Event "**Damage**" Estimator (weather, earthquake)*
- *An **"Impact"** prediction module (RecSIM application)*
- *A "**Consequence**" Analysis module*

Workflow



Monitoring of Natural Phenomena

Prediction (Acquisition) of Natural Events

Prediction of Damage Scenarios

Prediction of Impact

Consequences Analysis

Support of Efficient Strategies

CIPRNet DB

Web-GIS Interface

Damage Scenario
Vulnerability of CI components,
Severity of estimated (acquired) natural events

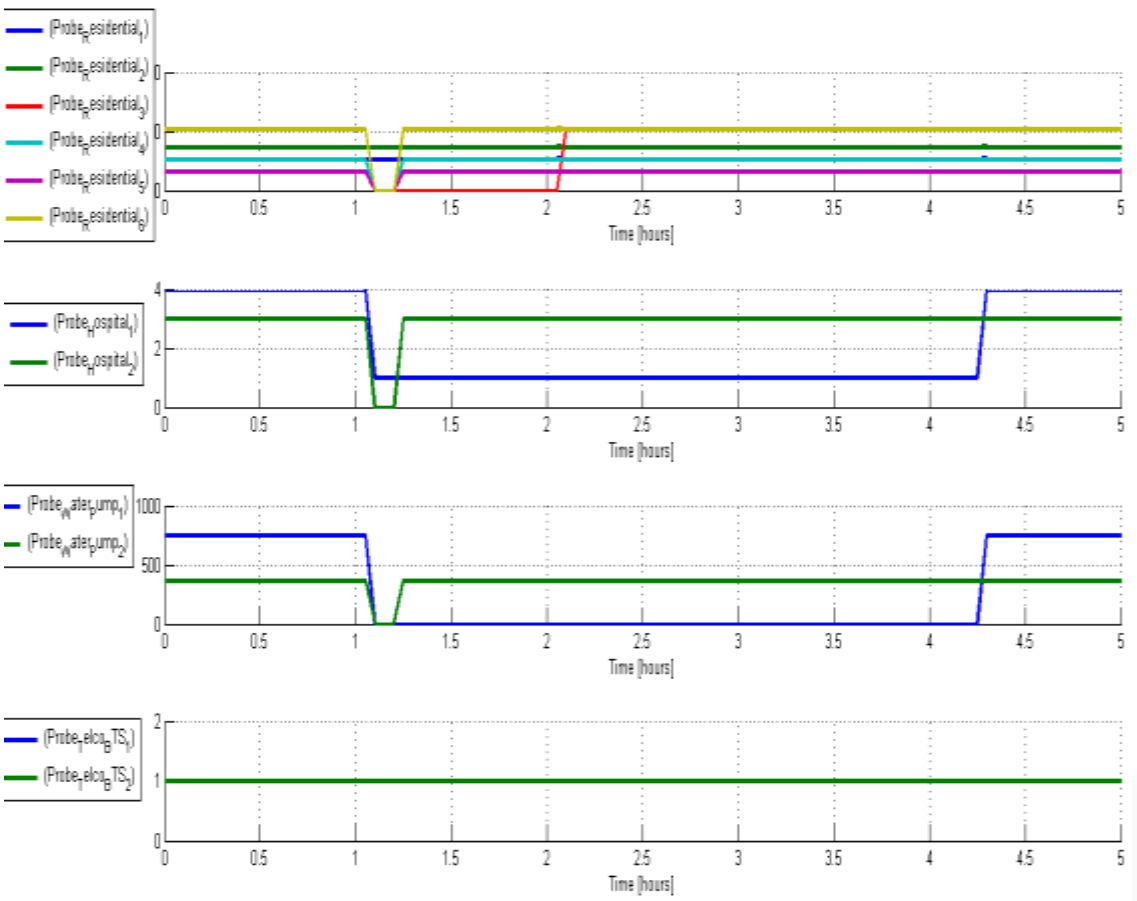
Impact Scenario
Interdependency phenomena

Consequence Analysis
Effects on society due to the degradation of CI services

Consequence Analysis

It allows to transform the outage duration of the different CI elements supplying specific primary services into an estimate of the ultimate consequences induced by the reduction (or loss) of primary services to the different societal sectors such as

- *the citizens*
- *the industrial (economic) sectors*



All that after having specified appropriate metrics to measure consequences

Measuring Consequences as 'generalized Wealth' reductions

*Suppose to have **N** CI elements providing a specific service (i.e. electricity) each of them providing its service to K_i societal elements (citizens or plants or other economic activities) for a period of time **t=[0,T]***

$$W = \int_0^T \sum_{i=1}^{N} u_i(t) K_i \, dt$$

*where $u_i(t)$ is a [0,1] bounded function expressing the capacity of the element to supply its service (1= fully, 0=at all). Let us call **W** the societal element **Wealth***

Measuring Consequences as 'generalized Wealth' reductions

If all $u_i(t) = 1$

$$W = W_e = MT$$

Let's call ***W*** *"generalized wealth" and* W_e *the "expected Wealth".*

If $u_i(t) \neq 1$ *for some* ***i*** *and/or some* ***t***

$$\Delta W = W_e - W = MT - \int_0^T \sum_{i=1}^{N} u_i(t) K_i \, dt$$

W *corresponds to a National Authorities' KPI measuring DSO's Quality of Services*

Definition of consequence as a 'generalized Wealth' reduction

*In a more complete version of Consequence Analysis, Wealth could be associated to the **simultaneous** access of societal elements **K** to different services (supplied by different elements of different CI), each service weighted according to its capability of contributing to the Wealth achievement.*

$$W = \int_0^T \sum_{i=1}^{M} \sum_{j=1}^{N} u_{ij}(t) K_{ij} r_{ij} \, dt$$

Elements of a service

services

Societal element

Service Access Wealth indices

Service Access Wealth (SAW) indices

SAW indices r_{ij} express the capability of the service ij to contribute to the Wealth of a specific sector.

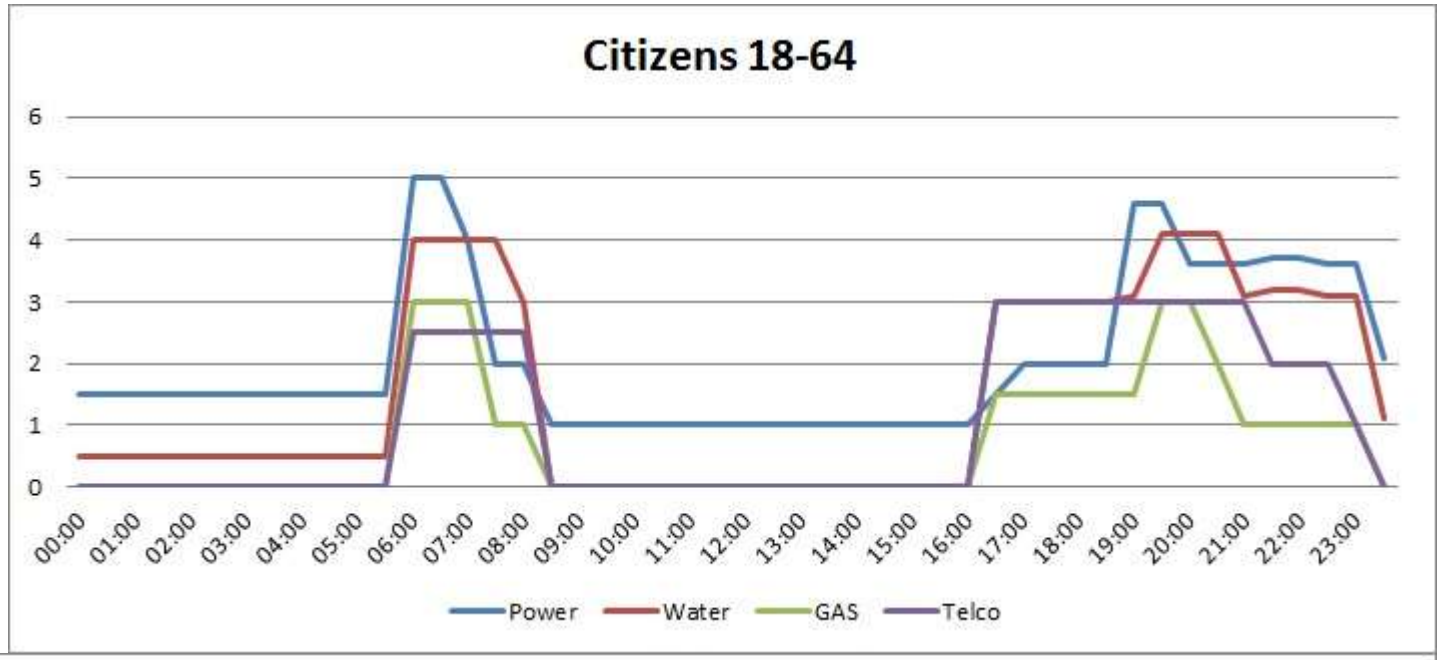
SAW indices can be inferred by statistical and economic data. They could be also time-dependent

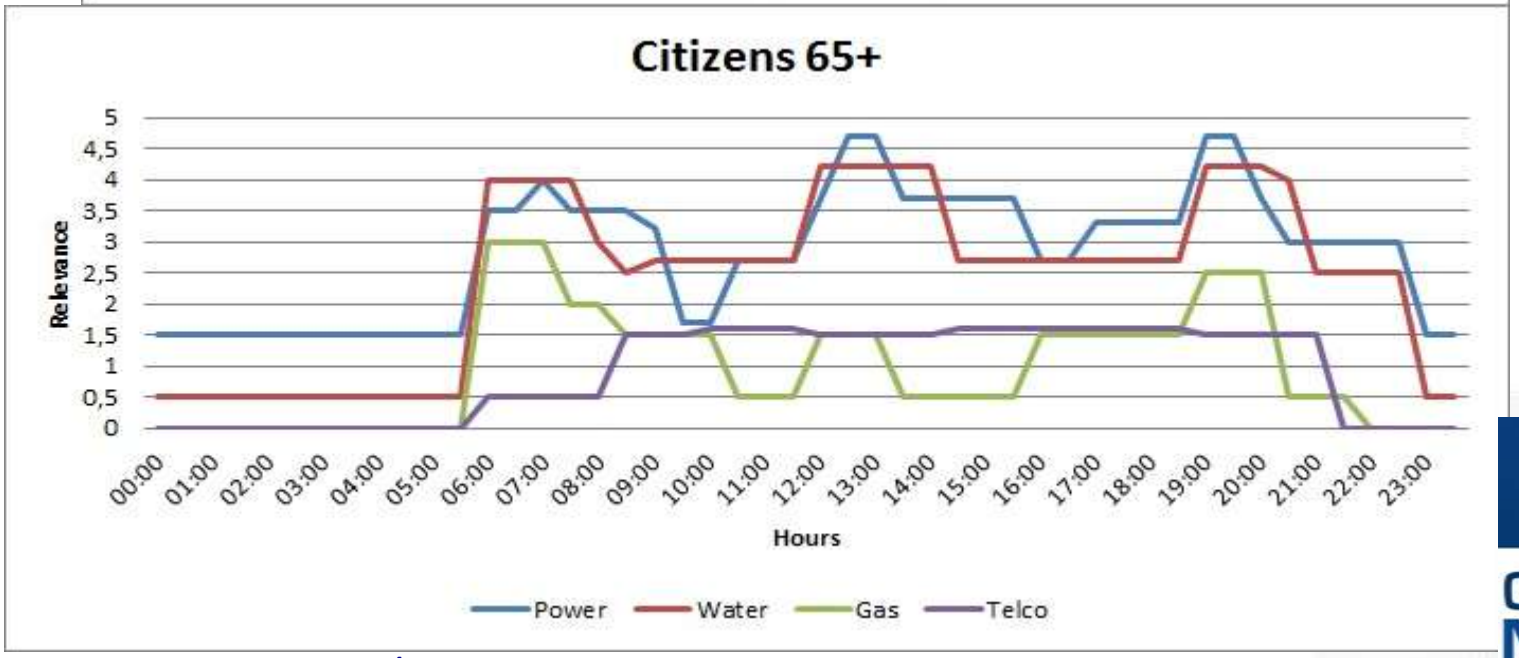
Criterion Element	Energy	Telecom	Water	Gas	Mobility
Primary Sector	0.400	0.006	0.186	0.0	0.408
Secondary Sector	0.300	0.058	0.231	0.0	0.411
Tertiary Sector	0.197	0.248	0.185	0.0	0.370

SAW indices properties

In a more accurate model, SAW indices could be defined as time-dependent parameters, capturing the activities variation of societal elements during the course of the day

SAW indices properties





Data availability (likely EU-wide)

Statistical Classification of Economic Activities in the European Community, Rev. 2 (2008)

--- Further files and information ---

Top of classification

Layout: Hierarchic

Back to classification list

Show Code

Select language of the data: English

Detail
+ A AGRICULTURE, FORESTRY AND FISHING
+ B MINING AND QUARRYING
+ C MANUFACTURING
+ D ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY
+ E WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES
+ F CONSTRUCTION
+ G WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES
+ H TRANSPORTATION AND STORAGE
+ I ACCOMMODATION AND FOOD SERVICE ACTIVITIES
+ J INFORMATION AND COMMUNICATION
+ K FINANCIAL AND INSURANCE ACTIVITIES
+ L REAL ESTATE ACTIVITIES
+ M PROFESSIONAL, SCIENTIFIC AND TECHNICAL ACTIVITIES
+ N ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES
+ O PUBLIC ADMINISTRATION AND DEFENCE; COMPULSORY SOCIAL SECURITY
+ P EDUCATION
+ Q HUMAN HEALTH AND SOCIAL WORK ACTIVITIES
+ R ARTS, ENTERTAINMENT AND RECREATION
+ S OTHER SERVICE ACTIVITIES
+ T ACTIVITIES OF HOUSEHOLDS AS EMPLOYERS; U0NDIFFERENTIATED GOODS- AND SERVICES-PRODUCING ACTIVITIES OF HOUSEHOLDS FOR OWN USE
+ U ACTIVITIES OF EXTRATERRITORIAL ORGANISATIONS AND BODIES

Granularity: City

Data availability (likely EU-wide)

A- Agriculture, Forestry and Fishing	126	3.845	31
B- Mining and quarrying	83	2.136.226	25.738
C- Manifacturing	9672	20.936.598	2.165
D- Electricity, gas, steam and air conditioning supply	541	14.403.309	26.623
E- Water Supply; Sewerage, waste management and remediation activities	324	1.501.426	4.634
F- Constructions	20132	6.854.538	340
G- Wholesale and retail trade, repair of motor vehicles and motorcycles	53313	43.933.922	824
I- Accomodation and food service activities	14087	3.261.850	232
H- Transportation and storage	8683	9.329.385	1.074
K- Financial and insurance activities	6293		
L- Real Estate activities	15014	2.495.419	166
M- Professional, scientific and technical activities	52374	8.225.424	157

M- Professional, scientific and technical activities	52374	8.225.424	157
N- Administrative and support service activities	13248	7.617.362	575
O- Public Administration and defence, compulsory social security			
P- Education	1845	338.635	184
Q- Human health and social work activities	21354	3.863.140	181
R- Arts, entertainment and recreation	7094	2.299.426	324
S- Other service activities	10111	829.671	82
T- Activities of households as employers, undifferenziated goods and services producing activities of households on own use			
U- Activities of extraterritorials organizations and bodies			

Granularity: City

Number of active companies

Istat website

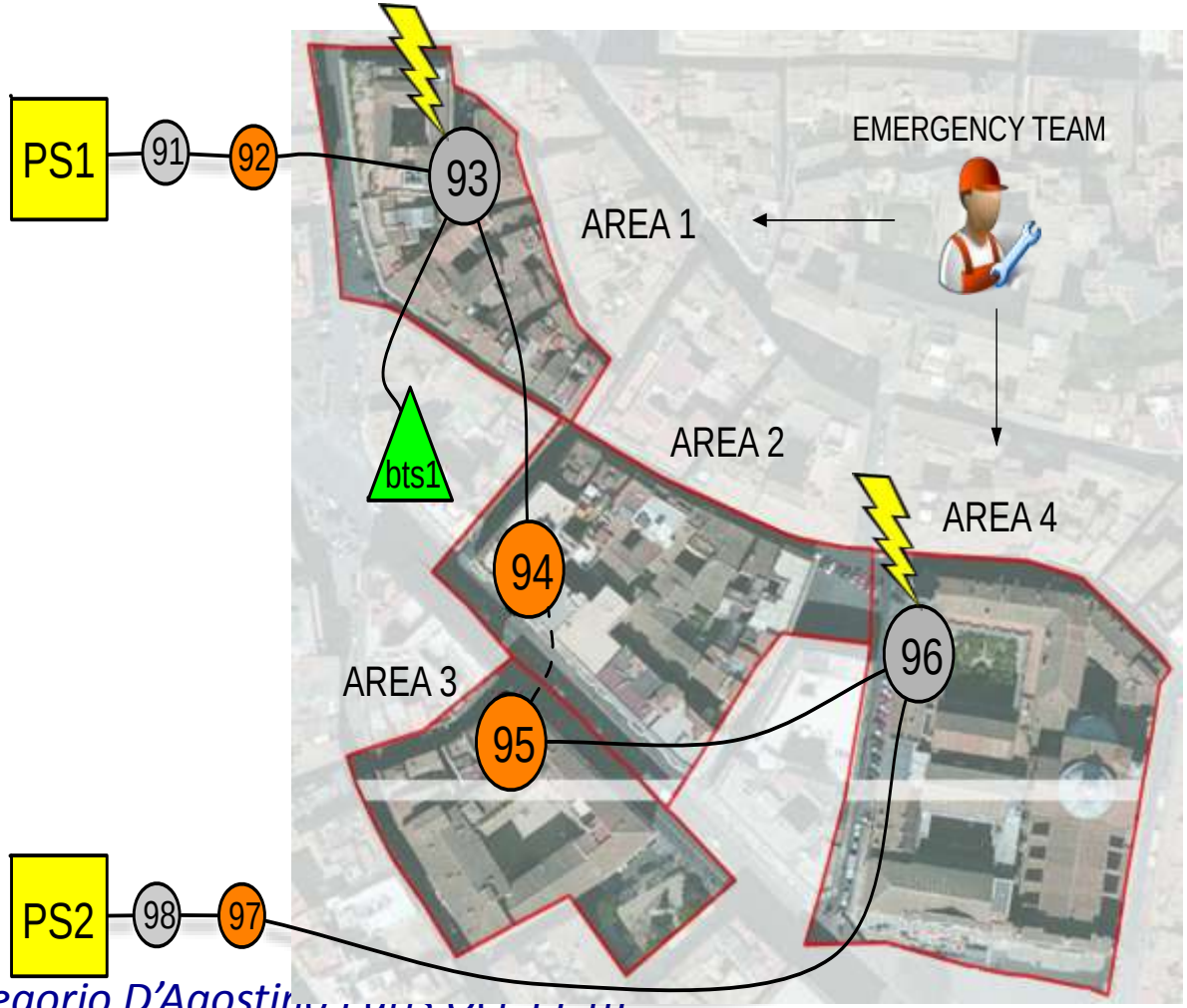
Total annual turnover (kEur)

Annual Statistic directory, Table14.9

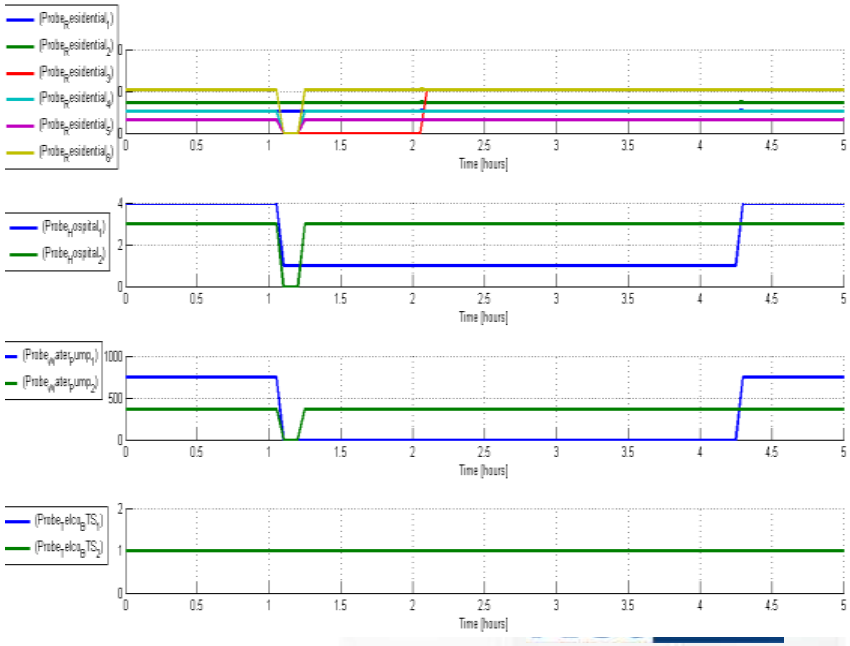
Average annual turnover (kEur)

Case study: social consequences

Area of a city where a sudden damage on the electrical distribution system produced the correlated outage of different distribution substations.

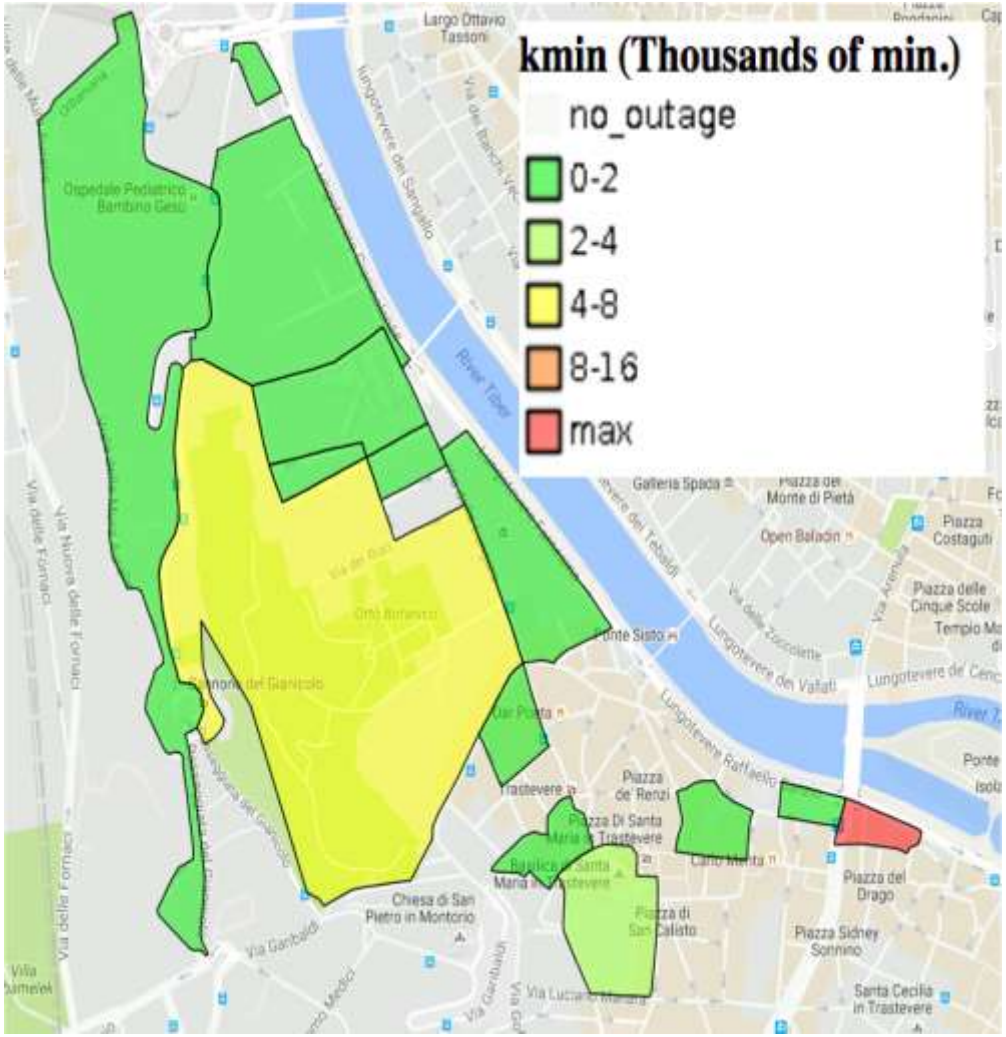


The Impact module determines the outage profile $\boldsymbol{u_i(t)}$ *for the involved substations.*



Case study: social consequences

Using $W = \int_0^T \sum_{}^{N} u_i(t) K_i \, dt$



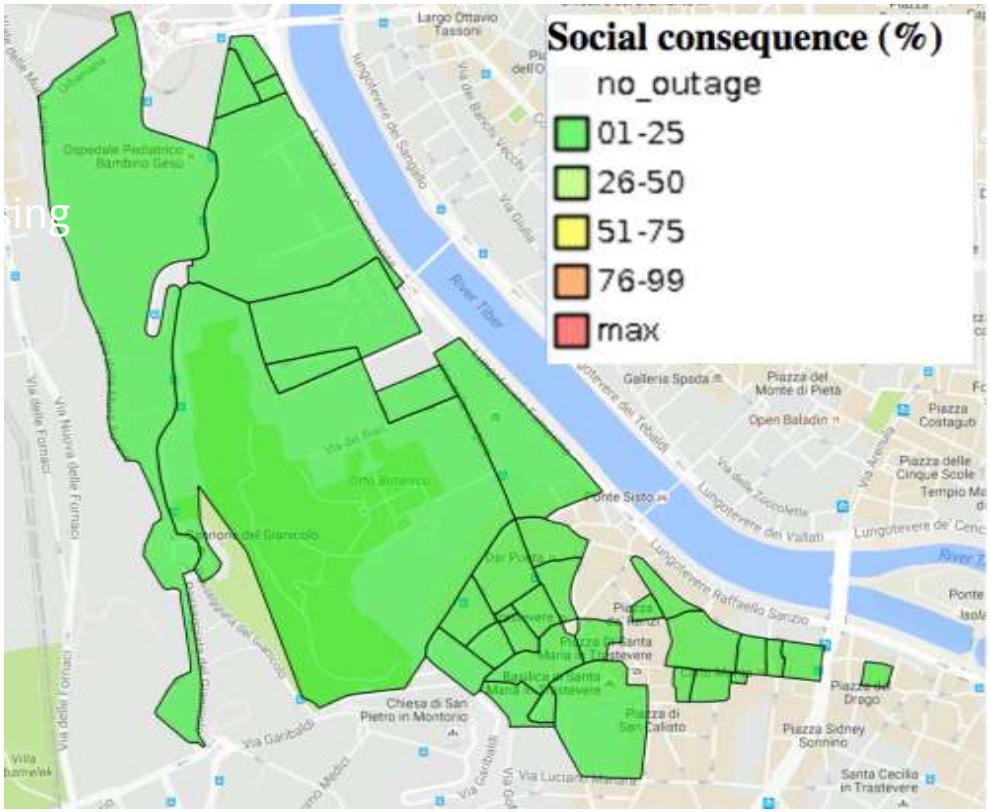
The Impact is distributed on the different societal elements $\mathbf{K_i}$ *(# citizens) present on the different areas served by each faulted substation.*

Case study: social consequences

Using $$W = \int_0^T \sum_{i=1}^{M} \sum_{j=1}^{N} u_{ij}(t) K_{ij} r_{ij} \, dt$$

The Impact is distributed on the different societal elements present on the areas served by each faulted substation by further considering

- *cascading effects on other CI (i.e. telco systems)*
- *the different vulnerabilities of citizens with respect to the outage of a given service (SAW indices).*



Conclusions

- *The **DSS CIPCast** allows to analyze the whole chain of events following predicted disruption on CI due to natural events.*
- *Prediction of societal consequences, made of the bases of the prediction of the cascading effects affecting one (or more) CI services are made by estimating*
  - *a pure "service continuity" value, normally used by National Authorities to score the Quality of Service of services DSO*
  - *a complex consequences metric where the unavailability of different services is considered, each service being weighted with respect to their effective relevance for the Wealth achievement of a specific societal sector*

Future work

- *Future activities will focus on*
  - *The model extension to other societal sectors (industrial &economic activities, public services)*
  - *The model extension to include the explicit time-dependence of the SAW indices*
  - *Simulation of complex synthetic scenario in urban environment accounting for the presence of multiple dependent CI (i.e. by including water and gas distribution systems aside the already considered electrical and telco ones).*

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The views expressed in this presentation are purely those of the presenter and may not in any circumstances be regarded as stating an official position of the European Commission an official position.