FP7 Grant Agreement N° 312450

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Project type: Network of Excellence (NoE)

Thematic Priority: FP7 Cooperation, Theme 10: Security

Start date of project: March 1, 2013 Duration: 48 months

D7.4 Implementation of the DSS with consequence analysis

Due date of deliverable: 30/06/2015
Actual submission date: 28/07/2015

Revision: Version 1

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

Project co-funded by the European Commission within the Seventh Framework Programme (2007–2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Security Assessment	**Eric Luiijf (TNO)**
Approval Date	20/7/2015
Remarks	One security issue found. The issue has been resolved.

The project CIPRNet has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 312450.

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1 Introduction

1.1 Purpose of the document

The objective of this document is twofold:

(i) to present the implementation details regarding the Impact Estimation module contained in the Decision Support System (DSS);

(ii) to present the metrics used to assess the effects that the lack or degradation of Critical Infrastructure (CI) services may cause to the society.

This document follows D7.1 where a design study of the Decision Support System (DSS) is presented and D7.2+D7.3 where the foundation of the Consequence Analysis is presented. This document will thus show the basic principle of integrating DSS and the Consequence Analysis blocks (see Figure 2) of the tool to provide a complete and coherent vision of the instruments that WP7 is going to develop.

In the following chapters the document will show the basic functions of the DSS, its building blocks and the outputs of the workflow. This starts from the forecast processing, the definition of a damage scenario, and ends up with the assessment of the impacts on services (also in a dependent or inter-dependent scenario) expressed as the availability or unavailability of the different services during the predicted time duration of the crisis. Last, the Consequence Analysis block gets the output of the previous blocks as input and attempts to assess " a severity" of the crisis by estimating its costs according to several evaluation Criteria.

1.2 Document structure

The document is organised as follows:

- **Chapter 2** describes the impact estimation block of the DSS, which is required for the Consequence Analysis module.
- **Chapter 3** describes the Consequence Analysis model and its basic formulation. A basic role in the CA model is played by the SAW (Service Access Wealth) Indices, which define the relevance of the access to a given Service for a specific subset of the Criteria used for estimating Consequences. In the same Chapter, we will also describe the way in which SAW Indices could be extrapolated from available Statistical Data. In the same Chapter, the interface between the DSS and the CA – required for a joined use of the two modules – will be presented.
- **Chapter 4** presents an application (case study) of the Consequence Analysis model to assess the effects of the reduction of the electricity service on the citizens of an area of Rome served by an electric and telecommunication.

2 Impact Estimation

This section first recalls the DSS architecture and main functions followed by an analysis of the impact estimation capability. Further details on the DSS architecture, functions and the software tools and platforms used can be found in [1].

2.1 DSS architecture overview

In order to describe the characteristics of the DSS, we first recall its architectural design. As shown in Figure 1, the DSS consists of four layers:

- **Presentation Layer**: This layer contains the components that implement the different Graphical User Interface (GUI) used by the DSS platform end-users. Such components are based on Geo-Platform, an Open Source Framework of the geoSDI research group ([5]) for creating Rich Web GIS Applications based on geospatial web-based software. The use of Geo-Platform allows building the so-called thin clients that do not require any installation w.r.t. desktop clients. In addition, being based on web browsers, Geo-Platform can also be used without providing admin rights on those networks where software installation may be restricted for security purposes.
- **Service Layer**: This layer contains all modules that implement the DSS business logic. A central component of the Risk Assessment Workflow is the Module that orchestrates all operations of the local DSS, e.g. user management, process monitoring, Earthquake and Weather Forecast workflows and GIS services to allow the visualisation.
- **Middleware Layer**: The Middleware Layer implements all the procedures to gather, on a 24/7 basis, data coming from external sources such as meteorological data needed to feed models and simulations enabling the prediction of future extreme natural hazards. It contains two modules that realise the HPC services and the data access logic. In particular, the Security module implements the availability requirements to ensure that DSS services and data are accessible to final end users even in case of equipment failures.
- **Persistence Layer**: This layer contains all data to be used within each DSS instance (in general, there will be different DSS instances running for different areas). Each DSS instance may store and/or retrieve these data in different databases: (i) a public GIS-Data DB storing the GIS layers compliant to INSPIRE and OGC standards such as territorial, socio-economical, technological infrastructure data; (ii) a private Local-DSS DB containing custom information specific for each DSS instance (e.g. the Geo-Platform users and projects); (iii) an EISAC DB containing data information common to all DSS instances and (iv) a set of External DBs to retrieve data that can be accessed outside the DSS-instance via specific protocols and interoperability standards (e.g. OCG standards for GIS data).

Each DSS instance is able to store data requiring different update frequencies. For example, the number of people living in a specific area need to be updated once a year whilst the historical events layer data (e.g., the earthquakes events in a specific area) needs to be updated with a frequency of minutes or hours (as it is constantly updated by polling a specific site of the National Institute of Geophysics which provides the national Earthquakes Alerting Service). The update procedures are performed using different procedures depending on data availability and update frequency requirement. In some cases, data updating operations depend on authorised data scraping automated procedures.

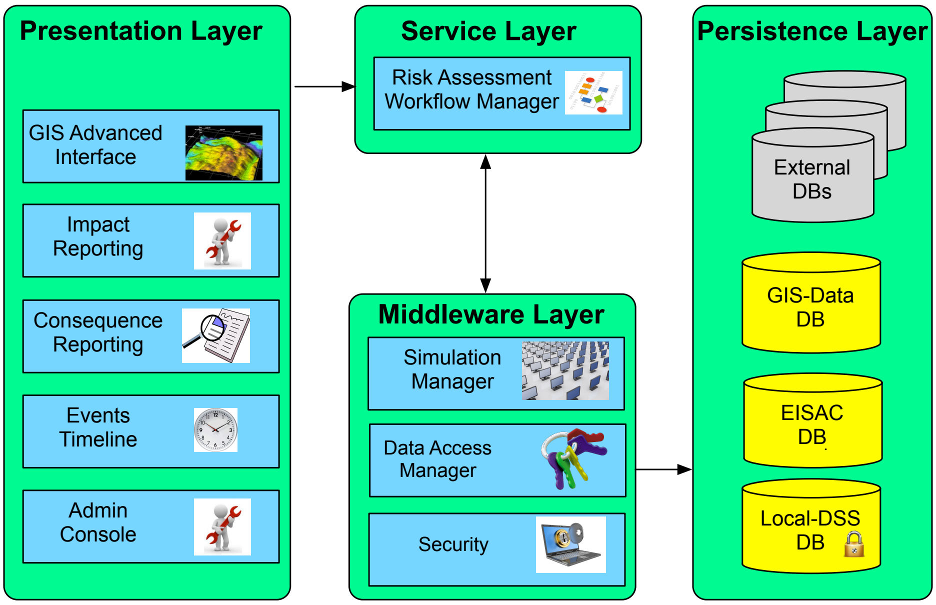

Figure 1: DSS 4-tier architecture diagram.

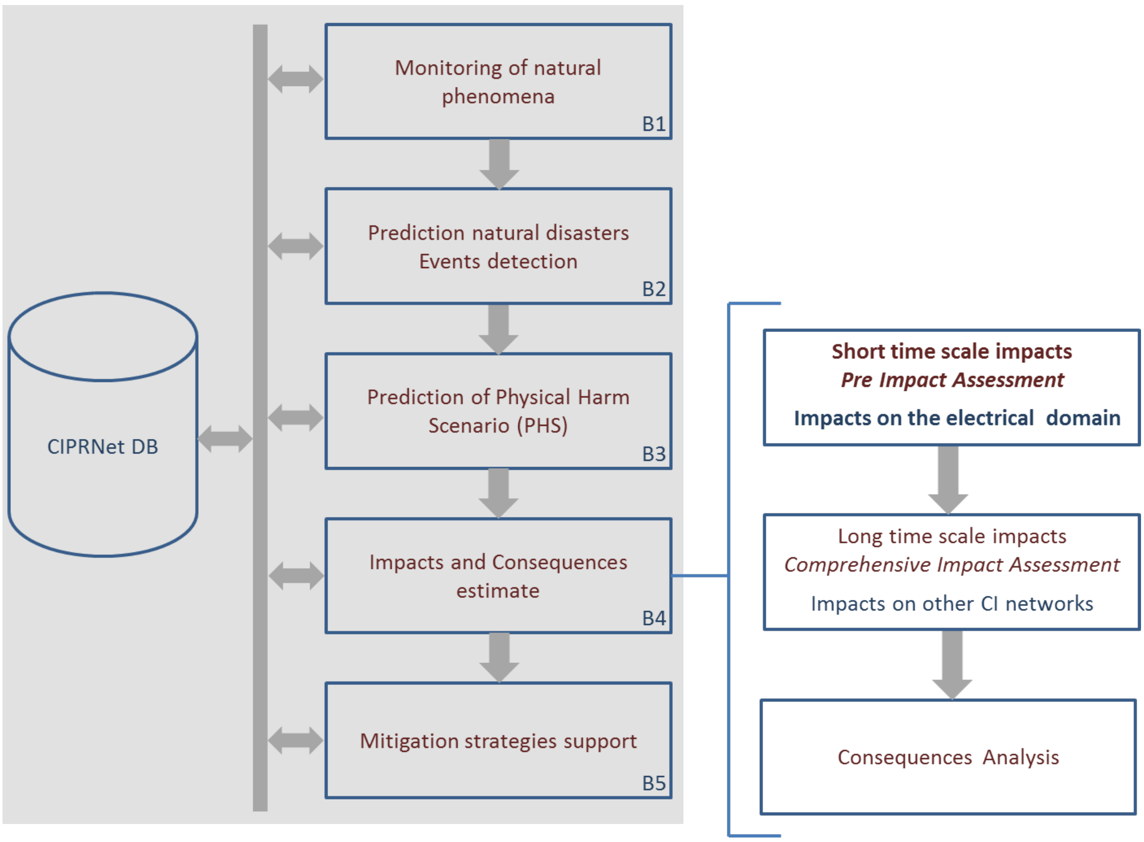

Figure 2: DSS Functional blocks.

2.2 DSS functions

In this section, we recall the main functionalities of the DSS that are required to implement the *Risk Assessment Workflow*.

The DSS consists of five components or *functional blocks* (B_n) as depicted in Figure 2:

- **B1: Monitoring of Natural phenomena**
- **B2: Prediction of Natural disasters and Events Detection**
- **B3: Prediction of physical harm scenarios**
- **B4: Estimation of impacts and consequences**
- **B5: Support of efficient strategies to cope with crisis scenarios**

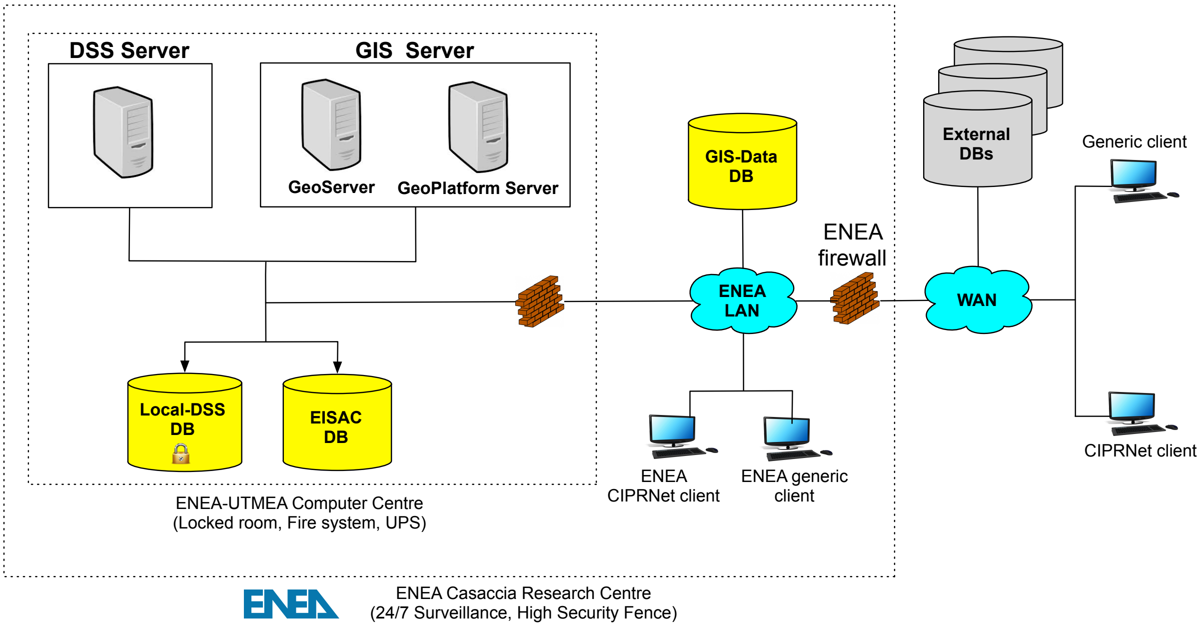

Figure 3: Deployment diagram.

In short, **B2** evaluates the probability of occurrence $\mathbf{Pr}(\boldsymbol{T_i})$ of the threat T_i by using all types of data provided by **B1** (e.g., weather forecasts). **B3** evaluates the **Physical Harm Scenario (PHS)** considering the strength of all possible threats affecting CI element in a given area and the intrinsic physical vulnerabilities of the elements. **B4** evaluates and predicts the impacts that the loss of the CI services would produce on the CI and the related consequences on the society.

Figure 3 shows the Deployment Diagram showing the interactions among the DSS server, the GIS server and the DB servers:

- the **DSS server** executes all the tasks needed for the Risk Assessment Workflow;
- the **GIS server** is based on two servers: (i) *GeoServer* to manage GIS data which can be provided to different kinds of clients such as web browsers and GIS desktops and (ii) *GeoPlatform,* which runs on Linux machines only and allows to build advanced GIS GUI;
- the **DB servers** consisting of the GIS-Data DB, the Local-DSS DB and the EISAC DB servers. The GIS-Information DB will be based on PostGIS DBMS v.2.x to manage GIS data whereas the other DBs will be based on PostgreSQL DBMS v.9.2.

Regarding the IT security, access control requirements is provided by two firewalls: (i) the CIPRNet servers software-based firewalls; and (ii) the ENEA Casaccia firewall and monitoring systems that constitutes the main barrier to ensure access control to CIPRNet data and systems. Further details about the data security features implemented to secure the CIPRNet data, can be found in [2].

2.3 Impact Estimation Methodology

The **B4** module **"Estimation of Impact and Consequences"** produces an estimate on the services delivered by the CI and the resulting consequences, i.e. the effects on citizens, services, economy, and the environment called Criteria (see [4]).

As shown in Figure 2, B4 implements a workflow including three different phases:

1. **Pre-Impact Assessment**. In this phase, strongly coupled infrastructures (i.e., the electrical grid and its SCADA system) are considered. Their strong coupling activates dependency mechanisms holding in a short time scale (from a few minutes up to one hour). On the other hand, the coupling of these infrastructures to other CI occurs with a larger latency: during very short times scales, other CI could be considered as "decoupled" from the previously cited infrastructures, in a sort of adiabatic approximation [3].
2. **Comprehensive Impact Assessment.** In this phase, an analysis of the dependencies among all the infrastructures (e.g., power grid→water distribution, water distribution→hospital) is performed to have a complete assessment of all the domains considered. This module takes as an input the expected outage duration of the distribution substations of the considered scenario calculated in the pre-impact assessment block and executes a dependency model based on i2Sim [6] to evaluate the overall impact on all CI resulting from dependency mechanisms. The outcome of the impact evaluation is called **Impact Scenario (IS),** defined by a vector containing the set of the variations ΔQi of the Quality of Service (QoS) associated to each CI.
3. **Consequence Analysis.** In this phase, employing census data and metrics aimed at measuring the vulnerability of the society to the degradation of CI services expressed by the IS, the DSS will estimate the consequences grouped by specific criteria. The outcome of the consequence estimation is called **Consequence Estimate (CE)**. The DSS will thus elaborate a severity grade of the crisis according to the consequences it will produce.

In the next Section, we focus on the Pre-Impact Assessment, which deals with the short time scale interaction between Electrical and Telecommunication networks.

2.3.1 Pre-Impact Assessment Implementation

The aim of the Pre-Impact Assessment phase of the risk assessment workflow implemented within the CIPRNet DSS is to obtain the most realistic impacts assessment of a specific *Physical Harm Scenario (PHS)* on the electrical distribution grid. To this end, it foresees the involvement in the loop of electrical and telecommunication network operators. This is beneficial for different reasons:

- CI operators have contingency plans to reconfigure their network after failures on one or more CI components;
- Contingency procedures depend on the current configuration of the CI network. Only CI operators have access to the current configuration of their networks;
- Contingency plans and CI network details are considered sensitive data that CI operators would not share and/or distribute.

The proposed Pre-Impact Assessment Loop (Figure 4) starts with the *Physical Harm Scenario* (PHS) i.e. the output of **B3**. Based on the received *PHS,* the application queries the CIPRNet DB containing CI networks dependencies information (the CI network dependencies data represent the minimal requirement for the CIPRNet DB) to find the electrical and telecommunication components directly impacted by the *PHS*. The ACEA (the electricity network operator serving Rome and supported us in the implementation of the impact evaluation procedure) and Telco module will then use these information to compute the possible reduction of their QoS. To this end, CI operators will simulate appropriate contingency procedures for the expected networks status. The Pre-Impact Assessment Loop will stop as soon as an equilibrium condition is reached (no further variation of network QoS expected).

The proposed Impact evaluation module implements the isolation and reconfiguration procedures adopted in ACEA (see ACEA module of Figure 4).

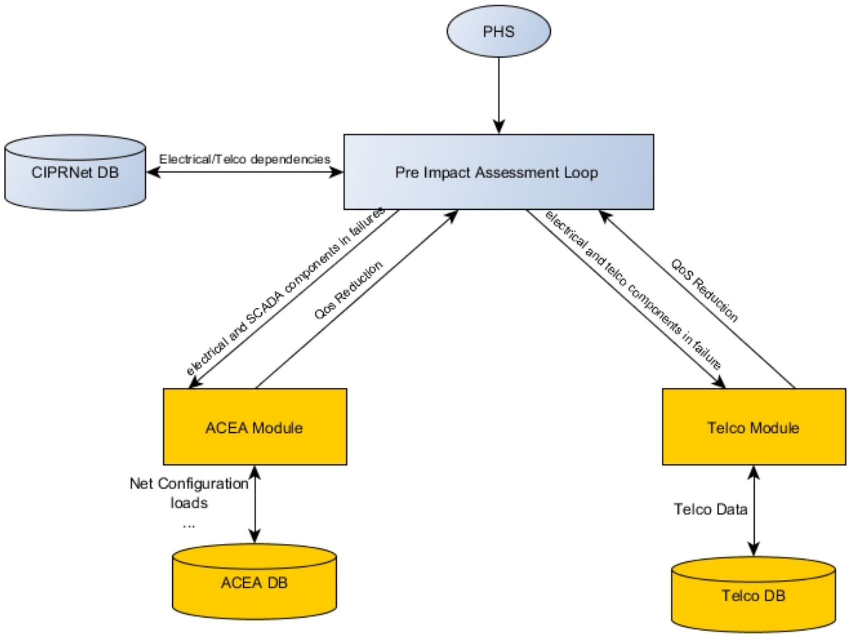

Figure 4: The Pre-Impact Assessment Loop

The isolation and reconfiguration algorithm implemented within the electrical module has been developed in collaboration with ACEA. The electrical distribution grid of Rome can be modelled as shown in Figure 5. The network is composed of a number of Primary Substations (PS). Each PS originates one (or more) Medium Tension (MT) semi-backbone(s) ending into a further PS. The term "semi" is used as the MT line is cut at a certain stage by a switch which decouples the line into two halves, each of them supplied by one of the two overlooking PS. Each semi-backbone connects a number of Secondary Substations (SS), some of them being remotely controlled. SS on a specific semi-backbone are fed, in the *normal configuration*, by a specific PS. The network can be configured (using the switches showed in Figure 5) so that the SS on a semi-backbone (or a subset of these substations) are fed by the *closest* PS (in Figure 5, the PS P_j can be considered the closest primary substation for P_i and vice versa). Each SS is modelled as a Finite State Machine as showed in Figure 6. In normal condition the SS is in the initial "FUNCTIONING" state.

Starting from this state, the secondary substation can move into one of two different states:

- FAILURE STATE: when a failure in the SS occurs, the transition *1* is activated. The SS remains in this state for the expected failure duration (the failure duration is contained in the *PHS*).
- NOT FUNCTIONING STATE: a SS can be in this state after the activation of protection devices. For example, when a SS moves into the FAILURE STATE all SS on the same semi-backbone move into their NOT FUNCTIONING STATE. A SS remains in this state

waiting for restoration. The duration of the restoration can be of a few minutes (about 3-5minutes) if the SS can be tele-controlled or much longer (50-55 minutes to a few hours) depending on several factors (e.g., time required by emergency crews to reach the faulted substation and to restore it).

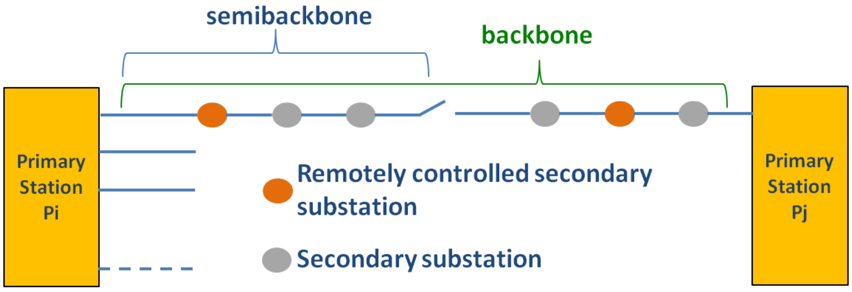

Figure 5: The electrical distribution grid model

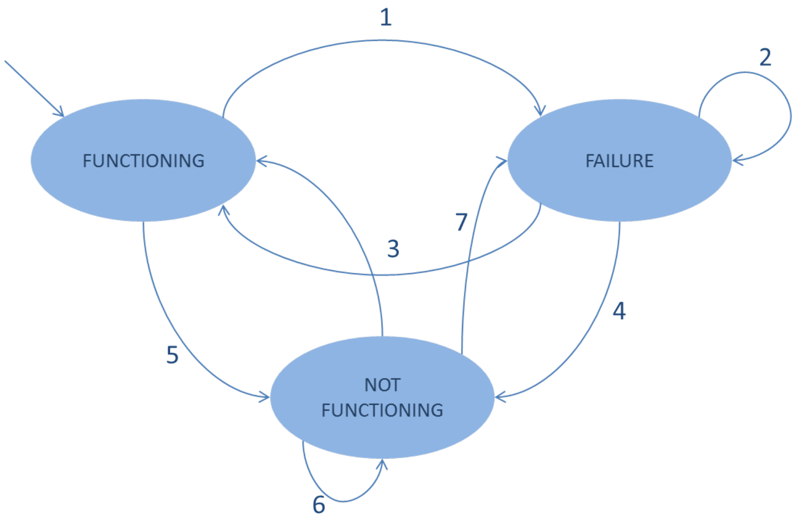

Figure 6: Secondary Substation finite state model.

Figure 7 shows a few cases that the algorithm needs to consider to compute the SS restoration time (the presented cases are not exhaustive).

Let us assume that a *t=t1* the electrical substation SS3 is in FAILURE STATE. All SS on the same semi-backbone will move into their NOT FUNCTIONING STATE starting from *t=t1*.

- In *Case a)* SS1 and SS2 can be restored in a few minutes (e.g., 5 minutes): SS2 can be remotely restored.
- In *Case b)* remote control cannot be used so that SS1 and SS2 restoration requires a manual procedure performed by emergency crews. The manual restoration of a SS would take 50-55 minutes (for real cases, this time can be estimated by historical data of the electrical operator), as it could imply the reach of the faulted SS (in a complex urban scenario).

The other two cases of Figure 7 - *Case c) and Case d)* - require the *closest* PS to restore SS on the semi-backbone after the SS in failure state. In *Case c)* SS3 can be restored using the next PS; in addition, considering that as SS3 is remotely controlled, restoration would take few minutes (e.g., 5). In *Case d)*, the SS3 cannot be restored using the next primary substation and the restoration duration would depend on the failure duration of the two failures on the backbone.

<u>The implemented algorithm takes into account all possible restoration cases</u>. A simplified sketch of the simulation algorithm of the ACEA restoration procedures is shown in Figure 8.

The input for the algorithm is constituted by the electrical grid topology, the telecommunication components providing services to the electrical grid SCADA system, mainly Base Transceiver System (BTS) and the *PHS* data. The BTS provides the mobile telecommunication connectivity services required by the SCADA system of the power distribution stations.

The output is represented by the power profile of the SS during the simulated time slot. After the initialisation phase, where the electrical grid topology is loaded from the CIPRNet DB as well as the *PHS* data, the main simulation loop starts. The simulation algorithm introduces a check order of incoming events (i.e. failures). First, the algorithm checks the state of the BTS. Each BTS is modelled using the model shown in Figure 9. Then, the procedure *check_telco_failures(time)* (step 5a of Figure 8) loops through all BTSs and updates their state accordingly (a BTS in failure moves its status from FUNCTIONING to FAILURE). The status of the BTSs will influence the functioning status of the electrical grid SCADA system (procedure *update_tlc_status(time)*).

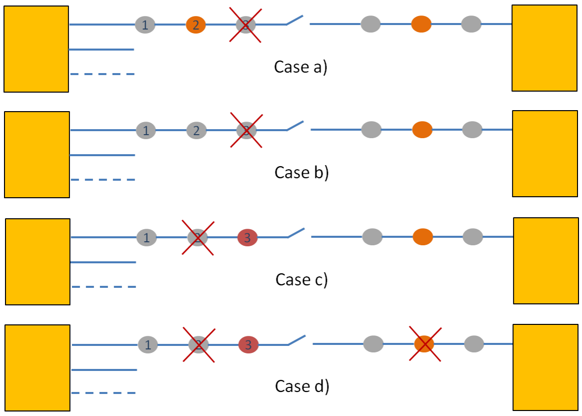

Figure 7: Different cases for the secondary substation restoration.

Then, (step 5.b of Figure 8) the algorithm updates the failure status of the SS. If a SS moves its state from FUNCTIONING to FAILURE the functioning state of the components (e.g. a BTS) powered by the SS will be updated as well.

1. Read data from DB (Electrical Distribution Grid topology, failures)
2. Initialize grid topology data structure
3. Initialize electrical and telco failures data structures
4. Initialize simulation constants *//start, end simulation time, simulation step*
5. **for** (*time*=0; *time*<END_SIMULATION_TIME; *time*+=SIMULATION_STEP){
    a. check_telco_failures(*time*) *//check if at t=time there are telco components entering in the failure state*
    b. check_electrical_failure(*time*) *//check if at t=time there are electrical components entering in the failure state*
    c. update_tlc_status(*time*)*//set tlc status = NOT WORKING for those secondary substations remotely controlled using a BTS that is not functioning (its functioning status = NOT WORKING)*
    d. update_net(*time*)*//this procedure update the state of each secondary substation*
6. }

Figure 8: Pseudo-code of the Impact Estimation Algorithm.

After the update of the status of the SCADA components (step 5c of Figure 8) the simulation loop calls the *update_net(time)* procedure (step 5d of Figure 8). This procedure updates the status of each SS. In particular, the procedure checks if it is possible to restore (i.e. shifts their status to the FUNCTIONING state) all SS that are in the NOT FUNCTIONING state. The *update_net(time)* procedure takes into account the different possible cases some of which are shown in Figure 7.

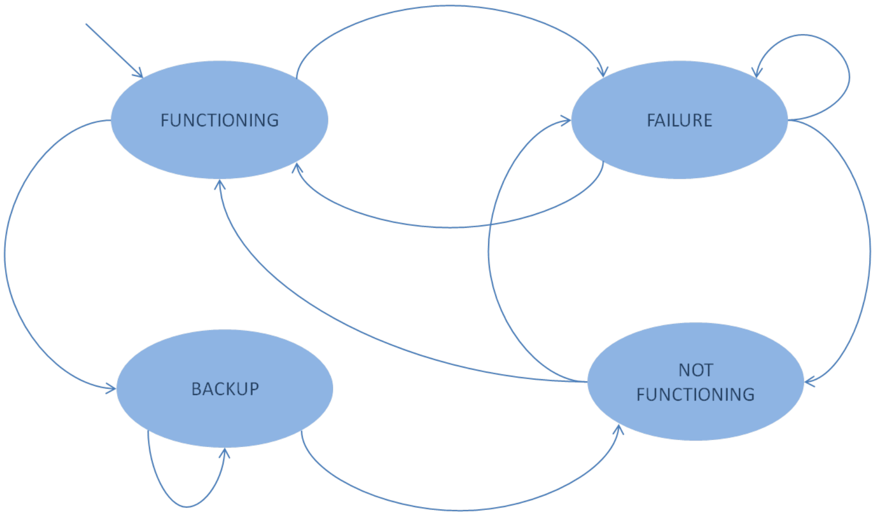

Figure 9: BTS finite state machine model.

2.3.1.1 Case Study

In this Section, we present the preliminary results of the application of our Impact evaluation module to the real case study of the power distribution grid of an area of the Rome City, consisting of: (i) 9 HT/MT substations (PS); (ii) 154 MT/LT substations (SS); (iii) 6 Telecom BTS and (iv) 3 hospitals. Each PS has a number of backbones consisting of several SS. Some of these may feed Telecom BTS or hospitals in addition to generic users (e.g., households).

Figure 10 shows a possible *PHS* (composed by all SS shown in red) i.e., the set of SS estimated to be in failure based on predicted Damages due to a natural event manifestation. Based on the presented reconfiguration procedure, the pre-impact assessment module estimates the *IS* i.e., the possible evolution of the power network (Figure 10) considering the assumption that all the BTS are working properly. Figure 11 shows the expected outage duration of the electrical secondary substations that are produced by the pre-impact assessment module.

It can be noticed that, at time t_1=0 the DSS estimates that four substations are expected to fail. Then, the algorithm verifies that approximately at time t_1=0, 33 substations will be automatically disconnected because of the estimated failures (SS28-SS36, SS49-SS59, SS120-127, SS64-SS68). This behaviour results from the fact that the electrical substations are connected in series configuration.

Considering that some substations can be reconnected through remote operations, the algorithm verifies those BTS that are still receiving power from the secondary substations (we suppose, in the worst case scenario, that BTS do not have electrical backup systems) and that are able to open switches to re-energise the disconnected substations (SS64, SS66-SS68, SS49, SS52, SS56, SS58, SS59, SS120, SS121, SS124, SS125, SS56, SS58, SS59, SS116-SS118, SS114, SS110, SS111, SS107, SS28, SS29).

The algorithm verifies that the failure of the secondary substation SS123 that feeds the Telco BTS07, which, in turn provides remote control to the SS96, has the effect that the semi-backbone SB02 cannot be connected (through the closure of the switch located in SS96) to SS36, leaving several substations in the semi-backbone SB02 in a failure state. This behaviour is shown in Figure 12 at time t=5 where 12 substations cannot be reconnected through remote control (SS30-SS36, SS53-SS55, SS122, SS123, SS65).

The figure also shows that, without the dependency information among the substations and the BTS, the decision makers (e.g., an electrical operator) receiving only the information of the possible damaged substations may not be able to infer that "additional" substations could be affected due to the failure of the BTS.

In addition, the information provided could also be used to plan an effective intervention of crewmen that will be sent to the affected substation in a sequence that minimises the overall number of the affected substations or the number of affected electricity consumers.

The expected outage duration of the electrical secondary substations is provided to the Comprehensive Impact Assessment module based on I2Sim that subsequently evaluates the resulting impacts on the other infrastructures present in the scenario. This outcome, i.e., the Impact Scenario together with census data available for the city of Rome, feeds specific metrics able to estimate the effects on the different societal Criteria to the predicted reduction or loss of Services. This information may be useful for decision makers to know, during crisis scenarios that in a specific area there might be a high concentration of citizens (e.g., elderly people, people with disabilities) that may be severely affected by the different outages of primary services (e.g., water, gas) and the cascading effects resulting from the unavailability of electrical power.

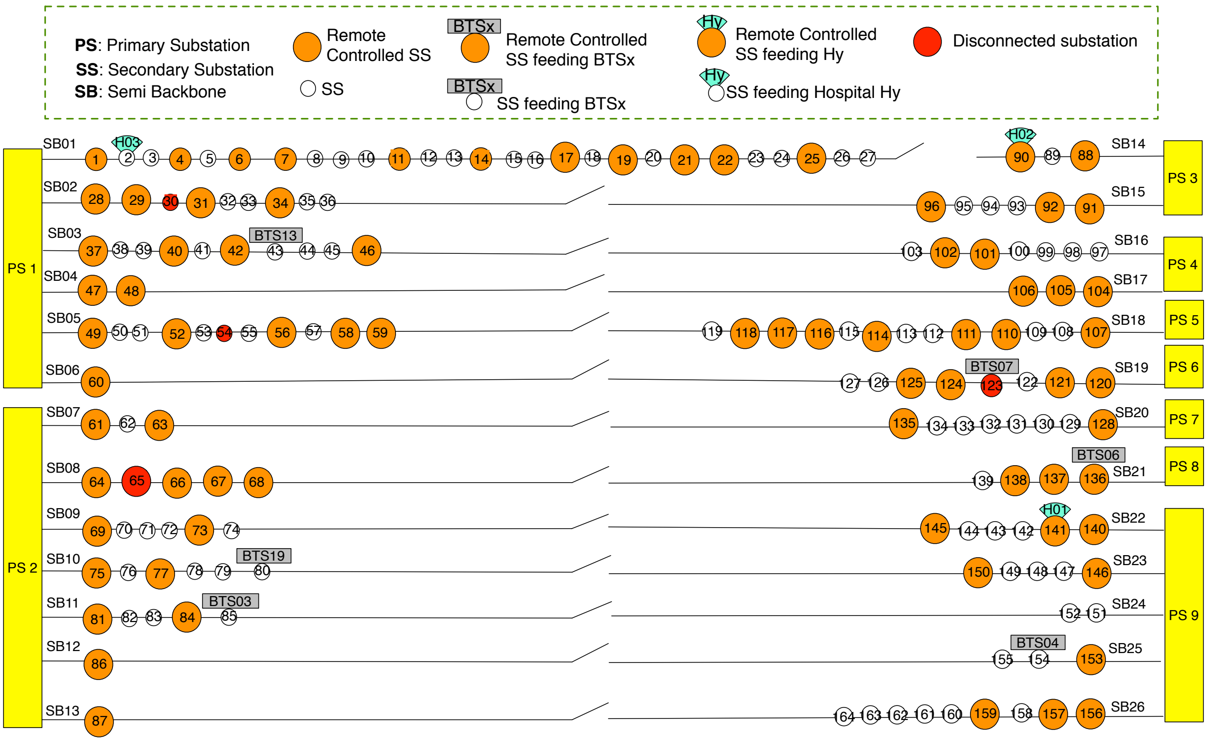

Figure 10: Representation of a section of a power distribution grid of Rome. Rome scenario at time $t=t_1$.

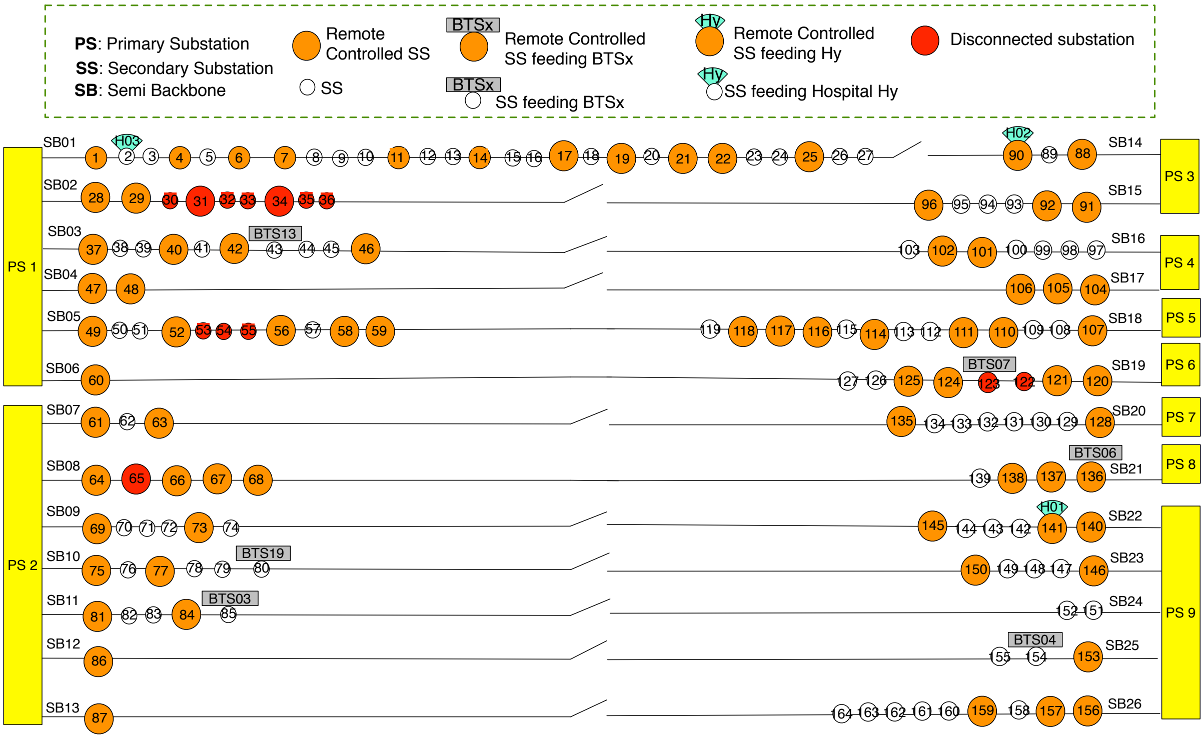

Figure 11: Representation of a section of a power distribution grid of Rome. Rome scenario at time t=t_2 (hypothesis: BTS are working properly).

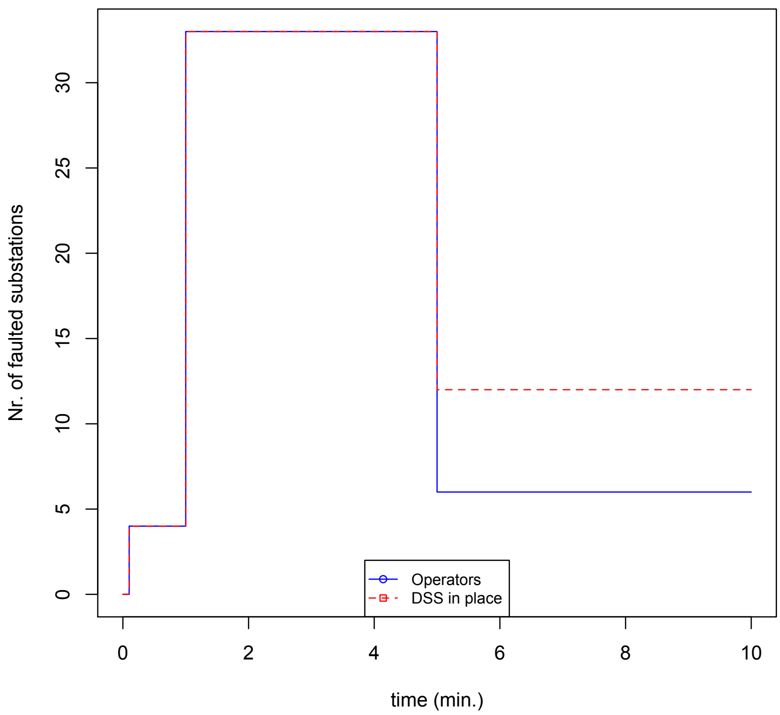

Figure 12: Estimated substations in failure state. The blue line represents the number of SS which will be predicted by the Operator (in presence of the information he/she has) during the first minutes of the crisis. The red line, in turn, indicates the CORRECT number of faulted SS during the same amount of time as evaluated to the scenario description taking into account the available and unavailable telecom BTS (as provided by the DSS).

2.3.2 Comprehensive Impact Assessment Implementation

In the comprehensive impact assessment phase all the dependencies from the electrical domain are considered in order to have a complete assessment of the considered crisis scenario. In order to model and simulate the dependencies among the different domains and mainly the dependencies of all CI domains from the electrical domain, the DSS integrates the i2Sim tool.

Figure 13 shows the procedures that have been implemented to build an i2Sim model from the data that have been collected within the CIPRNet database (in Figure 13 the database has been indicated as data warehouse to remark the fact that the CIPRNet database stores data coming from different sources, different formats and they are of different level of detail.)

The i2Sim DB tables, called also i2Sim Database Integration tables, represent a common data formalism to store and homogenize data of different CI networks. The i2Sim DB tables are read by the i2Sim model builder, which in turn, creates a model that can be simulated using i2Sim.

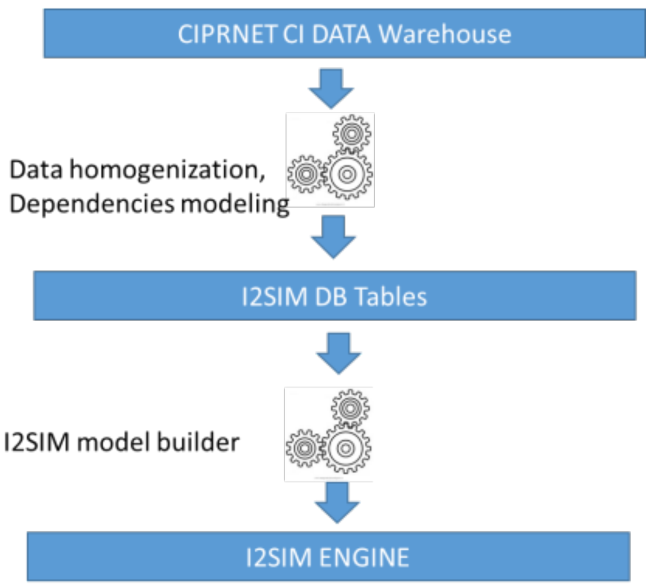

Figure 13 From CI operators data to i2Sim models.

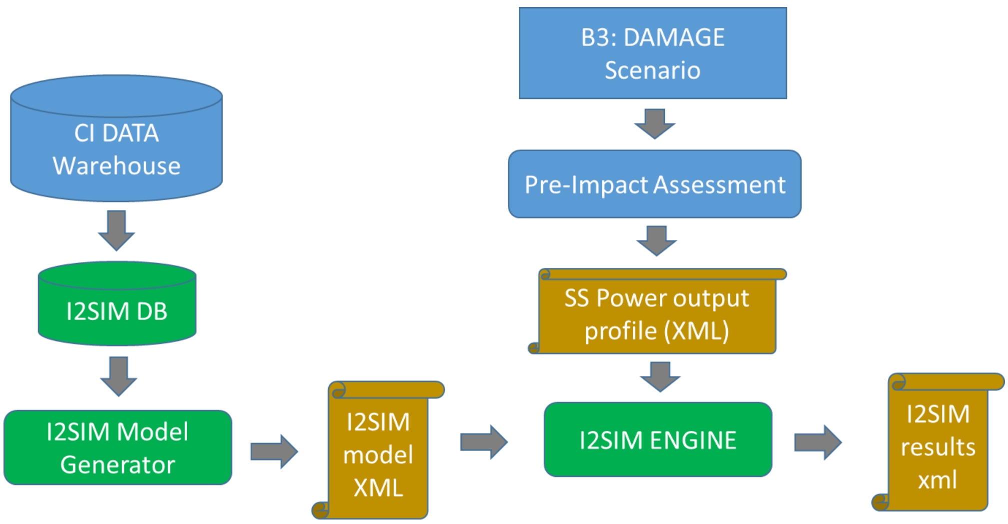

Figure 14 i2Sim Engine integration.

Figure 14 shows the architecture of the integration of i2Sim ENGINE within the DSS and in particular how i2Sim uses the results of the grid restoration simulator that has been described in the previous section.

In particular, the i2Sim Model Generator reads data from the data warehouse (using the i2Sim DB tables common formalism) to build a dependencies model. The dependencies model represents all the dependencies in the considered scenario. Then, the i2Sim ENGINE uses the grid restoration simulator output (the power profiles of all secondary substation involved in the scenario) to initialize the model and to run the simulation. The final result (an XML file) represents the output profile (QoS) of all entities considered in the scenario (e.g., hospitals, water pumps).

3 Consequence Analysis

This chapter, after recalling the main points of the Consequence Analysis (in the following, CA) framework as described in [2], updates on the technical concepts of our CA approach and goes into details about its implementation.

It is worth noting, however, that the implementation is an on-going process – influenced by the interaction with the other modules and by the operators' feedback and additional requests – so the ultimate description of the final implementation may require further (future) amendments until the DSS will be fully implemented and validated. This is true also for the conceptual framework that could be updated with minor amendments. Furthermore, a key and challenging aspect of the CA implementation is the SAWI indices elicitation, for which the proposed methodology is discussed and implemented addressing the situation of Rome, although pointing out that identified data sources are available at European level.

3.1 Consequence Analysis overview

In D7.2 and D7.3 [2], the (unprecedented) effort to specify the concept of CI-related "consequences" of a critical scenario in terms of "societal" wealth reduction, associated to the expected Impacts on CI-supplied Services, under different viewpoints (called ***Criteria***) has been described.

As mentioned in Chapter 2, the proposed model is particularly useful when associated to a risk analysis workflow. In fact, after the prediction of specific damages (resulting from natural or other types of threats) and the estimate of the related impacts on CI functioning, the resulting outages (called Services Unavailability) can feed a Consequence Analysis model that, through the use of specific Service Availability Wealth Indices (called SAWI, introduced in D7.2+D7.3 [2] as part of our innovative effort), allows to "weight" the Crisis Scenario. In the CIPRNet DSS workflow the CI related consequence analysis will be performed within the DSS B4 block.

A thorough research led to the conclusion that "the reduction or loss of well-being" – resulting from the impacts and to be estimated according to some specific metrics – is the "index" which fits better the "meaning of consequences of the related impacts on CI of a damage scenario". It is worth recalling that "affected well-being" could be related to different fields of the daily life and concerns the intrinsic well-being of citizens (their "wealth"), the integrity of their own assets, the wealth and the integrity of the environment (which could be damaged in terms of pollution, disruption and/or devitalisation of specific areas), the reduction of functionality of Primary Services that would, in turn, affect the well-being of citizens, the reduction of "wealth" of the different economic sectors which are directly or indirectly wounded by the Damages.

Taking into account the European Council Directive 2008/114/EC [7], which states that the significance of the impact produced by the disruption or destruction of a European Critical Infrastructure (ECI) shall be assessed in terms of cross-cutting *criteria* and include effects resulting from cross-sector dependencies on other types of infrastructure encompassing a list of ***Criteria***, called ***CA Criteria*** and hereby referred to as t_{ij} where i is the CA criterion index and j is its component, has been identified:

- ✓ **Casualties criterion** (assessed in terms of the potential number of fatalities or injuries);
- ✓ **Economic effects criterion** (assessed in terms of the significance of economic loss and/or degradation of products or services; including potential environmental effects);

- ✓ **Public effects criterion** (assessed in terms of the impact on public confidence, physical suffering and disruption of daily life; including the loss of essential services, as those services which, more than others, influence the well-being of the population, jeopardise the availability of primary services such as hospitals and schools, and are responsible for the functioning (or the stop) of industrial plants etc.

Criterion 1 relates to population, to citizens and encompasses the reduction of well-being to the most vulnerable population layers.

CA Criterion 1: Citizens

- t_{11} = Citizens 65+;
- t_{12} = Citizens 0-5;
- t_{13} = Citizens with disabilities;
- t_{14} = Citizens 18-64;

Criterion 2 relates to the Primary Services that affect the wealth and the well-being of the population. These might be ascribed to "public effects" criterion as they focus on assets/services that might be also of vital relevance (such as Hospitals) for citizens.

CA Criterion 2: Services

- t_{21} = Hospitals;
- t_{22} = Schools;
- t_{23} = Public Offices;
- t_{24} = Public Transportations;

Criterion 3 relates with the economic losses that depend, in turn, on the integrity and the lack of production hours/days due to Services outages. Segmentation has been done by using the industrial sectors (primary, secondary, tertiary) as this ontology is used to group available data.

CA Criterion 3: Economy

- t_{31} = Primary (agriculture, farmland);
- t_{32} = Secondary (manufacturing);
- t_{33} = Tertiary (services);

Criterion 4 relates to the environmental damages. Environment can be directly hit by disruptions (landslides, flooding etc.) but also by secondary effects (pollution, leakage from plants and other disrupted industrial sites, etc.)

CA Criterion 4: Environment

- t_{41} = Forests;
- t_{42} = Protected areas (Natural Parks etc.);
- t_{43} = Sea and shores;
- t_{44} = Natural and artificial basins.

As Primary Technological and Energy Services we identified:

- ✓ **Electricity**
- ✓ **Telecommunications (voice, IP etc.)**
- ✓ **Water (drinking water, waste water management)**
- ✓ **Gas and other energetic products**
- ✓ **Mobility (roads, railways)**

3.2 Consequence Analysis model

The Consequence Analysis basic formulation, as proposed by the CIPRNet Consortium and reported in [2], has been "tested" on a number of test cases (based on the first implementation of the DSS with CA) which suggested a few (minor) amendments, reported in section 3.2.2 after a short summary of the main points of the proposed Consequence Analysis model.

3.2.1 Consequence definition

As described in [2], the Consequence Analysis Estimator module is expected to calculate, based on the input provided by the Impact Analysis, a Consequences vector C containing the results of Consequences estimates according to the four different CA Criteria described in section 3.1:

$$C = \begin{Bmatrix} C^1 \\ C^2 \\ C^3 \\ C^4 \end{Bmatrix}$$

Equation 1: Consequence Vector *C*.

Each Criterion C^i has a number L_j of sub-criteria (also referred to as "components") C_j^i, which basically are the relevant parts composing a given Criterion. Each C^i, in order to take into account all the consequences for all the relevant components, is defined as:

$$C^i = \sum_{j=1}^{L_j} C_j^i$$

Equation 2: Consequence definition for the Criterion i

where:

$$C_j^i = M_{ij}\left[1 - \sum_{k=1}^{S_k} r_k \int_0^T Q_k(t)dt\right]$$

Equation 3: Consequence *C* on the CA Criterion Element t_{ij} with relevance r_k independent from time

and:

- S_k is the total number of the considered Services which contribute to Wealth (electricity, telecommunication, gas, water and mobility);
- Q_k is the unavailability (if $Q_k = 0$) or, in case of availability, the Quality of Service k. Q_k depends explicitly on time and describes the pattern followed by the outage of the k-th Service during the time course of the Crisis.
- M_{ij} is the metrics for Wealth measure (for example the number of people affected in the population segment j during the time period T, see [2] for the complete list).
- $r_k(t_{ij})$ is the ***relevance*** of the Service k for the achievement of the maximum level of the Wealth quantity M for a given element of Criteria.

It follows that, assuming $\sum_{k=1}^{S_k} r_k = 1$ (i.e. all the well-being of the citizens is dependent on Services)

$C_j^i = 0$ if $Q_k(t) = 1$ (no Consequence if no loss of services)

and:

$C_j^i = M_{ij}$ if $Q_k(t) = 0$ for each k (maximum consequence, for example - for the Citizens criterion - all citizens fully affected if all the Infrastructures are out of service).

3.2.2 Consequence evaluation

While confirming the general framework as reported above, the performed tests suggest a number of improvements and details deriving from the basic assumptions.

First of all, the maximum value to be assumed by C_j^i is expected to take into account also the duration of the loss of service so that the longer the out of service period, the higher the number.

$C_j^i = M_{ij}T$ if $Q_k(t) = 0$ for each k (maximum consequence, for example - for the Citizens criterion - all citizens fully affected if all the Infrastructures are out of service for a time period T).

Also, the elicitation of the relevance indexes r_k pointed out that assuming $\sum_{k=1}^{S_k} r_k = 1$ may lead to a distortion in the values and in their meaning whenever a Criterion or one of its components are not too much vulnerable to the loss of service. For example, children aged less than 5 are not dependent by telecommunication, nor by mobility and are moderately dependent by gas or electricity. However, if we impose $\sum_{k=1}^{S_k} r_k = 1$, the relevances of those services assume a proportion which is not realistic, correctly saying that a child's wealth related to all services if reduced (for example) by 40% but hiding the fact that the child will hardly notice the loss of service. Therefore we accept:

$$\sum_{k=1}^{S_k} r_k \leq 1$$

and, if $Q_k(t) = 0$ for each k

$$C_j^i = M_{ij}T \sum_{k=1}^{S_k} r_k$$

Then Equation 3 is modified to

$$C_j^i = M_{ij} \sum_{k=1}^{S_k} r_k \left(T - \int_0^T Q_k(t)dt \right)$$

Equation 4: Consequence *C* on the CA Criterion Element t_{ij} with relevance r_k independent from time

Please also note that, in the Equation 4, r_k is actually $r_k^{i,j}$. It is also worth noting that whenever one or more services are so critical for the Criterion component that even the loss of just one service will heavily disrupt the segment (for example, all those activities based on the e-commerce will lose customers and related revenue whether power or telecommunication is out of service) we could have $r_k = 1$ and therefore $\sum_{k=1}^{S_k} r_k > 1$. We impose $\sum_{k=1}^{S_k} r_k = 1$ whenever $\sum_{k=1}^{S_k} r_k > 1$.

Going on, while $C_j^i = 0$ has a clear meaning (no consequence!), whenever $C^i > 0$ the bare number – still good to be used in the DSS optimisation procedure as the goal is still to minimise its value – does not give any clue of the severity of the event.

In fact, whenever the number of affected people is big (which is quite common in a metropolitan area), even for short loss of services (with very limited real consequences) the previous equation will give very large number as output, wrongly suggesting a severe condition.

Also, people affected by more than one disruption could be counted multiple times.

Normalisation will mitigate these issues. Therefore, Equation 2 becomes

$$C^i = \frac{\sum_{j=1}^{L_j}\left(M_{ij}\sum_{k=1}^{S_k} r_k^j \left(T - \int_0^T Q_k(t)dt\right)\right)}{T\sum_{j=1}^{L_j}\left(M_{ij}\sum_{k=1}^{S_k} r_k^j\right)}$$

Equation 5: Consequence definition for the Criterion i

It is worth pointing out, moreover, that, in principle, considering the relevance of a not time-dependent service may lead to macroscopic errors in the consequence evaluation. For example, consequences on most shops are very limited if a power blackout occurs during the night. Also, r_k is (heavily) dependent on the duration of the loss of service (for example, the consequence on the food in the refrigerator is very limited if power interruption duration is less the one hour and quite severe if it is more than four hours).

Once we have evaluated the consequence, we can define a Crisis Scenario as *Light* or *Severe*. A crisis can be considered *Light* if the available resources to restore the normal network QoS are sufficient and/or the CE values are small. During a *Light* crisis scenario the knowledge of the QoS of the other CI networks and in particular of the other CI components providing services to the electrical infrastructure (as for instance, the fixed and mobile telecommunication network for the electrical infrastructure SCADA system) can be used to further improve the restoration procedures in order to minimise the disconnection time of users and critical loads. During a *Severe* crisis scenario, characterised by high values of CE values and/or inadequate available resources for restoration, the DSS output is used to optimise the available resources in order to mitigate the consequences of the crisis. Indeed, in this case, it will not be possible to restore (as in *Light* crisis situation) all users and critical loads in an acceptable time. In these cases, the Pre-Impact Assessment and DSS output in general will support the decision-making process. In the end, the CIPRNet DSS can be used as a what-if analysis tool and, in general, CI operators can use the DSS output to drive future network development programs. More detailed on the metric used to classify the severity of a scenario can be found in [2].

3.3 Elicitation of the SAWI indexes

As fully described in [2] and summarised in section 3.2.1, the Consequence value calculation needs essentially two parameters, $M(t_{ij})$ and $r_k(t_{ij})$, which are indicated as **Service Access Wealth (SAW) indices**. For each CA Criterion and, within a given CA Criterion for each CA Criterion element t_{ij}, we should evaluate specific SAW indices.

The present Section is meant to provide a methodology which, starting from usually available statistical data, could allow the user to make inferences between SAW indices for their quantitative determination. Although this methodology could be generalised, it is strongly dependent on statistical data availability. Even if in different countries statistical information can be diffused with different ontologies, their information content should be equivalent and thus the described methodology can be applied.

3.3.1 Data sources and output quality sensitivity

Before describing the implemented procedures (and found values) to evaluate the SAW indexes, it is worth pointing out that the thorough analysis aimed to their elicitation has prompted the following general conclusions:

1. The evaluation of the SAW indexes for the four Criteria may require the use of different approaches (and data sources). Most information about Citizens is provided by the National Institutes of Statistics and could be refined whenever utilities are willing to provide details about their service supply, while the information about the Economy sector could be obtained at the Chamber of Commerce or trade association category Associations or elicited by specific historical or ad hoc survey.
2. For each Criterion, multiple data sources may be used, either alternatively or jointly, to elicit the SAW indices leading to different results with different properties about effort required for the identification, flexibility to adapt to all the European countries and also different precision.

Being an unprecedented effort to assess the effects of CI-provided services on societal sectors (at the forefront at the state-of-the-art), all approaches look acceptable in certain conditions and their choice has to be evaluated based on the required precision and the available data and resources.

3.3.2 Criterion 1: Citizens

Table 1 below (already available in [2]) summarises the indices to be calculated for the Citizens Criterion, that is the relevance for elderly people, very young children, people with disabilities and people 18-64 years old of electricity, telecommunication, water, gas and mobility.

CA Criteria	Services				
	Electricity	Telecom	Water	Gas	Mobility
Citizens 65+ t_{11}	$r_1(t_{11})$	$r_2(t_{11})$	$r_3(t_{11})$	$r_4(t_{11})$	$r_5(t_{11})$
Citizens 0-5 t_{12}	$r_1(t_{12})$	$r_2(t_{12})$	$r_3(t_{12})$	$r_4(t_{12})$	$r_5(t_{12})$
Citizens with disabilities t_{13}	$r_1(t_{13})$	$r_2(t_{13})$	$r_3(t_{13})$	$r_4(t_{13})$	$r_5(t_{13})$
Citizens 18-64 t_{14}	$r_1(t_{14})$	$r_2(t_{14})$	$r_3(t_{14})$	$r_4(t_{14})$	$r_5(t_{14})$

Table 1: SAW matrix for the four different Elements of the Citizens Criterion

The first aspect to be clarified is the meaning of “relevance”. In fact, we could take into account from “small perturbations to daily life” up to real economic losses to physical suffering. As far as the Citizens criterion is concerned, we consider “relevant” any disruption (or perturbation) of daily life.

3.3.2.1 Data source: statistical data

The most direct and available data source for evaluating the relevance of the different services for the selected population segments is the National Institute of Statistics, in particular the multipurpose survey on households about a lot of aspects of daily life [8] and the survey about the economic conditions of households and their average monthly expenditure [9].

Both surveys are part of the program of all the European National Institutes of Statistics and are carried out at national level (in Italy, on a sample of 20,000 households and 50,000 people) and are both publicly available in a summary format (the Italian one contains about 740 pages) and available on request for research purpose in a very de-tailed format (742 fields for each individual of the 20,000 households, see Section Appendix A.

The following tables give details about the other population segments included in the analysis, not included in the main text to increase readability.

One parameter which is useful to evaluate the relevance of a service for different population segments is the bill they pay for it as it accounts for both consumption and willingness to pay.

Based on a number of papers, for example [10], we expect that monthly energy expenditure (and consumption) increases with the age of household members, mainly because “elderly people generally prefer higher room temperature for space heating”, spend more hours at home and live in less energy-efficient houses.

By analysing the data about *average monthly households expenditure* (see Figure 15) related to the Centre Italy (the area which includes Rome), we can elicit relevance of electricity and gas. Data about households **electricity** bill is highlighted in red.

Territorio	Centro											
Tipo dato	spesa media mensile familiare											
Misura	valori medi											
Numero di componenti	totale											
Condizione professionale	totale											
Anno	2013											
Tipologia familiare	persona sola con 35-64 anni	persona sola con meno di 35 anni	persona sola con 65 anni o più	coppia senza figli con p.r. con 35-64 anni	coppia senza figli con p.r.con meno di 35 anni	coppia senza figli con p.r. con 65 anni o più	coppia con 1 figlio	coppia con 2 figli	coppia con 3 e più figli	monogenitore	altro	totale
Gruppo di spesa												
totale	2041,88	1954,77	1690,06	2529,44	2770,55	2330,76	2765,47	3183,61	3182,28	2531,7	2742,69	2436,12
alimentari e bevande	347,67	333,88	344,13	484,97	361,34	515,86	544,16	608,27	668,5	492,78	598,91	477,25
non alimentari	1694,21	1620,9	1345,93	2044,46	2409,2	1814,9	2221,31	2575,35	2513,78	2038,92	2143,79	1958,87
tabacchi	22,27	17,98	7,78	23,89	..	10,45	23,06	27,8	21,07	20,74	27,72	19,72
abbigliamento e calzature	89,32	93,45	36,3	115,87	175,64	86,37	136,67	184,43	184,36	122,66	114,26	110,22
abitazione (principale e secondaria)	695,01	595,77	699,79	812,68	633,41	788,1	800,77	803,81	746,1	804,03	787,83	757,76
affitto	110,6	103,38	42,74	79,18	..	16,55	76,33	61,17	..	52,74	128,3	70,9
fitto figurativo	490,74	420,77	563,31	586,86	425,1	659,05	605,74	629,91	526,39	562,7	536,11	572,35
acqua e condominio	52,28	46,6	58,38	51,82	51,72	59,14	51,62	55,43	66,31	53,03	48,96	54,42
manutenzione ordinaria	11,49	..	5,77	..	..	12,66	14,05	17,25	..	15,36	24,36	12,81
manutenzione straordinaria	24,57	..	25,62	..	..	29,88	44,84	30,47	..	..	..	40,15
combustibili ed energia	92,65	87,72	103,93	125,69	122,68	149,6	151,21	163,94	166,69	140,25	168,25	132,85
energia elettrica	35,44	38,55	33,55	47,2	47,18	47,47	53,29	62,62	75,71	48,45	59,18	47,32
gas	45,03	43,78	57,43	63,53	71,86	81,27	79,27	82,28	87,88	71,29	88,72	69,09
riscaldamento centralizzato	6,15	..	6,4	..	..	9,52	5,79	7,44	..	8,15	6,74	6,83
mobili, elettrod. e servizi per la casa	78,24	87,26	119,37	81,36	95,75	93,66	109,75	146,05	149,71	89,04	122,38	107,45

Figure 15: Average monthly expenditure of Centre Italy households. Year 2013

Both for citizens 65+ and citizens aged 18-64 we have data as single and as couple (we use the data “without children”). Wanting to compare the relevance and not being interested in diseconomies, we have

$r_1(t_{11})$ = Citizens 65+ = 47,47/2 = 23,75 (€/month per person)

$r_1(t_{14})$ = Citizens 18-64 = 47,2/2 = 23,60 (€/month per person)

Please note that the relevance is not very different as heating in Italy is mostly fuelled by gas (for the relevance of gas, see below).

To elicit relevance of electricity for children, we calculate the average value of the difference between expenditure of households with 1-2-3 children and households without children (aged 35-64). Therefore,

$r_1(t_{12})$ = Citizens 0-5 = [(53,29-47,2)+(62,62-47,2)/2+(75,71-47,2)/3]/3 = 7,75 (€/month per child)

It is interesting to note the (counter-intuitive) result about the per-children expenditure, which increases when the number of children increases. This is likely due to living in larger houses and to energy inefficient behaviours as well as the fact that in Italy the price per kWh increases as soon as the consumption increases.

As far as the values sensitivity is concerned, comparing these values with those related to the whole Italy (see Figure 16), we would have

$r_1(t_{11})$ = Citizens 65+ = 47,97/2 = 24 (€/month per person) → +1%

$r_1(t_{14})$ = Citizens 18-64 = 41,34/2 = 20,2 (€/month per person) → -14,4%

$r_1(t_{12})$ = Citizens 0-5 = 9 (€/month per person) → +15,7%

most likely because of the effect of the Northern part of Italy. This is to say that depending on the analysis to be performed and the accuracy required (either a rough estimation or a reliable value) it is quite important to have good quality data.

Territorio	Italia											
Tipo dato	spesa media mensile familiare											
Misura	valori medi											
Numero di componenti	totale											
Condizione professionale	totale											
Anno	2012											
Tipologia familiare	persona sola con 35-64 anni	persona sola con meno di 35 anni	persona sola con 65 anni o più	coppia senza figli con p.r. con 35-64 anni	coppia senza figli con p.r.con meno di 35 anni	coppia senza figli con p.r. con 65 anni o più	coppia con 1 figlio	coppia con 2 figli	coppia con 3 e più figli	monogeni tore	altro	totale
Gruppo di spesa												
totale	2008,48	1906,83	1539,11	2710,33	2534,72	2397,15	2841,95	3023,33	3034,53	2357,55	2615,07	2419,27
alimentari e bevande	344,42	323,48	324,65	467,51	386,07	489,94	536,07	586,18	659,19	479,59	553,75	468,32
non alimentari	1664,07	1583,35	1214,47	2242,82	2148,64	1907,2	2305,87	2437,15	2375,34	1877,96	2061,31	1950,95
tabacchi	22,48	21,58	6,67	27,63	29,51	11,08	23,94	26,62	31,15	21,1	27,11	20,44
abbigliamento e calzature	98,96	108,56	51,11	138,4	125,78	80,06	153,13	180,68	178,7	124,25	118,42	119,85
abitazione (principale e secondaria)	628,87	559,12	604,39	779,76	683,44	813,55	745,87	738,32	658,26	673,55	710,99	700,04
combustibili ed energia	97,96	81,44	110,45	134,97	106,16	146,78	151,2	161,39	162,51	135,97	152,99	134,49
energia elettrica	32,8	29,56	32,12	46,56	36,13	47,97	56,06	63,51	73,43	47,41	57,61	47,82
gas	44,85	39,5	54,48	66,53	47,3	71,48	73,48	74,42	69,05	67,08	72	64,12
riscaldamento centralizzato	11,15	7,2	13,43	11,6	13,59	12,49	10,44	9,8	6,29	11,24	11,14	11,12
mobili, elettrod. e servizi per la casa	87,62	95,95	96,54	123,75	148,2	119,36	131,09	128,24	145,12	117,22	140,03	116,71

Figure 16: Average monthly expenditure of Italian households ([9]).

Should you be interested in calculating the loss of wealth just depending on the loss of electricity, this approach works well assuming the 100% value the total expenditure for all the services.

Going on to the relevance of **gas**, from Figure 17, taking into account both gas and centralised heating, we get

$r_4(t_{11})$ = Citizens 65+ = 41,985 (€/month per person)

$r_4(t_{14})$ = Citizens 18-64 = 33,85 (€/month per person)

$r_4(t_{12})$ = Citizens 0-5 = 4,417 (€/month per person)

Territorio	Centro
Tipo dato	spesa media mensile familiare
Misura	valori medi
Numero di componenti	totale
Condizione professionale	totale
Anno	2013

Tipologia familiare	persona sola con 35-64 anni	persona sola con meno di 35 anni	persona sola con 65 anni o più	coppia senza figli con p.r. con 35-64 anni	coppia senza figli con p.r.con meno di 35 anni	coppia senza figli con p.r. con 65 anni o più	coppia con 1 figlio	coppia con 2 figli	coppia con 3 e più figli	monogenitore	altro	totale
Gruppo di spesa												
totale	2041,88	1954,77	1690,06	2529,44	2770,55	2330,76	2765,47	3183,61	3182,28	2531,7	2742,69	2436,12
alimentari e bevande	347,67	333,88	344,13	484,97	361,34	515,86	544,16	608,27	668,5	492,78	598,91	477,25
non alimentari	1694,21	1620,9	1345,93	2044,46	2409,2	1814,9	2221,31	2575,35	2513,78	2038,92	2143,79	1958,87
tabacchi	22,27	17,98	7,78	23,89	..	10,45	23,06	27,8	21,07	20,74	27,72	19,72
abbigliamento e calzature	89,32	93,45	36,3	115,87	175,64	86,37	136,67	184,43	184,36	122,66	114,26	110,22
abitazione (principale e secondaria)	695,01	595,77	699,79	812,68	633,41	788,1	800,77	803,81	746,1	804,03	787,83	757,76
affitto	110,6	103,38	42,74	79,18	..	16,55	76,33	61,17	..	52,74	128,3	70,9
fitto figurativo	490,74	420,77	563,31	586,86	425,1	659,05	605,74	629,91	526,39	562,7	536,11	572,35
acqua e condominio	52,28	46,6	58,38	51,82	51,72	50,14	51,62	55,43	66,31	53,03	48,96	54,42
manutenzione ordinaria	11,49	..	5,77	..	..	12,66	14,05	17,25	..	15,36	24,36	12,81
manutenzione straordinaria	24,57	..	25,62	..	..	29,88	44,84	30,47	..	..	..	40,15
combustibili ed energia	92,65	87,72	103,93	125,69	122,68	149,6	151,21	163,94	166,69	140,25	168,25	132,85
energia elettrica	35,44	30,55	33,55	47,2	47,18	47,47	53,29	62,62	75,71	48,45	59,19	47,32
gas	45,03	43,78	57,43	63,53	71,86	81,27	79,27	82,28	87,88	71,29	88,72	69,09
riscaldamento centralizzato	6,15	..	6,4	..	..	9,52	5,79	7,44	..	8,15	6,74	6,83
mobili, elettrod. e servizi per la casa	78,24	87,26	119,37	81,36	95,75	93,66	109,75	146,05	149,71	89,04	122,38	107,45

Figure 17: Average monthly expenditure of Centre Italy households, gas and heating highlighted.

It is worth remarking that - as already mentioned for electricity - although the approach still works well while calculating the loss of wealth just depending on the loss of gas, there is a discrepancy between the calculated values and the expected relationship between r_1 and r_4 (gas looks much more relevant than electricity) as soon as the effect of both gas and electricity needs to be taken into account, even if they are both homogeneous in unit of measure.

The reason of this behaviour is to be found in the different cost of the two services and the different amount of resources needed for the different uses (example: heating uses much more gas than the electricity used for illumination, but heating and illumination are both important for citizens). This means that a conversion in TOE (tonne of oil equivalent), for example, wouldn’t work either, as what we are interested in is not how much resource – but how much service – is used. Things get even more complex as soon as we are interested in telecommunication relevance and plan to elicit it from the expenditure households take up for it as most of them accepted a flat bill which therefore is not linked to the relevance anymore.

Eliciting the relevance of the **telecommunication** service for the different population segments is possible by looking up in the raw micro-data files [9] collected by the National Institute of Statistics and available on request for research scope. The micro-data files are processed and summarised by the National Institute of Statistics in the multipurpose report [8]. However, for our purpose micro-data file works better than the multipurpose report as it allows to pick exactly the aspect we are interested in, for example not if one person owns or uses a computer but if it uses the Internet, and why, being different if it is for generic researches on Google or for interacting with the public government. Restriction to be mentioned includes the fact that the survey involved 20.000 households of all over Italy, therefore is not a specific survey, and the fact that its processing requires handling big data and therefore a big effort.

The list of the available information in the micro-data file can be found in [3]. The relevant fields for eliciting how much citizens’ wealth is linked to the availability of the Telco services are shown in the list below. We provide it in order to give a clue about the detail level and the possible metrics as well as pointing out that, although the values of the SAW indices will be different in different EU countries, the methodology is general.

291. Have you ever used the Internet?
292. Frequency of use of Internet in the last 12 months
293. Frequency of use of Internet at home in the last three months
294. Frequency of use of Internet at work for the past three months
295. Frequency of use of Internet at place of education in the last three months
296. Frequency of use of Internet at others' home in the last three months
297. Frequency of use of Internet elsewhere for the past three months
298. Tools used to access the Internet in places other than home or place of work in the last 3 months: mobile phone or smartphone with connection to mobile phone network
299. Tools used to access the Internet in places other than home or place of work in the last 3 months: mobile phone or smartphone with a wireless network connection (eg. WIFI)
300. Tools used to access the Internet in places other than home or place of work in the last 3 months: laptop (ie. Laptops, tablets) with access to a network of mobile as a modem using a USB stick, Sim-card or phone
301. Tools used to access the Internet in places other than home or place of work in the last 3 months: laptop (ie. Laptops, tablets) with connection to a wireless network (eg. WIFI)
302. Tools used to access the Internet in places other than home or place of work in the last 3 months: other handheld device
303. In the last three months he has sent or received email
304. In the last three months he phoned / video calls made
305. In the last three months she has posted messages on chat rooms, blogs, newsgroups or online discussion forum
306. In the last three months she has participated in social networks (creating user profile, posting messages or other on Facebook, Twitter, etc.)
307. In the last three months he has expressed opinions on political or social issues on the web (for example, through blogs, social networks, etc.).
308. In the last three months she has participated in online consultations or voting on social issues (civic) or political (urban planning, sign a petition, sign a petition)
309. Over the past three months he has seen a wiki to get information (eg. Wikipedia, other online encyclopaedias)
310. In the last three months she took part in a professional network (create a profile, posting messages or other contributions on LinkedIn, Xing, etc.)
311. Over the past three months she read newspapers, information, magazines online
312. In the last three months he has sought health information
313. Over the past three months she read books or downloaded online or e-book
314. In the last three months he has sought information on activities of education or training
315. In the last three months he searched for information on goods and services
316. In the last three months she has downloaded software (other than games)
317. In the last three months he has taken a course online
318. In the last three months she has sought job or sent a job application
319. In the last three months he has used services related to travel or stays
320. In the last three months she has sold goods or services
321. In the last three months he has used Internet banking
322. In the last three months she has signed subscriptions for regular news (including services RSS)
323. In the last 12 months he has used the Internet to obtain information from websites of PA
324. In the last 12 months she has used the Internet to download the modules PA
325. In the last 12 months he has used the Internet to send completed forms of PA
326. In the last 12 months he has used websites of PA or managers of public services to pay taxes
327. In the last 12 months he has used websites of PA or managers of public services to request social security benefits
328. In the last 12 months he has used websites of PA or managers of public services to request personal documents
329. In the last 12 months he has used websites of PA or managers of public services for requesting certificates (birth, marriage, death)
330. In the last 12 months he has used websites of PA or managers of public services for access to public libraries

331.	In the last 12 months he has used websites of PA or managers of public services for enrolment in high schools or universities
332.	In the last 12 months he has used websites of PA or managers of public services for change of residence
	…
352.	Have you ever bought or ordered goods and / or services for private use of internet
353.	In the last 12 months he has bought or ordered food
354.	In the last 12 months he has bought or ordered housewares
355.	In the last 12 months he has bought or ordered drugs
356.	In the last 12 months he has bought or ordered clothes, sporting goods
357.	In the last 12 months he has bought or ordered movies, music
358.	In the last 12 months he has bought or ordered books (including e-books)
359.	In the last 12 months he has bought or ordered newspapers, magazines
360.	In the last 12 months he has bought or ordered material for distance learning
361.	In the last 12 months he has bought or ordered computer software and / or updates (excluding video games)
362.	In the last 12 months he has bought or ordered Games
363.	In the last 12 months he has bought or ordered computer hardware
364.	In the last 12 months he has bought or ordered electronic equipment (eg. Cameras, video cameras, etc.).
365.	In the last 12 months he has bought or ordered telecommunications services (TV, broadband subscriptions, telephone subscriptions, phone cards, etc.).
366.	In the last 12 months he has bought or ordered insurance, banking and financial
367.	In the last 12 months he has bought or ordered nights holiday (hotels, pensions)
368.	Over the past 12 months has made other travel expenses (train and flight tickets, car rental, etc.).
369.	In the last 12 months he has bought or ordered tickets for shows
370.	In the last 12 months he has ordered or bought lottery tickets or gambling
371.	In the last 12 months he has bought or ordered medical examinations
372.	In the last 12 months he has bought or ordered wellness packages and beauty treatments
373.	In the last 12 months he has bought or ordered other products: more code
374.	Products bought or ordered over the Internet downloaded directly via web: movies or music
375.	Products bought or ordered over the Internet downloaded directly via web: books (including e-books), magazines, newspapers, material for distance learning
376.	Products bought or ordered over the Internet downloaded directly via web: computer software (including video games and their updates)
377.	In the last 12 months he has ordered or purchased goods and / or services for private use over the Internet by national seller
378.	In the last 12 months he has ordered or purchased goods and / or services for private use over the Internet by the seller of another EU country
379.	In the last 12 months he has ordered or purchased goods and / or services for private use over the Internet by the seller from the rest of the World
380.	In the last 12 months he has ordered or purchased goods and / or services for private use over the Internet without identifying the nationality of the seller
381.	The frequency with which you use the phone or a smartphone

Table 2: An example of the information available in the micro-data file provided by the Italian National Institute of Statistics

Although answers to the questions often had several possible values, in our analysis - being interested in understanding how a (hopefully reasonably short) loss of service would affect citizens at home and therefore picking the “continuous” users - we assigned 1 point to all the answers which identify “a continuous” user or a “critical” user (meaning those people who use Telco for actions - for example interaction with public/bureaucratic offices - which cannot be postponed) and 0 to the others. Each individual who took up the survey has therefore a score which hints how relevant telecommunication service is for him/her. The average value of all the individuals in each segment has been taken as the relevance for that segment.

Given that we do not have the complete file yet but we only have an example version, the elicited normalised values (unit-less numbers) are

$r_2(t_{11})$ = Citizens 65+ = 100

$r_2(t_{14})$ = Citizens 18-64 = 86,4

$r_2(t_{12})$ = Citizens 0-5 = 0

It is worth emphasising that dealing with not aggregated statistical data is not an easy task; it is thus recommended to possibly involve the Statistical Office as an active project partner for data processing during the DSS setup whenever possible, as this partner has superior abilities for data handling. The micro-data file is delivered periodically (up to once a year) and the indices can be easily updated just automatically processing the new data set.

To give an idea of the limitations occurring when using the summary tables provided in the multipurpose report, it is enough to show the only table related to Telco available in the report [8], shown (in Italian) in Figure 18. Please note that the only reported information is how often different population segments use the Internet (which is a fraction of the Telco use) without giving clues of the relevance of its use. It is worth noting, once again, that the granularity of this statistical survey is nation-wide.

Tavola 8.8 **Persone di 3 anni e più per frequenza con cui usano un personal computer e persone di 6 anni e più per frequenza con cui usano Internet per sesso, classe di età, regione, ripartizione e tipo di comune**
Anno 2014, per 100 persone della stessa classe di età, sesso e zona

ANNI CLASSI DI ETÀ	Uso del personal computer (a)					Non usano il pc	Uso di Internet (b)					Non usano Internet
	Sì	Tutti i giorni	Una o più volte alla settimana	Qualche volta al mese	Qualche volta all'anno		Sì	Tutti i giorni	Una o più volte alla settimana	Qualche volta al mese	Qualche volta all'anno	
						MASCHI E FEMMINE						
3-5	22,0	4,6	12,8	2,7	1,9	74,7	-	-	-	-	-	-
6-10	52,8	11,4	30,5	8,3	2,6	45,6	44,4	9,0	25,6	7,2	2,6	53,8
11-14	80,2	31,4	41,3	6,1	1,4	18,1	80,8	44,5	31,6	3,8	0,9	17,2
15-17	85,8	51,6	30,4	3,1	0,6	12,8	90,9	70,2	18,5	1,8	0,3	7,9
18-19	89,1	58,7	27,1	2,8	0,5	9,1	93,8	76,2	15,7	1,5	0,4	4,0
20-24	83,7	58,9	21,5	2,5	0,8	13,7	89,1	70,6	16,1	1,9	0,5	8,4
25-34	77,8	52,1	21,7	3,1	0,9	20,1	83,5	61,0	19,9	1,8	0,8	14,6
35-44	73,1	48,2	20,6	2,9	1,4	25,7	76,1	50,2	21,9	3,0	1,0	22,6
45-54	64,0	43,0	17,2	2,7	1,1	34,4	65,6	40,7	20,6	3,1	1,2	32,9
55-59	50,9	34,0	13,3	2,9	0,7	47,4	52,5	30,9	17,3	3,2	1,1	46,1
60-64	40,8	25,8	12,9	1,4	0,7	57,9	41,6	23,4	15,7	1,9	0,6	57,2
65-74	21,2	11,0	8,3	1,5	0,4	77,1	21,1	10,2	8,9	1,6	0,5	77,1
75 e oltre	4,7	2,3	1,9	0,4	0,1	93,4	4,3	1,9	1,8	0,4	0,2	93,9
Totale	**54,7**	**33,5**	**17,4**	**2,7**	**1,0**	**43,6**	**57,3**	**36,9**	**17,1**	**2,5**	**0,9**	**41,0**

Figure 18: Frequency of use of personal computer and the Internet (as reported in [8]).

Last but not least, gathering data about the use of some services can be even more challenging. For example, available data about **water** relevance is only in terms of "per capita demand" (in litres) of water, without taking into account population segments, or its usage.

To sum up, the main advantage of using (these) statistical sources is the availability of data at the European level, making it easy to extend this methodology to all the European countries. On the other hand, the disadvantage of using these sources is the difficulty to compare relevance indexes, even when they have the same unit of measure (which is not always the case). Furthermore, this approach cannot take into account time dependency of the relevance of services (for example, whenever people is not at home, any short loss of service has limited or no impact at all) which in principle can lead to macroscopic errors in the estimation.

3.3.2.2 Data source: measurements campaign

In order to have more accurate relevance indexes as well as - possibly - their time profile, it is worth changing the approach and focusing on the usage of each service (electricity, gas etc), the activities they enable (lighting, cooking, heating), their priority according to safety issues and discomfort level as well as on the time of the day (for example, not being able to switch on the light leads to discomfort during the daylight and safety issues during the night).

To do that, we started from the **electricity** for which enough data and studies as well as a (not very extended) measurement campaign ([13], [12]) are known and available.

After listing all (and only!) the relevant services, the most delicate aspect is the definition of the priority of a service. As far as electricity is concerned, studies about algorithms for load shaping as well as logic for automated management of electrical residential loads give us useful hints.

In [14], the authors defined as relevant - for the Italian case, just taking into account the most common situations and not considering people with disabilities, for example - the following power-enabled "services" ordered by priority: lighting, refrigerator and freezer, oven, TV, microwave, washing machine, dish washer, drier, iron. They also included in their analysis cooking facilities as they included kitchen with induction as an electrical load: its priority is lower than the fridge and higher than the oven.

The rationale behind the sequence above is the following. Lighting is the first service in order of importance because of the personal safety after dark, which would be affected by its absence and the fact that no activity is possible in the absence of illumination. The refrigerator and the freezer were placed nearly at the same priority level as their continued operation is essential for the proper storage of food which, should remain at room temperature for too long without being consumed, will be spoiled and should be thrown away. Next primary service is the kitchen, less important just than a refrigerator and freezer also because its massive use is limited at mealtimes, when usually no other parallel activities are in place. As it has been said before, in Italy the kitchen is usually gas powered but priority considerations are still valid.

Next appliances (and related services) in our priority list are electrical oven and TV. This is because, based on the frequency of use and perceived importance of the service provided, they can be seen as equally important. The microwave was placed after the TV as it does not really offer an essential service: in Italy, it is actually a substitute for traditional stoves, typically used to heat the food in a short time and rarely to cook.

Appliances like washing machine, dishwasher and dryer are considered less important than, for example, the microwave because of the duration of use. According to the authors of [14] in fact, considering that the microwave is usually used for short periods, it makes more sense - with respect to the perception of comfort - to interrupt a wash cycle rather than having to wait maybe an hour or more to warm a cup of tea.

Last, "other appliances" include all those appliances (iron, hair dryer, vacuum cleaner, coffee machine but also PC and videogames) whose use can be postponed or replaced. Please note that analysis assumes a "normal" initial situation to assess the priorities and we are aware that priorities during an emergency could change. As an example, charging batteries for mobile phones – according to what happened in the 2002 Flooding in Germany – could be a separately profiled function and could be high in rank.

The next step consists in defining, for each service, for each hour of the day and for each population segment a priority represented by a numerical value, which is higher, the greater the importance of the load to be supplied. As the priority could not be constant, the objective is therefore to condense in a graph the possible variations of the priority. Therefore, for each "service" enabled by electricity, for each population segment and with a granularity of 30 minutes we set the priority value to

- 1: if the service is most likely needed. Example: lighting in the early morning or in the evening

- 0.5: if the service may not be needed but – should it be needed – would be critical. Example: lighting late at night, when most people is sleeping
- 0: if not needed or not a big issue if missing. Example: lighting at home whenever people are at work, or also lighting at noon.
- 0.1: for loads and services, which can generally be postponed. Example: dishwasher or washing machine.

We assume the following profiles:

- Citizens 18-64: working or studying, they get up at 6 am, go sleeping at 11.30 pm, leave home at 8.30 am at the latest and return home at 4.30 pm at the earliest. Breakfast is usually between 6.00 am and 7.30 am, dinner between 8.00 pm and 9.00 pm.
- Citizens 65+: retired from work, getting up at 6 am and going to bed at 11.00 pm, they could be at home at any time. Breakfast is usually between 6.00 am and 7.30 am, lunch between 12.30 pm and 1.30 pm, dinner between 7.30 pm and 8.30 pm.
- Citizens 0-5: getting up at 6.30 am and going to bed at 9.30 pm on average, they usually are not at home between 8.30 am and 4.30 pm if they are older than 3, while – if younger than 3 – the younger the more likely that they are at home.

As far as electricity is concerned, the following profile can be elicited for Citizens 18-64 (working days):

	CITIZENS 18-64									
TIME	*Lighting*	*Refrigerator/ Freezer*	*Air conditioning*	*TV*	*Oven*	*Microwave*	*Washing Machine & Drier*	*Dishwasher*	*Other appliances*	**TOT ELECTRICITY**
00:00	0,5	1	-	-	-	-	-	-	-	1,5
00:30	0,5	1	-	-	-	-	-	-	-	1,5
01:00	0,5	1	-	-	-	-	-	-	-	1,5
01:30	0,5	1	-	-	-	-	-	-	-	1,5
02:00	0,5	1	-	-	-	-	-	-	-	1,5
02:30	0,5	1	-	-	-	-	-	-	-	1,5
03:00	0,5	1	-	-	-	-	-	-	-	1,5
03:30	0,5	1	-	-	-	-	-	-	-	1,5
04:00	0,5	1	-	-	-	-	-	-	-	1,5
04:30	0,5	1	-	-	-	-	-	-	-	1,5
05:00	0,5	1	-	-	-	-	-	-	-	1,5
05:30	0,5	1	-	-	-	-	-	-	-	1,5
06:00	1	1	-	1	-	1	-	-	1	5
06:30	1	1	-	1	-	1	-	-	1	5
07:00	1	1	-	1	-	-	-	-	1	4
07:30	1	1	-	-	-	-	-	-	-	2
08:00	1	1	-	-	-	-	-	-	-	2

08:30	-	1	-	-	-	-	-	-	-	1
09:00	-	1	-	-	-	-	-	-	-	1
09:30	-	1	-	-	-	-	-	-	-	1
10:00	-	1	-	-	-	-	-	-	-	1
10:30	-	1	-	-	-	-	-	-	-	1
11:00	-	1	-	-	-	-	-	-	-	1
11:30	-	1	-	-	-	-	-	-	-	1
12:00	-	1	-	-	-	-	-	-	-	1
12:30	-	1	-	-	-	-	-	-	-	1
13:00	-	1	-	-	-	-	-	-	-	1
13:30	-	1	-	-	-	-	-	-	-	1
14:00	-	1	-	-	-	-	-	-	-	1
14:30	-	1	-	-	-	-	-	-	-	1
15:00	-	1	-	-	-	-	-	-	-	1
15:30	-	1	-	-	-	-	-	-	-	1
16:00	-	1	-	-	-	-	-	-	-	1
16:30	0,5	1	-	-	-	-	-	-	-	1,5
17:00	1	1	-	-	-	-	-	-	-	2
17:30	1	1	-	-	-	-	-	-	-	2
18:00	1	1	-	-	-	-	-	-	-	2
18:30	1	1	-	-	-	-	-	-	-	2
19:00	1	1	-	-	1	1	0,1	-	0,5	4,6
19:30	1	1	-	-	1	1	0,1	-	0,5	4,6
20:00	1	1	-	1	-	-	0,1	-	0,5	3,6
20:30	1	1	-	1	-	-	0,1	-	0,5	3,6
21:00	1	1	-	1	-	-	0,1	-	0,5	3,6
21:30	1	1	-	1	-	-	0,1	0,1	0,5	3,7
22:00	1	1	-	1	-	-	0,1	0,1	0,5	3,7
22:30	1	1	-	1	-	-	-	0,1	0,5	3,6
23:00	1	1	-	1	-	-	-	0,1	0,5	3,6
23:30	0,5	1	-	-	-	-	-	0,1	0,5	2,1

Table 3: Priority values for the population segment "Citizens 18-64" of electricity-enabled services.

Table 6 and Table 7 show the relevance of different electricity-enabled services for elderly people and young children. It is worth repeating that the table above does not show the percentage of affected people (at home) but a numerical value in the range [0-1] showing the importance of the load to be supplied.

With the same approach we can identify the relevance of the other critical infrastructures, shown in Table 5 (please find Table 8 and Table 9 about elderly people and young). Please note that this methodology is quite sensitive to the number of identified CI-enabled services, as that number directly impact the maximum relevance a CI can have (for example, the maximum hourly relevance of power in Table 2, Table 3 and Table 4 is 9). Therefore it is critically important to identify all (and only!) the relevant “services” or functions avoiding functional duplication (for example, shower, bath and wash basin are included in personal care).

	CITIZENS 18-64														
TIME	*personal care*	*food preparation*	*drinking water*	*dish washing*	*washing machine*	*toilet*	TOT WATER	*stove*	*water heater*	*heating*	TOT GAS	*landline*	*mobile*	*internet*	TOT TELCO
00:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
00:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
01:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
01:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
02:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
02:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
03:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
03:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
04:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
04:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
05:00	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
05:30	-	-	-	-	-	0,5	0,5	-	-	-	0	-	-	-	0
06:00	1	1	1	-	-	1	4	1	1	1	3	0,5	1	1	2,5
06:30	1	1	1	-	-	1	4	1	1	1	3	0,5	1	1	2,5
07:00	1	1	1	-	-	1	4	1	1	1	3	0,5	1	1	2,5
07:30	1	1	1	-	-	1	4	-	1	-	1	0,5	1	1	2,5
08:00	1	-	1	-	-	1	3	-	1	-	1	0,5	1	1	2,5
08:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
09:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
09:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
10:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
10:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
11:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
11:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
12:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
12:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
13:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
13:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
14:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
14:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
15:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
15:30	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0
16:00	-	-	-	-	-	-	0	-	-	-	0	-	-	-	0

16:30	1	-	1	-	-	1	3	-	0,5	1	1,5	1	1	1	3
17:00	1	-	1	-	-	1	3	-	0,5	1	1,5	1	1	1	3
17:30	1	-	1	-	-	1	3	-	0,5	1	1,5	1	1	1	3
18:00	1	-	1	-	-	1	3	-	0,5	1	1,5	1	1	1	3
18:30	1	-	1	-	-	1	3	-	0,5	1	1,5	1	1	1	3
19:00	1	-	1	0,1	-	1	3,1	-	0,5	1	1,5	1	1	1	3
19:30	1	1	1	0,1	-	1	4,1	1	1	1	3	1	1	1	3
20:00	1	1	1	0,1	-	1	4,1	1	1	1	3	1	1	1	3
20:30	1	1	1	0,1	-	1	4,1	1	1	-	2	1	1	1	3
21:00	1	-	1	0,1	-	1	3,1	-	1	-	1	1	1	1	3
21:30	1	-	1	0,1	0,1	1	3,2	-	1	-	1	-	1	1	2
22:00	1	-	1	0,1	0,1	1	3,2	-	1	-	1	-	1	1	2
22:30	1	-	1	-	0,1	1	3,1	-	1	-	1	-	1	1	2
23:00	1	-	1	-	0,1	1	3,1	-	1	-	1	-	-	1	1
23:30	0,5	-	-	-	0,1	0,5	1,1	-	-	-	0	-	-	-	0

Table 4: Priority values for population segment "Citizens 18-64" of Water/Gas/Telco- enabled services.

The graphs below show the (not normalised) temporal profile of the relevance emphasising the absolute value (Figure 19, Figure 20 and Figure 21) and the contribute (Figure 22, Figure 23 and Figure 24) of each CI to the well-being of the citizens.

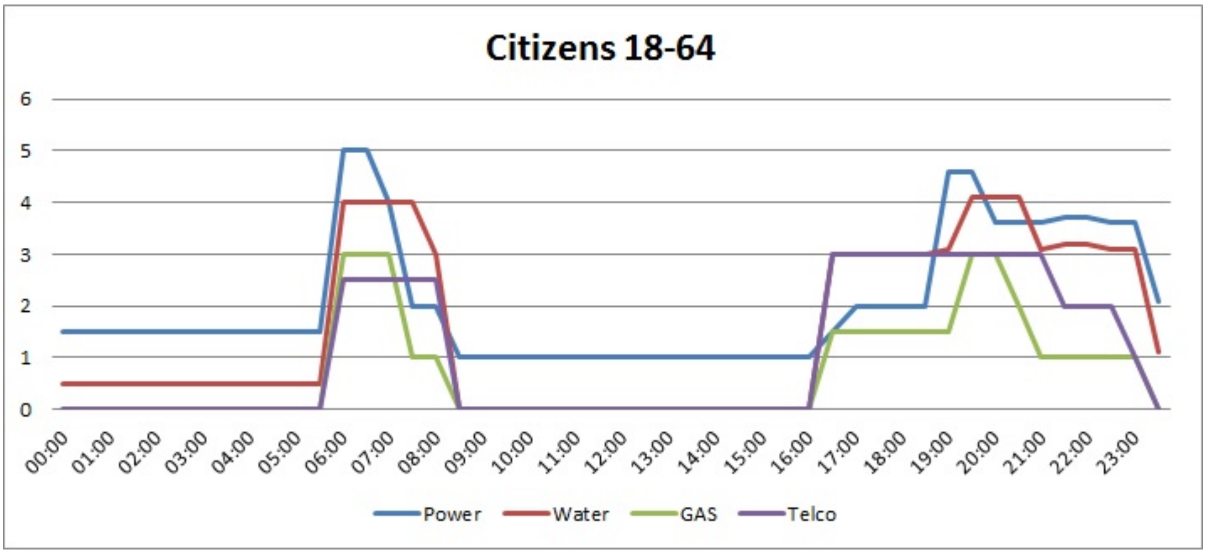

Figure 19: Temporal profile of the relevance of CIs for "Citizens 18-64"

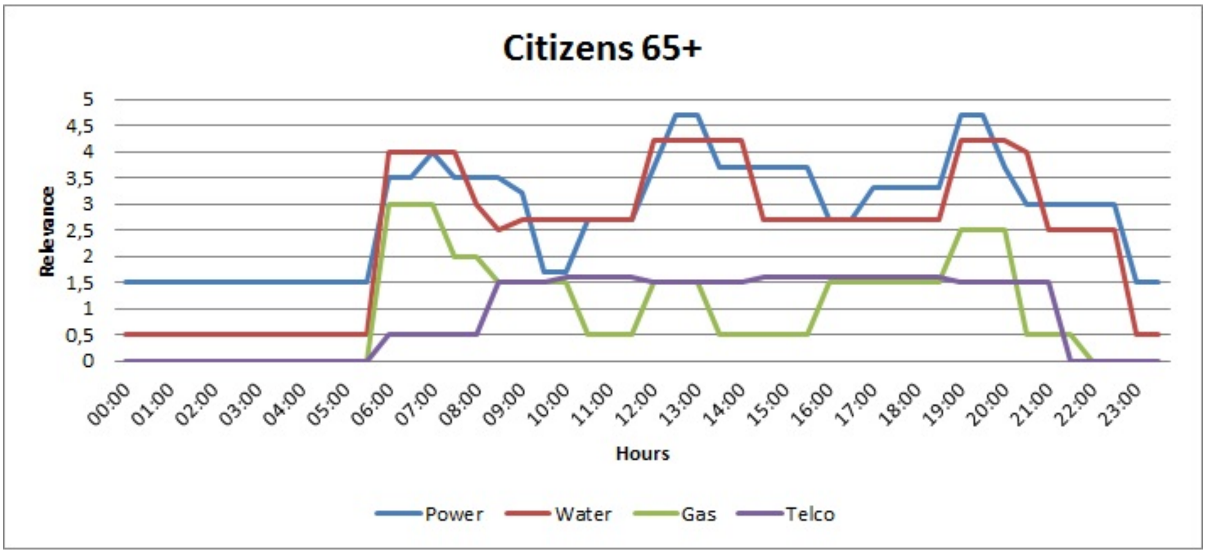

Figure 20: Temporal profile of the relevance of CIs for "Citizens 65+"

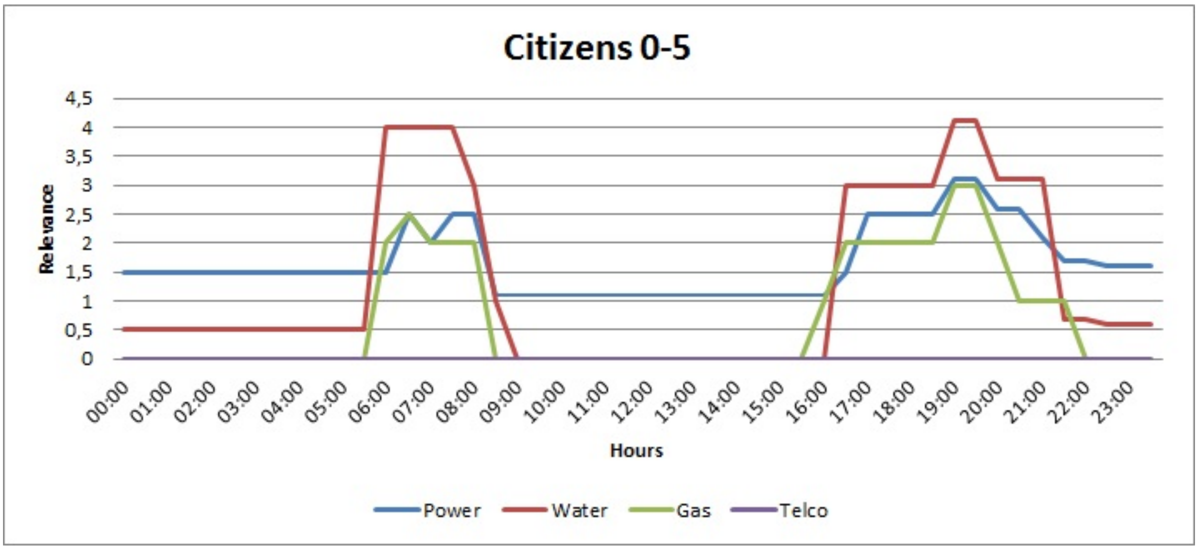

Figure 21: Temporal profile of the relevance of CIs for "Citizens 0-5"

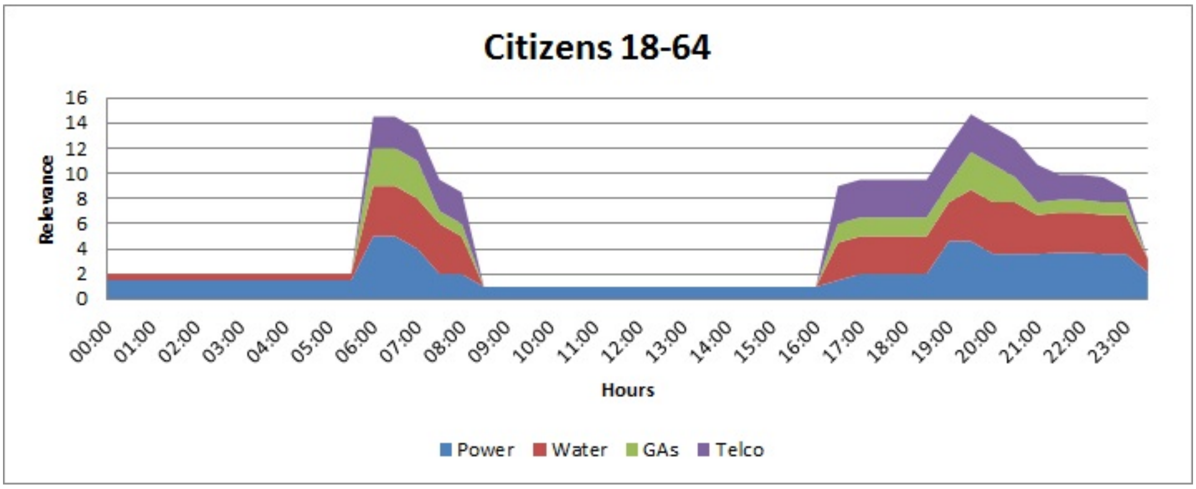

Figure 22: Cumulative temporal profile of the relevance of CIs for "Citizens 18-64"

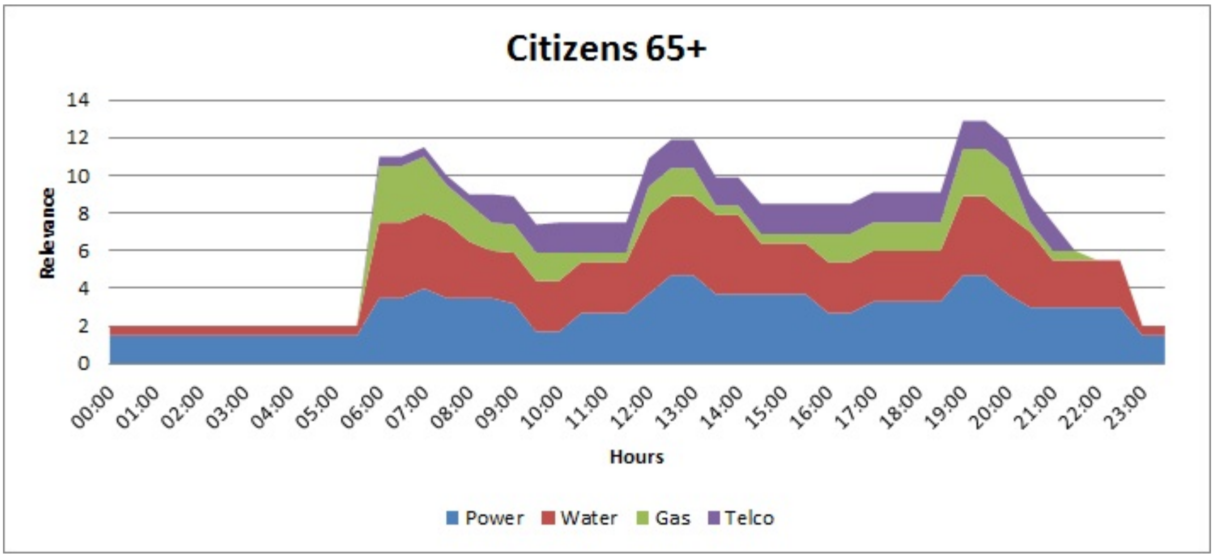

Figure 23: Cumulative temporal profile of the relevance of CIs for "Citizens 65+"

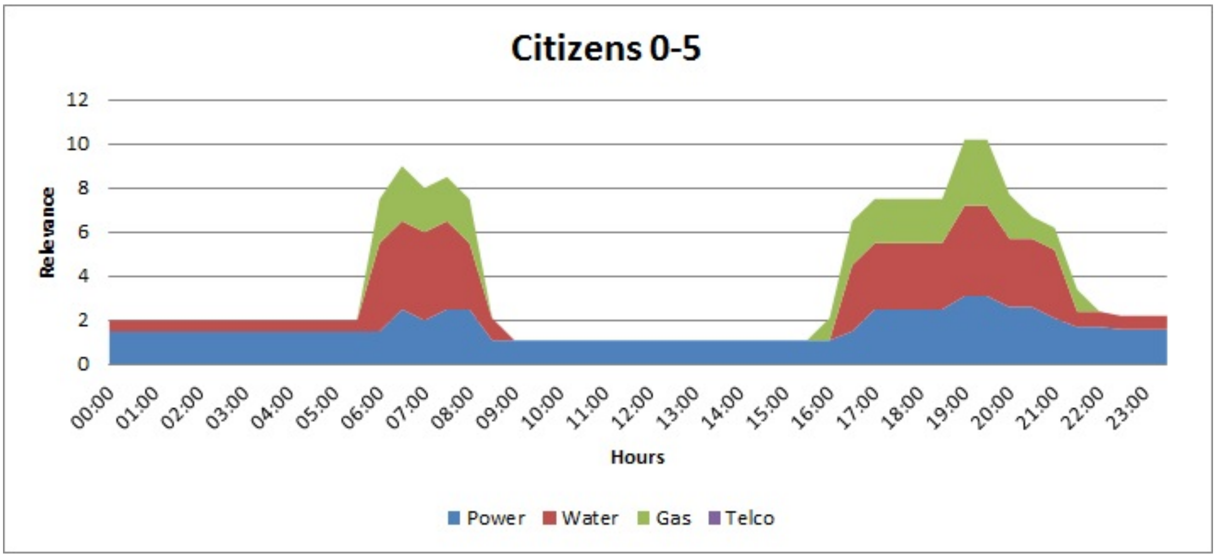

Figure 24: Cumulative temporal profile of the relevance of CIs for "Citizens 0-5"

The graphs hereafter (Figure 25, Figure 26, Figure 27 and Figure 28) show the relevance of each CI for different population segments.

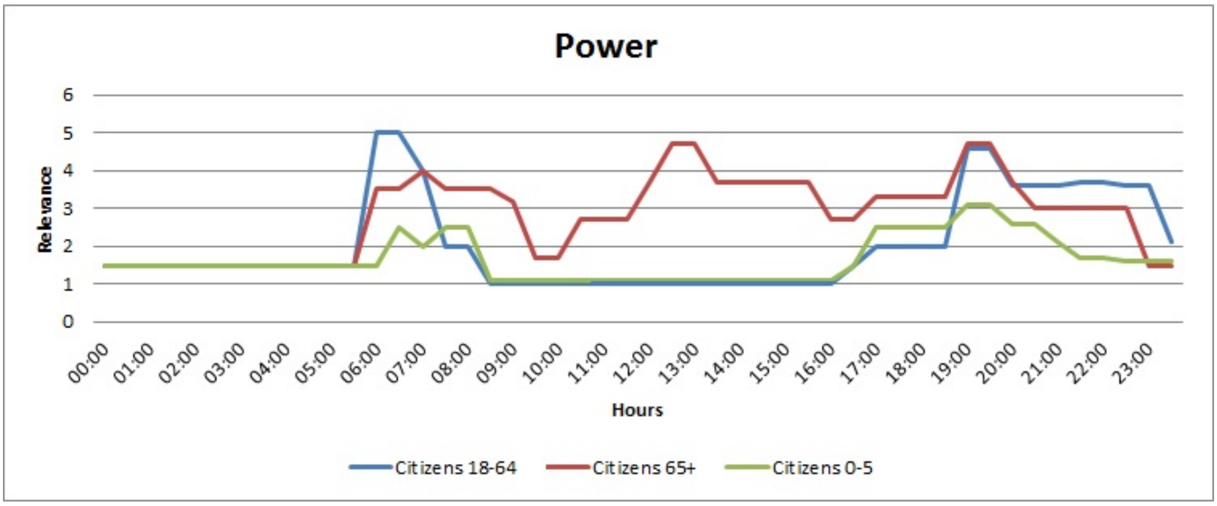

Figure 25: Temporal profile of the relevance of Power for different population segments

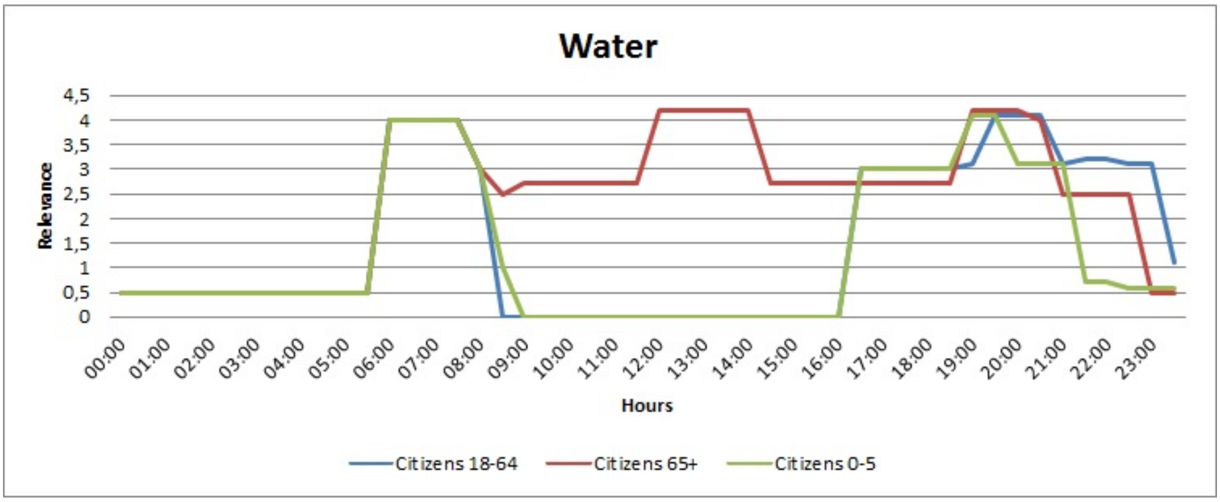

Figure 26: Temporal profile of the relevance of Water for different population segments

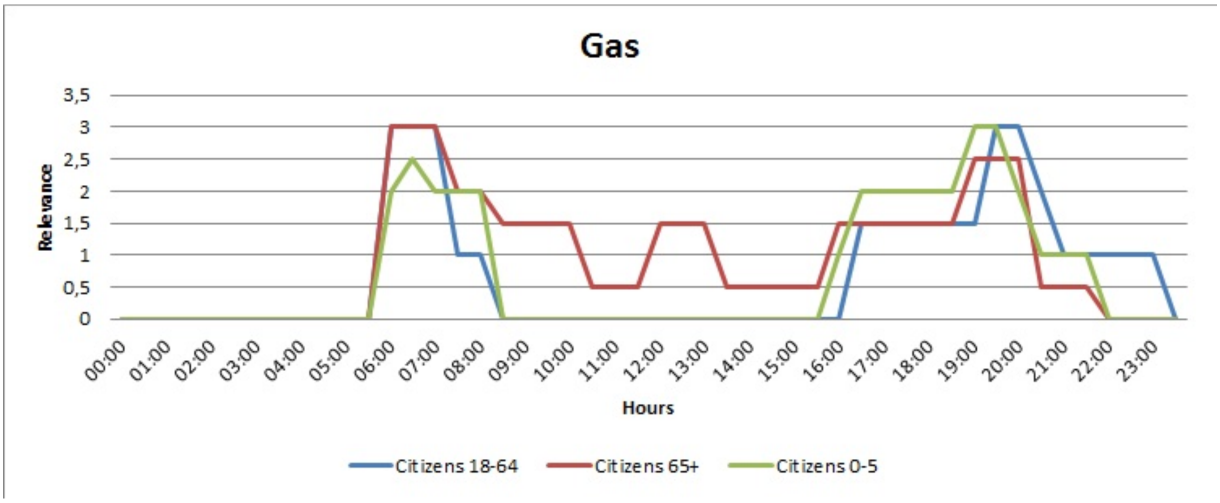

Figure 27: Temporal profile of the relevance of Gas for different population segments

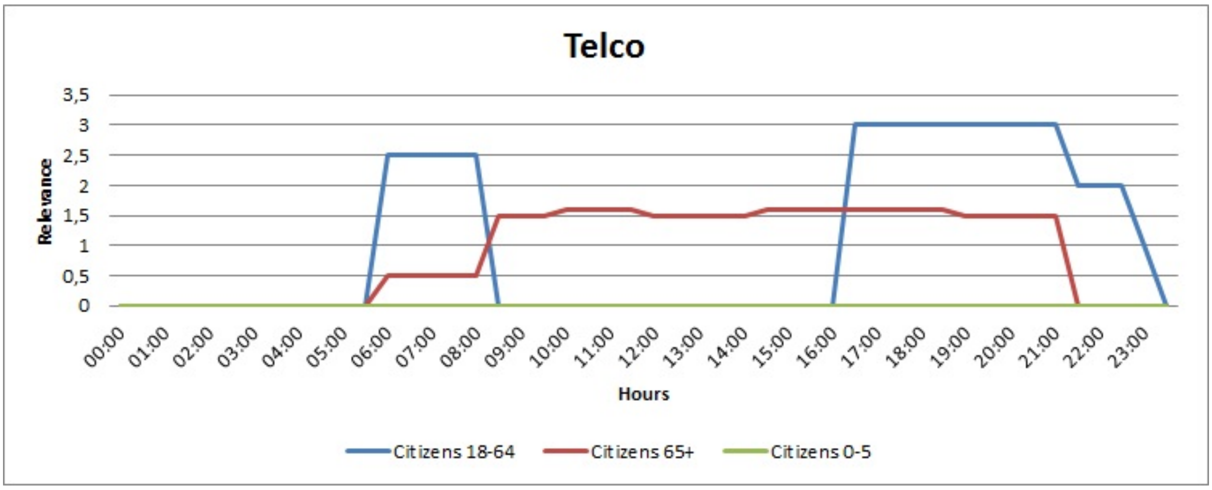

Figure 28: Temporal profile of the relevance of Telco for different population segments

Different profiles could be elaborated – using the same methodology – with different time granularity, distinguishing weekdays and weekend days, seasons and habits in different countries. Should the indexes be needed not time-related, we suggest using the normalised average values which are:

CA Criteria	Services			
	Electricity	Telecom	Water	Gas
Citizens 65+ t_{11}	0,398	0,126	0,343	0,134
Citizens 0-5 t_{12}	0,234	0	0,181	0,095
Citizens 18-64 t_{14}	0,288	0,145	0,212	0,097

Table 5: SAW matrix for the Citizens Criterion

3.3.3 Criterion 2: Services

Criterion 2 includes heterogeneous services (ranging from hospitals to public transportation), which need to be analysed and modelled separately. About schools and public offices, some information about expenditure and consumption of electricity can be elicited, however regulations about requirements for public places to be open (water available, for example) have a strong impact on their functioning and have to be taken into account by the model. SAWI indices will be published as soon as the related models will be consolidated.

3.3.4 Criterion 3: Economical Sectors

Fully convinced of the added value of considering the time variability of the relevance of a service, we started a survey by calling a few companies asking for working hours and relevance in their production chain of the different CI-services.

We therefore discovered that the methodology can be applied and it is valuable because otherwise we could incur in relevant estimation errors (surprisingly, most production plants are closed during the night). However, data gathered from the Chamber of Commerce are related to the headquarter while many production plants are in a different area of Italy, so a preliminary research to identify the realistic amount of production (and revenue) which would be halt because of a loss of service has to be carried out. Furthermore, Criterion 3 accounts for all the activities described by the NACE categories listed in [2] which have to be analysed separately. SAWI indices will be published as soon as the related models will be consolidated.

3.4 Interfacing the CA module

Access to the CA database and to the CA methods is available through the database manager implemented by the Java class **ca.Dbms** and described in Figure 30.

Figure 29 shows the interaction between the DSS and the CA module. Interaction with other modules (for example WIA) will be similar and will be discussed whenever required.

To make its calculation, the Consequence Estimation module has to be notified about the CIs status. The CI status – provided by the DSS – is described by the list of the Impacts (implemented as a Map, which has the name of the CI element – for example the secondary cabin – as a key), where the impact stores the complete temporal profile of each CI element quality of service (i.e., Q(t) in Equation 5).

The **`updateCIstatus()`** method is in charge of notifying the status of one or more CIs according to the output of the DSS (Impact assessment) module.

The CI type is specified by a static integer in order to minimise interface mismatching.

After updating the status of all the relevant CIs, the DSS (or any other module interfacing the CA module) can call the **`getCAResult`** method by specifying the required Criterion (once again, by a static integer in order to minimise interface mismatching) and it will get an integer value which represents the CA estimation according to Equation 5.

Please note that, apart from a numerical value representing the calculated consequence, the CA module is expected to provide a graphical output (GUI) in order to effectively display – not just report – the outcome of the analysis. The high level design of such functionalities – which is critical for usability by the stakeholders – is on-going and we expect to have a complete view and a comprehensive validation to deliver it.

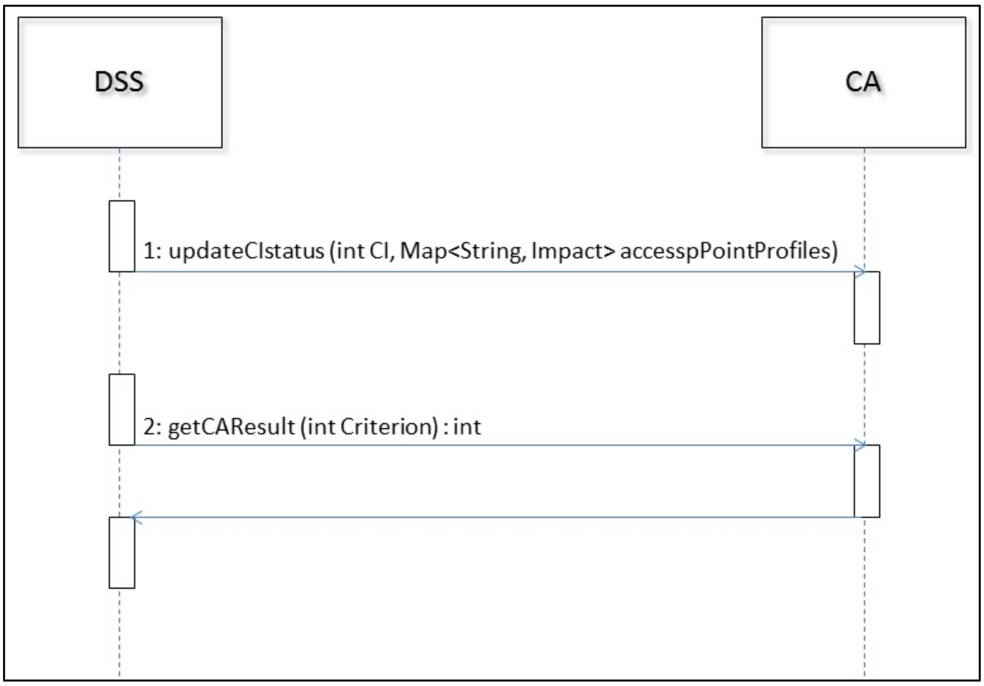

Figure 29: Sequence diagram showing the interaction between the DSS and the CA module

At the current development stage, the database delivered in [2] is still valid and no performances issues have been raised during the tests.

Figure 30: Class diagram for the interface classes between DSS and CA

4 Case Study

In this Section, we show an application of the proposed methodology of Consequence Analysis to a case study involving a section of a the electric and telecommunication system of Rome and show how the simultaneous estimate of the state of functioning of the components of both infrastructures allows to envisage an optimal sequence of actions with the aim of reducing the consequences for the citizens. The Pre-Impact Estimation methodology is first performed by using the procedure described in Section 2.3.1[1] and then the Consequence Analysis model described in Section 3 is then applied to evaluate the consequences for the citizens due to the degradation of CI services.

4.1 Assumptions

A real case study is shown in Figure 31 where we represent a section of the electric distribution grid serving an area of Rome described in Section 2.3.1.

The electrical grid consists of: (i) two electrical PS (PS1 and PS2); (ii) 8 electrical substations (SS91 - SS98) where the orange circles denote the remotely controlled SS and (iii) one Telecom BTS (bts1) providing tele-control capability to SS92, SS94, SS95 and SS97. Each electric SS serves a specific census parcel (or "area") that is characterised by a share of citizens in the same age group as shown in Figure 32 (ISTAT data). The Telecom bts1 is supplied power by the electric SS93. SS94 is the terminal node of the backbone and contains a normally open switch that, in case of a failure in the considered backbone, can be closed to connect SS94 to SS95. Four main assumptions are made on the case study: (i) the PHS estimates a disconnection of SS93 and SS96; (ii) only one emergency team is available to the electric operator to reach, and then to reconnect, the isolated SS; (iii) no power backup is available to bts1 and (iv) we do not consider the moving time required by the emergency team to reach the electric SS.

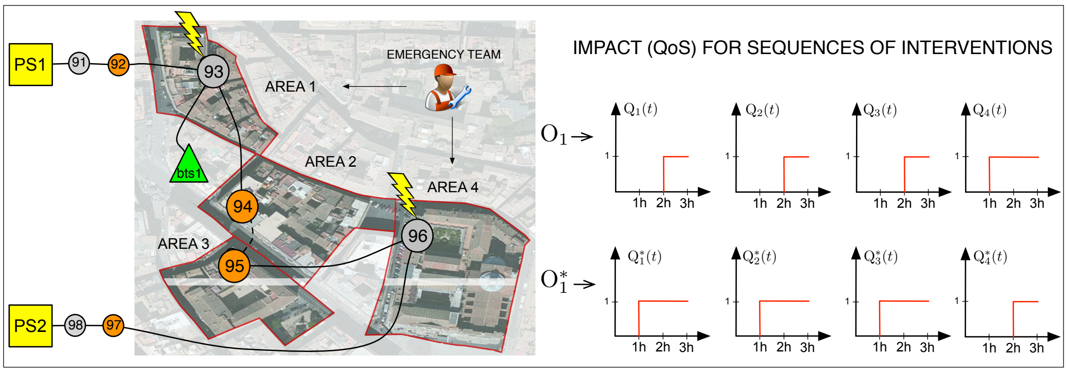

Figure 31: Case study: Estimation of impact in four census parcels of Rome due to disruptions in the electric distribution grid.

[1] We leave the Comprehensive Impact Assessment case study application to a further deliverable.

Citizens $M(e_i)$	Area 1	Area 2	Area 3	Area 4
Population (0-5) (e_1)	2	4	1	0
Population (18-64) (e_2)	71	119	25	7
Population (65 or older) (e_3)	16	20	3	0
Consequence $\mathcal{C}^{cit}(T)$	**Area 1**	**Area 2**	**Area 3**	**Area 4**
with sequence $\mathcal{O}_1$	58.6%	58.0%	57.6%	29.0%
with sequence $\mathcal{O}_1^*$	29.3%	29.0%	28.8%	58.0%

Figure 32: Case study: Consequences on citizens in four census parcels of Rome.

4.2 Results

Considering such assumptions and the properties of the considered electrical grid, the impact estimation procedure described in Section 4.1 estimates the following subsequent events:

1) At time t1 = 0, SS93 and SS96 are disconnected;
2) At time t2 = 0, all electric SS in the backbone will automatically disconnect (due to the failure of SS93 and SS96).

At this stage, considering that no electric SS can be reconnected through tele-control actions due to the loss of supply to bts1, a manual intervention to be performed by the emergency team is required. In addition, considering that the emergency team is only one, a choice about which manual intervention to be implemented first, should be taken by the electric operator. In Figure 31, we report the Impact Vector I(t) in terms of QoS reduction relative to the following sequences: $\boldsymbol{O_1}$ = {SS96; SS94} and $\boldsymbol{O_1^*}$ = {SS94; SS96}.

Considering $\boldsymbol{O_1}$, the following events are generated:

i. SS96 is reactivated manually in about one hour;
ii. SS97 and SS98 are now supplied;
iii. SS94 is reactivated manually in about one hour (average time to perform a manual intervention in the considered district of Rome);
iv. SS97 and SS98 are now supplied; SS94 is reactivated about five minutes later (average time to perform SCADA operations) through tele-control operations (due to the reactivation of bts1).

Considering $\boldsymbol{O_1^*}$, the following events are simulated:

i. SS94 is reactivated manually in about one hour;
ii. bts1 is now supplied by SS94 and allows the execution of the tele-control operation to reactivate SS94 and SS95 (through the closure of the normally open switch);
iii. SS96 is reactivated manually in about one hour;
iv. SS97 and SS98 are also supplied. Based on the Impact Vector I(t) produced for the two sequences $\boldsymbol{O_1}$ and $\boldsymbol{O_1^*}$, the relative consequences C^{cit}(T) are estimated as the wealth variation of citizens associated the QoS variation of the electricity service delivered by each SS over the time duration T = 3h of the crisis.

Figure 33 and Figure 32 report the relative results obtained for each census parcel for both sequences. The results obtained for the sequence $\boldsymbol{O_1^*}$ show an improvement of the ultimate effects on the citizens in the census parcels Area 1, Area 2 and Area 3 that is mainly due to the lower time duration of electric outage in the three areas obtained through the reactivation of bts1 that, in turn, allows the reactivation of SS94 and SS95. Moreover, results reveal similar figures for C^{cit}(T) in Area 1, Area 2 and Area 3 as such areas exhibit a similar proportion for the share of citizens.

In this case study, we only considered one backbone and two possible sequences to evaluate the relative consequences on citizens. However, wanting to consider the whole electric distribution grid of Rome and the different failures that can affect the electric SS, an optimisation technique can be used to estimate the best sequence that minimises the ultimate effects for the citizens.

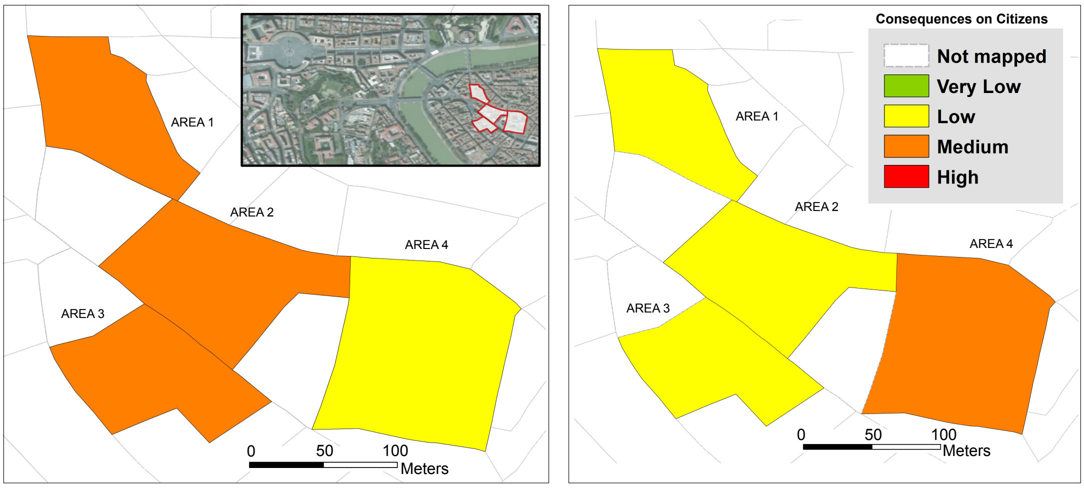

Figure 33: Case study: Map of consequences on citizens in four census parcels of Rome. Left side: Consequences obtained by implementing sequence O_1. Right side: Consequences obtained by implementing sequence O_1^*.

5 Conclusions

This document describes a few implementation details regarding the DSS capability of predicting impacts and consequences from events in a Critical Scenario.

In particular, we described a core component of the DSS system i.e., the Impact assessment module that is able to estimate the possible effects of specific natural threats to the electrical infrastructure. Indeed, the reduction of the quality of services of the electrical infrastructure may produce negative effects on all human activities and the societal life in general.

We also showed how the outcome of this module (i.e. the energy profiles of the different electrical substations) feed the Consequence Estimation module that can evaluate the effects of energy outages on the wealth of specific classes of the population. To make this calculation, the SAWI indices have a critical role and, although the task is still on going, we reported about the effort put so far to elicit them.

The case study presented in Section 4.2 shows how the DSS, based on the Impact Estimation and the Consequence Analysis methodologies, may be able to suggest actions to decision makers that would not be considered by contingency plans of infrastructures, which usually do not take into account interdependency phenomena.

6 References

[1] FP7 CIPRNet Project, Deliverable 7.1 “Design of the DSS with consequence analysis”.

[2] FP7 CIPRNet Project, Deliverable 7.2 + 7.3 “Database of the DSS with consequence analysis and Assessment and selection of vulnerability and risk estimators”.

[3] FP7 CIPRNet Project, Deliverable 7.4 “Implementation of the DSS with consequence analysis –ANNEX I Micro Data File”.

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[14] D. De Franceschi. Analisi dei consumi energetici residenziali e vantaggi connessi all'utilizzo di un manager energetico. Master Degree Thesis, 2011.

Appendix A – Priority profiles of CI-enabled services

The following tables give details about the other population segments included in the analysis, not included in the main text to increase readability.

	CITIZENS 65+									
TIME	*Lighting*	*Refrigerator/Freezer*	*Air conditioning*	*TV*	*Oven*	*Microwave*	*Washing Machine & Drier*	*Dishwasher*	*Other appliances*	**TOT ELECTRICITY**
00:00	0,5	1	-	-	-	-	-	-	-	**1,5**
00:30	0,5	1	-	-	-	-	-	-	-	**1,5**
01:00	0,5	1	-	-	-	-	-	-	-	**1,5**
01:30	0,5	1	-	-	-	-	-	-	-	**1,5**
02:00	0,5	1	-	-	-	-	-	-	-	**1,5**
02:30	0,5	1	-	-	-	-	-	-	-	**1,5**
03:00	0,5	1	-	-	-	-	-	-	-	**1,5**
03:30	0,5	1	-	-	-	-	-	-	-	**1,5**
04:00	0,5	1	-	-	-	-	-	-	-	**1,5**
04:30	0,5	1	-	-	-	-	-	-	-	**1,5**
05:00	0,5	1	-	-	-	-	-	-	-	**1,5**
05:30	0,5	1	-	-	-	-	-	-	-	**1,5**
06:00	1	1	-	1	-	0,5	-	-	-	**3,5**
06:30	1	1	-	1	-	0,5	-	-	-	**3,5**
07:00	1	1	-	1	-	0,5	-	-	0,5	**4**
07:30	1	1	-	1	-	-	-	-	0,5	**3,5**
08:00	1	1	-	1	-	-	-	-	0,5	**3,5**
08:30	1	1	-	1	-	-	-	-	0,5	**3,5**
09:00	1	1	-	1	-	-	0,1	0,1	-	**3,2**
09:30	0,5	1	-	-	-	-	0,1	0,1	-	**1,7**
10:00	0,5	1	-	-	-	-	0,1	0,1	-	**1,7**
10:30	0,5	1	1	-	-	-	0,1	0,1	-	**2,7**
11:00	0,5	1	1	-	-	-	0,1	0,1	-	**2,7**
11:30	0,5	1	1	-	-	-	0,1	0,1	-	**2,7**
12:00	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**
12:30	0,5	1	1	1	0,5	-	0,1	0,1	0,5	**4,7**
13:00	0,5	1	1	1	0,5	-	0,1	0,1	0,5	**4,7**
13:30	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**
14:00	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**
14:30	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**
15:00	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**
15:30	0,5	1	1	1	-	-	0,1	0,1	-	**3,7**

16:00	0,5	1	-	1	-	-	0,1	0,1	-	**2,7**
16:30	0,5	1	-	1	-	-	0,1	0,1	-	**2,7**
17:00	1	1	-	1	-	-	0,1	0,1	0,1	**3,3**
17:30	1	1	-	1	-	-	0,1	0,1	0,1	**3,3**
18:00	1	1	-	1	-	-	0,1	0,1	0,1	**3,3**
18:30	1	1	-	1	-	-	0,1	0,1	0,1	**3,3**
19:00	1	1	-	1	0,5	0,5	0,1	0,1	0,5	**4,7**
19:30	1	1	-	1	0,5	0,5	0,1	0,1	0,5	**4,7**
20:00	1	1	-	1	-	-	0,1	0,1	0,5	**3,7**
20:30	1	1	-	1	-	-	-	-	-	**3**
21:00	1	1	-	1	-	-	-	-	-	**3**
21:30	1	1	-	1	-	-	-	-	-	**3**
22:00	1	1	-	1	-	-	-	-	-	**3**
22:30	1	1	-	1	-	-	-	-	-	**3**
23:00	0,5	1	-	-	-	-	-	-	-	**1,5**
23:30	0,5	1	-	-	-	-	-	-	-	**1,5**

Table 6: Priority values for the population segment "Citizens 65+" of electricity-enabled services.

	CITIZENS 0-5									
TIME	*Lighting*	*Refrigerator/Freezer*	*Air conditioning*	*TV*	*Oven*	*Microwave*	*Washing Machine & Drier*	*Dishwasher*	*Other appliances*	**TOT ELECTRICITY**
00:00	0,5	1	-	-	-	-	-	-	-	**1,5**
00:30	0,5	1	-	-	-	-	-	-	-	**1,5**
01:00	0,5	1	-	-	-	-	-	-	-	**1,5**
01:30	0,5	1	-	-	-	-	-	-	-	**1,5**
02:00	0,5	1	-	-	-	-	-	-	-	**1,5**
02:30	0,5	1	-	-	-	-	-	-	-	**1,5**
03:00	0,5	1	-	-	-	-	-	-	-	**1,5**
03:30	0,5	1	-	-	-	-	-	-	-	**1,5**
04:00	0,5	1	-	-	-	-	-	-	-	**1,5**
04:30	0,5	1	-	-	-	-	-	-	-	**1,5**
05:00	0,5	1	-	-	-	-	-	-	-	**1,5**
05:30	0,5	1	-	-	-	-	-	-	-	**1,5**
06:00	0,5	1	-	-	-	-	-	-	-	**1,5**
06:30	1	1	-	-	-	0,5	-	-	-	**2,5**
07:00	1	1	-	-	-	-	-	-	-	**2**
07:30	1	1	-	0,5	-	-	-	-	-	**2,5**
08:00	1	1	-	0,5	-	-	-	-	-	**2,5**
08:30	0,1	1	-	-	-	-	-	-	-	**1,1**

09:00	0,1	1	-	-	-	-	-	-	-	**1,1**
09:30	0,1	1	-	-	-	-	-	-	-	**1,1**
10:00	0,1	1	-	-	-	-	-	-	-	**1,1**
10:30	0,1	1	-	-	-	-	-	-	-	**1,1**
11:00	0,1	1	-	-	-	-	-	-	-	**1,1**
11:30	0,1	1	-	-	-	-	-	-	-	**1,1**
12:00	0,1	1	-	-	-	-	-	-	-	**1,1**
12:30	0,1	1	-	-	-	-	-	-	-	**1,1**
13:00	0,1	1	-	-	-	-	-	-	-	**1,1**
13:30	0,1	1	-	-	-	-	-	-	-	**1,1**
14:00	0,1	1	-	-	-	-	-	-	-	**1,1**
14:30	0,1	1	-	-	-	-	-	-	-	**1,1**
15:00	0,1	1	-	-	-	-	-	-	-	**1,1**
15:30	0,1	1	-	-	-	-	-	-	-	**1,1**
16:00	0,1	1	-	-	-	-	-	-	-	**1,1**
16:30	0,5	1	-	-	-	-	-	-	-	**1,5**
17:00	1	1	-	0,5	-	-	-	-	-	**2,5**
17:30	1	1	-	0,5	-	-	-	-	-	**2,5**
18:00	1	1	-	0,5	-	-	-	-	-	**2,5**
18:30	1	1	-	0,5	-	-	-	-	-	**2,5**
19:00	1	1	-	0,5	-	0,5	0,1	-	-	**3,1**
19:30	1	1	-	0,5	-	0,5	0,1	-	-	**3,1**
20:00	1	1	-	0,5	-	-	0,1	-	-	**2,6**
20:30	1	1	-	0,5	-	-	0,1	-	-	**2,6**
21:00	1	1	-	-	-	-	0,1	-	-	**2,1**
21:30	0,5	1	-	-	-	-	0,1	0,1	-	**1,7**
22:00	0,5	1	-	-	-	-	0,1	0,1	-	**1,7**
22:30	0,5	1	-	-	-	-	-	0,1	-	**1,6**
23:00	0,5	1	-	-	-	-	-	0,1	-	**1,6**
23:30	0,5	1	-	-	-	-	-	0,1	-	**1,6**

Table 7: Priority values for population segment "Citizens 0-5" of electricity-enabled services.

	CITIZENS 65+														
TIME	*personal care*	*food preparation*	*drinking water*	*dish washing*	*washing machine*	*toilet*	**TOT WATER**	*stove*	*water heater*	*heating*	**TOT GAS**	*landline*	*mobile*	*internet*	**TOT TELCO**
00:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
00:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
01:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
01:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
02:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**

02:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
03:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
03:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
04:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
04:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
05:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
05:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
06:00	1	1	1	-	-	1	**4**	1	1	1	**3**	0,5	-	-	**0,5**
06:30	1	1	1	-	-	1	**4**	1	1	1	**3**	0,5	-	-	**0,5**
07:00	1	1	1	-	-	1	**4**	1	1	1	**3**	0,5	-	-	**0,5**
07:30	1	1	1	-	-	1	**4**	-	1	1	**2**	0,5	-	-	**0,5**
08:00	1	-	1	-	-	1	**3**	-	1	1	**2**	0,5	-	-	**0,5**
08:30	0,5	-	1	-	-	1	**2,5**	-	0,5	1	**1,5**	1	-	-	**1,5**
09:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	-	**1,5**
09:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	-	**1,5**
10:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
10:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
11:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
11:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
12:00	1	1	1	0,1	0,1	1	**4,2**	1	0,5	-	**1,5**	1	0,5	-	**1,5**
12:30	1	1	1	0,1	0,1	1	**4,2**	1	0,5	-	**1,5**	1	0,5	-	**1,5**
13:00	1	1	1	0,1	0,1	1	**4,2**	1	0,5	-	**1,5**	1	0,5	-	**1,5**
13:30	1	1	1	0,1	0,1	1	**4,2**	-	0,5	-	**0,5**	1	0,5	-	**1,5**
14:00	1	1	1	0,1	0,1	1	**4,2**	-	0,5	-	**0,5**	1	0,5	-	**1,5**
14:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
15:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
15:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	-	**0,5**	1	0,5	0,1	**1,6**
16:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
16:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
17:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
17:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
18:00	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
18:30	0,5	-	1	0,1	0,1	1	**2,7**	-	0,5	1	**1,5**	1	0,5	0,1	**1,6**
19:00	1	1	1	0,1	0,1	1	**4,2**	1	0,5	1	**2,5**	1	0,5	-	**1,5**
19:30	1	1	1	0,1	0,1	1	**4,2**	1	0,5	1	**2,5**	1	0,5	-	**1,5**
20:00	1	1	1	0,1	0,1	1	**4,2**	1	0,5	1	**2,5**	1	0,5	-	**1,5**
20:30	1	1	1	-	-	1	**4**	-	0,5	-	**0,5**	1	0,5	-	**1,5**
21:00	0,5	-	1	-	-	1	**2,5**	-	0,5	-	**0,5**	1	0,5	-	**1,5**
21:30	0,5	-	1	-	-	1	**2,5**	-	0,5	-	**0,5**	-	-	-	**0**
22:00	0,5	-	1	-	-	1	**2,5**	-	-	-	**0**	-	-	-	**0**
22:30	0,5	-	1	-	-	1	**2,5**	-	-	-	**0**	-	-	-	**0**
23:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
23:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**

Table 8: Priority values for population segment "Citizens 65+" of Water/Gas/Telco- enabled services.

	CITIZENS 0-5														
TIME	*personal care*	*food preparation*	*drinking water*	*dish washing*	*washing machine*	*toilet*	**TOT WATER**	*stove*	*water heater*	*heating*	**TOT GAS**	*landline*	*mobile*	*internet*	**TOT TELCO**
00:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
00:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
01:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
01:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
02:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
02:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
03:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
03:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
04:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
04:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
05:00	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
05:30	-	-	-	-	-	0,5	**0,5**	-	-	-	**0**	-	-	-	**0**
06:00	1	1	1	-	-	1	**4**	-	1	1	**2**	-	-	-	**0**
06:30	1	1	1	-	-	1	**4**	0,5	1	1	**2,5**	-	-	-	**0**
07:00	1	1	1	-	-	1	**4**	-	1	1	**2**	-	-	-	**0**
07:30	1	1	1	-	-	1	**4**	-	1	1	**2**	-	-	-	**0**
08:00	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**
08:30	-	-	-	-	-	1	**1**	-	-	-	**0**	-	-	-	**0**
09:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
09:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
10:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
10:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
11:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
11:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
12:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
12:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
13:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
13:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
14:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
14:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
15:00	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
15:30	-	-	-	-	-	-	**0**	-	-	-	**0**	-	-	-	**0**
16:00	-	-	-	-	-	-	**0**	-	-	1	**1**	-	-	-	**0**
16:30	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**
17:00	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**
17:30	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**

18:00	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**
18:30	1	-	1	-	-	1	**3**	-	1	1	**2**	-	-	-	**0**
19:00	1	1	1	0,1	-	1	**4,1**	1	1	1	**3**	-	-	-	**0**
19:30	1	1	1	0,1	-	1	**4,1**	1	1	1	**3**	-	-	-	**0**
20:00	1	-	1	0,1	-	1	**3,1**	-	1	1	**2**	-	-	-	**0**
20:30	1	-	1	0,1	-	1	**3,1**	-	1	-	**1**	-	-	-	**0**
21:00	1	-	1	0,1	-	1	**3,1**	-	1	-	**1**	-	-	-	**0**
21:30	-	-	-	0,1	0,1	0,5	**0,7**	-	1	-	**1**	-	-	-	**0**
22:00	-	-	-	0,1	0,1	0,5	**0,7**	-	-	-	**0**	-	-	-	**0**
22:30	-	-	-	-	0,1	0,5	**0,6**	-	-	-	**0**	-	-	-	**0**
23:00	-	-	-	-	0,1	0,5	**0,6**	-	-	-	**0**	-	-	-	**0**
23:30	-	-	-	-	0,1	0,5	**0,6**	-	-	-	**0**	-	-	-	**0**

Table 9: Priority values for population segment "Citizens 0-5" of Water/Gas/Telco- enabled services.