Decision-Making for DRM of CI systems supported by DMCI & GRRASP
Lombardy case studies

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DMCI – GRRASP Applications

1) **Vital Node Analysis** – INTERREG SICt project: Resilience of transportation CI between Italy and Switzerland

2) **Integrated Risk Analysis** – Wider EXPO 2015 area in Milan

3) **Critical Scenarios Analysis** – Meteorological event in Lombardy (heavy snowfall)
DMCI implementation in the JRC GRRASP (Geospatial Risk and Resilience Assessment Platform)

1. Mapping of CI Nodes, Hazards & Threats
2. Vital Node Analysis
3. Simulation of vulnerabilities and interdependencies
4. Resilience strategy design & evaluation

INTERREG SICt project (2018-2021)

- Strengthening the joint resilience capacities between Italy (Lombardy Region) and Switzerland (Canton Ticino) linked to events that may disrupt the continuity of critical transport infrastructures service with cross-border relevance

- Establishing a collaborative alerting and response to disruption events, by means of new coordinated plans for critical scenarios and a dedicated information-sharing platform

![Analysis](image1) → ![Implementation](image2) → ![Validation](image3)

- Various tools and methods
- Simulations DMCI-GRRASP
- Excercises Full-Scale 2022
Details of the Analysis phase

First phase of data collection

- Project Area Definition
- Mapping Nodes and Interdependencies
- Vital Node Analysis
- Mapping Threats
- Vulnerability Analysis

Second phase of data collection

- Analysis of Incident Scenarios on Critical Nodes
- Workshop
- Critical Events (scenarios)
Area definition & Mapping of nodes

322 Transportation nodes in Italy
- 3 Airports
- 58 Highways and Beltways
- 94 National/Principal Roads
- 48 Provincial/Secondary Roads
- 6 City Roads
- 72 Railway segments
- 10 Stations
- 24 Metro segments
- 7 Metro depots

10 Customs

122 Transportation nodes in Switzerland
- 32 Highways and Tangentials
- 14 National/Principal Roads
- 26 Provincial/Secondary roads
- 30 Railway segments
Data collection through collaboration with the operators

The PPC in Lombardy involves operators in the transportation sector

- Railways
- Metro lines
- Airports
- Highways
- National and regional road networks

The Swiss partners are working closely with the operators in the region on the data collection

**Data:** Infrastructure type, name, geo-localisation, operator name, physical and functional characteristics, interdependencies with other nodes and other infrastructures (es. energy, telecommunications), service type and capacity, standard service demand (including seasonality)
**Vital Node Analysis (VNA)**

**Critical nodes** have the property to influence and degrade the service capacity of other nodes and the infrastructure system as a whole.

**Sensible nodes** are susceptible to being disrupted by disturbances of other nodes in the system. They are dependent on the functionality of other nodes.

VNA is conducted through simulation campaigns in which each experiment assumes the total loss of functional integrity of one of the mapped nodes.

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**Risk mapping of Trigger Nodes**

- **Total service loss** (equivalent users)
- **Extension of the influence** (Impacted nodes [%])

**Risk mapping of Target Nodes**

- **Total service loss** (equivalent users)
- **Exposition index** (Impacting nodes [%])
Vulnerability analysis

- Static and dynamic parameters are specified to define the vulnerability (disruption-recovery) profiles of each node
- Collected from the infrastructure operators through GRRASP interface
Integrated risk analysis done for the wider EXPO 2015 area in Milan

• Integrated risk analysis
  • risk exposure of individual infrastructure nodes
  • node vulnerability to such events
  • probabilities for specific hazards and threats

- Exposure to H&T
- Vulnerability
Critical Scenarios Analysis (Impact Analysis)

- Simulations of selected scenarios of interest
- Evaluation of possible protection and resilience strategies by varying simulation parameters
- Case study - support for strategic decision making on a heavy snowfall event in Milan
Critical Scenarios Analysis (Impact Analysis)

- **Assessment of collaborative response strategies**
- Simulation Setting:
  - Target nodes: Beltways (#1, 3, 4); Highways (#13, 14); Malpensa Airport (#113); Railways (#156, 157)
  - Reducing nodes’ response time (from 10% up to 50%)
    - **Simultaneously in clusters of high agility nodes**
      - up to 11% impact reduction at system level, but with early saturation effect
    - **Exploiting replaceable services (roads vs railways substitution)**
      - Local reductions in disservice: 22% in roads and highways; 60% at Malpensa
Conclusions

- DMCI Functional modelling offers a good trade-off
  - Applicable to heterogeneous CI systems
  - Limited confidential data required (typical info sharing level within PPCs)
  - Import/export in MSExcel™ and Matlab®

- GRRASP-enabled enhancements
  - Modular structure
  - Web GUI, GIS integration
  - Simplified data collection (all in single place)
  - Combining other Risk Analysis tools

- Application portfolio
  - Vital Node Analysis
  - Resilience Characterisation
  - Collaborative response planning
  - Extension towards real time decision support
Thank you!

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Dynamic Functional Modelling of Vulnerability and Interdependencies of CIs (DMCI)

- **Vulnerable nodes** - susceptible to threats which can affect the node functionality (the service they provide);
- Threats that cause **missed service demand (MSD)** in vulnerable nodes
- **Functional and logical interdependencies** between vulnerable nodes
- **Propagation of inoperability** (disruption of node service due to cascading effects) and demand variations throughout the nodes of the same infrastructure and between interdependent CI

Vulnerable node characteristics:
- **Homogeneity**
- **Service autonomy**
- **Vulnerability**

Developed by POLIMI, to understand how disruptive events on CIs could spread to the whole network due to different types of interdependencies
DMCI simulation approach

- Threat impact
- (Inter)dependencies
  - Geographical int.
  - Functional int.
  - Internal Functional int.
  - Network Balancing
  - Logical int.

- Cause
- Driver
  - Loss of Functional Integrity
  - Inoperability
  - Demand balancing and shift

- Effect
  - Service Degradation
  - Actual Demand
Generalised disruption profile

- Disruptive event
- Time of full impact
- First response
- Initial impact
- Long term impact
- Preparation for recovery
- Recovery
Overview of the project methodology

**Analysis**
- Mapping transportation nodes
- Vital Node Analysis
- Mapping Threats and Hazards
- Vulnerability Analysis

**Implementation**
- Development of joined monitoring system
- Development of info-sharing platform
- Response Capacity Mapping
- Analysis of strategies

**Validation**
- Exercise Full-Scale 2022

**Simulations**
- DMCI-GRRASP
- READ Tool
- Coping Capacity Index Method

**Critical Nodes Identification**
- Critical events (scenarios)