Incident Evolution Methodology Overview

Cascading effect modelling consists of dynamically distributing system failures and effects across a geographic territory.
The Incident Evolution Methodology offers a decision support tool for crisis managers, critical infrastructure providers and other stakeholders at regional level.
This methodology can be used in preparation and response phases of for small and large incidents with cascading effects in a specific region (case).

Figure 1 shows the basic principles, the terminology and the steps used in the Incident Evolution Methodology.

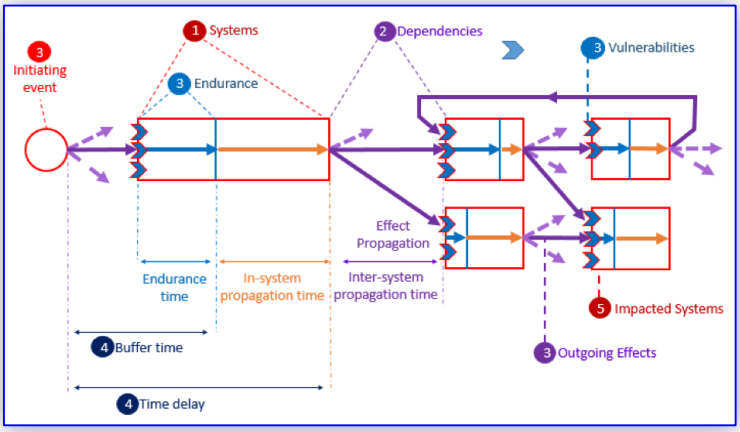

Figure 1 – Basic principles

The methodology follows these 6 steps (**Figure 2**):

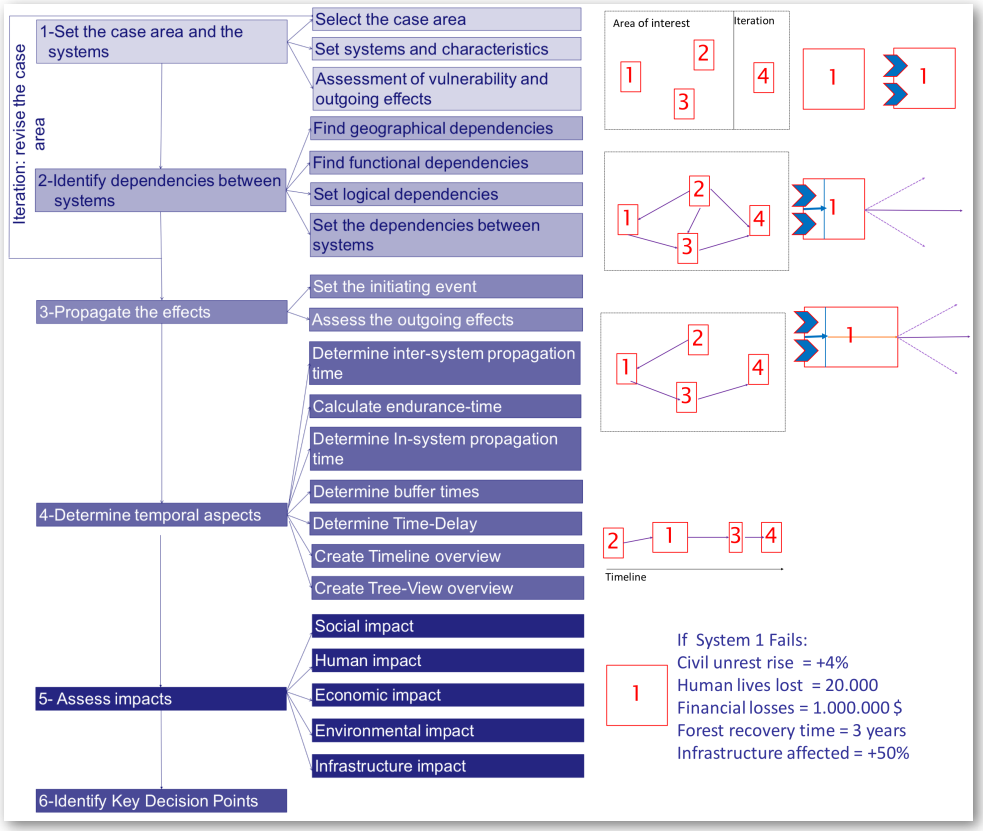

Figure 2 – 6 key steps of the methodology

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Modelling of dependencies and cascading effects for emergency management in crisis situations

Terminology

Buffer time : the time between the start of an outgoing effect in the originating system and the time before a cascading effect occurs in a dependent system, i.e. when the performance of the dependent system starts to degrade. The buffer time is the sum of the Propagation time and the Endurance time.

Dependency : mechanism whereby a state change in one system can affect the state of another system.

Dependent (impacted) system : a system that is negatively affected by either an initiating event or an originating system.

Effect : result of a cause in the presence of a hazardous situation (ISO 22559: 2014).

Endurance time : time a system can resist incoming effects before they start to create impact on the system.

Initial event (initiator) : the first in a sequence of natural (e.g. flood), accidental (e.g. fire) or intentional (e.g. bombing) events that may affect one or several systems.

In-system propagation : propagation of effects between sub-systems within the same system.

Intra-system propagation : propagation of effects between 2 different systems.

Originating system : a system in which a failure propagates to another system.

Propagation time : the time it takes for the effects from the initiating event or an output of a system to propagate and reach the borders of a dependent system. The concept can be used to understand how fast effects spread, irrespectively of systems abilities to tolerate disturbances. Some effects can be seen as having zero propagation time (i.e. infinite spreading rate), e.g. power outage.

System : a "system" refers to a distinct societal unit (such as a sector, function, collective, infrastructure or nature resource) which may be affected by, or give rise to, consequences in another unit.

Time delay : the time until when the output of a specific system is affected in relation to when the initiating event starts or the output of a system it depends upon is firstly affected. Time delay is hence the sum of the Buffer time and the Latent period. The concept can be used to signal "windows of opportunities" for breaking chains of cascading effects.

Vulnerability : intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence. (ISO 22300, 2012).

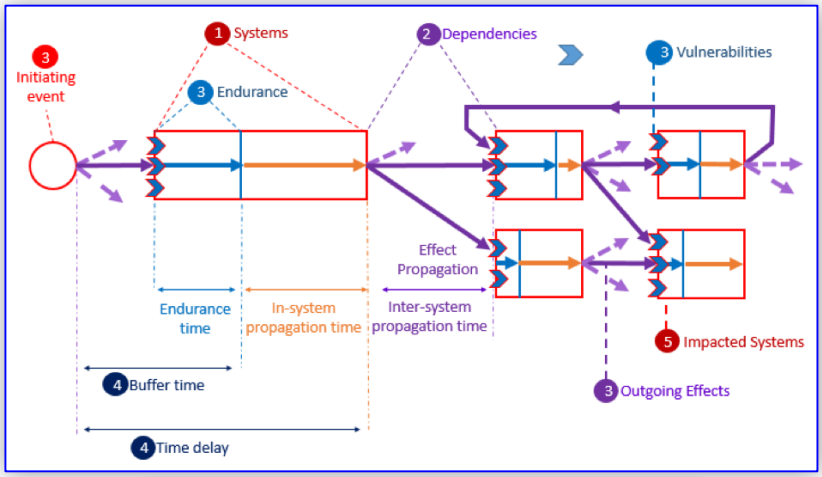

Figure 1 – Basic principles cascading effects

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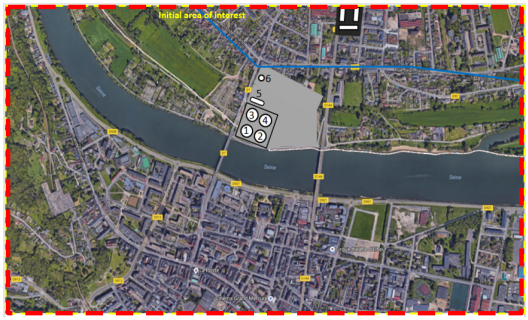
Step 1 : Set the case area and the systems

Objective : determine affected systems in scope

1.1 Select the case area

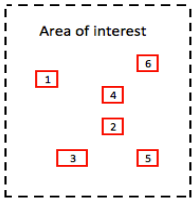
Determine suitable scope



Case area

1.2 Define the systems and their characteristics (system categories)

Identification of systems



Characterization of systems

- Geographical location and altitude
- Size or shape
- Components (physical and human assets)
- Required services necessary to function
- Provided services (functions)
- Categories (22 categories subdivided in subcategories)

System categories

Power supply	Sea transportation
Telecommunication	Agriculture
Water supply	Business and industry
Sewage supply	Media
Oil and Gas	Financial system
District heating	Governmental system
Education	Emergency response
Healthcare	The public
Road transportation	Environmental
Rail transportation	Political system
Air transportation	Food supply

1.3 Assessment of system vulnerabilities and potential outgoing effects

Effect categories

Effect categories	Effects sub-categories	Code
Natural	Flood / Water	WA
	Epidemics	EP
	Wild fire	FI
	Ground movement, earthquake	GM
	Storm	WS
	Tsunami	TS
Accidental	Blast	PRI
	Projectile	MI
	Fire/Thermal radiation	TH
	Emission of toxic release/dumping	TO

Effect categories	Effects sub-categories	Code
Functional	Communication Service Degradation	CS
	Water Service Degradation	WS
	Workforce Service Degradation	WFS
	Energy Service Degradation	ES
	Food Supply Degradation	FS
	Transport Service Degradation	TS
Intentional	Bombing	PRI
	Social rumour / effect	SO
	Hostage taking	HO
	Shooting	SH
	Fire	TH

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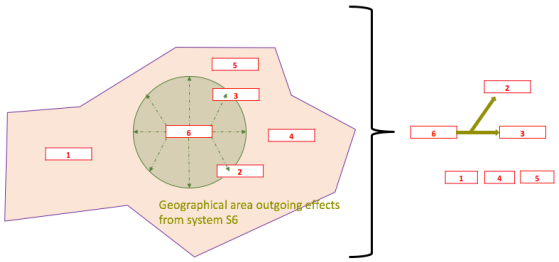
Step 2 : Identify dependencies between systems

Objective : identify different dependencies between systems

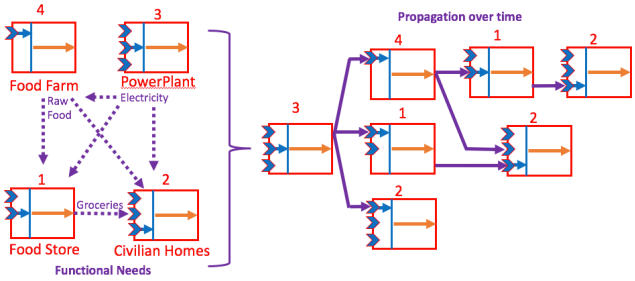
2.1 Geographical dependencies between systems

Based upon the geographical location, proximity



2.2 Functional dependencies between systems

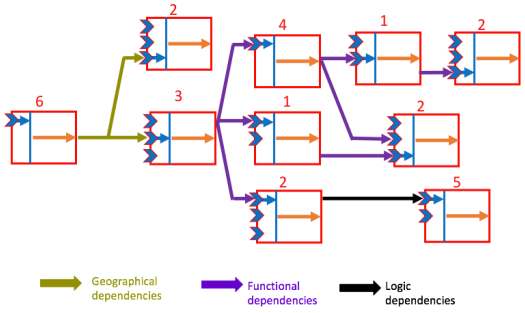
Based upon the funciontal relationship (output of services or products)



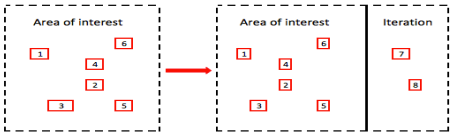
2.3 Logical dependencies between systems

All other dependencies that are not geographical or functional, but related to the logic choices made by persons (human component).

2.4 Identify the different dependencies between systems



2.5 Revise the case area (iteration)



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Step 3 : Propagate the effects between systems

Objective : identify the cascade

3.1 Set the initiating event

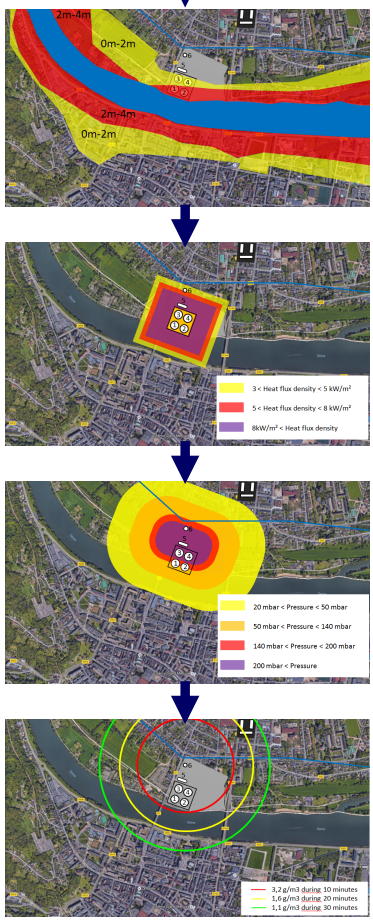
Characterization of the initiating event

- Location
- Type
- Intensity
- Propagation time

Characterization of the flooding of the river in the case area

3.2 Assess the risk conditiones and outgoing effects of impacted systems

Rise waterlevel river



First order cascading effects

Flooding of the river on the shores

Second order cascading effects

storage tank fire in the chemical plant

Third order cascading effects

BLEVE (explosion) of the storage tank

Fourth order cascading effects

Toxic gas cloud generated by storage tank

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Step 4 : Determine temporal aspects

Objective : determine timelines of cascade

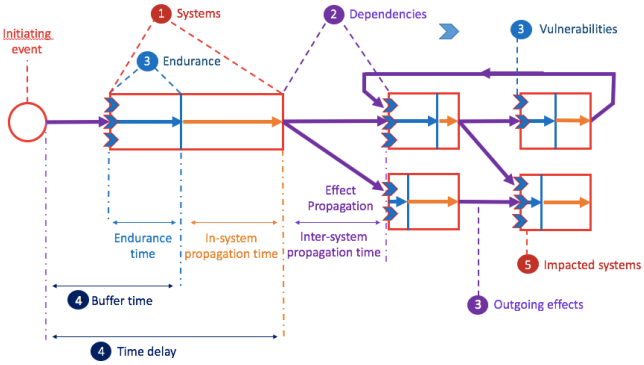
4.1 Determine the inter-system propagation time

4.2 Calculate the endurance time of each system

4.3 Determine the in-system propagation time

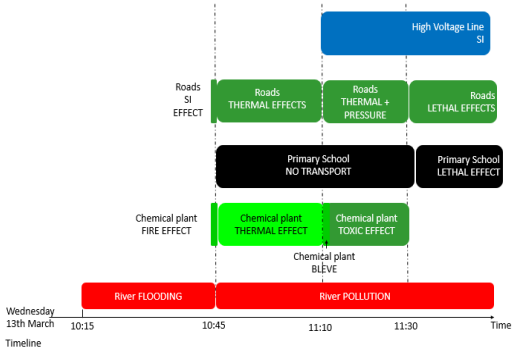
4.4 Determine the buffer time

4.5 Determine the time delay



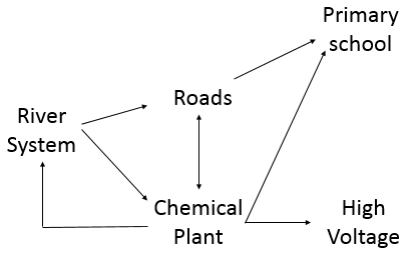
4.6 Create the timeline overview

Identify the longest time periods where it is still possible to mitigate the effects



4.7 Create the tree-view overview

Propagation model of cascading effects



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Step 5 : Assess the impacts

Objective : identify the potential impact of system failure

5.1 List and quantify the impacts of each system

5 impact categories

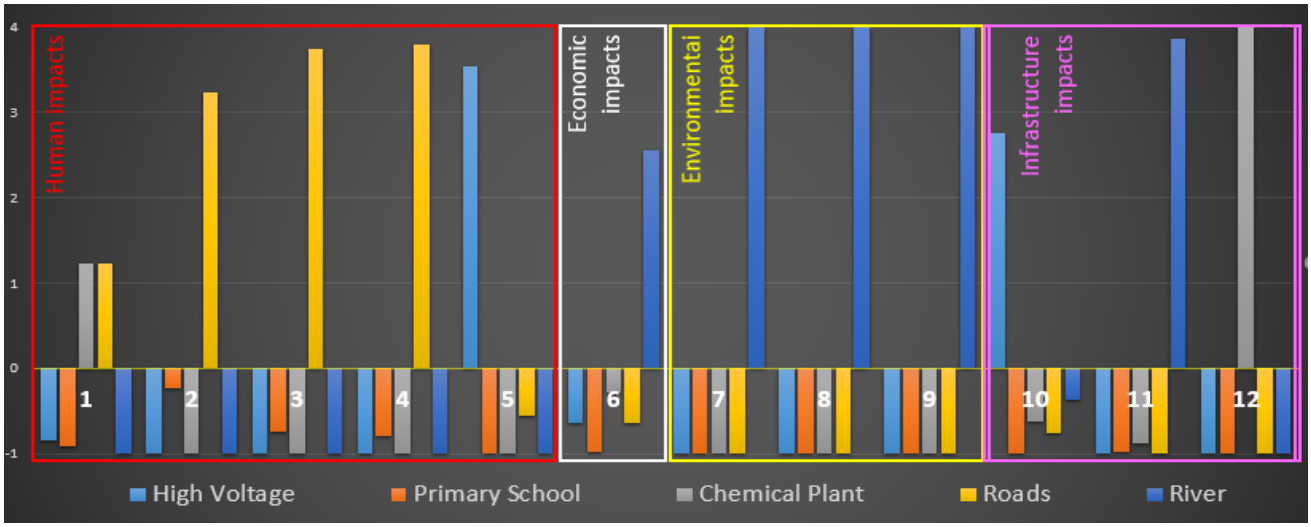
- Human
- Social
- Economic
- Environmental
- Infrastructure

Impact categories	Impact sub-categories	High Voltage	Primary School	Chemical Plant	Roads	River
Human	1-Fatalities	0	5	150	150	0
	2-Injuries	0	55	0	300	0
	3-Evacuated or confined residents >2h	0	55	0	1,000	0
	4-Mental health injuries	0	55	0	1,300	0
	5-People that has lost critical services	30,000	60	0	3,000	0
Economic	6-Direct and indirect economic costs (€)	1,000,000	50,000	2,000,000	1,000,000	10,000,000

Impact categories	Impact sub-categories	High Voltage	Primary School	Chemical Plant	Roads	River
Environmental	7-Polluted land (km)	0	0	0	0	30
	8-Polluted sea /water (km)	0	0	0	0	777
	9-Dead animals	0	0	0	0	10,000
Infrastructure (infrastructure downtime)	10-Number of users	300,000	60	30,000	20,000	50,000
	11-Lost makeup capacity	100% of 300 kV	100% of 60 students	80% of 800L	80% of 20.000 cars/day	0%
	12-Time expected for repair (in month)	0.25	6	30	0.25	1,200
	13-Cost expected for repair (in €)	50,000	100,000	300,000,000	100,000	0

5.2 Scorecard of impacts

Comparison of standardised values of the different impact subcategories of each system



Timeline overview (4.6) + Scorecard of impacts (5.2)

↓

Identification of suggested mitigation priorities

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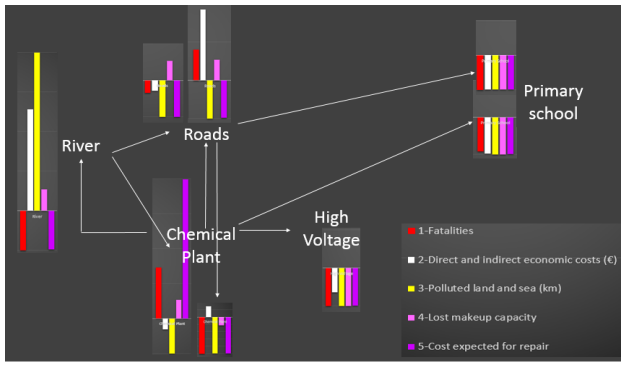
Step 6 : identify the key decision points

Objective: determine points in the cascade tree where decisions can be taken to break the cascade

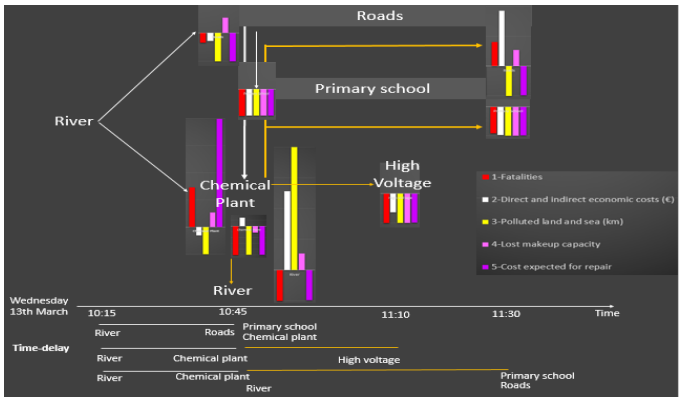
6.1 Compare impacts between systems

Visualisation of standardized score of system impacts on other systems



6.2 Consider the time delay

Estimation available timeframe to break the cascade



How can you find and identify the key decision points ?

Answer the following questions:

1. How much time does the decision-maker have to make a decision ?
2. What is the latest time that a decision must be taken and have an effect ?
3. What are the critical / main effects to be stopped or prevented ?
4. What is the time needed to put mitigation measures in place ?

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