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1 Introduction

1.1 Purpose of this document

This deliverable belongs to work package WP6: Joint Research Activities 1: CI fMS&A and external threats modelling for ‘what if’ analysis [DoW]. D6.3 describes the modelling activity required for preparing the simulation and analysis of the application scenarios that have been developed in D6.2. That is, it describes how the two Dutch-German cross-border crisis scenarios developed in deliverable D6.2 have been implemented for simulation as a basis for what we now call **CIPRTrainer**. It is a new application that provides a new capability for training crisis management (CM) staff: Exploring different courses of action and comparing their consequences (‘what if’ analysis), based on federated modelling, simulation and analysis (fMS&A). In this document, we will briefly introduce the rationale and building blocks of the CIPRTrainer as a guideline for explaining, which models are needed for which purpose. The CIPRTrainer (and the consequence analysis module) will be described in full scope in the forthcoming deliverable D6.4.

The main part of this document D6.3 will describe the heterogeneous modelling activities, which are required for implementing the CIPRTrainer. These include:

1. Modelling the CI that are required for federated simulation of the Dutch-German cross-border crisis scenarios (D6.2) with a focus on the derailment scenario,
2. Modelling the involved incidents (train derailment and flooding and their secondary effects, D6.2), and
3. Modelling mitigation actions for the user of the CIPRTrainer (the CM trainee)

In addition, it includes a rationale for the chosen level of modelling fidelity, the method used for converting CI data into models, potential additional measures like anonymisation or sanitisation of the data, and, if required, the used domain and federation ontologies [DoW]. Since such modelling activities are complex, we also document the process of acquiring data and turning them into models, and lessons learned while performing it for the Dutch-German cross-border crisis scenarios.

1.2 Relation to other CIPRNet deliverables

The ultimate tangible outcome of WP6 will be the CIPRTrainer, a technical demonstrator for the ‘what if’ analysis capability. It will be described in the forthcoming deliverable D6.4 “Implementation of the integrated CIP MS&A based on ‘what if’ analysis” [CIPRNetD64]. D6.4 will be based on this deliverable, D6.3, and the deliverables D6.2 “Application scenario” [CIPRNetD62] and D6.1 “Conceptual design of a federated and distributed cross-sector and threat simulator” [CIPRNetD61]. D6.1 and D6.2 have already been submitted. D6.2 describes a new cross-sector and cross-border application scenario located in the Dutch-German border region, where the river Rhine crosses the national border. In D6.2, we have identified several CI sectors and two different threats (a flooding and, as a separate event, a severe railway accident caused by a derailed cargo train in a German city) and data sources that are relevant for the required modelling activities. D6.3 now describes how we turned the acquired data into models for the CI simulators and other components of the CIPRTrainer application.

A crucial element of CIPRTrainer is the Consequence Analysis (CA), which is being developed jointly in WP7 and WP6. The current CA concept in CIPRNet divides the task into two parallel streams, namely CA for Critical Infrastructures, including vulnerability and impact assessment, and then CA for the environment and built infrastructure that does not belong to CI (“other” CA). The CA for CI part is being described in deliverables D7.2+D7.3 [CIPRNetD723] and D7.4 [CIPRNetD74]. For ‘what if’ analysis in CIPRTrainer, we plan to com-

bine the parallel CA streams into a comprehensive CA. The ‘CA for other’ stream and its combination with the ‘CA for CI’ stream will be described in the final deliverable D6.4 [CIPRNetD64] of WP6.

1.3 Structure of the document

The remainder of this document is structured as follows: In Section 2, we briefly present the main components of CIPRTrainer and indicate, which of these components require models and which components support modelling activities. In Section 3 we describe, what data we employed for the modelling activities. This section may be subject to restricted publication for security reasons (to be proposed by the Security Advisory Group and to be decided by the Project Officer). Section 4 describes the static and dynamic parts of the scenario that have been modelled with Fraunhofer’s modelling tool SyMo. SyMo is Fraunhofer Background that is employed in CIPRNet as scenario editor and simulation log analysis tool. Section 5 explains the flooding models. In the largest section, Section 6, we introduce the models for the CI simulators SIEMENS PSS[®] SINCAL, OpenTrack, and ns-3 that we employ for federated CI simulation in CIPRTrainer. Section 7 provides some guidelines for modelling that shall be used for adapting CIPRTrainer to other scenarios and for accelerating this adaptation (in the sense of ‘good practices’). We conclude with summarising our main insights and providing an outlook on the further steps towards finalising the working demonstrator of CIPRTrainer.

2 CIPRTrainer – WIA based on federated modelling, simulation & analysis

This section briefly introduces the CIPRTrainer rationale and architecture. CIPRTrainer is the system that shall enable crisis managers to train decision-making in crises involving cascading effects of Critical Infrastructures (CI). In general, the architecture description serves to understand the different components of the tool/framework and how these components are connected (see [CIPRNetD61]). The application scenario indicates which models are needed (see [CIPRNetD62]). Since CIPRTrainer has a heterogeneous architecture, different components of CIPRTrainer require different and separate models. In this document, we use the architectural sketch (Figure 1) as a guideline for explaining which models are placed where. A full documentation of CIPRTrainer will be provided in the forthcoming deliverable D6.4 [CIPRNetD64].

A novel capability of CIPRTrainer will be ‘what if’ analysis (WIA) in complex scenarios based on federated modelling, simulation & analysis of CI. For a description of the concept, please refer to deliverable D6.1 [CIPRNetD61]. The current design scheme of CIPRTrainer is depicted in Figure 1. The system consists of two large building blocks, a **design engine** and a **training engine**. The design engine has two main components, namely

- A scenario editor for creation of scenarios and storylines
- An analysis tool for the evaluation of the training results

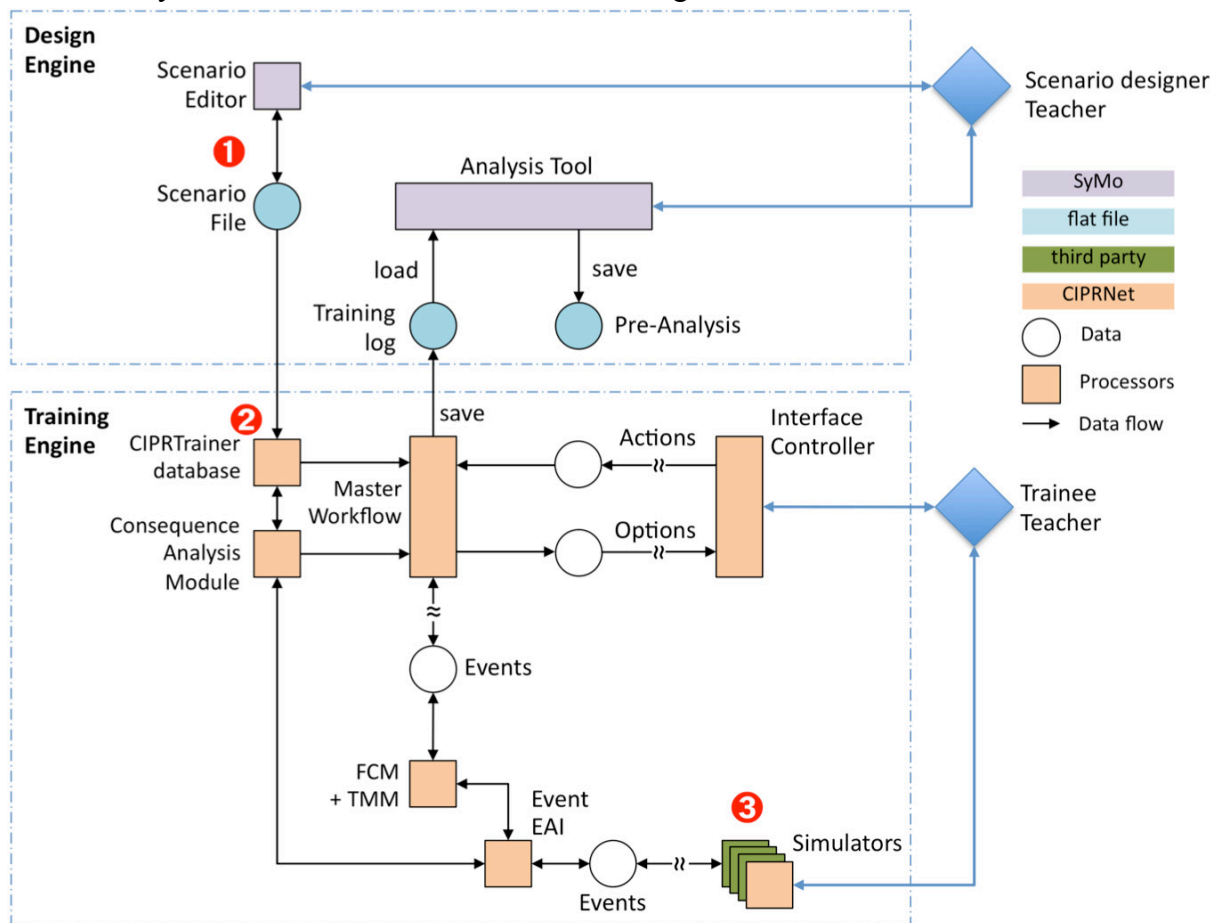


Figure 1: Diagram of CIPRTrainer architecture; ① scenario models; ② scenario model base including external threat models; ③ federate CI models and flooding model

The scenario editor is based on Fraunhofer tool SyMo. A SyMo scenario model contains classes and instances of model elements like involved disaster area, incident elements, respond-

ers, response actions, etc. More detailed descriptions about the content of a scenario are discussed in a knowledge-driven approach for CIP scenario development [Xie15a]. The design engine exports scenario models as plain files (cf. Section 4.3.5). The analysis tool is not relevant for this deliverable.

The training engine is the main part of CIPRTrainer. Its main components are

- A Graphical User Interface (GUI) for the trainer/trainee
- An interface controller for the GUI
- A master workflow engine (event processor)
- A CIPRTrainer database for storing some of the required data and models
- A consequence analysis module (CAM)
- A federation control module (FCM) and time management module (TMM)
- An Enterprise Application Integration (EAI) module for integrating the federated simulation
- A federated simulation consisting of CI simulators and a flood simulator.

The CIPRTrainer GUI is based on the csMap/csWeb¹ framework by CIPRNet partner TNO². It enables the realisation of the GUI as a single page web application and contains functions of a Geographical Information System (GIS) like using map services from OpenStreetMap. By means of csMap, we have produced a working prototype of the CIPRTrainer GUI [Sojeva15].

Simulators are coupled and form a distributed federated simulation environment, consisting of the CI simulators OpenTrack (Railway) [OpenTrack], SIEMENS PSS[®] SINICAL (Power transmission & distribution) [SINICAL] and ns-3 (Telecommunication) [NS-3], plus a flooding simulation that uses flood models provided by CIPRNet partner Deltares. The federation control module (FCM) is responsible for the coordination, for instance connection establishment between simulators and FCM, simulation start, simulation pause, etc. Simulators are developed independently and are not designed per se for the federated simulation. To synchronise the federated simulation among different domain specific simulators, a time management module (TMM) is introduced, which is basically a modified version of the TMM originally developed in the DIESIS project [DIESIS2].

Within the training engine, any activity within the simulators or by the users (trainee and trainer) is considered to be an ‘event’. Events are being represented in a standardised way. The main orchestrator in this training engine is the event processor, which handles all the events and routes event-related information to the other system components. It starts with reading and processing the scenario file and triggers simulators and GUI.

The CIPRTrainer contains the Consequence Analysis Module (CAM), which enables the user to understand the consequences (in terms of human, service and monetary losses) of the simulated impacts and of his chosen actions (or inactions). The user can request a report at any time of the simulation. The CAM utilises data from the CIPRTrainer database, and an array of implemented methods, to calculate the consequences for the population, and the critical and non-critical infrastructure in the affected region. There are methods for direct consequences of specific (natural) hazards (i.e. building damage through floods or storms), more general methods for loss of life and damage to property, as well as methods for indirect economic damage through the possible inoperability of (critical) infrastructure and economic sectors (input-output-model). The results are sent to the CIPRTrainer GUI to be displayed for the user. The CAM will be described in detail in the forthcoming D6.4 [CIPRNetD64].

¹ <https://github.com/TNOCS/csWeb>

² <http://www.tno.nl/>

Relevant CIPRTrainer components for modelling are:

- The CIPRTrainer database (2 in Figure 1), containing the scenario file (1 in Figure 1, to be presented in Section 4.3.5) produced by the design engine and other data, to be partly presented in Section 3; a full description would be contained in D6.4.
- The CI simulators, each of which has its own model (3 in Figure 1), to be presented in Section 6;
- The flooding simulator that uses pre-computed flooding models (also 3 in Figure 1), to be presented in Section 5.

3 Scenario data

3.1 Acquisition of data and information

Initial sources of information and data are described in deliverable D6.2 [CIPRNetD62]. In the following subsections, we will mention information and data sources per sector of involved CI. For some parts of the CI, we did not have access to real data. Therefore, we decided to use artificial data instead. The rationale behind this is twofold:

- First, although we would need to construct technically correct and realistic models for demonstrating our new capabilities, we would not necessarily need real data for all parts of our models (pragmatic aspect).
- Second, using realistic instead of real models also contributes to avoiding security issues (like revealing real vulnerabilities when using real data and models).

As a general classification of data sources, we used

- For **general information** on CI: Web sites and official reports from CI operators, statistical information, web sites and official publications from municipalities in the Dutch-German border region
- For **visualisation**: Maps and images from various sources, map services for GIS systems, tactical symbols provided by public agencies
- For **CI and other data**: OpenStreetMap, timetables, various sources for railway track information, and statistical data from public agencies.

3.1.1 Data sources for the Electrical Power Network

The typical coarse structure of the electricity infrastructure is divided into power generation, power transmission (via transport network), power distribution network (both including switching and transforming substations), and power consumers and metering. The latter two are out of scope of the modelling granularity. While real data on power generation and transport facilities are to a large degree publicly available, data on the distribution network are typically kept private.

- OpenStreetMap project on electrical power generators, power transmission lines, and some substations:
<http://www.flosm.de/html/Stromnetz.html>
- Data on power transmission lines (high voltage (380, 220, 110 kV) and medium voltage (10, 20, 25 and 30 kV))
<http://powerland.bplaced.net/>
- List of EHV substations in Germany:
https://en.wikipedia.org/wiki/List_of_EHV-substations_in_Germany
- Maps of default providers in the energy sector in Germany:
<https://www.enet.eu/portfolio/analysen/karten>
- Data on network structure of Stadtwerke Emmerich (utility of the city of Emmerich am Rhein):
<http://www.stadtwerke-emmerich.de/emmerichGips/Gips?SessionMandant=Emmerich&Anwendung=EnWGKnotenAnzeigen&PrimaryId=8&Mandantkuerzel=Emmerich&Navigation=J>
- Map and lists of German railway traction current facilities (see also Section 3.1.3 for a description)
http://de.wikipedia.org/wiki/Liste_von_Bahnstromanlagen_in_Deutschland

- Data provided by ENTSO-E
The association European Network of Transmission System Operators Energy (ENTSO-E) provides upon request a set of data on the European power transmission networks. The data are provided in the standardised CIM (Common Information Model³) format which can be read by electricity network simulators like SIEMENS PSS[®] SINICAL. For security reasons, the data lack geo-references. Fraunhofer has requested access to these data for evaluation purposes. The request was granted by ENTSO-E.

3.1.2 Data sources for the telecommunication networks

Data for the telecommunication networks could be found on the websites of the telecommunication providers.

- Vodafone: <http://www.vodafone.de/privat/hilfe-support/netzabdeckung.html>
- O2: <http://www.o2online.de/microsite/o2-netz/netzabdeckung>
- E-Plus: <http://geoinfo.eplus.de/evinternet>
- Telekom: <http://www.t-mobile.de/netzbausau>

Information on mobile antenna: <http://emf3.bundesnetzagentur.de/karte/default.aspx>

3.1.3 Data sources for the railway network

We were able to use quite a number of publicly available data sources for the required modeling activities for the railway network. We used some documents and information provided by the daughter company of the main German operator Deutsche Bahn, namely DB Netz, which is responsible for maintaining the railway network infrastructure. Other information was provided by DB Schenker, a logistics daughter of Deutsche Bahn, Keyrail, and more. Information on local railway traffic can be found on the mobility portal of the federal state of North Rhine-Westphalia (NRW) in Germany (Mobilitätsportal NRW).

- Mobilitätsportal NRW:
<http://busse-und-bahnen.nrw.de>
- DB Schenker
http://www.dbschenker.com/homenews_media/press/news/2226778/european_corridor.html?start=55&itemsPerPage=50
- DB Netz
<http://fahrweg.dbnetze.com/fahrweg-de/nutzungsbedingungen/infrastrukturregister/>
http://fahrweg.dbnetze.com/file/fahrweg-de/2397820/NQXqDxTWdL3BRt0RkPdx1vhe0L8/8356442/data/rw_302.9004.pdf
- Railway Infrastructure viewer of Deutsche Bahn AG:
http://stredax.dbnetze.com/ISRViewer/public_html_de/svg/index.html
- Keyrail (information on Betuweroute in the Netherlands):
http://www.keyrail.nl/betuweroute#eu_corridors

Wikipedia provides a list of German facilities of railway traction current, including generators, centralised and decentralised transformer substations, and coordinates of railway traction current lines crossing national borders:

- List and map of German railway traction current facilities
http://de.wikipedia.org/wiki/Liste_von_Bahnstromanlagen_in_Deutschland

³ <https://www.entsoe.eu/major-projects/common-information-model-cim/Pages/default.aspx>

- Itoworld provides a more general source of information and maps of railway electrification:

<http://www.itoworld.com/map/68?lon=6.33579&lat=51.74860&zoom=10&fullscreen=true>

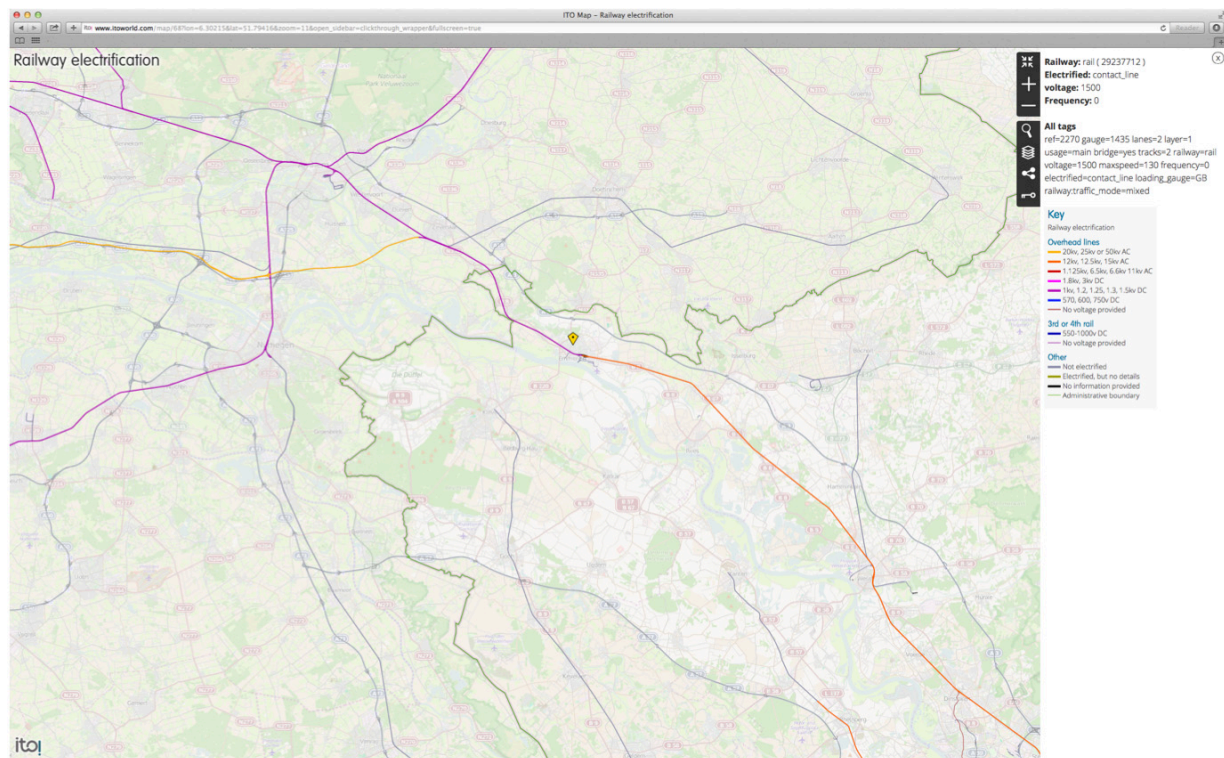


Figure 2: Screen shot of an itoworld map of railway electrification in an area covering the area of the NL-DE cross-border scenario. Centre: diamond indicates location of Emmerich. The legend shows additional information on the electrification of Emmerich as tags.

3.1.4 Data for flood maps and flood risk

For flooding, there are some publicly available sources of information and data:

- Flood risk and flood hazard maps in North Rhine-Westphalia (by Landesamt für Natur, Umwelt und Verbraucherschutz NRW (State office for nature, environment and consumer protection NRW)
<http://www.lanuv.nrw.de/wasser/hwrisiko.htm>
- Flood risk map for the Netherlands:
<http://www.risicokaart.nl>
- The 21st-century Water Safety maps provided by the Dutch Delta programme
<http://www.deltaportaal.nl/webmap/category/basiskaarten/>

These data map serve as orientation for flood risk and water safety. In order to produce flood models for predicting water levels at given geographical locations at given points in time, we have employed other information sources (see Section 5).

3.1.5 Other data sources

We used many public sources of information and data for elaborating the scenarios in D6.2. Some of this information will be needed for situation display at the CIPRTrainer GUI. The situation display should use information and graphical elements that are familiar to crisis managers in civil protection. A set of such familiar elements are the tactical icons in civil pro-

tection (cf. Figure 3) as recommended by the German Federal Office of Civil Protection and Disaster Assistance (BBK), and street signs as required by German law, provided by Bundesanstalt für Strassenverkehr (Federal Highway Research Institute, BASt).

- Tactical icons for civil protection (By Federal Office of Civil Protection and Disaster Assistance):
http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/FIS/DownloadsRechtundVorschriften/Volltext_Fw_Dv/SKK_DV_102_2012.html
- Official German traffic signs at Bundesanstalt für Strassenverkehr (BASt):
<http://www.bast.de/DE/FB-V/Fachthemen/v1-verkehrszeichen/unterseiten/symbole-rwb-2000.html?nn=605096>

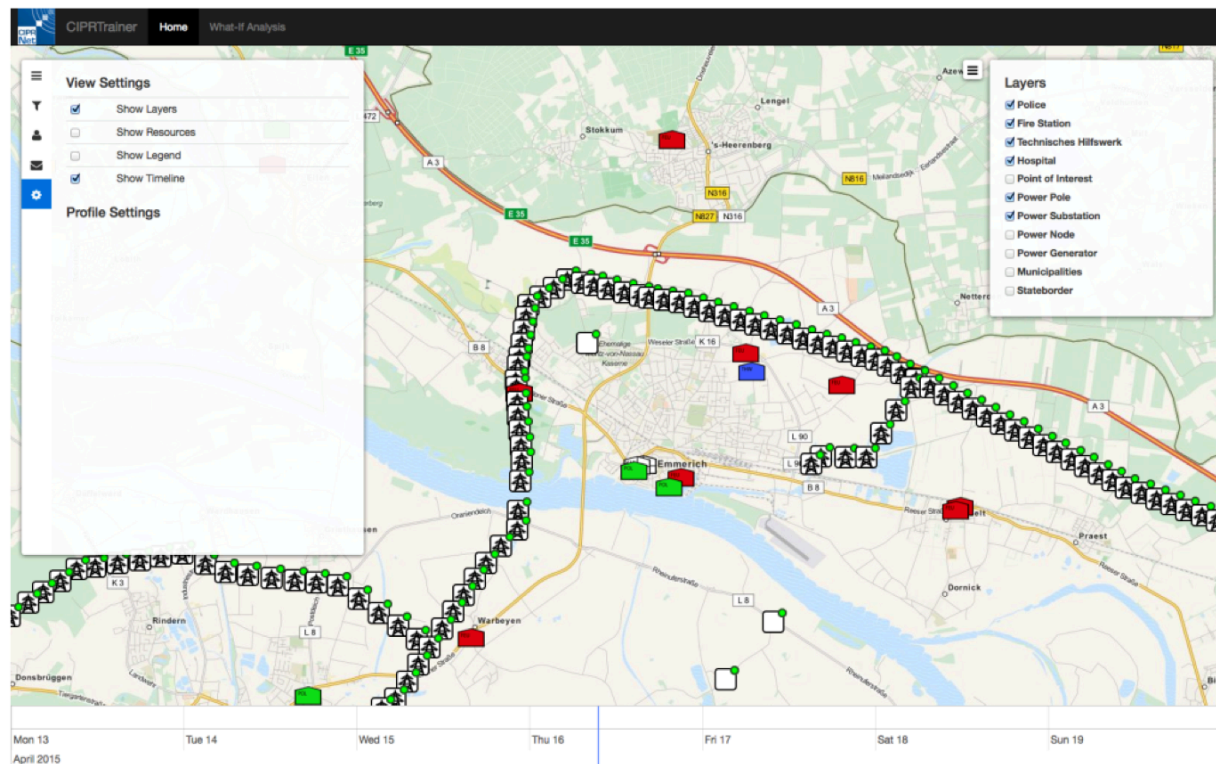


Figure 3: Screen shot of CIPRTrainer GUI. Centre: Map of city of Emmerich. Tactical icons of police (green) and fire-fighters' (red) stations, base of THW (blue). Other icons: poles of power transmission line, points of interest (POI).

Also, the knowledge of service regulations is required for the correct modelling of **mitigation and response actions**:

- Service regulations in civil protection (BBK, Germany):
<http://www.bbk.bund.de/DE/Service/Fachinformationsstelle/RechtundVorschriften/Rechtsgrundlagen/Bundeslaender/NW/NW.html?nn=1898896>
- Aids for planning, training, and operation of firefighters:
http://www.idf.nrw.de/service/downloads/downloads_hilfsmittel.php

Data and information on municipalities:

- www.citypopulation.de displays data and information provided by the Federal Statistical Office of Germany (DESTATIS), including the borders of municipalities etc.:
http://www.citypopulation.de/php/germany-nordrheinwestfalen_d.php?cityid=05154008

Other CI sector information and data:

- Map of gas transport network:
<http://www.fnb-gas.de/de/fernleitungsnetze/fernleitungsnetze.html>

Other geo data:

- Overview of sources of free geo data:
http://giswiki.hsr.ch/Freie_Geodaten

Socio-economic data:

In CIPRNet, socio-economic data are employed for Consequence Analysis (cf. D6.1, D7.2+D7.3). However, direct uses for crisis management are also possible, like identifying streets or quarters with a high percentage of elderly people that would require special attention when planning evacuations.

A great source of socio-economic data is the EU census of 2011 [EUCensus11]. Census data have been gathered all over the EU member states in a standardised way. However, there are differences in the way the data are provided by individual member states. The differences that matter for the modelling activities are the differences in spatial resolution. While some MS provide census data on a fine resolution like ZIP code areas or street level, Germany, for instance, provided the data until 2014 only at the resolution of entire municipalities. Since spring 2015, the German census data are also available in a 100 m x 100 m resolution and can be accessed for research purposes.

As the census 2011 data covers only households and private homes there was a need for geographical data of businesses and industry. For this we got access to commercial sources of socio-economic data from logistic enterprises. The databases contain NACE-Classification data for businesses and industry buildings (WZ2008 in Germany) on a street level. This data can be allocated to the 100m*100m grid of the census 2011 data to harmonise both data sets.

For the consequence analysis we needed additional data sources. Information about the potential reconstruction cost of buildings are derivable from data on build cost (“Normalherstellungskosten”).⁴ For the cost of power outages we used data from studies of the “Hamburgisches Welt-Wirtschaftsinstitut” [NS-3HWWI15], the “Institute of Energy Economics at the University of Cologne” [EWI13], and the Office of Technology Assessment at the German Bundestag [Petermann10]. Detailed data about energy (electricity and gas) consumption (standard load profiles) in Germany was available from “Bundesverband der Energie- und Wasserwirtschaft”.⁵ For the indirect economic consequences of inoperability of economic sectors we used national account and input-output data from the national statistics office.⁶ For the disruption of freight traffic there is high aggregated data on a national level from the national statistics office (“Verkehr Aktuell”).⁷ Detailed data for specific transport routes were not available, so we have to estimate the interruption effects from national data. Data for the cost of emergency force operations could be found for fire brigades⁸ and the THW⁹ (technical

⁴ <http://www.bundesanzeiger-verlag.de/fileadmin/BIV-Portal/Dokumente/PDF/Sachwertrichtlinie.pdf>

⁵ <https://www.bdew.de/>

⁶ <https://www.destatis.de>

⁷ <https://www.destatis.de>

⁸ <https://www.emmerich.de>

⁹ Verordnung über die Durchführung und Abrechnung von Hilfeleistungen des Technischen Hilfswerks (THW-Abrechnungsverordnung - THWAbbrV)

civil protection unit) in form of cost catalogues for human and technical resources (€ per hour).

3.2 Artificial data

For some sectors and domains, we are not able to retrieve real data. These domains include the electricity distribution systems and fixed line and telecommunication systems. The unavailability of data is due to privacy and security reasons. Parts of the data are being offered as commercial data sets.

However, in order to be able to complete the demonstrator for CIPRTrainer, we would need to have realistic and technically correct models of those domains that play a role in our scenario. Our approach to resolve this is to create artificial models of the required domains for which we do not have the real data. Luckily, we do have experts in these domains as partners in CIPRNet. For the electricity distribution subsystems, CIPRNet partner UCY provides the expertise and created a realistic model of the electricity distribution system of the German city of Emmerich. For the fixed line and mobile communication networks, CIPRNet partner UTP provided models of the systems in these sectors for the German part of the cross-border scenario.

4 Scenario Models with SyMo

For this chapter, we assume that the reader is familiar with the information in deliverable D6.2 [CIPRNetD62]: purpose and scope of the Dutch-German cross-border scenario, major stakeholders in the area, CI sectors (DE and NL), and some information and data sources on the CI in the Dutch-German border region. In the first two sections, we will briefly summarise the major features of the scenario's storylines. In the third section, we describe the major features of the scenario model created by the SyMo-based design engine.

SyMo (System Modeller) is a tool developed by Fraunhofer since 2008 and it is used in various projects for modelling and analysis purposes. SyMo is well-suited for modelling human-engineered systems (so-called E systems) and processes. In CIPRNet, SyMo is employed as a scenario editor for creating scenario files, and as an analysis tool.

For this deliverable, we will focus on SyMo's usage as a scenario editor for CIPRTrainer's design engine. This section is neither intended as a comprehensive primer in modelling with SyMo nor as a complete documentation of the scenario models created with SyMo. Instead, we will describe the basic modelling principles underlying SyMo and illustrate the modelling steps by providing concrete examples from the models created for CIPRTrainer.

4.1 Storyline: Cross-border flooding with a major dike breach on the Rhine near Rees city

In this storyline, we assume a major dike breach around Rees city in Germany. Affected infrastructures include a flooded transformer substation and a railway tunnel blocked by closed flood protection gates. Including the evolution time of the weather that leads to high water levels in the river Rhine, the time range of this storyline covers seven days.

4.2 Storyline: Cargo train derailment near Emmerich am Rhein main station (Germany)

In this storyline, we assume a sudden derailment of a cargo train in the city centre of Emmerich am Rhein, caused by a malfunctioning switch point due to a cyber-cyber-attack on the electronic railway control centre Emmerich. Fire, poisonous smoke and leaking chemicals affect citizens, built infrastructure and critical infrastructures. The immediate (cross-border) impacts of the crisis take place within a few hours, while the remedy of the impacts takes days and weeks.

4.3 Modelling with the SyMo-based design engine

4.3.1 General introduction – TAM modelling approach

Scenario models in SyMo are two-part and consist of a static model and the dependencies between elements of the static model. Typically, the tree-like static model (cf. Figure 4) may contain components like, an organisational structure, a taxonomy, technical systems, events, resources etc.

In SyMo's internal static model, these components are conceptualised as follows. The general representation of a type of element is called an **Aspect**. Aspects are **classes** or **types** of entities and are represented by **Variables**. SyMo can model two types of qualitative direct structural dependencies between elements of static models, namely tree-like direct dependencies (T relations) of an aspect's variables, and matrix-like dependencies (M relations) of variables of the same class (aspect). Both are represented by means of **operators**. Dependencies (T

relations) between elements are modelled using the **T operator** (cf. Figure 4). Detailed dependencies (M relations) are visualised as adjacency matrix using the **M operator**. Together, T and M operators yield a directed graph structure.

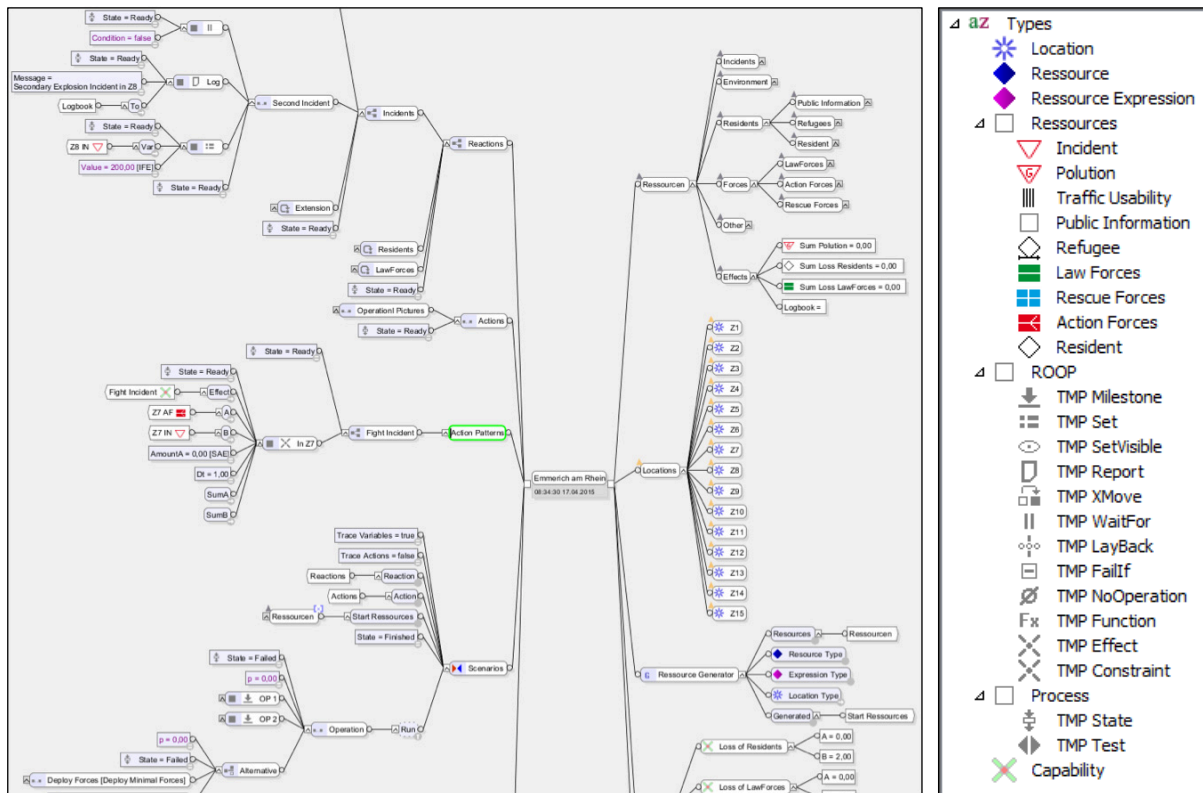


Figure 4: Screen shot of the Emmerich scenario model in SyMo. In the right window, the available attribute types (A operator) are displayed.

In order to model those qualitative dependencies between an aspect’s variables that are not relevant for the structural representation, SyMo provides a third type of relation, the **A relation**. By means of A relations, represented by the **A operator**, variables can get additional attributes (or properties) of certain types (Figure 4).

Scenario storylines can be modelled in SyMo as processes by means of the same three types of relations, namely T, A and M relations. In SyMo’s **TAM process model**, processes are modelled as Aspects (T operator). A process’ structural properties are assigned via the M operator, and the non-structural properties via the A operator.

It should be noted that a static scenario model created with SyMo contains a number of variables and parameters. That is, the model spans a space of possible instantiated concrete scenario storylines. In order to simulate the scenario in CIPRTrainer, the parameters and variables must get specific values. This is a second modelling step, the configuration of the scenario as a preparatory step for creating a scenario file that can be interpreted by other components of CIPRTrainer. After the configuration of the scenario storyline, SyMo’s output will be written into a **scenario file** (cf. Section 4.3.5), which is fed into a scenario database. The event-processing engine (master workflow engine) will fetch a scenario file from the scenario database and then run the scenario storylines by executing the events and triggering other components of CIPRTrainer.

To summarise: Modelling with SyMo consists of three steps: 1. Create a static model and a process model of the scenario, 2. Configure the model by choosing concrete values for variables and parameters, 3. Export the configured SyMo model into a scenario file and store it in a scenario database.

In the following sections, we will provide exemplary explanations of how we created the SyMo model for the scenario storyline of the cargo train derailment in the city of Emmerich.

4.3.2 Modelling response actions – resource oriented operation planning

The modelling of the scenario storylines for CIPRNet follows an approach that has also been used for other Fraunhofer security related projects. The approach is called **resource oriented operation planning (ROOP)**. The basic idea is that counteracting a disaster is a matter of available resources, remaining time, and situation of the disaster (like location and effects / impacts of incidents). The available resources at any given point in time limit the possibilities of response and mitigation actions. The situation of the disaster determines what would need to be done to counteract (or fight) it. Thus it is important to keep track of the used resources and the evolution of the disaster. Responders and action forces are considered and modelled as **resources**. In a uniform way, the attributes of the situation of the disaster are also modelled as “resources”. This is a legacy from using SyMo in the military context. The disaster could be considered a “foe” and the responders as “friend”. Both have resources and “use” them to “fight” each other.

For modelling the disaster incidents and the disaster management and response actions in the affected area, it is important to also know the locations of the resources. In order to facilitate the modelling in this respect, we start with partitioning the area where the disaster happens into zones. Using zones allows a simpler and quicker processing of geographical interactions. The zone borders are manually defined and oriented along landmarks such as rivers, main streets, railway tracks, historic city centres etc. (right image of Figure 5).

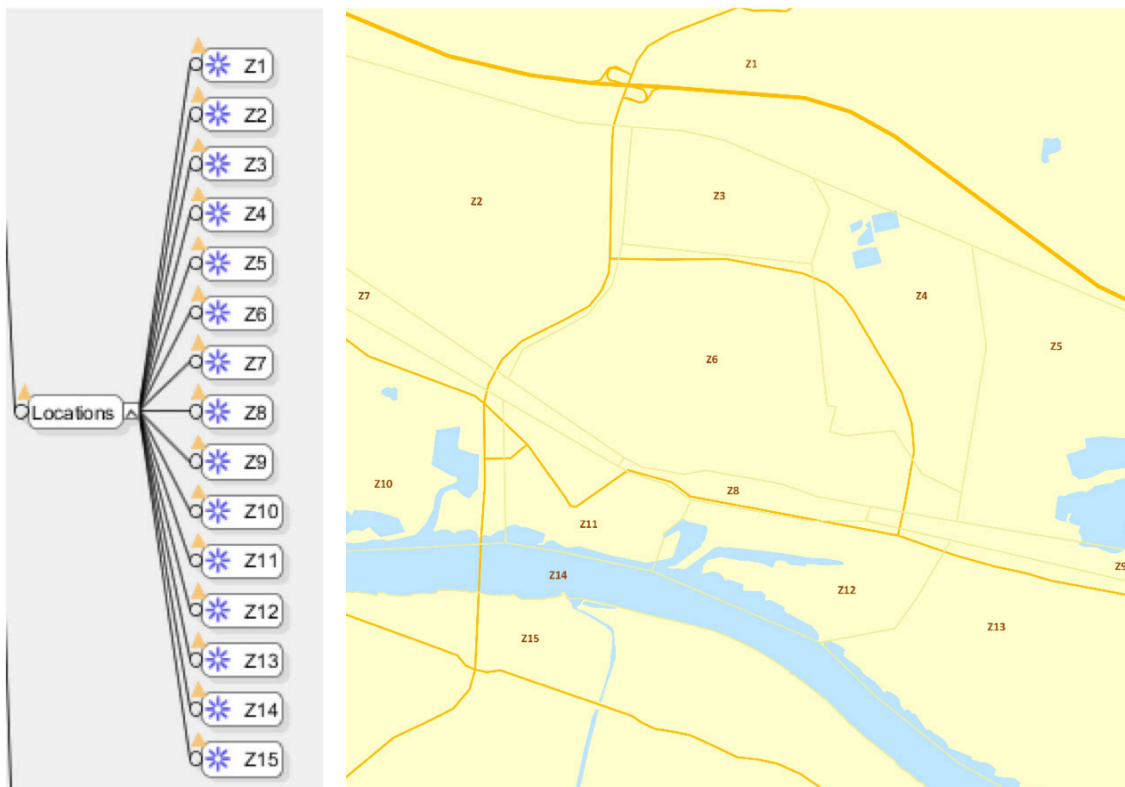


Figure 5: Screen shots of the locations aspect and the manually defined zones inside the map of Emmerich

Having done this, we just need to know in which zone which action or response forces are located and their strengths. We do not need to know the exact positions of, for instance, each fire-fighter at any given point in time. The Emmerich scenario area is divided into 15 zones, Z1–Z15 (left image of Figure 5).

For fighting an incident, the model assumes that the crisis manager deploys a certain amount of appropriate forces to the zone in which the incident is located. This is depicted in the example in Figure 6 by the leaf nodes at the left. The upper one shows the string Z7 AF and the fire-fighters' icon, and the lower one the string Z7 IN and the incident icon (red triangle). Currently, the granularity is chosen such that we assume that the forces do what they are trained to for fighting an incident. We do not specify if law forces block roads or if rescue forces evacuate a city quarter.

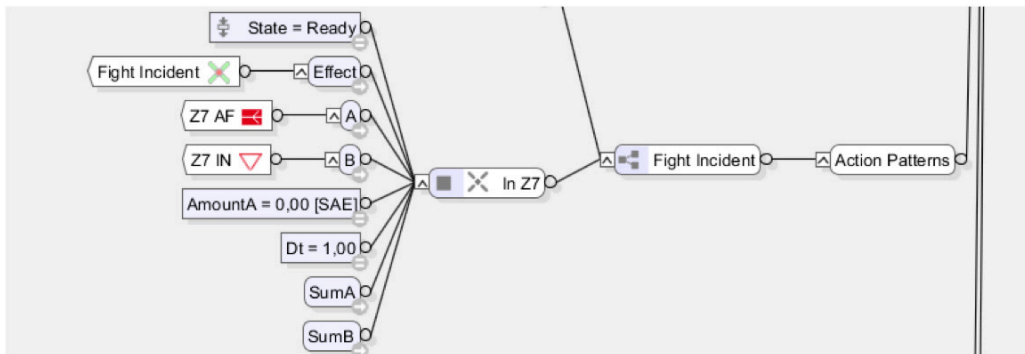


Figure 6: Class “Action patterns” for modelling the fighting of an incident in zone Z7. The incident (red triangle) is located in zone Z7, and the action forces (red rectangle) for fighting it are also located in Z7.

Similarly, other resources, like residents, traffic, and air pollution, are also assigned to zones. The resources can also be displayed inside the map as shown in Figure 7 (right side).

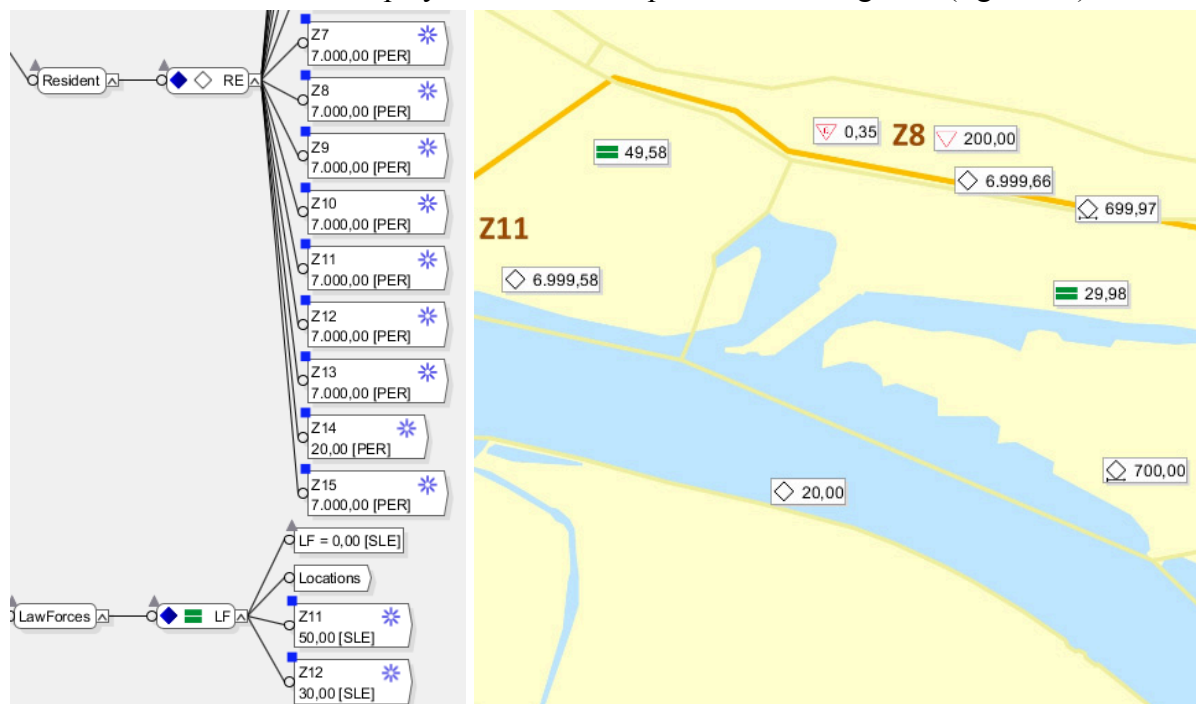


Figure 7: Screen shots of the resources graph and its attributes shown on the map. The lower two leaf nodes mean that 50 policemen are initially located in zone Z11 and 30 in zone Z12. The rectangles with the pointed right side link the resources with locations.

The rectangles with the pointed right side in the screen shot of the tree in Figure 7 link the resources to specific locations (zones). That is, in the TAM model, resources depend directly on locations and thus these dependencies can be visualised as a matrix. Figure 8 shows the initial configuration that describes which resources are located in which zones before the disaster happens. The first column of the matrix shows that there are no incidents. The sixth column displays the number of residents per zone (we started with an equal distribution, but this will be refined based on available data we have), and the following three columns show the

initial locations of the responders and action forces. During evolution of the scenario, the locations would change, and zones would fill up with incidents, traffic blocks, evacuee residents, deployed forces etc.

Type	IN	TB	AP	PI	RU	RE	LF	AF	RF	Resource Type	PI
* Z1	◆	◆	◆	◆	◆	7.000,00 [PER]	◆	◆	◆	◆	◆
* Z2						7.000,00 [PER]		100,00 [SAE]			
* Z11						7.000,00 [PER]	50,00 [SLE]				
* Z12						7.000,00 [PER]	30,00 [SLE]				
* Z13						7.000,00 [PER]		60,00 [SAE]			
* Z14						20,00 [PER]					
* Z15						7.000,00 [PER]					
* Z3						7.000,00 [PER]					
* Z4						7.000,00 [PER]		80,00 [SAE]			
* Z5						7.000,00 [PER]		120,00 [SAE]			
* Z6						7.000,00 [PER]					
* Z7						7.000,00 [PER]					
* Z8						7.000,00 [PER]					
* Z9						7.000,00 [PER]					
* Z10						7.000,00 [PER]			15,00 [SRE]		
* Location Type											

Figure 8: SyMo screen shot of the matrix of dependencies of resources and locations in the initial configuration.

4.3.3 Example: TAM static model of the derailment scenario in Emmerich

The static model of the derailment scenario in Emmerich is represented as a graph (Figure 4, left image). The root vertex symbolises the actual scenario and the leaves represent the scenario attributes in detail. To the right side of the graph a representation of the involved **scenario components** is displayed and on the left side models of **incident related aspects** are depicted. After creating the zone partition of the map of the disaster area, the modelling process continues with modelling the scenario components.

4.3.3.1 Modelling scenario components

The top-level model of the scenario components (right side) consists of resources, locations, effects and two technical elements, namely measurement units and a resource generator. The latter two are employed for instantiating variables when creating the scenario file. As mentioned in the last section, the dependencies between resources and locations have to be established in this modelling phase. The aspect “effects” models the types of impacts.

4.3.3.2 Modelling incident related aspects

The top-level model of the incident related aspects (left side) consists of reactions, actions, action patterns, parameters and a technical component named “scenarios”. The latter one is employed for instantiating variables when creating the scenario file. The aspect “reactions” is the interface to the consequence analysis. It describes how impacts and consequence of incidents affect the resources (Figure 9).

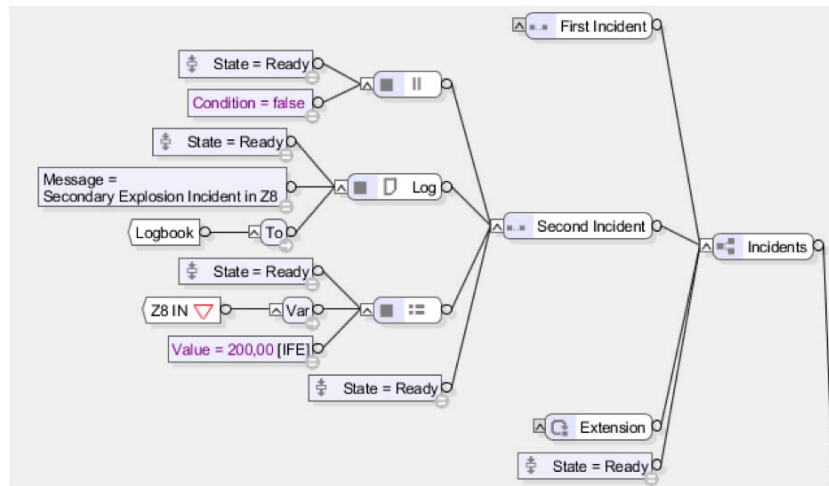


Figure 9: Screen shots of the incidents tree and its attributes.

The aspect “actions” (Figure 10) models the concrete responses to the incidents during the disaster. It covers deployment of any number of available forces and the states of their operations for fighting the assigned incidents. “actions” are instances of the aspect / class “action pattern”.

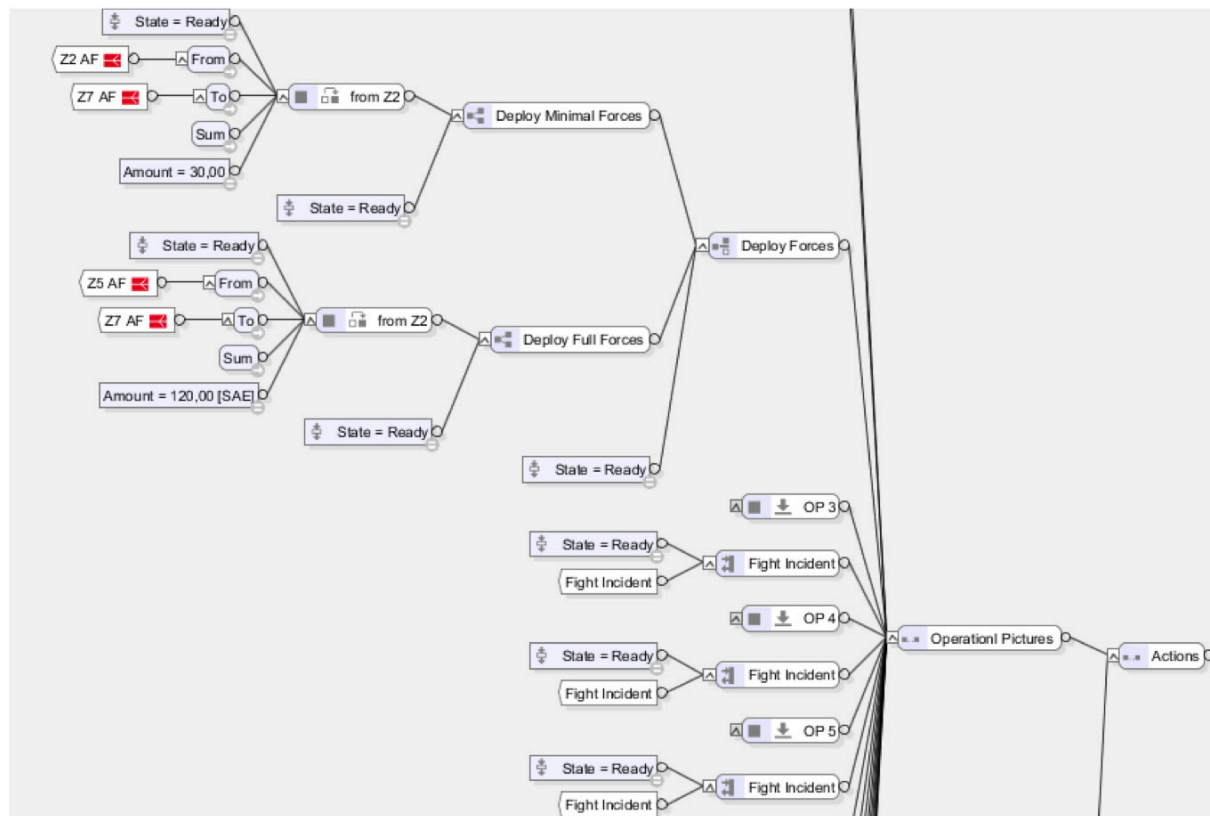


Figure 10: Screen shot of the Actions subgraph

The aspect “parameters” models incident parameters like spread rate of pollution (using simplistic assumptions), rate of residents that could escape from the areas hit by the disaster etc.

4.3.3.3 Modelling interactions of model components

After defining the involved scenario components as attributes and variables on the right side, the *interaction of the components* is modelled on the left side. Different operators are applied

to model the incidents, reactions and actions performed in a given time span. There are seven operators for different tasks:

- Sequence
- Parallel
- Race
- Action
- Alternative
- Iterator
- Call

The sequence operator executes the subsequent tasks sequentially. The parallel operator performs the tasks all at once. The race operator will execute the tasks in parallel and only evaluate the task that is finished first. The action operator simply executes the given task. The alternative operator leaves a second choice for the case that the first task cannot be successfully performed. The iterator operator is used for defining tasks that are then executed repeatedly in a loop. The call operator behaves like the action operator. The only difference is that a subfunction is called in contrast to executing an action directly. In Figure 11 the operators are shown with an example.

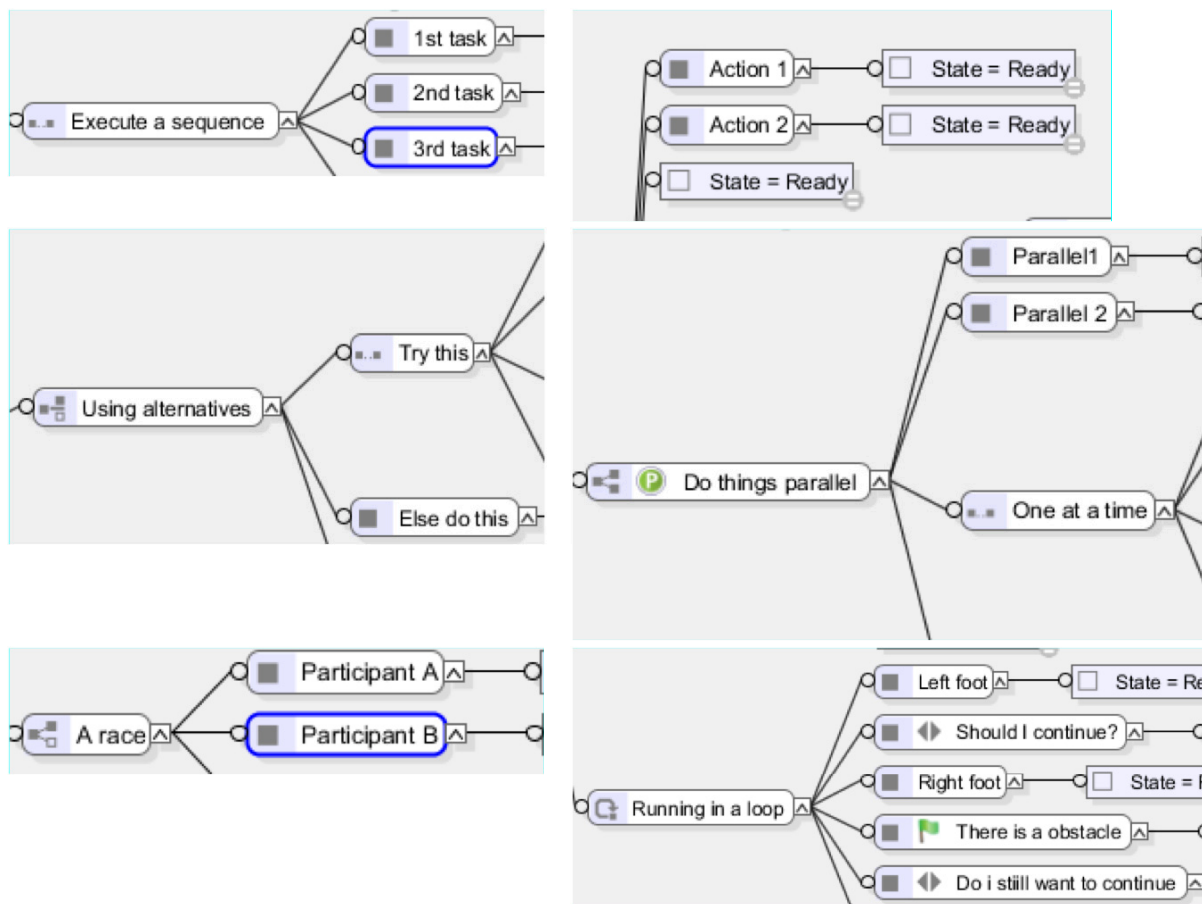


Figure 11: Screen shots of the different operators and how they are used inside SyMo

With these operators it is possible to model the incident related aspects of the scenario. For instance, the actions are modelled as a sequence of operations with alternatives for deploying the forces and parallel operations for moving the different forces from different locations. The action graph is shown in Figure 10.

4.3.4 Example: TAM process model of the derailment scenario in Emmerich

Based on the scenario components and the incident related aspects, the scenario file can be configured by using operators and variables assignment. First the “Start Resources” are selected, here the current incidents (which should be zero at the beginning), environment variables like traffic block and air pollution, amount and position of residents and forces is predefined. This is shown in Figure 12.

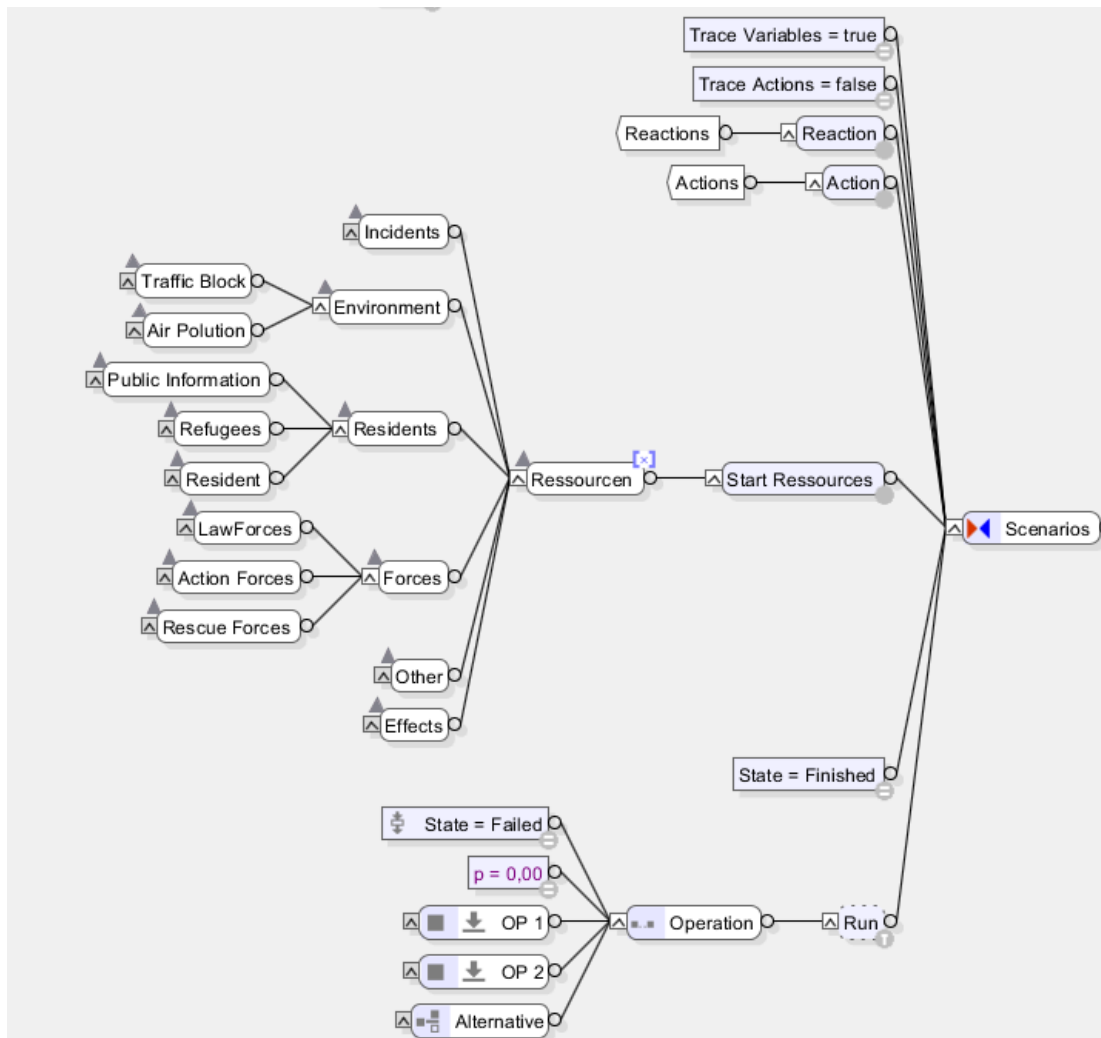


Figure 12: Screen shot of scenarios start resources

Important start resources for the scenario are the law forces, action forces and rescue forces. All of them are listed with an amount (like number of fire-fighters) and location. In the beginning they are all spread across different locations. When an accident happens the responders will be moved and concentrated on or near the location of the incident. The action that those forces should provide is simply called “fight incident”. The resulting effects are “loss of forces”, “loss of residents”, “sum of pollution” and “traffic block” for the train derailment scenario. The current scenario has two different options for fighting the incident: “Deploy full forces” and “Deploy minimal forces”. These are examples of two different strategies that can be applied for handling different incidents. Since the initial incident is only the start from a series of reactions, the simulation is able to check how the different strategies for deploying forces works out. In the end there will be an optional summary that tells the operator how much quantitative damage there was.

After the initialisation the first real operation at a particular time ($t = 1$) for a given incident (train derailment in zone 7) is simulated. For this the environment variables, residents and

action forces amount and position are changed. Typically the action forces are moving in the direction of the incident and the residents are moving away from the incident. This movement is simply modelled by listing each of the zones and their amount of the respective classes of residents and action forces. This is shown in Figure 13. By using this schema, it is possible to model complex scenarios with different events and actions.

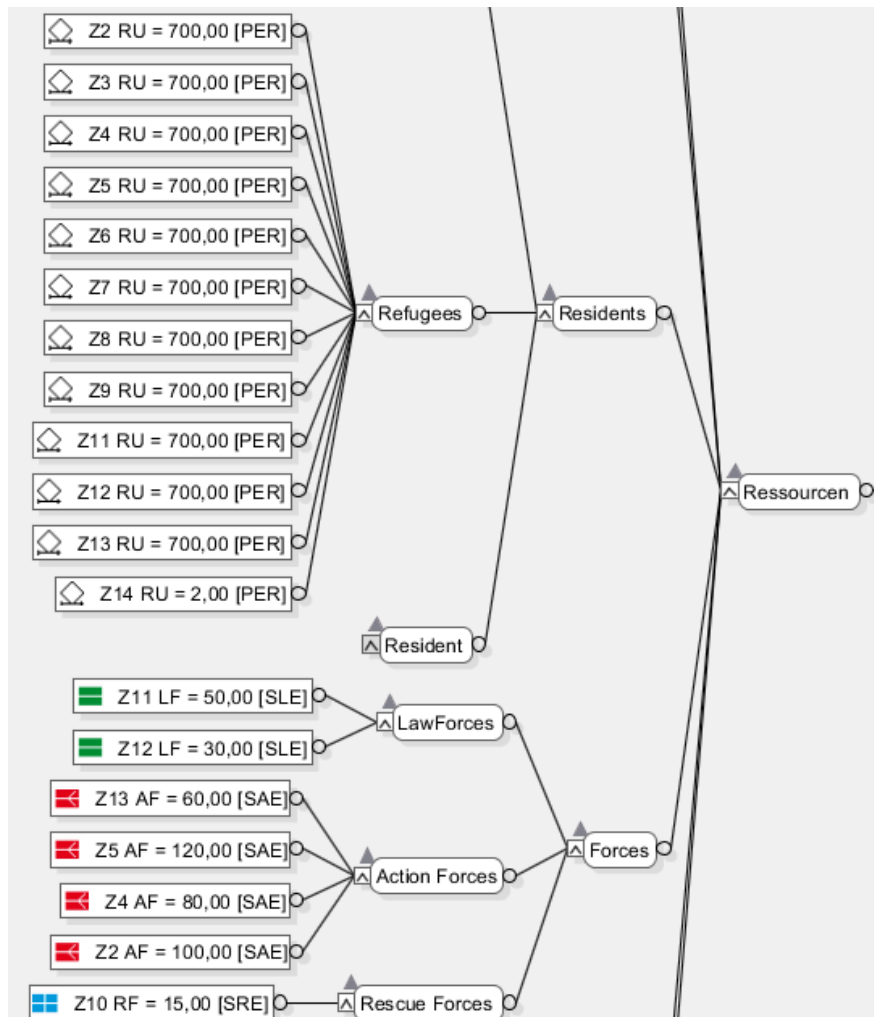


Figure 13: Screen shot of scenarios first operation

4.3.5 Example: Scenario file for use with Event Processor

After modelling the scenario details within SyMo and configuring and creating the scenario file, the resulting file can be parsed and serialised into a CSV file. The event-processing engine for initialisation of the start resources can then read the different operators, variables and timestamps and in addition events and actions are read and written into the event queue. The events and actions are ordered using the given timestamps from the SyMo model. Execution of all events and actions with timestamp=1 can then be executed by starting the event processor. The given events are then processed using special rules. These rules decide which events should be forwarded to the simulators and what actions the simulators have to perform as reaction.

4.3.6 Interplay between scenario design, runtime, and analysis phase

The scenario file created with the scenario editor SyMo is a particular instantiation of the scenario storyline modelled in SyMo. When the training shall be started, the master workflow

engine / event processor (EP) fetches the scenario file from the scenario database and starts interpreting it. First, the EP configures CIPRTrainer. That is,

- The GUI gets the relevant information (which scenario is loaded, what start time will be used, menu initialisation etc.)
- The required CI models of the federates are fetched from a database and read into the simulators
- If applicable, a flood model is selected and the flood simulator is initialised.

When the trainee pushes the start button, the GUI creates a start event that is sent to the EP. The EP then creates an empty log file and starts executing the initial events from the scenario file. It also sends start events to the simulators. An incident or event contained in the scenario file and interpreted by the EP may initiate a change in one of the simulators (like flooding of a CI element and failure of the CI element as an impact). In such a case, the simulator reports the change as an event to the EP, and the EP then

- Logs the event
- Displays relevant aspects of the event (like the failure of the CI element) at the user interface

In case of cascading effects, the EP would receive successive events from several simulators based on the modelled dependencies. The EP also applies some rules contained in the scenario file for determining if the next planned event is still applicable. For instance, if the scenario file contains a “planned” duration of a fire of five hours, then the fire triggers a number of impacts (damage events) during that time. But if the user fights the fire and terminates it after two hours, some of the damage events will never happen. Similarly, failures of CI elements may affect the action options of the user. In such cases, the EP will have to send events to the GUI that grey out some parts of the actions menu.

All events that pass through the EP are logged. The log file is a mixture of initial events as contained in the scenario file, interspersed with events created by the simulators, and events created by the user. It will have a similar syntactical format as the scenario file. After the training, the log file will be analysed by means of the analysis part of SyMo. This is work in progress and will be reported in the forthcoming D6.4.

5 Flooding models

The modelling of potential flood impacts as a basis for flood risk management is a crucial part for a low-lying, flood-prone country such as the Netherlands.

For this purpose, comprehensive computations on flood modelling have been carried out for the entire country under responsibility of the water boards and in close collaboration with research institutions and private consultants. Possible flooding scenarios have been defined using a harmonized national methodology and various pre-defined boundary conditions for all dike ring areas.

The simulation of flooding, including water depths, flow velocities and flood extents is a challenging task and requires high computational effort. Depending on the type of flooding and the required properties of the results, regarding the spatial resolution and accuracy, different modelling approaches are available: While for smaller areas with a distinctive representation of differences in elevation simplified GIS based approaches can be applied, larger areas require more complex two-dimensional or even three-dimensional flood models, which have to be implemented and calibrated.

In the Netherlands, most flood simulations are performed using the SOBEK open channel flow model. SOBEK is a deterministic model that simulates water flow in rivers by solving the Saint-Venant equations with the so-called staggered grid numerical scheme [Stelling03]. SOBEK is integrated in a modelling suite designed for water authorities and water management consultancies. It is suited for modelling and analysis of:

- Open channel hydraulics: local, regional and national water systems
- Sewerage and urban drainage systems
- Inundation and flooding scenario simulations
- Water quality predictions

and the design and optimization of control systems for canal and waterway automation.¹⁰

Generally, for the flood simulation the following input data is required:

- elevation model, e.g. SRTM90 (worldwide), AHN2 (The Netherlands), DTM (Germany),
- land use information and related roughness parameters, e.g. CORINE land cover (Europe), LGN3 (The Netherlands) or ATKIS (Germany),
- hydraulic boundary conditions, i.e. water level, inflow volume or a combination of both, and
- wind speed, if relevant for wind surge or wave modelling.

As part of the applied research project “Risk Analysis for the trans-boundary dike rings of the lower Rhine” (German title: Risikoanalyse für die grenzüberschreitenden Deichringe am Niederrhein) [MUNLV06] and previous research projects [Mierlo05], comprehensive flood models have been prepared and executed for the trans-boundary dike rings 42 (left bank) and 48 (right bank). Figure 16 and Figure 17 show the investigated dike breach locations for each dike ring.

The simulations are based on a predecessor of SOBEK, the fls-model [WL01]. FLS uses the two-dimensional shallow water equation to calculate stationary and in-stationary flows. The use of a finite differences approach enables relatively fast flood simulations (run time <1 day for 40 days of flooding for an area of 3500km², according to [MUNLV06]), compared to other flood models. The horizontal resolution of the fls-models is 100 m with a vertical resolu-

¹⁰ <https://www.deltares.nl/en/software/sobek/>

tion of the elevation model of 1 cm. The run times form however an issue for the application in federated models, for which reason they have to be pre-computed.

It is thus favoured to enable the re-use of flood simulations in future studies. Therefore, all results are stored and provided via the national flood database “Lizard flooding” (see <http://flooding.lizard.net/>). Lizard is the central national information and database system for flood scenarios in the Netherlands. Lizard facilitates the view of different flood scenarios (cf. Figure 14), related economic damages as well as the number of fatalities to be expected. It is further possible to access and download selected scenarios for further analysis, such as for the CIPRTrainer.

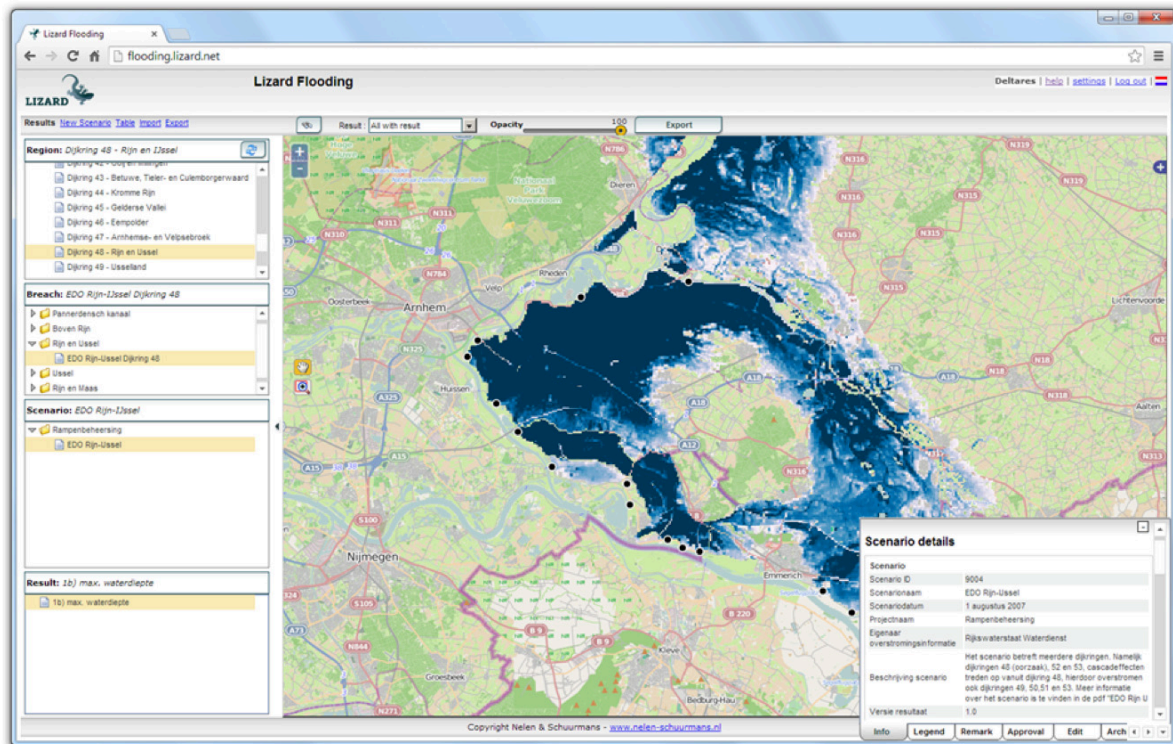


Figure 14: Screenshot of the Lizard database showing a flood scenario in dike-ring 48 (source: Lizard, 2015).¹¹

It is important to highlight that the scenarios are owned by the regional water boards. The water board Gelderland granted the CIPRNet project access for all trans-boundary scenarios of the aforementioned studies. Lizard covers at 16 breach locations on the left bank and 14 different dike breach locations on the right bank of the river.

¹¹ Lizard flood scenario database see <http://flooding.lizard.net>

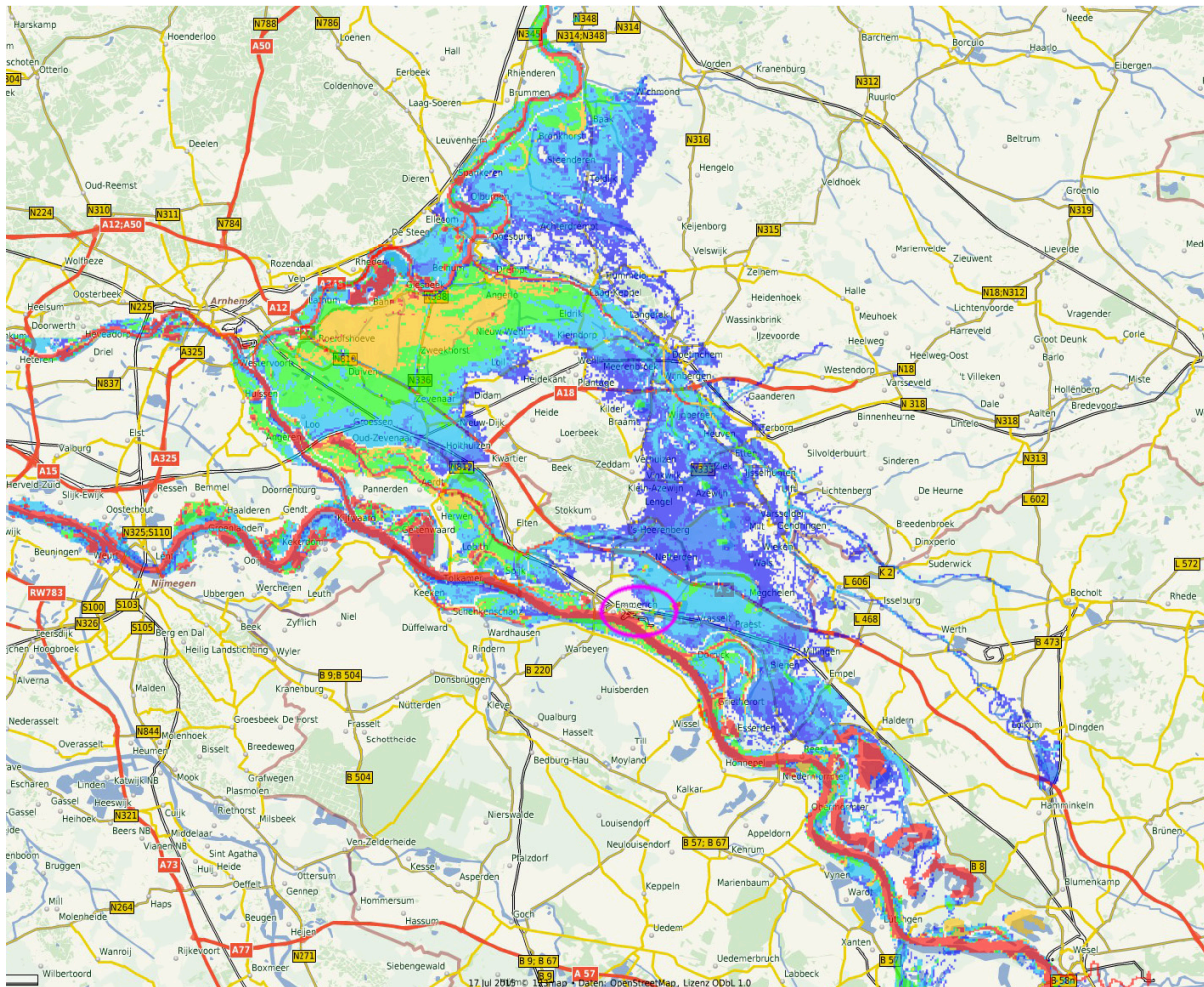


Figure 15: Screen shot of a simulated flood in the NL-DE cross-border scenario. Location of Emmerich is indicated by pink ellipse near the centre (flood map: Deltares; terrain map: flosm.de)

The flood models provided by Deltares are thus pre-computed. As described before, due to the enormous computing overhead, a real time simulation or even near real time is not feasible. That is, as part of a federated simulation, the models cannot be changed much. The only parameter that can be changed is the location of dike breaches. In order to be able to employ the flood models for WIA, several models have to be pre-computed. These models may differ in aspects like location and number of dike breaches or in considering counter measures like closing a dike breach at a certain location at a certain time.

In order to consider human interventions like sealing a dike breach or breaking a dike on purpose for saving a more endangered region, we need our own flood simulator. The simple flood simulator will access the stored models and use the ones that correspond to the human intervention. In this case, the human intervention would be limited by the number of pre-computed models and the courses of action determined at the time of designing the models. Therefore, it is important that these aspects of the flood models be validated by end-users.

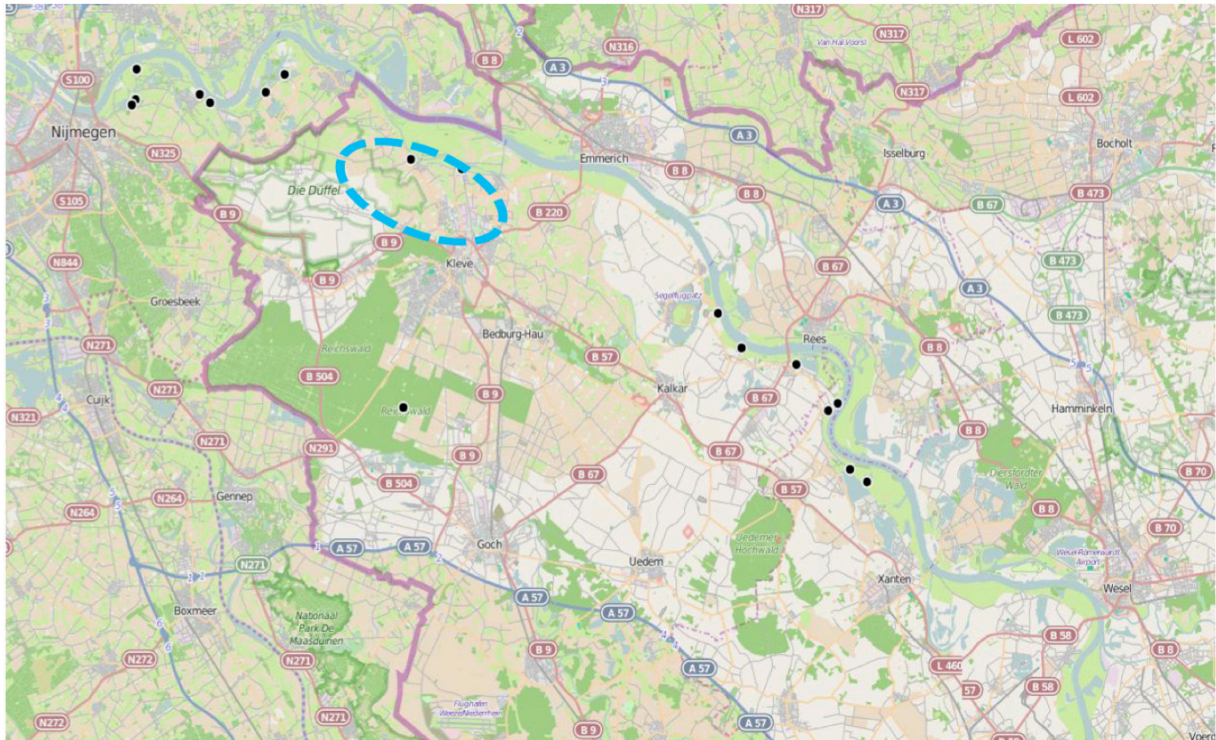


Figure 16: Location of hypothetical dike breaches for the NL-DE cross-border flooding scenario, left bank of the Rhine (source: LIZARD flood database, map: OpenStreetMap).

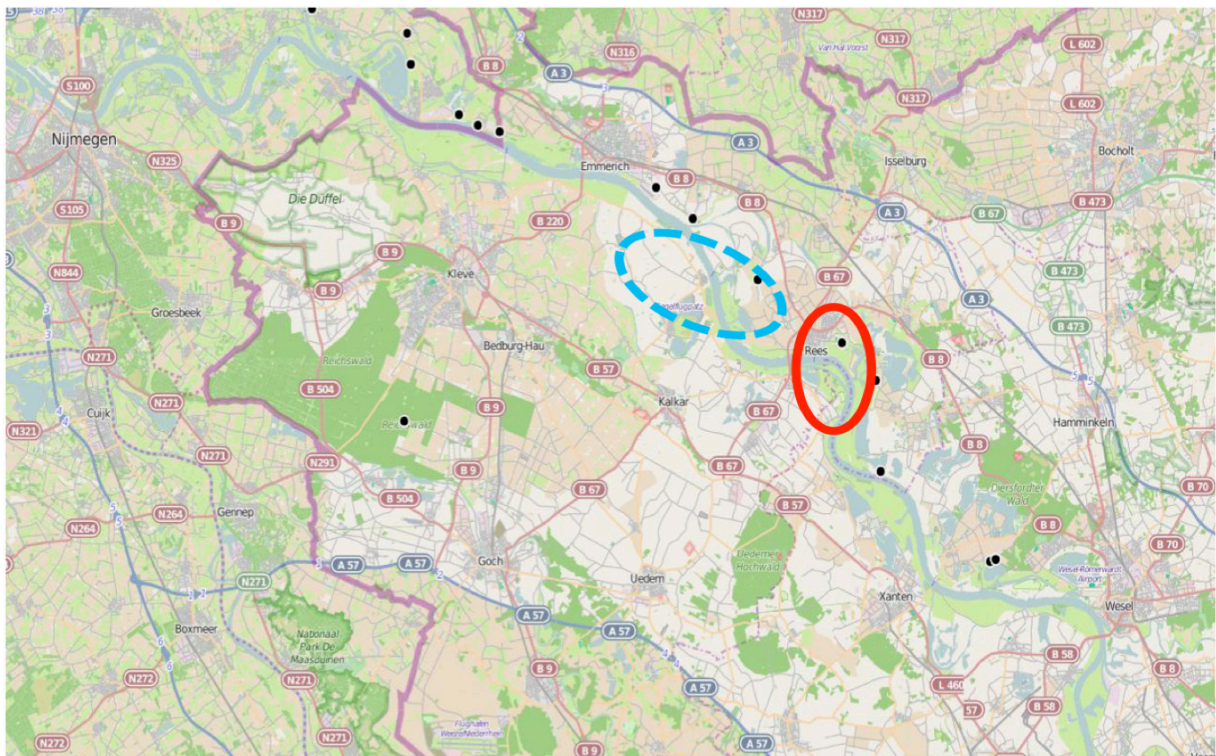


Figure 17: Location of hypothetical dike breaches for the NL-DE cross-border flooding scenario, right bank of the Rhine (source: LIZARD flood database, map: OpenStreetMap).

6 Models of critical infrastructure – Simulators

In this section, we will briefly introduce the DIESIS technical demonstrator on which the federated CI models and simulation will be based and explain the improvements we will make in CIPRNet. Thereafter, we will describe in three sections the modelling activities for the three CI simulators that are being employed for the federated CI simulation in CIPRTrainer. All three sections end with describing the mutual dependencies of the CI.

6.1 Previous work: DIESIS demonstrator

The technical part of CIPRTrainer that deals with federated modelling and simulation of interconnected CI is based on experiences gathered in past projects like FP7 DIESIS [DIESIS]. DIESIS developed a novel middleware for semantically interoperable federated CI simulations [Usov10]. The technical demonstrator [DIESIS2] realised an ontology-based information exchange for three CI sectors (electrical power distribution, fixed and mobile telecommunication, and railways), and a common threat simulator (flood simulator)(depicted in Figure 18).

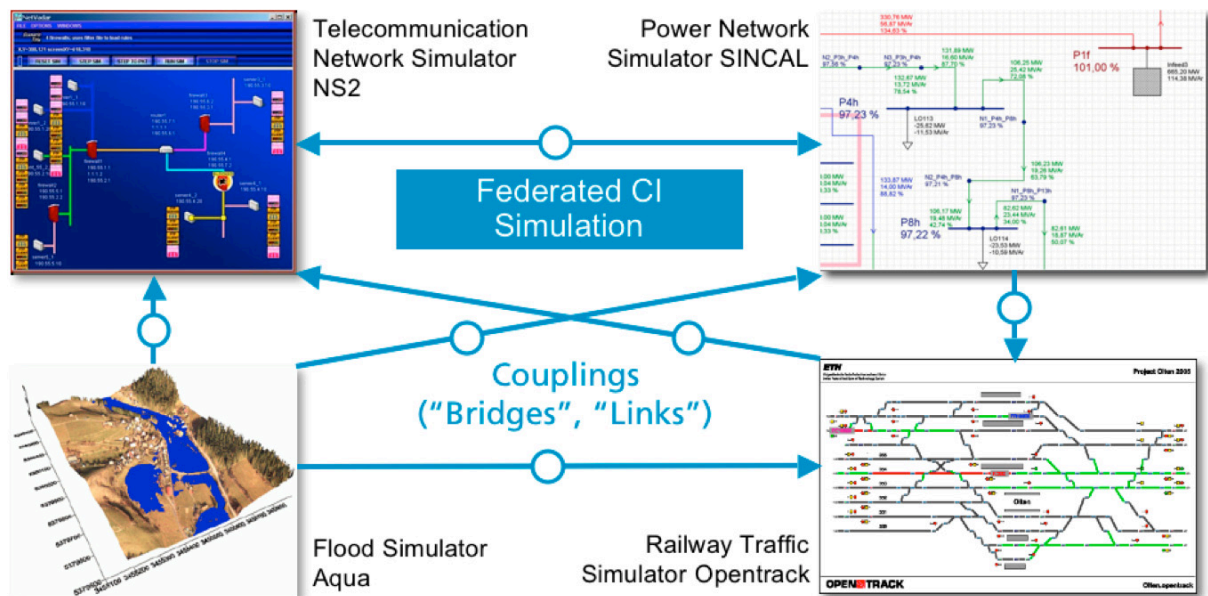


Figure 18: DIESIS technical proof of concept: Federated simulation of three CI (telecommunication: ns-2; electricity network: SIEMENS PSS® SINCAL; railway traffic: OpenTrack) and a flood simulator

The ICT architecture for distributed federations of simulations included a scenario-based approach for setting up distributed federations of CI simulators and a lateral coupling approach for connecting these simulators. The first version of interoperability middleware for coupling CI simulators consisted of:

- A Service-oriented Architecture (SOA)-based framework for linking simulators,
- A set of standardised links for exchanging data between simulators, and
- A time synchronisation meta-model for three different time and execution models.

A knowledge-based system (KBS) using the Web Ontology Language OWL was employed to support the ontology-based model connectivity and information exchange.

For analysis purposes, the demonstrator recorded events at federate level (for each simulator) and at federation level (entire coupled system). From these log files, a KML-file was extracted that could be used offline in a GIS tool for visualising the propagation of CI outages along the connections in the networked critical infrastructures.

The technical demonstrator of DIESIS was lacking a general event processing capability that is needed for realising complex storylines as in the CIPRNet scenarios. This is a new contribution from CIPRNet. Also, the underlying communication middleware will be replaced by standard communication protocols. Regarding simulators, CIPRNet will employ the latest versions of SINICAL and OpenTrack, ns-2 successor ns-3 (which uses a complete new model), and an own flood simulator that uses sophisticated state-of-the-art flood models.

6.2 Electricity infrastructure – SIEMENS PSS® SINICAL

The electricity infrastructure in the Emmerich area is modelled and simulated with SIEMENS PSS® SINICAL [SINICAL], a software package for planning and analysing electrical power systems. SINICAL is a steady state simulator, a property that will be important for time synchronisation. The electricity model covers both the transmission and sub-transmission network in and around the city of Emmerich, as well as the distribution network in the city itself. Due to the lack of available data and information regarding the distribution network in Emmerich, the model of this part of the infrastructure is purely fictive and intended to represent a plausible example of a medium sized city with about 30.000 inhabitants. Compared to the distribution network, there is a lot more information available for the transmission and sub-transmission network in and around Emmerich, so the model of this part of the power network matches the real-world conditions to a greater extend. As the main data sources for the transmission network model, two OpenStreetMap-based sources are used (*Powerland*¹² and *flosm*¹³). For an additional verification, the ENTSO-E common grid model is used.

6.2.1 Transmission / Sub-transmission Network in the Emmerich Area

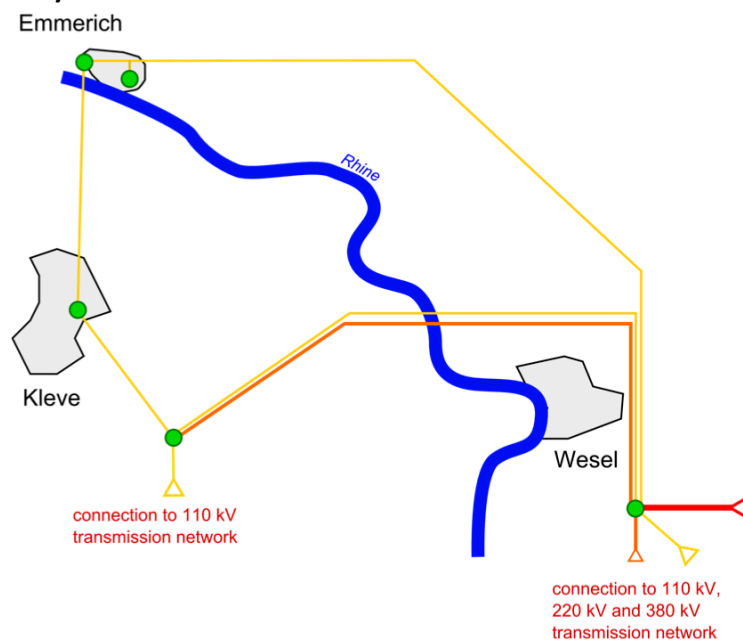


Figure 19: Schematic overview of the electrical transmission network around Emmerich. Green dots denote substations, thick red lines represent 380 kV overhead lines, thin orange lines 220 kV transmission lines and yellow lines denote 110 kV overhead lines. The connection to the overall power transmission network is implemented in two substations.

¹² <http://powerland.bplaced.net/>

¹³ <http://www.flosm.de/html/Stromnetz.html>

A major part of the transmission network around Emmerich is represented by 110 kV three-phase AC power lines. These lines are connected to the 220 kV and 380 kV transmission network at the *Station Niederrhein* substation. The connection of this 220 kV power line to the 110 kV sub-transmission network is implemented in the “*Station Pfalzdorf*” substation. The naming scheme of the lines is taken from the data sources and matches the real world names. Table 1 shows an overview of all power lines contained in the model.

Besides the transmission network operated by the transmission system operators, the traction power network operated by the German Railway (Deutsche Bahn) is also an important part of the modelled electricity infrastructure. In the Emmerich Area, two railway electrification systems are in use: German railway uses 15 kV AC at 16.7 Hz, the Dutch railway system is electrified with 1.5 kV DC. Both systems use overhead lines.

Table 1: Overview of the transmission network power lines contained in the model and their corresponding OpenStreetMap relation ID.

Power Lines	
Name	OSM Relation ID
110 kV	
Hüthum Ost	1083041
Emmerich Ltg	1776098
Millingen Ltg	1083033
Kleve Süd	1536592
Provisorium Hüthum - Löwenberg	1084009
Isselburg Trafo 3	1776097
Xanten Ost	1208427
Xanten West	1083043
Bocholt Ost	1083022
Bocholt West	1083970
220 kV	
Pfalzdorf Nord	1208426
Pfalzdorf Süd	1082973
380 kV	
Lippe Nord	1082805
Lippe Süd	1116357

OpenStreetMap is used to acquire the relevant operating parameters of the power lines. One crucial aspect is the length of the according lines. To calculate the lengths using OpenStreetMap data, the Python-based software-libraries *osmapi*¹⁴ and *geopy*¹⁵ are used.

The model of the electrical transmission network comprises furthermore several electrical transmission substations located in the Emmerich area. Substations connected to the transmission / sub-transmission network, i.e. power lines with voltages of 110 kV, 220 kV and 380 kV are captured by the model. Figure 19 shows a schematic overview of the transmission network around Emmerich with the several substations and power lines. It can be seen in the

¹⁴ <https://pypi.python.org/pypi/osmapi>

¹⁵ <https://github.com/geopy/geopy>

figure that the part of the transmission network captured by the CIPRNet model is connected to the overall transmission network at two transmission substations: “Station Niederrhein” and “Station Pfalzdorf”. From these two substations, the 110 kV transmission network which supplies the city of Emmerich with electrical power is fed. German railway operates its own 110 kV transmission network to supply the overhead wires of the railroad tracks, the electrical power for the Emmerich area is transformed to 15 kV traction current at the substation “Unterwerk Merhoog”.

6.2.2 Distribution Network in the Emmerich Area

Two transmission substations, Hüthum and Löwnberg, feed the distribution network of the Emmerich area. The substations transform the nominal 110 kV transmission voltage-rating to 20 kV. The 20 kV grid is the medium-voltage (MV) distribution network that will be provided in D6.4. The MV distribution network is implemented by MV underground cables, connecting the transmission substations to the distribution substations. The low-voltage cabinets (distribution substations) transform the MV to the low-voltage (LV) grid of 400 V_{line-to-line} but the LV is out of the scope of this project.

For those data about the existing distribution network of the Emmerich area that cannot be provided by the stakeholders, we have made some realistic assumptions to design the electrical power model. To create synthetic simulation results, it is assumed that:

- There are two industrial areas (South-East and South-West of the Emmerich area) and each one has its own MV substation;
- The power consumption has small variations during the year and we use the average consumption of each month;
- The historic load profile of the load is near the actual one;
- The MV distribution is at 20 kV

The detailed models of the distribution network will be provided in the next deliverable D6.4 in Work Package 6. An outline of the modelling work is provided in the following paragraphs.

According to the population census, Emmerich has 30,105 inhabitants and assuming that the average number of persons per household is 2.3 (Germany average is 2.1¹⁶, but since this is a small city it is expected that the average is slightly higher) there are about 13 thousand houses. By assuming that each low-voltage cabinet provides power to an average of 200 houses, 65 low-voltage cabinets are required. Two more low-voltage cabinets are assumed to feed activity buildings (such as stadiums/sports/yacht club) and entertainment buildings (malls). A third cabinet is needed to feed the hospital of Emmerich.

The railway electricity system will be modelled as a separate network connected to a third transmission substation, Unterwerk Mehrhoog. Even though the distribution networks seem to be decoupled, the three transmission substations are fed from the same network. Since the railways are not fed by the two transmission substations (Station Niederrhein and Station Pfalzdorf) the distribution network of the Emmerich area should include the two distribution substations for the industrial areas and the 68 low-voltage cabinets.

Approximate average load for each household:

- 2000 kWh / annum in average per person
- Average installed continuous power per person: 228 W
- For whole Emmerich: 6865 kW

¹⁶ http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Average_household_size_2011.png

The monthly average electrical power consumption rate of the Emmerich area is assumed to be equal to the ratio with the total electrical transmission energy consumption of Germany¹⁷. The monthly average ratio shows the transition of electrical power consumption of the distribution network of the Emmerich area, as seen in Figure 20.

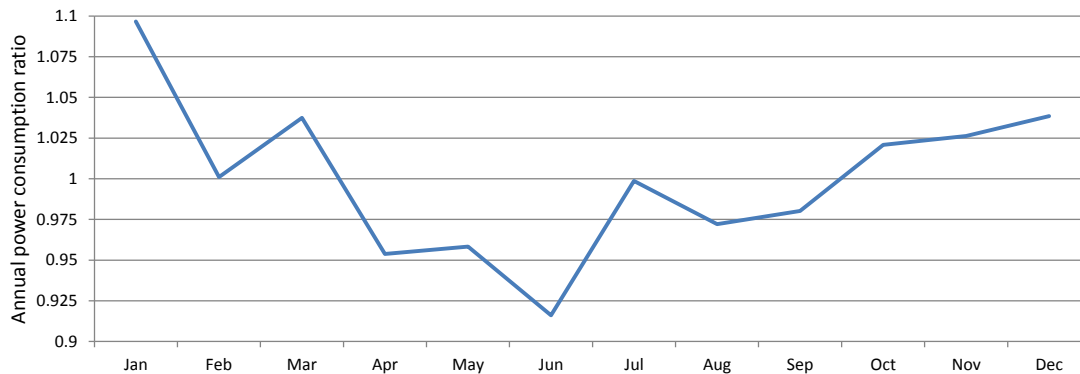


Figure 20: Monthly ratio of average electrical power consumption

6.2.3 Modelling with SINICAL

The electrical transmission and distribution network is modelled with the planning and simulation software package PSS[®] SINICAL [SINICAL]. Figure 21 shows an overview of the model as it is presented in the graphical user interface of PSS[®] SINICAL.

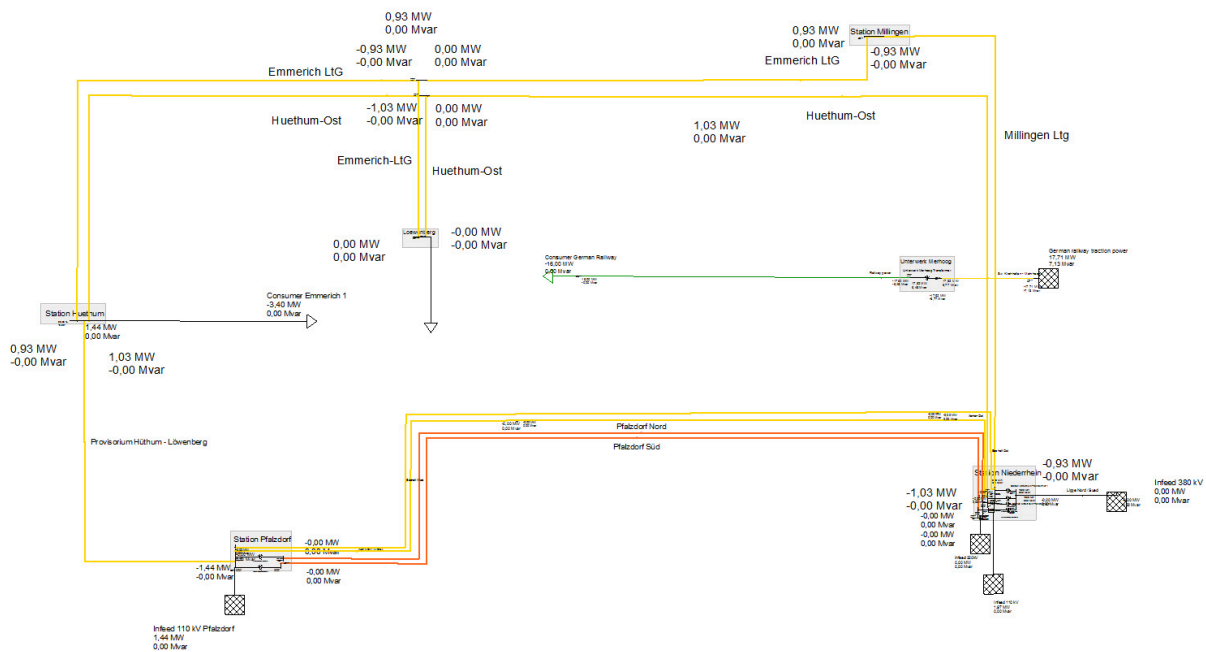


Figure 21: Overview of the PSS[®] SINICAL transmission network model. Yellow lines represent 110 kV 50 Hz transmission lines, orange lines 220 kV 50 Hz transmission lines, green lines represent 15 kV 16.7 Hz traction current lines. The grey areas depict transmission substations. The hatched squares depict power infeeders.

The model of the transmission network is built manually using the graphical user interface of PSS[®] SINICAL, as there are relatively few elements to consider, this approach was sufficient. The model makes use of several elements PSS[®] SINICAL provides specifically these are high-

¹⁷ <https://www.entsoe.eu/data/data-portal/consumption/Pages/default.aspx>

voltage overhead lines, medium-voltage underground cables, transformers and infeeders. The elements are connected with nodes and bus bars. The infeeders are used to model the connection points to the overall power transmission network outside the modelled area (cf. Section 6.2.2). The software provides functionality to conduct load flow calculations that can be considered as the actual simulation of the power network. The model itself as well as the outcome of the load flow calculation is stored within a database, which enables access to the data from outside PSS[®] SINCAL. Within CIPRNet, PSS[®] SINCAL is configured to use the MS Access database management system, which can be queried using an ODBC interface. PSS[®] SINCAL itself provides a COM-based interface which is used to control the software from outside, for example to trigger a load flow calculation. Both interfaces form the foundation for the interconnection with other simulators within the federated simulation. As mentioned in Section 6.2.2, the detailed models of the distribution network will be provided in D6.4 by using the modelling software Siemens PSS SINCAL.

6.2.4 Interconnections to other CIs

As power supply is crucial for operating almost every technical device, the function of the railway and telecommunication network is highly dependent from the electricity infrastructure. As the German railway operates its own electrical power infrastructure, there is no direct coupling of the railway and general electricity infrastructure in the Emmerich area. Electrical power for railway traction is transformed and fed into the railway power lines through the “Unterwerk Meerhoog” substation. A failure in this substation would of course cut off the German part of the railway line through the Emmerich area out of service; this means that there is a direct connection between the electrical transmission network and the railway infrastructure. As Emmerich main station is operated as a cross border station where the electrical traction power systems of the Netherlands and Germany end, the Dutch part of the railway route might be supplied with electrical power while the German part is not. Other elements of the railway infrastructure are also depended from the supply with electrical power, for example the signalling system. In real railway systems, signals are equipped with a so called “marker light” which indicates the state of a signal to the train driver. In case of a signal failure, the marker light will be dark and trains will have to stop and wait for further instructions from the control unit responsible (this is indicated through the post plate attached to the signal mast)¹⁸. On the technical level, these impacts on the railway infrastructure resulting from the loss of electrical power will be modelled through the event processing system by (declarative) rules, which is part of the CIPRNet software solution.

Similar considerations hold true for the interconnection between the electricity infrastructure and the telecommunication infrastructure. Data traffic through the infrastructure is generated by telephones, computers or other devices, and all these devices need electrical power when the backup battery runs out. If the devices are not equipped with a battery, they will not produce any data traffic immediately after the power supply stops. Data packages are conveyed through the network by routers, if these routers are not supplied with electrical power, data traffic will become immobilised. Since data sources and routers are supplied with electrical power through the distribution network, the connection of the according routers and the switchboxes of the distribution network is known. With this knowledge, routers can be deactivated within the telecommunication simulator as soon as the assigned switchbox fails.

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http://www.eba.bund.de/SharedDocs/Publikationen/DE/GesetzundRegelwerk/Bundesrecht/11_eso.pdf;jsessionid=FF8EDF8924F52667CCEDF2CCB42FFFA.live!043?_blob=publicationFile&v=3

6.3 Telecommunication infrastructure – ns-3

In order to model and simulate telecommunication aspects in the Emmerich area, we have used the Network Simulation version 3 tool (ns-3 [NS-3]). It is a discrete-event network simulator, provided free under a GNU GPLv2 license. Its purpose is to provide an “open simulation environment for networking research” [NS-3], including IP-based networks and non-IP based communication networks.

In CIPRNet, we use ns-3 for modelling the fixed line and mobile telecommunication networks of our scenarios. Since only very limited data of these networks is available, we decided to construct mostly artificial but technically correct networks models which are typical for an area like the Dutch-German border region [CIPRNetD62].

In this section, we will describe the main elements of the ns-3 telecommunication models and their interconnections to other CI.

6.3.1 Telecommunication network in the Emmerich Area

Since we are lacking the information about the real topology of core telecommunication network in the Emmerich area, we have made some conceptual and designing assumption while modelling. First, we assumed that the broadband network to Emmerich city is provided by node indicated as “0” in Figure 22. The city centre is connected via router indicated as “1”, that further connects western (router 7), eastern (router 8) and southern parts (router 2) of Emmerich. More details about links configurations are provided in the Table 3.

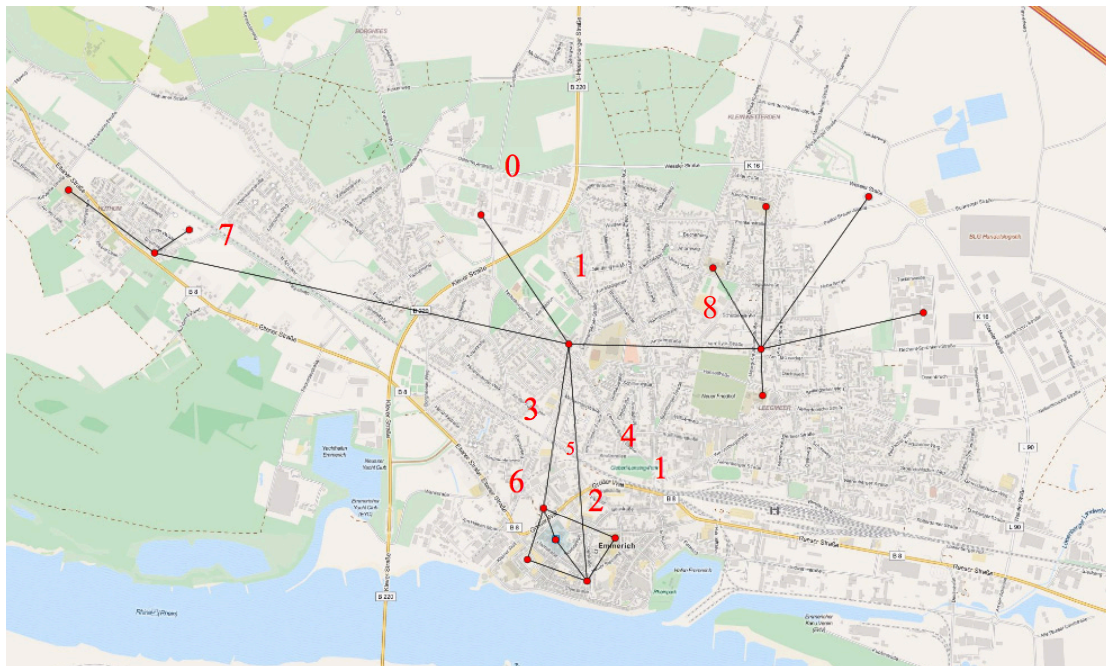


Figure 22: Core telecommunication network in Emmerich area. The red dots indicate main routers, while the links indicate physical connections between them.

The core nodes of the model are listed in Table 2. The geographical positions of these elements have been shown in Figure 22. In southern part of Emmerich there are redundant paths between routers. For instance, traffic from node 5 to node 1 can be established via node 3 or node 2. However, these paths have different characteristics and the link between node 1 and 3 has 20 ms delay in contrast to link between nodes 1 and 2, which has 2 ms delay.

Table 2: Overview of main nodes contained in the model

Node ID	Description
0	Core router near Armoured Division
1	Core router – Emmerich centre
2	Core router – southern Emmerich
3	Backup for core router – in southern Emmerich
4	Endpoint router – near Europaschule (Gemeinschaftshauptschule)
5	Endpoint router – near St. Willibrord-Hospital
6	Endpoint router – near Police station in Emmerich
7	Core router – western Emmerich
8	Core router – eastern Emmerich
9	Endpoint router – near power substation
10	Endpoint router
11	Endpoint router
12	Endpoint router
13	Endpoint router
14	Endpoint router – near fire service
15	Endpoint router

In case of the scenario, where node 2 fails, connection will be established via node 3. Therefore, we will observe the degradation of communication quality. As a result, this will disturb the communication between southern areas of Emmerich with remaining elements in the city.

Table 3: Overview of main physical telecommunication links contained in the model together with their properties (bandwidth and delay)

Link	Bandwidth	Delay
0-1	1Gbps	2ms
1-2	1Gbps	2ms
1-3	1Gbps	20ms
1-7	1Gbps	2ms
1-8	1Gbps	2ms

The geographical region with close proximity to node 8 has been indicated as urban area, where schools and households are located. The network elements located in this part of Emmerich will generate significant volume of traffic to other services (e.g. banks, hospitals, etc.).

6.3.2 Modelling with ns-3

In the ns-3 tools suite, the topology and the configuration of the simulation are provided either in *.py (python) or in *.cc (c/c++) files. Commonly, these files contain following information:

- ns-3 nodes definition (names, types , positions, etc.)
- Communication links definition (data rates and delays)
- Topology definition

- IP stack installation
- IP addresses assignment
- Routing definition
- Configuration of the application layer

In ns-3 the term node is used to name an abstract device connected to a network such as end-users hosts, end-systems, routers, switches, hubs etc. Since NS-3 does not focus on Internet technologies only, it is the responsibility of simulation creator to define nodes properly by adding applications, protocols stack, etc.

In ns-3 the concept of application is defined as an element that runs the simulation. It is the basic abstraction of a user program, which generates some network traffic.

In order to automate this process we have adapted the ns-3 topology generator, which aims at providing GUI and thus simplifying the process of creating the ns-3 topologies. The GUI allows the user to drag-and-drop specific elements onto the simulation canvas, define the elements types (routers, switches, end-user terminals, etc.), and to provide connectivity between them.

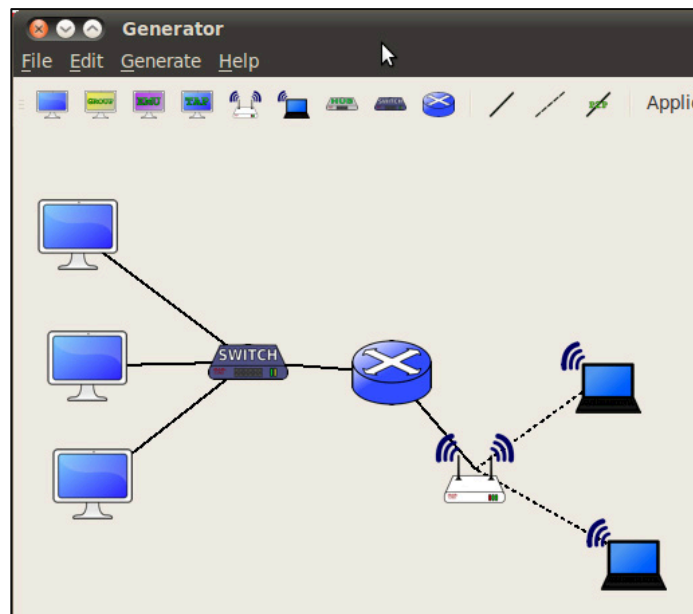


Figure 23: An example of network topology defined by means of ns-3 Topology Generator Tool.

6.3.3 Interconnections to other CIs

A working telecommunication infrastructure is crucial for the smooth operation of a rail operation. Rail companies usually operate their own communication network. The European Rail Traffic Management System (ERTMS)¹⁹ deals with the installation Europe-wide communication and train control standard. State of the art in railway communication is the adaption of digital wireless systems based on GSM-R. A cross-border train control system is realised through the European Train Control System (ETCS), which is planned to be implemented in the Emmerich area²⁰. Besides ETCS, a multitude of national solutions for train control and

¹⁹ <http://www.ertms.net/>

²⁰

http://www.mbwsv.nrw.de/presse/pressemitteilungen/Archiv_2013/2013_07_25_Ausbau_der_Bahnstrecke_Emmerich_Oberhausen_kommt_Bund_Nordrhein-Westfalen_und_Deutsche_Bahn_unterzeichnen_Finanzierungsvertrage/index.php (German)

train protection exist. Within the CIPRNet system, the interconnection can be modelled through the event- and rule system. Further research is needed to define the rules, which have to be engaged in the case of a failure within the telecommunication system.

The network control technology of electrical infrastructures relies mainly on an operating telecommunication network. Transmission networks are operated from centralised control units. Substations can be controlled remotely. If the communication with a substation is interrupted, remote control will not be possible. The event- and rule system in CIPRNet can also be used in this case to model the impact of such a failure. Further research needs to be conducted on defining a set of rules, which result in a plausible behaviour of the electrical infrastructure in case of a failure within the telecommunication infrastructure.

6.4 Railway infrastructure – OpenTrack

OpenTrack [OpenTrack], made by the Swiss company of the same name, is a commercial simulator for railway planning. The OpenTrack functions that are useful for CIPRNet include

- Analysis of the capacities of railway lines and stations
- Analysis of system failures
- Simulation of railway power supply systems
- Timetable construction
- Railway disposition in case of network disturbances.

In this section we will describe how we constructed the OpenTrack models for the Dutch-German cross-border scenario [CIPRNetD62]. The scenario area considered consists of the Arnhem-Nijmegen metropolitan area on the Dutch side, and the district of Kleve on the German side.

6.4.1 Railway network and traffic in the Dutch-German scenario area

The most important railway track in the scenario area is the Betuwe route, a double track freight railway from Rotterdam to Zevenaar, with extensions to Germany and the European hinterland (Rhine-Alps corridor of the railway network). It is a European Critical Infrastructure (ECI), as since 2011, nearly 80% of all goods trains between Rotterdam and the Dutch-German border took the Betuwe route. On the same route, also passenger trains are running, including international ICE lines. On the German side, the extension of the Betuwe route runs through the entire district of Kleve, with the city of Emmerich as the north-most station and the city of Wesel as the south-most. The part of the Betuwe route that runs through the incident region is the track between Arnhem (NL) and Emmerich (DE).

In case of a severe railway incident, trains have to be redirected along other routes. In order to be able to simulate such rerouting of trains, we modelled a larger rail network including all main railway traffic lines from Rotterdam to the German Ruhr region and further on southbound via Cologne (Figure 24).

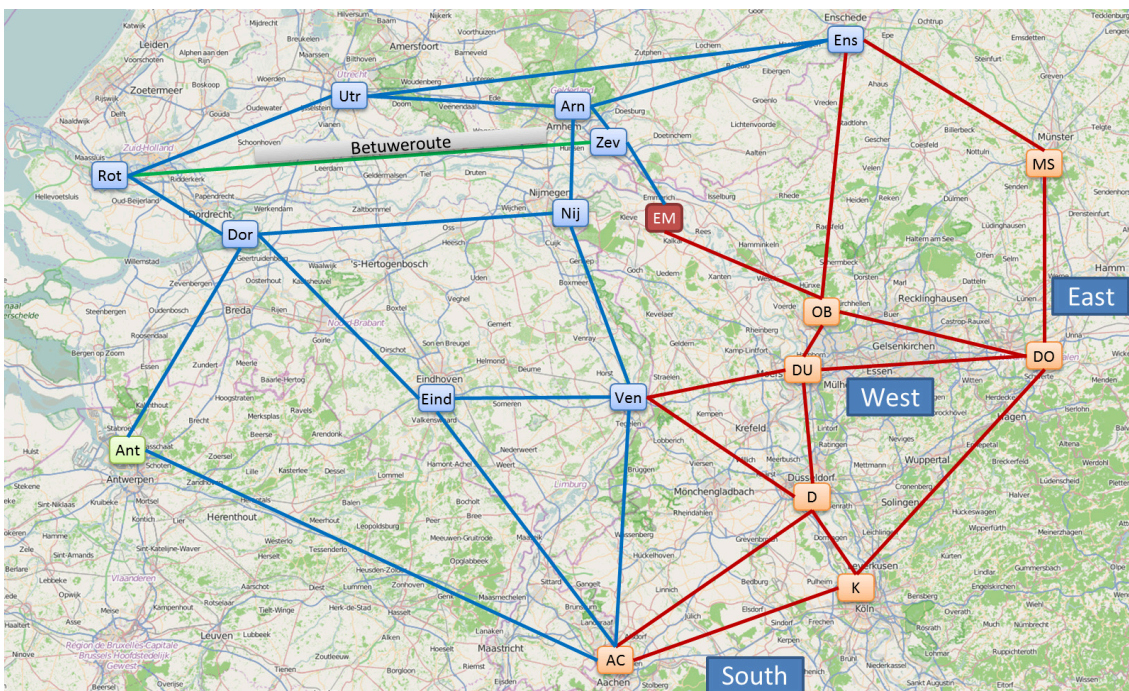


Figure 24: Main railway traffic lines from Rotterdam (Rot) to the German Ruhr region (OB, DU, DO) and further on southbound via Cologne (K). EM marks the city of Emmerich.

6.4.2 Description of Emmerich main railway station

Emmerich main railway station is the location of the derailment incident that was chosen as one of the cross-border scenario storylines. It is a through station for many goods trains and long distance passenger trains. Most goods train traffic is rolling on two tracks to and from Emmerich, connecting the Netherlands, Germany, Switzerland, and Italy. Figure 25 shows the map of the Emmerich main station. The double track from the Netherlands is entering in a curve on the right side of the map. At the end of the curve there is a switch from a side-track. This switch is the assumed cause of the derailment incident. Figure 26 shows the technical sketch of the station layout and the special service tracks.

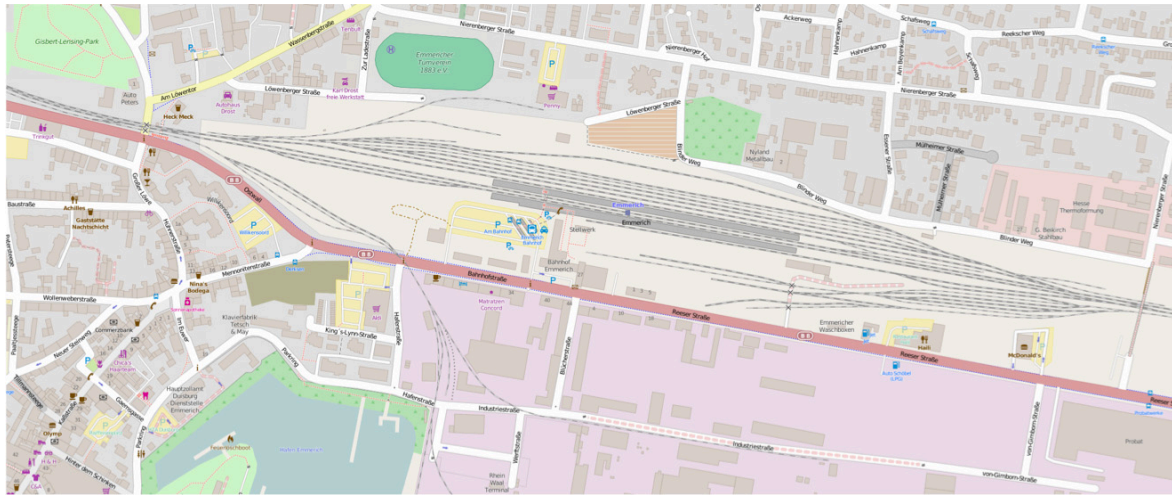


Figure 25: Emmerich am Rhein – main railway station in OpenStreetMap²¹

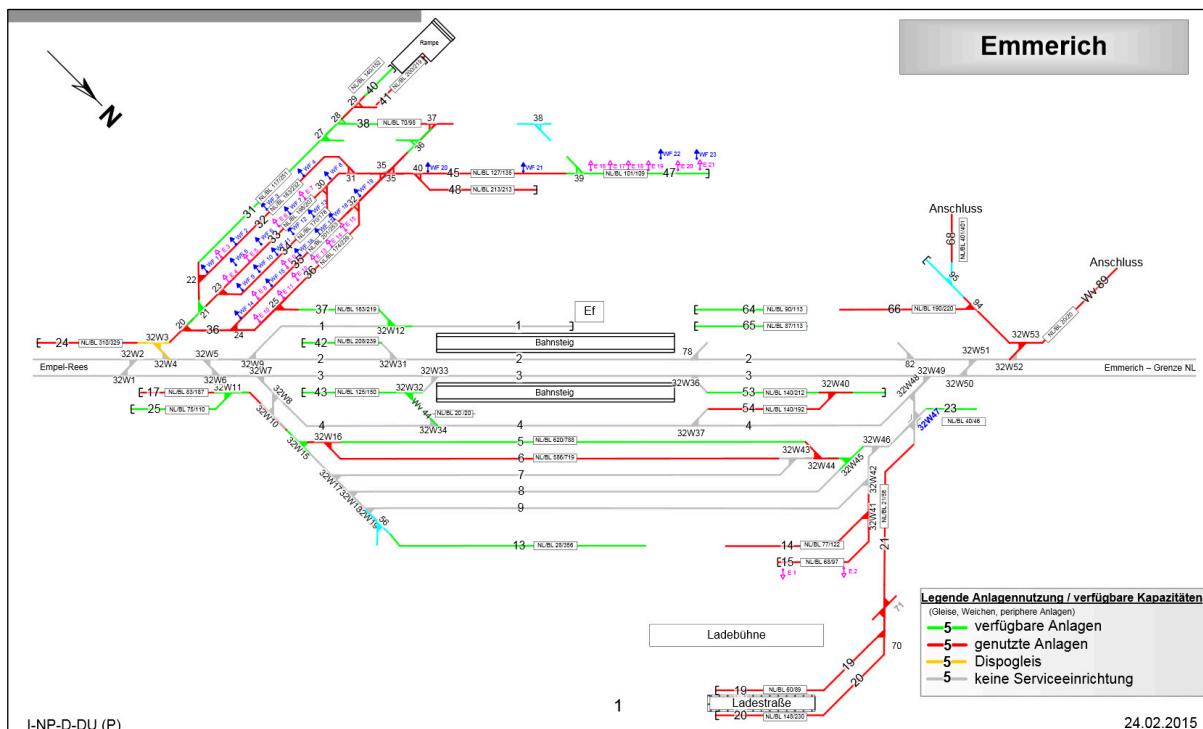


Figure 26: Emmerich am Rhein – main station layout²² and special service tracks

²¹ <http://www.openstreetmap.org/#map=17/51.83392/6.25713>, 2015-05-28

²² http://stredax.dbnetze.com/Dokumente/ISR/BS/NBS/E/EEM_NBS.pdf, 2015-05-28

6.4.2.1 Emmerich’s function as station at the Dutch-German Border

Goods trains from/to Rotterdam are non-stop passing Emmerich so there is no need for any toll regulations. Due to the EU free trade zone there is no border control required for passenger trains stopping at Emmerich station.

6.4.2.2 Change of electrical power system

German railways operate on AC 15 kV while the Dutch railway mainly operates on DC 1.5 kV. The goods train route Betuwe-route is mostly operating on AC 25 kV between Rotterdam and Zevenaar. Zevenaar is the last Dutch railway station close to the German border near Emmerich.

At the station of Emmerich multi-current machines change the electrical operation from one power system to the other while passing an insulated track section. If the machine works with only one electrical operation mode, it has to be exchanged at Emmerich railway station. After exchanging the machines the overhead wire electrical power is switched to the appropriate value. Figure 27 shows the varying electrical power systems along the Betuwe route between Rotterdam and Emmerich.



Figure 27: Electrical power systems along the Betuwe-route²³

6.4.2.3 Number of trains per day passing Emmerich

The numbers of trains per day passing Emmerich and the Dutch-German border²⁴ is shown in Table 4.

Table 4: Numbers of trains per day passing Emmerich, including estimates for 2015 and 2020.

	2008	2015	2020
Passenger trains	22	36	44
Goods trains	83	125	151
Total	105	161	195

²³ http://eisenbahn.egghof.com/uploaded_images/Betuweroute-720067.jpg, 2015-06-02

²⁴ [https://www.emmerich.de/c125747b002691ea/files/zugfrequenzen.pdf/\\$file/zugfrequenzen.pdf?openelement](https://www.emmerich.de/c125747b002691ea/files/zugfrequenzen.pdf/$file/zugfrequenzen.pdf?openelement), 2015-05-26

Almost all of these trains are non-stop-trains at Emmerich station. Just four international passenger trains stop at Emmerich. In the next sections, we briefly characterise the passenger and goods train connections running through Emmerich.

6.4.2.4 International passenger train connections via Emmerich

There are two international passenger train connections running through Emmerich, namely

- Railway route Oberhausen – Arnhem (Hollandstrecke)
- Railway Route Oberhausen Hbf – Emmerich Grenze, DB route number 2270 (Oberhausen main station to Emmerich border)

The maximum velocity on these lines is limited to 160 km/h.

6.4.2.5 Long distance trains stopping at Emmerich, timetable²⁵

Table 5: Timetable of long distance trains stopping at Emmerich.

Train	Departure	From	Emmerich	To
CNL 419 POLLUX	20:31	Amsterdam	22:17	München
CNL 40419 PEGASUS	20:31		22:17	Zürich
CNL 418 POLLUX	22:50	München	07:13	Amsterdam
CNL 40478 PEGASUS	20 :42	Zürich	07:13	

6.4.2.6 Long distance passenger trains passing Emmerich, timetable²⁶

Table 6: Timetable of long distance passenger trains stopping at Emmerich.

Train	Departure	From	Emmerich	To
ICE 121	07:05	Amsterdam	08:37	Frankfurt/Main
ICE 105	08:05		09:37	
ICE 123	10:35		11:57	
ICE 125	12:35		13:57	
ICE 127	14:35		15:57	
ICE 129	16:35		17:57	
ICE 227	18:35		19:57	
ICE 223	21:05		22:27	Köln

²⁵ <http://reiseauskunft.bahn.de>

²⁶ Table generated with data from <http://kursbuch.bahn.de/hafas/kbview.exe>, June 2015

Train	Departure	From	Emmerich	To
ICE 222	05:10	Frankfurt/Main	08:09	Amsterdam
ICE 226	07:27		10:09	
ICE 128	09:27		12:09	
ICE 126	11:29		14:09	
ICE 124	13:29		16:09	
ICE 122	16:29		19:09	
ICE 104	15:13	Basel SBB	20:33	
ICE 120	19:29	Frankfurt/Main	22:09	

6.4.2.7 Local passenger trains at Emmerich, timetable²⁷

Local trains from Emmerich serve German locations only. Currently there is no local railway service from Emmerich to the Netherlands. Local train lines are RB35, connecting Cologne (Köln) and Emmerich (Figure 28 and Table 7), and RB5, connecting Koblenz and Emmerich (Figure 29 and Table 8).

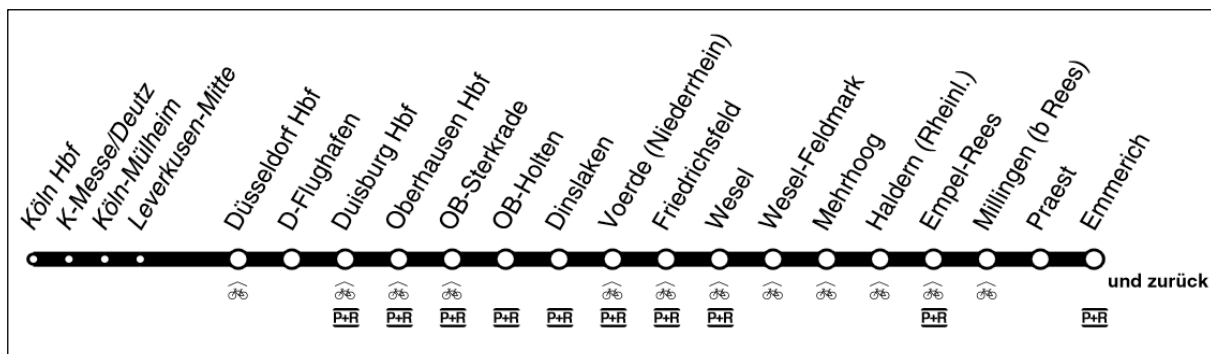


Figure 28: „Der Weseler“, RB 35, connecting Emmerich and Köln

Table 7: Time table of RB35 from Emmerich.

From/To	Departures	Stops
„Der Weseler“, RB 35, from Emmerich		
Duisburg Hbf	04:15 08:10 17:16 22:36	Emmerich, Dinslaken, Oberhausen, Duisburg Hbf
Düsseldorf Hbf	05:06 05:47 07:07	Emmerich, Dinslaken, Oberhausen, Duisburg, Düsseldorf Hbf
Köln Hbf	06:06 19:40	Emmerich, Oberhausen, Duisburg, Düsseldorf, Köln Hbf

²⁷ <http://www.vrr.de/imperia/md/content/fahrten/rerbs/rb/rb35.pdf>; <http://www.ticket-info.net/imperia/md/content/verbundfahrplan/re/re5.pdf>

From/To	Departures	Stops
„Der Weseler“ , RB 35, to Emmerich		
Duisburg Hbf	00:44 05:44 06:44 15:44 22:44	Duisburg Hbf, Oberhausen, Dinslaken, Emmerich
Düsseldorf Hbf	16:25 17:25 18:25	Düsseldorf Hbf, Duisburg, Oberhausen, Dinslaken, Emmerich

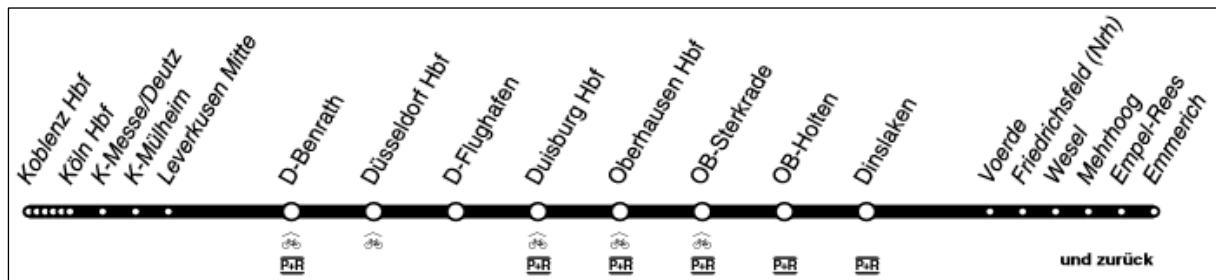


Figure 29: „Rhein-Express“, RE 5, connecting Emmerich and Koblenz

Table 8: Timetable of RB5 from Emmerich.

From/To	Departures	Stops
„Rhein-Express“ , RE 5, every 60 Minutes, from Emmerich		
Koblenz Hbf	04:33 05:33 06:36 07:40 08:36 09:40 10:36 11:40 12:36 13:40 14:36 15:40 16:36 17:40 18:36 19:40	Emmerich, Oberhausen, Duisburg, Düsseldorf, Köln, Bonn, Remagen, Andernach, Koblenz Hbf
„Rhein-Express“ , RE 5, every 60 Minutes, to Emmerich		
Koblenz Hbf	05:16 ... (16 trains) 20:16	Koblenz Hbf, Andernach, Remagen, Bonn, Köln, Düsseldorf, Duisburg, Oberhausen, Emmerich

6.4.2.8 Goods trains through Emmerich

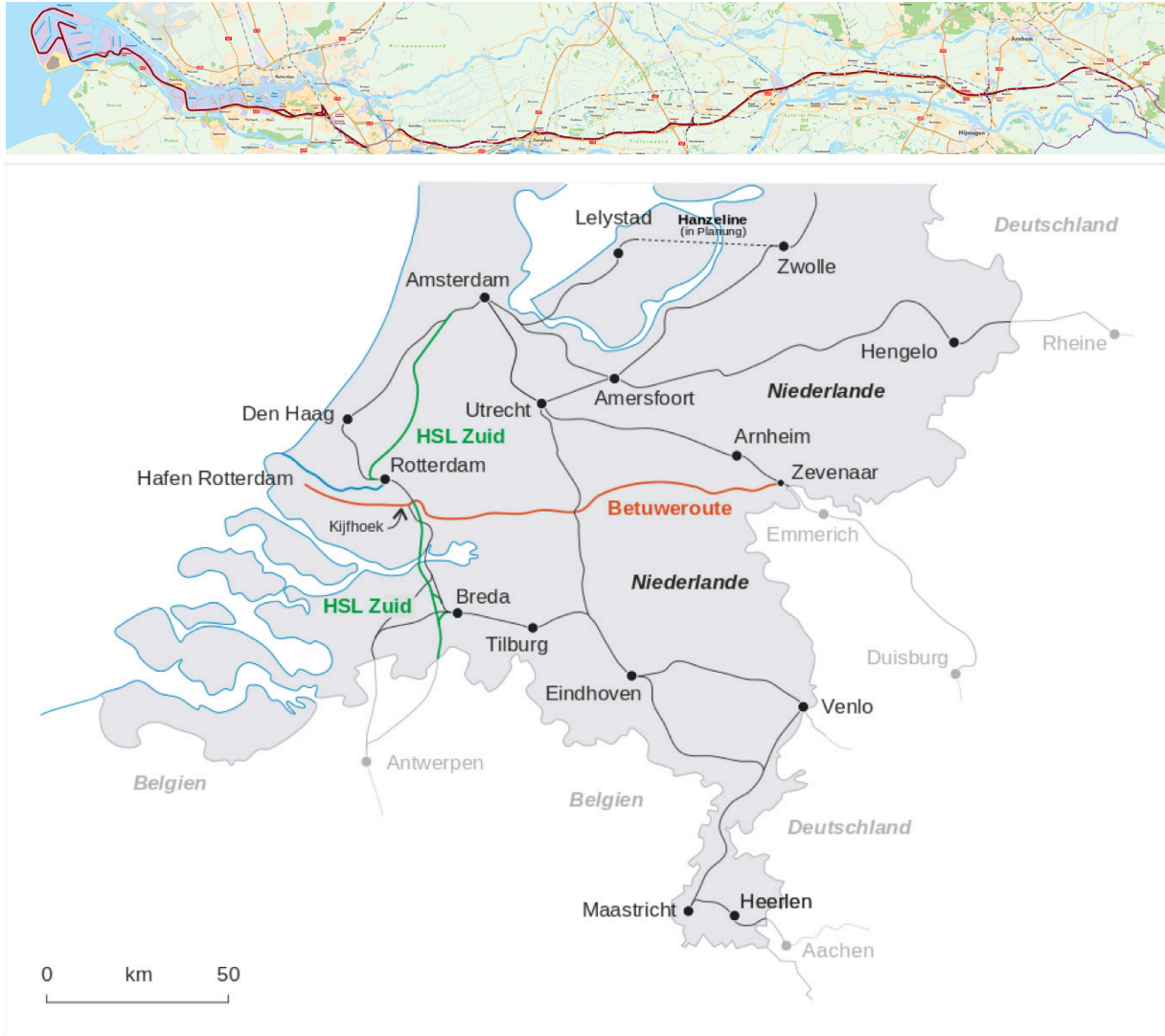


Figure 30: Goods train Betuwe-route from Rotterdam to the German border near Emmerich^{28 29}

The Betuwe-route is the main transportation line for goods trains between Rotterdam harbour and Germany, also as a freight transit connection to Switzerland and Italy (European hinterland). Use of the Betuwe-route started in 2008 with approximately 200 freight trains a week in both directions. The number of trains increased to 440 trains a week in 2011 and about 450 trains a week in 2012. In 2011 about 73% of goods trains used the Betuwe-route³⁰.

6.4.2.9 Signalling / Blocks

Railway security is achieved by dividing railway tracks into routes. A train may only enter a route if the corresponding signal for the route is free, i.e. no other train occupies that route. If a train occupies a route, then the route is blocked for other trains, indicated by a stop signal.

²⁸ <http://www.keyrail.nl/images/trace/betuwroute-afbeelding.new.png>, 2015-06-08

²⁹ <http://de.wikipedia.org/wiki/Betuwroute>, 2015-06-11

³⁰ <http://de.wikipedia.org/wiki/Betuwroute>, 2015-06-11

A sequence of routes is lined up to a path or itinerary that defines start and destination for trains. While a train is traveling along an itinerary one route after the other is signalled free or blocked depending on train occupations.

6.4.2.10 Railway Control Centre

In May 2012 a new Electronic Railway Control Centre (ERCC) was put into operation. This ERCC replaces six old analogue control centres and is responsible for the signal control and switch points from Oberhausen to the border of the Netherlands.³¹ The communication is digital and therefore potentially susceptible for cyber-attacks.

6.4.3 Modelling with OpenTrack

In this section we will describe how we modelled the railway network depicted in Figure 24.

6.4.3.1 Which elements are modelled?

To get a running OpenTrack model the following elements are required:

Railway network data

- Tracks
 - nodes to model positions in the railway network
 - edges contain distances between nodes in meters
- Stations constructed from
 - Station nodes marking all station tracks
 - Station buildings
 - Main signals for stations: home signal and exit signal
 - Stop signals at station nodes indicating the position of a stopping train
 - Groups of all station elements of a dedicated station



- Railway connections
 - Routes from signal to signal
 - Paths as a sequence of available routes to establish itineraries
 - Itineraries from a departure station to a destination station, containing all intermediate stops

Rolling stock data

- Trains
 - Machines – load, max. speed, resistance factor, tractive effect, Z/V-diagram, resistance equation, etc.
 - Trailers – load, length

Timetable data

- Courses/Services definition
 - Itineraries

³¹ <http://www.rp-online.de/nrw/staedte/emmerich/das-bringt-das-neue-stellwerk-aid-1.2790226>

- Trains
- Time parameters for all courses/cervices
 - Courses
 - Times

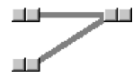
6.4.3.2 Modelling of tracks

Tracks in OpenTrack are modelled as a connection of two double-nodes. Each double-node sketches an incoming and an outgoing part. Each part of a double-node may have at most two incoming or outgoing edges. Connection edges are parameterised with length in meters.

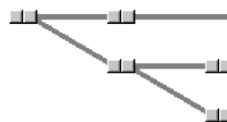
Modelling with double-nodes avoids additional information on switches. Either a track coming in branches into two alternative tracks,



or two incoming tracks are merged to be continued on one single track.



No other modelling of switches is possible, i.e. no triple incoming or outgoing is possible. If more than two tracks have to be merged or branched additional double-nodes have to be inserted.



6.4.3.3 Simplified model of the railway network around Emmerich

To consider railway redirections, a simplified (one direction) model of the railway network is shown in Figure 31.

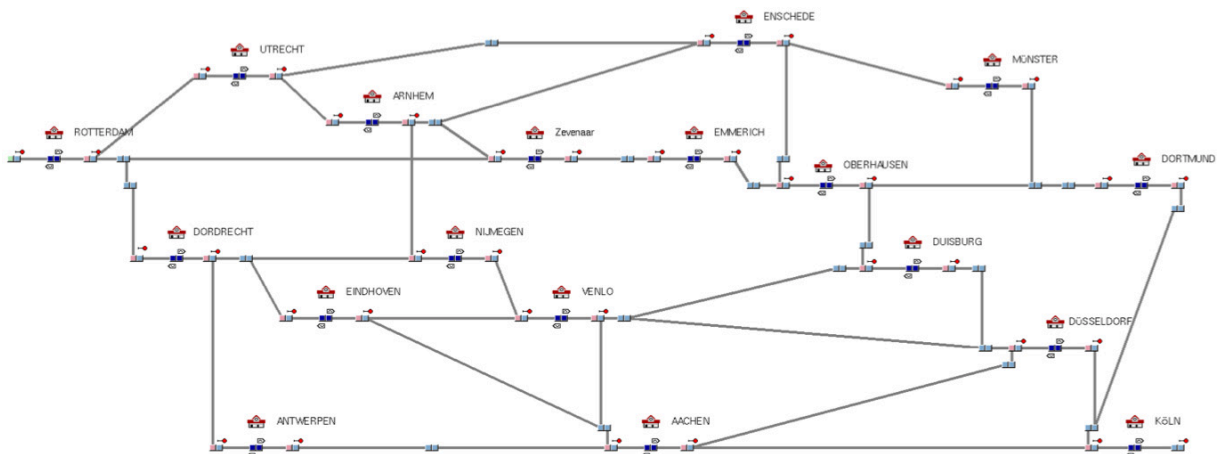


Figure 31: Schematic sketch of the model of the railway network in OpenTrack

Considering goods trains from Rotterdam to Cologne (Köln) the regular service is ROTTERDAM (NL) → ZEVENAAR (NL) → EMMERICH (DE) → OBERHAUSEN (DE) → DUISBURG (DE) → DÜSSELDORF (DE) → KÖLN (DE). In cases of blocked tracks from an incident in Emmerich redirections are required. Due to the high frequency of goods trains – in 2015 expected number of 125 trains through Emmerich – the trains have to be distributed on different routes through the Netherlands, Belgium, and Germany.

6.4.4 Interconnections to other CIs

Power networks

Railway facilities are connected to electricity infrastructure mostly by private power supply networks. Deutsche Bahn has its own private supply, DB Netze Energie (DB Energie GmbH). On their website³², they state that

“DB Energie is responsible for the management of 16.7 Hz traction current and direct current supply and thus provides the day-to-day basis for electrical railway operations in Germany. The company supplies energy to trains run by all railway undertakings which use 16.7 Hz traction current or direct current on the approx. 18,800 km electrified lines of Deutsche Bahn.”

DB Energie GmbH also supplies the 5700 railway stations located nationwide as well as the areas surrounding the stations and other railway facilities. Within the railway stations there are “around 1.5 million square metres of space that is used for commercial and business purposes. About 850,000 square metres of this area is leased to commercial companies. The rest is used by the DB Group itself for travel information centres, passenger lounges or administrative offices.”

Telecommunication network

DB Kommunikationstechnik³³ is the daughter company of Deutsche Bahn AG that handles security technology, automatic transaction machine, multimedia information systems and IT services as well as media and communications services. Like the DB Energie GmbH supplies a private power supply network for the German railway it is supposed that also the railway telecommunication network is a private network, owned by DB Kommunikationstechnik³⁴.

It has to be noted, that the DB Kommunikationstechnik is not responsible for the communication links between signals, control elements and the railway control centres. This is still part of the Deutsche Bahn AG.

Supply chain

Deutsche Bahn has diesel locomotives that depend on a supply with diesel fuel.

Train restaurants depend on supply of food and beverages.

The commercial facilities in railway stations depend on supply of food, beverages, and merchandising articles.

Miscellaneous (completeness not guaranteed)

Railway staffs in offices, stations, and other operating facilities depend on functioning infrastructures like energy infrastructure, drinking water supply, waste water systems, telecommunication systems, IT infrastructure, and more.

Deutsche Bahn AG also operates the largest privately owned sewer system in Germany.

³² http://www.deutschebahn.com/en/business/infrastruktur_schiene/energie/2211820/portfolio.html and <http://www.deutschebahn.com/de/geschaefte/infrastruktur/energie/3278416/unternehmensportrait.html?start=0>

³³ http://www.deutschebahn.com/de/geschaefte/it_tkinfrastruktur/db_kommunikationstechnik.html

³⁴ http://www.dbkommunikationstechnik.de/dbkt-de/start/im_profil/portraet.html

7 Lessons learned in modelling

In Section 4 the SyMo models are presented and elaborated. SyMo itself consists of different building blocks that provide substantial capabilities to model complex crisis scenarios involving multiple CI. However, in order to develop the scenario model presented in Section 5, only a small subset of the SyMo functionality is applied. The modelling work is done primarily by the lead developer of the SyMo software due to his comprehensive understanding of SyMo and limited documentation available. To improve this, the documentation work of the scenario editor, which is based on SyMo, will be improved in the forthcoming development phase: more team members should be able to handle the software and extend the current model if necessary. On the other side, from a pure modelling perspective, a good strategy to create fine-grained models is to start with a basic and coarse-grained rough model that contains the essential core elements to be handled. After that, different improvement can be applied to that simplified model and extend it step by step to build more concrete and detailed models while keeping the correctness and soundness.

In Section 5 the current approach for flood models was described. It has been discussed that all flood scenarios used in the CIPRTrainer are pre-computed due to the enormous computational effort for such a flood model. This is however not fully favourable for the intended use of the CIPRTrainer, as it limits the availability of flood scenarios and different human interventions in the WIA module, which is part of the CIPRTrainer application.

Currently, new interactive flood simulators are developed by Deltares, such as SOBEK3 or 3Di. Interactive models allow for inventions at any given time step, e.g. by changing boundary conditions or the elevation model (virtual dikes). The use of such flood simulators would substantially support the goals of CIPRTrainer, as human interactions or new situations, e.g. changed boundary conditions or dike breaches, can be calculated and provided for the federated modelling. The coupling of interactive flood models and federated CI models should therefore be investigated in future research projects.

In Section 6.2, the electrical network model, transmission networks in particular, is presented and elaborated. During the modelling of the transmission network in the Emmerich area, it turned out that most of the data needed is available to the public and on an appropriate level of details. The data adopted in the current model is partially based on OpenStreetMap and most of them seem to be valid (for instance, after comparing the geo location with other Google satellite images). The ENTSO-E database can serve as a mean for verification. However, as OpenStreetMap data is collected by volunteers, there is no guarantee that everything matches the real world. However, for the intended research prototype, these public available data sources are sufficient. The model of the transmission network around Emmerich is created manually based on the available data. An automatic extraction of all relevant power lines and substations from other data sources and then converting them to SINCAL recognised models turn out to be a challenging task that would require a significant amount of development work. The reason for this is that the OpenStreetMap-based data is mainly geometrical information, whereas the model used in SINCAL is more on a network-topological level, which is illustrated as a schematic diagram. However, with some experiences, manually creation of a transmission network model in SINCAL should be feasible within a reasonable amount of time even for larger networks. Nevertheless, if time permits, it is always a better alternative to automatically or semi-automatically convert the data from other source into the format that SINCAL accepts. This approach would save a huge amount of time if any errors are detected in the original data source or the original data sources are updated. Repeating the model creation work by hand would be a time-consuming, error-prone and tedious work.

As for the telecommunication network model discussed in Section 6.3, we learnt that it is important to have realistic information about the network topology, its configuration, dependen-

cies, and behaviours of user. Currently, it is difficult, if not impossible, to retrieve such data using publicly available data sources; therefore our model is based on several assumptions and simplifications that may not necessarily hold in a real world. For the purpose of CIPRNet research activities however, the simplified model should be sufficient.

Another problem encountered during the telecommunication network modelling is the limitation of ns-3 modeller. For example, the GSM model in the current implementation of ns-3 is replaced by other mobile technologies like WiMax (for long-range wireless communication) and LTE or WiFi (for short-range wireless communication). This makes the modelling work more challenging since some fundamental modelling blocks are missing. However, this should not influence the final analysis of CI interdependencies as long as we are interested in assessing the connectivity between different network segments without performing deep analysis of telecommunication characteristics, which are strongly related to the physical channels.

Finally, for the CAM we learned that there are a multitude of methods, which deal with consequences, but there are no general accepted concept of consequence and CA. Any advancement in this area would be beneficial for future work. Another issue is, that the proposed methods are either very general or very detailed and domain specific. There is a clear lack of methods on a “meso”-level (between micro and macro level). This gap in the literature needs to be filled with future research.

8 Conclusion

This deliverable, D6.3, described the heterogeneous modelling activities for creating one of CIPRNet’s new capabilities: ‘what if’ analysis based on federated modelling, simulation and analysis of critical infrastructures. The application that realises this capability is called CIPR-Trainer and will be used for providing crisis managers an added-value training that allows exploring different courses of action. The conceptual architecture for CIPRTrainer was described in deliverable [CIPRNetD61]. The basis for the modelling activities described here was the deliverable [CIPRNetD62].

D6.3 goes beyond the initially planned contents – federate CI models – in several aspects by including:

- A comprehensive description of the data sources for the models, their issues, and contingency measures for cases where data was missing
- Inclusion of a first description of the scenario model editor SyMo
- Describing the process of constructing several of the models and lessons learned during this process (“best practices”)
- Models of external threats, responders, and response and mitigation actions

The best practices experiences gained during the modelling process will help making this document a solid foundation to develop further models.

In order to provide a holistic view about the complete ecosystem of CIPRTrainer, we have also elaborated which components of CIPRTrainer require which models as guidance to the reader. We started by giving an overview about the implementation structure of the software system of CIPRTrainer. It is provided to give necessary information about the runtime environment of the created models. The CIPRTrainer software system has two parts: the **design** and **analysis** part, which correspond to the scenario design and training analysis phase of training; and the **runtime** part, which contains the GUI of the training application (including geospatial data like background maps and spatial layers), the CI simulators and models, and the event processor that controls the master workflow of the runtime part.

As the basis of the design and analysis tool, SyMo is briefly introduced in Section 4. To illustrate the SyMo modeling capabilities, the document includes a number of sample (preliminary) models, including the response related parts. In Section 5, we describe how the flooding models are created. They will be used for simulating the evolution of the flood in the second storyline of the Dutch-German cross-border flooding scenario described in D6.2. Both the SyMo models and the flood models model aspects that lie outside the federate CI models (like threats and incidents causing a disaster).

Creating models for domain-specific simulators is a complex task, which requires the close collaboration between domain experts and system modellers. To conduct the modelling process, a list of publicly available data sources is prepared at first. After that, separate datasets are retrieved and analysed by domain experts to assess its correctness and level of details. All these data sources are collected and presented in Section 3.

Based on the available data and the model requirements of the chosen domain-specific simulators, the relevant models could be created. The CI domain models comprise models of the **electrical transmission and distribution network** (for the simulator SIEMENS PSS SIN-CAL®), the **telecommunication network** (for the simulator ns-3), and the **railway systems** (for the simulator OpenTrack).

Finally, the experiences gained and lessons learned during the construction of various models are discussed in Section 7. It provides a general summary of the rationale and best practice about modelling different scales of CI and the threats, flooding in particular. For the special – but not rare – cases of incomplete or missing data, where a model of the real CI cannot be

constructed, we suggest to construct technically correct realistic models that are well suited to fulfil the research and demonstration purpose. For a deployment of the system into practical application, the realistic models could be replaced by real models, provided that the end-users would grant CIPRTrainer the access to the real data or ready-made models.

It should be noted that the modelling activities are not yet fully completed. We will first complete the derailment storyline and test it with the integrated CIPRTrainer prototype when it is ready. In parallel, we are working on getting more data from the Netherlands for completing the second storyline, the flooding incident. In addition, the best practices will be further applied to extend the models or create new models based on the new or newly disclosed data.

Regarding the next task “system implementation” in Work Package 6, the implementation details will be elaborated in D6.4 together with the methodology of model integration and WIA-based training. The models as the major output of D6.3 will provide one of the core components to develop a fully functional crisis management training system.

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Glossary

Attribute	Each component can have at least one attribute. Attributes have a name, a data type and a certain value. One can distinguish between basic attributes (e.g. the capacity of a generator or the amount of electrical power consumed by a consumer) and derived attributes (e.g. the load in a distribution line) which are calculated using the basic attributes.
Cascading failure	“A cascading failure occurs when a disruption in one infrastructure causes the failure of a component in a second infrastructure, which subsequently causes a disruption in the second infrastructure.” (source: [Rinaldi2001])
CI model	A \rightarrow CI model is a particular \rightarrow conceptual model for representing and simulating the behaviour of a \rightarrow critical infrastructure. For a network-like \rightarrow CI, the network topology part of the model consists of \rightarrow components and \rightarrow connections between them.
Component	A (network) component is an object in a \rightarrow CI model e.g. a generator, a pump, a transmission line, a physical transport, a node, a substation. Components have \rightarrow attributes and \rightarrow user-specified behaviour.
Conceptual model	A conceptual schema or conceptual data model is a map of concepts and their relationships. This describes the semantics of an organisation and represents a series of assertions about its nature. Specifically, it describes the things of significance to an organisation (entity classes), about which it is inclined to collect information, and characteristics of (attributes) and associations between pairs of those things of significance (relationships). (source: www.wikipedia.com)
Connection	Connections describe links between different \rightarrow components in a \rightarrow CI model. E.g. a generator can be linked to a transmission line. Connections may be realised as \rightarrow attributes but should be handled differently in the GUI due to their importance for network modelling.
Consequence	Outcome of an \rightarrow event affecting objectives NOTE 1 An event can lead to a range of consequences. NOTE 2 A consequence can be certain or uncertain and can have positive or negative effects on objectives. NOTE 3 Consequences can be expressed qualitatively or quantitatively. NOTE 4 Initial consequences can escalate through knock-on effects. (ISO Guide 73)
Crisis	Any \rightarrow incident(s), human-caused or natural, that require(s) urgent attention and action to protect life, property, or environment (ISO/PAS 22399:2007)
Disaster	\rightarrow Event that causes great damage or loss (ISO/PAS 22399:2007)
Discrete event simulation	In discrete event simulation, the \rightarrow system-specified behaviour is described as a series of \rightarrow (simulation) events that must be processed at a discrete point of the simulated time and that take a certain amount of real time. An event scheduler manages \rightarrow (simulation) events and usually enables offline simulations. Nevertheless, some simulators integrate real-time \rightarrow (simulation) events schedulers permitting online simulations. Online simulation requires taking into account inputs from the real network or from an application and the output of data that will be re-injected in the real network or sent to the application.
Emergency	Sudden, urgent, usually unexpected occurrence or \rightarrow event requiring immediate action (ISO/PAS 22399:2007)
Event	Occurrence or change of a particular set of circumstances NOTE 1 An event can be one or more occurrences, and can have several causes.

	NOTE 2 An event can consist of something not happening. NOTE 3 An event can sometimes be referred to as an “incident” or “accident”. NOTE 4 An event without consequences can also be referred to as a “near miss”, “incident”, “near hit” or “close call”. (ISO Guide 73)
Hazard	Source of potential harm (ISO guide 73); In CIPRNet the term → <i>threat</i> is preferred
Incident	→ <i>Event</i> that might be, or could lead to, an operational interruption, disruption, loss, → <i>emergency</i> or → <i>crisis</i> (ISO/PAS 22399:2007)
Mitigation	Limitation of any negative → <i>consequence</i> of a particular → <i>incident</i> (ISO/PAS 22399:2007)
Scenario	A scenario consists of a → <i>CI model</i> , the initial states of all → <i>components</i> and the → <i>scenario behaviour</i> that describes the → <i>events</i> that happen within the scenario.
Scenario behaviour	The scenario behaviour describes the “normal” → <i>events</i> that happen within a → <i>scenario</i> (e.g. a consumer changes the amount of electrical power that is consumed). The → <i>events</i> may be triggered by time or by other conditions defined in the scenario behaviour.
(simulation) event	A (simulation) event describes what happens to a → <i>component</i> in the → <i>CI model</i> if a condition is fulfilled, e.g. the tripping of a transmission line at a certain time.
System-specified behaviour	System-specified behaviour is behaviour of → <i>components</i> or → <i>scenarios</i> that is either too basic or too complicated to be described as → <i>user-specified behaviour</i> and therefore has to be implemented in a programming language by a developer.
Threat	Potential cause of an unwanted → <i>incident</i> , which may result in harm to individuals, a system or organisation, the environment or the community (ISO/PAS 22399:2007)
User-specified behaviour	User-specified behaviour is behaviour that can be designed and modified by the user using a special language for behaviour definition. User-specified behaviour can invoke other user-specified behaviour or → <i>system-specified behaviour</i> .
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a → <i>hazard</i> . (UDDR)

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List of Acronyms

AC	Alternating Current
API	Application Programming Interface
BASt	Bundesanstalt für Strassenverkehr (Federal Highway Research Institute)
BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (German Federal Office of Civil Protection and Disaster Assistance)
CA	Consequence Analysis
CC	Communication Controller
CE	Communication Element
CI	Critical Infrastructure
CIP	Critical Infrastructure Protection
CL	Communication Layer
CM	Crisis Management
COTS	Commercial off-the-shelf
DB	Deutsche Bahn AG
DC	Directed Current
DE	Two letter ISO code for Germany (Deutschland)
DES	Discrete Event Simulation
DSS	Decision Support System
ECI	European Critical Infrastructure
ENTSO-E	European Network of Transmission System Operators Energy
FCM	Federation Control Module
FOM	Federation Object Model
FONT	Federation Ontology
fMS&A	Federated modelling, simulation and analysis
FTP	File Transfer Protocol
GIS	Geographical Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HLA	High Level Architecture
HTTP	Hypertext Transfer Protocol
Hz	Hertz
ICT	Information and Communication Technologies
IONT	Infrastructure Ontology
IP	Internet Protocol
KBS	Knowledge Based System
kV	kilo Volt
LAN	Local Area Network
MS&A	Modelling, simulation and analysis

NL	Two letter ISO code for the Netherlands (Nederland)
NTP	Network Time Protocol
NRW	North Rhine-Westphalia
OS	Operating System
OSM	OpenStreetMap
OWL	Web Ontology Language
P2P	Peer-To-Peer
POI	Point of interest
SOA	Service-Oriented Architecture
SONT	Simulator Ontology
SWRL	Semantic Web Rule Language
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/ Internet Protocol
TMM	Time Management Module
WIA	'what if' analysis
XML	Extensible Mark-up Language