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RAPID-N
Rapid Natech Risk Assessment Tool

User Manual
Version 1.0

Serkan Girgin

2012

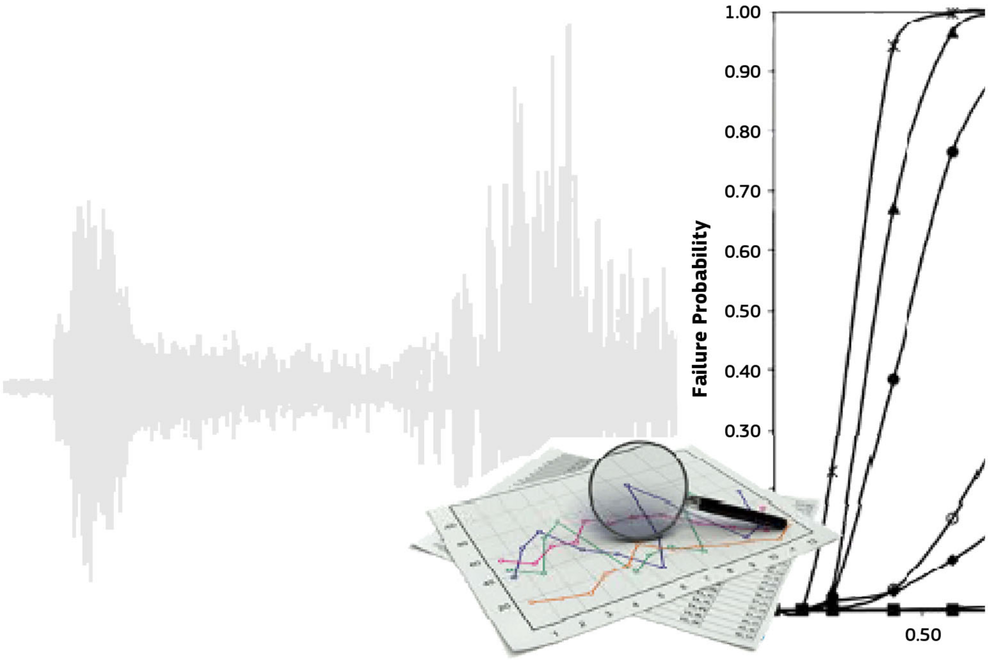

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Table of Contents

List of Tables

List of Figures

1 Introduction

Major accidents at chemical process facilities, which are triggered by natural hazards, can have serious consequences on the population, the natural and built environment, and the economy (Girgin, 2011; Krausmann and Cruz, 2008; Young et al., 2004; Showalter and Myers, 1994). Termed natechs, the risk of such accidents is expected to increase in the future due to the growing number of industries, the predicted change of natural hazard occurrence patterns due to emerging factors such as climate change, and the increasing vulnerability of the society that is becoming gradually more interconnected (iNTeg-Risk, 2010). Adequate preparedness and proper emergency planning are needed for the prevention of natechs and the mitigation of their consequences.

For this purpose, natech-prone areas should be identified and natech risks must be assessed in a methodical way. A recent survey has shown that hardly any natech risk maps exist within the EU or OECD. Where existing, natech risk maps simply overlay natural and technological hazards without considering site-specific features or the interaction of hazards (Krausmann and Baranzini, 2012). The need for a proper and systematic natech risk-mapping methodology is therefore evident.

In order to address this need, a probabilistic natech risk-mapping methodology was developed. The methodology is based on the calculation of damage probabilities at process and storage units of industrial facilities for different damage states, and the estimation of nature and extent of natech event consequences that may be caused by the natural hazard damage. For hazard damage assessment, on-site natural hazard parameters are calculated from hazard scenarios and fragility curves are used to determine damage states and corresponding probabilities. For natech risk assessment, damage states are converted into risk states that define probable consequence scenarios. Distances to the consequence endpoints are calculated by using the simplified modeling approach of the U.S. EPA Risk Management Program (RMP) Guidance for Offsite Consequence Analysis (U.S. EPA, 1999).

The methodology is implemented as a web-based software application, RAPID-N, which allows easy and user-friendly data entry, complementary data estimation, and rapid risk assessment. The results are presented as summary risk reports and natech risk maps.

The application features an integrated framework for natech risk assessment by providing data management and analysis tools for triggering natural hazards, industrial facilities and process units, hazardous substances, natechs, and natech damage. In order to facilitate risk assessment calculations, an extendable property estimation library was developed that can be used to calculate hazard parameters and site, process unit, and chemical substance properties. An expert system is provided for the selection of appropriate estimators based on the characteristics of related entities, input data availability, and geographic location. The importing of readily available hazard maps is also supported for hazard parameters. A basic set of fragility curves from the literature is provided for the damage assessment. If needed, custom damage states can be defined and fragility curves can be created for different types of process and storage units using past natech accident data and statistical curve-fitting methods. Conditional and non-linear probabilistic relations can be defined between natural hazard damage states and triggered natech events, which are used to model consequences. The results of the risk assessment can be obtained rapidly as summary risk reports and interactive risk maps.

The methodology and the RAPID-N application can be used for developing natech risk maps for land-use and emergency-planning purposes by using scenario hazards, or for rapid damage and consequence estimation immediately after the occurrence of a natural event. The web-based, online architecture of the application facilitates rapid damage and risk assessment.

1.1 About the Document

This document aims to provide basic information about the implementation and usage of the Rapid Natech Risk Assessment Tool: RAPID-N.

Following a short description of the technical details and components of the application, the user interface is described. Record-related common tasks are introduced and forms used for data entry are explained. Special features, such as multilingual support, fuzzy numbers, record locking, and mapping are described. Record types and tools that form the application are grouped into modules and detailed information is given for each record type in a separate subsection. Information on record types include general description, structure of data fields, details on data entry, and record specific statements, such as implementation details of related calculation methods and algorithms.

For each record type, a data field table is provided to summarize data that is contained in the record. Types of data fields are stated with reference to their form element types, details of which are given in the "Form Elements" section. Groups of form elements are listed under italic headings. Dynamic lists are indicated with **'List:'** prefix and their data items are listed as indented and in gray. Mandatory data fields are indicated by an asterisk (*) next to the field name. A list indicated as mandatory implies that at least one list row should be entered. If data fields are only available under certain conditions, these conditions are indicated as footnotes at the bottom of the table. For text data fields, the maximum allowable length of data is indicated in parenthesis next to the type definition. Special features of data fields (e.g. unique, multilingual) are indicated in parenthesis after the description. A sample annotated data field table is given in Table 1.1.

Table 1.1 Sample data field table

Field	Type	Description
Field A*	Text (64)	Mandatory, multilingual text field with a maximum length of 64 characters (multilingual)
Field B	Drop-down	Optional drop-down list field. Options are given as bulleted list: • Option A • Option B • Option C
Field C [1]	Unit	Unit field, available only if condition given in Footnote 1 is valid
Field Group		
Field D* [2]	HTML (64)	HTML field with a maximum length of 64 characters, available only if condition given in Footnote 2 is valid

Field	Type	Description
Field E	Fuzzy Scientific	Scientific number field supporting fuzzy numbers
LIST: List A*		*(Dynamic list with at least one mandatory row)*
Field A*	Token (8)	Mandatory token field with a maximum length of 8 characters
Field B*	Text (64)	Mandatory text field with a maximum length of 64 characters

[1] Available if **Field B** is **Option A**

[2] Available if **Field C** has a value of **Value A**

1.2 Acknowledgements

The research was financially supported from November 2010 to October 2011 by an International Post-doc Research Grant (2219) of the Scientific and Technological Research Council of Turkey (TUBITAK).

2 RAPID-N

RAPID-N is an open and collaborative web-based application. The primary aim of the application is rapid natech risk assessment and mapping with minimum data input. It has a database component for data storage and retrieval, and offers a rich set of analysis and data visualization tools. The application provides a user-friendly interface with advanced form elements, reporting tools, and a mapping component for the visualization of spatial data.

The software application has client-server architecture and features a multi-user environment with different levels of privileges. The server side (application) was developed with PHP programming language and works on a HTTP/1.1 compatible web server. The client side (user interface) is XHTML 1.0 Transitional, CSS 2 and JavaScript 1.5 compliant and works on common web browsers, such as Microsoft Internet Explorer, Mozilla Firefox, Google Chrome, Opera, and Apple Safari. The application uses MySQL as database management system. The relational, transaction safe (ACID safe) InnoDB storage engine of MySQL is used to store and query data. Google Maps API is utilized for geographical data visualization and mapping.

The application uses a custom web application development framework, which features XML-based record data and form definitions, advanced form elements, client and server-side data validation, automated data entry, modification, query, and display page generation, and logging support. It has a scientific computation library containing functions for descriptive statistics, interval arithmetic, fuzzy arithmetic, fuzzy statistics, interpolation, and unit conversion. It also contains a GIS library for spherical geometry calculations, proximity analysis, and mapping support. RAPID-N uses the framework to construct the user interface and define records needed for natech risk assessment. The analysis methods and algorithms also utilize scientific and GIS libraries provided by the framework.

RAPID-N has a modular structure. The modules are self-competent systems, which are closely linked to each other, with each focusing on a specific aspect of natech risk assessment. Each module covers several record types and includes all data entry interfaces, database queries, methods and tools related to those record types. There are six modules in the system:

- **Scientific Tools** module provides basic support for bibliographic citation, unit conversion, and GIS analysis. A generic entity property definition and estimation framework is also in this module.

- **Natural Hazards and Natechs** module includes source- and site-specific natural hazard information including catalog data. Natechs and natech related structural damage information is also covered.

- **Facilities and Process Units** module stores information on industrial facilities, process units, hazardous substances, and site characteristics.

- **Risk Assessment** module is the main module of the application and covers all functionalities required for natech risk assessment, including damage classifications, fragility curves, and risk states.

- **Administration** module supports web-related tasks and the management of the application.

- **Development Tools** module provides tools to facilitate further development of the application.

3 User Interface

RAPID-N can be accessed from http://rapidn.jrc.ec.europa.eu by using a web browser. The homepage of the application displays a map of recent natural events. Details of an event can be obtained by selecting it on the map. This information also includes natech risk assessments of the natural event, if they are publicly available. Links to common pages, such as legal notice, links, and contact form are given in the top menu. The top menu also includes a language drop-down list, which can be used to change the language of the application, and a link to the login page. Registered users can logon to the application by providing their e-mail address and a password. Registration is free and can be done from the registration page accessible from the login page by providing basic personal information. Once logged on, users can assess all records and tools from the personal page (Figure 3.1).

Figure 3.1 Personal page with access to records and tools

For each record type, the system provides standardized task pages to create, update, view, list and delete records (Figure 3.2). Listing pages can be accessed by clicking the icons available on the personal page. Records can be queried on listing pages by using various record-specific criteria. Found records are displayed in tabular form. The number and order of records in the table can be adjusted by changing the listing settings. A new record can be created by using “create page” available through the “create” button. Detailed record information can be obtained on the “record information page”, which is accessible by selecting the record from the listing page. Record view pages also contain a record history summary and a list of related records, maps, and other data visualization elements such as line plots. “Update” and “delete pages” of the record can be accessed by using the related buttons. “Update page” is similar to “create page” and is composed of a record-specific dynamic data entry form containing various form elements. It features data standardization and validation. Details of the data entry forms are given in the “Forms” section. Records can be deleted from “delete pages” by approving the action. The modification and deletion of records is restricted by user privileges. See the record-specific sections of the document for more details.

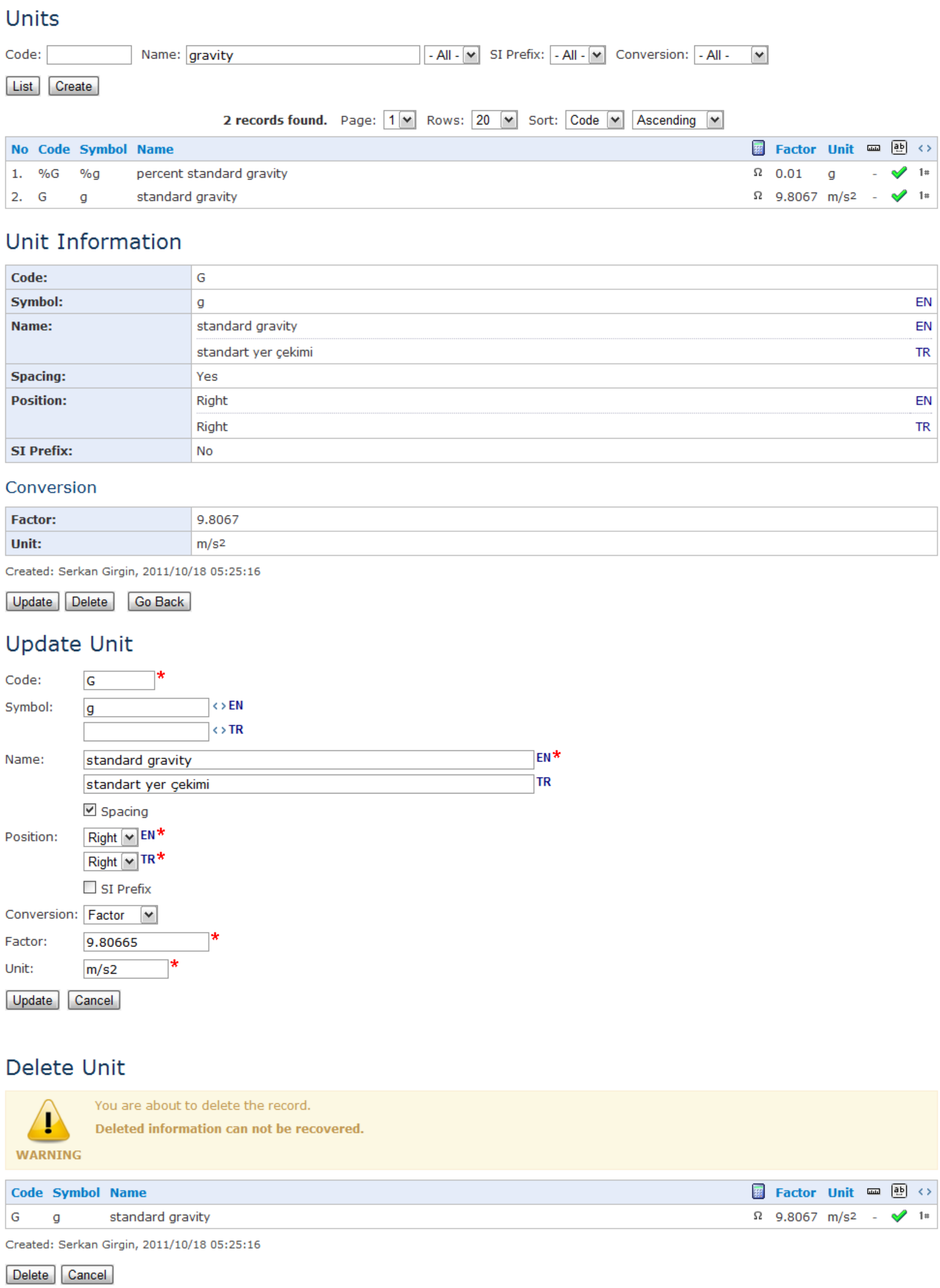


Figure 3.2 Sample record-related task pages

3.1 Forms

Data entry to the system is done through data forms working on web browsers. Data forms include standard user interface elements, such as text fields, drop-down lists, check boxes, and enhanced elements, such as wiki editors and calendars (Figure 3.2). Some of the form elements are dynamic and activated/deactivated according to values of other form elements. Data fields that should not be left empty are indicated by an asterisk (*). Text fields are generally restricted to entry of specific types of data, such as integer numbers, dates, or coordinates. Generally, such fields are indicated by special icons next to the field elements. The system supports fuzzy numbers for selected numeric data fields and multilingual data entry for selected form elements.

Form data is validated on the client side before submission of information to the server. If missing or invalid fields are found, they are displayed in yellow and indicated by using an exclamation mark (⚠) next to the related form element. A warning dialog is also displayed. After the submission, form data is validated for the second time on the server to prevent unauthorized actions and determine invalid fields that cannot be determined on the client side. Server-side validation of data prevents possible data-intrusion attacks, to which on-line systems are susceptible. Identified errors are indicated at the top of the form (Figure 3.3).

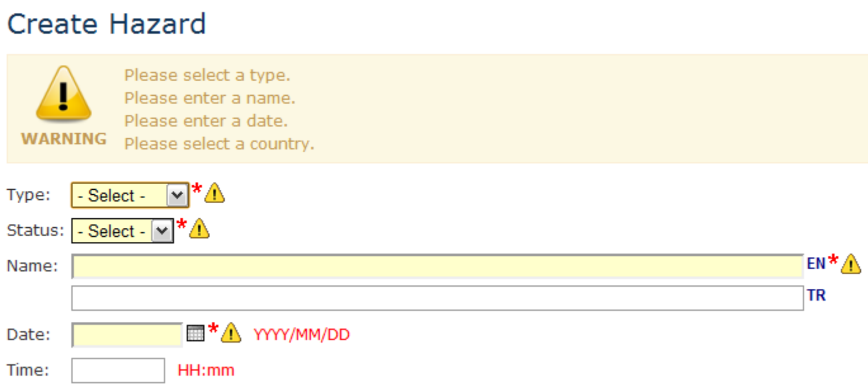


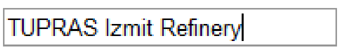
Figure 3.3 Form validation

3.1.1 Form Elements

Besides standard HTML form elements, RAPID-N also provides a rich set of advanced form elements to facilitate data entry. The supported form elements are described below:

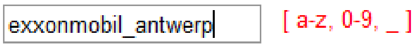
REMARK: Form elements may appear differently in different web browsers.

Text



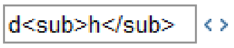
Standard single-line text field.

Token



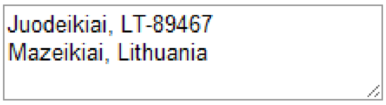
Single-line text field restricted to basic characters of the Latin alphabet (a-z), numbers (0-1), and underscore (_). String literal may be in lowercase depending on the context. Examples: natural_hazard, k2

HTML



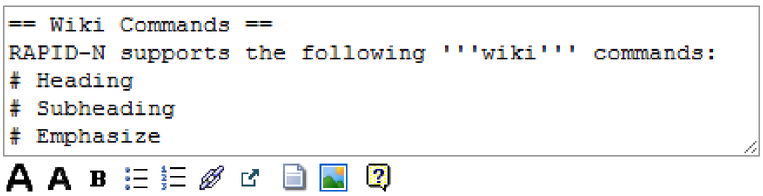
Single-line text field, which supports XHTML tags and entities. All XHTML entities and the following XHTML tags are supported: (bold), <i></i> (italic), (subscript), (superscript). Refer to W3C XHTML Recommendation for a complete list of supported entities (W3C, 2002). Examples: PGA_h, x²

Textarea



Standard multi-line text field.

Wiki



Multi-line text field supporting wiki tags. Wiki elements use a simple markup language to create formatted text output. Headings, lists (ordered and un-order), links (internal and external), images and inline contents are supported. Available wiki commands are listed in Table 3.1.

Table 3.1 Wiki commands

Icon	Command	Description

	Heading	To define a heading, enter the heading between == == tags.
		Syntax:
		`== Heading ==`
		`Information under the heading...`
		Output:
		Heading
		Information under the heading...

Icon	Command	Description

	Subheading	To define a subheading, enter the subheading between === === tags.
		Syntax:
		`=== Subheading ===`
		`Information under the subheading...`
		Output:
		Subheading
		Information under the subheading...

	Emphasize	To emphasize some words within the text, enter the words between ''' ''' tags. **Syntax:** `Emphasizing '''selected words'''.` **Output:** Emphasizing **selected words**.

	List	To define a list of items, enter each item separately to a new line starting with *.
		Syntax:
		`* Item 1`
		`* Item 2`
		`* Item 3`
		Output:
		▪ Item 1
		▪ Item 2
		▪ Item 3

	Ordered List	To define a list of items, enter each item separately to a new line starting with #.
		Syntax:
		`# Item A`
		`# Item B`
		`# Item C`
		Output:
		1. Item A
		2. Item B
		3. Item C

	Internal Link	To create a link to an internal page, enter the address of the page between [[ ]] tags. **Syntax:** `[[contact]]` **Output:** contact

Icon	Command	Description
		If you want to display a text instead of the page address, enter the text within the tag following a **|** after the address. **Syntax:** `You can access contact page from [[contact|here]].` **Output:** You can access contact page from here.

	External Link	To create a link to an external web page, enter the address of the page between **[ ]** tags.
		Syntax:
		`[http://www.google.com]`
		Output:
		http://www.google.com
		If you want to display a text instead of the page address, enter the text within the tag following a **|** after the address.
		Syntax:
		`Visit Google's [http://www.google.com|web site].`
		Output:
		Visit Google's web site.

Code

```
if ([NEHRP] == 'B') $S = 0;
if ([NEHRP] == 'C') $S = 1;
if ([NEHRP] == 'D') $S = 2;
return exp(4.16+0.69*[Mw]+1.24*log([de:km]+6)+0.12*$S);
```

Multi-line text field supporting function codes. PHP codes can be entered in these fields. Property estimators support an enhanced version of code fields. See Property Estimators section for more details.

Integer

123

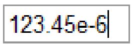
Single-line text field restricted to integer numbers. Numeric literals may be signed depending on the context. Examples: 1, -2, +3

Decimal

123.45

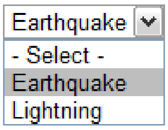
Single-line text field restricted to decimal numbers. Numeric literals may have an integer part or fractional part, or both. They may be signed depending on the context. Examples: 1, .2, 3.4, -5, -6.78, +9.10

Scientific



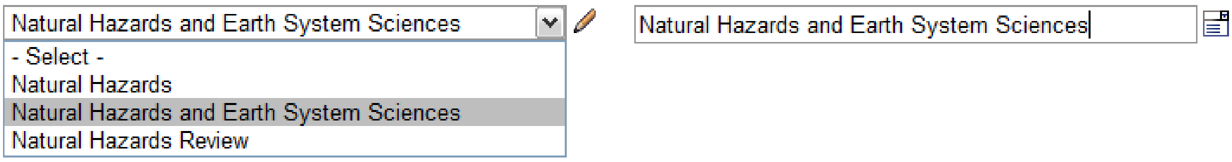
Single-line text field restricted to scientific numbers. Numeric literals are represented in scientific notation with a mantissa and exponent. Mantissa may be signed depending on the context, exponent may be signed unconditionally. Examples: 1.2e3, 1.2e-3, -1.2e3, -1.2e-3.

Drop-down list



Standard drop-down list.

Combo box



Combination of a drop-down list and a single-line text field. Combo box elements allow the user to either type a value directly or choose from the list of existing options. Use the pencil icon next to the control to switch between text field and drop-down list.

Checkbox

Standard checkbox.

Unit

Form element for entry of scientific units. Depending on the form settings, unit fields may be displayed in three different ways. A single-line text field allows the unit to be entered manually. The entered unit value is validated by the system. A drop-down list allows the unit to be selected from a set of predefined options. The unit may also be fixed to a certain value, which is displayed as a remark. Examples: cm/s2, kg, mg/L

URL

Single-line text field restricted to web addresses. All components of http and https schemes are supported. The scheme part is optional. Examples: http://ipsc.jrc.ec.europa.eu, www.tubitak.gov.tr

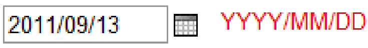
Coordinate

Form element for entry of coordinates as expressed by latitude and longitude. Latitude and longitude should be entered in the first and second text fields, respectively. Three different formats are supported:

- ddd.dddddd (decimal degrees, e.g. 12.12345)
- ddd mm.mmmmmm (degree minutes, e.g. 12 34.56789)
- ddd mm’ ss.sss’’ (degree minute seconds, e.g. 12 34’ 56.789)

Coordinates can be entered in any of the above three formats. The system automatically detects the format and converts the coordinate value into standardized format for data storage. Coordinate fields may be linked to maps for interactive entry of the coordinate by marking it on the map. See “Mapping” section for details.

Date



Single-line text field restricted to date values. Date can be entered manually or can be selected from the calendar widget accessible by clicking the calendar icon next to the text field. Three different formats are supported:

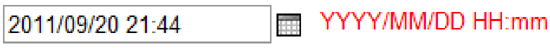
- YYYY/MM/DD (e.g. 2011/10/16)
- MM/DD/YYYY (e.g. 10/16/2011)
- DD/MM/YYYY (e.g. 16/10/2011)

Depending on the user interface language and user settings only one format is activated.

Time

Single-line text field restricted to time values. Depending on form settings, HH:mm or HH:mm:ss formats are supported. Examples: 16:45, 22:23:45

Datetime

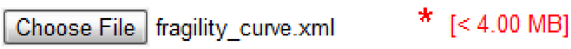


Combination of date and time fields.

Year

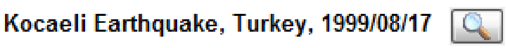
Single-line text field restricted to year values. Four-digit year values are supported.

File



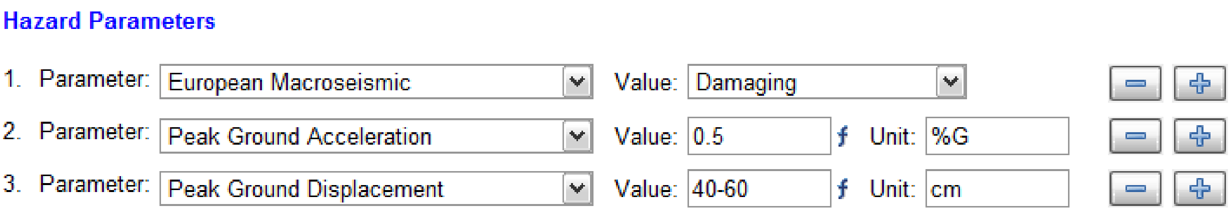
Standard file upload field. The maximum file size that can be uploaded is indicated as a remark. Depending on the form settings, it can be restricted to selected file types either by extension or MIME type. Supported file types are indicated as remark.

Reference



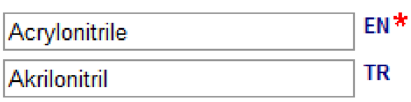
Form element for the selection of a reference record. By using the reference element, a specific record of a certain record type can be selected. Pressing the selection (🔍) button directs the user to the listing page of the record, where records can be queried by user-defined criteria. Selection of a record from the list of records directs the user back to the data entry form. The selected record is shown as single-line summary information.

Dynamic List



Form element that allows entry of multi-row data. Dynamic lists use other form elements to create data entry rows. A new data row can be inserted below a certain row by pressing the plus (+) button at the end the row. The minus (−) button can be used to remove a data row.

Multilingual Elements



Form element that allows data entry in multiple languages. Multilingual elements are based on other form elements. The form field of the base element is repeated for each supported language. The language of each item is indicated next to the form field by a two-character language code. For more information on multilingual features of the system, see the “Multilingual Support” section.

3.2 Multilingual Support

The system supports multiple languages. There are two levels of multilingual support in the system. The first level is the user interface level. Similar to other applications supporting internationalization, the user interface language can be changed by selecting the requested language from the language drop-down list located in the top menu. English and Turkish are fully supported in the current version of RAPID-N (Figure 3.4). Additional languages can be supported simply by translating the language definition file into the requested language.

(a) Substance Information

Locked

Name:	Acrylonitrile
CAS No:	107-13-1
EC No:	203-466-5
EC Index No:	608-003-00-4

(b) Madde Bilgileri

Korumalı

Ad:	Akrilonitril
CAS No:	107-13-1
EC No:	203-466-5
EC İndeks No:	608-003-00-4

Figure 3.4 Multilingual data display in a) English and b) Turkish

The second level of multilingual support is at the database level. Data access functions have been developed in a way that they can read and write data in multiple languages concurrently. If data is requested for a multilingual data field, the system first checks whether data is available in the requested language, which is by default the user interface language. If no data is available, other supported languages are checked consecutively. If data is found in one of these languages, it is returned as the result of the query together with information on the language. Data display functions of the system are able to notice if data is returned in a language different from the requested one and indicates the language next to the data value during display. This allows data to be displayed in the local language wherever possible or substituted by the value in the next available language if the local value is not available.

The system also features multilingual form elements. For each supported language, a separate form element is provided with the language codes indicated next to form element. If a form containing multilingual form elements is submitted, values in all languages are gathered and sent to the server concurrently. See the “Form Elements” section for more details on multilingual form elements.

The multilingual support of the system is useful for several reasons. Firstly, it allows information that is not available in the local language to be used without any confusion. For example, chemical names may be widely available in English, but not in the local language. In order to complete missing data one should either manually translate the names or substitute them with the ones in English. However, this results in a mixture of names in different languages, which are difficult to separate later. The multilingual support of the system solves this problem in a convenient way by supplying missing information in one language with the one available in other languages automatically without causing any confusion.

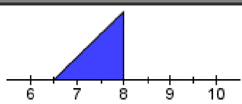
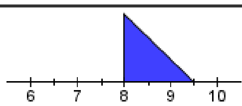
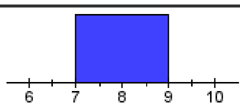
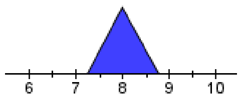
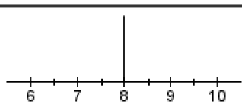
Another advantage of the multilingual support is the ability to generate reports in various languages. Information available in the system, including natech risk assessment reports, can be obtained in English or other languages for national needs (Figure 3.4).

3.3 Fuzzy Numbers

Especially for past natural hazards and natechs, for which limited information is available, certain data such as on-site hazard parameters or the number of damaged process units may not be known accurately. Uncertainties may also exist for chemical substance properties due to the use of statistical methods for calculating their values or limits of measurement techniques. Therefore, sometimes data may be available not as exact numbers, but as range or boundary values such as 2.0 – 2.2, < 10^{-3}, > 0.8. Taking this situation into consideration and not to lose accuracy by enforcing the user to round uncertain values to their approximates, the information system allows fuzzy numbers to be entered in selected numerical data fields. Numerical calculations are done on these fields using fuzzy arithmetic. Signed and unsigned integer, decimal and scientific fuzzy numbers are supported.

Taking the limited availability of data-specific fuzziness information into consideration, trapezoidal fuzzy numbers with constant slopes are used to represent fuzzy values (Buckley, 2006). A trapezoidal fuzzy number *M* is defined by four numbers *a ≤ b ≤ c ≤ d*, where the base of the trapezoid is the interval *[a, d]* and its core (top) is the interval *[b, c]*. In order to simplify calculations, five different fuzzy number types are defined, which describe *“less than”*, *“greater than”*, *“in between”*, *“about”* and *“exact value”* conditions that are encountered frequently. A value of 10% is selected as the default fuzziness amount, which results in 10% slope for one-sided conditions (less than and greater than) and 5% slope at sides for the two-sided condition (about). Examples of fuzzy number types supported by the system are given in Table 3.2.

Table 3.2 Types of fuzzy numbers supported by the system

Fuzzy Number	Description	Definition
< 8	Less than 8 	[7.2, 8.0, 8.0, 8.0]
> 8	Greater than 8 	[8.0, 8.0, 8.0, 8.8]
7 – 9	Between 7 and 9 	[7.0, 7.0, 9.0, 9.0]
~ 8	About 8 	[7.6, 8.0, 8.0, 8.4]
8	Exactly 8 	[8.0, 8.0, 8.0, 8.0]

3.4 Locking

Records available in the system are normally editable by their owners. This allows missing information to be completed gradually. Owners can also delete such records, if they are not used by the system, i.e. other records do not refer them. If a record should be preserved at a final condition, it can be locked for modifications by the administrators. Locked records can only be updated by the administrators. Locked records are indicated by a padlock at the top of the information pages (Figure 3.5).

Substance Information

Locked

Name:	1,1-Dimethylhydrazine
CAS No:	57-14-7
EC No:	200-316-0
EC Index No:	007-012-00-5

Figure 3.5 Locked record indicator

3.5 Mapping

The mapping module uses Google Maps, which is a platform-independent web mapping service featuring up-to-date high-resolution satellite imagery and map data. The module serves two functions. The first one is the visualization of geo-referenced spatial data, such as industrial facilities, process units, earthquake epicenters, and natech risks. An example of this functionality is illustrated in Figure 3.6.

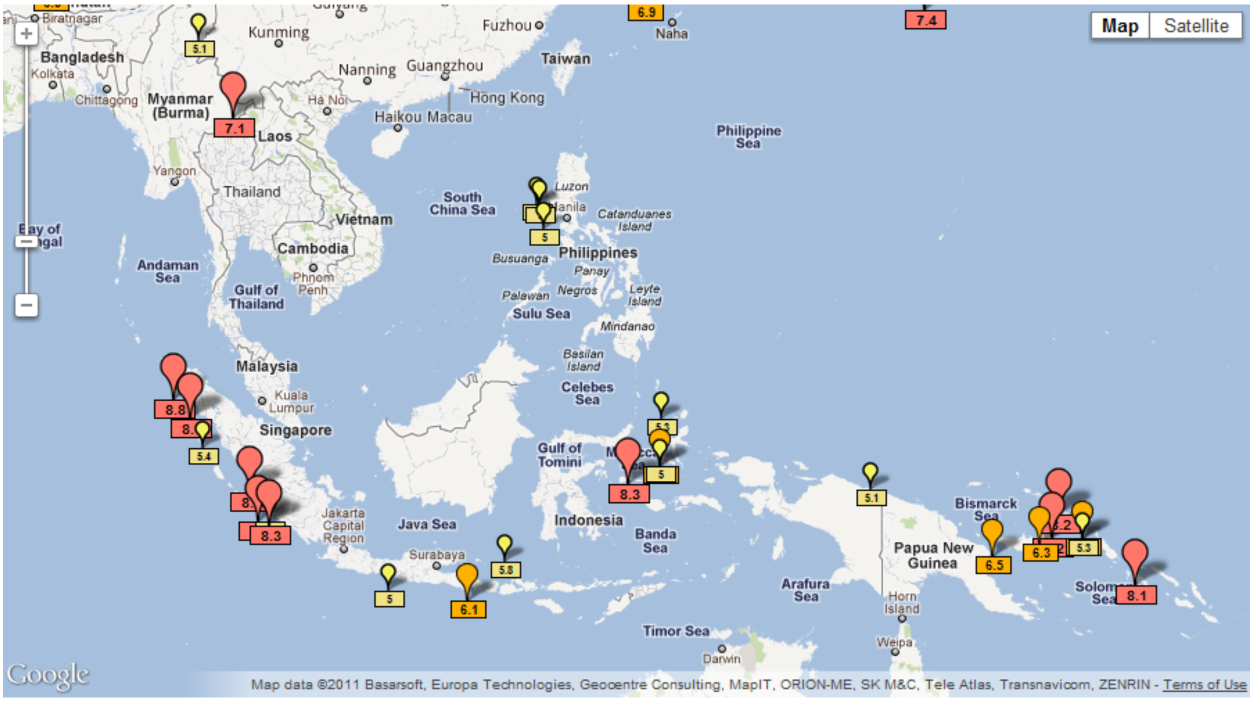


Figure 3.6 Map of earthquake epicenters

The second function is the rapid entry of geo-referenced data. A special web mapping application was developed, which allows the user to locate and delineate boundaries of industrial facilities, and mark their process units. Dimensions of the process units can be determined from the map and other properties can be easily specified. Process units and facilities are automatically linked to each other based on geographical proximity. An example of process unit data entry is given in Figure 3.7.

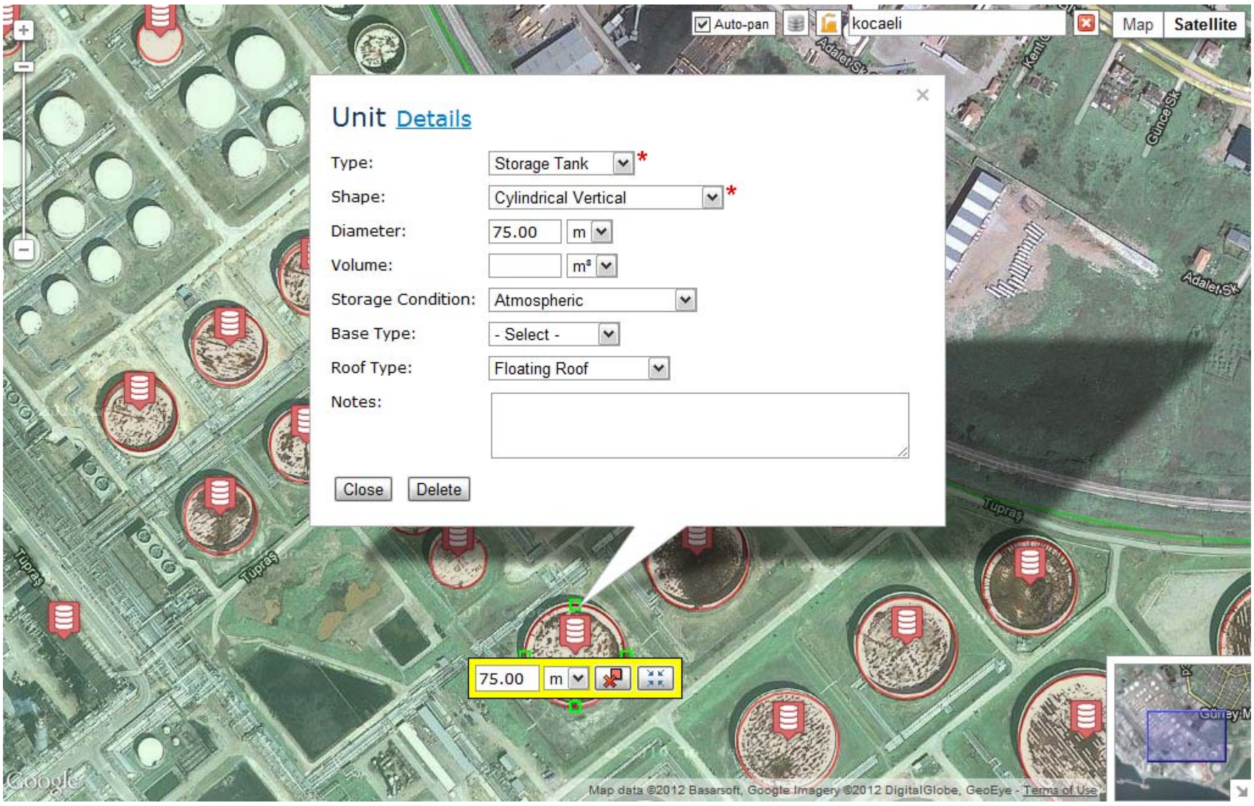


Figure 3.7 Map based rapid industrial facility and unit entry interface

4 Scientific Tools

The scientific tools section of the system serves two main purposes. The first one is supporting scientific tasks such as bibliographic citation, unit conversion, and GIS analysis. The system has a custom scientific computation library containing functions for descriptive statistics, interval arithmetic, fuzzy arithmetic, fuzzy statistics, interpolation, and unit conversion. Similarly, there is GIS library for spherical geometry calculations, proximity analysis, and mapping support. Some of these functionalities depend on the various record types described in the section. The second purpose of the scientific tools is to support the generic property definition and estimation framework of the system. Many record types in the RAPID-N tool used to describe physical entities (e.g. facilities, process units, substances), require defining characteristics of the entities. Although they describe completely different aspects, the characteristics of different entity types can be defined in a similar manner. The property definition framework handles this in a record type-independent manner. It also allows calculation of properties of the entities by using scientific calculation methods.

4.1 Units

RAPID-N has a powerful and generic unit conversion library, which can determine whether a user-entered unit is valid, test whether two units are convertible into each other, and convert a value given in one unit into its corresponding value in another unit if they are convertible. The conversion library uses unit records as the data source. The data fields of the unit records are listed in Table 4.1.

Table 4.1. Unit data fields

Field	Type	Description
Code*	Token (8)	Code of the unit (case-sensitive)
Symbol	HTML (16)	Symbol of the unit (multilingual)
Name	Text (64)	Name of the unit (multilingual)
Spacing	Checkbox	If checked, a space is put between the data value and the unit while displaying the unit
Position*	Drop-down	Position of the unit (multilingual) • Left • Right
SI Prefix	Checkbox	If checked, the unit is set to be SI prefixable
Conversion	Drop-down	Type of conversion to another unit: • None • Factor • Function
Unit* [1]	Unit	Destination unit to be used for the conversion
Factor* [2]	Scientific	Conversion factor from the unit to the destination unit
Function* [3]	Code	Conversion function from the unit to the destination unit
Inverse Function* [3]	Code	Conversion function from the destination unit to the unit

[1] Available if **Conversion** is **Factor** or **Function**
[2] Available if **Conversion** is **Factor**
[3] Available if **Conversion** is **Function**

Each unit is identified by a unique, case-sensitive code. Derived units can be defined by combining unit codes with appropriate operators, which are slash (/), dot (.), and numbers (1-9). Numbers following unit codes are evaluated as power values, whereas dot and slash denote multiplication and division, respectively. For example, kg.m/s2 represents kg·m/s^2 (which is Newton). The unit conversion library recognizes International System of Units (SI) prefixes. Therefore, SI prefixed units are not needed to be stored as separate records. While displaying units, multilingual symbols and names of the units are used instead of the codes if they are available. The position of the unit with respect to the data value can be specified as left or right. The spacing between unit and value can also be indicated. Units without spacing are displayed as attached to the value (e.g. 25°C) (Figure 4.1).

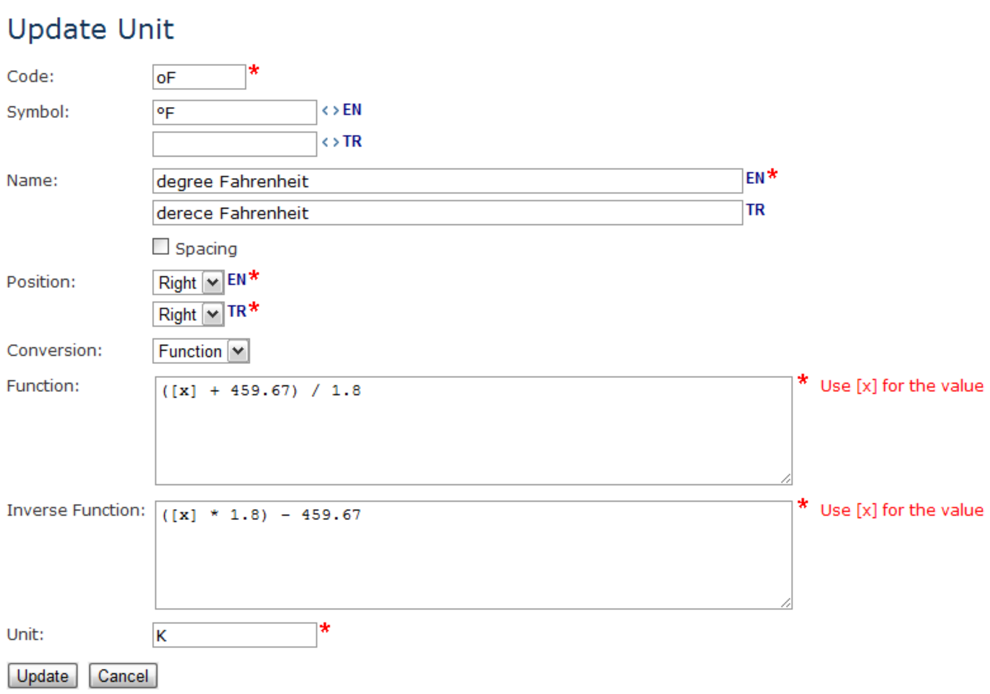


Figure 4.1 Unit data entry

There are three types of units supported by the system:

- **Base units** are nominally dimensionally independents units. SI defines seven base units, which are meter (m), kilogram (kg), seconds (s), ampere (A), kelvin (K), mole (mol), and candela (cd). All other units are derived from these base units. Internally, RAPID-N uses gram (g) instead of kg as the base unit for weight, since kg can be derived from g by using a SI prefix.

- **Units with conversion factors** are units that can be converted to other units by simple multiplication with numeric conversion constants. For example, 1 Pascal (Pa) is 1 N/m^2 (factor is 1) and 1 atmosphere (atm) is 101325 Pa (factor is 101325).

- **Units with special conversion functions** are units that can be converted to other units only by using custom conversion functions. Conversion of a temperature value from degrees Fahrenheit (^oF) to degrees Celsius (^oC) is an example.

The system can determine whether two units are convertible into each other. If they are, a value in the source unit is converted to its corresponding value in the destination unit using appropriate combinations of conversion factors and conversion functions, which are determined automatically. Conversion information is used in two-ways, both for source to destination and destination to source conversion. Hence, if a unit record containing conversion information of unit A to unit B exists in the database, another record to express conversion information of unit B to unit A is not required. Inverse conversion factors are automatically calculated by the library. User-defined inverse functions are utilized for units with conversion functions. The system is capable of converting derived units as well. For example, $lbs/cm^2 \cdot min$ can be converted to $kg/L \cdot s$.

For SI prefix enabled units, the unit conversion system generates SI prefixed units with their corresponding conversion factors and adds them to the list of available units. For example, MPa (mega Pascal) and kPa (kilo Pascal) are generated from Pa (Pascal) with conversion factors of 10^6 and 10^3 to N/m^2, respectively. The codes given in Table 4.2 are used as prefixes to the unit codes while generating new units. They are standard SI symbols, except for micro. Since µ is not a standard ASCII character it is replaced with u for data input, but it is properly displayed as µ.

Table 4.2. SI prefixes and symbols used by the system

Prefix	Symbol	Factor	Code
yotta	Y	10^{24}	Y
zetta	Z	10^{21}	Z
exa	E	10^{18}	E
peta	P	10^{15}	P
tera	T	10^{12}	T
giga	G	10^{9}	G
mega	M	10^{6}	M
kilo	k	10^{3}	k
hecto	h	10^{2}	h
deca	da	10^{1}	da

Prefix	Symbol	Factor	Code
deci	d	10^{-1}	d
centi	c	10^{-2}	c
milli	m	10^{-3}	m
micro	µ	10^{-6}	u
nano	n	10^{-9}	N
pico	p	10^{-12}	P
femto	f	10^{-15}	F
atto	a	10^{-18}	A
zepto	z	10^{-21}	Z
yocto	y	10^{-24}	y

REMARK: Units are accessible to everyone, but can be created or modified **only** by the administrators.

4.2 Common Units

The system is capable of listing all compatible units if a unit is given as the base unit. This capability is frequently used in data entry forms for allowing the user to enter data in the most convenient unit to himself without enforcing a certain unit. However, the number of listed compatible units may be too high if the base unit is a derived unit composed of several base units or is SI-prefixable. The majority of compatible units may be rarely used, therefore, the system uses common unit records to shorten the unit lists and make them more user-friendly.

If a request for listing compatible units is received, the system first checks common unit records to find out whether or not such units exist for the given base unit. If common units are found they are listed as compatible units, otherwise system-generated compatible units are listed. The volumetric units m^3 (cubic meter), ft^3 (cubic feet), and l (liter) are examples of common units.

Common unit records contain only a single field, which is the common unit. It can be a derived unit and should be unique (Table 4.3).

Table 4.3. Common unit data fields

Field	Type	Description
Unit*	Unit	Common unit (unique)

REMARK: Common units are accessible **only** by the administrators.

4.3 Regions

Regions are geographic zones of the Earth defined by closed polygon boundaries. They are used for two purposes in RAPID-N. The first one is to describe the location or extent of geographical entities, such as facilities or natural hazards. The country of a facility can be given as an example. The second one is to express the zones, for which selected records of the system are conditionally valid. Regions of a property estimator, which define locations where the estimator can be used to estimate the property, is a typical example of this usage. Regions are stored as region records in the system. The data fields of the region records are listed in Table 4.4.

Table 4.4. Region data fields

Field	Type	Description
Type*	Drop-down	Type of the region: • Country • Flinn-Engdahl Region • Craton
Code*	Token (8)	Code of the region
Name*	Text (80)	Name of the region (multilingual)
Bounds	Bounds	Geographic bounds of the region
Boundary	Boundary	Geographic boundary of the region
Icon	Token (32)	Icon of the region

The type field is used to distinguish different kinds of regions. Currently, three region types are supported by the system: countries, Flinn-Engdahl regions, and cratons. Details of these region types are given in the following subsections.

Each region is identified by an alphanumeric code, which should be unique among the regions of the same type. The name of the region should be indicated in the base (system) language. If possible, multilingual names should also be provided. The polygon boundary data of the region is stored in the boundary field. Multi-part polygons (i.e. islands) are supported. Rectangular bounds of the region, which are used to speed-up GIS analyses, are stored in the bounds field. See the “Calculate Bounds” section for more details on bounds and how they are used by the system. In order to represent the region in shorthand notation, an icon can be specified. Country flags can be given as an example.

REMARK: Regions are **read-only** in the current version of the RAPID-N.

4.3.1 Countries

248 countries of the World listed in the ISO 3166-1 standard are covered (ISO, 2006). Two-letter country codes (ISO 3166-1 alpha 2) are used as region codes. Country flags are provided as icons. Boundary data is extracted from the World Borders Dataset (Sandvik, 2009) and updated manually to reflect latest ISO 3166-1 countries. Bounds are calculated by using the “Calculate Bounds” tool of the system. An example country boundary is given in Figure 4.2.

Figure 4.2 Country boundary of Turkey

4.3.2 Flinn–Engdahl Regions

The Flinn-Engdahl seismic and geographical regionalization scheme (Flinn-Engdahl regions) is a division of the Earth into seismic zones, which are defined at one-degree intervals. They are mutually exclusive regions covering the whole surface of the Earth, including the oceans (Young et al., 1996). They are frequently used for localizing earthquakes. The USGS Earthquake Hazard Program is using Flinn-Engdahl regions to name the earthquakes. 757 regions (including 3 historical regions) from the 1995 revision are available in the system. Three digit region numbers are used as region codes. Boundary data is extracted from the Fortran program package provided by the USGS (USGS, 1997). Bounds are calculated by using the "Calculate Bounds" tool of the system. The Flinn-Engdahl region matching the country boundary given in Figure 4.2 is illustrated in Figure 4.3.

Figure 4.3 Flinn-Engdahl region of Turkey

4.3.3 Cratons

Cratons are stable continental regions of the Earth and they are used by RAPID-N in determining the tectonic setting of an earthquake by using the ShakeMap approach (Allen et al., 2008). Boundary data is taken from the OpenSHA ShakeMap Tectonic Polygons data file (OpenSHA, 2010), which is based on global craton maps provided by Johnston et al. (1994). Bounds are calculated by using the "Calculate Bounds" tool of the system. An example craton is illustrated in Figure 4.4.

Figure 4.4 South America craton

4.4 References

Many records in RAPID-N, such as damage classifications, fragility curves, property estimators, natechs, and natech damages, are based on information available in the scientific literature. Citation of the original data sources is important for quality control. It also allows users to access more detailed information when needed. The system provides a generic mechanism for the citation of references, which allows detailed bibliographic information to be stored for each reference. Reference records are used for this purpose. The data fields of the reference records are listed in Table 4.5.

Table 4.5 Reference data fields

Field	Type	Description
Type*	Drop-down	Type of the reference (see Table 4.6)
Title*	Text (200)	Title of the reference
Book Title* [1]	Text (200)	Book title of the reference
Authors* [1]	Text (200)	Authors of the reference (semi-colon separated)
Editors	Text (200)	Editors of the reference (semi-color separated)
Journal* [1]	Combo box	Journal of the reference
Year*	Year	Publication year of the reference
Volume	Text (16)	Journal volume of the reference
Number	Text (32)	Journal number of the reference
Pages* [1]	Text (16)	Page numbers of the reference
Series	Text (200)	Series of the reference
Institution	Combo box	Institution of the reference
Publisher	Combo box	Publisher of the reference
School	Combo box	School of the reference
URL* [1]	URL	URL of the reference
Abstract	Wiki	Abstract of the reference
LIST: Files		
File*	File	File of the reference
Type*	Drop-down	Type of the file • Public • Private
Source URL	URL	Source URL of the file
Data Protection		
Locked	Checkbox	If checked, reference is locked for editing

[1] Mandatory depending on the reference type. See Table 4.6.

The system supports a wide variety of bibliographic references, such as journal articles, books, and technical reports. Data fields of reference records are reference-type dependent, i.e. different data field combinations are requested for each reference type. For example, the journal name is asked for journal articles, whereas institution name is asked for technical reports. Depending on the importance of a data field for the completeness of the information, it is automatically set as required or optional. Title and publication year are mandatory for all reference types.

Bibliographic reference types supported by the system together with their required and optional data fields are listed in Table 4.6.

Table 4.6. Reference types and supported fields

Reference Type	Fields
Article	Title*, authors*, journal*, year*, volume, number, pages*, abstract
Proceeding	Title*, authors, book title, editors, year*, volume, number, pages, abstract
Book	Title*, authors, editors, year*, series, publisher, abstract
Book Chapter	Title*, authors*, book title*, editors, year*, pages, series, publisher, abstract
Report	Title*, authors, editors, year*, number, institution, publisher, abstract
Manual	Title*, authors, editors, year*, institution, publisher, abstract
M. Sc. Thesis	Title*, authors*, year*, school, abstract
Ph. D. Thesis	Title*, authors*, year*, school, abstract
Web Site	Title*, year*, institution, URL*, abstract

Authors and editors should be entered in a way that the names are separated by semi-colon. Journal, institution, publisher, and school fields are provided as combo boxes listing previously entered values. Hence, they can be selected easily if the required value is already in the database. The abstract of the reference can be entered as wiki (Figure 4.5). The system allows electronic copies of references to be stored as files attached to reference records. Multiple files can be uploaded for each reference. The source URL can be indicated and access rights can be set for each file. Public files are available to everyone, whereas private files can be accessed only by the owner and administrators. References of a certain record can be entered at the data entry form of the record. They are listed on the record information page as sorted by date (Figure 5.5). References can be searched for the type of reference, authors, keywords in title and abstract, and publication year. The resulting list of references can be sorted by title, type and publication year.

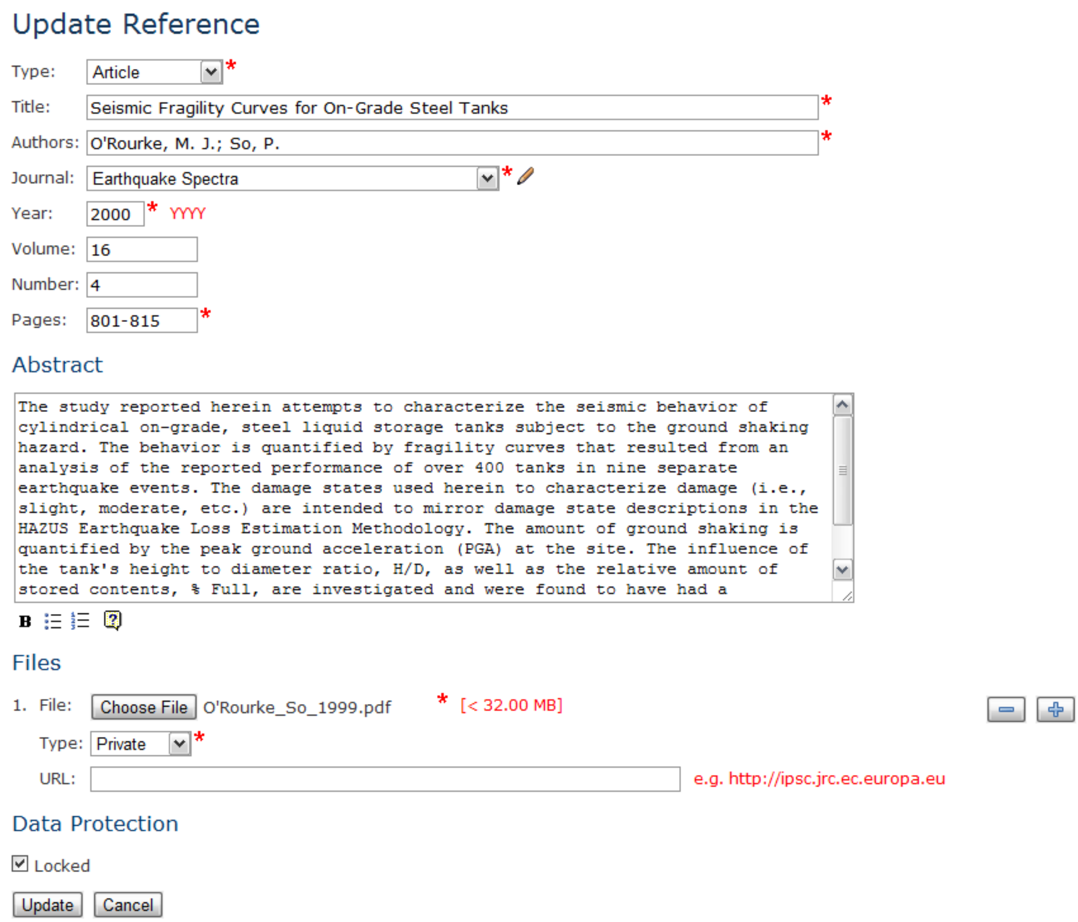


Figure 4.5 Reference data entry

4.5 Property Types

RAPID-N handles properties of physically different entities (e.g. hazards, substances) by using a common property record structure. The property estimation mechanism is also generic and independent of the nature of the property, i.e. the same methodology is used to estimate properties of different record types. However, for property data entry and visualization purposes, related properties should be grouped together. Property types are used to group properties and state their context. The data fields of property type records are listed in Table 4.7.

Table 4.7 Property type data fields

Field	Type	Description
Name*	Text (48)	Name of the property type (multilingual)
Context*	Drop-down	Context of the property type: • Hazard • Site • Facility • Process Unit • Substance

Field	Type	Description
Hazard Type* [1]	Drop-down	Type of the hazard • Earthquake • Flood • …
Group	Drop-down	Group of the property type • On-site • Risk assessment
View Order	Drop-down	View order of the property type (Auto or 1-10)

[1] Available if the **Context** is **Hazard**

For each property type, a descriptive name and a context should be indicated. There are five different contexts in RAPID-N, which are hazard, site, facility, process unit, and substance. They are the main record types of the system and correspond to entities in the physical world. The property data entry sections of the records allow the users only to enter properties having property types with the compatible context. For example, only the properties having property types in the substance context are allowed to be entered for a substance. The hazard type should be indicated explicitly for property types in the hazard context. Properties having such property types are valid only for the specified hazard type. For special cases, property types having different contexts are needed to be grouped together. Property type groups are used for this purpose. Currently, property types of on-site hazard parameters and properties used for risk assessment can be grouped. The viewing order of the property type can be specified in view pages. The list of currently used property types is given in Table 4.8.

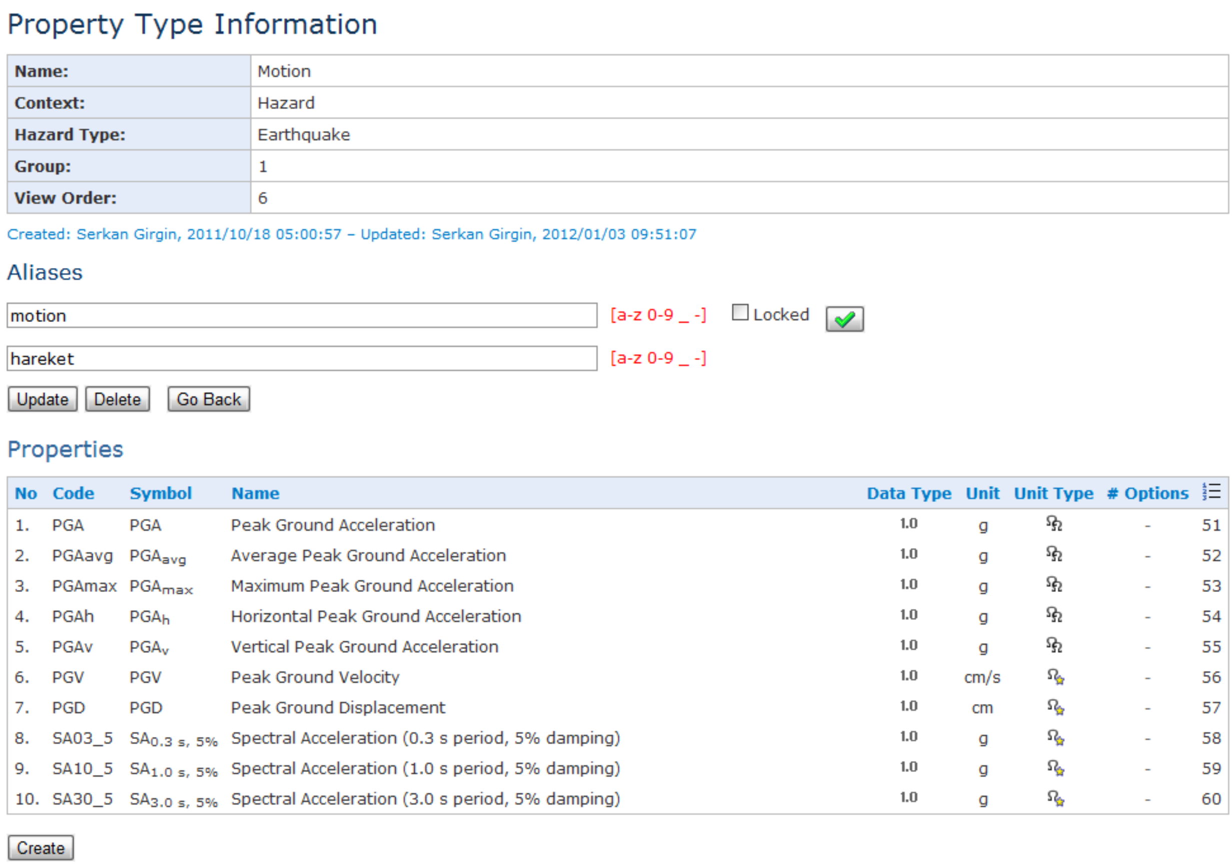
Table 4.8 Property types used by the system

Hazard	Site	Facility	Process Unit	Substance

Earthquake
  Magnitude
  Intensity
  Motion
  Distance
  Energy
  Mechanism
	Atmospheric
	Environmental
	Soil
		Construction
		Capacity
			Dimensional
			Structural
			Storage
			Safety
			Damage
				Physicochemical
				EPA RMP

Property types can be listed by name (multilingual), context, hazard type, and group. Properties defined with the property type can be accessed from the property type information page (Figure 4.6).

REMARK: Property types are accessible **only** by the administrators.



Property Type Information

Name:	Motion
Context:	Hazard
Hazard Type:	Earthquake
Group:	1
View Order:	6

Created: Serkan Girgin, 2011/10/18 05:00:57 – Updated: Serkan Girgin, 2012/01/03 09:51:07

Aliases

motion [a-z 0-9 _ -] Locked

hareket [a-z 0-9 _ -]

Update Delete Go Back

Properties

No	Code	Symbol	Name	Data Type	Unit	Unit Type	# Options	
1.	PGA	PGA	Peak Ground Acceleration	1.0	g		-	51
2.	PGAavg	PGA_{avg}	Average Peak Ground Acceleration	1.0	g		-	52
3.	PGAmax	PGA_{max}	Maximum Peak Ground Acceleration	1.0	g		-	53
4.	PGAh	PGA_h	Horizontal Peak Ground Acceleration	1.0	g		-	54
5.	PGAv	PGA_v	Vertical Peak Ground Acceleration	1.0	g		-	55
6.	PGV	PGV	Peak Ground Velocity	1.0	cm/s		-	56
7.	PGD	PGD	Peak Ground Displacement	1.0	cm		-	57
8.	SA03_5	$SA_{0.3\ s,\ 5\%}$	Spectral Acceleration (0.3 s period, 5% damping)	1.0	g		-	58
9.	SA10_5	$SA_{1.0\ s,\ 5\%}$	Spectral Acceleration (1.0 s period, 5% damping)	1.0	g		-	59
10.	SA30_5	$SA_{3.0\ s,\ 5\%}$	Spectral Acceleration (3.0 s period, 5% damping)	1.0	g		-	60

Create

Figure 4.6 Property type information

4.6 Properties

The natech risk assessment calculations performed by RAPID-N strongly depend on the characteristics of the related entities. Natural hazard parameters, physical conditions of the process units, chemical properties of the substances, etc. affect the outcome of the analysis. In order to be able to do the analysis and obtain results with acceptable accuracy, such data should be sufficiently available in the database before the analysis for the related records. For this purpose, the system features special data entry forms for all main record types, which can be used to enter property (characteristic) data.

Although they describe completely different physical aspects, properties of different entities can be defined in a similar manner. Independent of the entity type, e.g. substance or process unit, each property has a value in a restricted domain defined by either a numerical range or a set of pre-defined options. Generally, units are used to define the scales of numerical values. Some properties may be conditionally valid. For example, the diameter of a process unit can only be defined for units having spherical or cylindrical shape, and it is not valid for rectangular units. Similar conditions apply for hazard, facility, and substance properties. Considering this similarity, RAPID-N uses a common framework to define and evaluate properties of different entities, i.e. record types. Property records are used as the basis of this framework. The data fields of the property records are listed in Table 4.9.

Table 4.9 Property data fields

Field	Type	Description
Type*	Drop-down	Type of the property (see Property Types)
Code*	Token (8)	Code of the property (unique)
Symbol	HTML (32)	Symbol of the property (multilingual)
Name	Text (96)	Name of the property (multilingual)
Data Type	Drop-down	Data type of the property: • Integer • Numeric • Tabular
Unit [1]	Unit	Unit of the property
Unit Type [1]	Drop-down	Type of unit field: • Single unit only • Common units only • Compatible units
Sort [2]	Drop-down	Sorting criteria for the options: • Name • Code • List Order
View Order	Integer	View order of the property
Description	Wiki	Description of the property
Validation		
Empty	Text (64)	Empty message (multilingual)
Invalid	Text (64)	Invalid message (multilingual)
Active	Code	Condition at which the property is active (i.e. displayed)
Validate [1]	Code	Condition at which the property is valid
LIST: Options		
Code*	Token (8)	Code of the option
Name*	Text (64)	Name of the option (multilingual)
Description	Wiki	Description of the option (multilingual)

[1] Available if **Data Type** is **Integer** or **Numeric**

[2] Available if **Data Type** is **Tabular**

The type of the property determines the context and the group of the property. It is selected from the list of property types defined in the system. Details of property types are given in the "Property Types" section. Property code is used to represent the property in the property estimation functions. It is case-sensitive and should be unique. Symbols are used to represent property in shorthand notation for display (in views and tables). HTML tags can be used in symbols for subscript, superscript or italic output.

The data type defines the nature of the values of the property. Currently, three different data types are supported by the system, which are integer, numeric and tabular. The integer data type allows only integer values to be entered as the property value, whereas the numeric data type supports decimal and scientific values as well. Depending on the context of the property value, fuzzy numbers can also be entered. For both numerical (integer and numeric) properties, the unit of the property can be specified. The system treats the user-defined unit as the base unit, but also allows the user to enter property values in compatible units according to the unit type parameter. If unit type is set as *"Compatible units"*, all compatible units (including SI-prefixed and derived units) are allowed to be entered. If unit type is selected as *"Common units only"*, unit entry is restricted to the units specified in the common units section that are compatible with the base unit (see Common Units section for more details). *"Single unit only"* option enforces the user to use the base unit for data entry.

The tabular data type restricts the property value to certain options specified explicitly. The permitted options must be entered in the options list. For each option, a unique code and name should be entered. A description of the option can also be stated. For tabular properties, the system uses drop-down list elements to facilitate data entry. The options are listed in the drop-down list according to the sorting criteria. If sorting is set as name or code, the options are listed as sorted by the sorting criteria in the ascending order. If the list order is selected, they are listed according to their order in the options list. View order parameter controls the display order of the property in the view pages. The properties are grouped according to their property types and shown in the order of increasing view order.

Data fields listed under the validation section of the property records are used during property data entry. User-defined warning messages to be displayed by the system if no value is entered or if the entered value is not valid, are specified in multilingual "empty" and "invalid" fields, respectively. If the property should be activated only for a certain condition, the rule of the condition can be specified. For example, the height property can be disabled for a process unit having a spherical shape property. Similarly, a validation rule can also be specified to limit property data entry to certain values. A common use is the "value greater than zero" rule to allow only unsigned values (Figure 4.7). See the "Form Elements" section for more details on code fields and definition of rules.

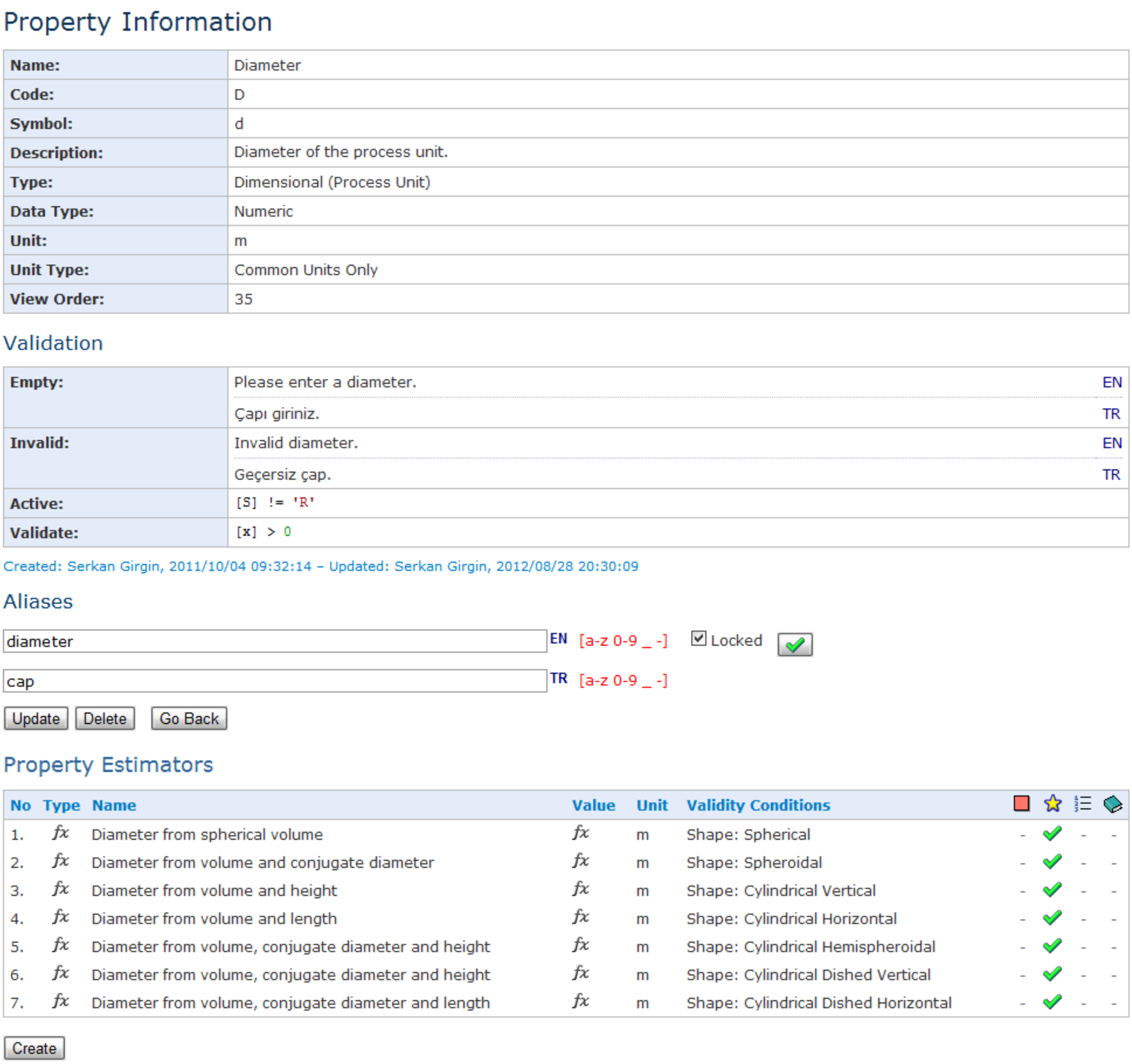


Figure 4.7 Property information

Table 4.10 Properties supported by RAPID-N

Property	Symbol	Code	Data Type (Unit)
CONTEXT: Site			
Soil			
Average Shear-Velocity (30m)	V_s^{30}	Vs30	Numeric (m/s)
NEHRP Site Class	NEHRP	NEHRP	Tabular: Hard rock, Rock, Very dense soil and soft rock, Stiff soil profile, Soft soil profile
Soil Depth	d_{soil}	Sd	Numeric (m)

Property	Symbol	Code	Data Type (Unit)
Environmental			
Topography		TOPO	Tabular: Urban, Rural
Atmospheric			
Ambient Pressure	P_A	PA	Numeric (atm)
Ambient Temperature	T_{amb}	TA	Numeric (°C)
Atmospheric Stability		AS	Tabular: Very Unstable, Unstable, Slightly Unstable, Neutral, Slightly Stable, Stable
Cloud Cover	c_C	CC	Numeric (%)
Maximum Wind Speed	u_{max}	vwm	Numeric (m/s)
Wind Speed	u	u	Numeric (m/s)
CONTEXT: Facility			
Construction			
Year of Construction		CYF	Integer
Year of Upgrade		UYF	Integer
Capacity			
Megawatt Electrical	MW_e	MWe	Numeric (MW)
Refining Capacity	$C_{refining}$	CR	Numeric (m^3/d)
CONTEXT: Hazard			
Magnitude			
Body-wave Magnitude	m_b	mb	Numeric
Chinese Surface-wave Magnitude	M_C	MC	Numeric
Code Length Magnitude	M_{CL}	MCL	Numeric
Duration Magnitude	M_D	MD	Numeric
Energy Magnitude	M_e	Me	Numeric
Japanese Meteorological Agency Magnitude	M_{JMA}	MJMA	Numeric
Local Magnitude	M_L	ML	Numeric
Moment Magnitude	M_w	Mw	Numeric
Regional Magnitude	M_{L-g}	MLg	Numeric
Surface-wave Magnitude	M_s	Ms	Numeric

Property	Symbol	Code	Data Type (Unit)
Surface-wave Magnitude (H Component)	M_{s-h}	Msh	Numeric
Surface-wave Magnitude (Z Component)	M_{s-z}	Msz	Numeric
Unknown Magnitude	M	M	Numeric
Mechanism			
Dip Angle	δ	EQ_DA	Numeric (°)
Fault Length	l_F	EQ_FL	Numeric (km)
Fault Width	w_F	EQ_FW	Numeric (km)
Faulting Mechanism	FM	FM	Tabular: Normal, Oblique, Reverse, Strike-slip, Thrust
Focal Depth	h	FD	Numeric (km)
Rise Time	t_r	EQ_RT	Numeric (s)
Rupture Speed	v_r	RS	Numeric (km/s)
Slip Angle	λ	EQ_SLA	Numeric (°)
Strike Angle	ϕ	EQ_SA	Numeric (°)
Tectonic Setting		TS	Tabular: Active Shallow, Stable Shallow, Subduction Interface, Subduction Slab, Volcanic
Energy			
Radiated Seismic Energy	E_s	Es	Numeric (J)
Seismic Moment	M_0	M0	Numeric (J)
Intensity			
China Seismic	CSIC	CSIC	Tabular: I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII
European Macroseismic	EMS	EMS	Tabular: Not felt, Scarcely felt, Weak, Largely observed, Strong, Slightly damaging, Damaging, Heavily damaging, Destructive, Very destructive, Devastating, Completely devastating
Instrumental Intensity	MMI	MMI	Numeric
Medvedev-Sponheuer-Karnik	MSK	MSK	Tabular: Not perceptible, Hardly perceptible, Weak, Largely observed, Fairly strong, Strong, Very strong, Damaging, Destructive, Devastating,

Property	Symbol	Code	Data Type (Unit)
			Catastrophic, Very catastrophic
Modified Mercalli	MM	MM	Tabular: Instrumental, Weak, Slight, Moderate, Rather Strong, Strong, Very Strong, Destructive, Violent, Intense, Extreme, Cataclysmic
Distance			
Distance to Energy Center	d_E	dE	Numeric (km)
Distance to Projection of Rupture Plane on Surface	d_f	df	Numeric (km)
Distance to Rupture Centroid	d_c	dc	Numeric (km)
Distance to Rupture Plane	d_r	dr	Numeric (km)
Distance to Seismogenic Rupture Plane	d_s	ds	Numeric (km)
Epicentral Distance	d_e	de	Numeric (km)
Equivalent Hypocentral Distance (EHD)	d_q	dq	Numeric (km)
Hypocentral (Focal) Distance	d_h	dh	Numeric (km)
Unknown Distance	d_U	dU	Numeric (km)
Motion			
Average Peak Ground Acceleration	PGA_{avg}	PGAavg	Numeric (g)
Horizontal Peak Ground Acceleration	PGA_h	PGAh	Numeric (g)
Maximum Peak Ground Acceleration	PGA_{max}	PGAmax	Numeric (g)
Peak Ground Acceleration	PGA	PGA	Numeric (g)
Peak Ground Displacement	PGD	PGD	Numeric (cm)
Peak Ground Velocity	PGV	PGV	Numeric (cm/s)
Spectral Acceleration (0.3 s period, 5% damping)	$SA_{0.3\,s,\,5\%}$	SA03_5	Numeric (g)
Spectral Acceleration (1.0 s period, 5% damping)	$SA_{1.0\,s,\,5\%}$	SA10_5	Numeric (g)
Spectral Acceleration (3.0 s period, 5% damping)	$SA_{3.0\,s,\,5\%}$	SA30_5	Numeric (g)
Vertical Peak Ground Acceleration	PGA_v	PGAv	Numeric (g)

Property	Symbol	Code	Data Type (Unit)
CONTEXT: Substance			
Physicochemical			
Boiling Point	T_b	Tb	Numeric (°C)
Density	ρ	d	Numeric (g/cm^3)
Heat of Combustion	ΔH_c^0	Hc	Numeric (kJ/kg)
Heat of Vaporization	$\Delta_v H$	dHv	Numeric (kJ/kg)
Lower Flammability Limit	LFL	LFL	Numeric (%v)
Molar Volume	V_m	Vm	Numeric (cm^3/mol)
Molecular Weight	MW	MW	Numeric (g/mol)
Specific Heat Capacity	c_p	cp	Numeric (J/kg·K)
Specific Heat Ratio	γ	RC	Numeric
State of Matter		SM	Tabular: Gas, Liquid, Solid
Substance Type		ST	Tabular: Flammable, Toxic
Upper Flammability Limit	UFL	UFL	Numeric (%v)
Vapour Pressure	P_v	Pv	Numeric Pa
EPA RMP			
RMP Density Factor	DF_{RMP}	RMP_DF	Numeric (ft^2/lb)
RMP Flash Fraction Factor	FFF_{RMP}	RMP_FFF	Numeric
RMP Gas Factor	GF_{RMP}	RMP_GF	Numeric
RMP Liquid Factor Ambient	LFA_{RMP}	RMP_LFA	Numeric
RMP Liquid Factor Boiling	LFB_{RMP}	RMP_LFB	Numeric
RMP Liquid Leak Factor	LLF_{RMP}	RMP_LLF	Numeric
RMP Plume Type	PT_{RMP}	RMP_PT	Tabular: Neutrally Buoyant, Dense
RMP Pool Fire Factor	PFF_{RMP}	RMP_PFF	Numeric
RMP Temperature Correction Factor	TCF_{RMP}	RMP_TCF	Numeric
RMP Toxic Endpoint	TEP_{RMP}	RMP_TEP	Numeric (mg/L)
CONTEXT: Process Unit			
Dimensional			
Conjugate Diameter		DC	Numeric (m)

Property	Symbol	Code	Data Type (Unit)
Diameter		D	Numeric (m)
H/D Ratio		HD	Numeric (m/m)
Height		H	Numeric (m)
Length		L	Numeric (m)
Shape		S	Tabular: Cylindrical Vertical, Cylindrical Dished Vertical, Cylindrical Hemispheroidal, Cylindrical Horizontal, Cylindrical Dished Horizontal, Spherical, Spheroidal, Rectangular
Volume		V	Numeric (m^3)
Width		W	Numeric (m)
Structural			
Base Plate Type		BPT	Tabular: Flat, Conical
Base Support Type		BST	Tabular: Anchored, Unanchored
Base Type		BT	Tabular: On-ground, Underground, Above Ground
Construction Material		CM	Tabular: Steel, Concrete, Wood
Construction Standard		CS	Tabular: API 650, AWWA 100, ACI 350.3, EUROCODE 8, NZSEE 2009, UL 142
Construction Type		CT	Tabular: Riveted, Bolted, Welded
Construction Year		CY	Integer
Foundation Type		FT	Tabular: Earthen, Concrete Ring, Concrete Ring Wall, Concrete Slab
Roof Support Type		RST	Tabular: Self Supported, Column Supported
Roof Type		RT	Tabular: Fixed Roof, Floating Roof, Internal Floating Roof, Vapor Dome, Open Roof
Upgrade Year		UY	Integer
Storage			
Fill Height	h_{FL}	hFL	Numeric (m)
Fill Level		FL	Numeric (%v)
Mass Concentration	ρ	Mc	Numeric (kg/m^3)

Property	Symbol	Code	Data Type (Unit)
Storage Capacity	$Q_{storage}$	STQ	Numeric (kg)
Storage Condition		STC	Tabular: Atmospheric, Pressure, Gas under pressure, Fully refrigerated, Refrigerated pressure
Storage Pressure	$P_{storage}$	STP	Numeric (atm)
Storage Temperature	$T_{storage}$	STT	Numeric (°C)
Storage Volume	$V_{storage}$	STV	Numeric (m^3)
Stored Quantity	Q_{stored}	QFL	Numeric (kg)
Stored Volume	V_{stored}	VFL	Numeric (m^3)
Volume Concentration	ϕ	Vc	Numeric (m^3/m^3)
Safety			
Active Release Mitigation Factor	$f_{m, active}$	ARMF	Numeric
Dike Area	A_{dike}	SA_Ad	Numeric (m^2)
Dike Height	h_{dike}	SA_hd	Numeric (m)
Dike Volume	V_{dike}	SA_Vd	Numeric (m^3)
Enclosure		SA_EC	Tabular: Building, Shed, Airtight Enclosure, No Closure
Passive Release Mitigation Factor	$f_{m, passive}$	PRMF	Numeric
Damage			
Atmospheric Transmissivity	τ_a	Ta	Numeric
Burn Degree		DM_BD	Tabular: First degree, Second degree, Third degree, Fourth degree
Combustion Rate	q_c	DM_qc	Numeric (kg/s)
Conditional Fire Probability	$P_{c, fire}$	DM_Pf	Numeric (%)
Conditional Release Probability	$P_{c, release}$	DM_Pr	Numeric (%)
Damage Probability	P_{damage}	DM_P	Numeric (%)
Duration of Combustion	t_c	DM_tc	Numeric (s)
Duration of Exposure	t_{exp}	DM_te	Numeric (s)
Endpoint Distance	d_e	DM_de	Numeric (m)
Endpoint Radiation Intensity	q_R	DM_qR	Numeric (W/m^2)
Evaporation Rate	$q_{evaporation}$	DM_qe	Numeric (kg/min)

Property	Symbol	Code	Data Type (Unit)
Explosion Yield Factor	f_{yield}	DM_fy	Numeric
Fire/Explosion Event		DM_EF	Tabular: No Fire, Pool Fire, Vapor Cloud Fire, BLEVE, Vapor Cloud Explosion
Fuel Quantity	Q_{fuel}	DM_Qf	Numeric (kg)
Hole Area	A_{hole}	DM_Ah	Numeric (cm^2)
Hole Diameter	d_{hole}	DM_dh	Numeric (cm)
Hole Height	h_{hole}	DM_hh	Numeric (m)
Involved Quantity	$Q_{involved}$	DM_Q	Numeric (kg)
Involved Volume	$V_{involved}$	DM_V	Numeric (m^3)
Involved Volume Percent	$f_{V,\ involved}$	DM_fV	Numeric (%v)
Liquid Height Above Hole	h_{liquid}	DM_hL	Numeric (m)
Natech Event Probability	P_{natech}	DM_Pn	Numeric (%)
Pool Area	A_{pool}	DM_AP	Numeric (m^2)
Pool Depth	h_{pool}	DM_hP	Numeric (cm)
Radiative Fraction of Heat of Combustion	R	RHc	Numeric
Reduced Release Rate	$q_{release,\ r}$	DM_qr	Numeric (kg/min)
Release Duration	$t_{release}$	DM_t	Numeric (min)
Release Rate	$q_{release}$	DM_q	Numeric (kg/min)
Released Quantity	$Q_{released}$	DM_Qr	Numeric (kg)
Released Volume	$V_{released}$	DM_Vr	Numeric (m^3)
RMP Reference Table	RT_{RMP}	RMP_RT	Tabular: Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, Table 14, Table 15, Table 16, Table 17, Table 18, Table 19, Table 20, Table 21, Table 22, Table 23, Table 24, Table 25, Table 26, Table 27, Table 28, Table 29
RMP Scenario		DM_RMP	Tabular: Worst-case, Alternative
Thermal Dose	D_T	DM_DT	Numeric (TDU)

4.7 Property Estimators

RAPID-N utilizes user-defined property values of entities as input to risk assessment calculations. However, such data may be incomplete or even not available in all cases. In order to make risk assessment possible with minimum data input yet obtain reasonable results, the system features a generic property estimation framework to calculate missing property data by using scientific estimation. The property estimation algorithm takes available property data as input and tries to calculate missing properties by using available property estimators, taking validity conditions of the estimators into consideration. If a missing property value is calculated, it is added to the list of available properties and the procedure is continued recursively until no further properties can be estimated with the available data.

Property estimators are utilized by the system for two main purposes. The first one is to calculate missing properties needed for the analysis, which can be derived from other available properties. For example, the volume of a process unit can be calculated if the dimensions of the unit are known. Similarly, certain parameters (e.g. diameter) can be computed if the volume and shape of the process unit are available. This reduces the amount of information that should be entered by the user and makes the system more user-friendly. Additionally, it increases the flexibility of the system. Such estimators can do many calculations that should normally be hard-coded into the system. RAPID-N does not include any built-in functions for the calculation of process unit volumes. All volume-related calculations are done by using property estimators. Therefore, if a new process unit type with a specific shape is added to the system, there is no need to update the source code. Only a new property estimator should be added to support the process unit, which can be done very easily through the data entry interface.

The second purpose of property estimators is to provide properties, which are not available explicitly and cannot be derived from other properties. For example, topography is a site-specific property and cannot be calculated. But, a property estimator can be defined to provide a default value for the topography, which can substitute the actual value. This usage is similar to making assumptions in calculations and allows the risk assessment procedure to be completed even with limited data by sacrificing some accuracy. The system allows certain validity criteria to be defined for property estimators, such as validity regions or conditional properties, to control the applicability of such estimators, which increases the overall accuracy of the calculations. Property estimator records are used to store property estimators. The data fields of the property estimator records are listed in Table 4.11.

Table 4.11 Property estimator data fields

Field	Type	Description
Name	Text (128)	Name of the property estimator (multilingual)
Property*	Drop-down	Name of the property (see Properties)
Type*	Drop-down	Type of the property estimator: • Value • Function
Exact Estimate	Checkbox	If checked, the estimate assumed to be exact
Value* [1]	Drop-down Fuzzy Scientific	Value of the property

Field	Type	Description
Function* [2]	Code	Property estimation function
Unit* [3]	Unit	Unit of the property
Precedence	Drop-down	Precedence of the property estimator (1-10)
Notes	Wiki	Notes (multilingual)
LIST: Validity Conditions		
Property*	Drop-down	Name of the condition property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the condition property for which the property estimator is valid
Unit* [3]	Unit	Unit of the condition property
LIST: Validity Regions [4]		
Region*	Reference	Region for which the estimator is valid
Location* [5]	Drop-down	Location to be checked for the region • Site • Hazard
LIST: References		
Reference*	Reference	Bibliographic reference of the property estimator

[1] Available if the **Type** is **Value**

[2] Available if the **Type** is **Function**

[3] Available if the **Property** has a unit

[4] Available if the context of the **Property** is not **Substance**

[5] Available if the **Property** is an **Onsite** property

For each property estimator, the estimated property should be selected from the list of available properties in the database. The type of the estimator can be selected either as a value or as a function estimator. For value estimators, the estimated value should be entered. The value can be selected from the list of allowable values for tabular properties. For numerical properties, the value can be specified as fuzzy number. However, the use of fuzzy numbers should be avoided as much as possible, since they increase the uncertainty of the calculations. For function estimators, the estimation function should be entered. The estimation function can be a simple single-line function or a complex function using internal functions and involving control structures (i.e. if conditions, loops). See the "Form Elements" section for more details on functions. As an extension to the basic function support provided by the framework, property estimator functions support the use of property values in function definitions. In order to use a property value in a function, the code of the property should be entered in square brackets. For numerical properties the value of the property can be obtained in a certain unit (compatible with the base unit of the property) by indicating the unit within the bracket after the property code, separated by a colon. If the estimated property value is exact, i.e. is definite for the given conditions, the "exact estimator" checkbox should be checked. Exact estimators are handled differently during the property estimation procedure. For properties having a unit, the output unit of the estimator should be indicated. The specified unit should be compatible with the base unit of the property. If required, the precedence of the property estimator over the other available property estimators of the same property can be specified. If available, bibliographic references of the property estimator can be indicated (Figure 4.8).

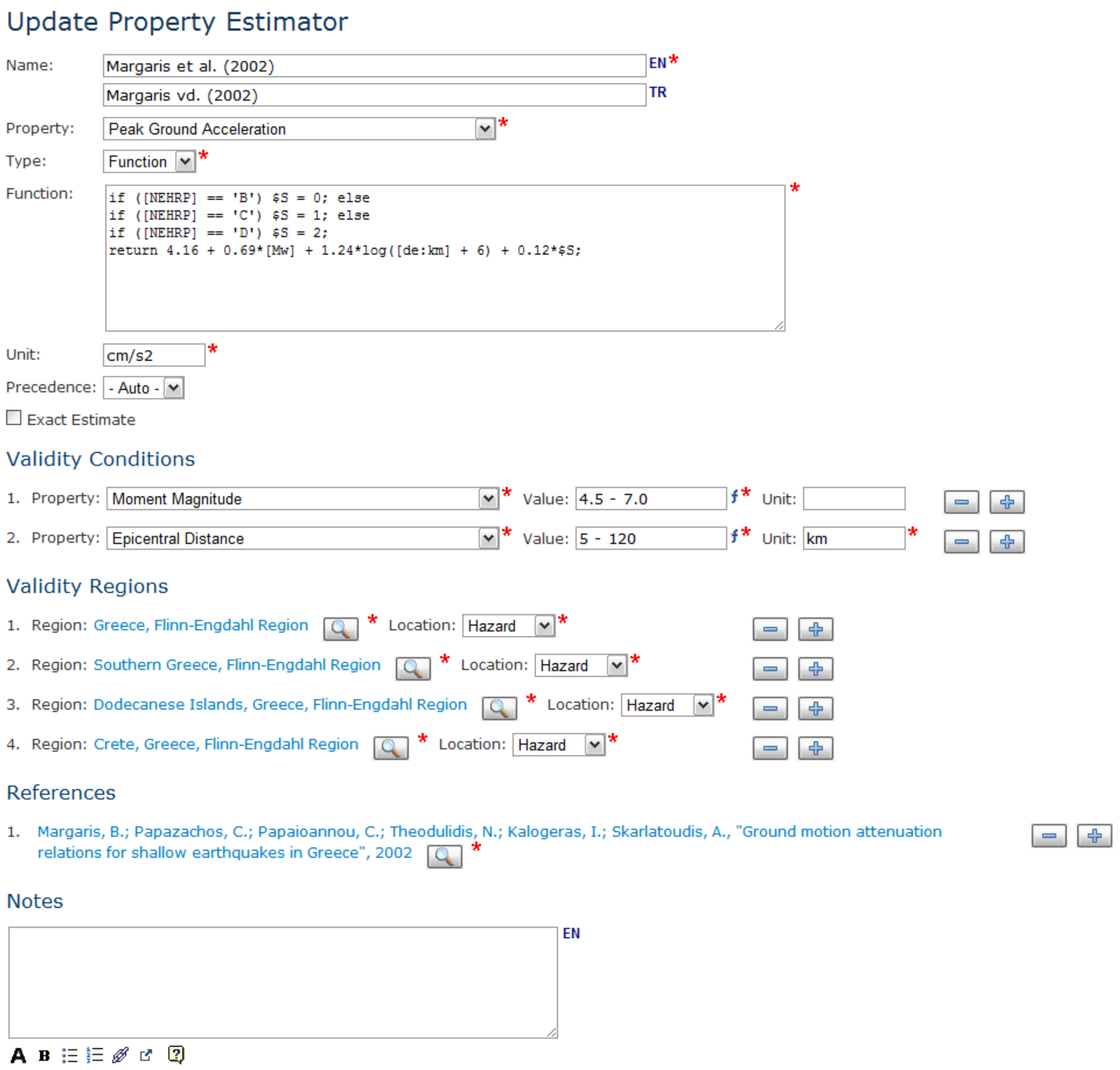


Figure 4.8 Property estimator data entry

Property estimators may be valid under certain conditions. For example, a process unit volume estimator may be valid only for a certain process unit shape (e.g. spherical) or a peak ground acceleration estimator may be valid for earthquakes having a magnitude greater than a certain threshold value (e.g. 5.0 in moment magnitude scale). In case of such validity conditions, an estimator should be used for estimation of the property only if the entity, for which the estimator is evaluated, fulfills these conditions. If validity conditions are provided, a consistency test is performed automatically by the system.

Validity conditions are defined by using properties available in the database with the same context (i.e. hazard, facility, process unit, substance) or the same group (e.g. on-site, risk assessment) as the estimated property. There is no limit in the number of condition properties. Multiple criteria can be specified for a single property by duplicating the property in list rows. Such criteria are evaluated with an *"or"* operator (e.g. MMI = 5 OR 6 OR 7). Thus, the validity of a single criterion is enough to make the estimator valid for the selected condition property. Criteria of different properties are evaluated with an *"and"* operator (e.g. (MMI = 5 OR 6 OR 7) AND PGA ≥ 0.2g).

For each criterion, the conditional value of the property should be indicated. For tabular properties, the value can be selected from the drop-down list of options provided by the system. For numerical properties, the value should be entered manually. If the property has a base unit, the unit of the conditional value should also be indicated. User-defined units have to be compatible with the base unit. For numerical properties, fuzzy numbers can also be entered. These fuzzy numbers are not evaluated as ordinary fuzzy numbers (see "Fuzzy Numbers" section), but as range expressions as defined in Table 4.12.

Table 4.12 Fuzzy expressions for property estimation conditions

Fuzzy Number	Description	Definition
< 8	Less than 8	$x < 8$
> 8	Greater than 8	$x > 8$
7 – 9	Between 7 and 9	$7 \leq x < 9$
~ 8	About 8	$[7.6, 8.0, 8.0, 8.4]$
8	Exactly 8	$x = 8$

Besides the dependence on the values of other properties, property estimators may depend on geographic location, as well. For example, a peak ground acceleration estimator may be valid only for a specific country. Environmental properties, e.g. soil classification, topography, are also variable from location to location. Therefore, estimators of such properties are likely to be location-dependent. For properties that are location dependent, regions for which the estimator is valid can be indicated by using region records.

Regions can be defined for all properties, except the ones in substance context, which by definition cannot be location-dependent. Multiple regions can be specified to define a combined, broad geographic extent (Figure 4.8). Multiple regions are evaluated with an *"or"* operator. Hence, the validity of a single location criterion is enough for the estimator to be valid for a specific location. While testing the validity of the regions, the location to be tested is automatically determined by the system by using the property context as reference. For example, hazard location is used for hazard properties, or facility location for facility properties. For on-site hazard properties (i.e. properties having hazard context and on-site group), the type of location to be checked for validity should be explicitly specified for each region. If the location is selected as hazard, the hazard location is used for evaluation. Otherwise, the location of the site (i.e. facility or process unit) is utilized.

Property estimators can be queried by estimated property, condition properties, type of the estimator, and exact estimate status. Details of a property estimator record can be accessed from the property estimator information page. Validity conditions, regions and references are tabulated besides basic information including the estimation function (Figure 4.9).

Property Estimator Information

Name:	Margaris et al. (2002)
Property:	Peak Ground Acceleration
Type:	Function

Function:	`if ([NEHRP] == 'B') $S = 0; else`
	`if ([NEHRP] == 'C') $S = 1; else`
	`if ([NEHRP] == 'D') $S = 2;`
	`return 4.16 + 0.69*[Mw] + 1.24*log([de:km] + 6) + 0.12*$S;`

Unit:	cm/s2
Exact Estimate:	No
Precedence:	Auto

Validity Conditions

Moment Magnitude:	4.5–7
Epicentral Distance:	5–120 km

Validity Regions

No	Region	Type	Location
1.	Greece (364)		Hazard
2.	Southern Greece (368)		Hazard
3.	Dodecanese Islands, Greece (369)		Hazard
4.	Crete, Greece (370)		Hazard

References

No	Reference
1.	Margaris, B.; Papazachos, C.; Papaioannou, C.; Theodulidis, N.; Kalogeras, I.; Skarlatoudis, A., "Ground motion attenuation relations for shallow earthquakes in Greece", 2002

Created: Serkan Girgin, 2011/11/04 11:58:51 – Updated: Serkan Girgin, 2012/08/19 22:38:54

Figure 4.9 Property estimator information

The property estimation algorithm of RAPID-N estimates properties of an entity not individually, but at once as a group. For this purpose, first, user-defined property values are taken from the database. Then, property estimators having the same context with the entity are extracted from the database. Each property estimator is evaluated to determine whether the available property data is enough to run the estimator. Since value estimators do not require any other property value, they are accepted automatically. For function estimators, the syntax of the estimation function is examined and the required properties are determined. If the available property data includes all required properties, the estimator is accepted. For each accepted estimator, conformity to the validity conditions and regions is evaluated. Successful property estimators are used to calculate property values.

If there is only one successful estimator for a property, it is directly used for calculation. If there are multiple property estimators, which are successful, the priority is given in the following order:

1. Estimators with higher precedence values are preferred over those with less.

2. If all required input properties are user-defined or exact, estimators requiring more input parameters are preferred over the ones requiring less number of parameters. Estimators with a higher number of input parameters are assumed to be more advanced and hence more accurate.

3. If there are estimated input parameters, the estimators using a lower number of estimated parameters are preferred, as they are assumed to accumulate less uncertainty and are hence more accurate.

Estimated properties are shown in red and marked with an asterisk on the record information pages, so that they can be differentiated from user-defined properties. If the unit of a property value is different from the base unit of the property, its value in the base unit is also calculated and displayed in gray and in parenthesis next to the user-defined (or estimated) property value. All property values are displayed according to the view order of the properties. Properties having lower view order values are displayed first, followed by properties having higher view order values. Properties with the same view order are displayed in ascending order according to their property names in the active language of the system (Figure 4.10).

Properties

Shape:	Cylindrical Vertical
Volume:	49494 m3 *
Height:	12.822 m *
Diameter:	230 ft (70.104 m)
H/D Ratio:	0.1829 m/m *
Roof Type:	Floating Roof
Base Type:	On-ground *
Base Support Type:	Unanchored *
Construction Material:	Steel
Fill Percent:	85 %v *
Fill Height:	10.899 m *
Stored Volume:	42069 m3 *
Storage Volume:	49494 m3 *
Storage Condition:	Atmospheric
Passive Release Mitigation Factor:	1 *
Active Release Mitigation Factor:	1 *

Figure 4.10 Property estimation output with estimated and standardized properties

5 Natural Hazards and Natechs

The natural hazards and natechs module includes information on natural hazards, hazard maps, natechs, and natech damage. Together with hazard maps, natural hazard records cover source (e.g. epicenter, magnitude) and site specific (e.g. intensity, ground acceleration, ground velocity) hazard data. The system features web-based agents to follow on-line data sources and automatically updates the local hazard database used as input for the risk assessment module. The primary aim of natech and natech damage records is to supply statistical data for the development of fragility curves applicable to various process unit types and damage states. Information on these record types are given in the following subsections.

5.1 Hazards

Information on natural hazards that triggered or had the potential to trigger natech events are stored in the hazard records. Description, location, extent, and characteristics of hazards can be specified. Besides historical hazards, the system also allows scenario hazards to be defined, which can be used for risk assessment purposes. Historical hazards are real hazards that occurred in the past, whereas scenario hazards are user-defined and fictitious hazards. The hazard record type is one of the main record types of the system. The data fields of the hazard records are listed in Table 5.1.

Table 5.1 Hazard data fields

Field	Type	Description
Type*	Drop-down	Type of the hazard
Status*	Drop-down	Status of the hazard • Historical • Scenario
Name	Text (64)	Name of the hazard (multilingual)
Date*	Date	Date of the hazard
Time	Time	Time of the hazard
Location		
Country*	Drop-down	Country of origin of the hazard
Province	Text	Province of origin of the hazard
Origin	Coordinate	Coordinate of the origin of the hazard (linked to the map)
LIST: Countries Affected		
Country*	Drop-down	Country affected by the hazard (unique)
LIST: Hazard Parameters		
Parameter*	Drop-down	Name of the hazard parameter (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the hazard parameter
Unit* [1]	Unit	Unit of the hazard parameter
Notes	Wiki	Notes on the hazard

Field	Type	Description
Data Protection		
Locked	Checkbox	If checked, hazard is locked for editing

[1] Available if the **Property** has a unit

For each hazard, the hazard type, a descriptive name, and the occurrence date should be specified. For minor earthquakes, it is common practice to use the Flinn-Engdahl region name of the earthquake as the name. The hazard type determines the hazard parameters, which can be entered for the hazard. The status of the hazard can be indicated either as historical or scenario. Structurally they are equal, but they differ in their purpose of usage. Historical hazards are mainly used to validate the natech risk assessment methodology of RAPID-N, while scenario hazards can be used to assess the vulnerability of facilities to natech risks and to evaluate the effectiveness of various engineering and design decisions in terms of prevention and mitigation.

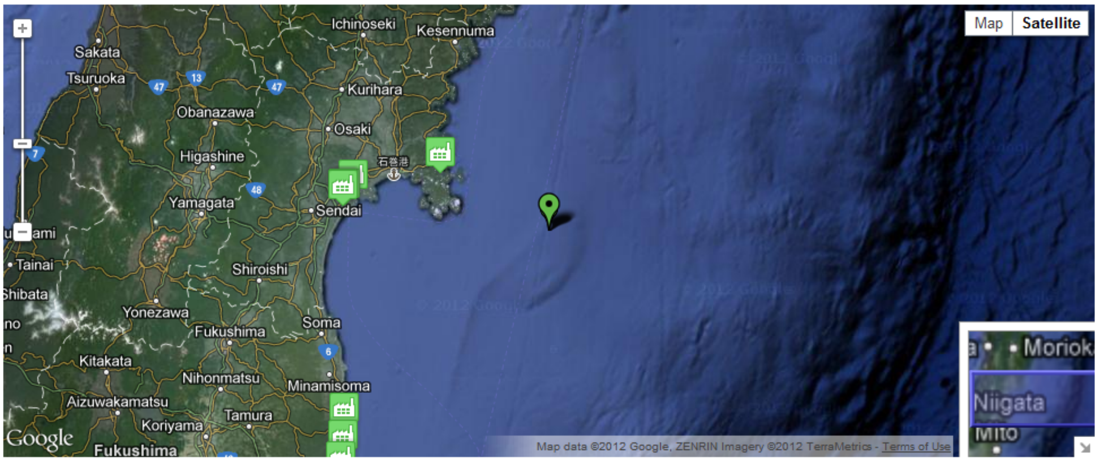
If the occurrence time of the hazard is known, it can be specified explicitly. The time should be in UTC to prevent possible confusion among the records due to location-specific time-zone settings. The location of the hazard can be stated by country and province. The country list is linked to the map and updates the map extent to display the selected country. The source location of the hazard can be indicated as latitude and longitude, either by manual entry or by marking on the map. See the “Mapping” section for more details on mapping support of the system. Besides the country of origin, other countries affected by the hazard can be specified by selecting appropriate countries in the “countries affected” list. Affected countries should be unique. Detailed information on hazard parameters (e.g. magnitude, intensity) at the origin can be specified by using the generic property mechanism of RAPID-N. Depending on the hazard type, the system only lists hazard properties that are available for the hazard type. Hazard parameters should be unique, but fuzzy numbers can be specified for numerical parameters. By using the property estimators, missing hazard parameters are calculated wherever possible. For earthquakes, the system has the capability of automatically defining and updating hazard parameters by using earthquake catalog data. Details of this functionality are given in the ”Earthquake Catalog Data” section.

Records, which are related to the hazard, can be accessed from the hazard information page. Hazard maps, which contain regional (on-site) hazard parameters available for the hazard, are listed. For earthquakes, catalog data of the earthquake can be accessed. Natechs that were triggered by the hazard and risk assessments performed for the hazard are displayed if they exist (Figure 5.1).

5.2 Hazard Maps

RAPID-N is capable of estimating on-site hazard parameters away from the source location of the hazard, both for historical or scenario hazards. The parameter estimation is done by using the generic property estimation mechanism, which allows a wide range of estimators to be defined starting from simple equations up to advanced methods. Based on the available input data, the system tries to use the most appropriate methods available in the system for the estimation of the parameters. However, hazard parameter estimation is not the primary aim of the system and therefore its capabilities in this respect are currently limited. In order to make use of the more precise on-site hazard parameter values calculated by advanced models or tools, the system supports the importing of external hazard parameter data in map form. Multiple hazard parameters are supported for each map and on-site values are found by 2-D spatial interpolation. Hazard map records are used to store map data. The data fields of hazard map records are listed in Table 5.2.

Hazard Information



Type:	Earthquake
Status:	Historical
Name:	Miyagi-Ken-Oki (Sendai) Earthquake
Date:	1978/06/12
Time:	08:14:26

Location

Country:	Japan
Origin:	38° 11.400000', 142° 01.680000'

Hazard Map

Hazard Map:	ShakeMap (XML, Gzipped), 2008/11/08 14:40:16

Hazard Parameters

Body-wave Magnitude:	6.8
Surface-wave Magnitude (Z Component):	7.7
Unknown Magnitude:	7.5
Focal Depth:	44 km

Created: System

Earthquake Catalog Data

No	Catalog	Time	Epicenter	Focal Depth	Magnitude
1.	NEIC	08:14:26	38° 11.400000', 142° 01.680000'	44 km	6.8 m_b
2.	NEIC	08:14:26	38° 11.400000', 142° 01.680000'	44 km	7.5 M
3.	NEIC	08:14:26	38° 11.400000', 142° 01.680000'	44 km	7.7 M_{s-z}

Hazard Maps

No	Type	Date	File Size
1.	ShakeMap (XML, Gzipped)	2008/11/08 14:40:16	140.36 KB

Natechs

No	Country	Facility	On-site Hazard Parameters
1.	Japan	JX Nippon Oil & Energy Corp. - Sendai Refinery	-
2.	Japan	LPG Storage Facility [Untitled]	-
3.	Japan	Electrical Substation [Untitled]	-

Risk Assessments

No	Name	Date	# Facilities	Type
1.	Miyagi-Ken-Oki (Sendai) Earthquake	2012/08/31 09:11:34	8	

Figure 5.1 Hazard information

Table 5.2 Hazard map data fields

Field	Type	Description
Hazard*	Reference	Natural Hazard of the map
Type*	Drop-down	Type of the map • ShakeMap (XML) • ShakeMap (XML, Gzipped) • ShakeMap (XYZ)
Bounds*	Bounds	Bounds of the map
File*	File	Data file of the map
Date	Datetime	Date of the map
Source URL	URL	Source URL of the map
LIST: References		
Reference*	Reference	Bibliographic reference of the map
Notes	Wiki	Notes on the map
Data Protection		
Locked	Checkbox	If checked, hazard map is locked for editing

For each hazard map, the natural hazard of interest should be selected from the list of hazards available in the system (Figure 5.2). The type of the hazard map indicates the format of the hazard parameter data. Currently, three types of hazard maps are supported by the system: ShakeMap XML, ShakeMap XML (Gzipped) and ShakeMap Text XYZ. All these types are used for earthquakes and include tabular PGA, PGV, intensity (MMI), and spectral acceleration (at 0.3, 1.0, and 3.0 s periods with 5% damping) data in regular latitude/longitude grids. Gzipped XML type is the compressed version of XML type with Gzip compression algorithm. Details of the formats can be found in the ShakeMap Manual (Wald et al., 2006). The bounds of the hazard map should be specified. Facilities within the map bounds are automatically determined by the system and displayed on the hazard map information page together with the bounds (Figure 5.2). Production date and source (as URL) of the hazard map can be indicated and descriptive notes can be entered. Bibliographical references of the hazard map can be cited by selecting required references from the available reference records in the system.

RAPID-N features a web agent application, which periodically follows the ShakeMap RSS feed of the USGS (USGS, 2011a). If a new ShapeMap is published for an earthquake that is found in the RAPID-N database, it is automatically downloaded in XML format and stored in GZipped format. For each ShakeMap a hazard map record is created and the ShakeMap is made available for natech risk assessment purposes. The agent uses date, source URL, and notes fields to store meta-data on the downloaded ShakeMap (Figure 5.2).

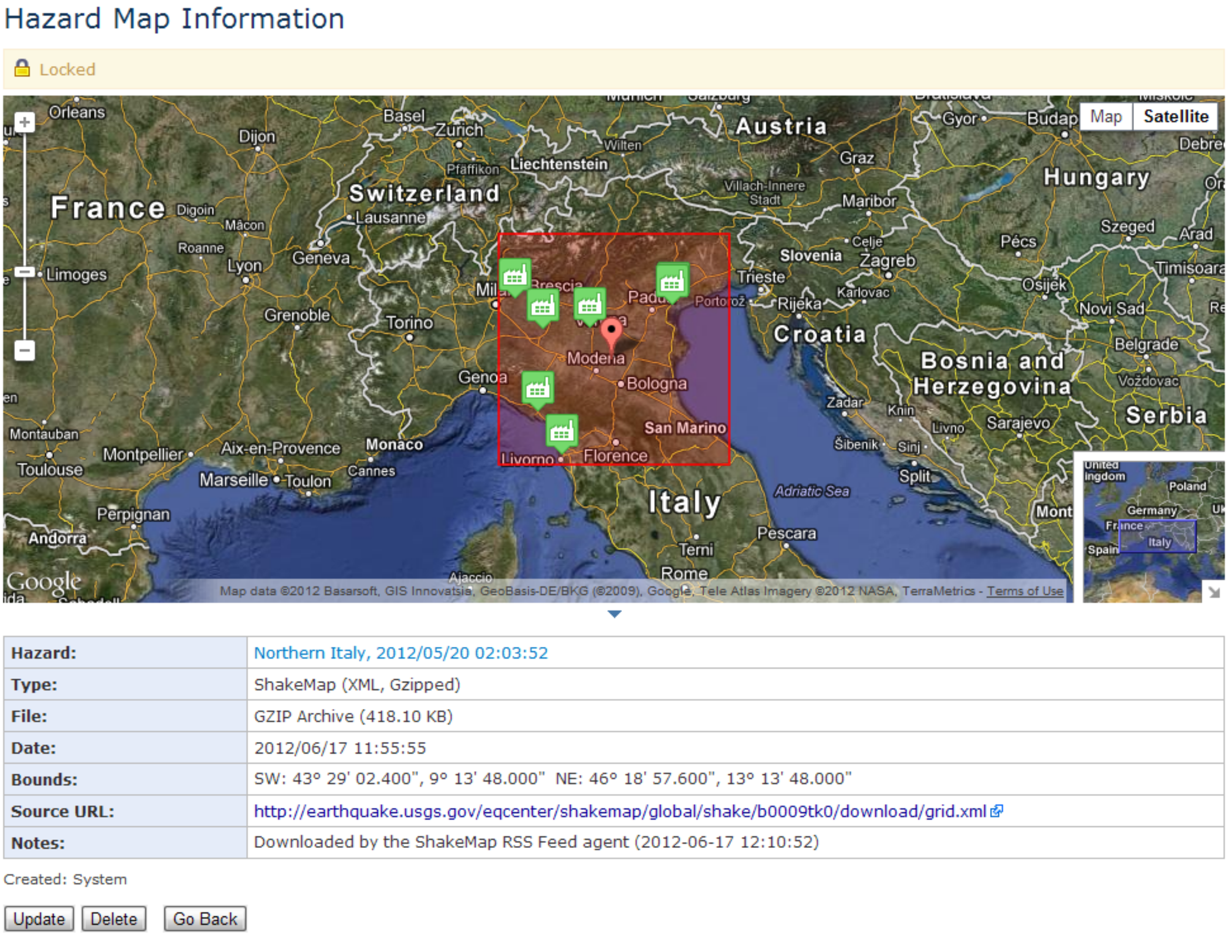


Figure 5.2 Hazard map information

5.3 Earthquake Catalog Data

In the last decades, considerable effort has been expended in the collection and dissemination of global hazard information. Especially for earthquakes, there are various on-line databases publishing near real-time hazard data. Such data can easily be used as input to natech risk assessment. In order to benefit from these sources, RAPID-N allows simple earthquake catalog data to be stored. It also has tools to follow on-line data sources to capture recent earthquake information and convert them into hazard records with hazard parameters. Earthquake catalog data records form the basis of this functionality. The data fields of the earthquake catalog data records are listed in Table 5.3.

Table 5.3 Earthquake catalog data fields

Field	Type	Description
Earthquake*	Reference	Earthquake of the catalog data (see Hazards)
Catalog*	Drop-down	Catalog of the earthquake data: • EMSC • NEIC • USGS
Time*	Time	Time of the earthquake

Field	Type	Description
Epicenter*	Coordinate	Epicenter of the earthquake
Focal Depth*	Decimal	Focal depth of the earthquake (km)
Magnitude*	Decimal	Magnitude of the earthquake
Scale*	Drop-down	Scale of the magnitude (see Properties)
Source URL	URL	Source URL of the catalog data

The earthquake associated to the catalog data should be selected from the earthquakes available in the system. For each catalog data, the source catalog should be specified. Currently, three catalogs are supported by the system: European Mediterranean Seismological Centre (EMSC), U.S. National Earthquake Information Center (NEIC), and U.S. Geological Survey (USGS). Since the date of the earthquake is available in the hazard record, only the time is asked in the catalog data record. Epicenter, focal depth, and magnitude (with a scale) are requested as hazard parameters. The scale can be selected from the list of magnitude parameters available in the system. No mapping support is provided for the entry of the epicenter coordinates, since the catalog data comes from an external source and its value should be known explicitly. The source URL of the catalog data can be specified (Figure 5.3).

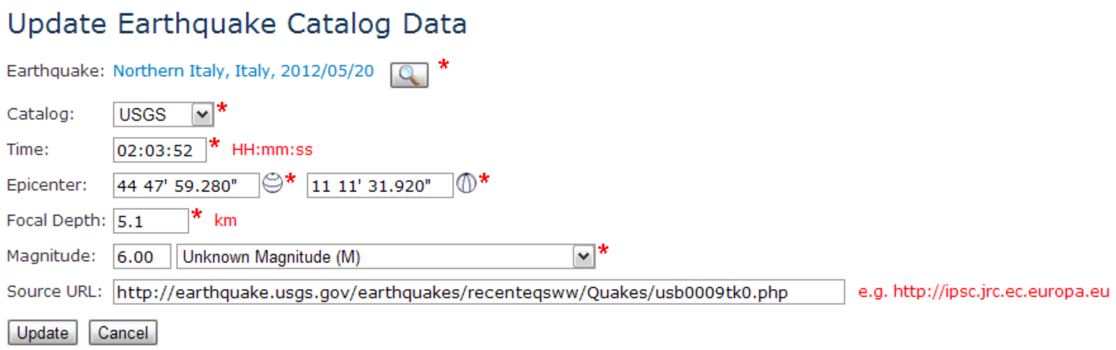


Figure 5.3 Earthquake catalog data entry form

RAPID-N is pre-loaded with catalog data of earthquakes with a magnitude greater than 5.5 that occurred since 1973. The data source is NEIC database (U.S. NEIC, 2010). The system also has a web agent, which periodically follows earthquake catalog RSS feeds of the USGS (USGS, 2011b) and the EMSC (EMSC, 2011). If a new earthquake data is published at these sources, the system first checks whether the earthquake is available in the RAPID-N database. Epicenter, date and time of the earthquake are used to check the existence of the earthquake. Since these parameters are not exact and may differ slightly from catalog to catalog for a single earthquake, the system applies flexible thresholds for the comparison. Two earthquakes less than 30 seconds apart in time and 1.0 degree in distance are assumed to be the same. If the earthquake is found in the database, its hazard parameters are updated with the new catalog data. More recent catalog data is assumed to be more precise than the older ones. If the earthquake is not found in the database and if it has a magnitude greater than 5.5 (on any scale), a new hazard record is created for the earthquake with the hazard parameters in the catalog data (Figure 5.4). Catalog data is also stored separately as a catalog data record. Earthquakes with a magnitude of less than 5.5 are neglected to keep the earthquake database at a reasonable size. If needed, earthquakes with a lower magnitude can be added manually.

Owing to this automated follow-up feature, the earthquake database of RAPID-N is always kept up-dated. In the next version of the system, an automated risk assessment step will follow this step. The probability of natech events at the industrial facilities found in the database will be assessed for the earthquake and results will be reported on the RAPID-N web site in near real-time.

Earthquake Catalog Data

Catalog: - All - Country: - All - Date: Earthquake:

List Create

49319 records found. Page: 25 Rows: 20 Sort: Date Descending

No	Date	Earthquake	Time	Epicenter	Focal Depth	Magnitude
481.	2012/04/15	Off the West Coast of Northern Sumatra	05:57:38	2° 37' 12.000", 90° 17' 24.000"	10 km	6.2 M_w
482.	2012/04/15	Off the West Coast of Northern Sumatra	05:57:38	2° 32' 56.400", 90° 16' 37.200"	15.2 km	6.2 M
483.	2012/04/15	Off the West Coast of Northern Sumatra	05:57:38	2° 38' 24.000", 90° 16' 12.000"	10 km	6.2 M_w
484.	2012/04/15	Off the West Coast of Northern Sumatra	05:57:38	2° 32' 57.120", 90° 16' 37.200"	15.2 km	6.1 M
485.	2012/04/15	Off the West Coast of Northern Sumatra	05:57:38	2° 39' 00.000", 90° 18' 00.000"	10 km	6.2 M_w
486.	2012/04/14	Vanuatu	22:05:26	18° 59' 51.720", 168° 46' 16.680"	8.7 km	6.5 M
487.	2012/04/14	Vanuatu	22:05:25	18° 57' 00.000", 168° 48' 00.000"	3 km	6.3 M_w
488.	2012/04/14	South Sandwich Islands Region	20:53:55	56° 50' 30.120", -25° 18' 12.960"	18.3 km	5.5 M
489.	2012/04/14	South Sandwich Islands Region	20:53:53	56° 51' 36.000", -25° 09' 00.000"	10 km	5.5 m_b
490.	2012/04/14	Sunda Strait, Indonesia	19:26:44	6° 51' 00.000", 105° 25' 12.000"	60 km	5.8 M_w
491.	2012/04/14	Sunda Strait, Indonesia	19:26:43	6° 48' 00.000", 105° 29' 24.000"	60 km	5.9 m_b
492.	2012/04/14	Sunda Strait, Indonesia	19:26:42	6° 52' 26.400", 105° 22' 41.880"	49 km	5.9 M
493.	2012/04/14	Off W Coast of Northern Sumatra	15:21:58	0° 22' 48.000", 92° 09' 00.000"	30 km	5.5 m_b
494.	2012/04/14	Off W Coast of Northern Sumatra	15:21:57	0° 16' 48.000", 92° 08' 24.000"	30 km	5.5 m_b
495.	2012/04/14	Kuril Islands	15:13:11	49° 27' 00.000", 155° 40' 48.000"	60 km	5.5 m_b
496.	2012/04/14	Kuril Islands	15:13:11	49° 21' 29.880", 155° 40' 44.400"	63.8 km	5.6 M
497.	2012/04/14	Drake Passage	10:56:21	57° 33' 36.000", -65° 22' 12.000"	30 km	5.9 m_b
498.	2012/04/14	Drake Passage	10:56:21	57° 34' 12.000", -65° 21' 36.000"	30 km	5.9 m_b
499.	2012/04/14	Drake Passage	10:56:21	57° 33' 36.000", -65° 22' 48.000"	30 km	5.9 m_b
500.	2012/04/14	Drake Passage	10:56:18	57° 37' 48.000", -65° 19' 48.000"	10 km	6.2 M_w

Figure 5.4 List of earthquake catalog data records

> **REMARK:** Catalog data is open to everyone, but can be created/modified **only** by the administrators.

5.4 Natechs

In order to collect essential information on natechs triggered by natural hazards and the resulting damage on process units, RAPID-N features a basic natech database. The primary aim of the database is to support risk assessment calculations by providing statistical natech damage data classified according to on-site hazard parameters. Statistical data will be used to generate custom fragility curves for different process unit types and for different process unit property combinations in the next version of the system. Natech records are used to store basic natech information. The data fields of the natech records are listed in Table 5.4.

Table 5.4 Natech data fields

Field	Type	Description
Hazard*	Reference	Hazard that triggered the natech
Facility*	Reference	Facility where the natech occurred
LIST: On-site Hazard Parameters		
Parameter*	Drop-down	Name of the hazard parameter (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the hazard parameter
Unit* [1]	Unit	Unit of the hazard parameter
LIST: References*		
Reference*	Reference	Bibliographic reference of the natech
Notes	Wiki	Notes on the natech
Data Protection		
Locked	Checkbox	If checked, natech is locked for editing

[1] Available if the **Property** has a unit

For each natech record, the natural hazard that triggered the natech and the facility where the natech occurred should be selected. Scenario hazards are not allowed to be selected as triggering hazards. On-site hazard parameters, which resulted in the natech, can be specified by selecting appropriate parameters and entering parameter values either as fuzzy numbers (for numeric parameters) or selecting from the drop-down value list (for tabular parameters). According to the type of the hazard, the system automatically lists compatible hazard parameters. For each parameter, the unit of the parameter value should be indicated if the property has a unit. Bibliographic references, which include information on the natech, can be specified. At least one reference is mandatory to assure data quality. General notes on the natech can also be indicated.

Natechs can be queried by natural hazard type, hazard name, facility name, and country of the facility. Details of a natech are displayed on the natech information page. Statistical data on damaged process units at the facility due to the natech can also be accessed from the information page (Figure 5.5). Because the primary focus of the natech section is to provide information required for the creation of the fragility curves, natech records do not include information on natech events, consequences, response activities, or lessons learned. For more detailed natech information, please refer to the comprehensive eNatech database of the European Commission's Joint Research Centre (European Commission, 2010).

Natech Information

Hazard:	Kocaeli Earthquake, Turkey, 1999/08/17
Facility:	Turkish Petroleum Refineries Corp. (TUPRAS) Izmit Refinery, Turkey

On-site Hazard Parameters

European Macroseismic:	Destructive
Modified Mercalli:	Destructive*
Medvedev-Sponheuer-Karnik:	Damaging*
Instrumental Intensity:	8.202*
Epicentral Distance:	7.9845 km*
Hypocentral (Focal) Distance:	18.782 km*
Peak Ground Acceleration:	42.618 %g* (0.4262 g)
Horizontal Peak Ground Acceleration:	0.25 g
Vertical Peak Ground Acceleration:	0.2 g
Peak Ground Velocity:	49.195 cm/s*
Peak Ground Displacement:	40–60 cm

References

No	Reference
1.	Girgin, S., "The natech events during the August 17, 1999 Kocaeli Earthquake: aftermath and lessons learned", 2011
2.	Suzuki, K., "Report on damage to industrial facilities in the 1999 Kocaeli earthquake, Turkey", 2002
3.	Steinberg, L. J. and Cruz, A. M., "When natural and technological disasters collide: lessons from the Turkey Earthquake of August 17, 1999", 2004
4.	Danış, H.; Görgün, M., "Marmara earthquake and TÜPRAŞ fire", 2005
5.	Durukal, E.; Erdik, M., "Physical and economic losses sustained by the industry in the 1999 Kocaeli, Turkey earthquake", 2008

Created: Serkan Girgin, 2011/10/18 15:48:13 – Updated: Serkan Girgin, 2011/12/06 15:06:46

Update Delete Go Back

Natech Damages

No	Process Unit Type	Process Unit Properties	Damage Classification	Damage State	Damaged	Undamaged
1.	Storage Tank	Roof Type: Floating Roof; Base Support Type: Unanchored; Construction Material: Steel; Storage Condition: Atmospheric	Seligson et al. (1996)	DS2 (Light)	30	15

Create

Figure 5.5 Natech information

5.5 Natech Damage

Besides natech information in the form of natech records, RAPID-N also allows natech damage data to be stored in the database as natech damage records. Natech damage records include information on the extent and characteristics of damage and the number and properties of affected (damaged and undamaged) process units. This information can be used to calculate descriptive statistics to support the construction of custom fragility curves. The data fields of the natech damage records are listed in Table 5.5.

Table 5.5 Natech Damage data fields

Field	Type	Description
Natech*	Reference	Natech which resulted in damage
Process Unit Type*	Drop-down	Type of the process units which are damaged (see Process Unit Types)

Field	Type	Description
Damage Classification*	Drop-down	Damage classification used to describe the damage (linked to the process unit type)
Damage State*	Drop-down	Damage state that defines the damage (linked to the damage classification)
Damaged*	Fuzzy Integer	Number of damaged process units
Undamaged	Fuzzy Integer	Number of undamaged process units
LIST: Process Unit and Damage Properties		
Property*	Drop-down	Name of the process unit or damage property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the process unit or damage property
Unit* [1]	Unit	Unit of the process unit or damage property
LIST: References*		
Reference	Reference	Bibliographic reference of the natech damage
Notes	Wiki	Notes on the natech damage
Data Protection		
Locked	Checkbox	If checked, natech damage is locked for editing

[1] Available if the **Property** has a unit

For entering a natech damage record, first the natech that resulted in damage should be selected from the natechs available in the database. Then, the type of the process units for which damage data will be entered should be indicated. According to the indicated process unit type, the system lists compatible damage classifications and corresponding damage states that can be used to describe the extent of damage. In order to complete the damage record, the total number of damaged and undamaged process units should be indicated. Only the number of damaged units is mandatory (Figure 5.6). If exact numbers are not available, fuzzy numbers can be used to give the best estimates.

The approach used by RAPID-N to collect natech damage information is not based on individual process units, but on groups of process units having similar process unit and damage characteristics. Therefore, common characteristics of the process units should be indicated by entering appropriate process unit property values. Similar to other records types, property values can be specified either as fuzzy numbers with units or by selecting suitable option from the provided drop-down lists. Multiple values of a single property can be entered to define a wide range of process units. For example, the storage conditions can be indicated both as atmospheric and pressurized by adding the storage condition property twice to the list of process unit properties. In this case, damaged and undamaged values reflect the total number of process units with atmospheric and pressurized storage conditions. Similar to process unit properties, damage properties can also be specified to describe the extent of damage and consequences, such as quantity of substance involved in the natech event, hole dimensions, release duration, and pool area. Damage properties can be used to estimate the conditional probability of release and fire events and fine-tuning risk states used for risk assessment.

Bibliographic references, which include information on the damaged process units, can be indicated. At least one reference is mandatory to assure data quality. Case-specific notes can be specified. Natech damage records can be queried by natural hazard type, process unit type, and damage classification. A sample natech damage record information page is shown in Figure 5.6.

Natech Damage Information

Natech:	Turkish Petroleum Refineries Corp. (TUPRAS) Izmit Refinery, Turkey, Kocaeli Earthquake, Turkey, 1999/08/17
Process Unit Type:	Storage Tank
Damage Classification:	Seligson et al. (1996)
Damage State:	DS2 (Light)
Damaged:	30
Undamaged:	15

Process Unit Properties

Roof Type:	Floating Roof
Base Support Type:	Unanchored
Construction Material:	Steel
Storage Condition:	Atmospheric

References

No	Reference
1.	Girgin, S., "The natech events during the August 17, 1999 Kocaeli Earthquake: aftermath and lessons learned", 2011
2.	Danış, H.; Görgün, M., "Marmara earthquake and TÜPRAŞ fire", 2005

Created: Serkan Girgin, 2011/10/18 16:46:12 – Updated: Serkan Girgin, 2011/12/06 16:20:01

Update Delete Go Back

Figure 5.6 Natech damage information

6 Facilities and Process Units

Natechs are complex accidents where natural hazards and technological accidents collide. Naturally, the two main components of natech risk assessment are natural hazards (trigger) and industrial facilities together with their process units (source). Because the occurrence of natech events requires the presence of hazardous (toxic, flammable or explosive) substances, the amount and characteristics of the substances found in the facilities is also important. Therefore, sufficient process unit and substance information should be provided for proper natech risk assessment.

Considering this requirement, RAPID-N features a facilities and process units module, which includes industrial facility, process unit type, typical process units, process units, process unit groups and substance records to store site-specific information. Details of these record types are given in the following sub-sections.

6.1 Facilities

Information on industrial facilities is stored in the system as facility records. Data on facilities includes the facility name, industrial activity, location information, operator information and site conditions such as environmental factors or soil properties. The data fields of the facility records are listed in Table 6.1.

Table 6.1 Facility data fields

Field	Type	Description
Name*	Text (64)	Name of the facility (multilingual)
Activity*	Drop-down	Industrial activity of the facility (NACE code)
Status	Drop-down	Status of the facility: • Operational • Closed • Under Construction • Hypothetical • Unknown
Location		
Country*	Drop-down	Country of the facility
Province	Text (48)	Province of the facility
City*	Text (48)	City of the facility
Address	Text	Address of the facility
Coordinate	Coordinate	Coordinate of the facility (linked to the boundary)
Boundary	Boundary	Boundary of the facility (linked to the map)
Operator		
Name	Text (128)	Name of the operator
Address	Text	Address of the operator
Phone	Phone	Phone number of the operator

Field	Type	Description
Fax	Phone	Fax number of the operator
Web Site	URL	Web site URL of the operator
LIST: Properties		
Property*	Drop-down	Name of the property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the property
Unit* [1]	Unit	Unit of the property
Notes	Wiki	Notes on the facility
Data Protection		
Locked	Checkbox	If checked, facility is locked for editing

[1] Available if the **Property** has a unit

When entering facility information, the name of the facility can be stated in multiple languages. The industrial activity should be selected from the list of available activities (NACE codes) in the database. The status of the facility, indicating whether the facility is operational, shutdown or will be available in the future, can be mentioned. Descriptive location information includes country, province, city and address. The exact location of the facility can be marked on the map by drawing the polygon boundary, or its central geographic coordinate can be indicated as latitude and longitude. The coordinate field is linked to the map and updated automatically according to the drawn boundary. See "Mapping" section for more details on the mapping features of the system. The name of the operator of the facility can be indicated and contact information can be entered such as mailing address, phone, fax, and web site address (Figure 6.1).

Site-specific properties of the facility can be indicated by using the generic property definition mechanism of the system. Facility properties are divided into two groups: The first group is in the facility context and related to the physical characteristics of the facility itself, such as year of construction or year of last major upgrade. The second group is in the site context and related to the site and its surroundings. Soil characteristics (e.g. soil class) or environmental properties (e.g. topography) can be given as example properties in this group. Similar to other record types, facility properties support fuzzy values and available property estimators can estimate missing properties wherever possible.

Facility properties in the site context are considered valid also for the process units located at the facility. RAPID-N performs risk assessment calculations at process unit level and reports the results for facilities. While performing the calculations, the system tries to use more accurate and detailed data wherever possible. Since process units are located within a facility and site conditions do not vary significantly within the facility boundaries, facility properties are used to approximate site-specific properties of process units.

The records related to the facility can be accessed from the facility information page. Process units and process unit groups of the facility available in the database are listed. Natechs that occurred at the facility and risk assessments that cover the facility are displayed, as well.

Facility Information

Name:	Turkish Petroleum Refineries Corp. (TUPRAS) Izmir Refinery
Activity:	Manufacture of refined petroleum products (19.20)
Status:	Operational

Location

Country:	Turkey
Province:	Izmir
City:	Aliaga
Coordinate:	38° 48' 42.450", 26° 56' 29.651"

Operator

Name:	Turkish Petroleum Refineries Corp. (TUPRAS)
Address:	Guney Mah. Petrol Cad. No: 25 41790 Korfez, Kocaeli - Turkey
Phone:	+90-262-3163000
Fax:	+90-262-3163010
Web Site:	http://www.tupras.com.tr

Properties

NEHRP Site Class:	**Soft soil profile** *
Average Shear-Velocity (30m):	**<180 m/s** *
Topography:	**Urban** *
Ambient Temperature:	**25°C** *
Ambient Pressure:	**1 atm** *
Year of Construction:	1972
Year of Upgrade:	2010

Created: System – Updated: Serkan Girgin, 2011/10/14 13:38:18

Figure 6.1 Facility information

6.2 Substances

The consequences of natech events mainly depend on the quantity and characteristics of the substances involved in the event and their storage conditions. Certain consequences are only possible for selected substances. For example, fire is probable only if the released substance is flammable. The nature of dispersion of a gaseous substance depends - among other factors - on its molecular weight. For liquid substances, the amount that will be dispersed is a function of boiling point and vapor pressure. The concentration, which results in a certain level of adverse effect on human health or environment, also differs from substance to substance. Therefore, besides natural hazard and process unit properties, the consideration of substance properties is a necessity for the assessment of natech risks. For this purpose, RAPID-N features a substance database that includes information on the physical and chemical properties of substances. Substance records are used to store these data. The data fields of the substance records are listed in Table 6.2.

Table 6.2 Substance data fields

Field	Type	Description
Name*	Text (64)	Name of the substance (multilingual)
CAS No*	Text	CAS number of the substance
EC No	Text	European Commission number of the substance
EC Index No	Text	67/548/EC Directive Annex I index number of the substance
Identifiers		
Formula	Text	Chemical formula of the substance
SMILES	Text	SMILES of the substance
InChI	Text	International Chemical Identifier of the substance
LIST: Properties		
Property*	Drop-down	Name of the substance property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the substance property
Unit* [1]	Unit	Unit of the substance property
Notes	Wiki	Notes on the substance
Data Protection		
Locked	Checkbox	If checked, substance is locked for editing

[1] Available if the **Property** has a unit

Basic information stored in the system on substances includes name, identifier and structure data (Figure 6.2). Multilingual substance names may contain Greek symbols. Italic, subscript and superscript formatting supported as well. If a substance has multiple names according to different naming conventions and notations, they can be entered by using semi-colon as separator.

Since substance names are not unique and difficulties exist in finding a substance solely from its name, frequently used chemical identifiers are included to the substance information. Available identifiers are:

- Chemical Abstracts Service (CAS) Registry No of the American Chemical Society,
- European Inventory of Existing Chemical Substances (EINECS), and European List of Notified Chemical Substances (ELINCS) No (EC No) of the European Union,
- 67/548/EEC Directive Annex I Index No (EC Index No).

The CAS number is mandatory for each substance. Information on the structure of the substance is stored as chemical formula and compact linear strings in International Chemical Identifier (InChI) (Stein et al., 2003) and Simplified Molecular Input Line Entry Specification (SMILES) (Weininger, 1988) notations. Besides giving insight into the chemical structure of the substance, these identifiers can also be used to estimate chemical properties by using structure-property relationships. This possibility will be explored in the next versions of the RAPID-N.

Substance Information

Locked

Name:	Acrylonitrile
CAS No:	107-13-1
EC No:	203-466-5
EC Index No:	608-003-00-4

Identifiers

Formula:	C3H3N
SMILES:	N#CC=C
InChI:	InChI=1/C3H3N/c1-2-3-4/h2H,1H2

Properties

Substance Type:	Toxic
State of Matter:	Liquid
Molecular Weight:	53.06 g/mol
Density:	49.677 lb/ft^3* (0.7958 g/cm^3)
Boiling Point:	77.35°C
Vapour Pressure:	108 mmHg (14399 Pa)
RMP Plume Type:	Dense
RMP Toxic Endpoint:	0.076 mg/L
RMP Density Factor:	0.61 ft^2/lb
RMP Liquid Factor Ambient:	0.018
RMP Liquid Factor Boiling:	0.11
RMP Liquid Leak Factor:	39

Created: System

Figure 6.2 Substance information

The properties of substances can also be indicated by using the generic property definition mechanism of the system. Similar to other records, property values in standard units are automatically calculated for numerical properties. Missing property data can be estimated by using property estimators if sufficient data is available (Figure 6.2). Currently, there are two types of substance properties used for risk assessment calculations. The first type is common physical and chemical properties, such as molecular weight and boiling point. The second type is specific to the consequence calculations by using U.S. EPA's RMP Guidance for Offsite Consequence Analysis methodology and includes toxic endpoints, nature of the released plume, and substance-specific factors to facilitate computations. See Table 4.12 for the list of supported substance properties with short descriptions.

6.3 Process Unit Types

Although there are different types of process units in a facility, natech risk assessment methodologies developed so far mainly focused on a single type, which is the storage tank. Since natech events are directly related with hazardous substances and storage tanks generally contain such substances in high quantities, it is reasonable to give priority to storage tanks in risk assessment. Moreover, numerous studies highlighted the vulnerability of atmospheric storage tanks to natural hazards (Krausmann et al, 2011; Salzano et al., 2003; Shih, 1981). However, other types of process units are also important and may cause major natechs. Considering this fact, RAPID-N supports not only storage tanks, but also other types of process units by providing a generic process unit type definition mechanism for the administrators. The data fields of the process unit type records are listed in Table 6.3.

Table 6.3 Process unit type data fields

Field	Type	Description
Name*	Text (64)	Name of the process unit type (multilingual)
Properties*	Checklist	Process unit properties valid for the process unit type

For each process unit type, a descriptive name should be entered and process unit properties valid for the process type should be indicated (Figure 6.3). Since process unit properties are defined independent of the process unit type, not all process unit properties are valid for every process unit type. For example, the storage condition property is meaningful only for storage tanks. Hence, it should not be listed on process unit data entry forms for other types of process units. This cross-check is automatically performed by RAPID-N by using process unit properties defined for each process unit type. Valid process unit properties can be selected from the list of process unit properties provided by the system, which includes all process unit properties found in the database. Selection of at least one property is mandatory.

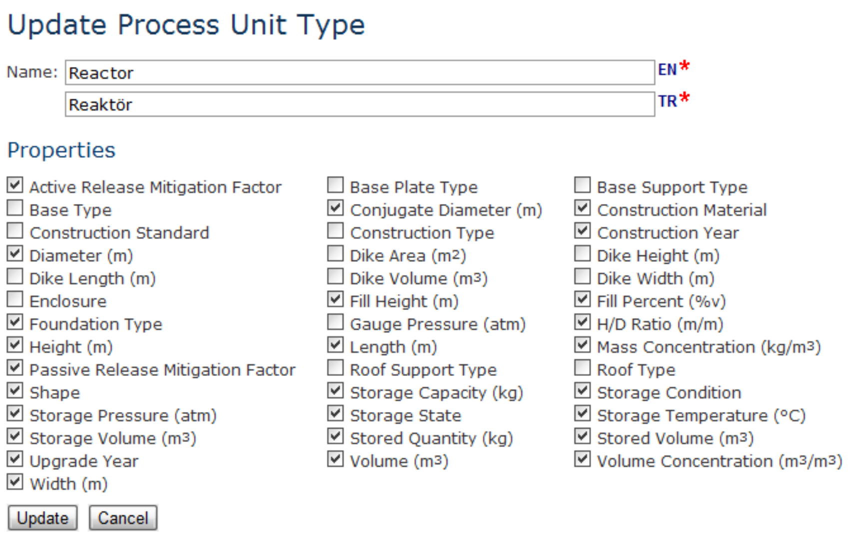


Figure 6.3 Process unit type data entry

REMARK: Process unit types can be accessed **only** by the administrators.

6.4 Process Units

The natech risk assessment methodology of RAPID-N is based on the estimation of damage probabilities of process units located at industrial facilities for a certain natural hazard scenario, and the calculation of distances to endpoints by using basic consequence modeling techniques. Hence, the focus is on process units and their physical characteristics, their structural behavior against the forces created by the natural hazards, and the substances stored or processed therein. Process unit records are used to store information on process units, including related properties and substances. The data fields of the process unit records are listed in Table 6.4.

Table 6.4 Process unit data fields

Field	Type	Description
Facility*	Reference	Facility of the process unit
Type*	Drop-down	Type of the process unit (see Process Unit Types)
Code	Text (20)	Code of the process unit
Location		
Coordinate	Coordinate	Coordinate of the process unit (linked to the boundary)
Boundary	Boundary	Boundary of the process unit (linked to the map)
Substance		
Substance	Reference	Substance stored in the process unit
LIST: Properties		
Property*	Drop-down	Name of the process unit property (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the process unit property
Unit* [1]	Unit	Unit of the process unit property
Notes	Wiki	Notes on the process unit
Data Protection		
Locked	Checkbox	If checked, process unit is locked for editing

[1] Available if the **Property** has a unit

For each process unit, the facility where the process unit is located and the type of the process unit should be specified. The facility can be selected from available facilities in the database. If available, the code number of the process unit (e.g. TK-201, S-60) can be indicated. The midpoint coordinate of the process unit can be entered manually as latitude and longitude. Coordinate fields are linked to the map and updated automatically if the location of the process unit is marked on the map. The boundary of the unit can also be drawn as polygon. For process units having a circular shape (e.g. spherical tank, vertical cylindrical tank), the boundary is drawn using a circle instead of a polygon (Figure 6.4). If diameter property is available, it is linked to the circle and updated automatically by the system.

The substance stored in the process unit can be specified by selecting the substance from the list of substances available in the database. The amount and concentration of the substance stored in the process unit can be indicated by using various parameters, such as stored quantity, stored volume, fill height, fill level, mass concentration, or volume concentration, which can be entered by using properties as explained below.

The characteristics of the process unit can be indicated by using the property definition framework of the system. Properties should be unique, but uncertain values of numerical properties can be specified by using fuzzy numbers. The system only lists properties valid for the selected process unit type according to process unit type settings. See “Process Unit Types” section for more details. The availability of certain properties depends on the values of other properties. For example, the diameter property is not available if the shape is set as rectangular or the roof type property is available only for cylindrical vertical tanks under atmospheric storage conditions.

Process Unit Information

Facility:	Turkish Petroleum Refineries Corp. (TUPRAS) Izmit Refinery, Turkey
Type:	Storage Tank
Coordinate:	40° 44' 51.515", 29° 46' 15.131"
Substance:	Naphtha (8030-30-6)

Properties

Shape:	Cylindrical Vertical
Volume:	31979 m3*
Height:	13.46 m*
Diameter:	55 m
H/D Ratio:	0.2447 m/m*
Roof Type:	Floating Roof
Base Type:	On-ground*
Base Support Type:	Unanchored*
Construction Material:	Steel
Fill Level:	85 %v*
Fill Height:	11.441 m*
Stored Volume:	27182 m3*
Storage Volume:	31979 m3*
Storage Condition:	Atmospheric
Storage Pressure:	1 atm*
Storage Temperature:	25°C*
Passive Release Mitigation Factor:	1*

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Figure 6.4 Process unit information

6.5 Process Unit Groups

Although plant layouts, safety reports, on-line public information sources and high-resolution satellite imagery can be used to collect data on process units, sometimes it may not be possible to find detailed information for each process unit individually. Especially for historical natechs, available data sources describe process units not individually but as group of process units having similar characteristics (e.g. similar dimensions, roof type, stored substance). Also, if the location of the process units is not exactly known, there is no additional benefit in entering the process units having similar characteristics as separate records since the same on-site hazard parameters will be calculated during the damage estimation for all similar process units. Taking this into consideration and with the aim of making data entry more convenient, RAPID-N supports process unit groups, which include lumped information about process units without location data. Process unit group records are used to store information on process unit groups, including related properties and substances. The data fields of the process unit group records are listed in Table 6.5.

Table 6.5 Process unit group data fields

Field	Type	Description
Facility*	Reference	Facility of the process unit group
Name*	Text (128)	Name of the process unit group
Type*	Drop-down	Type of the process unit group (see Process Unit Types)
Number of Units	Integer	Number of process units within the group
Substance		
Substance	Reference	Substance stored in the process units
LIST: Properties		
Property*	Drop-down	Name of the process unit group property (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the process unit group property
Unit* [1]	Unit	Unit of the process unit group property
Notes	Wiki	Notes on the process unit
Data Protection		
Locked	Checkbox	If checked, process unit group is locked for editing

[1] Available if the **Property** has a unit

For each process unit group, the facility where the process units are located should be selected from the available facilities in the database. A name describing the group should be provided and the type of the process units should be specified. If the number of units within the group is known, it can be indicated explicitly. The substance stored in the process units can be specified by selecting the substance from the list of substances available in the database. The characteristics of the process units, including amount and concentration of the substance stored, can be indicated by using the property definition framework of the system (Figure 6.5). The system assumes that the entered properties are representative of a single process unit within the group. Hence, individual but not total numbers should be entered for quantitative properties. Properties should be unique. Uncertain values of numerical properties can be specified by using fuzzy numbers. The system only lists properties valid for the selected process unit type according to process unit type settings. See “Process Unit Types” section for more details.

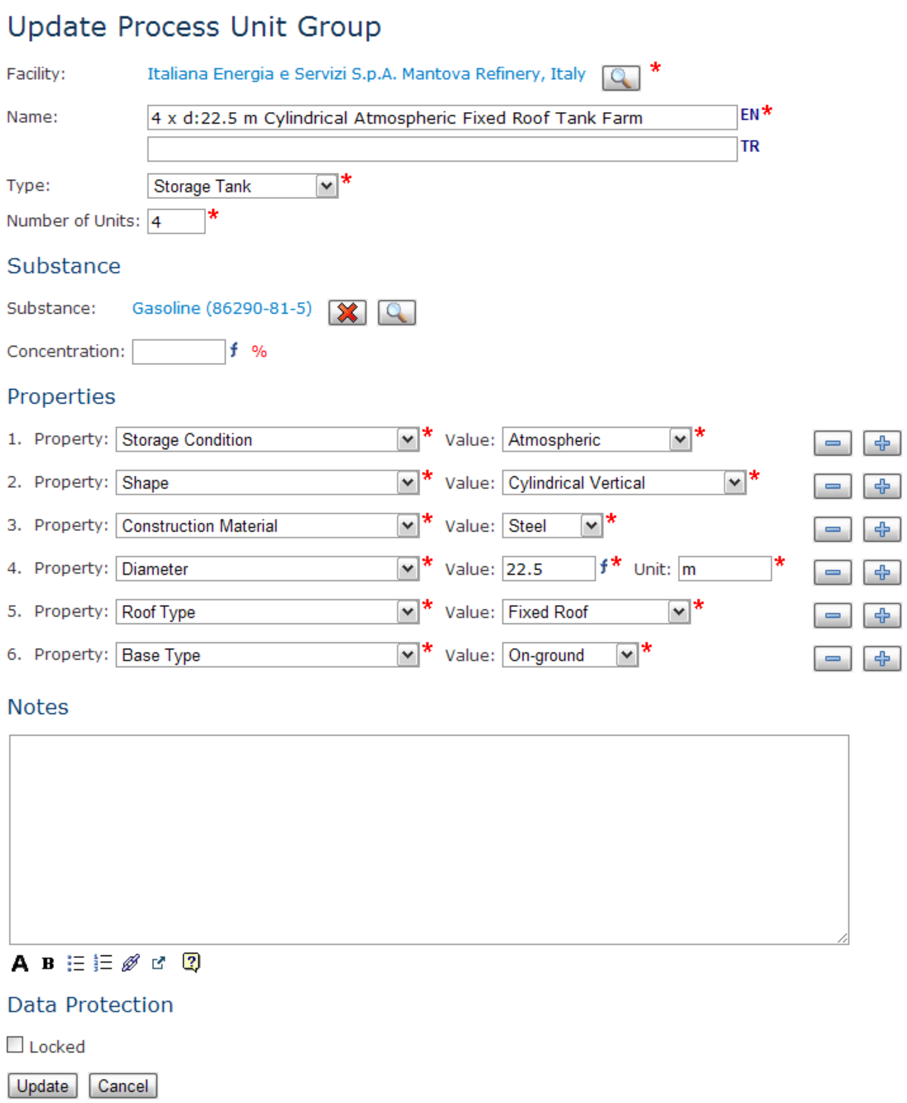

Figure 6.5 Process unit group data entry

6.6 Typical Process Units

For the estimation of natech risks, RAPID-N requires process unit data, which can be entered as process unit or process unit group records. However, process unit data may not be available for every facility. Especially for regional studies, it is quite common to have only the facility information with some indicators such as industrial activity and production capacity, but without specific details about process units. Since having only a very rough estimate of damage and consequence probabilities is better than having no information, RAPID-N tries to estimate which kind of process units may be present at such facilities and conducts the risk assessment accordingly. Representative process units are called typical process units and can be industrial activity and facility property dependent. Typical process unit records are used to store information on typical process units, including related substance, properties and validity conditions. The data fields of the typical process unit records are listed in Table 6.6.

Table 6.6 Typical process unit data fields

Field	Type	Description
Type*	Drop-down	Type of the typical process unit (see Process Unit Types)
Code	Text (20)	Code of the typical process unit
Substance		
Substance	Reference	Substance stored in the typical process unit
LIST: Properties		
Property*	Drop-down	Name of the typical process unit property (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the typical process unit property
Unit* [1]	Unit	Unit of the typical process unit property
LIST: Valid Activities		
Activity*	Drop-down	Industrial activity valid for the typical process unit (NACE code)
LIST: Validity Conditions		
Property*	Drop-down	Name of the condition property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the condition property
Unit* [1]	Unit	Unit of the condition property
Notes	Wiki	Notes on the typical process unit

[1] Available if the **Property** has a unit

Similar to process units, for each typical process unit the type of the process unit should be specified. A descriptive code number (e.g. TPU-001) can be indicated. The substance stored in the typical process unit can be specified by selecting the substance from the list of substances available in the database. The characteristics of the typical process unit, including amount and concentration of the substance stored, can be indicated by using the property definition framework of the system (Figure 6.6). Properties should be unique. Uncertain values of numerical properties can be specified by using fuzzy numbers. The system only lists properties valid for the selected process unit type according to process unit type settings. See “Process Unit Types” section for more details. For each typical process unit, the industrial activities for which the typical process unit is valid can be indicated. The system allows selection of multiple industrial activities. If no industrial activity is selected, the typical process unit is assumed to be valid for all facilities.

Similar to the property estimators, validity conditions can be specified for typical process units. Facility properties are used as condition properties. Hence, a typical process unit can be defined for facilities with specific production capacities or construction dates after a certain year (Figure 6.6). See “Property Estimators” section for more details on the definition and evaluation of validity conditions.

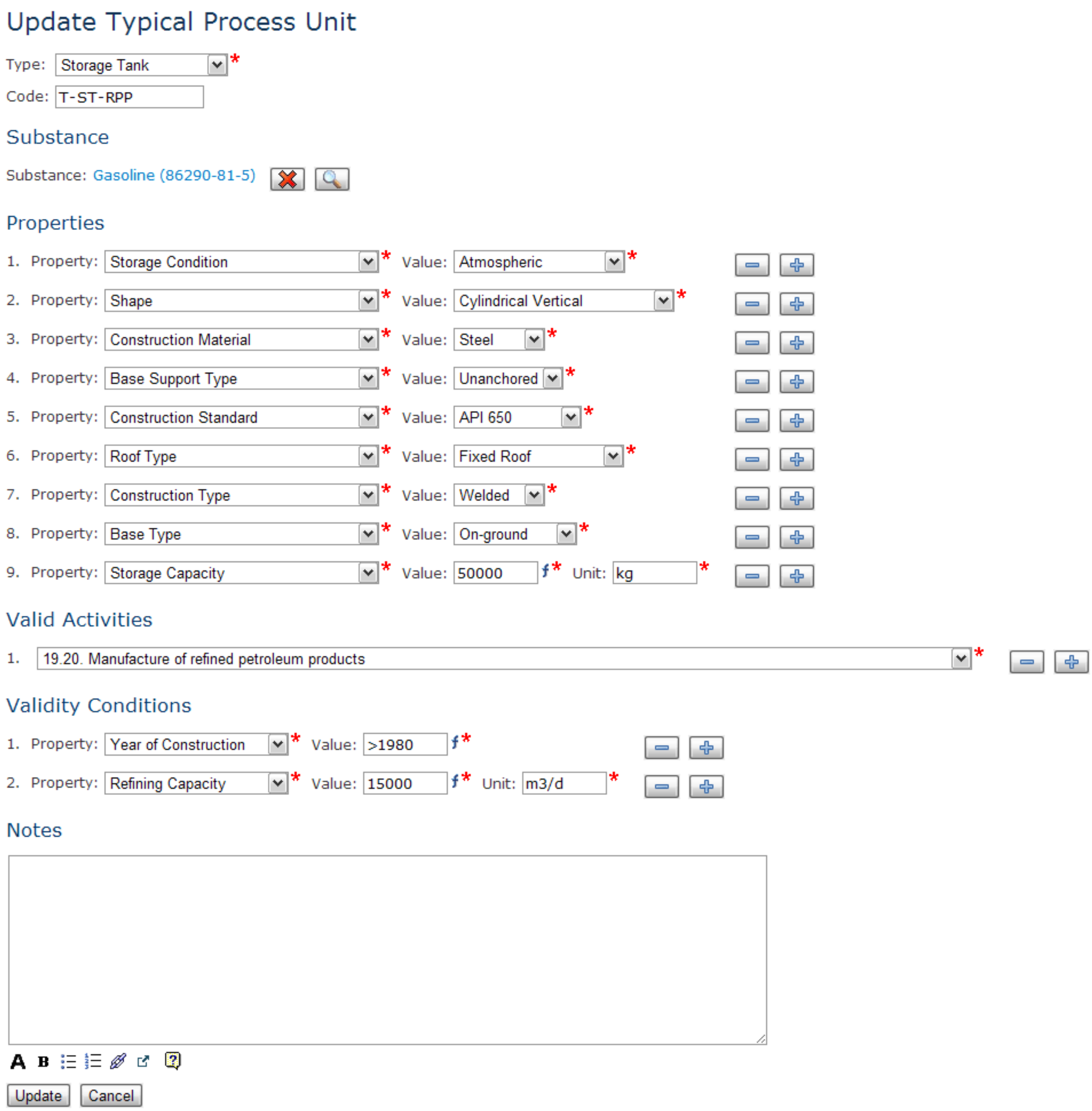

Figure 6.6 Typical process unit data entry

7 Risk Assessment

The main module of RAPID-N is the risk assessment module. This module is responsible for hazard damage and probability calculation, consequence modeling, natech risk estimation, and risk mapping tasks. The other modules of the system, which are explained in the previous sections, primarily work for this module and provide data and methods for risk calculations. The risk assessment module includes:

- Damage classifications to define natural hazard related damage states at process units,
- Fragility curves to calculate the probability of damage states for certain hazard parameters,
- Risk states to describe possible natech scenarios that can be triggered by the damage states, and
- Risk assessments to describe and evaluate natech scenarios and create risk assessment reports and maps.

Details on these records and the natech risk assessment methodology of RAPID-N are given in the following sub-sections.

7.1 Damage Classifications

The estimation of the potential damage due to a natural event is based on the calculation of the probability of a certain damage given a set of on-site natural hazard parameters. Because the extent of damage to an engineered structure (e.g. building, process unit, storage tank) may vary significantly from case to case, a simplification is necessary to facilitate the calculations. Generally, this is done by grouping similar damage severities into a pre-defined set of damage states, ranging from no to complete damage in a gradual manner in several steps (U.S. FEMA, 1997). A typical damage classification is given in Table 7.1.

Table 7.1 Damage classification of HAZUS for storage tanks (U.S. FEMA, 1997)

Damage State	Description
None	No damage.
Slight/Minor	Minor damage without loss of content or functionality (minor damage to the tank roof due to water sloshing, minor cracks in concrete tanks, or localized wrinkles in steel tanks).
Moderate	Considerable damage, but only minor loss of content (elephant foot buckling for steel tanks without loss of content or moderate cracking of concrete tanks with minor loss of content).
Extensive	Severe damage and going out of service (elephant foot buckling for steel tanks with loss of content, stretching of bars for wood tanks, or shearing of wall for concrete tanks).
Complete	Collapse and loss of all content.

Damage states can be defined by using various criteria, such as the extent of structural damage or the cost of replacement. The selection of the criteria mainly depends on the target application area, e.g.

economic risk assessment or consequence analysis. Damage states are also commonly used for natech damage estimation and form the basis of fragility curves. RAPID-N also utilizes damage classifications and the corresponding damage states in its natech risk assessment methodology. They are stored as damage classification records. The data fields of the damage classification records are listed in Table 7.2.

Table 7.2 Damage classification data fields

Field	Type	Description
Name*	Text (64)	Name of the damage classification (multilingual)
Hazard Type*	Drop-down	Hazard type for which the classification is valid
Process Unit Type	Drop-down	Process unit type for which the classification is valid
Description	Wiki	Short description of the damage classification (multilingual)
LIST: States*		
Code*	Token (16)	Code of the damage state
Name	Text (24)	Name of the damage state
Description*	Wiki	Short description of the damage state
LIST: References*		
Reference*	Reference	Bibliographic reference of the damage classification
Data Protection		
Locked	Checkbox	If checked, damage classification is locked for editing

Since damage states are natural hazard specific, a hazard type should be selected for each damage classification. The name of the damage classification and a short description should be provided. By default, the damage classification is valid for all process unit types. A process unit type can be specified explicitly, if the damage classification is defined only for that process unit type (e.g. storage tanks).

Multiple damage states can be defined for each damage classification. At least one damage state is mandatory. Damage states are identified by damage classification-specific unique codes. Common practice is to use sequential numbers prefixed by *"DS"*, e.g. DS1, DS2, DS3. If available, names such as *"None"*, *"Light"*, *"Moderate"* can also be specified for more information (Figure 7.1). A short description of the damage state should be provided to depict the type and extent of damage covered by the damage state.

Bibliographic references of the damage classification can be indicated by selecting the references from the list of references available in the database. At least one reference is mandatory to assure data quality. Risk states related to the damage classification can be accessed from the damage classification information page. See "Risk States" section for more details on risk states and how they are used to assess natech risks.

Damage Classification Information

Locked

Name:	Seligson et al. (1996)
Hazard Type:	Earthquake
Process Unit Type:	Storage Tank
Description:	Damage classification for horizontal storage vessels by Seligson et al. (1996).

States

No	Code	Name	Description
1.	DS1	None	None or insignificant structural damage.
2.	DS2	Light	Slight movement of tank from support.
3.	DS3	Moderate	Failure of some connected piping; repairable damage to the tank support system; moderate likelihood of release of tank contents.
4.	DS4	Severe	Failure of most piping connections; tank support system completely failed; almost certain release of tank contents.
5.	DS5	Total	Failure of all piping connections; tank support system completely failed; tank itself damaged (possible buckling); contents of tank released.

References

No	Reference
1.	Seligson, H. A.; Eguchi, R. T.; Tierney, K. J.; Richmond, K., "Chemical hazards, mitigation and preparedness in areas of high seismic risk: a methodology for estimating the risk of post-earthquake hazardous materials release", 1996

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Risk States

No	Damage State	Damage Parameters	Validity Conditions
1.	DS3	Involved Volume Percent: 10 %v Conditional Release Probability: 50 %	-
2.	DS4	Involved Volume Percent: 50 %v Conditional Release Probability: 80 %	-
3.	DS5	Involved Volume Percent: 100 %v Conditional Release Probability: 100 %	-

Create

Figure 7.1 Damage classification information

7.2 Risk States

In order to estimate the risk of natech events (i.e. hazardous chemical releases, fires, and explosions) damage states of process units, which are calculated from on-site hazard parameters and fragility curves, should be related to appropriate consequence scenarios that can be used for risk assessment. Similar to the simplification applied in describing damage, possible consequence scenarios are also simplified as risk states to facilitate the analysis in practice (Salzano et. al, 2003).

Simple one-to-one relations were used in the literature to relate damage states to risk states (Salzano et al., 2003; Fabbrocino et al., 2005). Going one-step further, RAPID-N supports conditional risk state definitions for each damage state. Conditional risk states allow different risk assessment scenarios to be defined for a certain damage state, depending on process unit properties (e.g. storage condition, construction material, volume) and substance properties (e.g. type of substance, boiling point, vapor pressure). RAPID-N stores risk state definitions as risk state records. The data fields of the risk state records are listed in Table 7.3.

Table 7.3 Risk state data fields

Field	Type	Description
Damage Classification*	Drop-down	Damage classification for which the risk state is defined
Damage State*	Drop-down	Damage state for which the risk state is defined (linked to the damage classification)
Precedence	Drop-down	Precedence of the risk state (Auto, 1-10)
LIST: Damage Parameters*		
Property*	Drop-down	Name of the damage parameter (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the damage parameter
Unit* [1]	Unit	Unit of the damage parameter
LIST: Validity Conditions		
Property*	Drop-down	Name of the condition property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the condition property
Unit* [1]	Unit	Unit of the condition property
LIST: References		
Reference*	Reference	Bibliographic reference of the risk state
Notes	Wiki	Notes on the risk state
Data Protection		
Locked	Checkbox	If checked, risk state is locked for editing

[1] Available if the **Property** has a unit

For each risk state, a damage classification and related damage state should be specified. Damage parameters, which are taken into consideration during consequence analysis and natech risk assessment, can be specified. These parameters include scenario parameters (e.g. U.S. EPA RMP scenario (worst-case or alternative), conditional release probability, atmospheric stability), source-term parameters (e.g. release rate, release duration, hole dimensions, pool area, evaporation rate), and consequence parameters (major fire/explosion event (no fire, vapor cloud fire, pool fire, BLEVE, vapor cloud explosion), target endpoint concentration, U.S. EPA RMP reference table). A complete listing of damage parameters is given in Table 4.10.

The possibility to indicate custom damage parameters, such as percent volume of process unit involved in the event, or conditional release and fire probabilities, allows non-linear damage-risk state relations to be defined in RAPID-N. This results in a more realistic risk assessment, e.g. in the case of damage to piping (generally regarded as a minor structural damage) or elephant-foot buckling with minor loss of content (generally regarded as major structural damage). In these cases, classical damage-risk relations would result in the over- or under-estimation of risk due to their linear behavior where a higher damage state automatically implies a higher risk state. Although this may be correct for economical losses or structural damage, it is not necessarily the case for natech events since the amount of released substance, storage conditions and substance properties also play important roles besides structural damage and affect risk assessment calculations significantly. By specifying a smaller volume involved or release probability values and indicating their validity conditions, such cases can be assessed more adequately in RAPID-N.

In addition to non-linear damage-risk state relations, conditional risk states can also be defined (Figure 7.2). Similar to the case of property estimators, validity conditions for the risk state can be indicated by selecting the appropriate properties and setting value criteria (see "Property Estimators" section for more details). Because risk states and relevant event scenarios highly depend on process unit conditions and substance characteristics, both process unit and substance related properties can be specified as conditional properties. For example, risk states can be defined for atmospheric floating-roof tanks constructed before a certain year, in which substances with a high heat of combustion are stored. Since conditions with more criteria are preferred over conditions with less criteria according to the condition evaluation algorithm of RAPID-N, detailed risk state definitions are used if they are valid for a given situation. This allows very detailed and case-specific risk states to be defined, without disabling generic risk state definitions applicable to other common situations.

Risk State Information

Damage Classification:	American Lifelines Alliance (2001)
Damage State:	DS3 (Moderate)
Precedence:	Auto

Hazard Parameters

Passive Release Mitigation Factor:	55% (0.55)
Active Release Mitigation Factor:	0%
Hole Diameter:	10 cm
Involved Volume Percent:	20 %v
Conditional Release Probability:	50%
RMP Scenario:	Alternative

Validity Conditions

Base Support Type:	Anchored
Construction Material:	Steel
Construction Year:	>1986

Figure 7.2 Risk state information

7.3 Fragility Curves

Fragility curves are X-Y plots relating a hazard parameter (e.g. PGA) to the damage probability of a structure for a certain damage state (U.S. FEMA, 1997). They are frequently used to estimate natural hazard, especially earthquake, damage to engineered structures such as housings, bridges, or industrial process units. Typically, fragility curves are prepared by statistical analysis of historical natural hazard and damage data (O'Rourke and So, 2000). Recently, fragility curves based on computational numerical analysis and modeling studies have also been developed (Berahman and Behnamfar, 2009). A typical fragility curve is given in Figure 7.3.

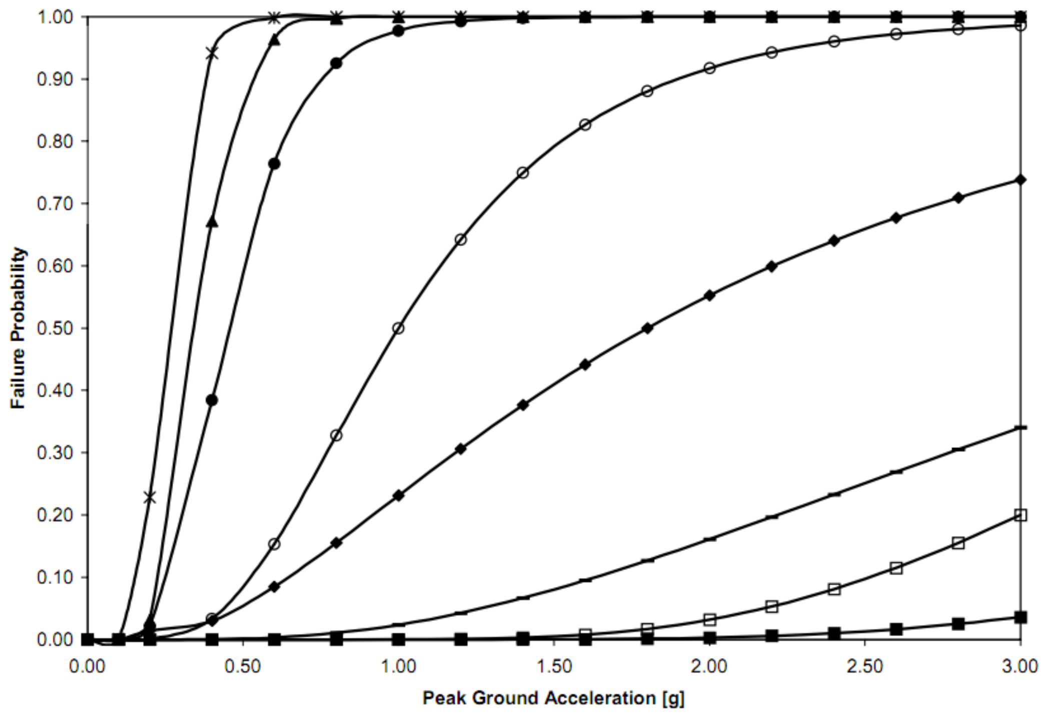


Figure 7.3 HAZUS fragility curve for peak ground acceleration (PGA) (U.S. FEMA, 1997)

RAPID-N uses fragility curves in the damage estimation part of the risk assessment, details of which are given in the "Risk Assessment" section. For the definition of fragility curves, the system features a generic fragility curve framework supporting different hazard and process unit types by utilizing damage classifications. Fragility curves can be described by various mathematical functions and their validity conditions can be indicated. The system is also capable of visualizing the fragility curves in an interactive manner. Fragility curve records are used to store fragility curve data. The data fields of the fragility records are listed in Table 7.4.

Table 7.4 Fragility Curve data fields

Field	Type	Description
Name*	Text (64)	Name of the fragility curve
Abbreviation*	Text (16)	Abbreviation of the fragility curve
Damage Classification*	Drop-down	Damage classification of the fragility curve
Process Unit Type*	Drop-down	Process unit type for which the fragility curve is valid
Hazard Parameter*	Drop-down	Hazard parameter of the fragility curve (see Properties)
Unit* [1]	Unit	Unit of the hazard parameter
Functional Form*	Drop-down	Functional form of the fragility curve: • Log-normal (median) • Log-normal (mean) • Probit • Dataset

Field	Type	Description
Precedence	Drop-down	Precedence of the fragility curve (Auto, 1-10)
LIST: Validity Conditions		
Property*	Drop-down	Name of the condition property (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the condition property
Unit* [1]	Unit	Unit of the condition property
LIST: Data*		
Condition*	Drop-down	Equivalence condition: • ≥ (equal or greater) • = (equal)
Damage State*	Drop-down	Damage state for which the data is valid
Median* [2]	Scientific	Median value
Mean* [3]	Scientific	Mean value
Standard Deviation* [2, 3]	Scientific	Standard deviation
k_1* [4]	Scientific	k_1 constant
k_2* [4]	Scientific	k_2 constant
Values* [5]	Scientific	Parameter values (semi-colon separated)
Probabilities* [5]	Scientific	Probability values (semi-colon separated)
LIST: References*		
Reference	Reference	Bibliographic reference of the fragility curve
Notes	Wiki	Notes on the fragility curve
Data Protection		
Locked	Checkbox	If checked, fragility curve is locked for editing

[1] Available if the **Property** has a unit

[2] Available if the **Functional Form** is **Log-normal (Median)**

[3] Available if the **Functional Form** is **Log-normal (Mean)**

[4] Available if the **Functional Form** is **Probit**

[5] Available if the **Functional Form** is **Dataset**

For each fragility curve, a descriptive name and an abbreviation should be provided. The damage classification that the fragility curve is based on should be selected. The type of process unit, for which the fragility curve is valid (e.g. storage tank), should be specified. The list of process unit types is linked to the damage classification and updated automatically to list process unit types that are valid for the selected damage classification. The hazard parameter (independent variable) of the fragility curve should be selected from the list of hazard parameters. The list includes properties that are only defined for the hazard type of the selected damage classification. If the parameter is a numerical property with a base unit, the unit used for the fragility curve should be indicated explicitly (Figure 7.4).

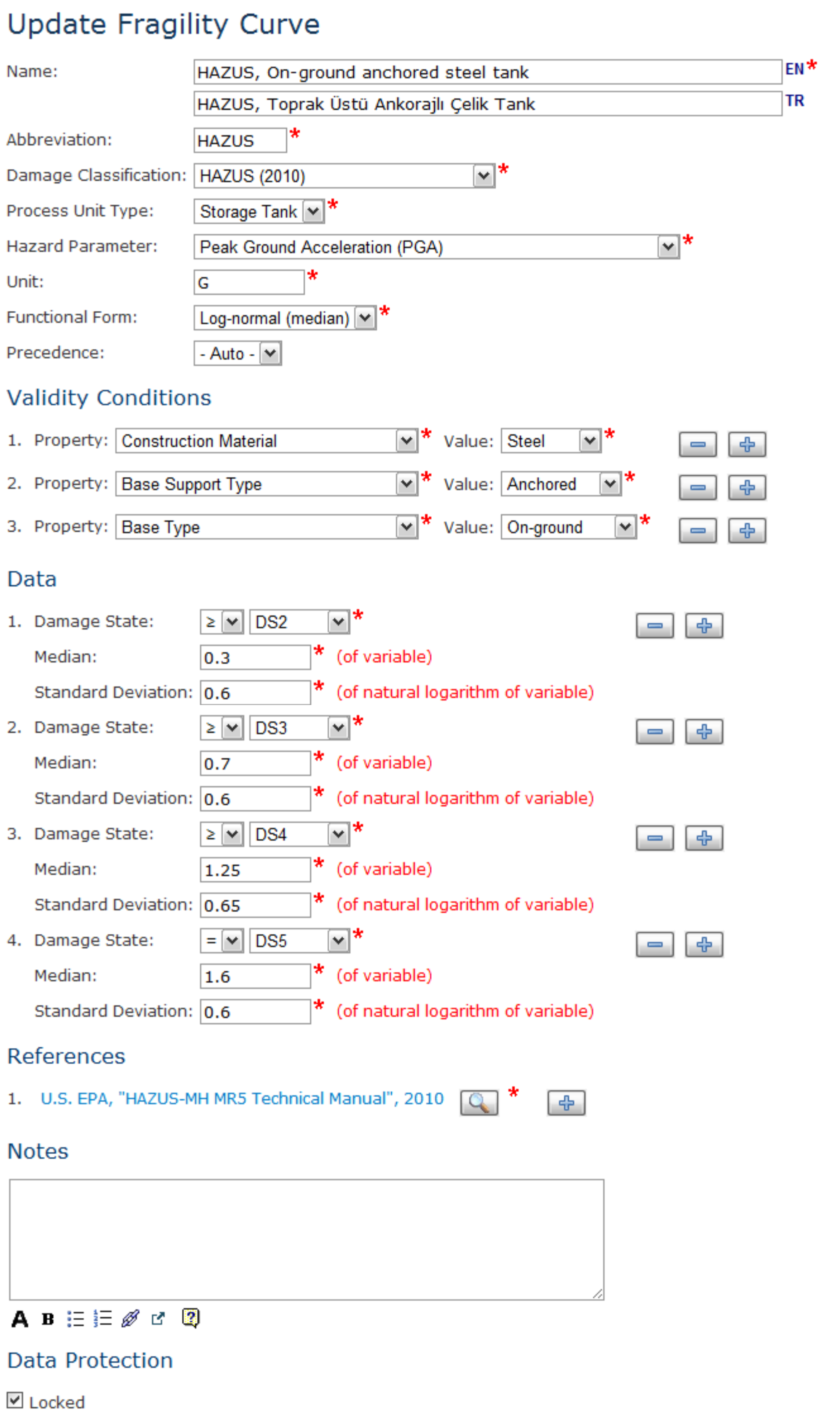


Figure 7.4 Fragility curve data entry

The type of the fragility curve denotes the data source of the curve. Pre-defined fragility curves are based on data available in the scientific literature. Custom fragility curves are based on historical natech damage data available in the database. Support for custom fragility curve preparation is currently under development and will be available in the next version of RAPID-N. For pre-defined fragility curves, four different functional forms are supported, which are listed in Table 7.5. Most, if not all, fragility curves found in the literature are in one of these functional forms. Hence, there should be no difficulty in adding fragility curves to the RAPID-N database.

Table 7.5. Functional forms supported for fragility curves

Functional Form	Parameters	Equation
Log-normal (median)	Median (m) Standard deviation (σ)	$\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{\ln x-\ln m}{\sigma\sqrt{2}}\right)\right]$
Log-normal (mean)	Mean (μ) Standard deviation (σ)	$\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{\ln x-\mu}{\sigma\sqrt{2}}\right)\right]$
Probit	k_1 k_2	$\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{(k_1+k_2\ln(x)-5}{\sqrt{2}}\right)\right]$
Dataset	Parameter values Probabilities	Quadratic Interpolation

For pre-defined fragility curves, curve data should be entered separately for each damage state. It is not mandatory to enter data for all damage states. Therefore, a subset of damage states can be used. Damage states have to be unique, i.e. it is not possible to enter different damage definitions for the same damage state. In addition to the damage state, its context either as equal (=) or equal or greater (≥) should also be indicated for each data row. The standard deviation, and mean or median should be entered for each data row for log-normal fragility curves. Probit curves require k_1 and k_2 constants. For curves defined by a dataset, semi-colon separated parameter and probability values should be entered. The number of parameter and probability values should be equal to each other. In order to calculate the damage probability for a certain value of the hazard parameter, quadratic interpolation is used for dataset-based fragility curves. Equations used for other functional forms are listed in Table 7.5.

Similar to the property estimators, validity conditions can be specified for fragility curves. Therefore, a fragility curve can be created specifically for a selected type of process unit with certain kinds of properties (e.g. atmospheric fixed-roof cylindrical storage tanks). See “Property Estimators” section for more details on the definition and evaluation of validity conditions. Unless “flexible fragility curve selection” is activated, only compatible fragility curves are used for damage estimation at a process unit. If the flexible selection is active, the most suitable fragility curve is used if no compatible fragility curve is found. See “Risk Assessment” section for more details on damage estimation.

For pre-defined fragility curves, bibliographic references should be indicated to provide information on the origin of the fragility curve data. At least one reference is mandatory to assure data quality. For custom fragility curves, list of bibliographic references is automatically generated by the system by using the references of natech damage records used for the calculation of the fragility curve.

Fragility curve information is presented in tabular form on the view page, together with curve data, validity conditions, and bibliographic references. Interactive fragility curve plots are provided for each damage state. Fragility curves are plotted on the same graph as separate series, so that they can be compared easily. By moving the mouse pointer over the curves, numerical values of damage probabilities can be obtained. A sample fragility curve information page is shown in Figure 7.5.

Fragility Curve Information

Name:	HAZUS, On-ground anchored steel tank
Abbreviation:	HAZUS
Process Unit Type:	Storage Tank
Damage Classification:	HAZUS (2010)
Hazard Parameter:	Peak Ground Acceleration (PGA)
Unit:	g
Functional Form:	Log-normal (median)
Precedence:	Auto

Validity Conditions

Base Type:	On-ground
Base Support Type:	Anchored
Construction Material:	Steel

Data

No	Damage State	Median	Standard Deviation
1.	≥ DS2	0.3	0.6
2.	≥ DS3	0.7	0.6
3.	≥ DS4	1.25	0.65
4.	= DS5	1.6	0.6

References

No	Reference
1.	U.S. EPA, "HAZUS-MH MR5 Technical Manual", 2010

Fragility Curve

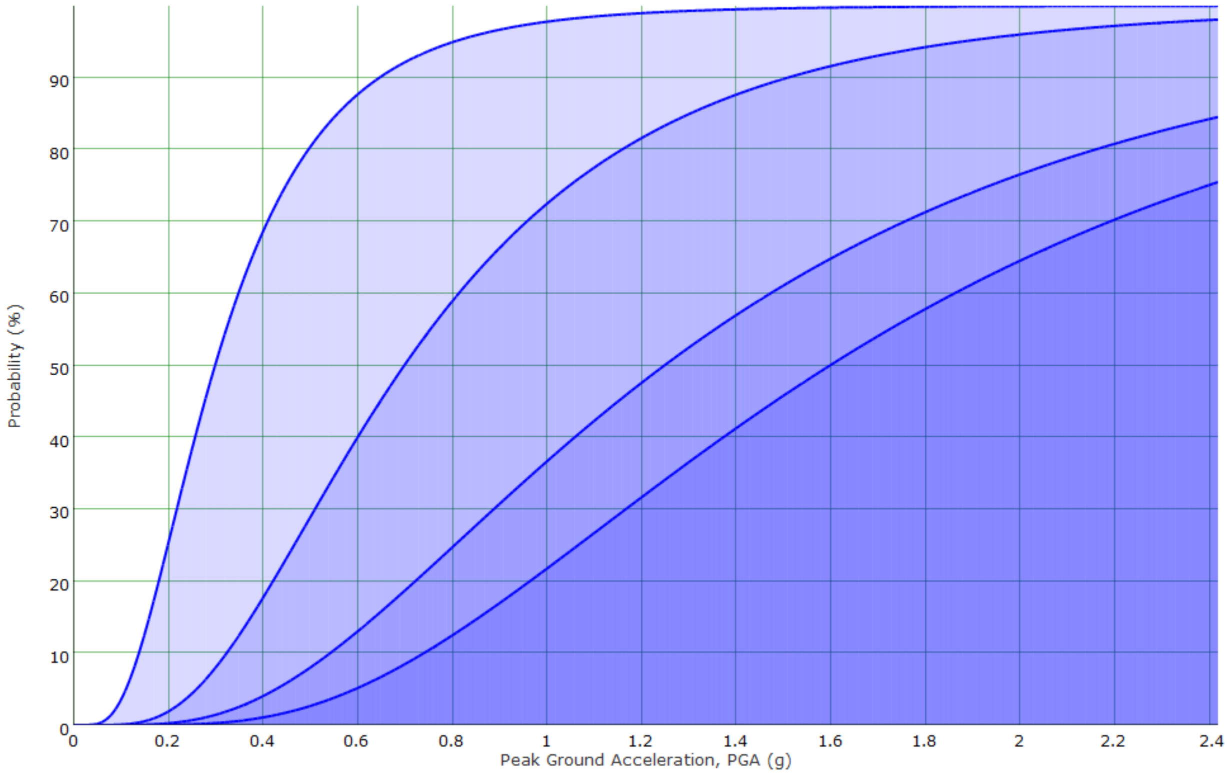


Figure 7.5 Fragility curve information

7.4 Risk Assessment

Natech risk assessment and mapping, which is the primary functionality of RAPID-N, is carried out in two steps. In the first step, the structural damage probability of process units located at facilities is calculated by using the hazard parameters of a scenario natural hazard as input. For this purpose, the on-site hazard parameters are calculated either by using hazard-specific property estimators, or by using pre-calculated values available as hazard maps. Manual entry of on-site hazard parameters is also supported. The damage probabilities are calculated for possible damage states by utilizing fragility curves. By using risk states relating damage states to major events, probable consequence scenarios are determined. The U.S. EPA RMP Guidance for Offsite Consequence Analysis methodology (U.S. EPA, 1999) is used to estimate the distance to the endpoints for toxic and flammable substances and the results are converted into risk maps. The risk assessment records are used to select natural hazard scenarios, define settings for natech risk assessment, store output data, and visualize the results. The data fields of the risk assessment records are listed in Table 7.6.

Table 7.6 Risk assessment data fields

Field	Type	Description
Name*	Text (128)	Name of the risk assessment
Date*	Date	Date of the risk assessment (read-only)
Type*	Drop-down	Type of the risk assessment • Public • Private
Hazard Information		
Hazard*	Reference	Hazard scenario of the risk assessment
Hazard Map	Drop-down	Hazard map to be used for damage assessment (linked to the hazard, default is none)
Facility Information		
Facility	Reference	Facility that should be included in the risk assessment. If not specified, all facilities within the cutoff distance are included in the risk assessment.
Cutoff Distance* [1]	Decimal	Cutoff distance for automatic selection of the facilities (km)
LIST: On-site Hazard Parameters [2]		
Property*	Drop-down	Name of the on-site hazard parameter (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the on-site hazard parameter
Unit* [3]	Unit	Unit of the on-site hazard parameter
Damage Estimation		
Damage Classification	Drop-down	Damage classification to be used for the damage assessment (linked to the type of the hazard, default is auto)
Fragility Curve [4]	Drop-down	Fragility curve to be used for the damage assessment (linked to the damage classification, default is auto)

Field	Type	Description
Flexible Fragility Curve Selection [5]	Checkbox	If checked, flexible fragility curve selection procedure is applied
Evaluate Compatible Process Units Only [4]	Drop-down	If checked, process units that are compatible with the selected damage state (and fragility curve is specified) are included to the risk assessment
LIST: Damage Parameters		
Property*	Drop-down	Name of the damage parameter (unique) (see Properties)
Value*	Drop-down Fuzzy Scientific	Value of the damage parameter
Unit* [3]	Unit	Unit of the damage parameter
Notes	Wiki	Notes on the risk assessment

[1] Available if **Facility** is not specified

[2] Available if **Facility** is specified

[3] Available if **Property** has a unit

[4] Available if **Damage Classification** is specified

[5] Available if **Fragility Curve** is not specified

For each risk assessment a descriptive name should be specified. The date of the risk assessment is automatically assigned by the system. The type of risk assessment can be indicated as public or private. Public risk assessments are available to everyone, whereas private risk assessments can only be accessed by the owners. The triggering natural hazard, for which risk assessment will be performed, should be selected from the available hazards in the database. Both historical and scenario hazards can be used. If hazard maps are available for the selected natural hazard, they are listed automatically in the hazard maps drop-down list. Selecting a hazard map from the list enforces the system to use the hazard map instead of property estimators to calculate on-site hazard parameters at the target facilities.

For the estimation of damage probabilities, the system is capable of determining the most suitable damage classification and fragility curve for each process unit individually. But if needed, a specific damage classification can be defined. Selecting a damage classification activates the fragility curve drop-down list. This list contains fragility curves defined for the selected damage classification. By default, a fragility curve from this list is automatically assigned to each process unit considering process unit properties and the flexible fragility curve selection status. If needed, the system can be forced to use a certain fragility curve for all process units by selecting a custom fragility curve from the list. Process units, which are not compatible with the selected damage classification or fragility curve, can be exempted from risk assessment by activating the *"Evaluate compatible process units only"* checkbox. Because process unit information is mostly not readily available, many facilities in the database may not have process unit data. Normally, risk assessment is not possible for such facilities. However, to give at least an idea about possible damage probabilities, the system puts imaginary typical process units at such facilities during the risk assessment and reports the results accordingly. If this feature is not needed, facilities without process units can also be excluded from the analysis by activating *"Exclude facilities without process units"* option (Figure 7.6).

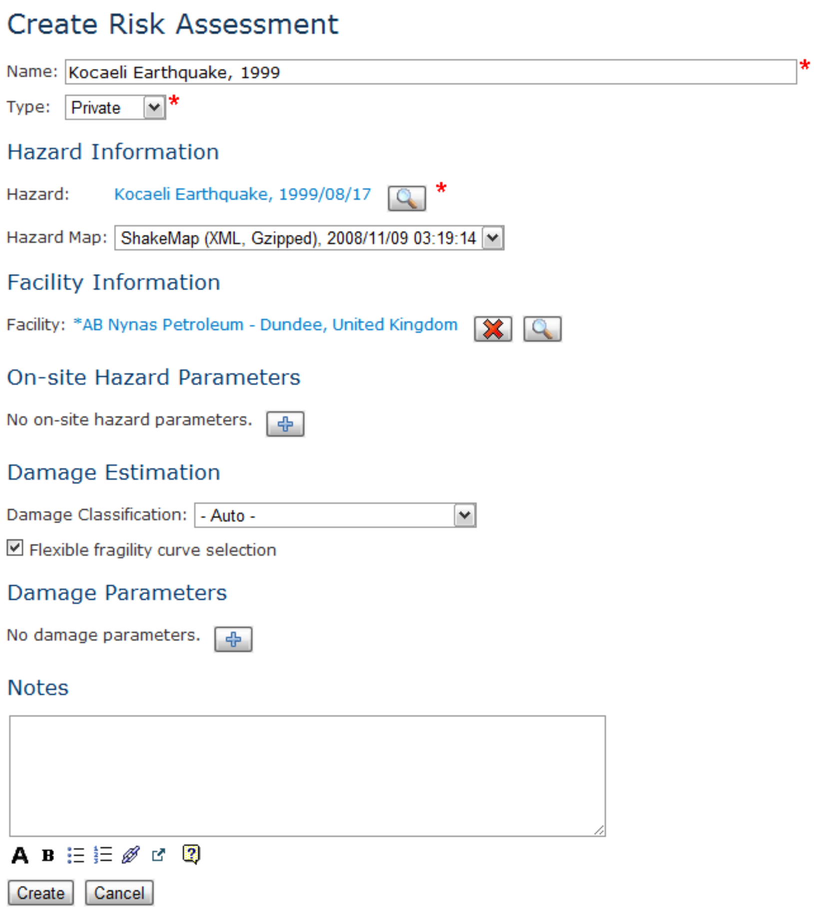


Figure 7.6 Risk assessment data entry form

By default, facilities that should be covered in the risk assessment are automatically determined by the system. To speed-up the analysis, a user-defined cutoff distance is used to eliminate facilities far away from the origin of the hazard. If the analysis should be limited to a selected facility, it should be selected from the facilities available in the database. For a user-defined facility, the system allows manual on-site hazard parameters entry in addition to calculating hazard parameters by using property estimators or the hazard map. On-site hazard parameters should be unique, but fuzzy numbers can be specified for numerical parameters.

For consequence analysis and natech risk assessment, RAPID-N uses damage parameters specified in the risk states. For a given natural hazard scenario and taking process unit properties into consideration, the system determines suitable risk states and in the order of their precedence, uses their damage parameters as input parameters for the calculations. It is also possible to enter custom damage parameters specifically for each risk assessment. If they are available, custom damage properties overwrite damage parameters obtained from the risk states. Custom damage parameters should be indicated in the damage parameters section. Fuzzy numbers are supported for numerical parameters.

Once all natech risk assessment data are specified, the risk assessment is carried out in two main steps. In the first step, the natural hazard damage estimation is performed to determine the damage probability of process units located at the facilities due to the natural hazard. In the second step, likely major events are identified and the severity of the consequences are calculated by using the U.S. EPA RMP Guidance for Offsite Consequence Analysis methodology.

The damage estimation procedure follows the steps listed below:

1. In the first step of the damage assessment, the facilities for which the risk assessment will be done are determined. If a custom facility is selected, it is used for the analysis. Otherwise, for each facility available in the database, the distance to the origin of the hazard is calculated and compared to the cutoff distance. Facilities that are within the cutoff distance are selected for risk assessment. If the "*Exclude facilities without process units*" option is activated, facilities without process units are excluded from the list of selected facilities.

2. For each selected facility, on-site hazard parameters are calculated. If a hazard map is specified, first the hazard parameters found in the hazard map are interpolated to find the parameter values at the facility location. Then property estimators are used to estimate additional parameters by using the interpolated hazard parameter data as input. Facilities located outside the hazard map boundary are excluded from the risk assessment. If no hazard map is specified, source hazard parameter data from the system's database is used as the input data and on-site hazard parameters are calculated by using property estimators. If on-site hazard data is available either as a on-site hazard data record for the facility or as manual input to the risk assessment (for the selected facility), they are directly included in the list of on-site hazard parameters.

3. For each facility, process units that should be included in the risk assessment are determined. For this purpose, process unit properties are determined for each process unit by using available process unit property estimators and taking user-defined process unit properties as input. If a certain fragility curve is specified for risk assessment and the "*Evaluate compatible process units only*" option is checked, process units that are not compatible with the fragility curve are excluded from the analysis. Otherwise all process units are used.

4. For each process unit, a suitable fragility curve is determined. If a fragility curve is specified explicitly for the risk assessment, that fragility curve is used directly. Otherwise, the validity conditions of the available fragility curves are tested against the process unit properties and fragility curves appropriate for the process unit are added to the list of candidate fragility curves. If a damage classification is specified explicitly for risk assessment, only the fragility curves defined for the damage classification are used for the evaluation of candidate fragility curves. Among the candidate fragility curves, the curve with the highest number of validity conditions is selected as the fragility curve for the damage estimation. If no candidate curves are found, the system checks the "*Flexible fragility curve selection*" option. If this option is active, the curve fulfilling the maximum number of validity conditions is selected for the damage estimation. Otherwise, the process unit is excluded from the risk assessment procedure.

5. By using on-site hazard parameters calculated in step 2 and the fragility curve selected in step 4, damage probabilities are calculated for each damage state of the fragility curve.

The risk assessment procedure follows the steps listed below:

1. If the damage probability calculated for a process unit is less than 0.001% (10^{-5}), the unit is excluded from the risk assessment.

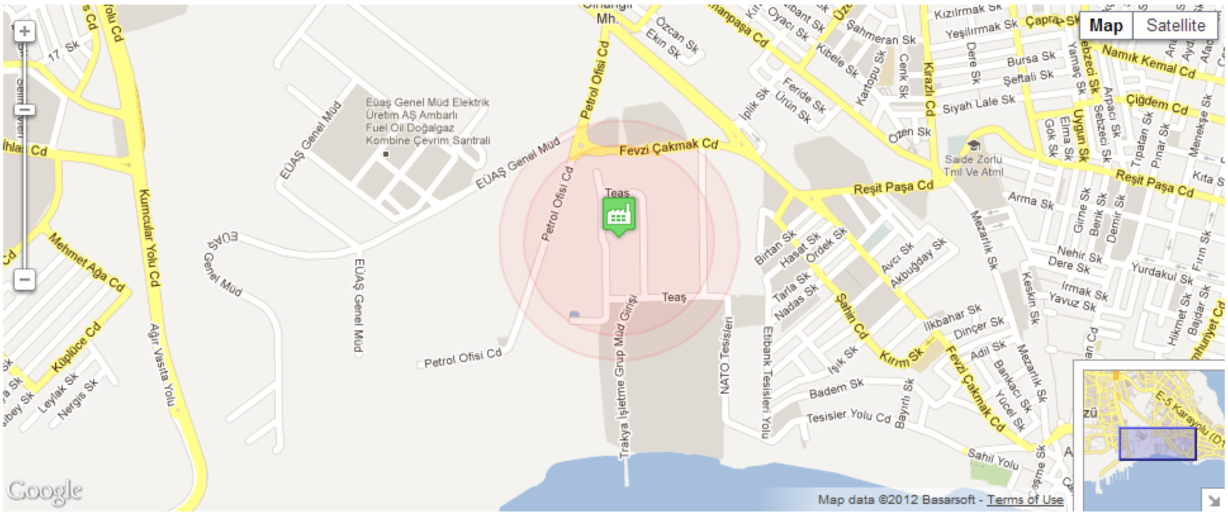
2. If information on substances found in the process unit is not available, the damage probability of the process unit is reported and the unit is excluded from the risk assessment.

3. For each damage state having an occurrence probability greater than 0.001% (10^{-5}), the risk state corresponding to the damage state is found. For this purpose, risk states available in the database for the damage state are examined and their validity conditions evaluated for the process unit. Similar to the suitable fragility curve selection procedure, the risk state for which the validity conditions are fulfilled and which has the highest number of conditions is selected for the risk assessment. Both process unit and substance properties are used to evaluate validity conditions.

4. According to the damage parameters of the selected risk state and custom damage parameters specified in the risk assessment record, the distance to the endpoint calculations are conducted by using the U.S. EPA RMP Guidance for Offsite Consequence Analysis methodology (U.S. EPA, 1999). RAPID-N includes a self-implementation of the U.S. EPA RMP methodology by using the property estimation framework. All equations and rules required for the analysis are entered into RAPID-N as property estimators. Hence, suitable combinations of equations are automatically selected by the system. Use of the property estimation framework allows parameters used by the equations to be modified and alternative equations to be substituted easily. For example, endpoint distance criteria, which are set as second-degree burns, can be changed for first or third-degree burns, or the atmospheric dispersion model, which uses lookup tables, can be substituted with a more advanced model. By modifying the damage parameters different scenarios can be evaluated without any modifications to the system code and without any disturbance to the existing system functionality.

The results of the risk assessment are presented as summary reports and interactive risk maps showing natech event probabilities and the areas possibly affected by the events. A sample risk assessment report and corresponding risk map are given in Figure 7.7.

Risk Assessment Information



Name:	Kocaeli Earthquake Single Plant [Test]
Date:	2012/08/28 13:11:13
Type:	Private

Hazard Information

Hazard:	Kocaeli Earthquake, 1999/08/17
Hazard Map:	ShakeMap (XML, Gzipped), 2008/11/09 03:19:14

Facility Information

Facility:	Ambarli Gas Power Plant, Turkey

Damage Estimation

Damage Classification:	Auto
Flexible fragility curve selection:	Yes

Facilities

1. Ambarli Gas Power Plant, Turkey

No	Process Unit	Hazard Parameters	Fragility Curve	Damage Estimate	Damage Parameters	End-point Distance
1.	Storage Tank (T-STR)* [Gasoline]	PGA: 18.777 %g; EMS: Slightly damaging; MM: Strong; MSK: Strong; MMI: 6.4866; d_e: 101.38 km; d_h: 102.79 km; PGA_h: 74.415 cm/s2; PGV: 15.573 cm/s «	OS00-F50-G	≥ DS2: 4.0546%	Fire/Explosion Event: Vapor Cloud Explosion; $Q_{involved}$: 4250 kg; $f_{m,\ passive}$: 1; $P_{c,\ fire}$: 100%; $f_{V,\ involved}$: 10 %v; $V_{involved}$: 5.7432 m3; $P_{c,\ release}$: 30%; f_{yield}: 0.1; RMP Scenario: Worst-case; $t_{release}$: 10 min; $q_{release}$: 425 kg/min; $Q_{released}$: 4250 kg; A_{pool}: 6146.1 ft2; h_{pool}: 1 cm; $q_{release,\ r}$: 425 kg/min; T_a: 1; R: 0.4; q_R: 5000 W/m2; t_{exp}: 40 s; D_T: 342 TDU; d_e: 270.58 m; Q_{fuel}: 4250 kg; P_{damage}: 4.0546%; P_{natech}: 4.0546% «	271 m: 4.0546%
				≥ DS3: 0.004631%	Fire/Explosion Event: Vapor Cloud Explosion; $Q_{involved}$: 8500 kg »	341 m: 0.004631%
				≥ DS4: Very low	-	-

Created: Serkan Girgin, 2012/08/28 13:11:13

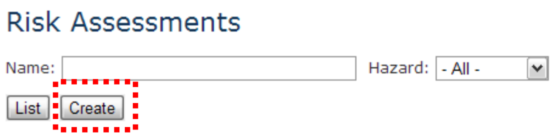
Update Delete

Figure 7.7 Sample risk assessment report and map

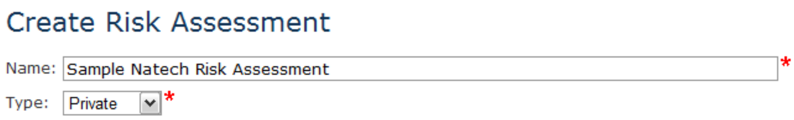
8 Risk Assessment Tutorial

1. After you login to the application, click the “Risk Assessments” icon on the personal page.

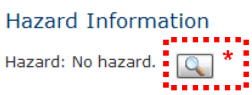
Click the “Create” button on the risk assessments page.

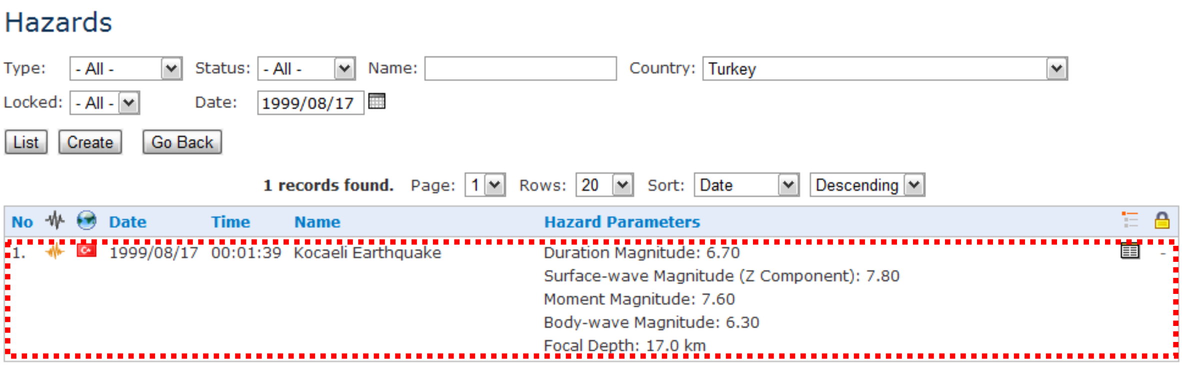


2. Enter the name of the risk assessment and select its type. Private risk assessments can only be accessed by you (the owner) and the administrators. Public risk assessments are accessible by everyone.

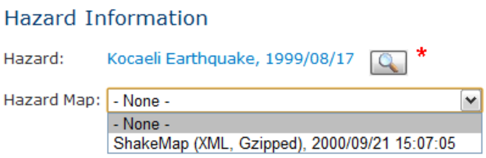


3. Select the hazard, for which the risk assessment will be done. When you click the “find” button next to the hazard field, the application will take you to the listing page of the hazards available in the database. By using filtering options do a search for the hazard and select the hazard by clicking its row at the hazards table displayed by the application. Both scenario and historical hazards can be selected for risk assessment.

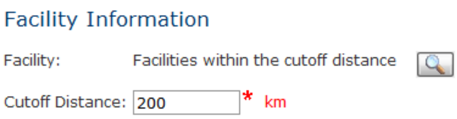




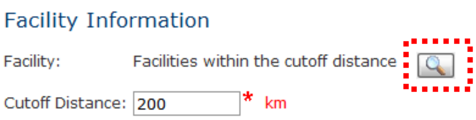
4. Once you select the hazard, the application will return to the risk assessment form. If hazard maps are available in the database for the selected hazard, they will be listed under the hazard maps drop-down list. Select a hazard map from the list if you want to use pre-calculated on-site hazard parameters available in a hazard map for damage assessment calculations. If no hazard maps are available or none is selected, the application uses the property estimation framework to calculate the required on-site hazard parameters. The property estimation framework is also utilized if a hazard map is selected, but in that case it is used only to calculate missing data.

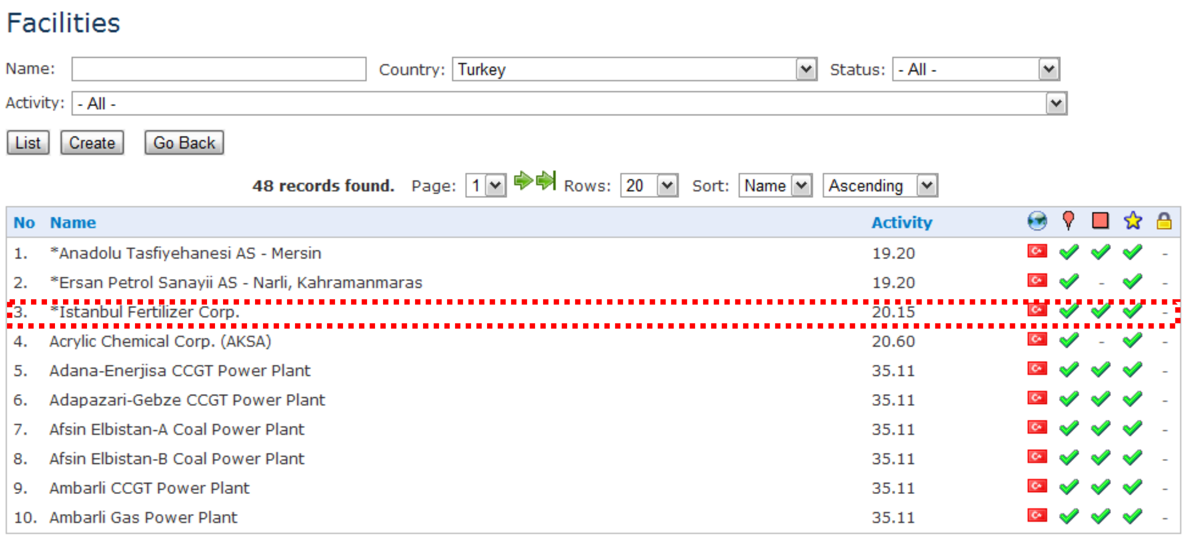


5. By default, RAPID-N calculates natech risks at the industrial facilities located close to the natural hazard. The facilities are determined automatically by using a cutoff distance (in km) measured from the source of the natural hazard. All facilities located within the cutoff distance are included in the risk assessment. In order to broaden or restrict the number of facilities, you can modify the cutoff distance by entering a custom distance value.

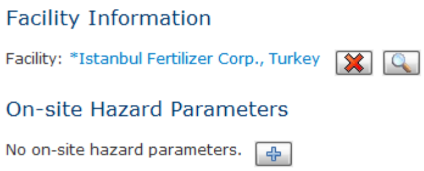


6. If you want to restrict risk assessment to a certain industrial facility, select the facility by clicking the "find" button next to the facility field. Similar to the hazard selection, the application will take you to the listing page of the facilities available in the database. By using filtering options do a search for the facility and select the facility by clicking its row at the hazards table displayed by the application.

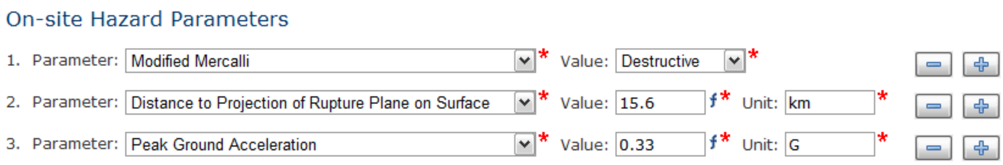




Once you select the facility, the application will return to the risk assessment form. Cutoff distance field will be disabled, and on-site hazard parameters section will be enabled.

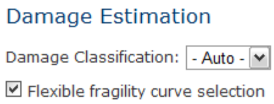


By using the on-site hazard parameters section, you can enter custom on-site hazard parameters for the facility, which will overwrite the parameters taken from the hazard map (if a hazard map is selected) or that will be calculated by the system by using the property estimation framework. You can use this functionality to modify an existing hazard scenario for a specific case in a quick way, or provide additional on-site hazard data not available in the hazard map and which cannot be estimated by the available property estimators.

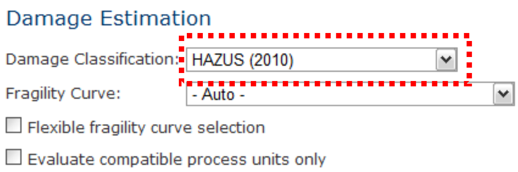


On-site hazard parameter entry is not possible if facilities are automatically selected by the system by using the cutoff distance. But on-site hazard data records can be used to supply facility-specific on-site hazard data for the selected hazard.

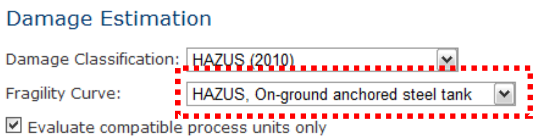
7. By default, RAPID-N selects the most appropriate damage classification and fragility curve for each process unit located at the facilities included to the risk assessment. For this purpose process unit properties are compared with the validity conditions of the available fragility curves. Fragility curves, for which all validity conditions are met and for which the value of the on-site hazard parameter used in the fragility curve is available, are ranked and the one with the highest ranking is selected as the fragility curve used. If "Flexible fragility curve selection" option is active, fragility curves that partially fulfill the validity conditions are also included in the ranking procedure.



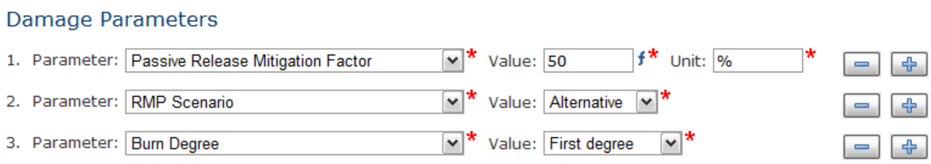
In order to impose a specific damage classification for the damage estimation, select the damage classification from the damage classification drop-down list. Selecting a damage classification enables the fragility curve drop-down list and “Evaluate compatible process units only” option. If you want to evaluate only the process units, which are compatible with the selected damage classification, activate this option.



In order to impose a specific fragility curve for the damage estimation, select the fragility curve from the fragility curve drop-down list. Selecting a fragility curve disables “Flexible fragility curve selection” option.

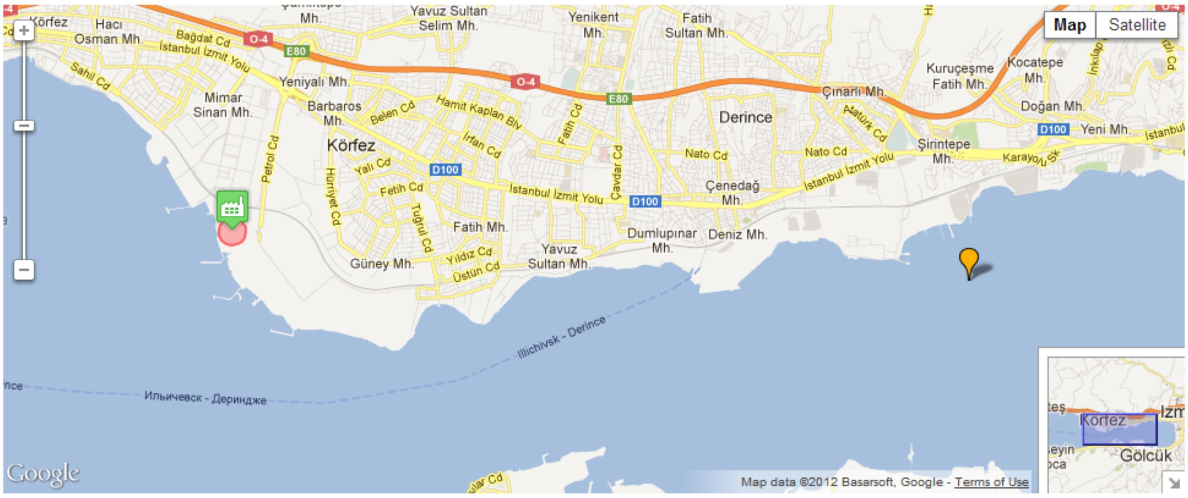


8. By default, RAPID-N conducts consequence analysis and natech risk assessment by using damage parameters specified by the risk states that correspond to the estimated damage state and that are valid for the process unit and substance conditions. See Section 7.4 for detailed explanation of the risk assessment. If you want to modify default damage parameters, specify your custom damage parameters in “Damage Parameters” section.



9. Press the “Create” button to start the risk assessment. Natural hazard damage estimation will be performed to determine the damage probability of process units located at the facilities due to the natural hazard. Then likely natech events will be identified and the severity of the consequences will be calculated. The results will be presented as a summary report and interactive risk map showing natech event probabilities and endpoint distances.

Risk Assessment Information



Name:	Kocaeli Earthquake [Test]
Date:	2012/08/22 08:13:17
Type:	Private

Hazard Information

Hazard:	Kocaeli Earthquake, 1999/08/17

Damage Estimation

Damage Classification:	Auto
Flexible fragility curve selection:	Yes
Facility:	*Istanbul Fertilizer Corp., Turkey

Facilities

1. *Istanbul Fertilizer Corp., Turkey

No	Process Unit	Hazard Parameters	Fragility Curve	Damage Estimate	Damage Parameters	End-point Distance
1.	Storage Tank	d_e: 8.8778 km, d_h: 19.179 km, PGA: 37.375 %g	OS00-F50-G	≥ DS2: 31.123%	$f_{V,\ involved}$: 10 %v, $V_{involved}$: 777.13 m3, $P_{c,\ release}$: 30%, DM_RMP: Worst-case, $t_{release}$: 10 min, h_{pool}: 1 cm, P_{damage}: 31.123%, $f_{m,\ passive}$: 1	No Consequence
				≥ DS3: 1.6246%	$f_{V,\ involved}$: 20 %v, $V_{involved}$: 1554.3 m3, $P_{c,\ release}$: 50%, DM_RMP: Worst-case, $t_{release}$: 10 min, h_{pool}: 1 cm, P_{damage}: 1.6246%, $f_{m,\ passive}$: 1	No Consequence
2.	Storage Tank	d_e: 8.8146 km, d_h: 19.149 km, PGA: 37.384 %g	OS00-HD07-G	≥ DS2: 34.66%	$P_{c,\ fire}$: 100%, $f_{V,\ involved}$: 10 %v, $V_{involved}$: 150.21 m3, $P_{c,\ release}$: 30%, $Q_{involved}$: 93477 kg, DM_EF: Vapor Cloud Explosion, f_{yield}: 0.1, DM_RMP: Worst-case, $t_{release}$: 10 min, $q_{release}$: 9347.7 kg/min, $Q_{released}$: 93477 kg, A_{pool}: 0 m2, h_{pool}: 1 cm, $q_{release,\ r}$: 9347.7 kg/min, τ_a: 1, R: 0.4, q_R: 5000 W/m2, t_{exp}: 40 s, D_T: 342 TDU, d_e: 164.42 m, Q_{fuel}: 934768 kg, RT_{RMP}: Table 7, P_{damage}: 34.66%, P_{natech}: 34.66%, $f_{m,\ passive}$: 1	164.415 m: 34.66%
				≥ DS3: 2.7681%	$P_{c,\ fire}$: 100%, $f_{V,\ involved}$: 20 %v, $V_{involved}$: 300.41 m3, $P_{c,\ release}$: 50%, $Q_{involved}$: 186954 kg, DM_EF: Vapor Cloud Explosion, f_{yield}: 0.1, DM_RMP: Worst-case, $t_{release}$: 10 min, $q_{release}$: 18695 kg/min, $Q_{released}$: 186954 kg, A_{pool}: 0 m2, h_{pool}: 1 cm, $q_{release,\ r}$: 18695 kg/min, τ_a: 1, R: 0.4, q_R: 5000 W/m2, t_{exp}: 40 s, D_T: 342 TDU, d_e: 164.42 m, Q_{fuel}: 934768 kg, RT_{RMP}: Table 7, P_{damage}: 2.7681%, P_{natech}: 2.7681%, $f_{m,\ passive}$: 1	164.415 m: 2.7681%

Created: Serkan Girgin, 2012/08/16 23:28:04 – Updated: Serkan Girgin, 2012/08/22 08:13:17

Update Delete

9 Administration

Although it is an advanced scientific tool for natech risk assessment, RAPID-N is fundamentally a multi-user web-based application running through a web portal. Therefore, in addition to technical tools and records, the system also features a set of tools and records in the Administration module to support web-related functionalities. These include user administration, content management, user feedback through custom messages and comments, management of user-friendly URL addresses, file type management for uploaded files, and an automated user actions and record data history follow-up mechanism. Details of these records and tools are given in the following subsections.

REMARK: Records described in this section are *only* accessible by the administrators.

9.1 Users

The main objective of RAPID-N is to facilitate natech risk assessment and mapping, and enhance information sharing on natechs by providing a collaborative, open-access environment. For this purpose, the system is developed to support multiple users.

The information available in the system, except for private natech risk assessment records, are open to everyone through the Internet. Registered users can contribute to the system by supplying facility, process unit, hazard, natech, or natech damage data and benefit from the system for natech risk assessment and mapping purposes. Registration to the system is free and can be done from the registration page accessible from the login page by providing basic personal information. Information on users are stored in user records. User records also include basic system usage statistics and user preferences besides personal information.

The data fields of the user records are listed in Table 9.1.

Table 9.1 User data fields

Field	Type	Description
Type* [1]	Drop-down	Type of the user • User • Administrator
Name*	Text (32)	Name of the user
Surname*	Text (32)	Surname of the user
E-mail*	E-mail	E-mail address of the user (unique)
Status* [1]	Drop-down	Status of the user: • Active • Pending • Suspended
Password*	Password	Password of the user (encrypted)

Field	Type	Description
Date Format	Drop-down	Date format preference for the user interface: • YYYY/MM/DD • MM/DD/YYYY • DD/MM/YYYY
Coordinate Format	Drop-down	Coordinate format preference for the user interface: • ddd.dddddd (decimal degrees) • ddd° mm.mmmmmm (degree minutes) • ddd° mm' ss.sss'' (degree minute seconds)

[1] Available to the administrators

There are two types of users with different user privileges: users and administrators. Users have data entry and modification rights; hence, they can contribute to the contents of the system. They can perform public or private natech risk assessments. Following the basic principle of open-content systems, many record types are allowed to be created by the users. However, to maintain the record integrity, if not explicitly stated otherwise, records can only be modified or deleted by the users who created them, i.e. the owners. The administrators can restrict modification rights of an owner by locking the record. Users can freely comment on records that are created by other users.

Administrators are responsible for the management of the system and have complete control over the system components. They can create, update or delete records regardless of record specific user privileges and locking mechanism applied by the system. There are also certain record types that can be accessed (e.g. contents, messages, logs) and tasks that can be performed (e.g. user management, alias management) only by the administrators, which are explained in the following sections.

In order to register to the system, name, e-mail and password should be provided. The e-mail address is used for user login. Only one user account is allowed for a single e-mail address. Administrators are allowed to delete users. However, due to the record history (logging) mechanism of the system (see "Logs" section), users who created or modified a record cannot be deleted. Such users can be prevented from logging on to the system by setting their status to suspended. The status of newly registered users and users who modified their e-mail address is set to pending until they validate their e-mail address by approving the notification e-mail sent by the system. Pending users can also temporarily not log on to the system.

Users are allowed to customize selected system settings. Currently, this feature is limited to date and coordinate formats, which determine how such data items are displayed on the data entry and view pages. Three different date formats are supported. The selected date format is binding for data entry, i.e. user-entered data should conform to the format. Similar to the date formats, three different coordinate formats are supported. However, the system supports all coordinate formats simultaneously for data entry, determines the format used by the user, and standardizes the coordinate automatically. For more details on date and coordinate data items see the "Form Elements" section.

The system collects basic system usage data for each user. The collected information includes registration date, date of the last login, total number of logins and total number of page views. This information is only used to calculate the user activity. A summary of the record-related actions performed by the user is also provided for the administrators by using information available in log records. The summary includes number of created, updated, and deleted records listed by record type (Figure 9.1).

User Information

Name:	Serkan Girgin
Type:	Administrator
Status:	Active
E-mail:	girgink@gmail.com
Password:	[Encrypted]
Registration Date:	2011/05/26 07:05:00

User Interface Settings

Date Format:	YYYY/MM/DD
Coordinate Format:	ddd° mm.mmmmmm

Login Information

Login Date:	2012/09/09 02:58:05
Login Count:	474
Page count:	43939

Record Information

Record Type	Created	Updated	Deleted
Activity	1	-	-
Alias	2	4	-
Catalog Data	1	2	-
Comment	1	-	1
Common Unit	4	-	1
Content	5	6	2
Damage Classification	6	17	3
Facility	13	61	1
Fragility Curve	11	2	-
Hazard	3	5	-
Help	2	1	-
Message	1	-	1
MIME	14	5	-
Natech	12	6	-
Natech Damage	2	4	-

Record Type	Created	Updated	Deleted
Onsite Hazard Data	1	-	-
Process Unit	172	225	19
Process Unit Group	4	2	1
Process Unit Type	14	19	2
Property	120	49	1
Property Estimator	214	80	15
Property Type	18	8	-
Reference	40	3	-
Risk Assessment	6	16	2
Risk State	14	21	-
Substance	10	4	-
Typical Process Unit	2	6	-
Unit	6	1	-
User	-	13	-

Created: System – Updated: Serkan Girgin, 2011/09/29 14:35:52

Update Delete Go Back

Figure 9.1 User Information

9.2 Contents

In addition to record-oriented dynamic content generated by the system, RAPID-N also includes static pages to provide complementary information, e.g. legal notice, contact information, links. Such pages are stored as content records. The data fields of the content records are listed in Table 9.2.

Table 9.2 Content data fields

Field	Type	Description
Title*	Text (64)	Title of the content (multilingual)
Published	Checkbox	If checked, the content is published
Introduction*	Wiki	Introduction (multilingual)
Body	Wiki	Body (multilingual)

Each content record is composed of title, introduction and body sections, all of which are multilingual. The title is mandatory and used as the heading of the content. The introduction should be entered at least for the base (system) language. Generally, it is used as the body of the content for short pages. For long pages both introduction and body sections are utilized. They are displayed on the content view pages as if they were a single entity. Content records can also be used as inline contents in the wiki fields. See Form Elements section for more details. Only content records marked as published are accessible to the users and visitors. Hence, the administrators should change the status to published once the content is finalized. Contents can be listed by content (title, introduction, and body, either separately or altogether), published status, and existence of the body section (Figure 9.2).

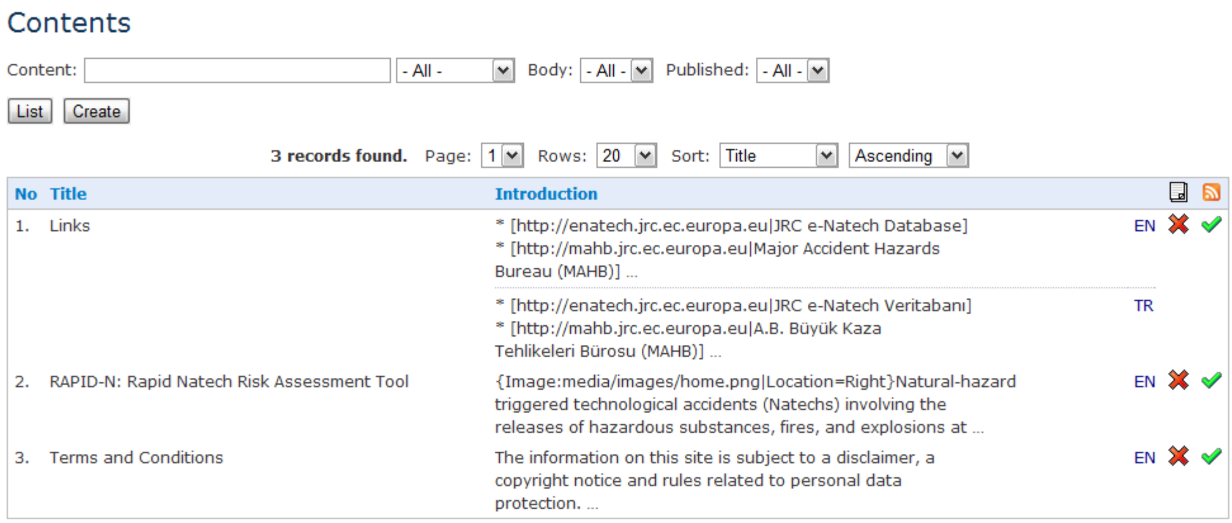


Figure 9.2 List of content records

9.3 Messages

Users of the system, including unregistered visitors, can ask questions or make comments on the system's functionality by using the contact form provided on the contact information page, which is accessible from the top menu. These messages are stored in the message records. The data fields of the message records are listed in Table 9.3.

Table 9.3 Message data fields

Field	Type	Description
Date*	Date	Date of the message (read-only)
Name*	Text (64)	Name of the sender
E-mail*	E-mail	E-mail address of the sender
Subject*	Text (128)	Subject of the message
Message*	Text	Message

Message records are read-only records, therefore they can not be modified even by the administrators. In order to submit a message, name, e-mail address, subject, and message body should be entered. The date of the message is automatically assigned by the system. Administrators can access all messages through a message list. Replies to a message should be sent manually by using an external e-mail application.

9.4 Comments

The system allows registered users to comment on selected record types. Comments are listed as the last item on the record information pages. For each comment, date and user name are indicated. They are displayed in decreasing order with respect to the creation date. Without leaving the page, users can add comments or update existing ones written by themselves by using the provided comment entry form (Figure 9.3). The administrators can list all comments by record type, record ID, date, user, and comment text. If required, comments can also be updated or deleted by the administrators by using comment-specific record update and delete pages.

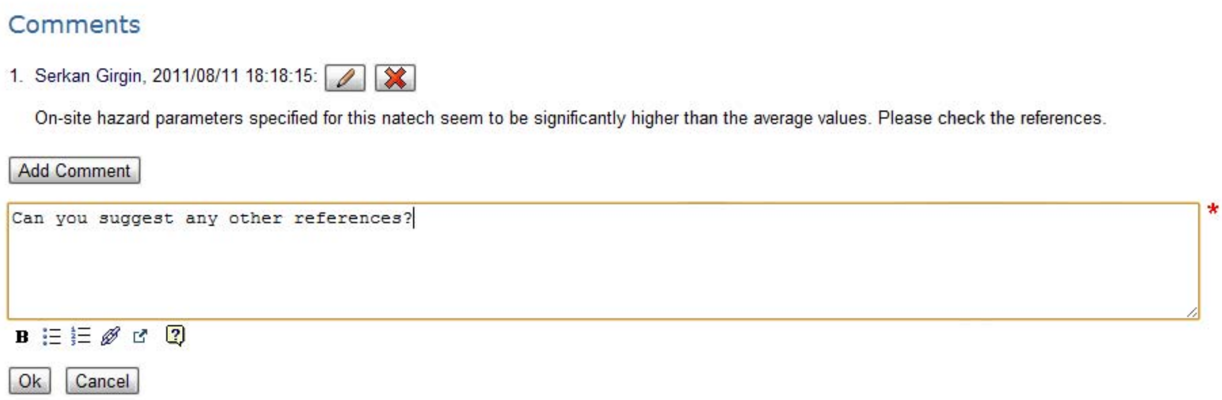


Figure 9.3 Comment entry form

9.5 Aliases

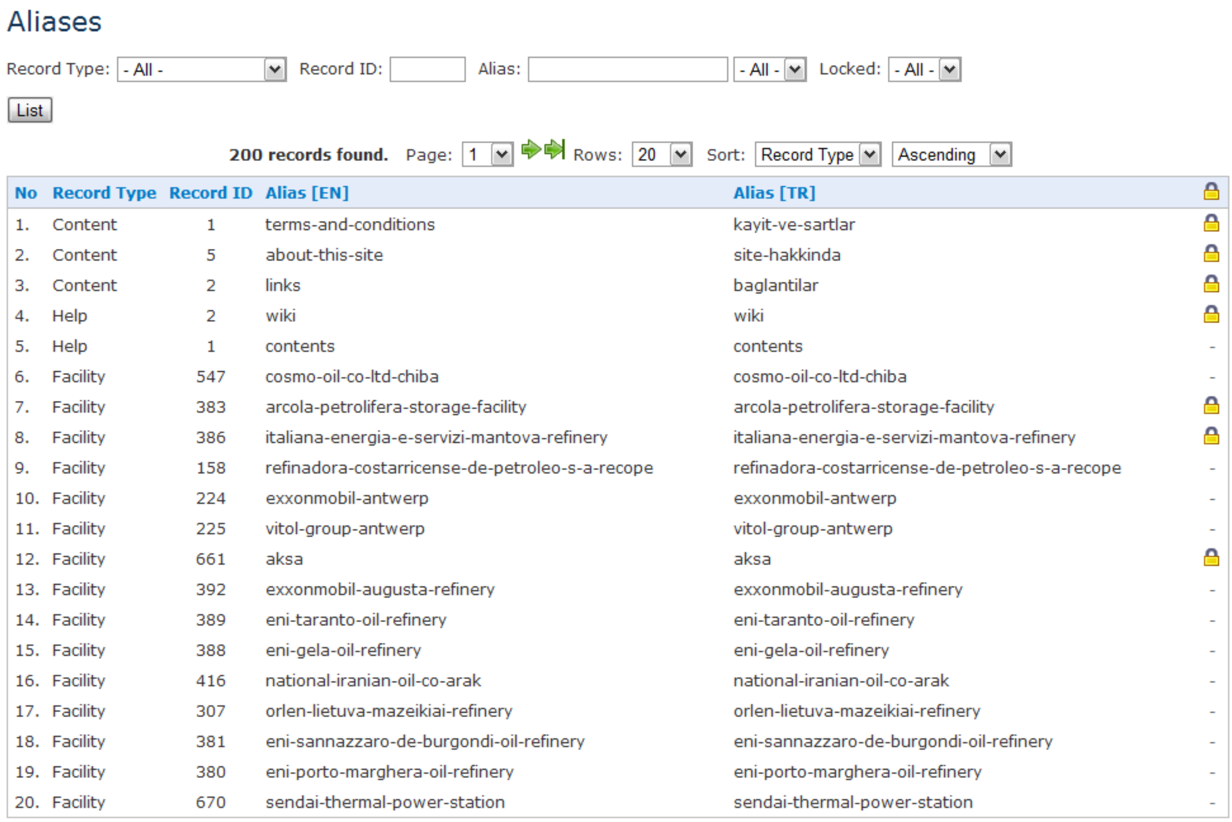
Each record in the system has a unique numerical identifier. These identifiers are used internally to refer to records in record-related actions, such as view, update, or delete actions. Since the system is a web-based application, each action is accessed through a URL and record identifiers are part of these URLs. A typical system URL is in the form of *[record type]/[record action]/[record id]*, e.g. *facility/view/224*. Although some system URLs are only used internally, some others, especially URLs of record view pages, are used to refer to the records externally, for example for giving links to the records. Since numerical identifiers are not easy to remember and do not give any insight in the contents of the record, the system supports the use of alpha-numeric aliases instead of numerical record identifiers. This leads to more meaningful, user- and search engine-friendly URLs, e.g. *facility/view/exxonmobil_antwerp* instead of *facility/view/224*. Alias records are used to store such aliases. The data fields of the alias records are listed in Table 9.4.

Table 9.4 Alias data fields

Field	Type	Description
Record Code*	Integer	Code of the record type (read-only)
Record ID*	Integer	Numerical identifier of the record (read-only)
Alias*	Token (64)	Alias of the record (multilingual)
Locked	Checkbox	If checked, the alias is locked

Each alias record has a record code denoting the type of the record and a record ID, which should be unique. Multiple alias records are not allowed for the same record. Both record code and record ID are read-only and cannot be changed once the alias record is created. However, one could delete the alias record and create a new one with new record code and ID. The alias that should be used to identify the record instead of the numerical identifier should be specified. Only the alias in the base (system) language is mandatory. Aliases in other languages may be left blank. Similar to record identifiers, aliases (including multilingual ones) should be unique among the records of the same record type. If available, the system uses the alias in the active (user interface) language to generate URLs, so that all URL components are concordant to each other. For example, the URL *facility/view/tupras_refinery* in English becomes *tesis/goster/tupras_rafinerisi* in Turkish. If the alias in the active language is not available, the one in the base language is used as the default alias. If the multilingual aliases of a record are deemed to be in final form, the alias record can be locked to prevent the automatic alias updating described below. Alias records can be listed by record type, record ID, alias (in multiple languages), and locked status (Figure 9.4).

In order to facilitate aliasing of records, the system provides two mechanisms. The first one is automated aliasing of records once they are created. A user-defined combination of record data fields, which is designated by the *“alias”* attribute of the data definition section of the record form, is used to generate such aliases. Aliases are generated for all supported languages by using the data field values in different languages wherever possible. If a generated alias exists in the database, a sequential numerical prefix is appended to the alias to obtain a unique alias. Unless the alias record is locked, aliases are automatically updated if the record is modified. For example, if the name field is designated as the automated alias field for a record type and the user modifies the name of a record, then the alias is also automatically modified in line with the name change. The automated aliasing mechanism provides an efficient way to create aliases without any user intervention.



No	Record Type	Record ID	Alias [EN]	Alias [TR]	
1.	Content	1	terms-and-conditions	kayit-ve-sartlar	
2.	Content	5	about-this-site	site-hakkinda	
3.	Content	2	links	baglantilar	
4.	Help	2	wiki	wiki	
5.	Help	1	contents	contents	-
6.	Facility	547	cosmo-oil-co-ltd-chiba	cosmo-oil-co-ltd-chiba	-
7.	Facility	383	arcola-petrolifera-storage-facility	arcola-petrolifera-storage-facility	
8.	Facility	386	italiana-energia-e-servizi-mantova-refinery	italiana-energia-e-servizi-mantova-refinery	
9.	Facility	158	refinadora-costarricense-de-petroleo-s-a-recope	refinadora-costarricense-de-petroleo-s-a-recope	-
10.	Facility	224	exxonmobil-antwerp	exxonmobil-antwerp	-
11.	Facility	225	vitol-group-antwerp	vitol-group-antwerp	-
12.	Facility	661	aksa	aksa	
13.	Facility	392	exxonmobil-augusta-refinery	exxonmobil-augusta-refinery	-
14.	Facility	389	eni-taranto-oil-refinery	eni-taranto-oil-refinery	-
15.	Facility	388	eni-gela-oil-refinery	eni-gela-oil-refinery	-
16.	Facility	416	national-iranian-oil-co-arak	national-iranian-oil-co-arak	-
17.	Facility	307	orlen-lietuva-mazeikiai-refinery	orlen-lietuva-mazeikiai-refinery	-
18.	Facility	381	eni-sannazzaro-de-burgondi-oil-refinery	eni-sannazzaro-de-burgondi-oil-refinery	-
19.	Facility	380	eni-porto-marghera-oil-refinery	eni-porto-marghera-oil-refinery	-
20.	Facility	670	sendai-thermal-power-station	sendai-thermal-power-station	-

Figure 9.4 List of alias records

The second mechanism provided by the system is the alias entry form, which is displayed at each record view page for the records defined as alias-able (Figure 9.5). By using the form, existing aliases can be easily modified, deleted, or locked by the administrators. Once the aliases are modified on the form, the *Ok* button should be clicked to save the data. The form communicates with the server asynchronously; therefore, no form submission is required. Similar to other record types, alias records can also be updated or deleted by using alias-specific record update and delete pages.

Figure 9.5 Alias entry form

9.6 MIMEs

The MIME (Multipurpose Internet Mail Extension) type is a two-part identifier for file formats on the Internet. The identifiers were originally defined for use in email, but their use has expanded to various applications including web browsers. They are mainly used to identify media files, such as graphic files (e.g. JPEG, PNG, and GIF) and documents (e.g. PDF, DOC, and XLS). The system uses MIME types to identify files uploaded to the system, for example hazard maps.

Data fields of the MIME records are listed in Table 9.5.

Table 9.5 MIME data fields

Field	Type	Description
Type*	Text (48)	MIME type
Unique	Checkbox	If checked, the MIME type is considered to be unique
Name*	Text (64)	Name of the MIME type
Extension*	Token (16)	Extension of the MIME type
Icon*	Drop-down	Icon of the MIME type
LIST: Equal Types		
Type*	Text (48)	Equal MIME types (unique)

For each MIME, the type and a descriptive name should be specified. In practice, multiple file types may have the same MIME type (e.g. text/plain). Hence, the type is not necessarily unique. In case of multiple MIME records with the same type value, the system uses user-defined extensions to determine which MIME record to use to represent the file type. In general, the extension is a three-character string composed of letters and numbers. The extension should be unique among the MIME records. In shorthand notation, icons are used to represent the MIME type. Therefore, an icon should be specified for each MIME record by making a selection from the provided drop-down list. Icons defined in the common style sheet and having a prefix of *"m_"* are listed in the icon drop-down list (Figure 9.6).

Since MIME types are not standardized, different MIME types may refer to the same file type. The selection of the MIME type depends on the client application, which is the web browser of the user for the case of RAPID-N. Currently there are many web browsers available in the market (e.g. Microsoft Internet Explorer, Mozilla Firefox, and Google Chrome) using different MIME types. For example, Microsoft Internet Explorer uses *application/pjpeg* to denote JPEG images, whereas other browsers use *application/jpeg*. In order to standardize such MIME types, equal types are introduced by the system. MIME types, which are defined as the equal types of a MIME type, are automatically converted to the base MIME type. Hence, conflicting MIME types are eliminated in the database. For each MIME type, multiple but unique equal MIME types can be specified (Figure 9.6).

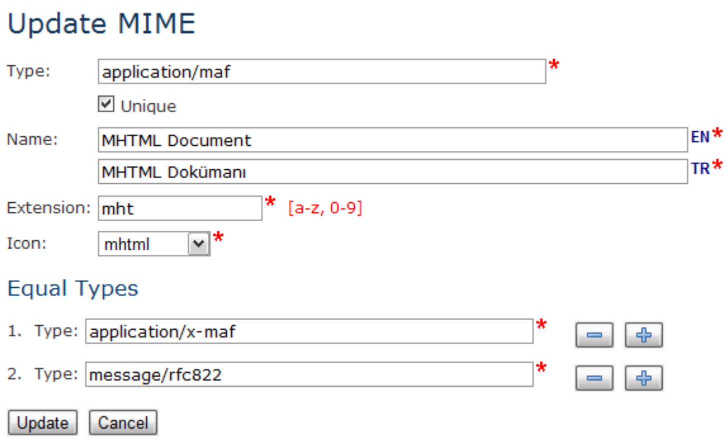


Figure 9.6 MIME data entry

When a new file is uploaded to the system, its MIME type is extracted from the file information provided by the web browser. If the MIME type is already defined in the database, either as a MIME record or as an "equal type", it is matched to the corresponding MIME record. Otherwise, MIME records are searched for the extension of the uploaded file. If a matching MIME record is found, it is used to identify the file type. If no MIME record is found fulfilling the criteria, a new MIME record is created automatically by using the MIME type. The extension of the uploaded file is used as the extension of the MIME type. Its name is generated by converting the extension into upper case and appending "File" to the end in a multilingual manner (e.g. KML File for file.kml). The administrators can modify system-generated MIME records to set an appropriate icon or enter a custom name.

9.7 Logs

An important feature of the system is its integrated record history. Before processing a data modification request (i.e. deletion or update) on a record, first a snapshot of the current record data is created together with all related entities. Then, the modification request is evaluated and the resulting final record data is compared with the snapshot data to determine whether any changes have occurred or not. If changes are found, the snapshot data is compressed and stored in the database together with information on type, date and user of the request.

Data display functions of the system, which retrieve data from the database and generate output for presentation, are developed in such a way that they can work on both current and historical data. In other words, they can process historical data and create output as if they were processing recent data in the database. The system is capable of comparing output generated by the display functions and can automatically determine and mark differences between them.

Log records are used to store and visualize historical record data. Type and ID of the record, date and type of the action (insert, update and delete), name of the user who performed the action, and the presence of a parent log are indicated in each log report. The record information is displayed in such a way that parts of a record that are added, changed or removed between two points in time are highlighted. Added or deleted information can be toggled on and off, so that only the initial or the final state of the record is obtained (Figure 9.7).

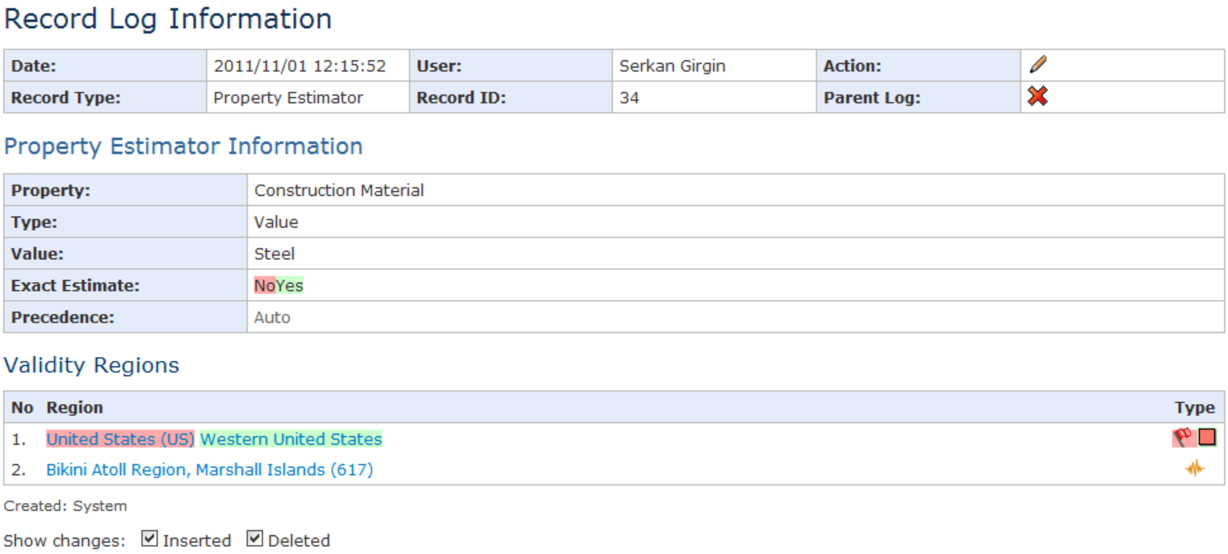


Figure 9.7 Log information

Logs can be listed by the type and date of action. The record type and record ID can also be specified. If needed, logs belonging to a certain user can be listed. Listed logs can be sorted by date, action, record type, and record ID (Figure 9.8).

Log records allow the administrators to follow the actions of the users and the data evolution stored in each record. In case improper actions are noticed, such as removal of valuable information or insertion of inappropriate data, they can be rolled-back using the historical data in the log records.

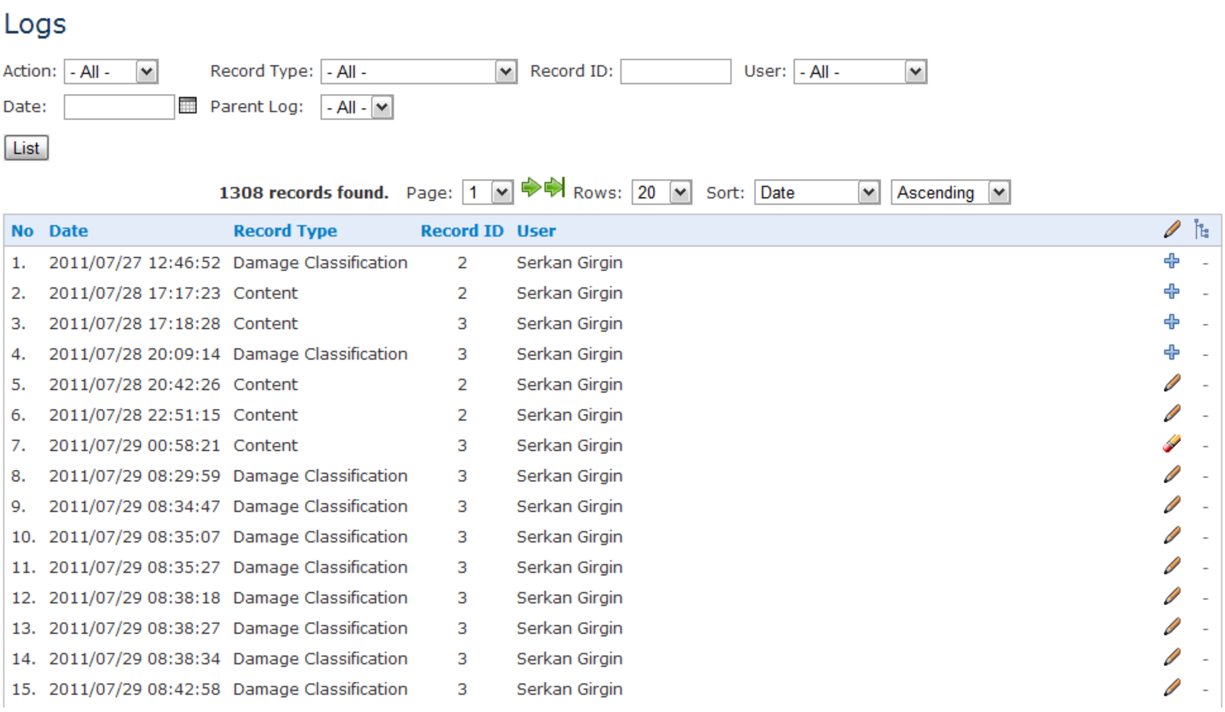


Figure 9.8 List of log records

10 Developer Tools

In order to facilitate further development of RAPID-N, various tools are provided in the developer tools module. These include a synchronization tool for the comparison of different installations, a language defines checker for the validation of internalization support, a function checker for the clean up of obsolete functions, a polygon bounds calculator for supporting GIS analyses, and context sensitive help records. Details of the tools are given in the following subsections.

REMARK: Tools described in the section are *only* accessible by the developers.

10.1 Synchronization

The synchronization tool compares two RAPID-N installation versions (source and target) and determines files that are added to, updated in, or deleted from the source installation. Differences between the installations are reported by filename and status (Figure 10.1). The primary aim of the tool is to facilitate the deployment of release versions of the system to the main application server.

Figure 10.1 Synchronization report

Added or deleted files are found by comparing the directory listing of the installation versions. Updated files are determined by calculating and comparing MD5 hashes of the files having the same path and filename. Files and folders that should be excluded from the comparison, such as setting files or folders containing temporary files, can be explicitly specified. Because MD5 hash calculation is a time and processor intensive operation, certain folders can also be exempted from this step. Files in such folders are compared only by file size. Files with the same name, but with different sizes are assumed to be updated. Folders holding large files, such as hazard maps, are recommended to be exempted from the MD5 calculation (Figure 10.2).

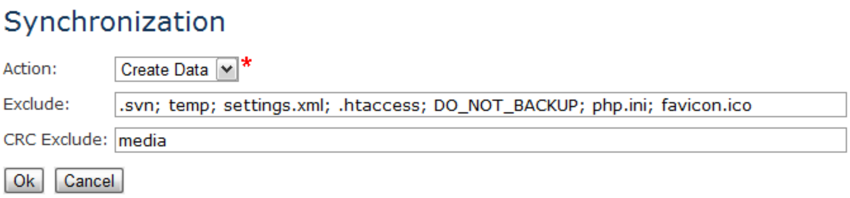


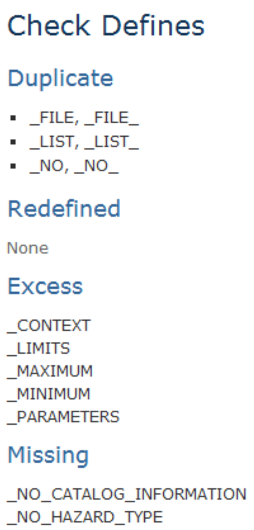
Figure 10.2 Synchronization form

In order to obtain a synchronization report for two installation versions, first the tool should be run at the source installation by selecting the action as *"Create Data"*. Once the tool is run, the system will create a synchronization data file that includes information on synchronization settings and checksum data for each file in the installation. Then, the tool should be run at the target installation by selecting the action as "*Upload Data"* and uploading the synchronization data file created previously. The tool will examine the target installation with the same synchronization settings indicated in the data file and create a synchronization report similar to the one given in Figure 10.1. Based on the report, the system administrator should upload newly added or updated files to the target installation and remove the ones that are deleted from the source installation by using an external FTP-client.

10.2 Check Defines

The "Check Defines" tool examines multi-lingual language definitions used by the system and finds redefined, duplicate, excess, or missing defines (Figure 10.3). All server-side code (PHP) and form (XML) files are checked, which are under the root and system-related sub-folders. Help contents are also checked.

Language defines are checked only for the active language. In order to check defines for a specific language; one should change the active language by using the language selection box located at the top menu. There should be no re-defined, excess, or missing defines in the release versions of the system. Duplicate defines are possible due to linguistic differences in supported languages.



Check Defines

Duplicate

- _FILE, _FILE_
- _LIST, _LIST_
- _NO, _NO_

Redefined

None

Excess

_CONTEXT
_LIMITS
_MAXIMUM
_MINIMUM
_PARAMETERS

Missing

_NO_CATALOG_INFORMATION
_NO_HAZARD_TYPE

Figure 10.3 Check defines report

10.3 Check Functions

The "Check Functions" tool examines server and client-side code (PHP, JS) and form (XML) files, and determines excess functions that are not used by the system (Figure 10.4). Excess functions can be safely removed from the release versions of the system.

Check Functions

Excess

PDF_Normal
PDF_StandardNormal
apply
combination
compatible_units
init_map
lookup_flinn_engdahl
num_rows
takeout
xml_bounds
xml_options

Figure 10.4 Check functions report

10.4 Calculate Bounds

In order to speed-up GIS analyses, such as the calculation of nearest features to a point or polygon, or point in polygon (e.g. determining the Flinn-Engdahl region of an earthquake) and polygon in polygon (e.g. determining the facility to which a process unit belongs) comparisons, the system uses pre-calculated rectangular bounds of polygon features (Figure 10.5). In general, such bounds are not available in the original polygon feature data; hence, they should be calculated manually. The "Calculate Bounds" tool is provided to facilitate this task and calculates the bounds automatically.

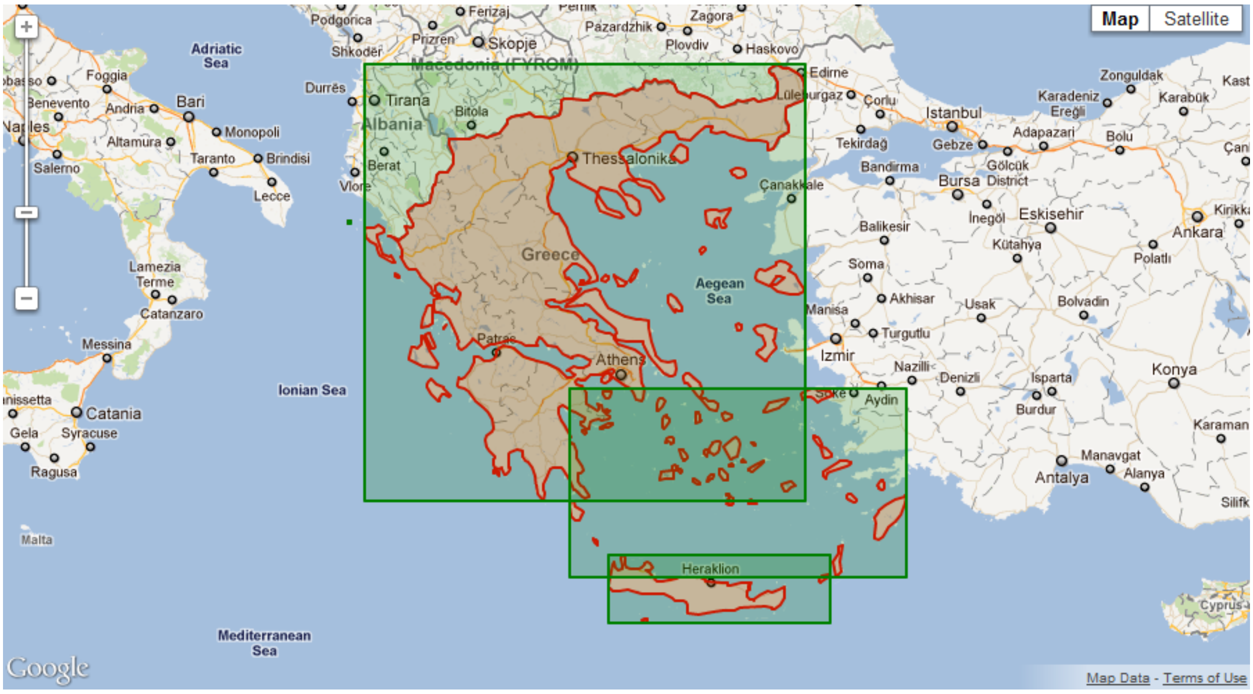


Figure 10.5 Polygon boundaries (red) and rectangular polygon bounds (green)

The tool lists database tables that include polygon boundary data and offers two actions, either the calculation of bounds from polygon boundary data, or the calculation and optimization of bounds and boundaries simultaneously. The first action takes polygon boundary data as-is and calculates bounds for each polygon. If a polygon is a complex polygon comprised of multiple parts (i.e. islands), bounds are calculated separately for each part. The second action first examines boundary data of each polygon and determines the polygon parts that can be grouped to decrease the total number of bounds for each polygon. Polygon boundary data is updated in the database to reflect the optimized part groups and then bounds are calculated. For both actions, the calculated bounds are stored in the corresponding field of the selected database table. If the table does not include a bounds field, it can be created automatically by checking *"Add bounds column if not existing"* checkbox. Similarly, for records without a polygon boundary data, existing bounds data can be cleared by checking the *"Clear bounds if boundary is empty"* item (Figure 10.6).

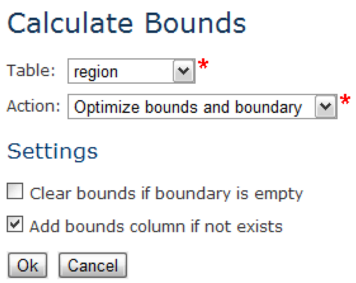


Figure 10.6 Calculate bounds settings

10.5 Help

RAPID-N features an integrated context-sensitive help system to guide the users in performing system-related tasks. The help contents are stored in the database as separate help records. For each record type and task, a specific help content can be specified by using the *"help"* attribute of the task definitions in the record forms. ID or alias in the base (system) language of the related help record should be set as the value of the help attribute. The system displays a help icon next to the main heading in the task pages for which the help content is defined. If the user clicks the help icon, a pop-up dialog containing the help content is shown (Figure 10.7). Form elements also support context sensitive help. Similar to the task pages the "help" attribute should be set to enable help support.

Data fields of the help records are listed in Table 10.1.

Table 10.1 Help data fields

Field	Type	Description
Title*	Text (64)	Title of the help content (multilingual)
Type*	Drop-down	Type of the help content: • Wiki • Code
Content* [1]	Wiki	Help content (multilingual)
Code* [2]	Code	Source code of the help content

[1] Available if **Type** is **Wiki**

[2] Available if **Type** is **Code**

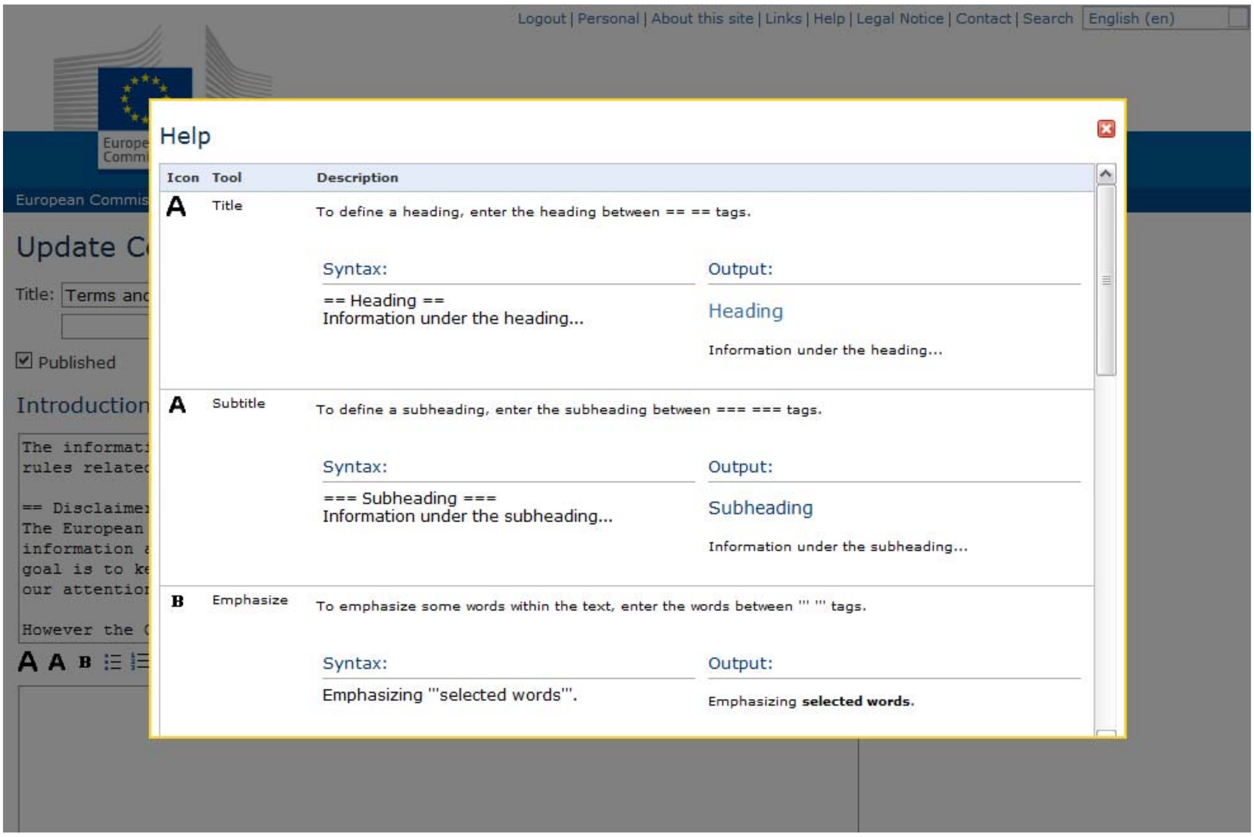


Figure 10.7 Help dialog

For each help record, a multilingual title should be specified. The system supports two types of help contents: wiki and code. Wiki-based help contents are basic contents, which can be written by using wiki tags supported by the system. They support multilingual content. Code-based help contents are advanced contents, which allow the administrators to use the server-side function library provided by the system to enrich the help content. Multilingual aspects of the help content should be solved within the source code for such help contents.

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Abstract

Major accidents at chemical process industries, which are triggered by natural hazards, can have serious consequences on the population, the natural and built environment, and the economy. Termed natechs, the risk of such accidents is expected to increase in the future due to the growing number of industries, the occurrence of larger-scale natural hazards due to climate change, and the vulnerability of the society that is becoming gradually more interconnected. Adequate preparedness and proper emergency planning are needed for the prevention of natechs and the mitigation of their consequences. For this purpose, natech-prone areas should be identified and natech risk must be assessed in a methodical way. A recent survey has shown that hardly any natech risk maps exist within the EU or OECD. Where existing, natech risk maps simply overlay natural and technological hazards without considering site-specific features or interaction of hazards. The need for a proper and systematic natech risk-mapping methodology is therefore evident.

In order to fill this gap a probabilistic natech risk-mapping methodology was developed. The methodology is based on the calculation of damage probabilities at process and storage units of industrial facilities for different damage states, and the estimation of the nature and extent of the consequences that can be caused by the natural hazard damage. For damage assessment, on-site hazard parameters are calculated from hazard scenarios and fragility curves are used to determine damage states and corresponding probabilities. For natech risk assessment, damage states are converted into risk states that define probable consequence scenarios, and the distance to endpoints of the consequences are calculated by using a simplified modeling approach used by US EPA. The methodology is implemented as a web-based software application, RAPID-N, which allows easy and user-friendly data entry, complementary data estimation, and rapid risk assessment. The results are presented as summary reports and natech risk maps.

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