CARAT – An Operational Approach to Risk Assessment Definitions, Processes, and Studies

K.G. Phillips <phillig@novachem.com>
NOVA Chemicals Corporation,
PO Box 5006,
Red Deer, Alberta, T4N 6A1.

Introduction

'Risk Assessment' means different things to different people. In many cases a given risk assessment term can have a variety of meanings depending on the background, education, and experience of the individual using the term. This ambiguity makes it difficult to communicate concepts and processes for conducting risk assessments and can result in confusion among stakeholders. For example, the term 'Risk Assessment' could mean a detailed Quantitative Risk Assessment to one person, but another may simply interpret the term as a detailed hazard review. The potential for confusion increases as the usage crosses national boundaries and terms are translated into different languages.

The Chemical Accident Risk Assessment Thesaurus (CARAT) is a database of entries that represent laws, regulations, guidance documents and definitions of terms related to the risk assessment of accidental releases of chemicals from fixed installations. The database also contains entries on the application of risk assessment using specific examples of potential chemical releases. These entries do not simply reproduce the original documents but convert the documents into 'operational language', thereby reducing or eliminating confusion that often arises with the interpretation of specific wording or translation from one language to another. The data is based on a common set of operational terms that have been selected as appropriate translations of the intended meaning derived from the source document. The CARAT contains information entered by various international and national agencies, chemical companies, and individuals regarding risk assessment processes related to chemical releases. The entire system is accessible via the Internet at http://www1.oecd.org/ehs/carat/v3.0/htm/default.htm

The CARAT is a useful resource for developing requirements for risk assessment of chemical accidents and comparing results to existing guidance. For example, the reports generated by the searches are able to clearly show how risk assessments should be conducted under law, free of the complexities of how regulations are drafted in a jurisdiction. In the case of specific risk assessment entries, the basic processes and assumptions can be determined based on a consistent hierarchy. Definitions of terms are represented in operational language in a standard format independent of the language or style of the source.

Background

As a result of a workshop on Risk Assessment held in Paris in July, 1995, the Working Group on Chemical Accidents of Organization for Economic Cooperation and Development (OECD) recognized the potential for problems associated with misinterpretation of terms, which, in turn, creates uncertainty of the significance of the results obtained. They urged the development of a Thesaurus to improve communication dealing with risk assessment of hazardous installations. A task team was established to address this concern and was given the mandate to establish a tool that would reduce and possibly eliminate the potential for such confusion. The result of this work is the Chemical Accident Risk Assessment Thesaurus (CARAT). The difficulty of communication is based in large part on the fact that certain "terms of art" have different meanings in different countries and cultures, or that different terms of art are used to address the same concept. The CARAT is designed to circumvent these difficulties, and is especially useful as a tool to analyze the definitions of terms related to risk assessment.

Hence, the development of the Chemical Accident Risk Assessment Thesaurus was initiated:

- To make more transparent the various approaches to risk assessment of the accidental release of chemicals from fixed installations used in different countries;
- To promote understanding of, and communication about, chemical accident risk assessment processes including the commonalties and differences among the various approaches; and
- To facilitate communication concerning chemical accident risk assessment between, and within, countries, helping to overcome the problems introduced because of different cultures and language.

The CARAT does not attempt to harmonize or establish standard terminology or to make judgement on the value of various risk assessment methodologies. Instead, the CARAT captures only what risk assessment professionals understand to be the state of understanding of particular laws, regulations, or procedures currently in effect or in use. It can be viewed as a "translation engine" which captures the intended meaning of a risk assessment item and "translates" it into objective or operational language. This is the subject matter of the database. The System has evolved over several development cycles, and was previously known as the OECD Computer Dictionary/Thesaurus of Risk Assessment Processes, or simply the OECD Dictionary/Thesaurus.

Structure and Hierarchy of the Entries

There are four classes of information that can be entered into the System:

1. Definitions of words and phrases associated with risk assessment;
2. Laws and regulations concerning risk assessment of hazardous facilities;
3. Guidelines, policies or codes related to risk assessment; and
4. Specific risk assessment studies that have been conducted on particular cases.

Persons making an entry into the database interpret the meaning they attach to their entry by responding to a series of questions that lead the person through the System hierarchy and, at each level, probes successively deeper using more specific expressions to convey the meaning. There are five levels in the hierarchy:

1. *Generic elements*, a set of related, operationally defined process steps;
2. *Sub-elements*, one of the operationally defined process steps contained in a Generic Element;
3. *Terms*, the concept which is the subject of the process defined in the Sub-element;
4. *Categories*, a set of examples used to give specific operational meaning to a Term; and
5. *Descriptors*, single examples illustrative of specific operational situations in the Category.

At its highest level, the CARAT hierarchy consists of four broad *generic elements* representing the commonly accepted stages in the process of assessing the risks associated with hazardous installations. They can be loosely described as

- hazard identification;
- hazard release and exposure scenarios;
- source and subject interaction; and
- expression of the risk.

In addition, there are two other elements that may be utilized to capture aspects that are generally considered outside the risk assessment process, *per se*. A Pre-assessment element captures features that are judged to precede risk assessment processes, such as a statement of the scope of the entry; and a Post-assessment element that describes features that generally follow the risk assessment process itself, such as, risk management or risk communication. The Pre- and Post-assessment elements are free-form text facilities, lacking the hierarchical structure of the four generic elements.

The four Generic Elements are presented in Figure 1. Because the risk assessment process is presented in operational language, i.e., uses no ‘terms of art,’ the language of the Generic Elements tends to be wordy, and uses words that lack immediate connection to any specific risk assessment.

Figure 1- The Four Generic Elements of CARAT

Generic Element I: Identification of sources with the potential to cause undesired outcomes to subjects of concern that is the focus of the estimation of likelihood.

Generic Element II: Identification of possible sequences of events leading to loss of containment of the potential to cause undesired outcomes to a subject of concern resulting in its entry into a domain of the ecosystem. Estimation of possible distributions of both the released potential and the subjects of concern over time periods within compartments delimited by specified boundaries or end-points.

Generic Element III: Identification and description of how the specified undesired outcome is related to the intensity, time, and mode of contact of a specified potential to cause the undesired outcome to the subject(s) of concern.

Generic Element IV: Consists of two parts: Part A: Identification of the methods for estimating and expressing the likelihood of a specified effect and describing the quality of such estimates. Part B: Identification of the basis for comparing derived estimates of likelihood to specified guidelines and describing the dependence of these estimates on explicitly specified alternative assumptions.

Generic elements have varying numbers of *sub-elements*. Sub-elements are procedural in nature and represent operations, methodologies, actions, or process steps that encompass a phase of the generic element in the risk assessment process. Each sub-element has an associated *term* that is the subject of the action defined by the sub-element. In grammatical terminology, terms are noun phrases, lacking any notion of 'action,' and sub-elements are verb phrases, containing the notion of 'action on a subject.' Figure 2 illustrates *sub-elements* and *terms* for Generic Element I.

Figure 2. - Sub-elements and Terms Corresponding to Element I

Element I

Sub-element I i: Identification of sources with the potential to cause undesired outcomes to subjects of concern

Term I i: Sources with the potential to cause undesired outcomes

Sub-element I ii: Identification subjects of concern

Term I ii: Subjects of concern

Sub-element I iii: Identification undesired outcomes to subjects of concern

Term I iii: Undesired outcomes to subjects of concern

Each term is divided into *categories* of specific sets of *descriptor* examples that are the operational representation of the intended meaning. Descriptors allow the person entering an item to describe the risk assessment operation with ultimate specificity. Figure 3 shows the Categories associated with Sub-element I, Term 2.

Figure 3 - Categories Corresponding to Element I, Sub-element I, Term 2: Subjects of concern

Categories:

People
Ecosystems/environment
Cultural assets
Property and physical systems
Facilities
Other subjects of concern

In Figure 4, one can trace a specific path through the hierarchical structure. Element I deals with the operation of "identifying sources of the potential to cause undesired outcomes to subjects of concern". This is decomposed into three Sub-elements (operations), one of which is "Identification of subjects of concern". The Term for this Sub-element is "Subjects of concern". Associated with this Term are Categories of descriptors such as 'people', 'property', 'ecosystems' etc. Each category contains specific Descriptors. For example, the Category 'people' contains Descriptors such as 'residents,' 'workers,' 'pregnant women,' etc. The system also contains provisions for entering additional descriptors in a Category, or indeed new Categories if the suggested ones do not directly capture the intended meaning in a given situation.

Figure 4
Partial Hierarchical Path for Subjects of Concern

Element I

Sub-element I ii: Identification subjects of concern
Term I 2: Subjects of concern
Categories:
People
Descriptors:
Residents
Sensitive resident populations
Pregnant residents
Transient people
Workers at facilities containing a source with potential to cause undesired outcomes
Trans-boundary populations
Undefined people
Other

In summary, Table I shows the amount of detail into which a risk assessment process can be decomposed.

Table I - Hierarchy of the OECD CARAT

Hierarchical Feature	Number of Components
Elements	4
Sub-elements	19
Terms	19
Categories	70
Descriptors	368

Specific aspects of the Entry Process

The data entry process provides the opportunity to add levels of detail or to provide general descriptions of the specific reference being entered. These items include the following:

- the name of the entry for search purposes, the identify of the country to which the entry applies, and the name of the organization that is making the entry.
- full reference information that will allow clients to request the source material from public sources.
- the URL of an Internet web site where the reference might be viewed or downloaded if the document is available on the web.
- the ability to skip an element or sub-element if they are not addressed in the item being entered
- the ability to add new descriptors to the system to capture new usage and approaches.
- the client may select "undefined" as the descriptor if the category is not specific in regard to characterizing the category.
- the client needs to decide whether the entry addresses the item "*explicitly*" or "*implicitly.*"
- the client can indicate that there are either "*criteria*" and/or "*tools*" associated with the selection and enter the details of these items.
- the client can give reference details that will allow for library retrieval of the reference material related to the particular item.
- a free-text comment field is available that allows the client to elaborate on the reasons for, or explanation of, the particular selection.
- the client is permitted to add other descriptors. The client may type in wording that better describes the meaning under that category. The system adds the new item to the existing list. As many additional descriptors as are required for the entry may be entered.

All entries are placed into the 'working space' in the system. When the data entry process is completed and the client is satisfied with the entry's accuracy and completeness, the client informs the CARAT Application Manager electronically that the entry is complete. The Application Manger will then examine the entry for typographical errors, obvious inconsistencies, conformance to certain standards of entry, and omissions of certain required data fields. After review, the entry is transferred to the public space in the CARAT where it is available for access by the general public along with all other finalized entries.

Query Capability

The greatest value to the user is probably the public access to the information contained in the CARAT by means of the query module. The query module can search the CARAT for its entries and present the results on-screen for immediate examination or send the results of the search to a local printer. A "Comparison" facility allows the user to make a side-by-side comparison of the CARAT entries of laws, regulations, Specific Risk Assessments, Risk Assessment Guidance, or definitions, in any combination. The comparison can be made at the element, term, category, or descriptor levels. The final query can perform searches by identifying entries that contain either certain combinations of hierarchical details (Hierarchy searches), or certain combinations of descriptor details (Descriptor searches). Both types can be conducted in Boolean 'and/or' mode, and the Descriptor searches can specify items that are to be excluded from the search.

Example 1
Comparison of Two Risk Assessments of Chlorine Storage

Editorial Note: In this report, the check marks indicate that the hierarchical item is "addressed" in the entry. The bolded text is the specific selection by the data entry person of the appropriate descriptor, indicating further whether the entry addressees the item explicitly (e) or implicitly (i).

Case 1 Chlorine Truck Storage QRA
Case 2 Continuous Chlorine Release from One Tonne Container

1	2	Addressed:	e explicitly	i implicitly
		Element I		
✓	✓	Identification of sources with the potential to cause undesired outcomes to subjects of concern that is the focus of the estimation of likelihood		
✓	✓	Identification of sources with the potential to cause undesired outcomes to subjects of concern		
✓	✓	Substances		
e	e	**Toxic to humans**		
✓		Energy		
i		**Pressure**		
✓		Physical situations		
	e	**Systems containing regulated chemicals**		
✓		Legally specified sources		
e		**Listed substances**		
✓	✓	Identification of subjects of concern		
✓	✓	People		
e	e	**Residents**		
e		**Sensitive resident populations**		
e		**Transient people**		
e		**Workers at facilities containing a source with potential to cause undesired outcomes**		
✓	✓	Identification of undesired outcomes to subjects of concern		
✓	✓	undesired outcomes for people		
e		**Death**		
	e	**Immediately dangerous to life or health**		
		Element II		
✓	✓	Identification of sequence of events that can lead to loss of containment of the potential to cause undesired outcomes and its entry into a domain defined by specified boundaries. Identification of the basis for estimating the distribution of both the released potential and the subjects of concern within this domain		
✓	✓	Identification of the basis for generating sequences of events leading to a loss of containment resulting in the entry of the potential to cause undesired outcomes into a domain that may be occupied by a subject of concern		

✓ ✓ Sequence of events based on past events or experience

e e **Insurance or industry records**

i **Professional judgment**

✓ Sequence of events based on technical analysis

e **Fault-tree analysis for sequence of events**

e **Event-tree analysis for sequence of events**

e **HazOp**

e **What If**

✓ ✓ Identification of the basis for estimating distributions of the released potential within domains of interest

✓ ✓ Distributions based on technical analysis

e **Event-tree analysis for distribution of the release**

e **SAFETI model**

e **WHAZAN Computer modeling**

✓ ✓ Identification of the basis for estimating distributions of subjects of concern within domains of interest

✓ ✓ Historical data

e **Census data**

e **Local Surveys**

e **Survey of plant and neighbor work locations**

✓ ✓ Identification of the basis for establishing boundaries that delimit estimates of the distribution of the released potential

✓ ✓ Boundaries or end-points based on technical analysis

e **Chlorine inhalation dose-response relationship**

e **Immediately Dangerous to Life or Health**

Element III

✓ ✓ Identification and description of how the specified undesired outcome is related to the intensity, time and mode of contact of a specified potential to cause the undesired outcome to the subjects of concern

✓ ✓ Identification of the way the specified potential to cause the undesired outcome makes contact with to the subject of concern to cause the specified undesired outcome

✓ ✓ Mode of contact between the potential to cause undesired outcomes and people

e e **Inhalation**

✓ ✓ Identification of the basis of the relationship used to predict how the undesired outcome is related to contact with the potential to cause the undesired outcome

✓ ✓ Relationship to people

e i **Human epidemiological data**

✓ ✓ Description of the dimensions/measurement units of the potential to cause the undesired outcomes that are used to predict the undesired outcome

✓ ✓ Concentration of the substance with the potential to cause the specified undesired outcome that interacts with the subject over a specified time period

e **Actual dose response relationship for inhalation of chlorine**

e **ppm over an unspecified period of time**

Description of the dimensions/measurement units used to express the undesired outcome response

Number of the undesired outcome events experienced by the specified population of subjects

e **Number of deaths**

Frequency of the undesired outcome events experienced by the specified population of subjects

e **Frequency of deaths**

Element IV

✓ ✓ Consists of two parts: Part A: Identification of the methods for estimating and expressing the likelihood of a specified effect and describing the quality of such estimates. Part B: Identification of the basis for comparing derived estimates of likelihood to specified guidelines and describing the dependence of these estimates on explicitly specified assumptions

Identification of the basis of estimating the likelihood that specified undesired effects will

✓ ✓ occur, that is, that a specified undesired outcome of a specified magnitude for a specified subject of concern will occur

✓ ✓ Quantitative methods of estimating likelihood

e **Quantitative event-tree analysis for estimating likelihood**

e **Quantitative fault-tree analysis for estimating likelihood**

e **SAFETI model**

Semi-quantitative methods of estimating likelihood

i **Specific semi-quantitative method of estimating likelihood**

Methods of estimating likelihood based on historical data

e **Method of estimating likelihood based on extrapolation of historical data**

Identification of the method of expressing the likelihood that specified undesired effects will occur, that is, that a specified undesired outcome of a specified magnitude for a specified subject of concern will occur

Quantitative expressions

e **Frequency**

e **Probability of a specified sequence of events resulting in a specified undesired effect in a specified time period**

i **Probability of a specified undesired effect if a specified sequence of events occurs**

e **Probability of a specified undesired effect in a specified time period**

✓ Identification of the undesired outcome of a specified magnitude for a specified subject of concern for which the likelihood is being estimated

✓ Specified member of the population of concern that experiences a specified undesired outcome

e **Average member of the population of concern**

e **Average member of a specified cohort of the population of concern**

e **Member closest to the release of the potential**

e **Member at a specified location**

✓ Specification of a group of N or more subjects of the population of concern that experiences a specified undesired outcome simultaneously

e **N or more specified members of the population of concern**

✓ Specification of the undesired outcome resulting from the presence at specified location(s) of the specified potential at concentrations/intensities over time that would be sufficient to cause the undesired outcome for specified subjects of concern

e **Death to residents**

✓ Identification of description of the quality/uncertainty of estimates of likelihood

Characterization of estimate

e **Best estimate**

✓ Identification of the approach used to compare the estimates of likelihood with relevant standards and guidelines

Type of standard or guideline

e **Business**

✓ Identification of the metrics or other information needed for comparisons of estimated likelihood against standards or guidelines

✓ Comparison metrics

e **The likelihood of a specified undesired outcome for any member in a population of the subjects of concern resulting from a specified series of events**

e **The likelihood of a specified undesired outcome for any member in a population of the subjects of concern resulting from a specified series of events if the facility employed all practicable measures to reduce the likelihood and magnitude (ALARP)**

e **Plots of the frequency per year of sequences of events (accidents) resulting in N or more fatalities to people as a function of the number of fatalities**

e **An estimate of the average number of fatalities per unit time in a population of subjects of concern**

e **Contours of areas within which the likelihood of a subject experiencing a specified undesired outcome is greater than an estimated level**

e **An assessment of the adequacy of measures for preventing or containing releases using methodology and specifications for adequacy, using measures of prevention and containment defined in the law, guideline, or standard that is the basis of the comparison**

e **Comparison of new to existing facility**

✓ Identification of specified alternative assumptions on the estimates of likelihood

✓ Alternative assumptions

e **Consideration of sheltering in place**

Application of the CARAT System

Most comparisons using CARAT will focus on comparing various laws and regulations, definitions or specific risk assessments. But the system is much more powerful, especially to corporate users. Companies can put specific standards, guidelines, risk assessments, or other risk-related applications into the system and use the comparison feature to determine where the specific input may be at variance with the legal system in the country. For a company like NOVA with facilities in several countries, a comparison of the risk assessment standard to the laws and regulations in the various countries can verify that the standard

meets the requirements of all or some of the countries. This type of comparison provides guidance regarding areas where changes should be meet to assure compliance.

The system source code can also be obtained from the OECD and installed on a company's local server. Using this facility the company can enter specific standards and codes of practice and compare work from the various sites to assure that the requirements have been met. The system could also be used as repository for specific risk assessments. These could be accessed by employees within the company and used as guidance for other risk assessments. It would also provide an archive facility for those wishing to update risk assessments on a regular basis.

Users of the database can compare entries to determine areas of conformity and areas of difference. This is especially important when existing programs or processes are be used to meet legal requirements in different countries or jurisdictions. The system can also be used to assure that specific risk assessments meet the requirements outlined in specific legislation or guidance.

Although the experience in using CARAT in the earlier developmental stages indicated that the data entry process required an intensive effort, participants noted a number of benefits that extended beyond the mere entry of risk assessment approaches into a computer system. Remarkably, participants noted a deepening understanding of their own country's or agency's laws and regulations, and they gained insight into areas of weakness or ambiguity. Through the clarity of operational language, the CARAT is a convenient source of guidance on the risk assessment processes required at individual facilities, and assists, in general, in designing and managing risk assessment programs.

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