COMPREHENSIVE RISK ASSESSMENT

Applying the Cultural Property Risk Analysis Model to the Canadian Museum of Nature

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Abstract: Comprehensive environmental assessments of risks to the collections of the Canadian Museum of Nature were completed in 1993, 1998, and 2003. The assessments are based on comprehensive identification of specific risks within a framework of sources of hazards, called agents of deterioration, and expected frequency of risk events, ranging from continuous to less than one event per century. Between these assessments, numerous projects were undertaken to mitigate risks to collections. These activities have resulted in a significant net reduction in total risk to collections but not all changes in assessed risks relate to changes in actual risk.
Comparison of results among the three risk assessments indicates that differences result from:

- Changes in perception of risks
- Changes resulting from improved understanding of, or ability to quantify, risks
- Changes to magnitudes of specific risks as a result of risk treatments

In addition to enabling priority setting for further collection care and conservation research activities, repeated risk assessment has greatly increased staff, management and governance awareness of collection care issues and of changes in risks to collections over time. The results allow estimation of the benefits of proposed risk treatments and of the expected benefit of further risk characterization.

1. Introduction

The Canadian Museum of Nature (CMN) completed comprehensive assessments of risks to the collections in 1993, 1998, and 2003, using a method now termed the Cultural Property Risk Analysis Method (CPRAM) [7–9]. During

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Figure 1. The CMN's Natural Heritage Building (NHB), 1997. This purpose-built collection holding facility is a tangible result of collection risk analysis. (Photo and Copyright: Martin Lipman.)

the five years between the first two assessments the CMN designed, constructed, and moved into a purpose-built collection-holding institution (Figure 1). In addition, numerous collection management and conservation projects were undertaken to mitigate risks to collections. These activities resulted in both total risk reduction and improved understanding of remaining risks.

Maintaining collections requires that potential risks to collections be considered comprehensively [9]. The requirement for a comprehensive assessment leads to this being an environmental risk assessment in the sense of considering the whole environment affecting collections. Once identified, risks need to be evaluated rationally. Comprehensiveness, clarity in purpose and scope, and rationality (minimally semi-quantitative and preferably quantitative) are characteristics of any good risk assessment method [2, 3]. In this paper, special attention is given to identification of risks and to lessons learned from repeated risk assessments.

2. Cultural Property Risk Analysis Model

The basic steps involved in the CMN's CPRAM are:

- Define project scope, including—for example—collection contents and values considered.
- Divide overall institution collection holdings into units for assessment.

- Identify specific risks to assess.
- Quantify risks.
- Analyze and present results.
- Plan collection care projects.
- Refine estimates of uncertain risks through research.

3. Scope and Assessment Unit Divisions

Collections were defined as being all, and only, formally accessioned objects. Excluded from the scope was material in temporary custody for research, consignment, etc., and material for consumptive use (Category 5 material within the value classification system of Price and Fitzgerald [5]). The period of time over which risks were projected was one century. This is an arbitrary choice, but one that is appropriate in a museum collection context for several reasons. Most simply, large museums have existed for one or two centuries. One century is about three curatorial career spans and is an easily conceptualized timeframe for collection care professionals. Finally, planning to deliver collections with minimal expected losses (risk) to a time 100 years in the future is equivalent to assuming a discount rate of about 1%, which is appropriate for protecting a property that is highly valued for the public good.

Overall collection holdings were divided into 19 collection units according to a range of criteria, including administration, nature of specimen material, primary storage hardware, and storage environment.

4. Risk Identification

Risks were comprehensively identified within a framework of ten sources of risk, called "agents of deterioration" in the museum sector, and three types of risk. The agents of deterioration [6] are:

- Physical forces
- Fire
- Water
- Criminals
- Pests
- Contaminants

- Light and ultraviolet radiation and electromagnetic fields
- Incorrect temperature
- Incorrect relative humidity
- Dissociation

This set of agents has been shown through many years of application to be comprehensive in incorporating all sources of risk (e.g., hazards, threats) to museum collections. Other groupings of sources of risk could be used. An essential characteristic of an acceptable "sources of risk" framework is that it be comprehensive. Desirable features of a framework include minimal ambiguity and minimal requirement for arbitrary decisions about where a specific risk belongs. Due to multiple dependencies of expected losses, some arbitrary assignments of specific risks to these categorical sources of risk are inevitable. For example, the embrittlement of cellulose and cellulose ester films is strongly dependent on temperature, relative humidity, and contaminants. The eventual crumbling of these embrittled materials will be the result of a physical force-related risk. Eventually a museum risk assessment may be able to keep track of mutual interdependencies and prorate the risk appropriately among categorical sources of risk. At present, however, an institution will choose one of these categorical sources of risk within which it will identify and evaluate the risk.

Because most agents of deterioration can manifest over a wide range of frequency and severity, three types of risk are distinguished. These range from Type 1, rare and catastrophic events, to Type 3, constant but persistent processes (Figure 2). Recognizing different types of risks facilitates both identifying risks comprehensively and finding sources of authoritative information on hazards and risks.

Frequency / Intensity	Continual	Sporadic	Rare
Catastrophic	·····Type 1·····		
Severe	·····Type 2·····		
Gradual/Mild	·····Type 3·····		

Figure 2. Three types of risk range in frequency and severity.

Risk identification is as much, or more, art than science. Within CPRAM a combination of source of hazard and type of risk, such as physical forces—Type 2—is termed a generic risk. Within each generic risk, a number of specific risks are defined to reflect more particular sources of risk or vulnerabilities of cultural properties. This hierarchical approach of describing sets of specific risks within each generic risk enables comprehensive risk identification while minimizing double-counting of risks. Using comprehensiveness as the dominant goal in initial stages of risk identification, brainstorming with diverse groups of stakeholders followed by inventive thinking about how framework-structured checklists can be completed has proven most useful for museum collection risk assessment as it has for nature preserves [4].

Table 1 illustrates, with examples of risks to CMN collections, how a source of risk is combined with a type of risk to arrive at a "generic risk" and then how a clear scenario is described to establish a "specific risk."

The goal in risk identification is to identify enough of the most significant specific risks within each generic risk to be confident that most (perhaps 90% or more) of the total magnitude of the generic risk is captured. In the case of Type 3 risks—and to a lesser extent Type 2 risks—this can be achieved with some confidence. This concept is shown in Figure 3, where the non-shaded portions of each rectangle represent suspected portions of each generic risk that have not been identified.

Combining the suspected proportion of unidentified risks with the estimated magnitude of risk gives a rough estimate of the magnitude of risk being overlooked, and hence the importance of investing in more thorough

TABLE 1. Selected examples of specific risks within the three generic risks resulting from the "physical forces" source of risk.

Generic risk	Specific risk
Physical forces—Type 1	Earthquake causing building collapse resulting in breakage or crushing of collection objects
	Earthquake causing toppling of storage units or objects resulting in breakage or crushing of collection objects
	Snow loading causing roof collapse resulting in breakage or crushing of collection objects
Physical forces—Type 2	Accidental physical damage to collection objects during use
Physical forces—Type 3	Poor support causing distortion of collection objects
	Overcrowded storage causing abrasion, breakage, etc. to collection objects

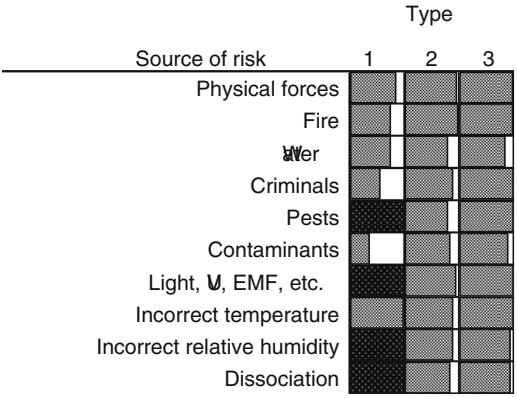

Figure 3. Gray area of each rectangle depicts suspected proportion of actual magnitude of generic risks represented by identified and assessed specific risks. Darkest shaded rectangles reflect implausible combinations of source and type of risk.

risk identification. For many Type 1 risks, uncertainty of risk identification remains a major challenge. In practice, one continues to identify and roughly estimate specific risks within a generic risk until it is clear that additional risks have magnitudes much less than 10% of the highest specific risk within that generic risk.

Following comprehensive risk identification, several cycles of qualitative or semi-quantitative screening are conducted. In the first cycle, risks judged as irrelevant or implausible are noted and set aside. For example, snow loading causing roof collapse, a significant risk for flat-roofed buildings in Canada, would be excluded from further consideration for an assessment of a museum in Lisbon. Risks that are considered potentially significant are then quantified.

5. Quantify Risks

The Magnitude of Risk (MR) was defined as the expected loss in value of the collection over the next 100 years, considering other factors such as collection growth, use, societal value changes, and so on, to be constant over that time. The use of ratio scales with clearly defined upper and lower endpoints allowed the mathematical operations of addition and multiplication to be properly applied [1]. In addition, ratio scales enable a precautionary approach through conservative estimation of probable upper bounds for each risk variable. Although any number of ratio variables can be multiplied together, four variables were always employed in the determination of MR as shown in Eq. (1).

$$\mathbf{MR}\ (\text{Magnitude of Risk}) = \mathbf{FS}\times\mathbf{LV}\times\mathbf{P}\times\mathbf{E} \quad (1)$$

Where

FS = Fraction Susceptible

LV = Loss in Value

P = Probability

E = Extent

Each of these variables is determined for every plausible combination of specific risk and collection unit. First, the Fraction (of the collection) Susceptible (FS) to the specific risk is determined. Next, considering objects characteristic of the FS, Loss in Value (LV) that could result from a worst-case occurrence of the risk is estimated. The product of FS × LV can be considered the maximum "theoretical" part of the collection value subject to loss from that specific risk. The Probability for Type 1 risks is the chance of at least one event of a specified severity occurring over the next century. It is determined with help from and in collaboration with appropriate national or international agencies and organizations. The Extent reflects the amount of the FS that will be affected, the degree to which the LV will be realized, or both. It is estimated by projecting the effect of one century of exposure to the current setting, collection care, and use circumstances. Simple multiplication of the four variables, which are all fractions between 0 and 1 inclusive, gives the Magnitude of Risk, which itself is a fraction between 0 and 1 inclusive. The Magnitude of Risk is the expected loss in utility value of the collection over the next century, assuming the current collection care situation to continue.

For most collection units, the magnitudes of risks range over many orders of magnitude, even though only those risks considered relevant and plausible enough to identify and estimate were evaluated. Overall results of the 1998 CMN collection risk assessment (Figure 4) demonstrate the complex relations of risks to collection units.

The total risk to CMN's collection holdings due to each generic risk (combination of agent of deterioration and type of risk) was estimated by summing for each generic risk across all collection units after normalizing to express risks as risk to the total (number of objects in the) CMN collections. Figure 5 shows a comparison of generic risks to total CMN holdings as assessed in 1993 and again in 1998. All but two generic risks were reduced, primarily by the building project but also by other collection management projects. The two generic risks that increased slightly were Water-2, anticipated sporadic leaks through the roof causing water damage to exposed objects, and RH-2, incorrect fluid preservative levels and concentrations. The Water-2 risk increased as a result of all collection

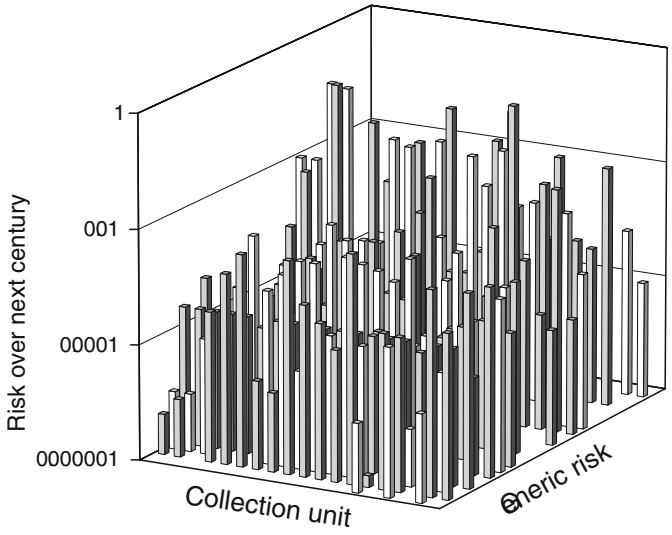

Figure 4. Magnitudes of 22 generic risks affecting 19 collection units (CMN 1998 NHB risk assessment). Note the overall complexity of the risk management situation and that magnitudes of risks range over more than five orders of magnitude.

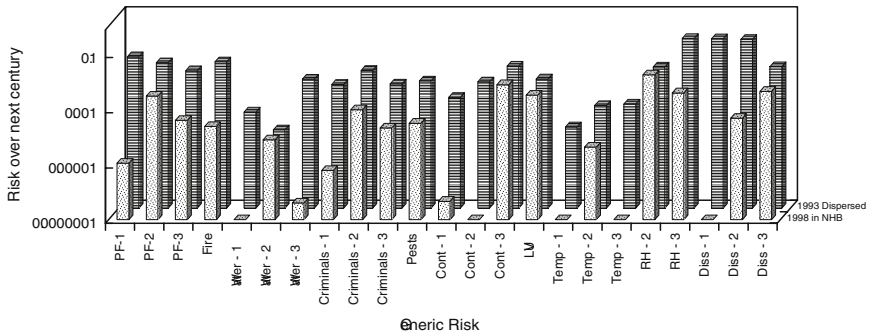

Figure 5. Comparison of generic risk, as fraction of entire Canadian Museum of Nature collection holdings, between 1993, back bars, and 1998, front bars. PF-1, Physical forces—Type 1; e.g., earthquake causing breakage. PF-2, Physical forces—Type 2; e.g., accidental breakage. PF-3, Physical forces—Type 3; e.g., poor support causing distortion. Fire—Consumption by fire; Water—Type 1; e.g., inundation by river flood. Water—Type 2; e.g., roof leaking. Water—Type 3; e.g., rising damp. Criminals—Type 1; e.g., major theft. Criminals—Type 2; e.g., isolated vandalism. Criminals—Type 3; e.g., pilfering. Pests, e.g.; insects and rodents. Cont-1, Contaminants—Type 1; e.g., smoke from a nearby disaster. Cont-2, Contaminants—Type 2; e.g., dust from construction activity. Cont-3, Contaminants—Type 3; e.g., Permanent gaseous pollutants. LUV, light and radiation. Temp-1, Temperature—Type 1; e.g., melting of an ice core collection. Temp-2, Temperature—Type 2; e.g., incorrect temperature causing softening or melting. Temp-3, Temperature—Type 3; e.g., higher than ideal. RH-2, Relative Humidity—Type 2; e.g., drastic change leading to fracture. RH-3, Relative Humidity—Type 3; e.g., too high, accelerating paper degradation. Diss-1, Dissociation—Type 1; e.g., collection abandonment. Diss-2, Dissociation—Type 2; e.g., misfiling an object. Diss-3, Dissociation—Type 3; e.g., failure to ensure transfer of legal title for gifts.

now being under a flat roof where previously some were held in multistory buildings. The RH-2 risk increase was a result of reduced levels of routine maintenance activities while staff attention was diverted to building planning and move preparation activities.

6. Risk Treatments and Their Results

In 1993, CMN collections occupied 12 leased warehouse spaces. Some collections were held in inferior storage hardware. In 1996–1997, during the time between the first two assessments, the CMN designed, had built, and occupied a purpose-built collection housing building (Figure 1). At the same time, storage hardware was upgraded to modern museum standards. In addition, following the move, and before the 1998 risk assessment, a collection emergency preparedness plan was developed and disseminated. Training in emergency response procedures and methods was conducted. A number of smaller, targeted risk remediation projects were also undertaken.

Of particular interest to consideration of emergency preparedness is evaluation of the changes in Type 1 risk and the relative contribution of Type 1 risks to total risk. These comparisons are shown in Figure 6.

Over the period 1993–1998, Type 1 risks were the most reduced of the three types of risk. There are several reasons for this. First, much protection against the effects of Type 1 risks is afforded at the levels of location, site characteristics, and building construction and systems. These were considerably improved by the building project. Second, many systems that provide life safety protection also contribute to property protection from Type 1 risks. Buildings designed and built to the most modern building codes will afford better property protection against Type 1 risks. Finally, consolidating staff in

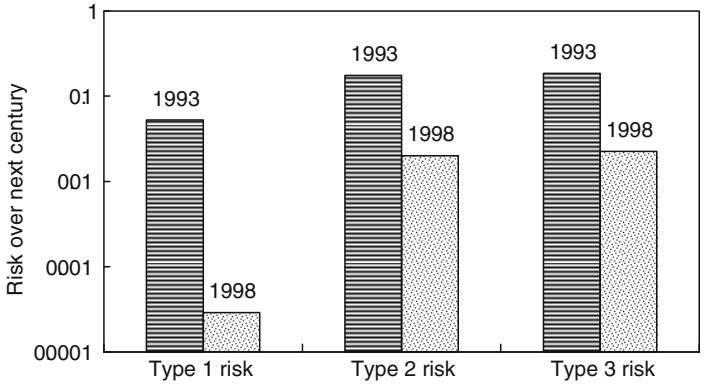

Figure 6. Comparison of risk to the CMN's collections by type of risk for 1993 and 1998.

one location, completing an emergency preparedness plan, and training staff in emergency response further mitigated against the effects of Type 1 risks.

It is also evident in Figure 6 that the totals of both Type 2 and Type 3 risks are approximately two orders of magnitude (100 times) greater than the total of Type 1 risks. Consequently, current collection care priorities are now focused on reducing Type 2 and 3 risks.

7. Actual and Understood Changes in Assessed Risks

Although differences in perceptions, understanding, and methods of assessing risks produced some of the differences, most of the changes between the 1998 and 2003 risk assessments reflect real reductions in levels of risk. Without the influence of a major capital project, differences in risk assessments conducted in 1998 and 2003 were much reduced and were of comparable magnitude for changes in understanding and for changes due to risk treatments, rates of collection use, or other objective, quantifiable measures (Figure 7). It is evident in Figure 7 that in terms of gross change in assessed risk, the total changes due to understanding only are of comparable magnitude to, but 50% higher than, total actual changes in risk. When considered as net differences, the sum of actual changes in risk is negative and nearly five times greater than the sum of changes due to understanding only. Most changes in actual

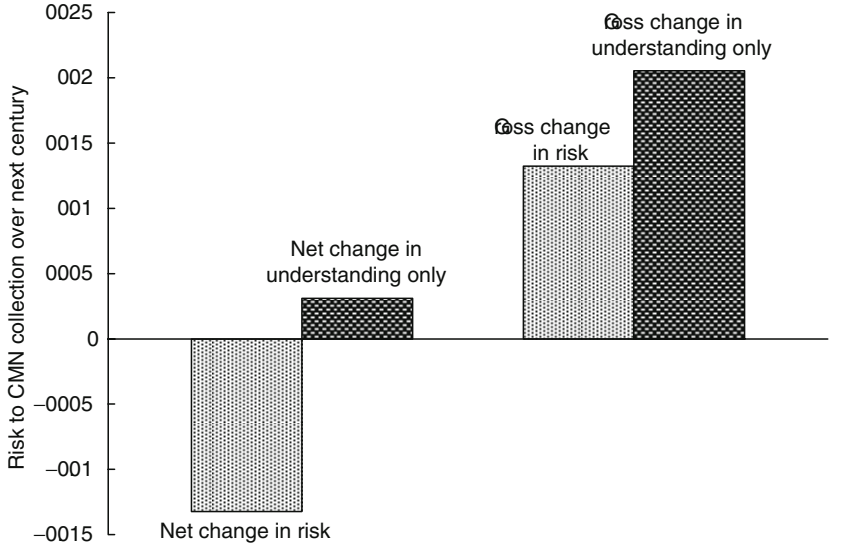

Figure 7. Comparison of net and gross (sum of absolute values) changes in risk for both actual changes in risk due to risk treatments and perceived changes due to changes in understanding only.

risk were reductions as a result of projects intended to reduce risks. In contrast, changes in understanding are more likely to either increase or decrease assessed risk. For change in understanding, the fact that net change in risk is about seven times smaller than gross change indicates near balance between changes in knowledge causing increases or decreases in risk.

8. Conclusion and Lessons of Interest to General Environmental Risk Assessment

Application of the CPRAM to the CMN has led to more rational allocations of resources for collection preservation. Senior management could be presented with reports offering opportunities for risk reduction instead of just petitions for more resources. This resulted in improved resource commitments to collection preservation. By anticipating those risks that will become priorities for treatment in coming years, it is possible to plan research activities to provide knowledge of key issues as and when required.

The risk assessment system was defined such that cultural property collections are considered static rather than dynamic systems. This great simplification permitted a comprehensive "snapshot" view of risks to be developed. It is understood that risk assessments must be conducted in a regularly repeated fashion to account for changes in the current collection environment as well as changes in understanding of risks. A second critically enabling simplification was to consider only the proportion of total value at risk. Doing this allowed sidestepping of the very difficult and controversial issue of valuation of cultural property.

Although the CPRAM was developed specifically for application to cultural property, certain lessons learned during its development are thought to be of interest to the broader risk analysis community. These lessons include:

- Risks to cultural heritage, despite sparse relevant knowledge, can be identified within a comprehensive framework of sources and types of risks.
- Exploring varied perspectives of risk information allows risk treatment and risk research priorities to be identified.
- Risks to cultural heritage can and should be considered as part of any comprehensive environmental assessment.

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References

1. Barzilai, J., 2005. Measurement and preference function modeling. *International Transactions in Operational Research* 12:173–183.
2. Boroush, M., 1998. "Understanding risk analysis." American Chemical Society (ACS) Resources for the Future (RFF). Available at: http://www.rff.org/misc_docs/risk_book.pdf
3. Buchanan, M., Porter, N., Goodwin, D., MacDiarmid, S., and Knight, K. (Eds.), 1999. Guidelines for managing risk in the Australian and New Zealand public sector. HB 143:1999. Standards Association of Australia, Strathfield, Australia.
4. Carey, J., Beilin, R., Boxshall, Burgman, M., and Flander, L., 2007. Risk-based approaches to deal with uncertainty in a data-poor system: stakeholder involvement in hazard identification for marine national parks and marine sanctuaries in Victoria. Australia. *Risk Analysis* 27(1):271—281.
5. Price, J. C., and Fitzgerald, G. R., 1996. Categories of specimens: a collection management tool. *Collection Forum* 12(1): 8–13.
6. Michalski, S., 1990. An overall framework for preventive conservation and remedial conservation. In K. Grimstad (Ed.), *9th Triennial Meeting: Preprints*. ICOM Committee for Conservation, Los Angeles, CA, 589–591.
7. Waller, R. R., 1994. Conservation risk assessment: a strategy for managing resources for preventive conservation. In A. Roy and P. Smith (Eds.), *Preventive Conservation Practice, Theory and Research*, preprints of the contributions to the Ottawa Congress, 12–16 September 1994. The International Institute for Conservation of Historic and Artistic Works, London. Available at: http://www.museum-sos.org/docs/WallerOttawa1994.pdf
8. Waller, R. R., 1995. Risk management applied to preventive conservation. In C. L. Rose, C. A. Hawks and H. H. Genoways (Eds.), *Storage of Natural History Collections: A Preventive Conservation Approach,* 21–28. Society for the Preservation of Natural History Collections, Iowa City. Available at: http://www.museum-sos.org/docs/WallerSPNHC1995.pdf
9. Waller, R. R., 2003. *Cultural Property Risk Analysis Model: Development and Application to Preventive Conservation at the Canadian Museum of Nature*. Göteborg Studies in Conservation 13. *Göteborg Acta Universitatis Gothoburgensis*, Göteborg.
10. Waller, R., and Michalski, S., 2004. Effective preservation: from reaction to prediction. *Conservation, the GCI Newsletter* 19(1):4–9. Available at: http://www.getty.edu/conservation/publications/newsletters/19_1/feature.html