23E CONGRÈS MONDIAL DE LA ROUTE PARIS 2007

23rd WORLD ROAD CONGRESS PARIS 2007

Assessing critical and vulnerable structures: An efficient method to manage risks related to Ministry of transportation's structures

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Ministère des Transports Québec

Presentation

- Issue
- Managing risks as a possible solution
- Methodology
- Process description
- Conclusion

Issue

- 29 000 km road network
- 5,535 structures : 3903 bridges + 1632 culverts
- an increasing number of risks
- major consequences
- the domino effect

Government Requirements

"... all government departments and agencies should apply a strict risk management process, and that controls are set up to improve effectiveness and efficiency."

(*2004-2007 Modernization Plan,* Government of Québec, May 2004)

Legal Requirements

- **The Civil Protection Act (2001) requires that all government departments and agencies declare their risks and take the necessary measures to ensure proper maintenance of their essential properties and services when facing a natural disaster.**

- **In view of Québec's Sustainable Development Act (2006), the Ministry must consider risk management on the basis of the following principles:**

  - Health and quality of life
  - Prevention
  - Precaution

Setting up a multidisciplinary team of experts

- civil engineers specialized in structures
- hydraulics engineers
- geotechnical engineers
- risk management specialists

Estimated benefits

- enable us to identify critical structures involving some degree of vulnerability with respect to various risks
- support and document the decision-making process
- focus actions on priorities

Scope

- **Analyzing 3,903 bridges and 1,632 culverts under the responsibility of the Ministère**
- **Four stages**
- **The first stage was completed in the spring of 2007:**
  - adopting the methodology
  - assessing risks (step 1)
  - Steps 2,3,4, and 5 for the risk of “flood-flooding”

Strategic Road Transportation Network in Support of Foreign Trade

- **Its main vocation is to maintain and develop access to foreign or external markets, namely that of Ontario and the U.S.A.**
- **It serves over 88% of Québec's population and more than 92% of the total workforce in Québec**
- **At present, it covers 8,000 km comprised of both highways and main roads**

Methodology

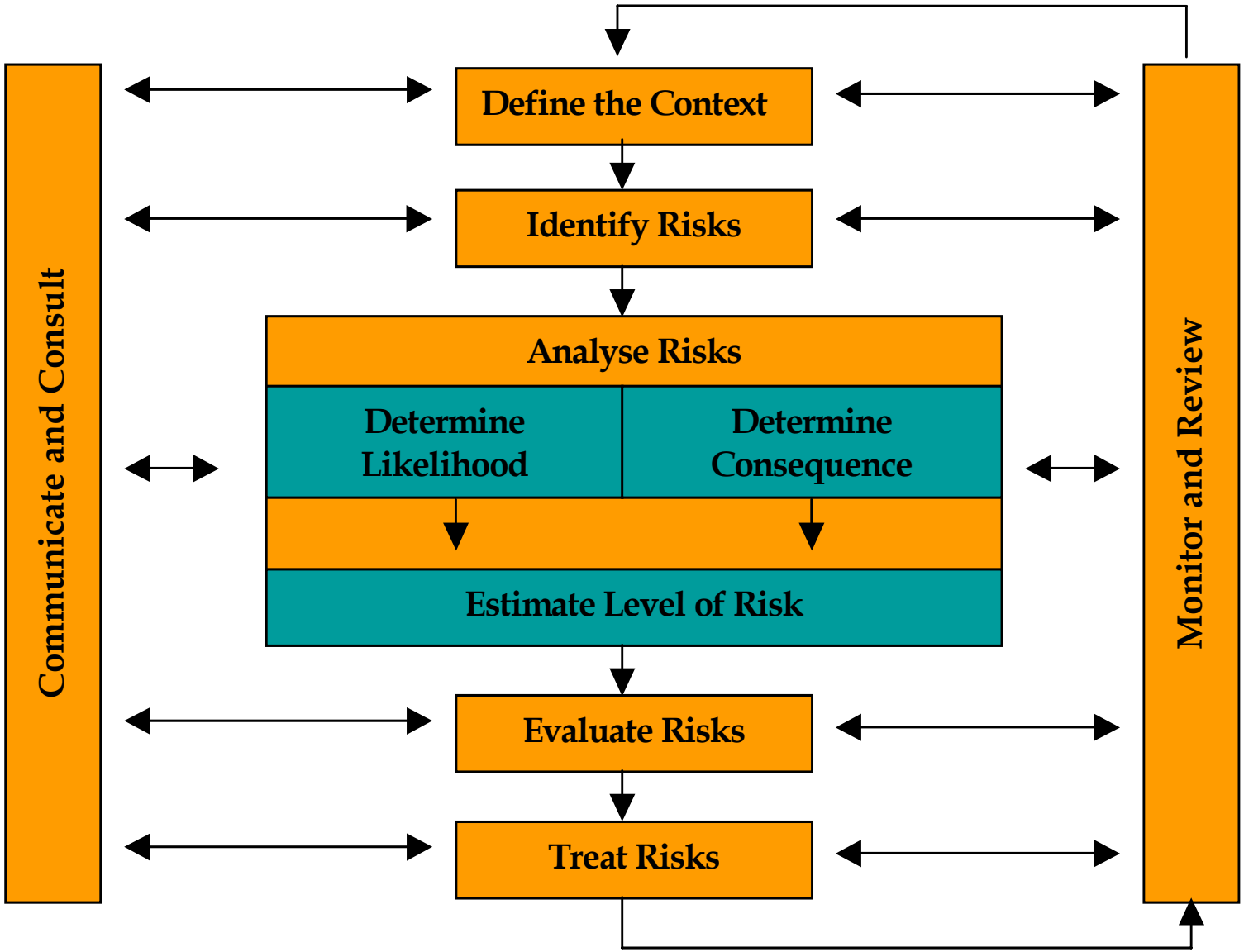
- **It is derived from the combination of two proven approaches in this regard:**
  - ***Standard AS/NZ 4360* on risk management**
  - ***Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* developed in 2002 for the *American Association of State Highway and Transportation Officials* (AASHTO) with respect to the terrorist risk.**

Methodology: 10 steps

AASHTO Methodology's

1. Assessing the risks
2. Determining structures to be analyzed
3. Estimating consequences
4. Assessing vulnerability
5. Prioritizing structures
6. Pooling results for all risks
7. Taking an inventory and determining measures
8. Estimating costs
9. Operational planning and implementing measures
10. Putting measures in place

Risk management process (step 1)



Assessing critical and vulnerable structures methodology

CONTRACTOR'S FINAL REPORT

A Guide to Highway Vulnerability Assessment

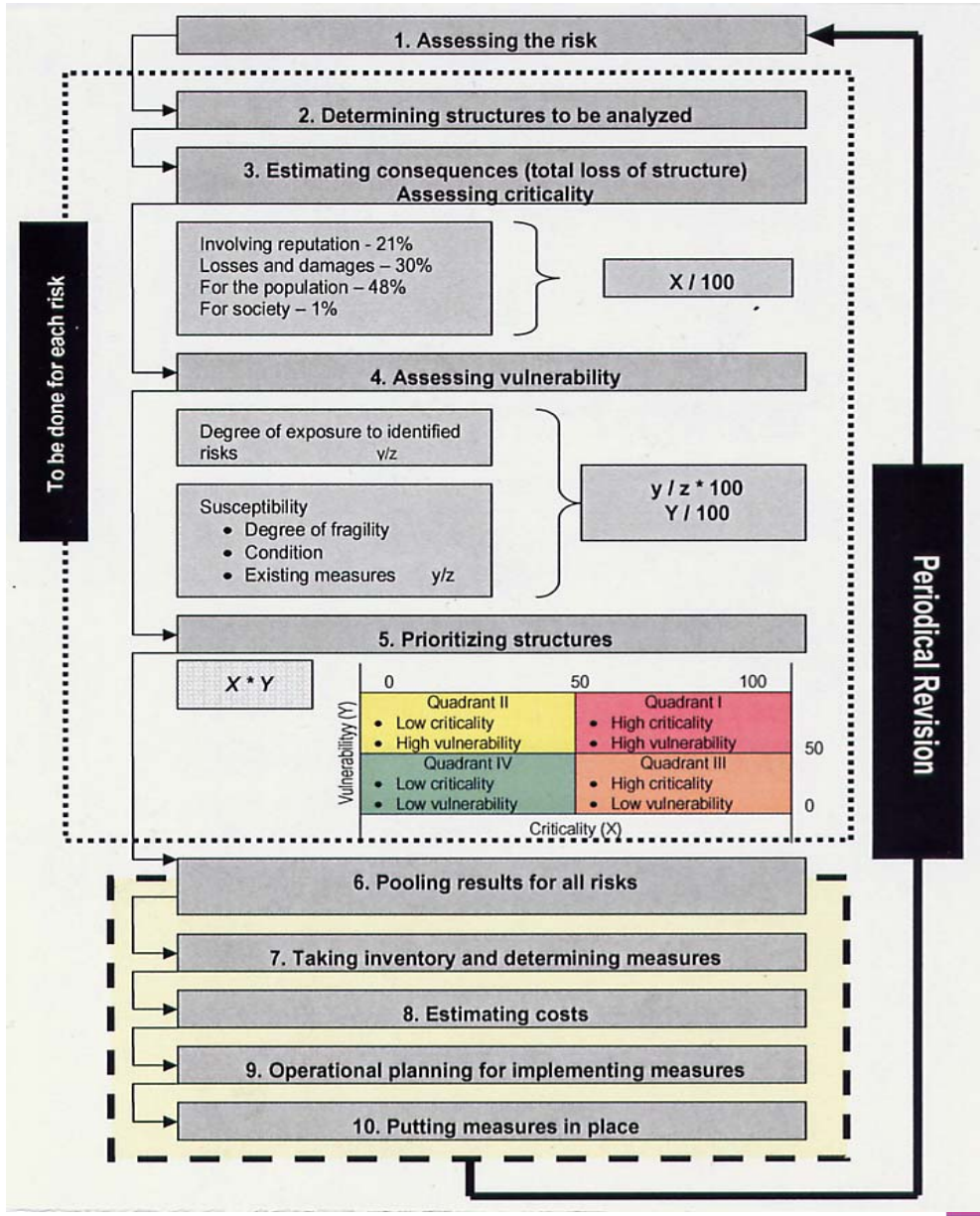
for Critical Asset Identification and Protection

Prepared for
The American Association of State Highway and Transportation Officials' Security Task Force

As National Cooperative Highway Research Program Project 20-07/Task 151B

Prepared by
Science Applications International Corporation (SAIC)
Transportation Policy and Analysis Center
7990 Science Applications Court
Vienna, VA 22182

May 2002



Step 1: Assessing the risk

What is a risk?

The presence of a risk is assumed if there is probability of a hazard combined to a potential of vulnerability with predictable damaging consequences

Risk = f (hazard and vulnerability and consequences)

Risks with a high destructive potential

Two methods to identify risks:

1. **The history of major hazards having impacted one or several structures**

2. **Identifying the various hazards that were apprehended (i.e., probable and most likely destructive)**

Risks with a high destructive potential

Natural	Man-made
Flood-flooding	Marine accident
Ice jam	Traffic accident
Earthquake	Hazardous materials
Landslide	Overloaded trucks
Ice storm	Terrorism
High winds	

Characterizing risks

- To assess their amplitude
- To prioritize how risks with higher destructive potential are to be dealt with

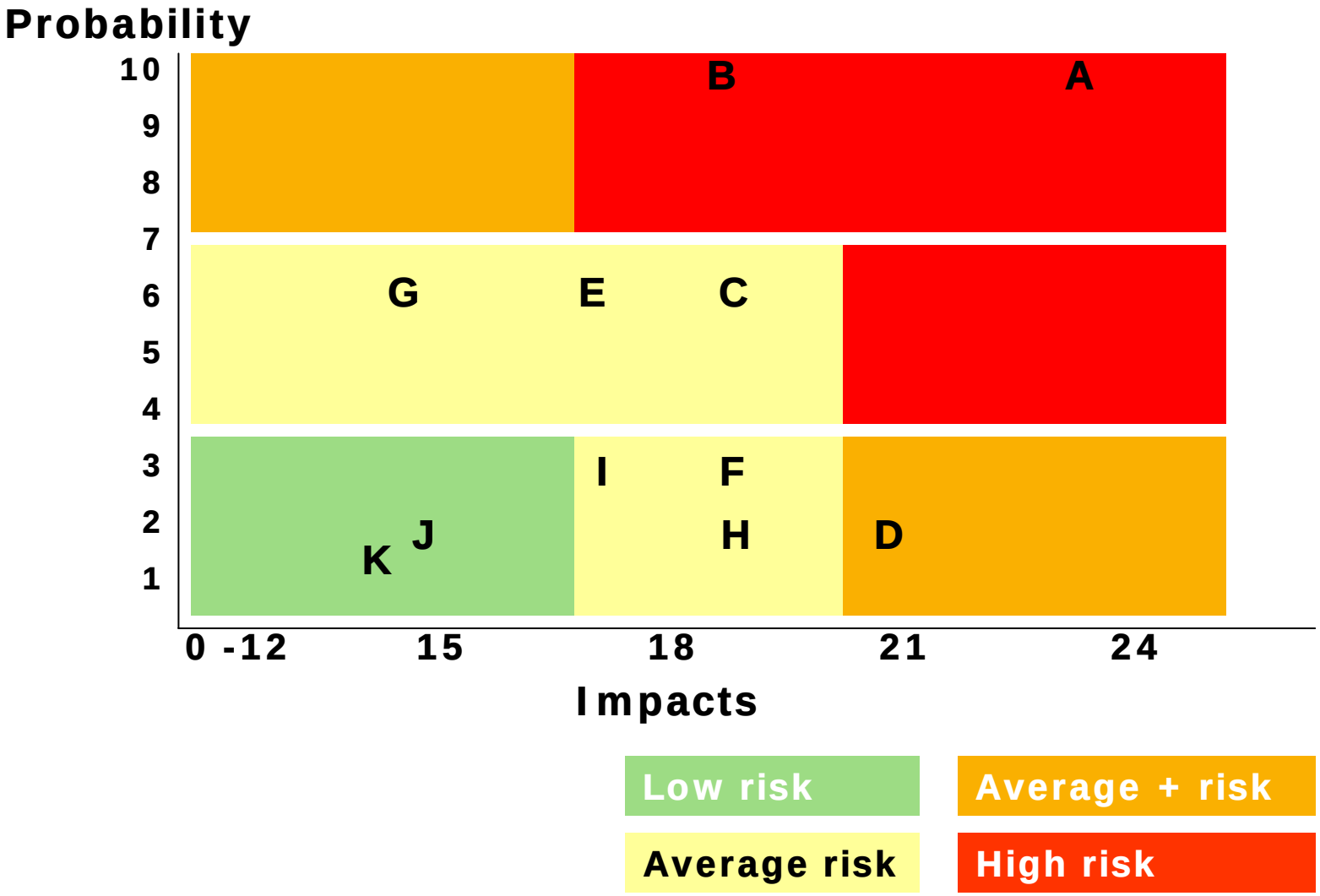
Risk assessment grid

PROBABILITY	Occurrence	Very frequent (10)	Frequent (6)	Occasional (3)	Rarely (2)	Very rarely (1)
Multiply by						
IMPACTS	Impact area	Non localized (5)	Localized or not (5)	Localized (1)		
	Territory	The whole province (5)	Part of the province (3)	On waterways (1)		
	Duration	Up to a few days (5)	Sudden (4)	Diffuse or sudden (2)	Undetermined (0)	
	Moment	At any time (5)	2 seasons and up (3)	One season (1)		
	Predictability	No (2)	Yes (1)			
	Control of hazard	No (2)	Yes, depending on amplitude (2)	Yes (0)		

Results

	Risks	Level	Level
A	Flood-flooding	230	High
B	Traffic accident	190	High
C	Landslide	114	Average
D	Earthquake	42	Average +
E	Overloaded trucks	102	Average
F	Ice 25mm +	57	Average
G	Ice jam	90	Average
H	High winds 120km/hr +	38	Average
I	Hazardous materials	51	Average
J	Marine accident	30	Low
K	Terrorism	14	Low

Results: map of risks



Step 2: Determining structures to be analyzed

- Assessing risks
- Sorting structures
- Estimating consequences
- Assessing vulnerability
- Prioritizing
- Pooling
- Measures
- Costs
- Planning
- Putting in place

- **Sorting criteria are determined to identify structures that could potentially be vulnerable to various risks.**
- **In the case of the "flood-flooding" risk, the following sorting criteria were applied:**
  - **Structures on watercourses only less:**
    - **those having a shallow foundation resting on rock**
    - **rectangular / circular-shaped culverts made of reinforced concrete**
  - **In the case of the "flood-flooding" risk, 666 structures were considered.**

Step 3: Estimating consequences and determining the criticality level

Assessing risks
Sorting structures
Estimating consequences
Assessing vulnerability
Prioritizing
Pooling
Measures
Costs
Planning
Putting in place

- **Consequences are being ESTIMATED, not assessed**
- **The multidisciplinary team called upon a few specialists to validate the criteria selected:**
  - **one public relations specialist**
  - **one traffic (AADT) specialist**
- **The work done was meant to come up with an estimation of consequences on the basis of known facts.**

Types of consequences

On the agency's reputation

- Media and political impact
- Trust

In losses and damages

- Loss of human lives
- Environmental impact
- Replacement costs

On the population

- Alternative
- Utilities
- Socio-economical repercussi s
- Replacement time
- Impacting on other systems

On society

- Symbolic importance and heritage

Weighting scale of consequences

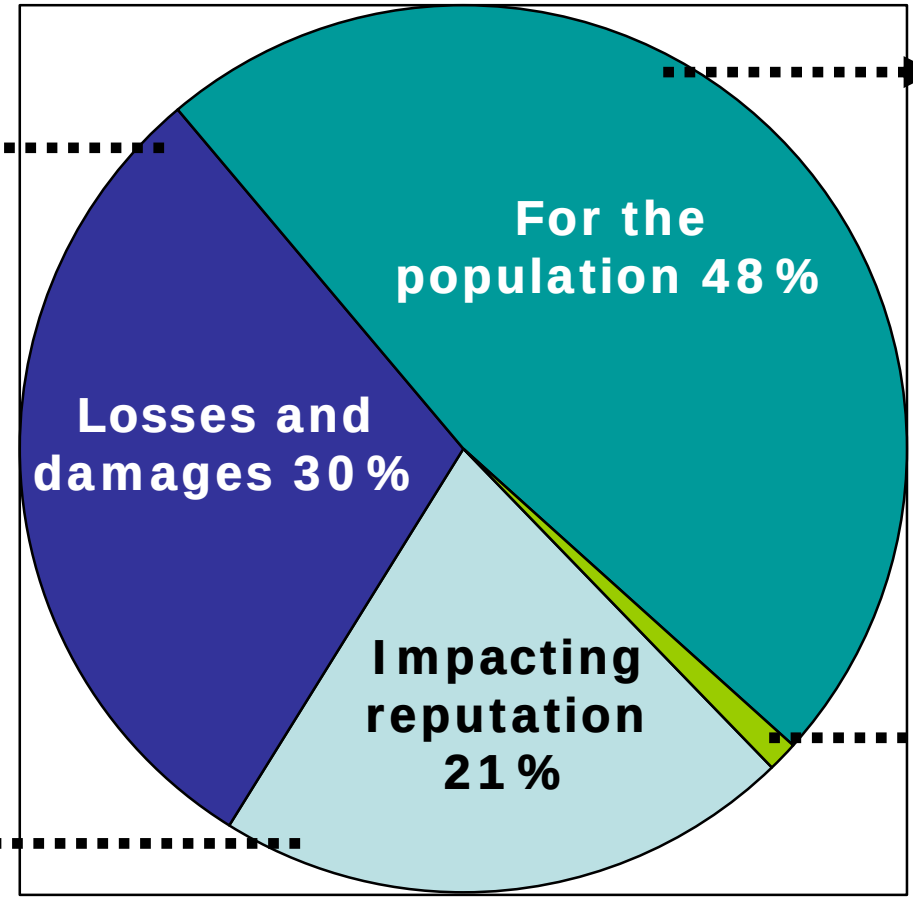
Impacts were classified according to objective criteria on a scale of 0 to 5 : Examples

Impacts	0	1	2	3	4	5
Trust	N/A	Unpredictable and uncontrollable natural hazard	Unpredictable but controllable natural hazard or predictable but uncontrollable	Unpredictable and uncontrollable man-made hazard	Unpredictable but controllable man-made hazard or predictable but uncontrollable	N/A
Estimated loss of human lives	N/A	AADT < 100 on or under the structure	AADT 101 – 1,000 on or under the structure	AADT 1,001 – 5,000 on or under structure	AADT 5,001 – 50,000 on or under the structure	AADT > 50,000 on or under the structure

Weighting scale of consequences

- **Each of the impacts was weighted according to the average significance given**
- **This weighting value is expressed as a percentage of the overall rating**
- **The maximum rating given has a bearing on the influence of the sub-consequence in the overall result and determines the criticality level of a structure (on 100)**

Weighting scale of consequences



Loss of human lives (1-5)	17
Environmental impact (0-3)	5
Replacement cost (1-4)	8

Alternative not available (1-5)	10
Dependency on utilities (0-4)	10
Socio-economical repercussions (1-4)	12
Replacement time (1-3)	8
Impacting on other systems (0-2)	8

Media and political impact (1-5)	15
Impacting trust in the agency (1-4)	6

For society 1 %

Symbolic importance and heritage (0-3)	1

Step 4: Assessing vulnerability

Assessing risks
Sorting structures
Estimating consequences
Assessing vulnerability
Prioritizing
Pooling
Measures
Costs
Planning
Putting in place

- **Allows the measurement of the vulnerability level for a given risk**
- **In relation to:**
  - **the degree of exposure to risk**
  - **the structure's sensibility**

Degree of exposure

- **Allows to determine to what extent a structure can be affected by a given risk**

- **It is determined using technical and scientific data:**

  - **Mapping areas at risk**
  - **Statistics**
  - **etc.**

Sensibility

Assessing sensibility allows one to draw up the factual and overall profile in relation to:

- **<u>The structure's fragility</u>: makes reference to the design and construction of the structure (time of construction, conformity to standards, type, etc.)**
- **<u>The structure's condition:</u> makes reference to maintenance**
- ***<u>In situ</u>* <u>measures:</u> they lower vulnerability to a hazard**

Measures

- **Design measures: accounting for natural events within standards as well as building and safety codes**
- **Management measures: systematic inspection procedure as well as training and user information**
- **Maintenance measures: improving, making repairs**

Weighting scale for vulnerability factors

- **Objective factors are determined, related to exposure and sensibility, allowing to assess vulnerability**
- **These factors are specific to each of the risks**
- **They are weighted on a scale from 0 to 5 according to their mutual significance**
- **The overall rating for a structure is based on 100, which makes it possible to assess its vulnerability level**

Weighting scale for vulnerability factors

The following weighting grid shows factors used to assess the structures' vulnerability for the "flood-flooding" risk.

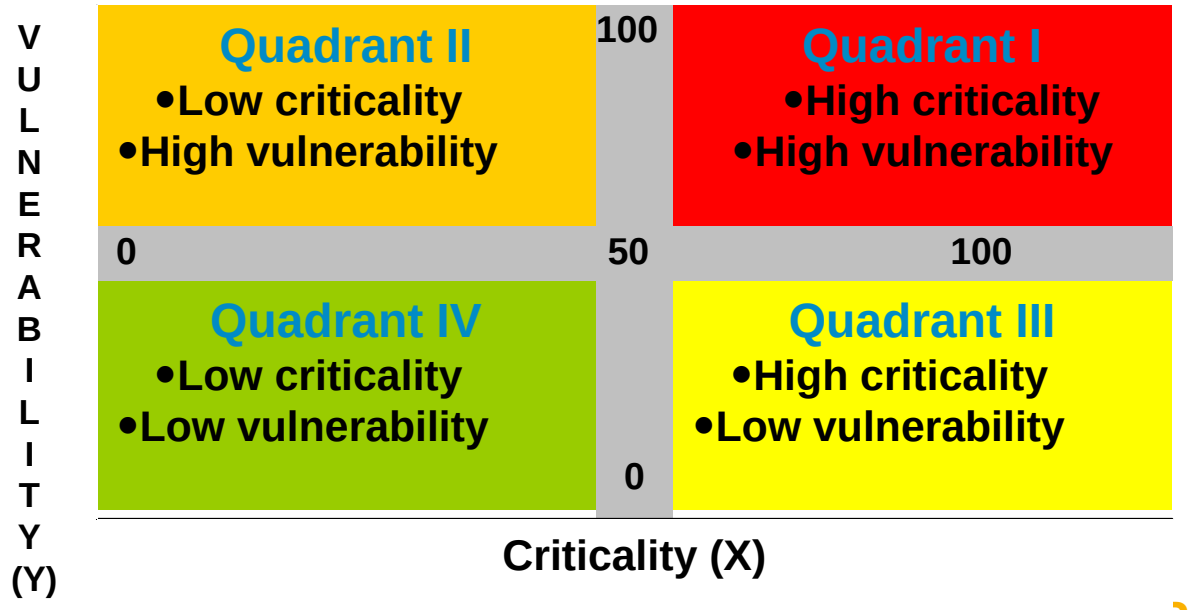
EXPOSURE	0	1	2	3	4	5
Elevation of footing level with respect to the river bed	N / A	N / A	N / A	N / A	N / A	N / A
River slope	N / A	N / A	N / A	N / A	N / A	N / A

Weighting scale for vulnerability factors

Sensibility		0	1	2	3	4	5
Fragility level	Foundation	N / A	Deep foundation on any type of soil	N / A		N / A	Shallow foundation, any type or unspecified type of soil
Structure's condition	Subject to scouring or listed as a bridge being the subject of a follow-up	N / A	No	N / A	Cote 3	Cote 2	Yes or Cote 1
Existing measures	Scouring inspection	N / A	No date	Past or next date	Past and next date	N / A	N / A

Step 5: Prioritizing structures

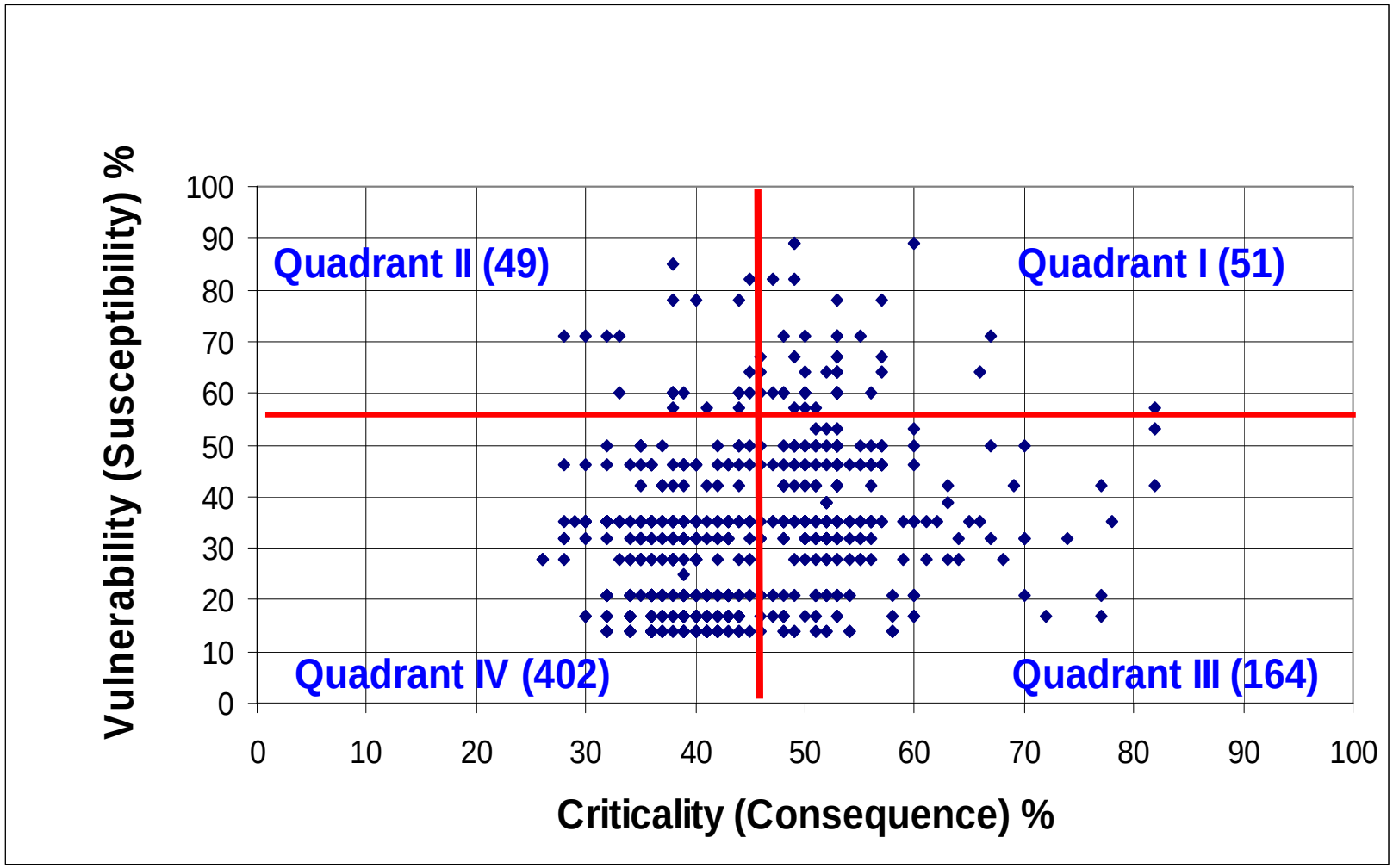
- Each of the structures examined has a rating (X/100) determining its criticality level for a given risk
- Each of the structures has a (Y/100) rating determining its vulnerability level for a given risk
- These ratings are in line with specific coordinates that can be used to classify structures in one of the four quadrants of the criticality and vulnerability mapping



Structures mapping

- Quadrant I includes structures with the highest vulnerability and criticality
- They should therefore be given priority
- Quadrant II has priority over Quadrant III since it was decided to first address structures that are more vulnerable than critical.
- This decision is based on a preventive rather than reactive approach
- Structures in Quadrant IV do not have priority

Structures mapping for the “flood-flooding” risk



Step 6: Pooling results for all risks

Assessing risks
Sorting structures
Estimating consequences
Assessing vulnerability
Prioritizing
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Measures
Costs
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Putting in place

In order to:

- **get an overall picture of the level of risk for each of the structures**
- **determine structures that are critical and vulnerable to more than one risk**
- **provide an overall assessment of all measures that must be put in place for a given structure**

Steps 7 & 8: Taking an inventory, estimating and determining measures

Assessing risks
Sorting structures
Estimating consequences
Assessing vulnerability
Prioritizing
Pooling
Measures
Costs
Planning
Putting in place

- Identify measures to be put in place to mitigate or eliminate risks
- Cover the four areas namely, prevention, preparedness, intervention, and recovery
- Insist on those relating to prevention and preparedness

Criteria for selecting measures

- Cost / benefit ratio
- Risk mitigation potential (residual risks)
- Administrative effectiveness
- Impact on the economy
- Risk creation
- Political acceptability
- Reactions from the public and pressure groups
- Impact on the environment
- Residual impact

Steps 9 & 10: Operational planning for implementing and putting measures in place

Assessing risks

Sorting structures

Estimating consequences

Assessing vulnerability

Prioritizing

Pooling

Measures

Costs

Planning

Putting in place

- Stakeholders' responsibilities
- Implementation methods
- Implementing schedule
- Expected results
- Required budget
- Performance indicators
- Review process to be put in place

Periodical review

- New contingencies may appear
- The environment can also change
- Ageing takes its toll on structures
- There can be degradation or improvement in the condition of a structure following the implementation of corrective measures
- All such factors point to the necessity of periodically reviewing the assessment of these structures' vulnerability

To conclude

- Risk management is an effective way to identify critical and vulnerable structures
- It gives a rigorous process
- It supports decision-making with data
- It justifies actions being taken
- This project breeds consensus and unanimity
- It puts the expertise of specialists to the forefront

Questions?

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