


Infrastructure Adaptation Decision-Making Using the Triple Bottom Line Approach

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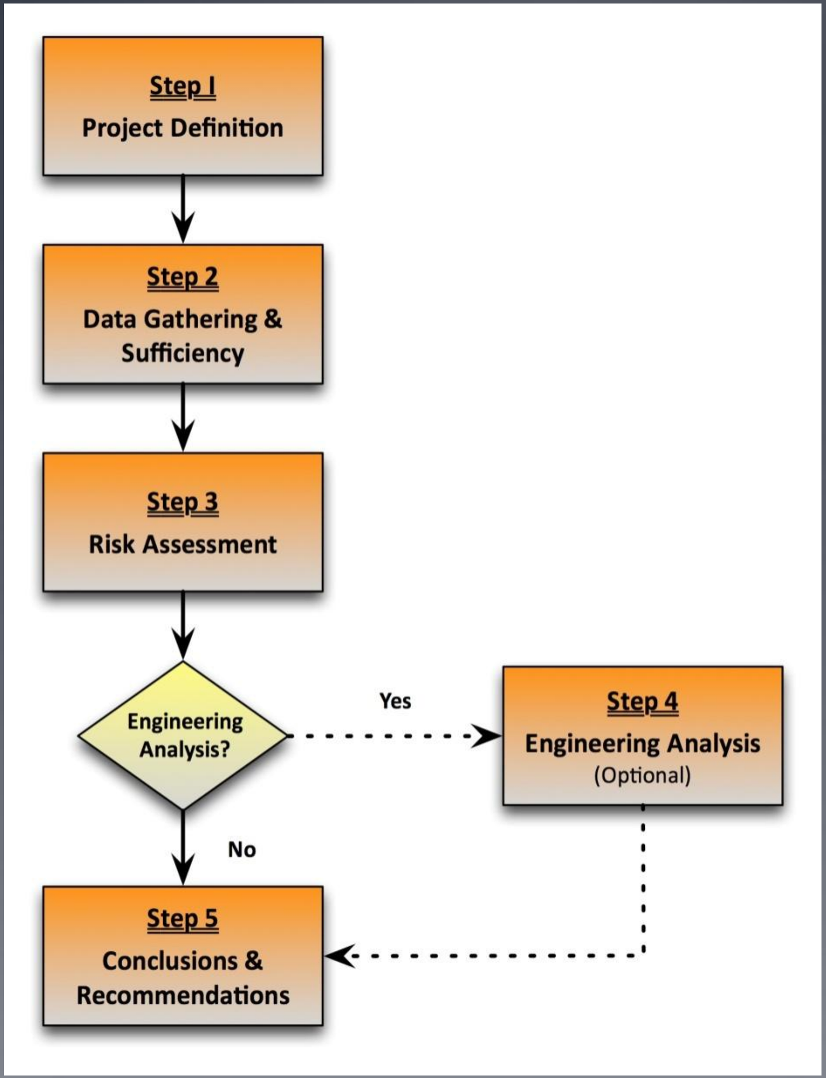
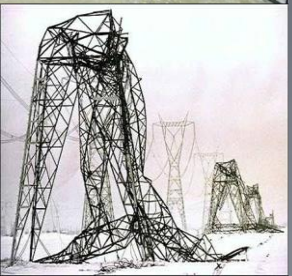
PIEVC Engineering Protocol
The First Five Steps



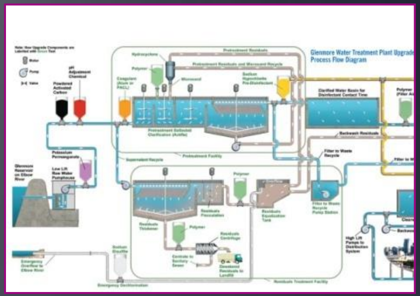
Background

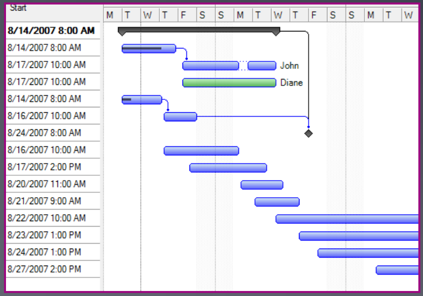
- Necessity to adapt to climate change is clear
  - Professional obligations
  - Insurance perspective
  - Legal considerations and requirements
- Infrastructure adaptation decisions must be made on technical criteria, but also involve social, environmental and economic (triple-bottom-line) considerations
- To meet this need, Engineers Canada developed the Triple Bottom Line (TBL) decision support tool, an optional additional analysis tool within the PIEVC Engineering Protocol
- Protocol → identifies vulnerabilities
- TBL analysis → develop and assess potential solutions based on TBL criteria



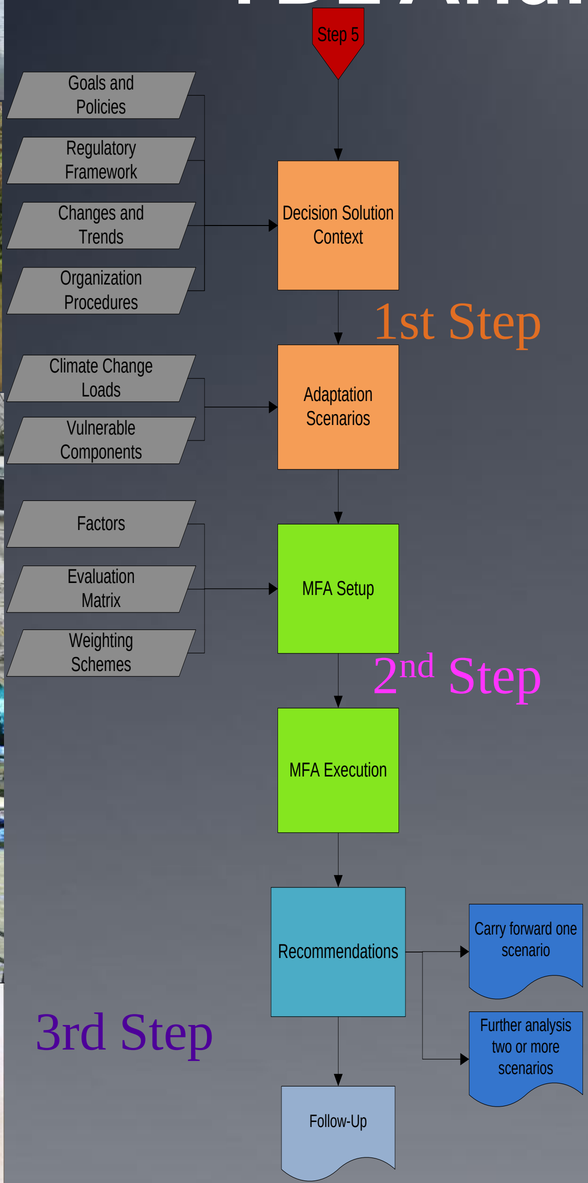
Characteristics of TBL Analysis





- High level planning exercise and Decision Support System
- **Structured methodology** for debating issues, assess their importance to overall decision
- Utilizes **professional judgment**, meetings and workshop(s)
- Introduces TBL criteria explicitly into the decision making process
- Facilitates **documentation** of key steps
- Allows organizations to assess their progress continuously
- Promotes **participant and organizational learning**
- Knowledge enhances **organizational resilience**

TBL Analysis Methodology



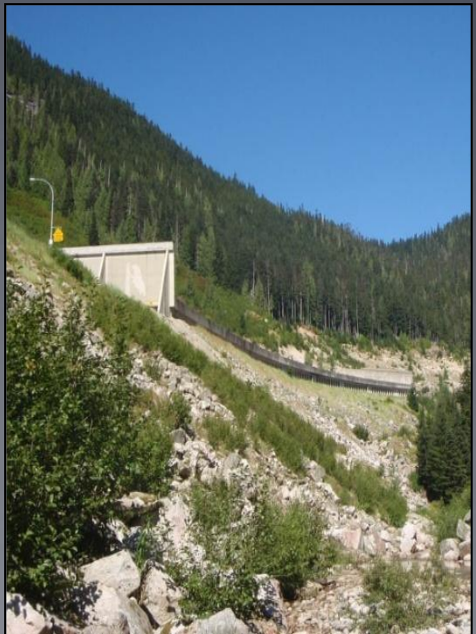
- TBL analysis employs **multi-factor analysis** (MFA) as core analysis framework
- 1st step: Define alternative solutions to address infrastructure vulnerabilities
  - Consider goals, policies, technical requirements, climate change issues
- 2nd step: Define and execute multi-factor analysis
  - Introduce and evaluate TBL based factors, judge importance through weighting
- 3rd step: Make recommendations

TBL Analysis – Development and Testing

- TBL Analysis methodology development initiated in summer 2010
- Development ended March 2012: 1st version available for use
- TBL analysis applied to test case, British Columbia Coquihalla Highway Culverts Study, January 2012
  - 50 km segment of the Coquihalla Highway, 1 000 m elev. change in mountainous terrain

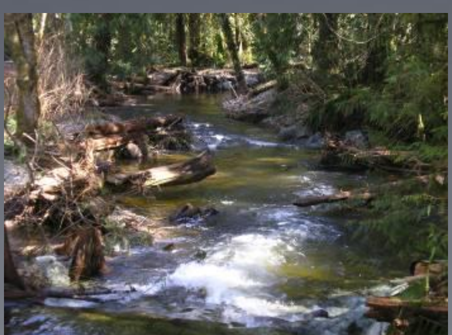
BC Coquihalla Highway Case Study

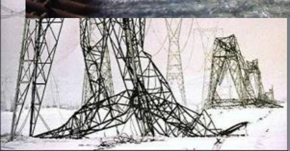
- TBL analysis case study to find optimal solution for climate change induced vulnerabilities in large (>3m) culverts:
  - Increased frequency and magnitude of precipitation and storm events
  - Erosion, culvert blockage, insufficient capacity → flows overtopping highway, potential failure



Alternatives for Comparison

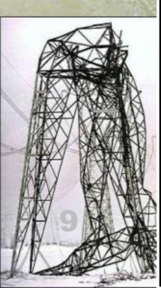
Scenarios	Reactive Phase	Information Gathering	Preventative Upgrades
Business as usual	• Monitor deterioration • Improve headwall anchoring • Waterproof gaps in headwall and wingwall	• Post-event data gathering • Hydraulic assessments • Observations tied to weather • Inventories and as-built information	• Do nothing;
Maintenance+	• Idem.	• Idem.	• Rebuild headwall and wingwall • Install rip rap at inlet and outlet • Construct sediment trap/basin before inlet
Relief Culvert	• Idem.	• Idem	• Construct relief culvert below crown of existing culvert to accommodate additional flows







TBL Evaluation Factors for Coquihalla Culverts

Social	Environment	Economy
○**Loss of use – duration** ○Loss of use – frequency ○Disaster performance ○Fee structure ○Service interruptions •Number of users affected ○Loss of use ○Service interruptions •Social acceptability ○Public perception •Public health and safety ○Emergency services ○**Impact on user safety** ○Impact on operator safety ○**Injuries/fatali**	○GHGs ○Noise pollution •**Natural environment** ○Soil quality ○**Water quality** ○Vegetation ○Habitat ○Wildlife corridors •Compatibility with regulatory frameworks/policies •Resource Consumption ○Material sourci	○**Maintenance &Operation** ○Replacement value of asset ○Cost of service per capita ○Cost reliability •Time ○Project timeline ○Construction time ○Loss of time ○Service Life •Level of service •Flexibility of the solution •Property requirem

Weighting Schemes Tested

Factor	Group	Social Bias	Environment Bias	Economic Bias
Social	**20**	**50**	**14.3**	**16**
Decreased use	*6*	*15*	*4.3*	*4.8*
Impact on User Safety	*14*	*35*	*10*	*11.2*
Environmental	***30***	***18.8***	***50***	***24***
Water Quality	*30*	*18.8*	*50*	*24*
Economic	***50***	***31.3***	***35.7***	***60***
Capital costs	*30*	*18.8*	*21.4*	*36*
M/O Costs	*5*	*3.1*	*3.6*	*6*
Durability	*15*	*9.4*	*10.7*	*18*
Total	***100***	***100***	***100***	***100***

Scenario 1 – Maintenance+

Factor	Performance Indicator	Performance Evaluation	Comment
Social Factors			
Decreased use	Qualitative	No impact	Construction does not impact roadway. No impact on lane capacity expected
Impact on User Safety	Qualitative	No change	No changes to driver safety expected
Environmental Factors			
Water Quality	Qualitative	Improved	Construction of sediment basin will temporarily decrease water quality, but can be managed with mitigation. Basin operation allows sediment deposition = improving water quality downstream
Economic Factors			
Capital costs	$	$80,000	$25,000: reconstruction of headwall & wingwall; $25,000: installation of rip rap at inlet & outlet; $30,000: construction of sediment basin
M/O Costs	$	$350,000	$25,000/10 yrs: maintenance of rip rap at inlet & outlet (50 yr timeframe, excl. $25K for initial installation); $5,000/yr for annual cleanout of sediment basin over and above maintenance contract (50 year timeframe);
Durability	Qualitative	Best	New sediment basin, headwall , wingwall construction is best case in terms of durability;

Scenario 1 – Maintenance+

Factor	Performance Indicator	Performance Evaluation	Comment
Social Factors			
Decreased use	Qualitative	**5**	Construction does not impact roadway. No impact on lane capacity expected
Impact on User Safety	Qualitative	**5**	No changes to driver safety expected
Environmental Factors			
Water Quality	Qualitative	**5**	Construction of sediment basin will temporarily decrease water quality, but can be managed with mitigation. Basin operation allows sediment deposition = improving water quality downstream
Economic Factors			
Capital costs	$	**3**	$25,000: reconstruction of headwall & wingwall; $25,000: installation of rip rap at inlet & outlet; $30,000: construction of sediment basin
M/O Costs	$	**1**	$25,000/10 yrs: maintenance of rip rap at inlet & outlet (50 yr timeframe, excl. $25K for initial installation); $5,000/yr for annual cleanout of sediment basin over and above maintenance contract (50 year timeframe);
Durability	Qualitative	**5**	New sediment basin, headwall , wingwall construction is best case in terms of durability;

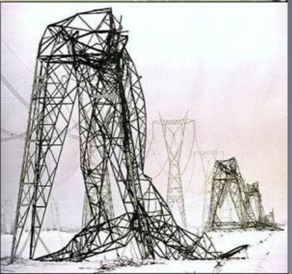
	Weighting Scheme	Sensitivity Testing		
	Group	***Social Bias***	***Environment Bias***	***Economic Bias***
Scenarios				
Business as Usual	62	76	50	64
Maintenance+	84	90	89	81
Relief Culvert	30	26	27	32
Rank				
Business as Usual	2	2	2	2
Maintenance+	**1**	**1**	**1**	**1**
Relief Culvert	3	3	3	3

Not a desirable solution in the face of climate change

Applications and Further Work

- TBL analysis has both climate change and non-climate change related applications
- Excellent for high-level screening, and planning decisions that must balance multiple criteria
- Ability to engage multiple stakeholders in consultative process
- Application to strategic level planning decisions, as well as tactical solutions
- Further refinement to apply this approach to infrastructure adaptation decision-making – Learn by Doing!
- Available as part of the PIEVC Engineering Protocol

Questions



For more information on the PIEVC Engineering Protocol and the Triple Bottom Line Module contact:

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