Risk Management

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Risk Identification & Analysis for Engineering Projects

CASE STUDY EXAMPLES

The Link between Qualitative & Quantitative Risk Analysis

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Selected Case Study Examples

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1. Risk of unstable ground occurring during a tunnel construction project;
2. Risk of a flood inundating sensitive assets in a new residential housing development;
3. Risk of an odour complaint from neighbours of a chemical process facility;
4. Risk of a toll road proving to be unviable due to the risk that road usage is different from forecast;
5. Risk of a bicycle rider being injured by a collision with an opening car door in an urban shared roadway;
6. Risk of train derailment and passenger injury on a tourist railway.

Case Study Example- 1

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1. **Risk of unstable ground occurring during a tunnel construction project;**

Case Study Example- 1

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A qualitative assessment will help list the potential risks of tunnel failure due to all causes including unstable ground conditions.

The tunnel design & construction team must be involved in the risk assessment workshop.

Case Study Example- 1

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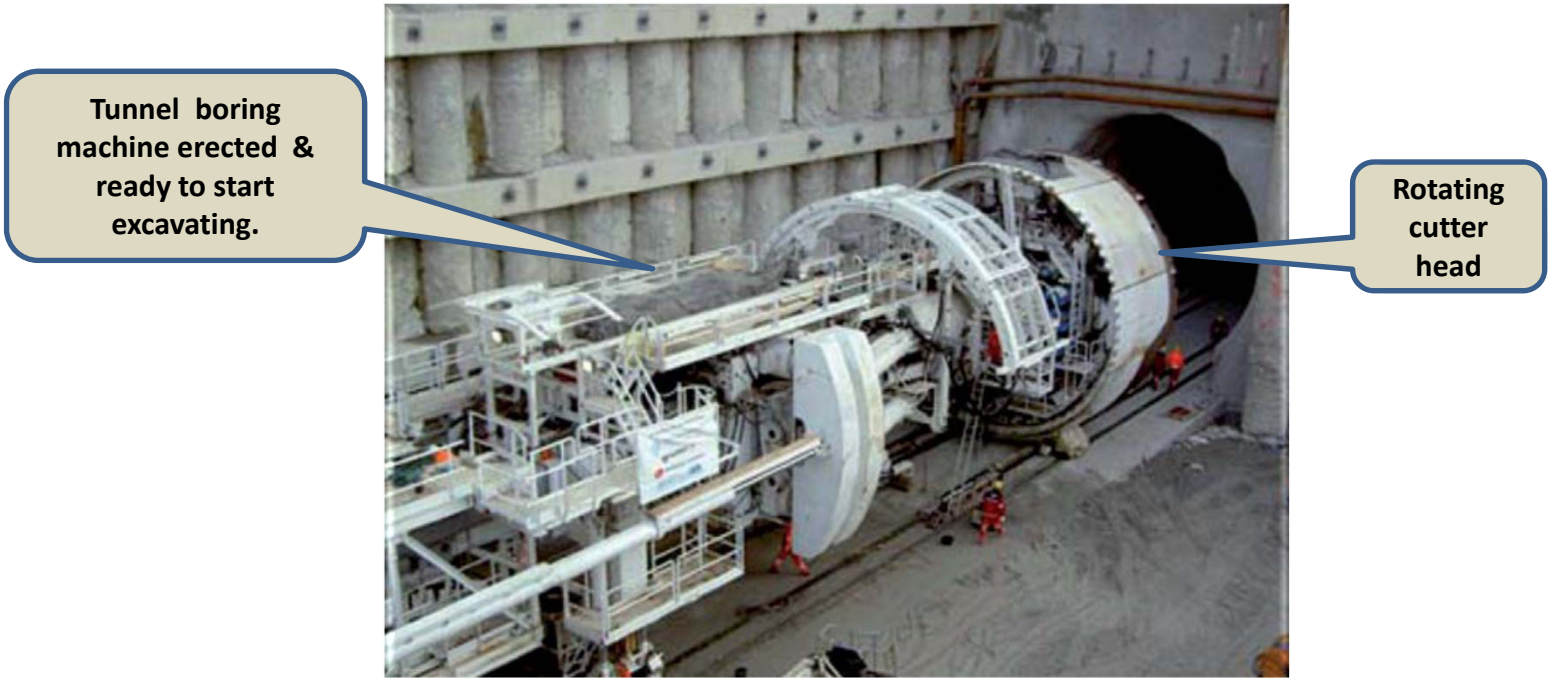
An assessment of data from large settlement/ sinkhole cases for seven major projects, divided by main risk areas confirms that variable ground conditions are a key risk.



Failure events for tunnels excavated using a tunnel boring machine have been analysed to assess the likely-hood of identified risks converting into major failures.

Case Study Example- 1

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An assessment of data from large settlement/ sinkhole cases for seven major projects, divided by main risk areas confirms that variable ground conditions are a key risk.

Risk area	Number
Launching the shield	10
Breaking into recovery shaft	4
Interfaces between stable and unstable soils	6
Mixed faces of rock, or hard cohesive soil, and granular soil	15
Head access for maintenance	13
Mechanical failures	5
Others	4
Total	57

57 documented cases are divided by the major associated factor in each case, except for four cases which do not fall readily into any of these categories.

Case Study Example- 1

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Identifying variable ground conditions:

Geotechnical investigation data is the starting point for design of tunnel construction methods & tunnel linings as well as for identification of the risk of changes in ground conditions.

The investigation data is used to derive a "number" to describe the ground conditions and this is used to identify the risk and location of potential unstable ground.

Case Study Example- 1

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"RMR" (Rock Mass Rating) or "Q" (Quality)is a tool for assessing the behaviour of the ground surrounding a tunnel and is used for designing primary support and secondary permanent lining.

The RMR is defined as the sum of six rock quality parameters:

- uniaxial compressive strength of rock material,
- rock quality designation (RQD),
- spacing of discontinuities,
- condition of discontinuities,
- groundwater conditions and
- orientation of discontinuities.

The RMR is quoted on a scale from 0-100 with higher values being stronger.

Case Study Example- 1

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- There is a limit as too how much expensive ground investigation is justifiable and therefore a statistical evaluation of available data is required to understand the confidence level of any decisions made on the basis of an RMR derived from limited investigation data.

- As tunnel design/construction Engineer, you could be asked to evaluate investigation data, recommend how much investigation is required and/or provide an opinion on the frequency and severity of unstable ground conditions expected to intersect the tunnel.

The skills you are learning in quantitative risk analysis will be essential to do your job.

Case Study Example- 2

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2. **Risk of a flood inundating sensitive assets in a new residential housing development;**

Case Study Example- 2

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A qualitative risk assessment will help identify the causes of flood events in a catchment and identify measures to mitigate the frequency & severity of such events.

However, this assessment is based on the risk analysis of catchment characteristics and the frequency & severity of rainfall events.

Case Study Example- 2

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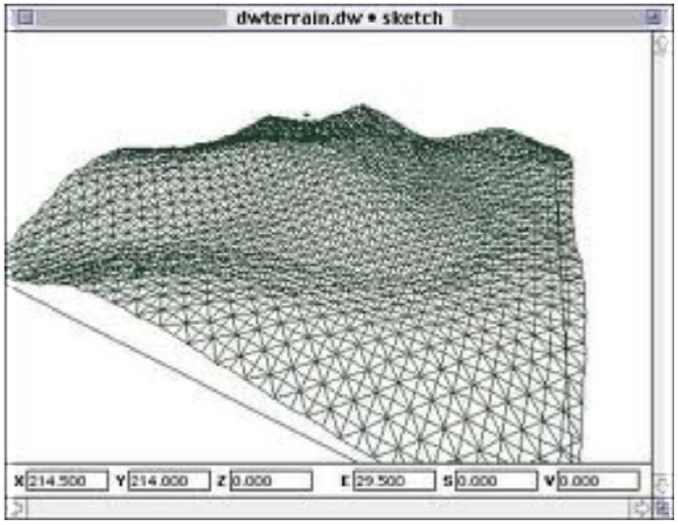
The assessment of primary risks of flooding requires analysis of numerous inter-related data sets.

Each set of data has inherent risks which determine it's accuracy and compatibility with other data.



Catchment topography

Weather patterns

Case Study Example- 2

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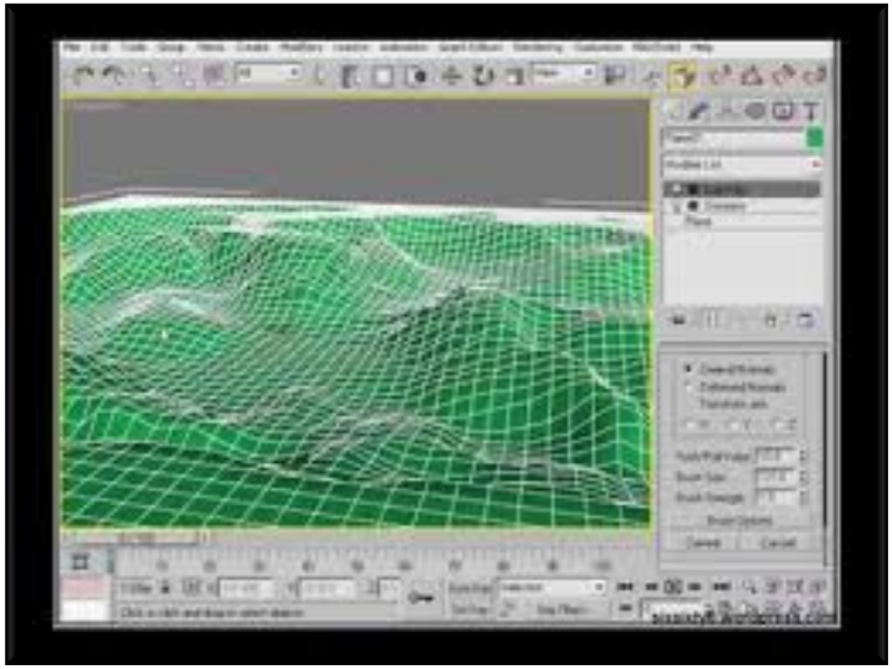
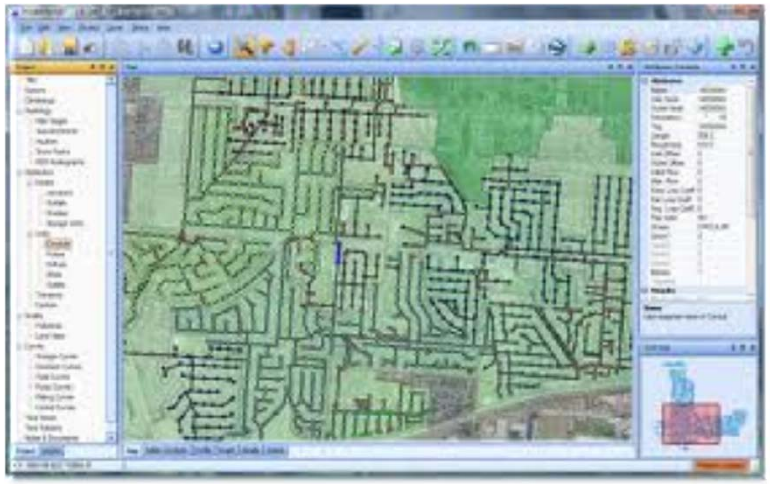
Catchment data includes:

- **topography;**
- **Surface run-off coefficients;**
- **Influences such as physical barriers and throttle points, if any;**



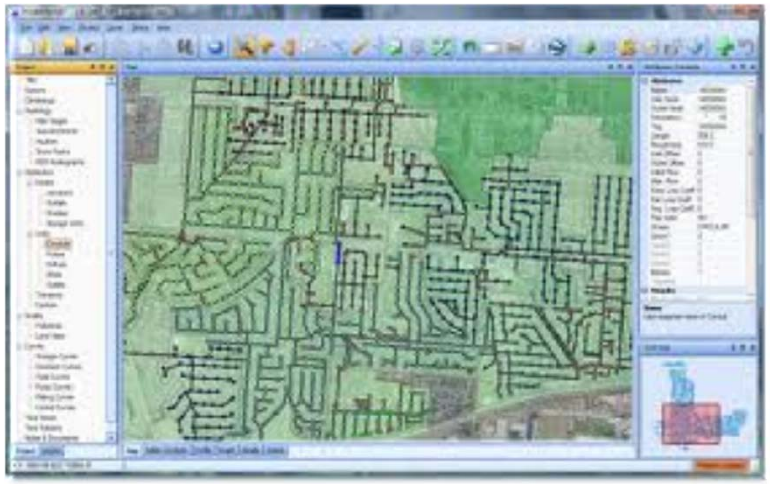
Case Study Example- 2



The use of this data requires assessment of the risk of the data being inaccurate, and the risk that the physical conditions may change temporarily or permanently after the flood analysis has been made.

For example grassed or forested areas being changed to hard surface areas in future with a corresponding change in run-off co-efficient.

Case Study Example- 2



How would you deal with this possibility of future changes in current conditions?

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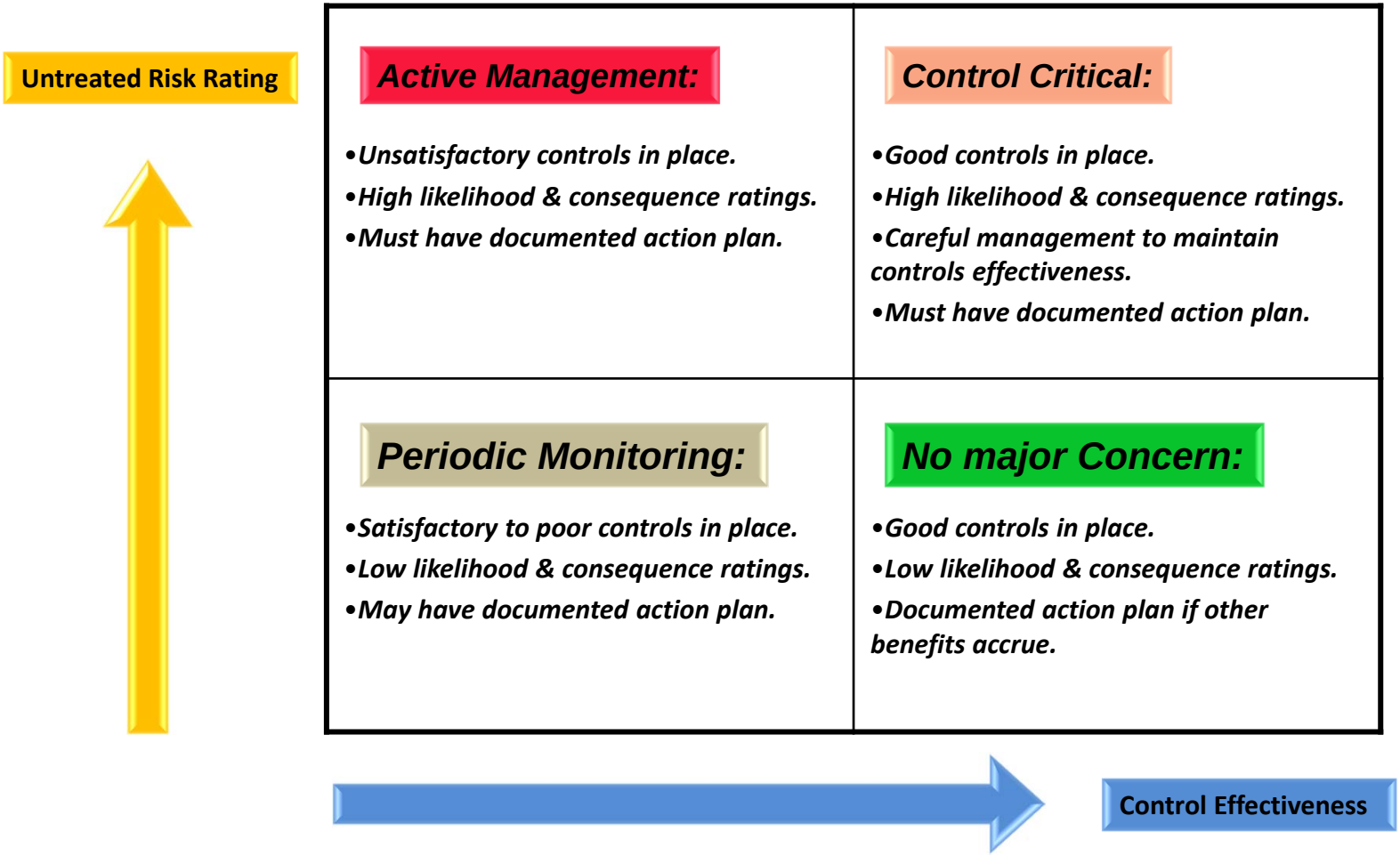
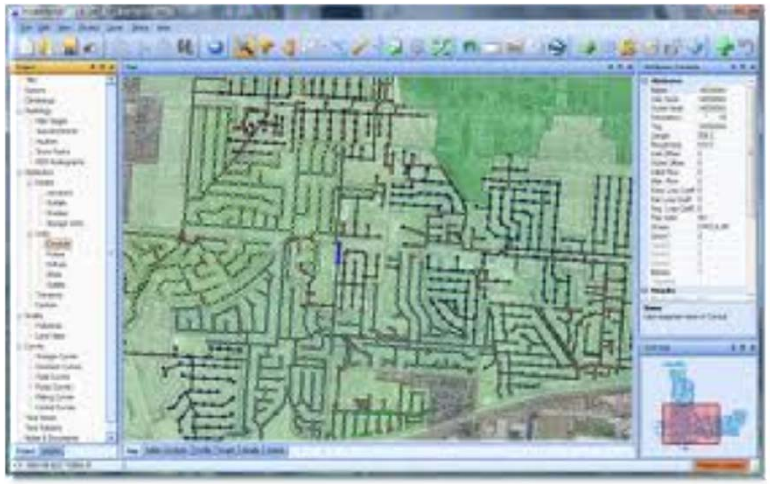
First classify the remaining risks:



Case Study Example- 2



Nominate ongoing management proposals for the remaining (or residual) risk that the run-off conditions may change, such as:

- ***Conduct a numerical analysis to determine a worst case scenario by sensitivity checks and increase drainage capacity at key "bottlenecks" now.***
- ***Initiate an ongoing monitoring programme to identify changes. This may propose a review of the risk say every 5 years.***

Case Study Example- 2

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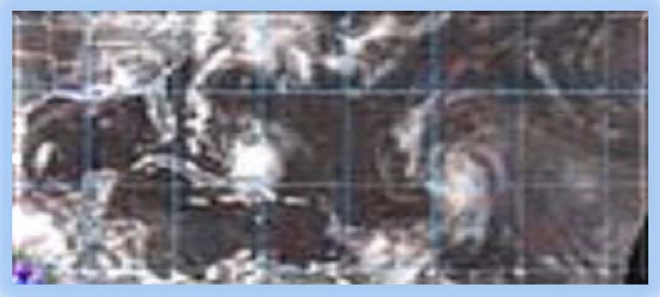
Rainfall data includes:

- ***long term averages and trends;***
- ***frequency & severity of storms;***
- ***location of storms of different frequency & intensity;***

The use of this data requires assessment of the risk of the data being inaccurate, the probability that critical location events may occur concurrently and the risk of long term weather trends exacerbating critical events. *(Australian Rainfall & Runoff (ARR) guidelines launched in December 2015)*



How would you manage these possible changes in your risk assessment?

Case Study Example- 2

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How would you manage these possible changes in your risk assessment?

Nominate ongoing management proposals for the remaining (or residual) risk that the rainfall conditions may change, such as:

- ***Conduct a numerical analysis to determine a worst case scenario by sensitivity checks and increase drainage capacity at key "bottlenecks" now.***
- ***Initiate an ongoing monitoring programme to identify changes. This may propose a review of the risk say every 5 years.***

Case Study Example- 2

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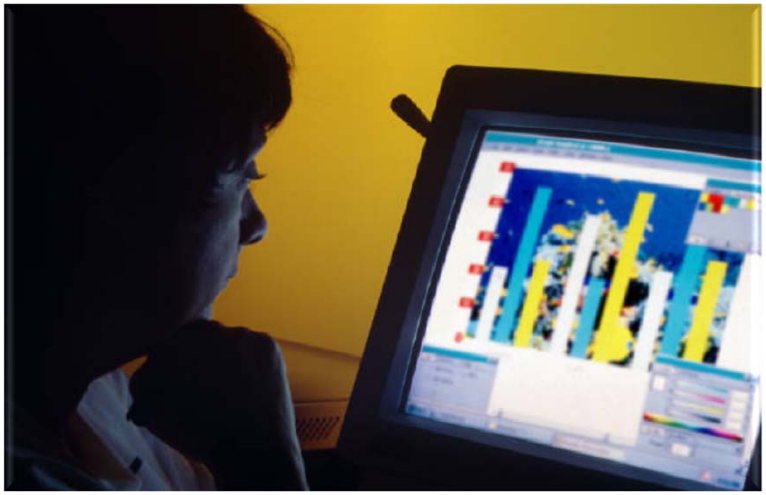
This is another example where:

qualitative risk analysis requires → **input from quantitative risk analysis.**



The skills you are learning in quantitative risk analysis will be essential to do your job.

Case Study Example- 3

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3. **Risk of an odour complaint from neighbours of a chemical process facility;**

Case Study Example- 3

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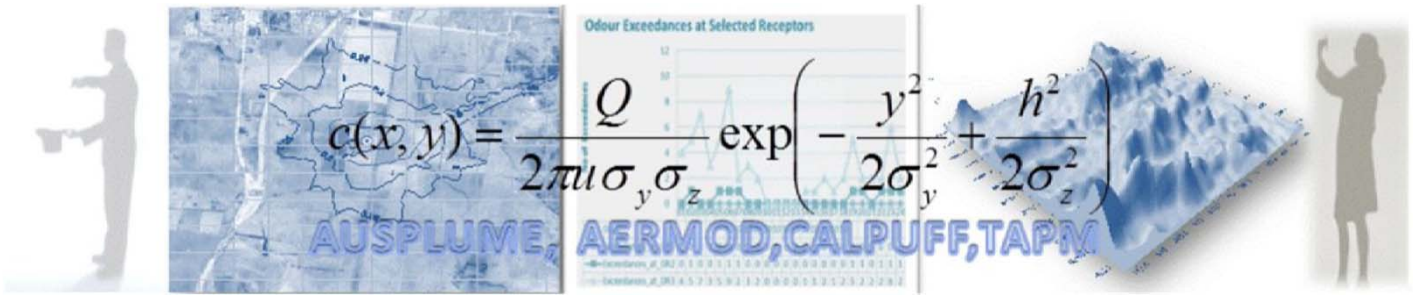
There are many proprietary analytical models to estimate the emissions from process plants whether to track visibility, toxicity or odour.

All are dependant on the assessment of risks affecting the consistent performance of the process plant as well as risks of factors affecting assumed weather patterns.



Case Study Example- 3

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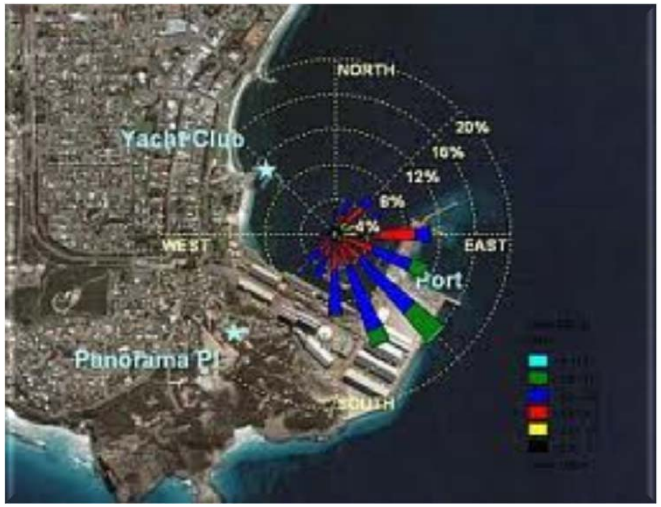
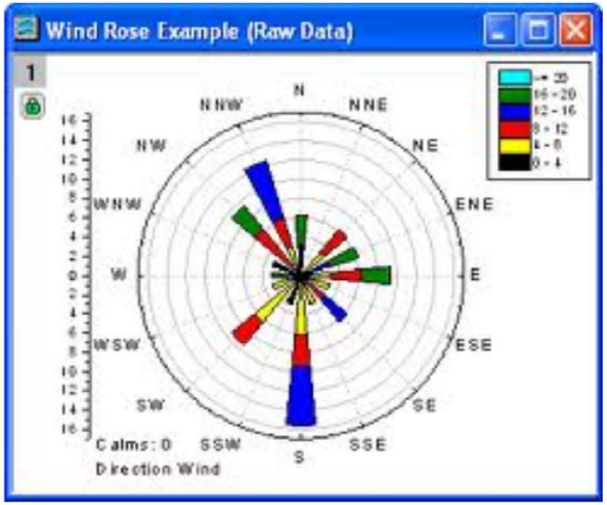
There will be a probability relationship between weather patterns, the times when emissions are at peak odour and the times when sensitive receivers are in the path of the emission.

All are dependant on the assessment of risks affecting the consistent performance of the process plant as well as risks of factors affecting assumed weather patterns.





Case Study Example- 3

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A further risk to managing odour complaints is the variability of the olfactory senses of individuals in determining what is an unacceptable odour.

The term annoyance is used to describe the complex set of reactions that a person experiences as a result of an immediate exposure to an unpleasant odour which, if continued and the person cannot avoid it, causes that person to suffer stress.

Tools such as odour annoyance surveys, odour diaries and complaints data are used to correlate measured odour units & gas composition with receivers' perceptions of when an odour is unacceptable.

Olfactory Gas Chromatography

Case Study Example- 3

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The composition of gases causing odour complaints can be chemically analysed to identify which element of an emission is contributing most to the odour and what measures can be taken to dilute or blend to reduce the odour.

When several elements in an emission are analysed as odour contributors, a statistical analysis of odour complaints and emissions analyses may be needed to design mitigation measures to reduce the risk of complaint.

Gas Chromatograph

Case Study Example- 3

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If you are employed as the Project Engineer at a process plant, whether for production of chemical compounds or for treatment of waste material, you could be asked to report on the odour emissions for the following reasons:

- **To defend a claim from neighbours that odour has caused commercial loss;**
- **To respond to a legal action from the EPA regarding non compliance with the emissions licence for the plant ;**
- **To prepare a submission to the Government Regulator for a modification to the process plant involving a change to existing emissions;**

Describe some of the "what if" risks you would have to include in your risk assessment?

Case Study Example- 3

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Describe some of the "what if" risks you would have to include in your risk assessment?

- **What if the plant output is increased?**
- **What if the plant chemical process changes in future?**
- **What if the peak emission time coincides with the worst wind conditions?**
- **What if new sensitive receivers move close to the process plant?**
- **What if our neighbour's emissions are worse than ours?**

Case Study Example- 4

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4. **Risk of a toll road proving to be unviable due to the risk that road usage is different from forecast;**

Case Study Example- 4

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- **The forecasting of road traffic volumes and road traffic patterns requires significant risk assessment and probability analyses;**

- **The risk factors to be taken into account include:**
  - **Human behaviour and preferences;**
  - **Traffic accidents;**
  - **Traffic growth or decline;**
  - **Traffic mix (cars, trucks);**
  - **Planned and unplanned traffic generation events;**
  - **Regional development changes over time;**

Case Study Example- 4

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Simulation modelling of traffic patterns is a well developed science and a specialist expertise;

However, as with all modelling, boundary assumptions and the robustness of input data are critical to the quality of the output;

A quantitative risk analysis is therefore required to identify the design range of input data and the probability of outlying events creating an unacceptable risk;

The Use of Micro-simulation Traffic Models for On-road Public Transport

Implementing National Best Practice for Traffic Control at Worksites - Risk Management, Auditing and Field Operations

Case Study Example- 4

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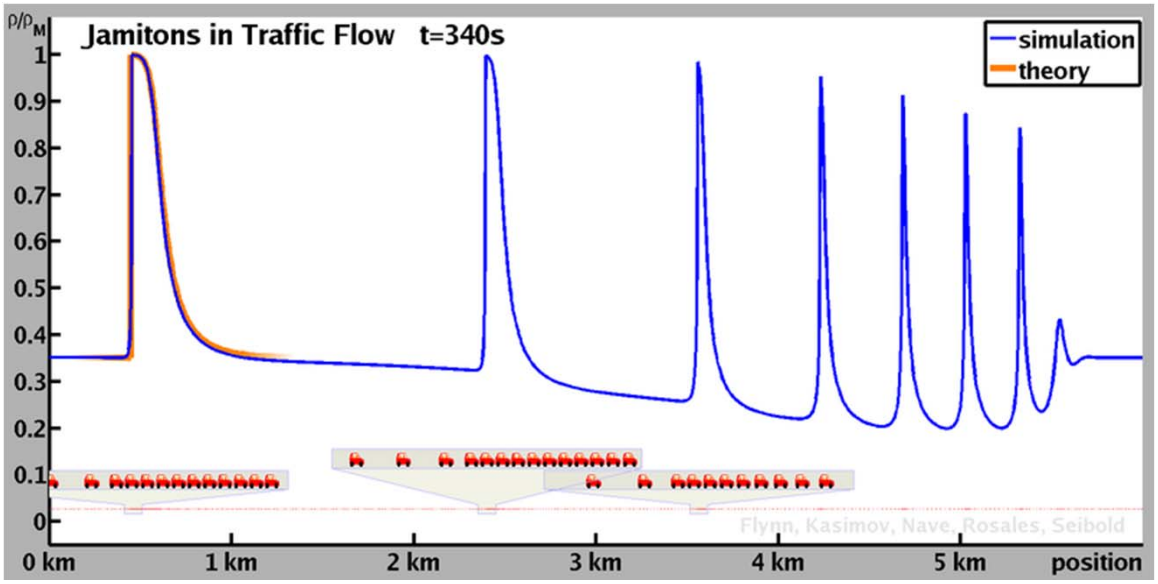
Traffic Modeling - Phantom Traffic Jams and Traveling Jamitons

Morris R. Flynn (University of Alberta); Aslan R. Kasimov (KAUST); Jean-Christophe Nave (McGill University);
Rodolfo Ruben Rosales (MIT); Benjamin Seibold (Temple University)



The graph shows a simulation of a long road with a small initial disturbance. The instability grows into a "jamiton". The shape of the "jamiton" converges to the theoretically predicted shape. In addition, a train of "jamitinos" is triggered, each of which grows to an independently travelling "jamiton".

Case Study Example- 4

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The forecast traffic volumes and the traffic mix for a toll road are used to predict revenue and hence viability for a 20year + capital investment;

The Investor will require a risk assessment of all aspects of the revenue projection to have confidence in down-side projections of viability;

Case Study Example- 4

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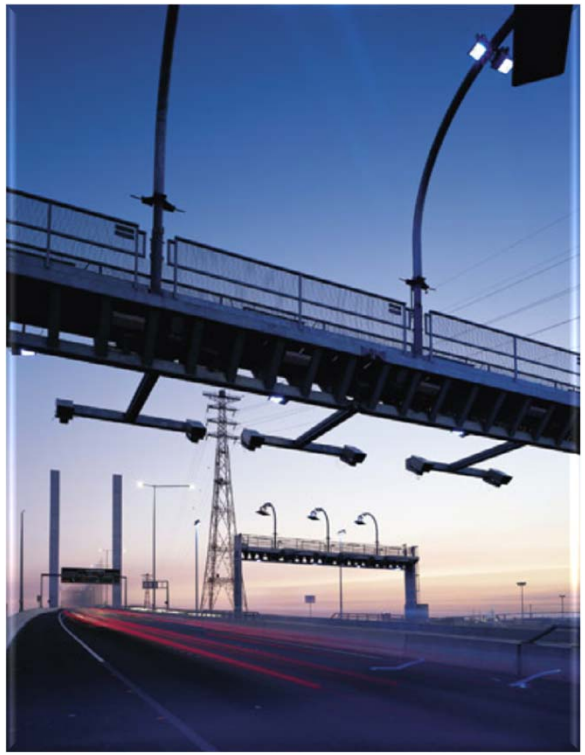
If you are the Project Manager or Traffic Engineer for the proposal you will conduct a qualitative risk assessment to identify the relevant hazards and risks;

This assessment will inevitably rely on quantitative risk analysis of the many variables that will impact on the mitigation measures identified for consideration;

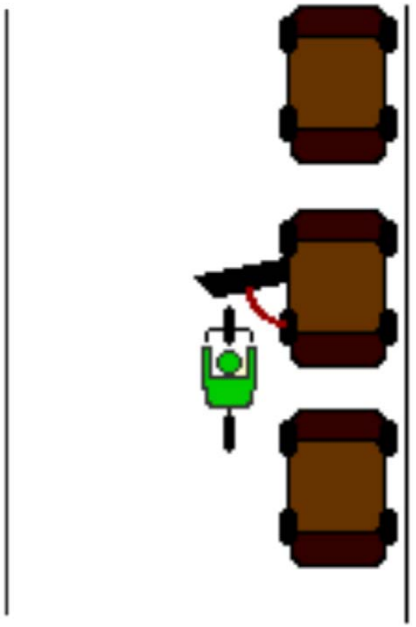
For example, one revenue risk mitigation measure could be to increase the toll charges. However, this will impact on traffic forecasts and an iterative quantitative assessment is therefore required ;



Describe some "what if" risks you would have to include in your risk assessment?

Case Study Example- 5

5. **Risk of a bicycle rider being injured by a collision with an opening car door in an urban shared roadway;**



Case Study Example- 5

Dual hazard zone bike lane on Hillsborough Street in NC

The conventional arrangement is for the bicycle lane to be located between parked cars and the carriage way;

Case Study Example- 5

The conventional arrangement for bicycle lanes in a shared road/bicycle situation creates a hazard for bicycle riders;

Case Study Example- 5

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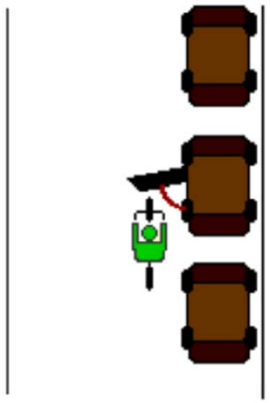
A qualitative risk assessment can be used to identify risk mitigation measures and their suitability & effectiveness:

1. **Remove the bicycle lane (remove the hazard);**
2. **Remove the parked cars (remove the hazard);**
3. **Relocate the cars so the driver door does not open into the bike lane;**
4. **Relocate the bike lane onto the footpath;**
5. **Improve lighting in bike lanes for night situations;**
6. **Enforce bike riders to use high visibility clothing plus an audible alarm;**
7. **Enforce slower speeds for bike riders;**



Case Study Example- 5

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First choice -- remove the hazard!

It is not socially or politically acceptable to eliminate the hazard by removing cars from the road way or removing bicycles for the roadway

Case Study Example- 5

An alternative arrangement is for the bicycle lane to be located between parked cars and the footpath. This arrangement disadvantages car drivers;

A reduced speed limit of 50km/h speed limit applies, there is a reduced car traffic capacity and drivers open their door into a car traffic lane.

Case Study Example- 5

This alternative arrangement does not eliminate all risks to the bike rider and requires a significant re-construction of the road surface & signage;

A driver education program is also required;

A trial was conducted in Albert Street Melbourne, and the cost of this 2Km section was $340,000.

Case Study Example- 5

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An alternative arrangement is for the bicycle lane to be relocated & shared with pedestrians

"Leading Law Firm Confirms Councils and RTA Can Be Liable for Deaths and Injuries on Shared Bicycle Paths"

Case Study Example- 5

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As a Traffic Engineer or Road Designer you could be asked to assess and report on the risks of car/bicycle shared use inherent in an existing road or in a proposed new road design;

You could be asked to also provide fully costed risk mitigation measures and to recommend a preferred ranking based on a triple bottom line assessment (financial, social and environmental factors) ;

You will commence this task with a qualitative risk assessment using workshop techniques involving key stakeholders to identify risks and possible mitigation measures;

You will also use this workshop to back-up your research into all available information and risk/cost data about road/bicycle shared roads;

Case Study Example- 5

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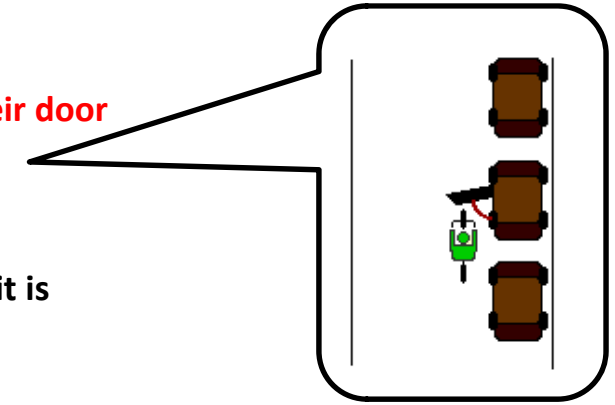
You will discover key facts about bicycle crashes in Victoria:

- **Approximately 30% of bike rider casualties occur when a driver crosses the path of an oncoming bike rider.**
- **7% of bike rider casualties occur when a driver opens their door into the path of a bike rider. This is much higher in inner Melbourne.**
- **7% of fatal and serious injury to bike riders occurs when it is mainly the rider coming off the footpath.**
- **5% of fatal and serious injury to bike riders occurs when it is mainly the car driver emerging from a driveway.**
- **28% of bike rider fatalities involved a bicycle and heavy vehicle colliding. On average 4% of bike rider serious injuries occur as a result of a bicycle and heavy vehicle collision.**



Case Study Example- 5

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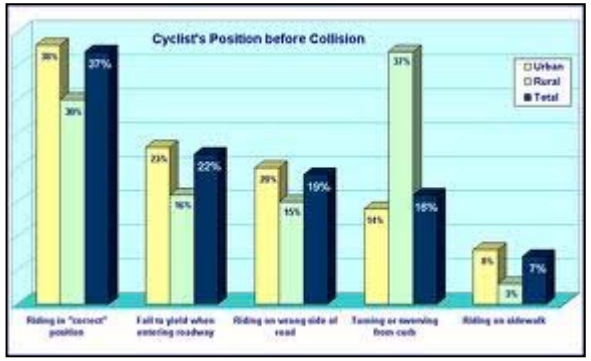
You will use properly analysed statistical information to determine the frequency & severity of bicycle/car door incidents and sort these by location

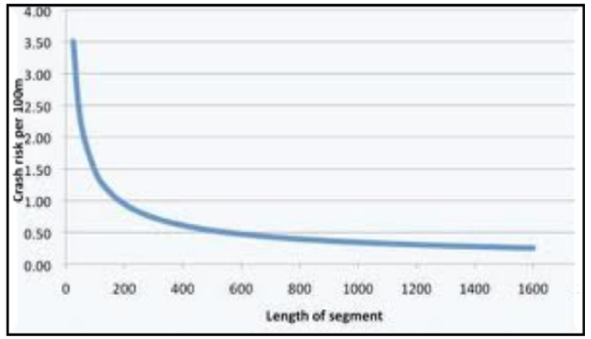
You will use properly analysed statistical information to determine what situations create the worst results for bicycle/car door incidents.

(This could be peak period (hurrying Courier drivers and peak bicycle numbers and only on particular roads.)

You will evaluate the cost/benefit of mitigation measures to reduce the frequency and severity rates.

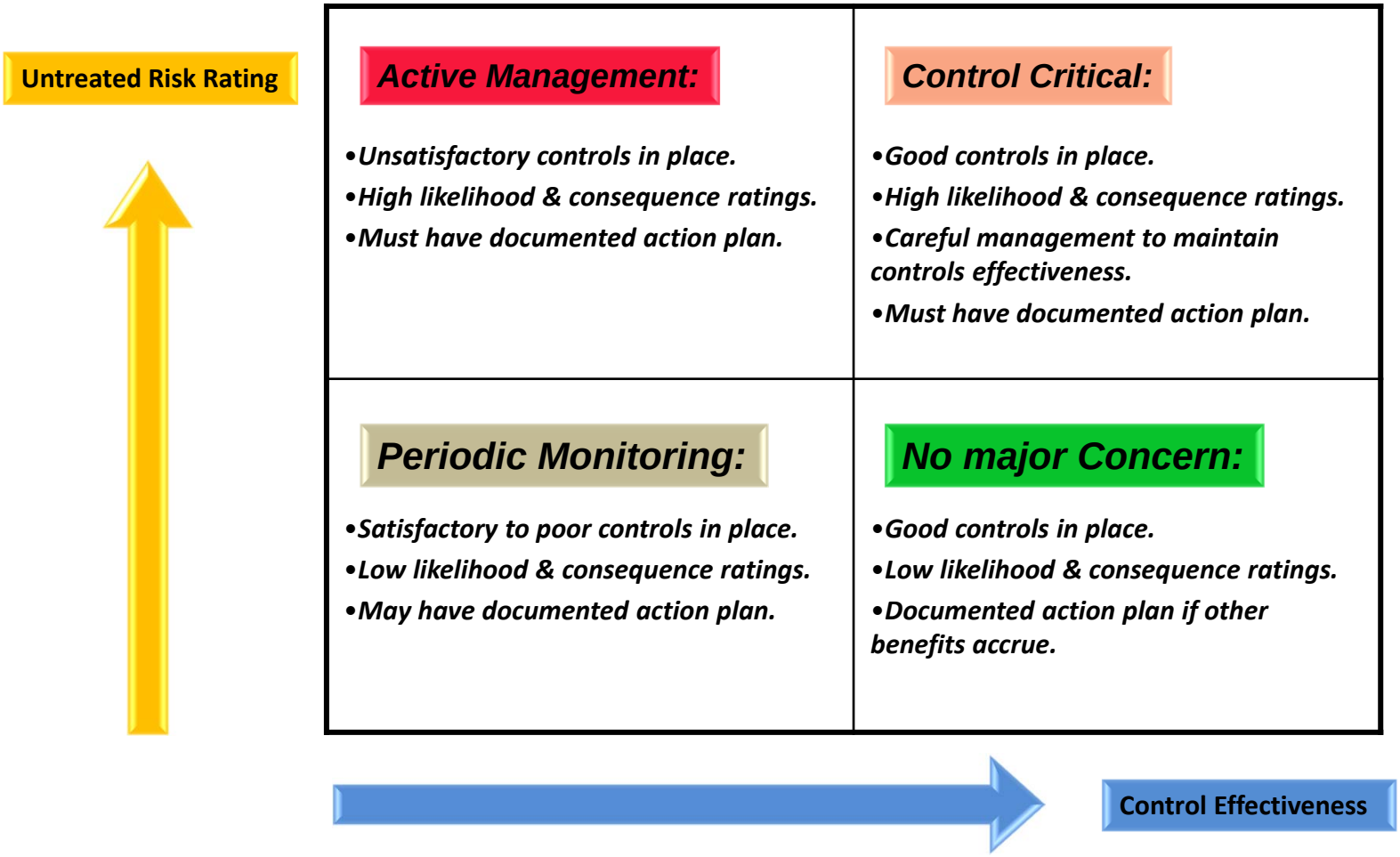
You will rank the mitigation measures and provide a recommended action plan.





Case Study Example- 5

Your conclusion may indicate a need for "Active Management" ongoing.



Case Study Example- 5

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Your conclusion may indicate a need for "Active Management" ongoing.

What active management tasks would you specify?

Case Study Example- 5

Your conclusion may indicate a need for "Active Management" ongoing.

- **Educate car drivers to watch for bicycles before opening doors;**
- **Enforce bike riders to use high visibility clothing plus an audible alarm;**
- **Enforce slower speeds for bike riders;**
- **Improve lighting in bike lanes for night situations;**

Case Study Example- 6

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6. Risk of a train derailment or passenger injury on a popular tourist railway.

Case Study Example- 6

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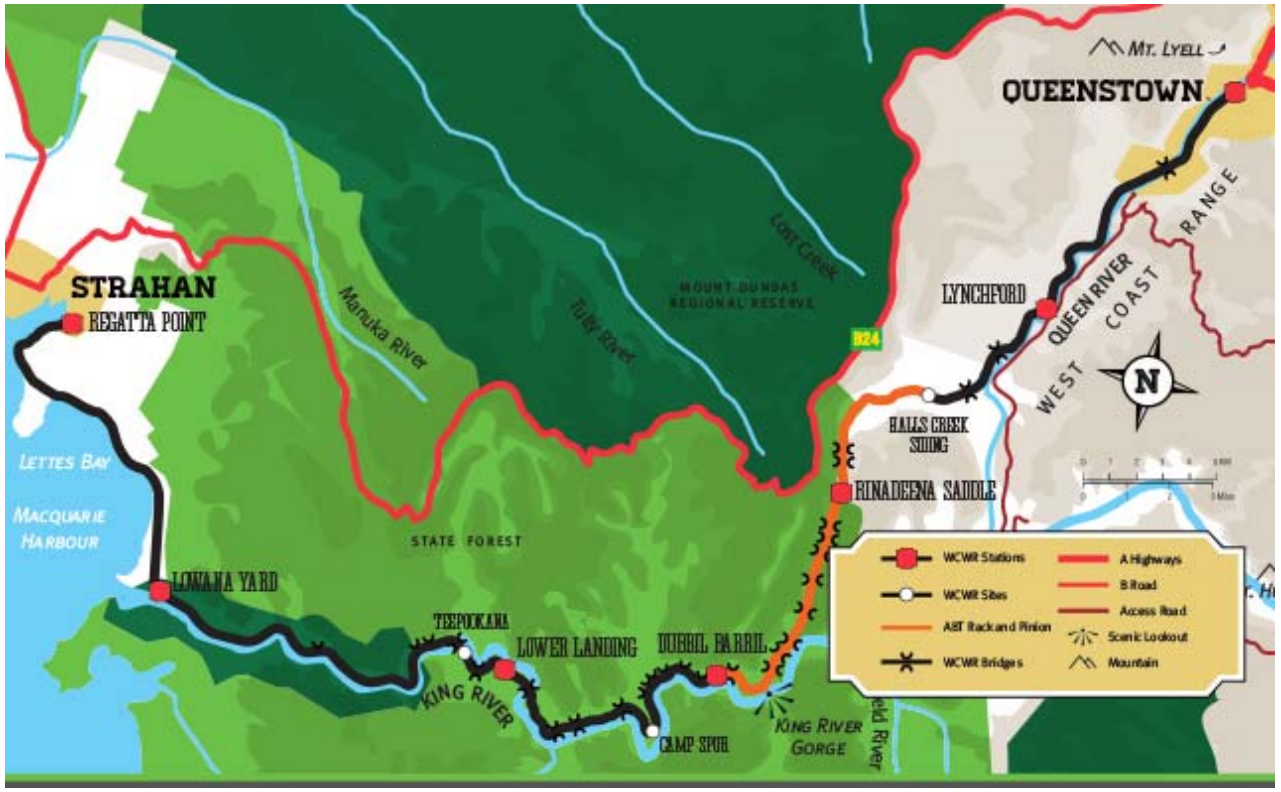
The 100 year old railway was constructed for mining services and was abandoned when the mines stopped operating.



Case Study Example- 6

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The route passes through scenic forests.
So in 2007 it was restored to operate as a tourist railway.

Case Study Example- 6

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It received Government funding to proceed and was strongly supported by the community.

It offered a new tourism business for the region including local employment

Case Study Example- 6

Before the train can operate and carry passengers, you are required to conduct a safety audit including a risk analysis. You are required to certify, in writing that the railway design, construction and operation is safe for carrying passengers.

Case Study Example- 6

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Your analysis indicates that the horizontal curves along the track are less than accepted industry practice and there is a risk that a derailment could occur on some curves.

What risk mitigation measures would you use to reduce this risk to an acceptable level?

Your conclusion may indicate a need for "Active Management" ongoing.

Case Study Example- 6

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Under the hierarchy of risk management the best solution would be to remove the hazards. That is, remove the small radius curves by cutting through the forest to make larger radius curves.

The Railway Owner objects to this solution because the forest is important for the visitor experience.

Case Study Example- 6

The risk could be mitigated by introducing management measures.

The Railway Owner agrees to slower train speeds on small radius curves with signs and driver training to ensure the speeds are not exceeded.

The train timetable is extended to enable drivers to keep trains "on time"

Case Study Example- 6

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Your analysis also indicates that the clearance from the train carriages to the trees alongside the track is less than normal industry practice.

The risk is that a passenger could lean out from a carriage and hit a tree

What risk mitigation measures would you use to reduce this risk to an acceptable level?

Your conclusion may indicate a need for "Active Management" ongoing.

Case Study Example- 6

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Under the hierarchy of risk management the best solution would be to remove the hazards. That is, remove the trees from the side of the rail track.

The Railway Owner objects to this solution because the forest is important for the visitor experience.

Case Study Example- 6

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The residual risk must therefore be mitigated by introducing management measures.

The Railway Owner agrees to:

- **Modify carriage windows to minimise the opportunity for passengers to lean out.**

- **Place signs in the carriages warning passengers not to lean out.**

- **Instruct drivers to announce warnings at high risk areas along the track.**

Case Study Examples

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Risk Identification & Analysis for Engineering Projects

CONCLUSION