PRIORITIZATION OF REPAIR/REPLACEMENT OF AGED GRAY CAST IRON PIPELINES BASED ON RISK ASSESSMENT

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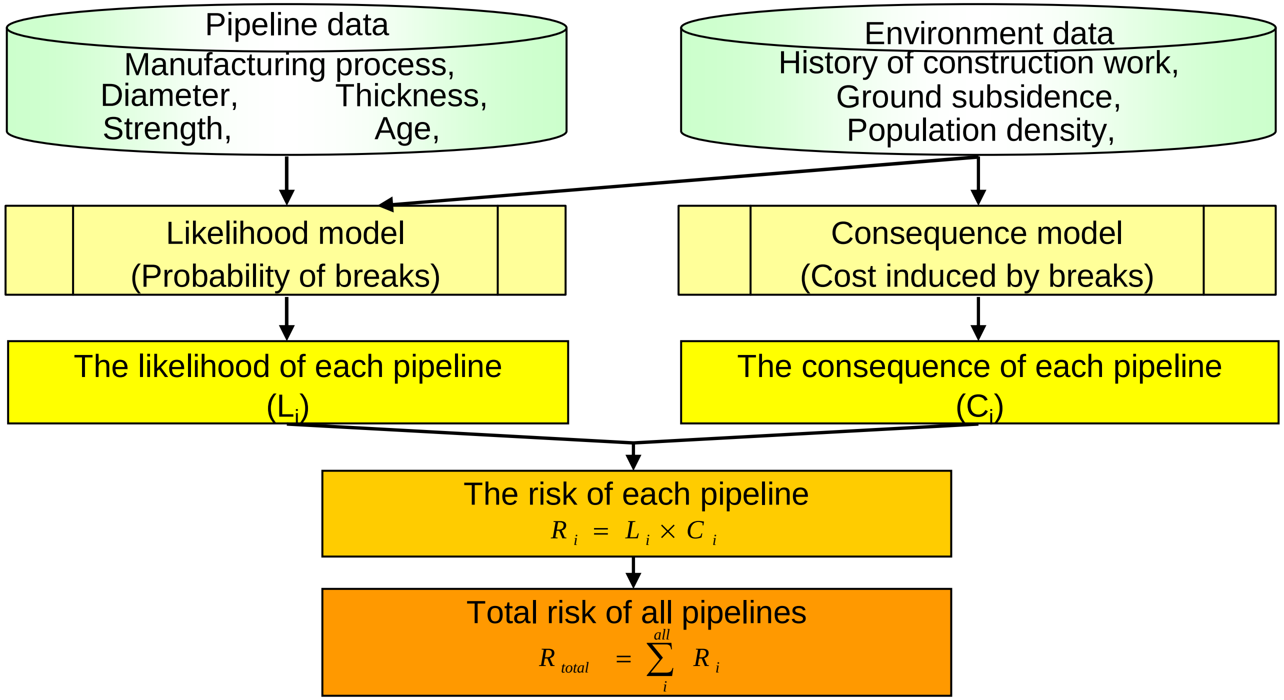
Objective

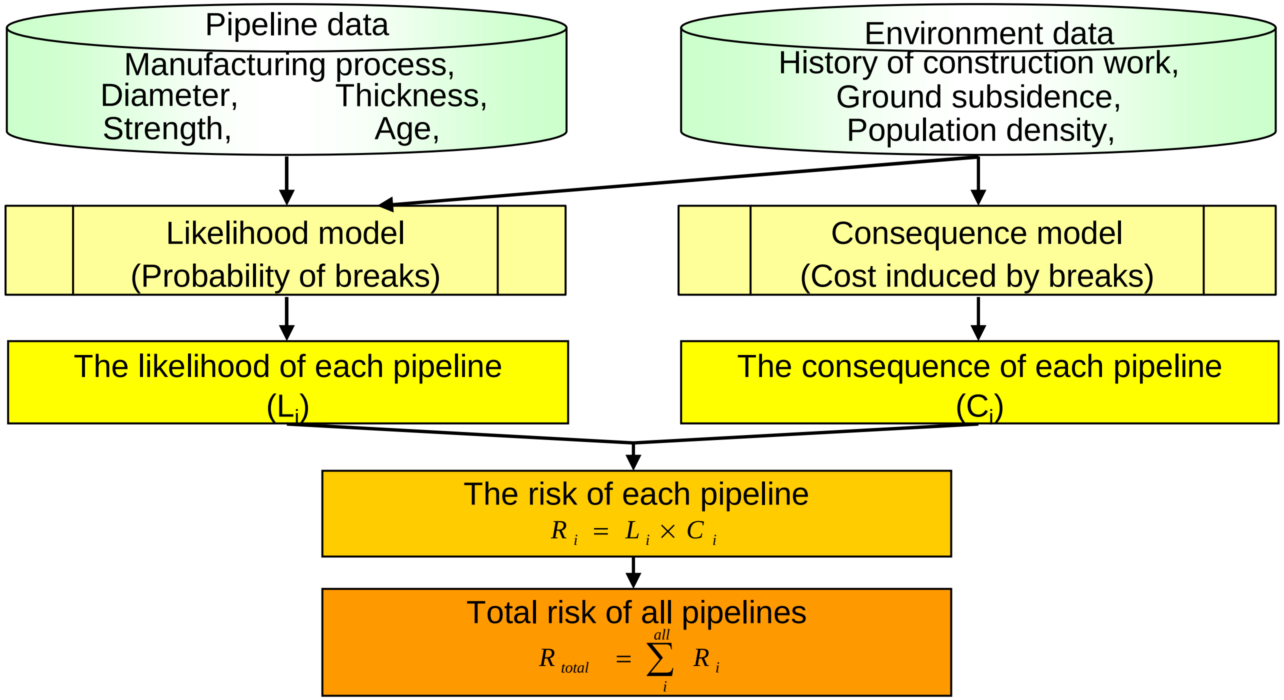
- Gray cast iron (GCI) is one of the old pipe materials for low pressure pipelines.
- Due to its small elongation and high susceptibility to corrosion, the aged GCI pipelines often break and cause gas leakage.
- Because the amount of leaking gas due to a break in a GCI pipe is relatively high, the gas could flow into a building through the ground, and possibly cause an accident.
- To efficiently reduce the risk induced by the breaks in the GCI pipelines and improve their safety level, a method for assessing the risk of each GCI pipeline using a geographic information system (GIS) was developed.

Risk assessment flow



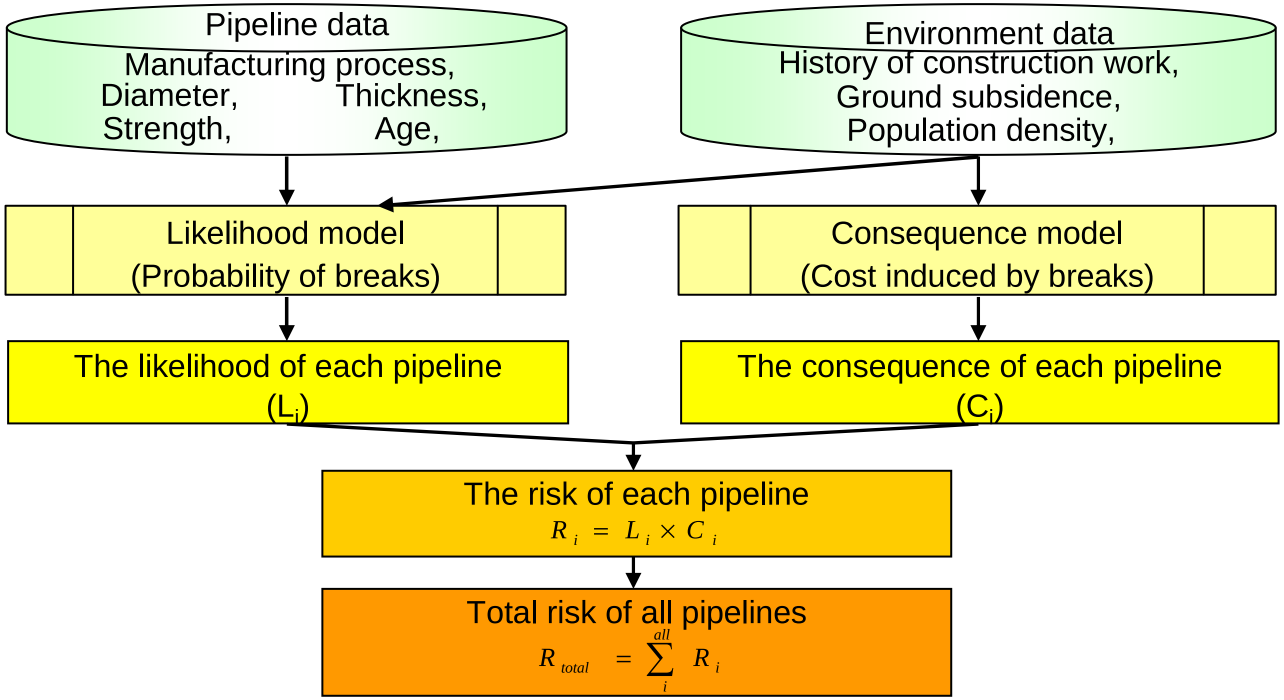
- A "likelihood model" provides the likelihood of a break using the detailed data of the pipeline and the environment for each GCI pipeline.

Risk assessment flow



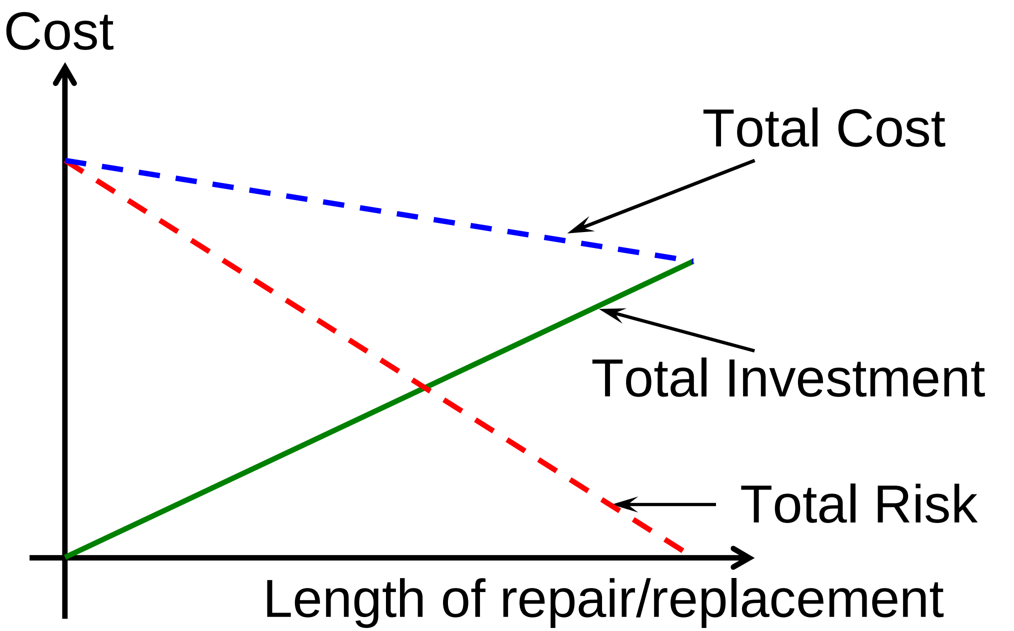
- A "consequence model" provides the consequence of an accident for each GCI pipeline using the detailed data of the environment.

Risk assessment flow



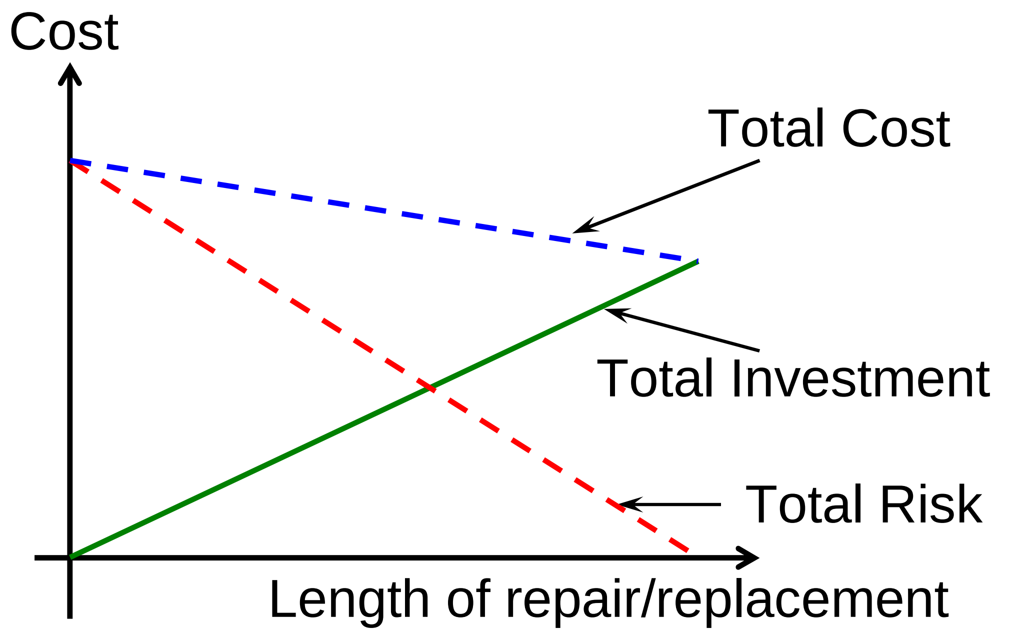
- The risk of each GCI pipeline is calculated by the likelihood multiplied by the consequence.

Relationship of total risk, total investment and total cost



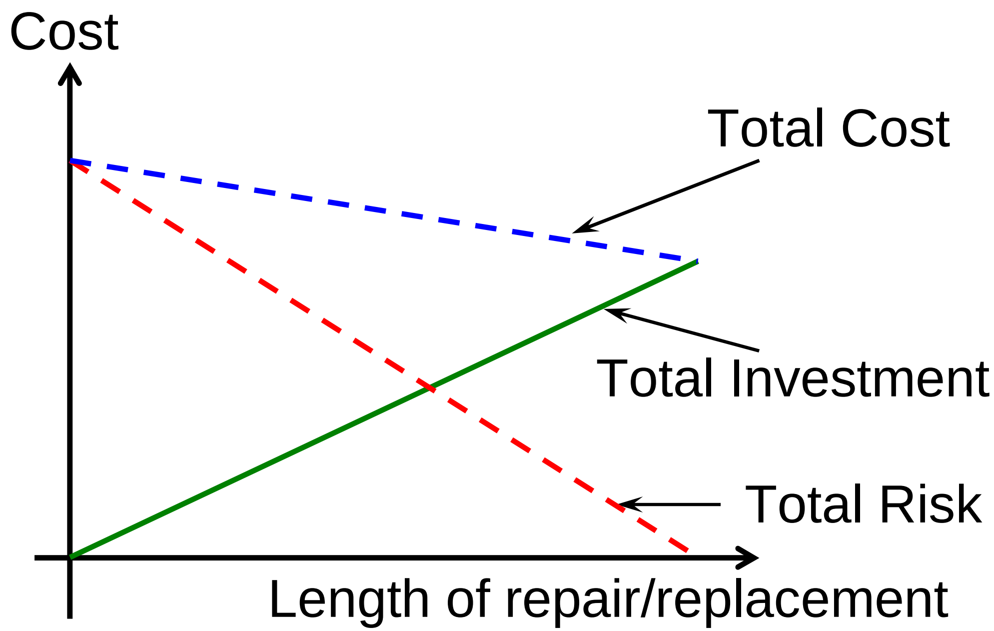
- The total risk is the sum of the risk of all the GCI pipelines. The total investment is the sum of the costs for the repair or replacement of the GCI pipelines.

Relationship of total risk, total investment and total cost



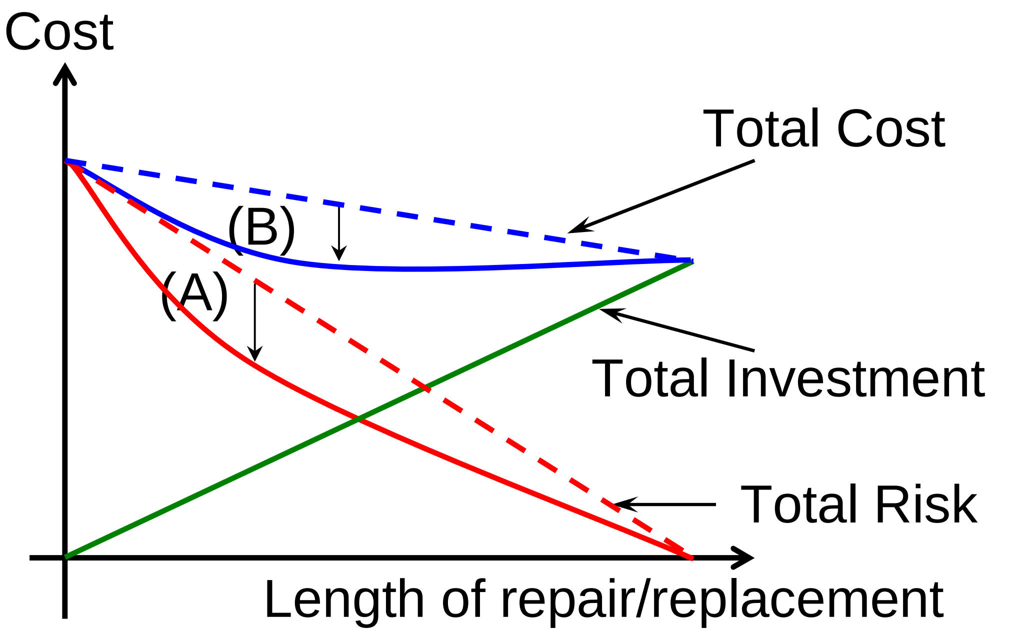
- As the length of the repair or replacement increases, the total investment linearly increases, and the total risk decreases as shown by the dashed red line.

Relationship of total risk, total investment and total cost



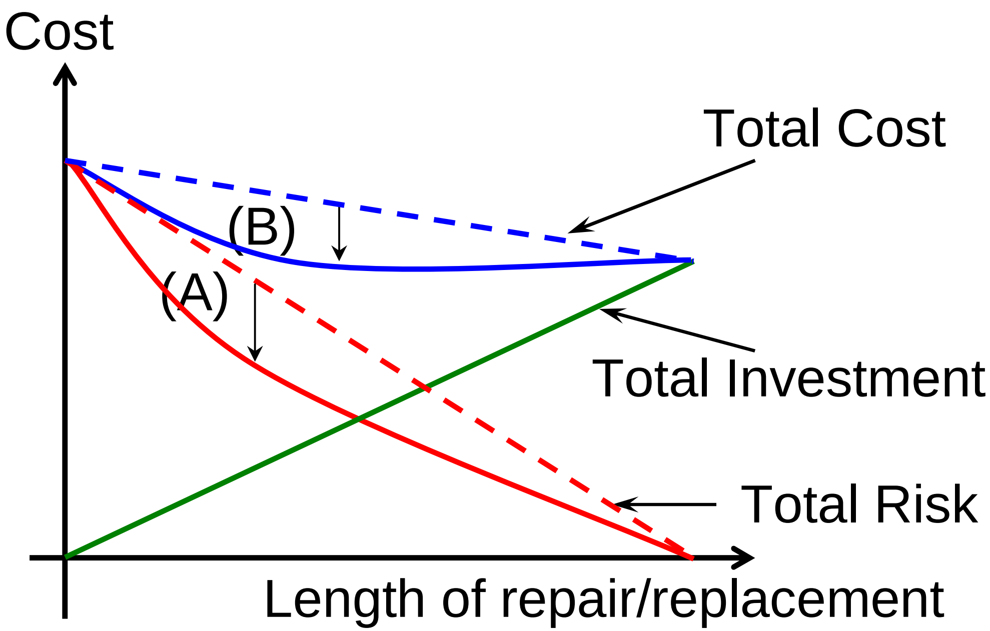
- When the risk of each GCI pipeline is calculated, the GCI pipelines having a higher risk can be repaired or replaced prior to those having a lower risk.

Relationship of total risk, total investment and total cost



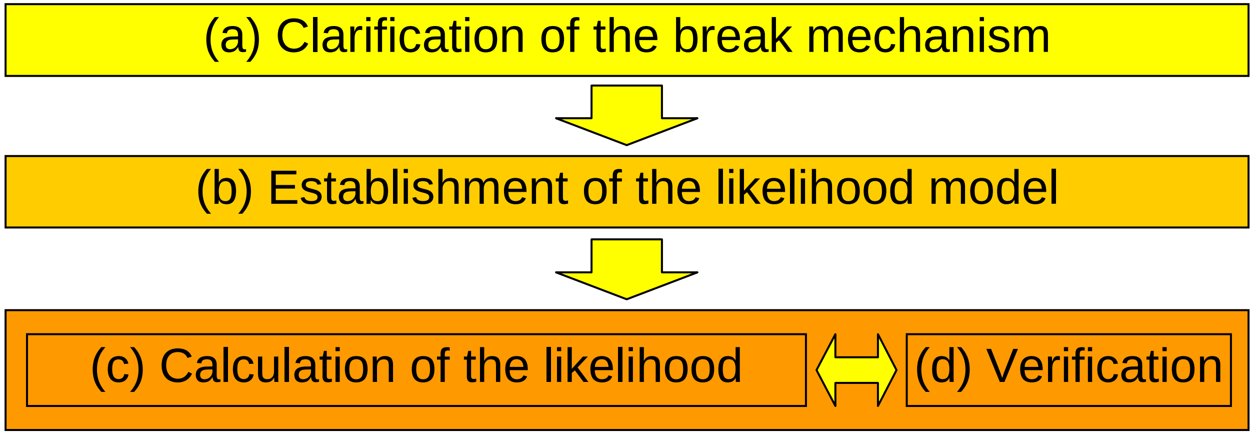
- The total risk rapidly decreases in the early stage of the repair or replacement, and the total risk curve changes as shown by the solid line (A).

Relationship of total risk, total investment and total cost



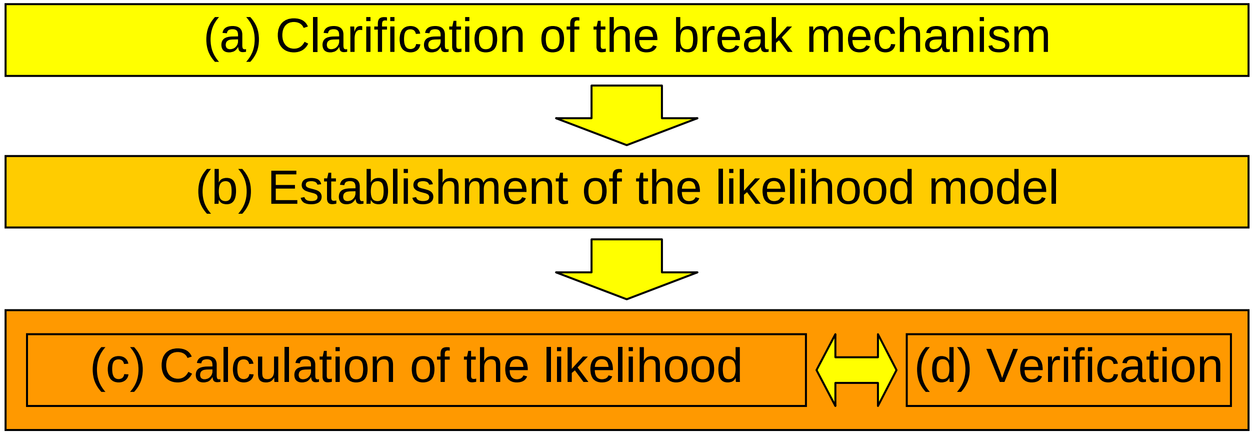
- As a result, the total cost can be reduced as shown by the solid line (B).

The procedure for the likelihood assessment



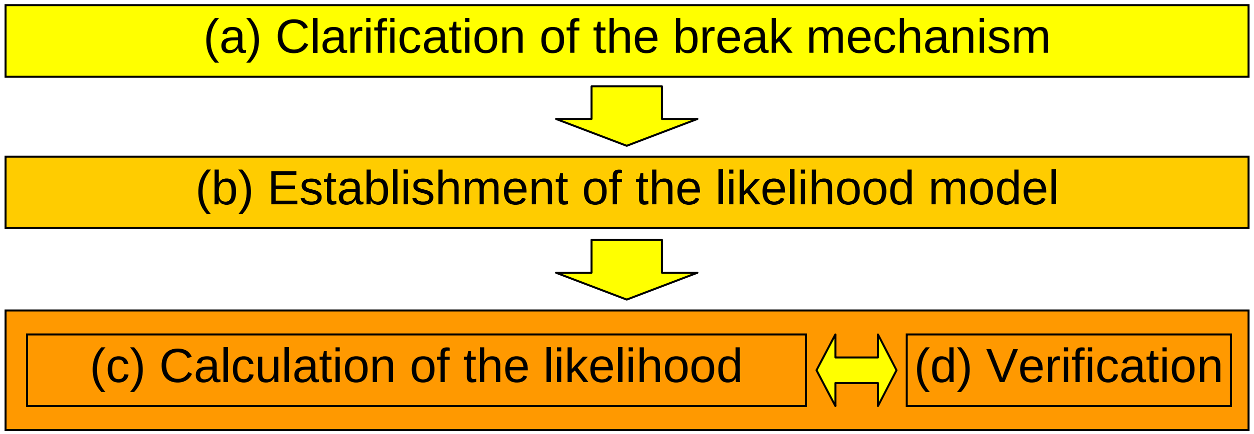
- (a) Survey at the sites where the GCI pipes have broken and a laboratory investigation clarified the break mechanism of the GCI pipes.

The procedure for the likelihood assessment



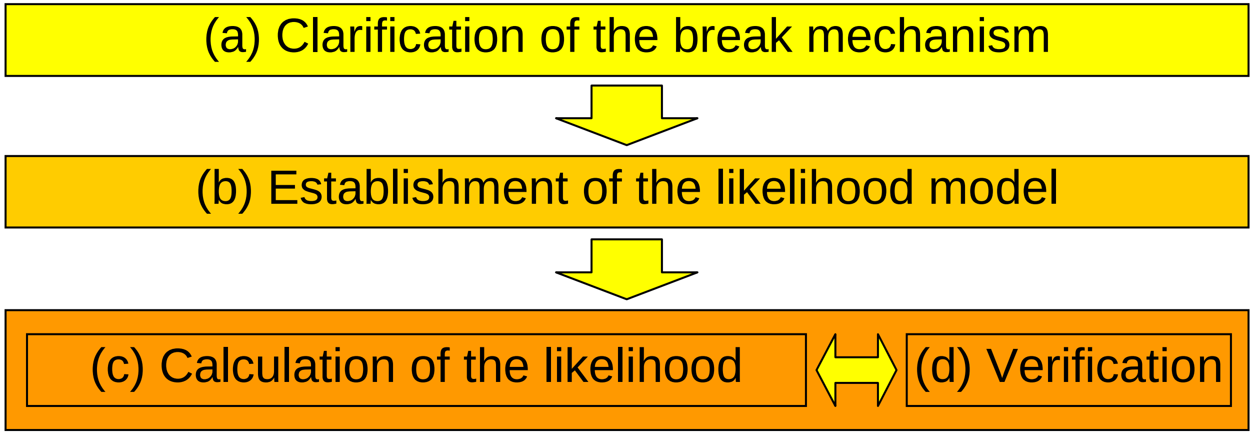
- (b) The likelihood model was then established based on the break mechanism.

The procedure for the likelihood assessment



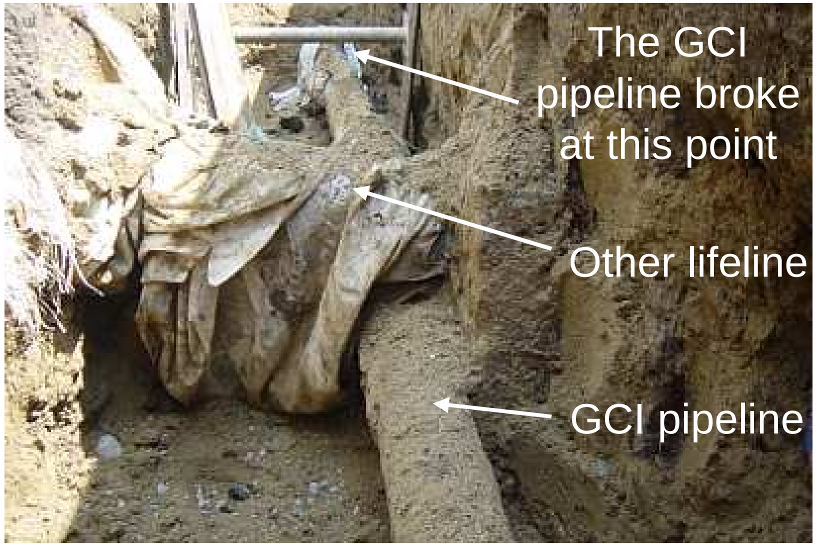
- (c) The established model calculates the likelihood of a break in each GCI pipeline.

The procedure for the likelihood assessment



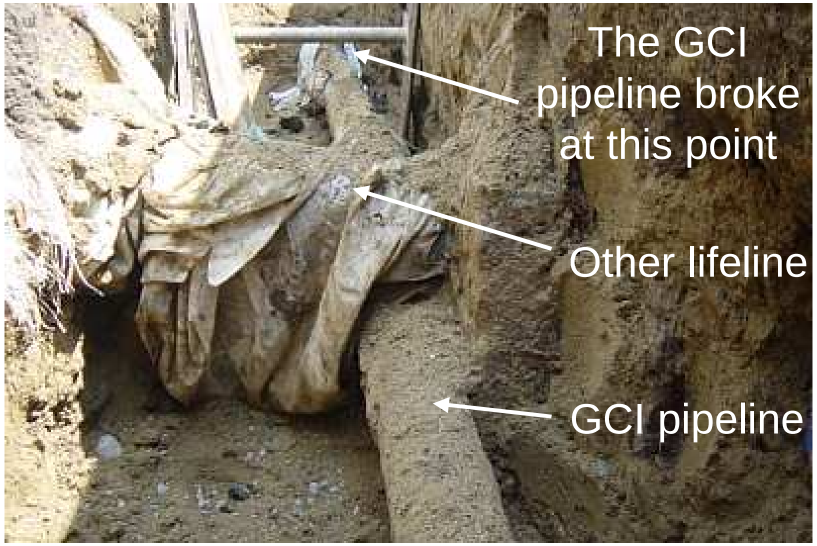
- (d) To verify the likelihood model, the calculated likelihood was compared with the data from breaks in the past.

Site survey & laboratory investigation



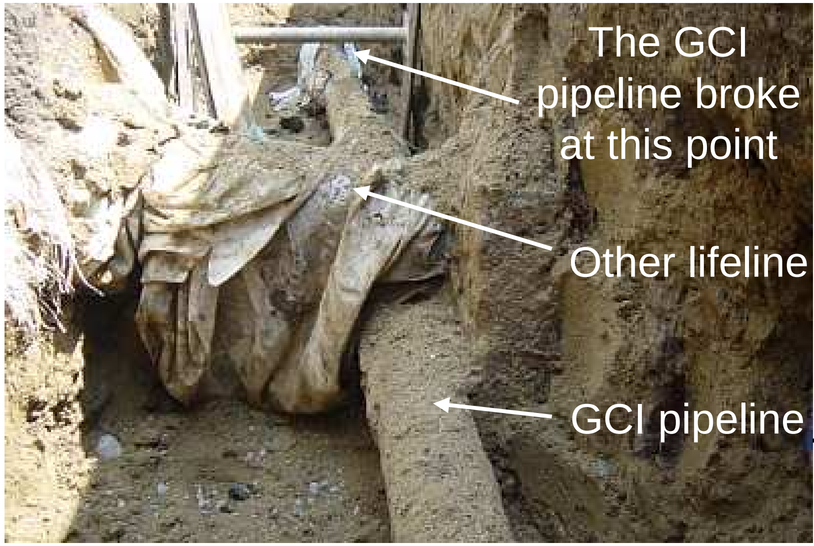
- Figure shows a typical site survey.

Site survey & laboratory investigation



- Figure shows a bending test in our laboratory.

Site survey & laboratory investigation



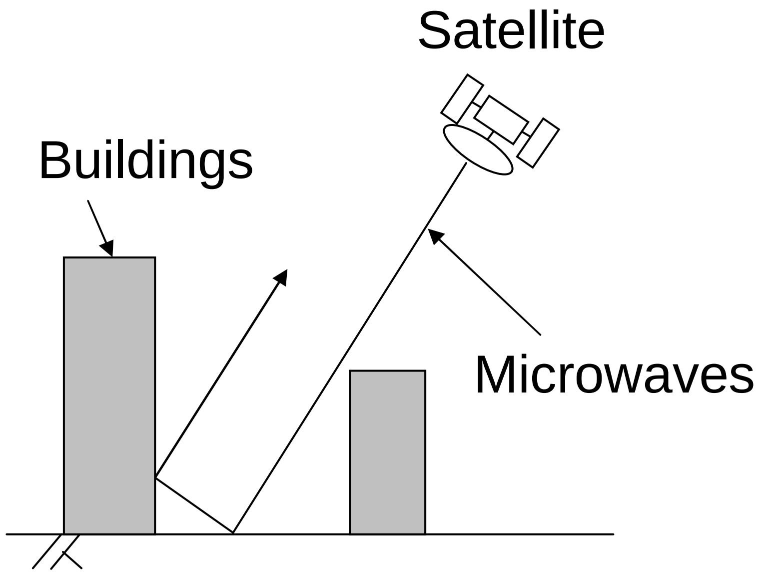
FEA

- Finite element (FE) analyses were then conducted to evaluate the stress based on the results of the site surveys and the laboratory investigations.

Break mechanism

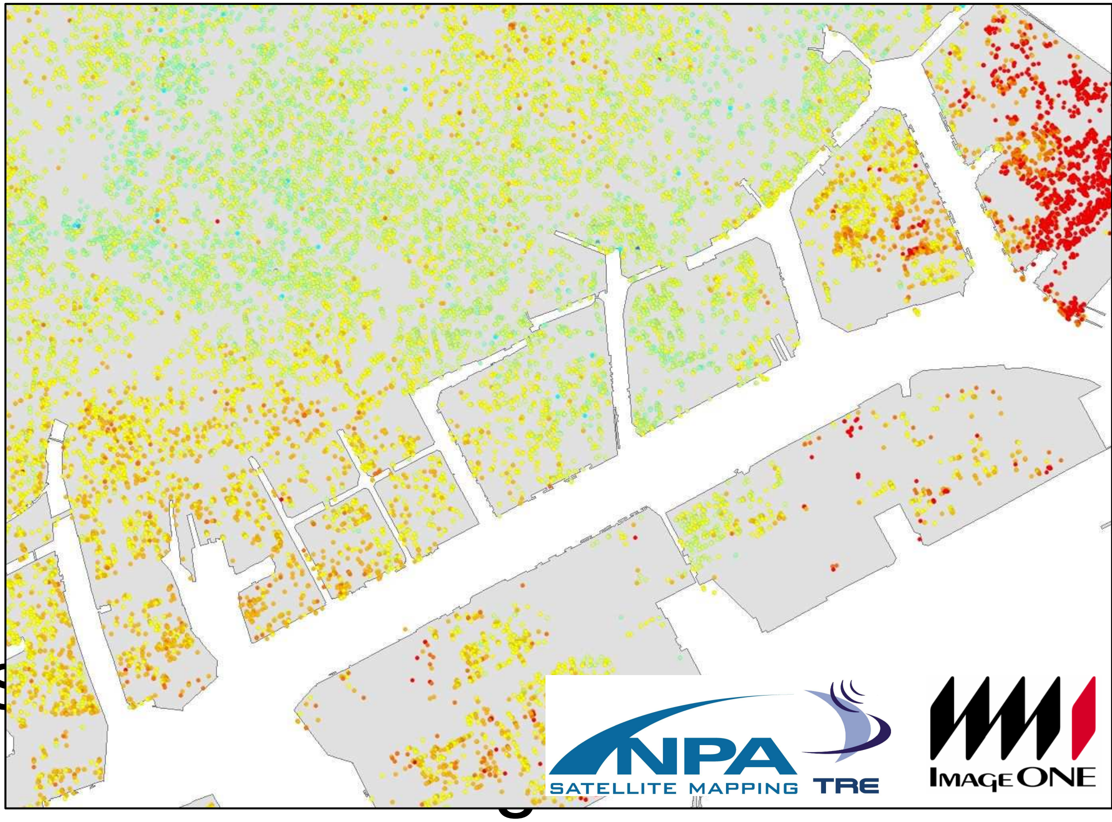
- Our study showed that the ground subsidence is one of the most important factors affecting the break mechanism. Based on the result, the ground subsidence was obtained for the likelihood calculation using PSInSAR technology.

PSInSAR Technology



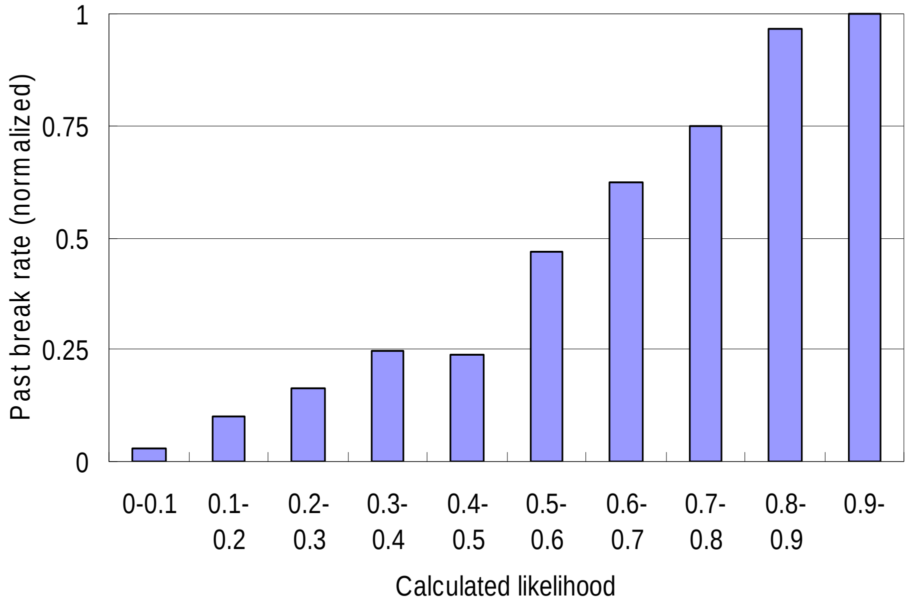
- Figure shows the evaluation of the ground subsidence using the PSInSAR technology.

PSInSAR Technology



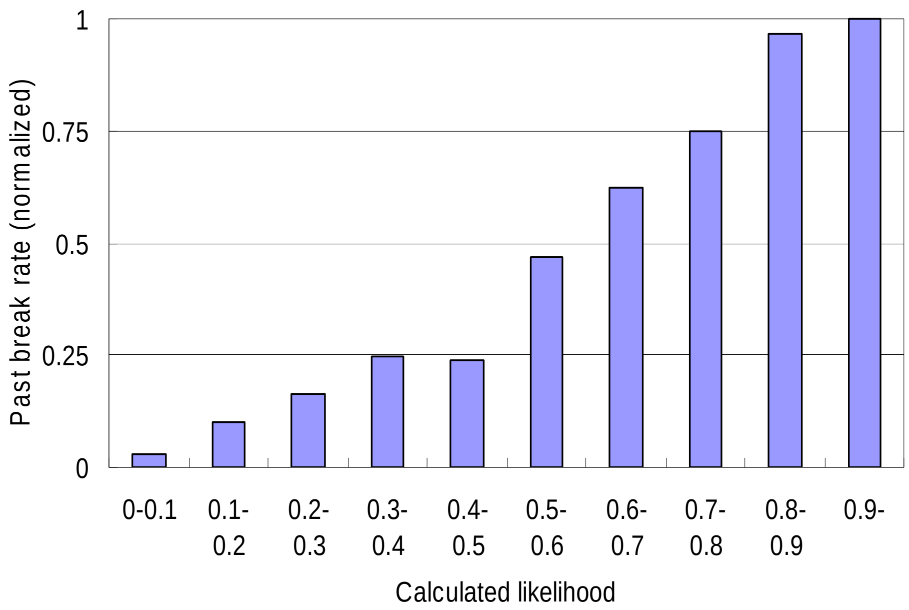
- The s ce can be m g om satellites.

Likelihood calculation



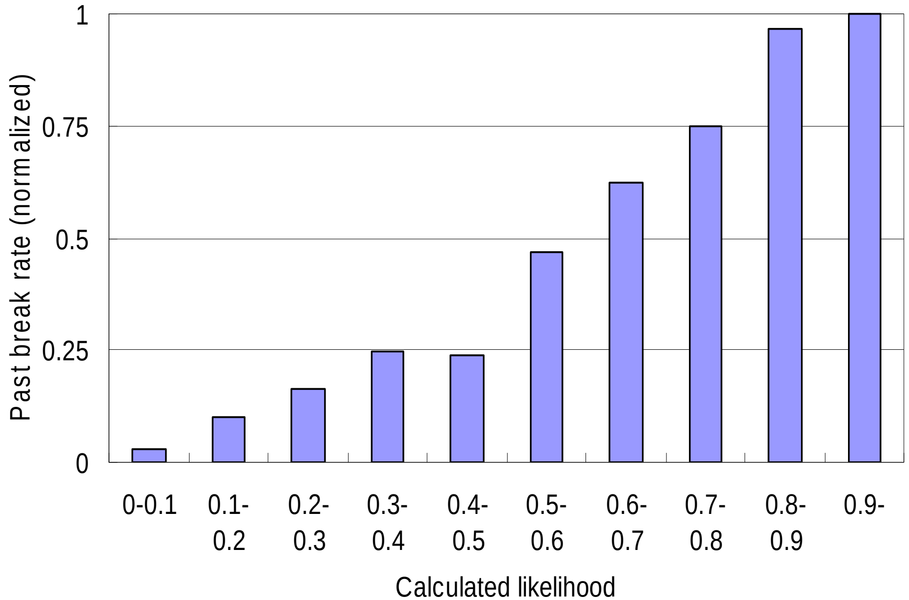
- Figure shows the relationship between the calculated likelihood and the break rate per unit length of the GCI pipelines in the past.

Likelihood calculation



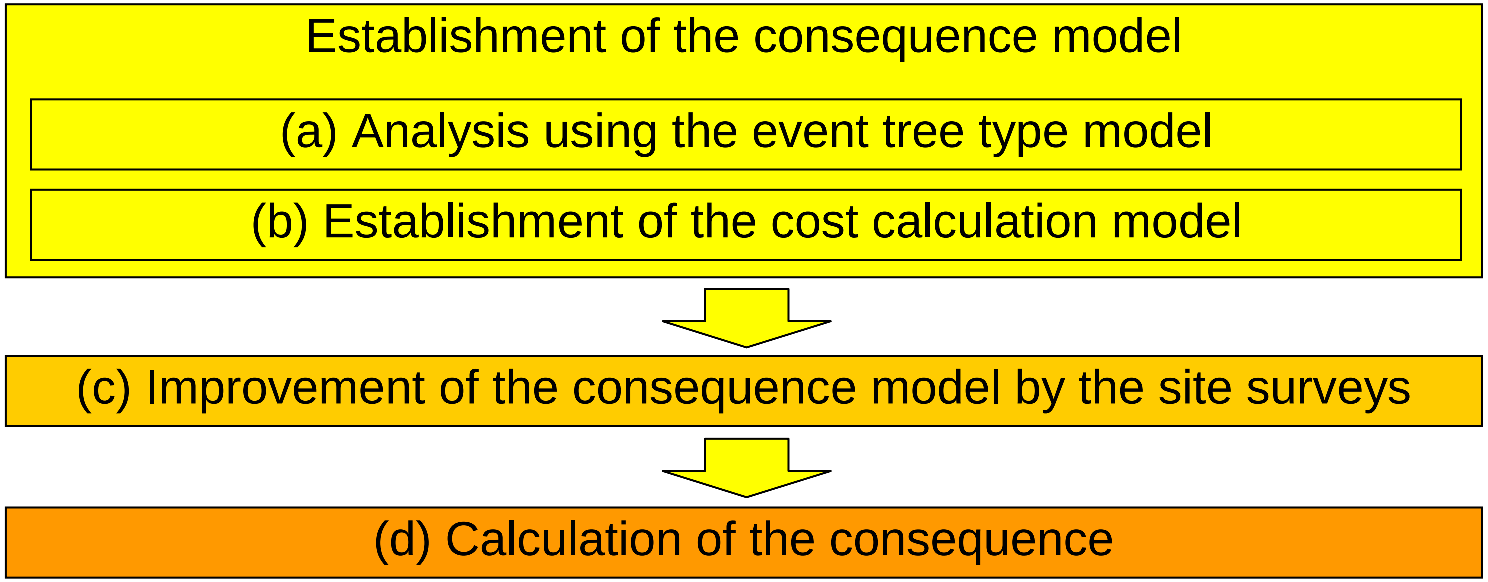
- This figure shows that there exists a good correlation between the calculated likelihood and the past break rate.

Likelihood calculation



- The result indicates that the present likelihood model is applicable for predicting breaks in the GCI pipelines.

The procedure for the consequence assessment



- A consequence model was initially established.

The procedure for the consequence assessment

Establishment of the consequence model

(a) Analysis using the event tree type model

(b) Establishment of the cost calculation model

↓

(c) Improvement of the consequence model by the site surveys

↓

(d) Calculation of the consequence

- The consequence model consists of (a) an event tree type model which can calculate the probability of accidents induced by the break of the GCI pipeline, and (b) a cost calculation model which can calculate costs incurred by the accidents.

The procedure for the consequence assessment

Establishment of the consequence model

(a) Analysis using the event tree type model

(b) Establishment of the cost calculation model

↓

(c) Improvement of the consequence model by the site surveys

↓

(d) Calculation of the consequence

- The event tree type model assumes the scenarios of the accidents induced by the breaks in the GCI pipelines. In this study, the event tree type model calculated the probability of each accident using the results of past accidents.

The procedure for the consequence assessment

Establishment of the consequence model

- (a) Analysis using the event tree type model
- (b) Establishment of the cost calculation model

↓

(c) Improvement of the consequence model by the site surveys

↓

(d) Calculation of the consequence

- The cost calculation model provides not only the direct costs, such as the repair or replacement costs, but also indirect costs, such as the loss in revenue due to a reduced gas demand and change in the regulatory policy.

The procedure for the consequence assessment

Establishment of the consequence model

(a) Analysis using the event tree type model

(b) Establishment of the cost calculation model

↓

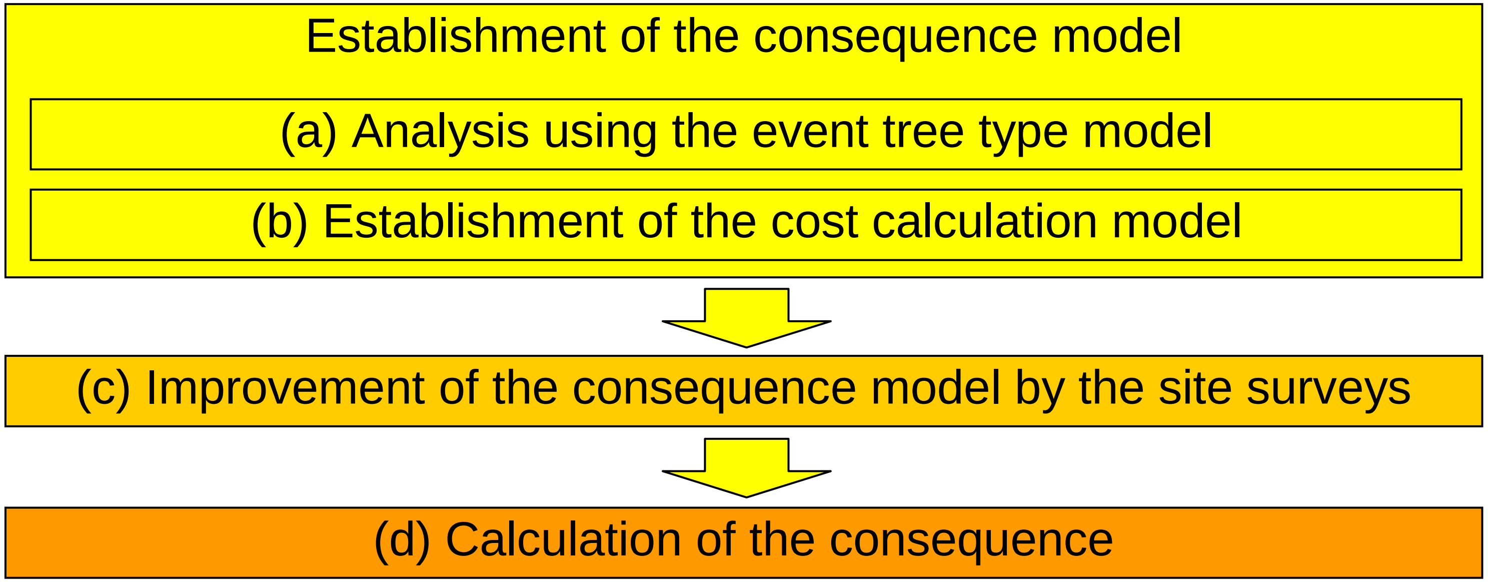
(c) Improvement of the consequence model by the site surveys

↓

(d) Calculation of the consequence

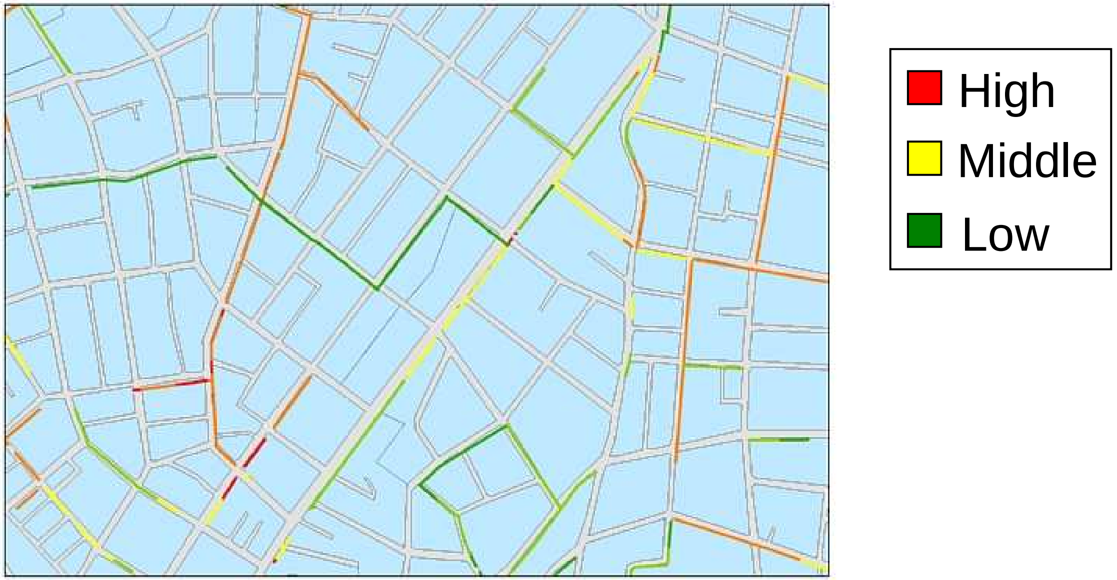
- After the establishment of the consequence model, (c) the site surveys improved the consequence model.

The procedure for the consequence assessment



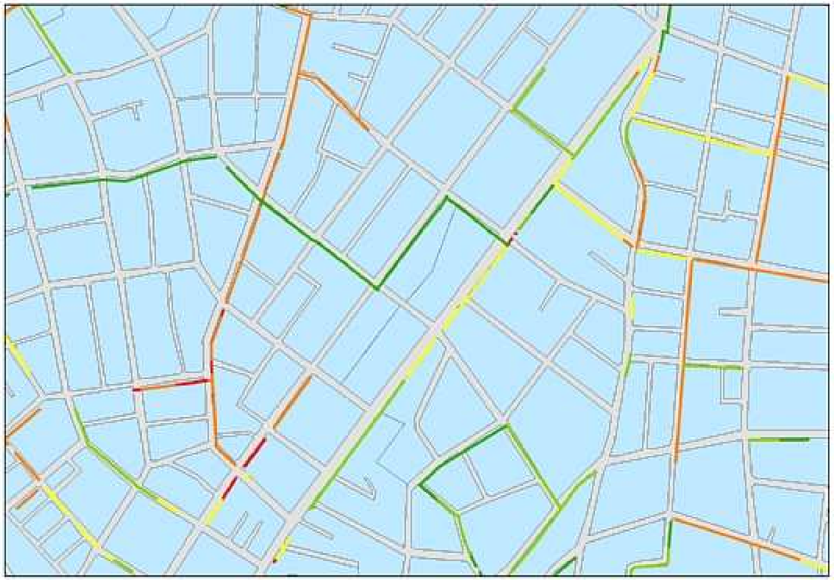
- (d) The consequence of a break for each pipeline was then calculated using the improved consequence model.

Risk calculation



- The risk of each GCI pipeline is the calculated likelihood multiplied by the calculated consequence.

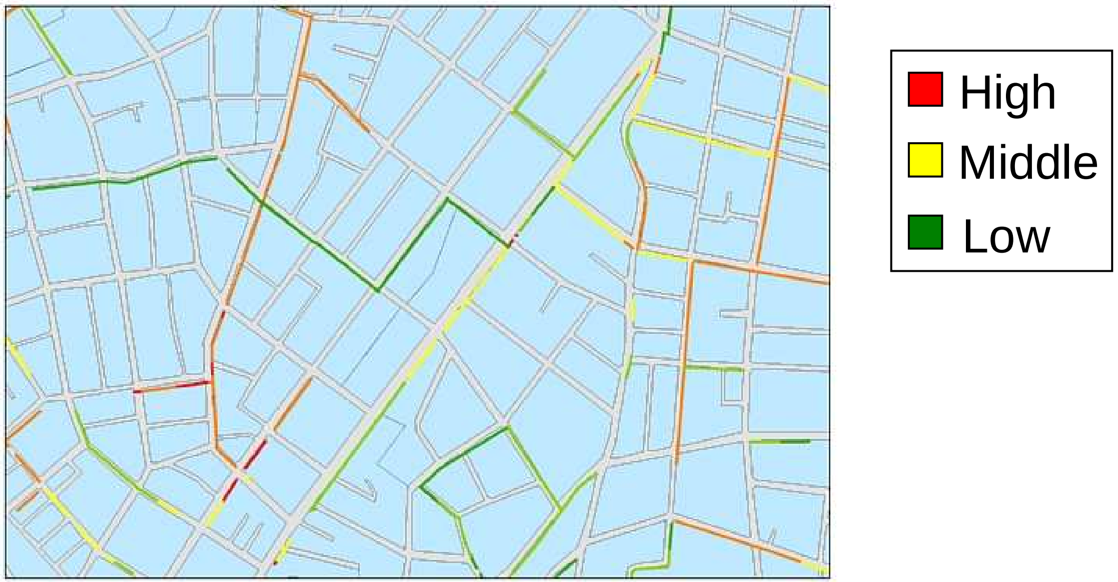
Risk calculation



High
Middle
Low

- Figure shows a typical result of the risk calculation for the GCI pipelines. In this figure, the red lines denote a higher risk, the yellow ones denote an middle risk, and the green ones denote a lower risk.

Risk calculation



- The risk calculation enables us to prioritize the repair or replacement of the GCI pipelines; the GCI pipelines having a higher risk can be repaired or replaced prior to those having a lower risk.

Conclusion

- The site surveys and the laboratory investigations clarified the break mechanism of the GCI pipes.
- The likelihood model was established based on the break mechanism of the GCI pipes.
- As a result of the likelihood calculation, a good correlation was observed between the calculated likelihood and the past break rate of the GCI pipelines.
- The improved consequence model calculated the consequence induced by the break for each GCI pipeline using the environmental data.
- The risk calculation enables us to prioritize the repair or replacement of the GCI pipelines.

Thank you for your kind attention.