ICUD-0578 Uncertainty based decision making for water quality failures caused by sewer overflows

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Summary

Utility companies face the risk of paying penalties if they fail to comply with regulatory/policy guidelines. Urban drainage models can be used to take actions to manage this risk. Hence, any uncertainty in these models can have a significant effect on the decision making process. This study proposes an uncertainty based decision making framework for water quality failure. A probability of failure is obtained for each decision alternative. Risk of a decision alternative is expressed as expected cost of failure. Minimising the sum of actual cost and risk, gives the optimal decision alternative however, the uncertainty in estimation of risk results in a range of optimal alternatives.

Keywords

decision making under model uncertainty, water quality failure, combined sewer overflows, uncertainty propagation

Introduction

Urban drainage models are often used to take decisions to manage spills from Combined Sewer Overflows (CSO), hence any uncertainty in these models can have a significant effect on the outcome of the decision making process. Uncertainty in model outputs can have various sources (e.g. Deletic et al., 2012), and these different uncertainties propagate through to the model outputs (Swayne et al., 2010). This makes the objective decision making difficult unless the decision maker understands this uncertainty. As far the authors are aware, there is a significant gap in the application of uncertainty based decision making in water quality failure analysis, and a new decision making framework taking uncertainty into account is required.

Methods and Materials

Conceptual decision making framework including uncertainty

Fig. 1 summarises the novel framework concept. In order to evaluate decision alternatives to manage risk from water quality failure caused by CSO spills appropriate assessment criteria needs to be defined. Based on the assessment criteria and the available decision alternatives, a suitable model output can be considered such as pollutant concentration in the CSO discharge. Probabilistic representation of uncertainty around this model output can be obtained by performing uncertainty analysis

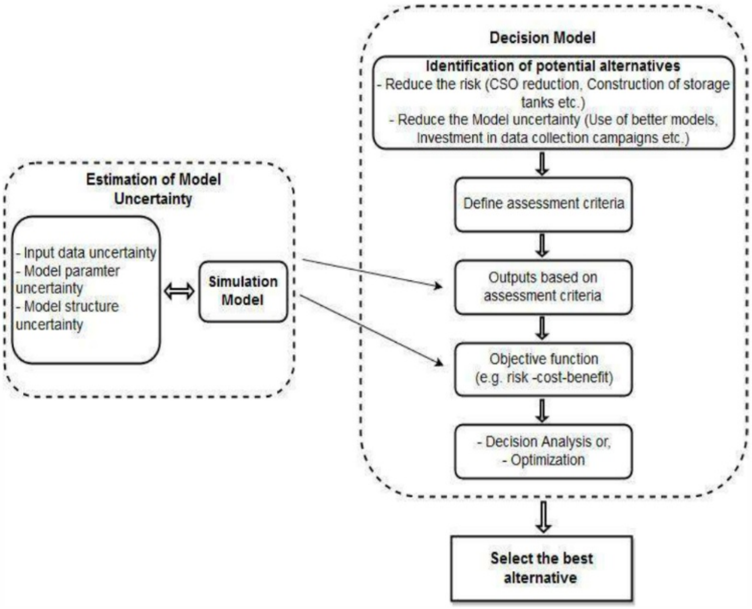

Fig. 1. *Step-wise action plan for uncertainty based decision making. Single arrows point to the next action while the double arrow indicates a feedback relationship between two processes.*

Risk around each decision alternative can be expressed as expected cost associated with failure (Freeze et. al., 1990):

$$R_f = P_f\, C_f\, \gamma(C_f) \qquad (1)$$

Where, P_f = probability of failure; C_f = cost of failure; and $\gamma(C_f)$ = normalized utility function. If C_i is the actual cost of the decision alternative *i* and R_{fi} is the risk of failure calculated from eq. (1), then we can determine optimal decision alternative by minimising the 'Total cost' which is equal to the sum of the actual cost C_i and the probabilistic cost R_{fi}. However there could be uncertainty around C_f due to multiple failure states and difference in the cost assessment techniques. Similarly, depending on the risk preference of the decision makers $\gamma(C_f)$ could be uncertain as well, thereby causing uncertainty in the 'Total cost' which can be further represented as multiple curves. Minima of these multiple curves give a range of optimal decision alternatives (Fig. 2).

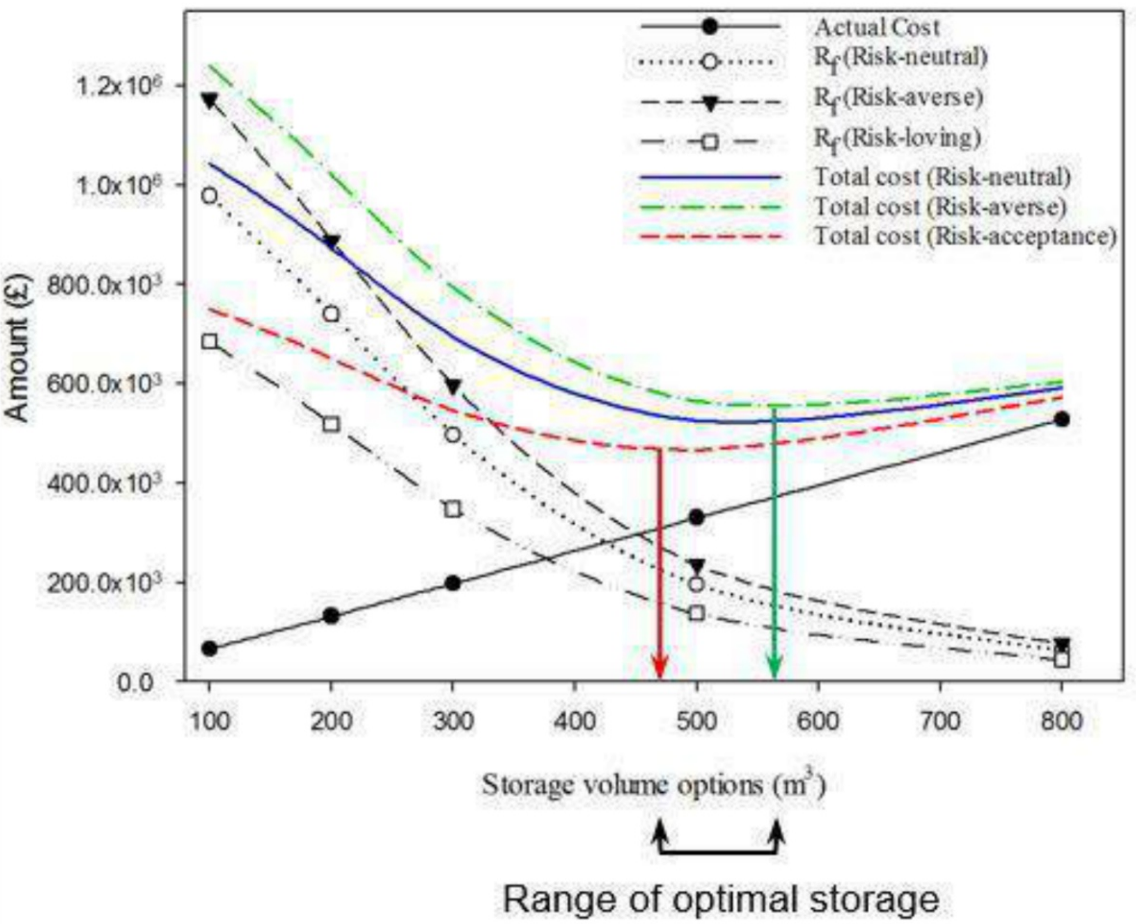

Fig. 2. *Risk vs Actual cost trade off to select optimal decision alternative.*

Results and Discussion

Illustration of conceptual framework

A calibrated InfoWorks CS sewer network model has been used to simulate CSO spill volumes in the UK. Construction of a storage tank is selected as a prevention measure to avoid a penalty set at a fixed sum if the CSO spill volume threshold is exceeded. Risk R_{fi} for each decision alternative is calculated using eq. (1). Uncertainty analysis provided a probability distribution of CSO spill volume for each storage volume option. P_{fi} is set as the probability that the CSO spill volume threshold will be exceeded whereas the fixed penalty is used as C_f. Cost of construction C_i for the storage tank is assumed to be increasing linearly with the volume of the tank. Three values of $\gamma(C_f)$ less than, equal to and greater than 1, have been used to reflect risk-acceptance, risk-neutral and risk-averse behaviour of decision makers respectively. Fig. 2 displays the trade-off between Risk R_{fi} and cost of construction for storage tank C_i and the resulting curves of 'Total cost'. The minima of these curves give a range of optimal storage options. Alternatively, objective functions can be defined to express these trade-offs followed by a suitable decision analysis to select optimal decision alternatives.

Conclusions

The current work focuses on the risk-cost trade off with regard to CSO spills complying with water quality regulations in the UK under the conceptual decision making framework. Among decision alternatives are building additional storage volumes. The results of the current study will be included in the conference paper.

Acknowledgement

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