Article, Published Version

Simm, Jonathan; Meadowcroft, Ian

Performance of Flood Risk Management Measures - COMRISK Subproject 4

Die Küste

Zur Verfügung gestellt in Kooperation mit/Provided in Cooperation with:
Kuratorium für Forschung im Küsteningenieurwesen (KFKI)

Die Küste, 70 (2005), COMRISK, 47-56

Performance of Flood Risk Management Measures COMRISK Subproject 4

JONATHAN SIMM, IAN MEADOWCROFT

Summary

In managing the risk of flooding in the southern North Sea Region, both physical defences (dikes and sea walls) and non-structural measures play a significant role, but their performance must be clearly understood, monitored and managed.

This paper presents the results of an comparative study of approaches to performance management in the countries bordering the southern North Sea, with a particular focus on performance indicators.

The paper introduces concepts of performance and performance evaluation in the context of flood management, building on a source- pathway-receptor conceptualisation. Flood risk assessments are promoted as providing an overall measure of the performance of the system of flood risk management measures.

In all countries performance of linear defences remains a key feature. In managing defence assets the concepts of defence fragility and a geographical, geometrical and structural hierarchy of performance assessment are found to be helpful. Reliability analysis is seen as a way forward to achieve a consistent estimate of defence failure probability.

The paper concludes that more work is required to develop better and more consistent performance indicators for NSR countries, distinguishing between output performance measures for organisations and outcome performance measures related to the actual reduction of flood risk.

Zusammenfassung

Beim Management der Risiken von Sturmfluten im südlichen Nordseeraum spielen sowohl technische Maßnahmen (Deiche) wie auch nicht-technische Maßnahmen eine signifikante Rolle. Ihre jeweiligen Leistungen sollten jedoch eindeutig verstanden, überwacht und gehandhabt werden.

In diesem Beitrag werden die Resultate einer vergleichenden Untersuchung über die jeweiligen Ansätze zum Umgang mit Leistung in den Nordsee-Anrainerstaaten mit einem Fokus auf die benutzten Leistungsindikatoren dargestellt.

Der Beitrag stellt Leistungskonzepte und deren Bewertung im Kontext des Flutmanagements vor, aufbauend auf dem sog. „Source-Pathway-Receptor-Prinzip". Flutrisikoanalysen werden befürwortet als allgemeine Grundlage für die Leistungsbewertung von Maßnahmen des Flutrisikomanagements.

In allen Partnerländern ist die Leistung von linienhaften Schutzmaßnahmen Hauptaugenmerk. Die Untersuchung hat gezeigt, dass in der Pflege und Unterhaltung der Schutzmaßnahmen der Unterhaltungszustand sowie eine geographische, geometrische und strukturelle Hierarchie der Leistungsermittlung hilfreich sind. Sicherheitsanalysen stellen eine Verbesserung dar um eine konsistente Einschätzung der Versagenswahrscheinlichkeit von Schutzwerke zu ermitteln.

Es wird gefolgert, dass weitere Untersuchungen erforderlich sind um zu besseren und konsistenteren Leistungsindikatoren für die Nordsee-Anrainerstaaten zu gelangen. Dabei soll unterschieden werden zwischen Leistungsindikatoren für die Verwaltung und solchen für die tatsächliche Reduzierung der Risiken.

Keywords

Coast, risk management, flood defence, performance indicators

Contents

1. Introduction: assessing performance of risk management measures as part of COMRISK

The risk of flooding in North Sea coastal lowlands may be managed by physical defences (eg embankments, sea walls, dunes), flood warning and response, and non-structural measures such as control of development in flood prone areas. The performance of these measures under a range of possible conditions including extreme storms needs to be understood in order to assess and manage risk. This report on the performance of risk management measures comprises the outcome of sub-project 4 of the COMRISK study (COMmon strategies to reduce the RISK of flooding in coastal lowlands).

An earlier study by the North Sea Coastal Managers Group showed that the quality and type of performance indicators varies considerably between member states. A more consistent approach to establishing the performance of flood risk management measures will improve flood risk management in coastal lowlands. Sub-project 4 (SP4) within COMRISK aims to support the development of best practice in the North Sea Region and contribute to improved flood risk assessment and management.

2. Aims and outputs of COMRISK sub-project 4

The aims of COMRISK Subproject 4 (SP4) – "Performance of risk management measures" were:

- to create an inventory of current performance indicators in the NSR including a technical review based on case studies
- to evaluate the ability of different approaches to answer the need of risk managers and planners
- to recommend international best practice and to improve cross-border dissemination and application of methods.

The anticipated outputs of SP4 were to include:

- an inventory of performance indicators used in the NSR, including data requirements, information content and usage for decision-making
- a meta-database of performance indicators
- to produce a comparative review of the set of performance indicators to establish common ground, and to identify gaps among the participating countries.

3. Flood defence performance

Flooding from rivers, estuaries and the sea poses a threat to many millions of the citizens of Europe and remains the most widely distributed natural hazard in Europe leading to significant economic and social impacts. For example, the 1953 North Sea floods caused about 2500 deaths across the UK, Netherlands, Belgium and Germany and concentrations of fatalities in river floods are associated with flash floods, such as Vaison-la-Romaine (1992), and the mudflows at Sarno (1997). Over half of the population of the Netherlands lives below mean sea level; in the UK about 10 % of the population lives in areas of fluvial, tidal or coastal flood risk. The national scale of economic importance of flood and coastal defence activities has been documented for England and Wales (BURGESS et al, 2000) as preventing annual average damages of approximately 4 Billion, with the value of assets at risk of river and coastal flooding being about 300 Billion. In the Netherlands estimates of the possible damage due to flooding vary from 300 to 800 Billion. These and other floods in the past decade in many parts of Europe have focussed attention nationally and within the EU on the need to understand and manage flood risks. The potential for flood damage is also increasing from social and economic development bringing pressures on land use.

In the UK, the autumn of 2000 featured a number of extreme weather events over 25 days that were the wettest for 270 years. 10,000 properties were flooded costing the insurance industry over £1 billion. Various types of flooding occurred including fluvial, pluvial and coastal. The UK Government, the Environment Agency, stakeholders and the public all had to "heed the wake up call" to the risks and consequences of extreme flooding events. An analysis of the causes of the property flooding in 2000 showed that the source risks were split between four causes; overtopping of or breaching of river defences, lack of flood protection on rivers, exceedence of capacity in streams and ditches, and inadequate drainage.

The performance of local flood defence measures also came under closer scrutiny and interest rose dramatically in temporary protection systems and barriers and available measures to protect domestic property.

4. Definition of performance and performance evaluation

A useful definition of 'performance' is *'The creation or achievement of something that can be valued against some stated aim or objective.'*

Evaluating performance is important so that:

- we can report on achievement
- we can learn from experience
- we can identify problems
- better links can be formed between the observed state and what we're trying to achieve
- we can focus on what's important - outcomes
- we can review the past and manage the future

In the case of flood and coastal erosion management, the objective is to reduce risk to the developed and natural environment. An essential aspect of the risk management process is ongoing monitoring of flood and coastal erosion risks. Monitoring takes place on a range of scales from local site-specific measurements to data that is assembled on a national basis by NSR countries. Performance Evaluation will then be able to contribute to ongoing risk monitoring by providing a periodic insight into the efficiency of investment in risk management actions and a periodic opportunity for reflection on the information being provided by ongoing monitoring activities.

Performance evaluation is applicable to all areas of significant investment in flood and coastal risk management, including:

- capital works of flood and coastal defence (design, procurement and implementation)
- operation and maintenance of flood and coastal defences
- major monitoring programmes
- flood forecasting and warning
- informing the statutory planning process in order to control development in flood risk areas
- policy development
- plan and strategy development
- research and development.

A useful way of thinking of these activities is as a hierarchy of processes, from high level policy and strategic processes to more detailed implementation and operation processes. The underlying concept is that of a tiered approach to risk-based decision-making with an interactive suite of tool, models and data addressing the national, catchment / coastal cell, and local (i.e. asset/defence management and river reach) levels.

Flood defence assets can also be thought of in a hierarchical way, with three main levels in the hierarchy:

- the geography of the defence asset – where it is, specifically its alignment
- the geometry of the defence asset – its overall physical shape, which is particularly important in limiting overtopping and flooding
- the structure of the defence asset – its physical condition which is important in terms of ensuring integrity under loading and avoidance of breach or erosion.

The advantage of this type of approach is that it has the potential to capture all of the diverse activities that contribute to flood and coastal management in one coherent picture. The majority of Performance Evaluation will focus on site-specific, detailed processes, but the results can also be aggregated to provide higher level measures of performance. Aggregation should take account of the criticality of low-level processes to the performance of higher level processes.

Performance evaluation involves collecting evidence about how a given flood or coastal management process is performing when compared with its objectives. The high level aim is likely to be associated with a desire to reduce flood or coastal erosion risk. This overall aim is then reflected in increasingly detailed and more specific objectives for subsidiary flood and coastal erosion management processes. (For example, a dike in a particular locality might have objectives set for it related to resisting overtopping and avoiding breaching.)

Performance Evaluation therefore involves consideration of both objectives and behaviour. Performance Objectives are statements of one or more target levels of behaviour of the process under consideration. Information on how the process behaves relative to the stated objectives can be obtained from measurable characteristics known as Performance Indicators. In the case of flood risk management these will have to take account (see Fig. 1) of:

- sources of flooding
- pathways for flooding
- receptors of flooding
- consequences of flooding

Thus the key steps in Performance Evaluation are:

1. Establish clear Performance Objectives for the process being evaluated.
2. Identify characteristics (Performance Indicators) of that process that can be used to measure how it is performing relative to objectives.

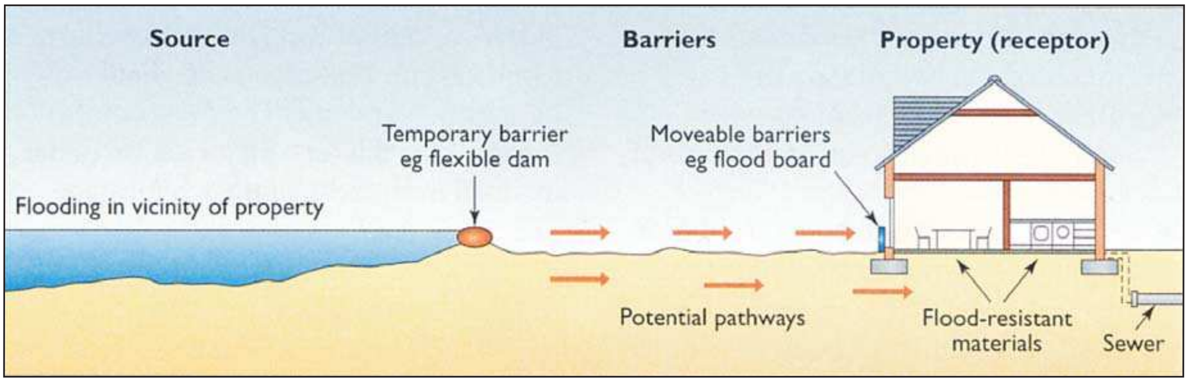

Fig. 1: Source / Pathway / Receptor / Consequence model for flood risk

3. On the basis of measurable evidence, establish how the process is performing compared with objectives.
4. Communicate the results of the evaluation as appropriate.
5. Decide what further action needs to be taken as a result.

In general Performance Indicators lie on a range from 'hard' to 'soft' measurements. Hard Performance Indicators have widely accepted methods and scales of measurement (such as weight and cost). Soft Performance Indicators cannot be precisely measured and are often expressed in linguistic terms (e.g. High, Medium or Low). Soft Performance Indicators are therefore inevitably less informative than hard Performance Indicators and the method of measurement (for example elicitation from experts or stakeholders) will tend to be more prone to bias. But there are important aspects of system performance that can only be measured in soft terms.

Performance Indicators may be directly informative in the format in which they are measured, or they may require some processing or analysis in order to be useful. Processing may, for example, involve summing or averaging several measurements.

5. Fragility curves

Often, in order to be useful, some analysis of the context or environment in which Performance Indicators were measured will be required. This will be essential for measurements of system (or more specifically defence structure) response to random loading. In order to obtain information about whether the response was satisfactory or not it is essential to analyse the loading conditions and to do so may require additional data collection or modelling (for example hindcasting). A convenient way of separating system response from the loading imposed upon it is to use a fragility function as a performance indicator. A fragility function (see example *fragility curve* in Fig. 2) is the defence response, $P(D|x)$, *conditional upon a given loading condition, x*.|

There will usually be more than one performance indictor for any given process, but the number of Performance Indicators should be efficient and should as far as possible relate directly to objectives.

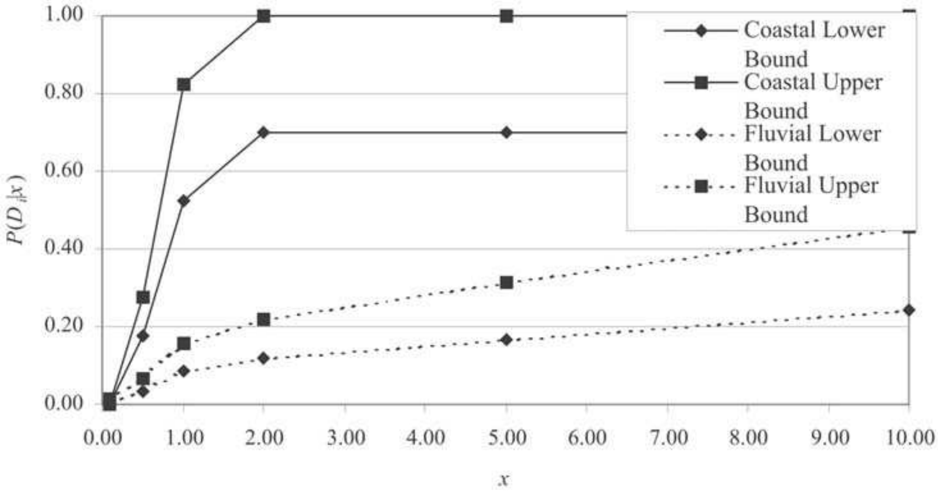

Fig. 2: Typical fragility curve

6. Defence asset condition assessment

Management of defence assets is a particularly important part of the overall performance management process described in the previous section. Performance-based defence asset management of the system must consider:

- the whole life cycle of systems (to secure the greatest return on investment)
- maintenance, renewal, and replacement options with the goal of optimising defence asset performance.

The objective must be to assess performance on a continuous basis and at appropriate times. Maintenance, renewal or replacement interventions are initiated to restore the original performance capability and to extend or re-initiate the residual life of the system or defence asset (Fig. 3). For such a process, it is essential that the monitoring involves a process of *con-*

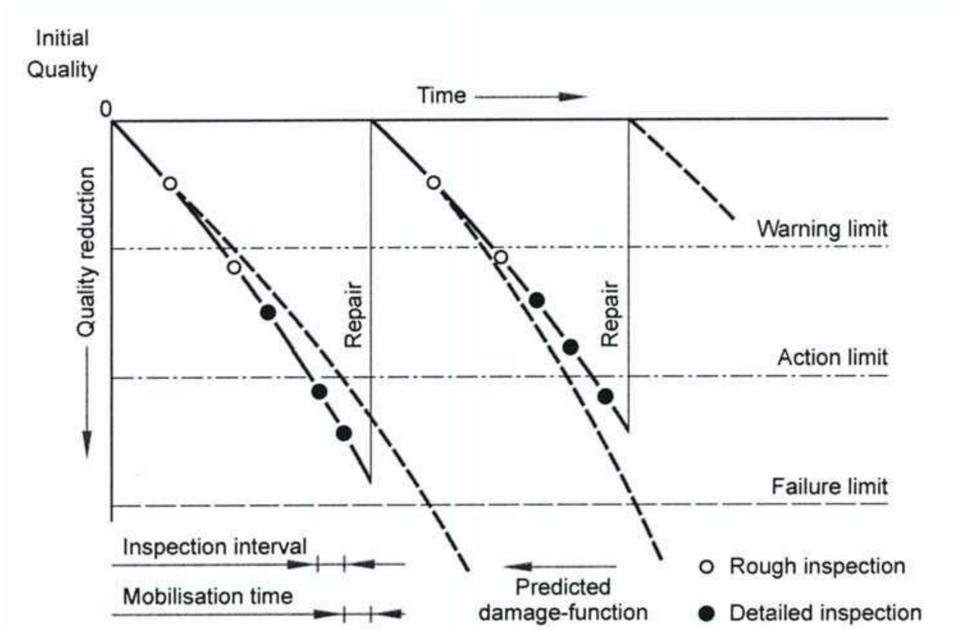

Fig. 3: Condition-based defence asset management (CIRIA/CUR, 1991)

dition characterisation which is unambiguously related to performance levels and not just to a subjective assessment of structural condition.

Together, condition assessments and fragility curves can give an indication of the current and likely future ability of a structure to perform to its original design limits.

7. Performance Indicators used in NSR countries – similarities, differences and gaps

a. *Using assessments of future flood risk as a performance indicator.*

Most countries are considering a move from a safety standard approach towards flood risk assessment. This will be based not just on predictions of the probabilities of defence overtopping under given events but also on the flooding consequences and their assessment in socio-economic terms. However, so far only the United Kingdom and the Netherlands have made decisions to move towards this goal. Work still to be completed to enable such overall flood risk assessments to be carried out includes:

- obtaining appropriate data and/or setting up databases on defences and flood risk areas
- agreeing on national methodologies for flood risk assessment.

When such work is complete it should be possible to set up measures such as:

- **Effectiveness** of measures in reducing the economic value of national or regional assets at risk from flooding
- **Efficiency** of measures in reducing national or regional flood risk per Euro invested. This is the annual Benefit to Cost ratio for the national spend on flood risk management.

Such work will also enable the significance of a particular defence asset in providing flood risk reduction to be assessed.

b. *Geographic indicator of shoreline position.*

Most countries have some kind of objective in relation to the future shoreline position and are undertaking monitoring of that to identify whether the objective is being achieved or indeed is appropriate for the long term. The basic questions to be answered in terms of performance indicators are:

Where is the defence asset?
Is it moving, and at what rate?
Are these answers acceptable?

c. *Geometric indicators for shape and crest elevation of defences, including dunes*

The assessment of likely future loadings, whether an individual event or a more risk-based approach is a key condition for proper geometrical performance assessment. This includes predicting all sources risk, such as rainfall, river flow, wind, waves etc. This service includes:

- Development of design information for defences, based on data collection, analysis and prediction of river or sea conditions.
- Real time flood warning services for the public.

Given an understanding of the likely loadings, in most cases the performance indicator for defences is still set in rather deterministic terms as a maximum allowable overtopping rate (typically 2 l/s/m) not to be exceeded under a given design event.

In the future this will be modified as a more risk-based approach is adopted for linear defences, taken on a cell by cell basis. Key geometric performance indicators used to confirm acceptable performance include:

- Crest elevation. Both global settlement is assessed and also localised depressions which give rise to weak spots. In lower Saxony, for example, defences are designed for certain design conditions and crest levels are checked 20 years or more frequently
- Slope gradients (also used as a structural indicator of movement of defences)
- For sand dunes and beach systems, overall volumetric assessment of material within a defined geographical band is normally used

The basic questions to be answered can therefore be summarised as:

- What is the current level of risk associated with the defence asset?
- What is the geometry associated with that level of risk?
- Are these changing and at what rate?
- Are these answers acceptable?

Note that secondary defences are also important in some countries, designed to mitigate flooding should the main defences be overtopped. Performance objectives for such defences are quite variable.

d. *Structural indicators for the condition of the defences themselves and their vulnerability to breach under extreme loading.*

A wide range of approaches are adopted for assessing defence condition. These include

- Visual loss – exposure of clay
- Degree of clay deterioration/erosion
- Slope gradients. (In Germany, for example, a maximum slope of 1/3 is permitted)
- Piping and fissuring (tested by non – intrusive tests or by internal measurement)
- Assessments of safety factors against geotechnical failure

Whatever indicators are used, the basic questions to be answered are:

- What are the potential failure modes?
- What inspection, data collection and analysis are needed to assess these modes?
- What is the defence asset condition now and is it adequate for purpose?
- How quickly will the defence asset deteriorate?
- When will maintenance (or further inspection) be needed?

e. *Performance indicators for pumps and gates.*

More significant pump/gate assets have specific operations manuals setting detailed performance requirements. This may not be the case for smaller and/or older less significant assets. Where performance assessment guidance is provided, it usually requires answers to questions of the form:

- What is the pump/gate asset condition?
- What inspection, data collection and analysis is needed to facilitate assessment of pump/gate asset condition?
- How quickly will the pump/gate asset deteriorate and what is its future residual life?
- How frequently will inspection and/or maintenance be needed?

In most cases the overall performance requirements for barriers are:

- That their overtopping performance should be consistent with the associated linear defences
- That they should be closed properly and in time to defend against an extreme event.

In the case of pumps and culverts, the overall questions to be answered are more of the form:

- What flow capacity does the pump/gate asset provide?

- Is the pump/gate asset actually available when needed?
- How reliable is the pump/gate asset when capacity is demanded of it?

f. *Objectives for reducing the consequences of flooding should it occur*

A wide range of objectives were noted here but include:

- Control of new property development in flood risk areas
- Educating and making the public aware of the possibility of flooding and its consequences.
- Flood proofing of properties by individual members of the public.
- Person and property emergency rescue. This includes the rescue of individuals, plus movement of valuable property to avoid damage.

The overall questions which the performance objectives and indicators need to be able to answer here is "What are the receptors and associated risk consequences and how have they changed?" For example, if flooding or coastal erosion occurs, then its impact will be affected by changes in:

- The degree of development in a flood risk area or area at risk from erosion.
- The ability to issue accurate flood or erosion risk warnings.
- The ability to respond to issued warnings, including moving flood prone people and goods out of the flood risk zone.
- The availability and speed with which temporary or demountable flood defences can be installed either as defences to individual properties or communities.

g. *Non-flood-risk objectives*

Most countries have other objectives other than flood risk reduction which they must also meet in the integrated management of their coastal zones. Some of these are legal requirements. They include:

- environmental acceptability, particularly in terms of reducing impacts on designated habitats, geological exposures, water quality, etc.
- contribution to public safety and reduction of social vulnerability
- amenity and tourism requirements
- sustainability objectives

The EU ICZM (Integrated Coastal Zone Management) Recommendation and the Water Framework Directive are expected to have a significant impact on such broader objectives

However, in these cases it is generally not possible to give clear expression for performance indicators. Rather the evaluation should be a more general one, examining the extent to which the original performance objectives have been met.

8. Appropriateness of performance indicators for needs of risk managers and planners

Most of the *outcome performance indicators* used by risk managers and planners in regard to flood risk reduction in the coastal regions of the North Sea seem to be appropriate for their purpose, particularly those which are focussed on the sources, pathways and receptors of flooding.

In most of the NSR countries there is some kind of national database in which flood risk management data is held. Generally this includes socio-economic and defence asset data and hydrodynamic data (perhaps real -time). In some cases there are also records of flood defence works and costs and information about planned works.

However, much of the raw data that are collected and stored in databases are, on the whole, not tailored to the needs of Performance Evaluation. Additional processing and / or data collection is generally needed to isolate specific performance indicators. Many of the databases were developed for other purposes and were now being adapted to meet the needs of risk and performance management; however, the information and even the structure of the databases is not necessarily ideal for this purpose.

Better performance indicators need to be developed to assess the social impacts of policy. Without such data and indicators, it is difficult to assess the impacts of a particular policy option on societal behaviour.

Some risk managers and planners also collect *output performance measures* (e.g. Defra High Level Targets in the United Kingdom.) These are mainly intended to monitor and audit the effectiveness and efficiency of the coastal management organisation in meeting operational targets. As such they do not refer directly to flood risk reduction and their role in assessing *outcome* performance is limited.

9. Concluding statements

1. Flood risk management (FRM) objectives come from national policy/law via strategic planning. *Outcome performance indicators* can be defined from FRM objectives.
2. Performance of linear defences (dikes) remains a key element of FRM; reliability analysis permits a consistent estimate of structure failure probability.
3. Whilst necessary, *output performance measures* of FRM organisations do not refer directly to flood risk reduction and their role in assessing *outcome* performance is limited.
4. More work is required to develop better and more consistent performance indicators in NSR countries, tailored to the policies and strategies being pursued.

10. Literature

HR WALLINGFORD: Risk, Performance and Uncertainty in Flood and Coastal Defence – A Review. Defra / Environment Agency R&D Report FD2302, 2002. www.environment-agency.gov.uk/floodresearch

SIMM, J. D.: Report of COMRISK Subproject 4: Performance of risk management measures. HR Wallingford and Environment Agency, 2004