This is a publication by

The Ministry of Infrastructure and the Environment (Rijkswaterstaat)

www.rijkswaterstaat.nl/english
0800 - 8002

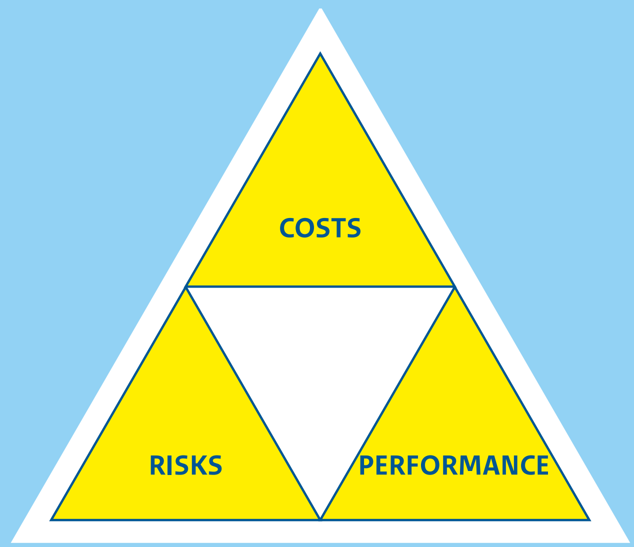
february 2017 | NN3101LL051

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Performance-based Risk Assessment (PRA)

A performance-based systems approach

Water. Wegen. Werken. Rijkswaterstaat.



The Ministry of Infrastructure and the Environment (Rijkswaterstaat, RWS) works to ensure system performance. Performance-based risk assessment (PRA) is an important tool in this process, as it analyses the balance between an object's performance, the potential risks to that performance, and the costs of maintaining it. Performance-based risk assessment aids RWS in making well-founded construction, control, and maintenance decisions.

For each system, performance control starts with determining the functionality it must provide. This involves answering the following question: What must the system be able to do? After determining functionality, the performance requirements can be established using a set of criteria known as RAMSHEEP. These help to answer the question: How well should the system perform? A risk analysis then clarifies which threats may adversely affect system performance and which measures will improve it. This results in a consideration of: How well does the system perform in its current state? The final step involves the analysis of control measures. There is a certain cost to maintaining performance at certain levels. These costs can change if a system is not performing at the proper level (i.e. improvements) or if it is performing at a much higher level than necessary (economization). As a whole, PRA answers the following question: How much does performance cost? In this way, PRA ensures transparent and efficient deployment of resources.

Risk control: the basics

Performance-based risk assessment looks at the relationships between the performance, risks, and costs of an object. It can be applied to the construction, control, and maintenance of all of the public works managed by RWS. PRA provides ongoing and clear information on the condition of our infrastructure.

PRA: Step-by-step

This brochure describes the steps used in PRA that systematically determine the current status of an object.

The steps are as follows:

- A) Determine functionality and functionality requirements. What must the system be able to do?
- B) Define performance requirements. How well should the system perform?
- C) Identify risks. How well does the current system perform?
- D) Select control measures. How much does performance cost?

The following pages explain the above process in greater detail. The step-by-step plan is depicted on the centre spread.

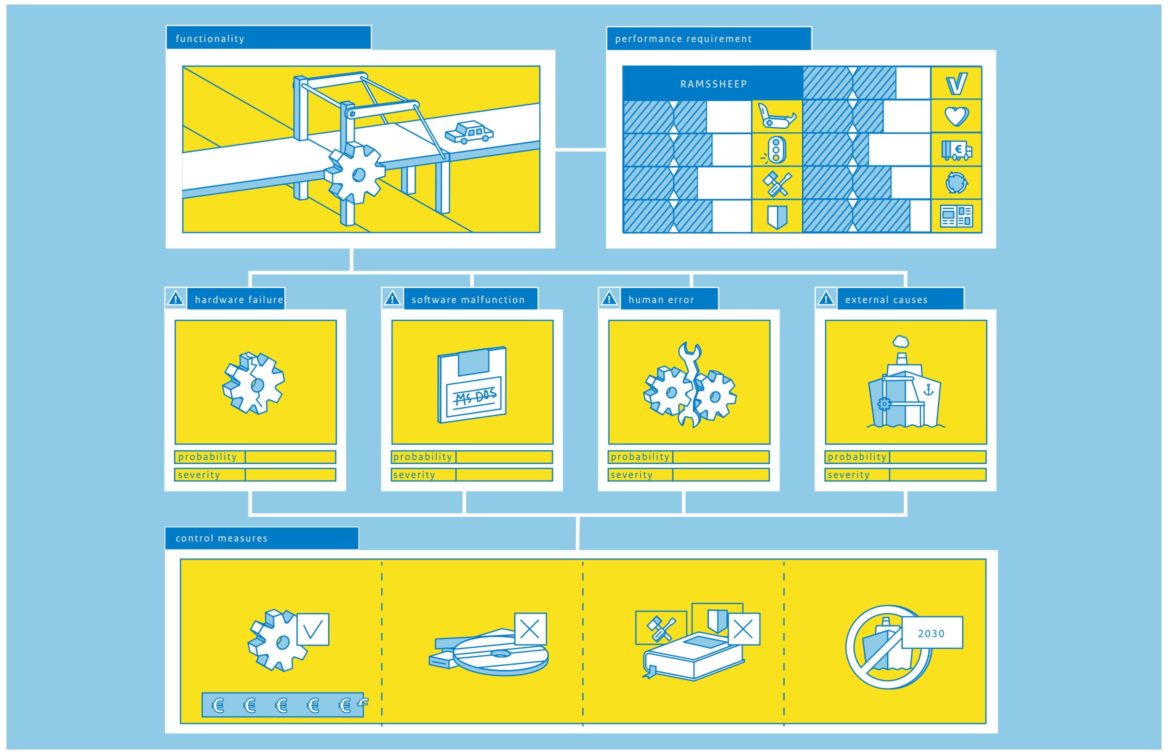
EXAMPLE

A simplified example will help to illustrate the process. Let us analyse a moveable bridge, the functionality of which includes facilitating both road traffic and the passage of boats.
However, there are various risks that may adversely affect the bridge's performance, such as broken gears, software malfunctions, technician errors, or boating collisions.
The analysis involves looking at the probability of a certain risk and the severity of the associated consequences. These risks can be managed through the preventive replacement of the gears, carrying out software updates, additional training for technicians, or banning large ships from passing the bridge. Each measure comes at a certain cost that, combined with the probability and severity of a risk, can help decide which measures should be implemented and which are not necessary.

A) Functionality

Systems exist to provide functionality. For example, the function of the main road network, expressed in simple terms, is to 'permit vehicle transport from A to B'. The initial step in PRA is to determine which object functionality (or functionalities) are under examination. This process sometimes reveals multiple (or sometimes even conflicting) functionalities within the same object. The PRA is carried out for each function separately; functional optimization comes afterwards.

EXAMPLE OF A MOVEABLE BRIDGE



Complete the steps in the plan to experience the PRA for yourself

functionality

performance requirement

hardware failure

probability

severity

software malfunction

probability

severity

human error

probability

severity

external causes

probability

severity

control measures

RAMSSHE€P

Reliability: The likelihood that a system will function without failure for a given period of time and under certain conditions.

Availability: The anticipated fraction of the total time that a system will function under certain conditions. This also includes the likelihood that a system will function when called upon at any given moment in time (under certain conditions).

Maintainability: The likelihood that a system (or system component) will be available for inspection, repair, or preventive maintenance within a specific timeframe and under certain conditions.

Safety: The likelihood that a system will not cause any harm to humans (injury or death) during a certain timeframe and under certain conditions.

A comprehensive explanation of RAMSHEEP (including the other five categories) can be found in the PRA information pack.

B) Performance requirements

The next step in the PRA involves setting performance requirements. A key instrument for doing so is RAMSHEEP, an acronym for the nine performance categories. When taken together, these constitute the object's performance requirements.

Reliability
Availability
Maintainability
Safety
Security
Health
Economy
Environment
Politics

EXAMPLE
One example of 'Availability' is the portion of time during which a section of road or a tunnel is in use. RWS often imposes a maximum time limit on its contractors (e.g. 45 hours per year) for restricting the operation of an object. This results in an availability requirement of (8760 hours [hours per year] - 45 hours) / 8760 hours ≈ 99.5 per cent.

C) Risks

Once the performance requirements have been set, the potential threats that may adversely affect performance and the measures improving performance are identified. In practice, these are referred to as 'risks'. The term encompasses the probability of an event occurring, combined with the 'consequences' of the event.

EXAMPLE
On average, gears break once every 100,000 revolutions. The time taken to deliver and repair a gear means that the bridge cannot be opened again for some time.

There are four risk categories: hardware failure, software failure, human error, and external causes. Multiple risks are identified in each category.

Hardware failure
Any physical component of an object is susceptible to hardware failure. In bridges, for example, these include the foundations, columns, arches, hinges, engine, brakes, and road surface. The probability of failure and the associated consequences are determined for each component.

Software malfunction
Some RWS objects use software. What is the probability of the software failing to send the right signal to the machinery at the right time? The probability of errors and the associated consequences for system functionality are determined for each software module.

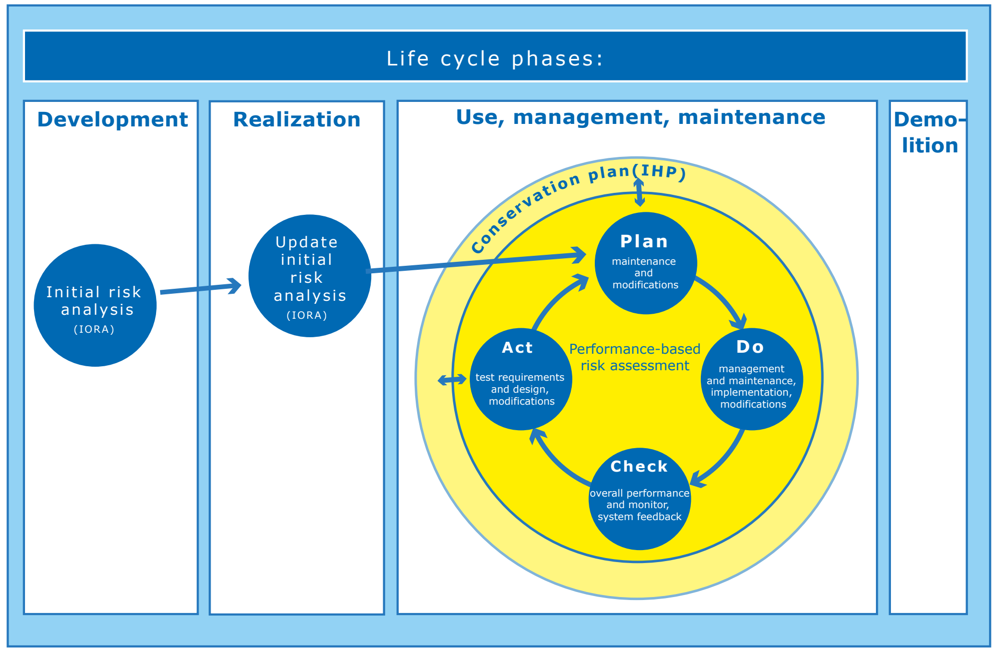
Human error
Objects are created and controlled by people. Errors can be made at any stage: construction (failure to tighten bolts), maintenance (forgetting to do so), or when resolving system failures. The effect of each error on system functionality is taken into account.

External causes
The functionality of RWS systems can also be affected by 'external causes'. These include the probability of failure due to aspects such as weather conditions (heavy rainfall, lightning), floods, forest fires, or collisions.

D) Control measures

If all performance requirements are met after having identified the risks, maintaining the current situation will be sufficient. If there is any leeway, the decision may also be made to postpone maintenance in order to save money. If action is necessary, however, the above model will aid in selecting which measures to implement. After all, different measures will affect the object's performance in different ways. The performance and risks are weighed up against the costs, allowing the selection and transparent justification of the most efficient measure.

EXAMPLE
For example, the decision may be made to keep an expensive spare gear on hand to enable immediate repairs, or to accept the longer delivery time.



PRA: Detailed description

Each PRA is based on a qualitative system analysis, which in turn is based on the knowledge and expertise of the professional carrying it out. They go through steps using a standard failure and consequence methodology. The qualitative risk analysis results in a set of measures that keeps the risk of system failure to an acceptable minimum. This is sufficient for non-critical RWS infrastructure.

However, RWS also wishes to apply quantitative requirements to some objects. In these cases, the qualitative analysis is supplemented by a quantitative analysis: a mathematical calculation of the probability of failure with respect to reliability and availability.

The level of accuracy here may vary, with the stringency of requirements and system complexity determining the accuracy of the analysis. For example, the highest level of accuracy is required when ensuring that storm surge barriers comply with statutory requirements. Less critical objects permit a more simplified approach, in which case the risk analysis will provide a conservative estimate of the object's actual performance levels.
In both cases, the quantitative variant also produces a set of measures, but one that demonstrably ensures compliance with the set of quantitative performance requirements.

How does PRA guarantee the performance of my system?

A PRA is more than just a snapshot of an object's performance. The PRA is the beginning of the cycle used to manage the performance of the system, which is called the 'Deming cycle' and involves the following steps: Plan, Do, Check, Act.
The control and maintenance activities prescribed by the risk analysis (Act) are documented in the IHP (Plan), implemented (Do) and measured (Check). The differences between the required and measured levels of performance are then recorded and updated in the risk analysis (Act). Improvements and possible optimizations are also scheduled where necessary (Plan), in turn relaunching the
PDCA cycle. This control process allows demonstrable and ongoing compliance with the set requirements.

The benefits of PRA

Full and successful implementation of PRA allows infrastructure administrators to:
- remain in control of the set of infrastructures and avoiding higher (than necessary) maintenance costs and lower (than expected) performance;
- demonstrate compliance with legislation and Service Level Agreements (SLAs);
- communicate in an unambiguous fashion with contractors (and, indirectly, users) in order to provide performance transparency in cases of remote control; and
- optimize maintenance costs and revenue at object and network level.

That's why Rijkswaterstaat adopts performance-based risk assessments as Asset Management methodology.