BTO *Executive Summary*

Gondwana can now also take resilience into account in the operational optimisation, for instance, of drinking water supply under crisis scenarios

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A method and a tool were developed to quantify and optimise the resilience of drinking water distribution systems under crisis scenarios. The calculation of a resilience indicator was implemented in *Gondwana*, the software platform for the optimisation of distribution systems. *Gondwana* has thus been adapted for operational optimisation. The method and tool were tested on the Helmond-Mierlo (Brabant Water) drinking water distribution system. Maximising the resilience under a crisis scenario, such as a pipe fracture, is achieved by modifying valve positions in order to maximise the supply of water to customers. The results of a case study show that the current system, thanks to its ample dimensions, is resilient to pipe fractures, and that there is little room for improvement in this specific instance. Naturally, this cannot be assumed to be the case for other areas and instances. Drinking water utilities can apply the approach developed to test the resilience of existing *and* new or projected infrastructures under different crisis scenarios. They can therefore identify sensitive areas and elaborate automated operational plans for crisis scenarios. The approach also offers the possibility of including resilience as a performance indicator in the design of new infrastructures, and of weighing this indicator against other objectives, such as installation costs and water quality.

Interest: enabling maximum supply of drinking water, even under crisis scenarios

Drinking water distribution systems are vulnerable to all sorts of threats and crisis scenarios, from the aging of the infrastructure, which can lead to component failure, to natural disasters like flooding and earthquakes, cyber-attacks and contaminations (intentional or not). Such crisis scenarios can impact the performance of a distribution system, with a resulting decrease in the quantity and the quality of the water supplied. Drinking water utilities are therefore concerned about the resilience of their distribution systems, and about how they can maximise this resilience. A method is therefore needed to quantify the impact of crisis scenarios on the distribution of drinking water to customers, to assess the performance of distribution systems, and to automatically optimise the configuration of a network, for the purpose of minimising impact and maximising resilience.

Approach: definition of resilience and optimisation of valve positions

First, a measurable indicator for resilience was elaborated. *The relationship between the water actually supplied and the demand for water* was chosen. This indicator quantifies the capacity of a distribution network to supply water under a crisis scenario, and therefore the impact that such a scenario has on customers. This indicator was implemented in the *Gondwana* optimisation platform developed by KWR. This also requires the use of a pressure-dependent pipe network simulator, which is a simulator in which the water supplied depends on the pressure available at a point of use in the network. The approach behind the *Scenario Planner* tool was then used to draw up an inventory of possible crisis scenarios. This provided an overview of the different threats to the different components of a water distribution system. Lastly, the approach was used in a case study: five different crisis scenarios (shut-down of specific pipes) were calculated for the Helmond-Mierlo distribution network (Brabant Water). The resilience of the current network was calculated under each scenario, after which the valve positions were automatically manipulated to maximise the resilience.

Results: current structures are resilient

The Helmond-Mierlo distribution system grew organically and was designed to minimise customer minutes lost (CML) and maximise supply continuity. This means the network is strongly meshed and that its resilience under the selected scenarios is very high: the ratio between the actual supply of water during the considered crisis scenarios and the demand for water exceeds 90%. The hand-designed system thus performs well, even in scenarios in which two pipes are shut down. With *Gondwana* it is possible to identify which valves can be turned off to raise the volume of supplied water a little more. The results achieved are not generic; in other words, it cannot be assumed that the resilience is also high in other areas and under other scenarios.

Implementation: crisis-scenario response strategy and resilient system design

Gondwana has been adapted for the optimisation of operational choices. In this case, the closing and opening of valves in the event of a pipe fracture. This offers multiple possibilities for both development and application.

Drinking water utilities can apply the method and tool developed to test the resilience of the existing infrastructures under different crisis scenarios, to identify sensitive areas in the existing pipe networks (as a complement to the supply assurance test already used), and then to determine response strategies during crisis scenarios. A tool of this kind is increasingly important, because the drinking water sector staff is aging, and more and more experienced experts are leaving the drinking water utilities without having formally embedded their knowledge. Moreover, the Dutch drinking water utilities are fully engaged in the review of their distribution system infrastructure and the design of network blueprints. In this context, the aim is often to design leaner, branched networks, for example to improve water quality. This can however have implications for the resilience of these systems. The approach developed can potentially be used to explicitly take resilience into account in the design of a blueprint, be it as an objective or part of the framework conditions. The latter means that it is possible for example to use *Gondwana* to adjust the pipe diameters, or the number, location and control of valves in a network, in such a manner that maximises resilience. *Gondwana* can also simultaneously optimise multiple objectives, like water quality *and* resilience, and thus generate a series of designs in which the water quality and resilience are optimal in different proportions. This is a powerful way of weighing parameters like water quality and resilience on a quantitative basis. It is also possible to weigh investment costs against resilience. *Gondwana* can calculate how much additional resilience water utilities can achieve by making an extra investment in the installation of pipes or valves.

Report

This research is described in the report *Veerkracht van leidingnetwerken onder crisisscenario's* (BTO-2019.040).

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