

TNO report 2014 R11698

Measuring resilience

Kampweg 5
3769 ZG Soesterberg
Postbus 23
3769 ZG Soesterberg
The Netherlands

www.tno.nl

T +31 88 866 15 00
F +31 88 866 39 77
wegwijzer@tno.nl

Date	03 December 2014
Author(s)	Hanneke Duijnhoven, Beitske Boonstra, Martin van de Lindt, Inge Trijssenaar, José Kerstholt, Diederik Wijnmalen, Marcel van Berlo
Copy no	
No. of copies	15
Number of pages	179 (incl. appendices)
Number of appendices	11
Sponsor	External Scientific Affairs, Research and Documentation Centre, Ministry of Security and Justice
Project name	Measuring resilience
Project number	060/0/06453

© External Scientific Affairs, Research and Documentation Centre, Ministry of Security and Justice, 2014

Summary

Problem

As a result of increased interdependencies between systems and infrastructures, society has become more complex over the last decades. This has resulted in an intrinsically enlarged vulnerability with respect to disruptions and a larger uncertainty about its nature and consequences. Given these developments, the Dutch Ministry of Security and Justice, in particular the National Coordinator for Security and Counterterrorism (NCTV) feels the need to have a deeper understanding of the possibilities to measure the resilience of the Dutch society on a regular basis (preferably quantitatively).

TNO is asked to investigate the (im)possibilities by conducting an explorative study with as main research question: which set of indicators can be used to determine the resilience level of the Dutch society and in which ways can these indicators be measured and condensed in an effective and justified manner?

Although the original research question uses 'indicators', in this study we will first look for the most relevant stocks, i.e. the key components of resilience defined from a system-dynamic perspective towards resilience. In a next step these stocks can be further operationalized into indicators (entities with which the status and quality of stocks can be measured using appropriate measurement methods).

Research questions

Derived from the identified problem, the following five research questions were formulated:

1. What are the advantages and disadvantages of a generic measurement of resilience (irrespective of the nature of the threat) versus a specific measurement of resilience (related to specific threats)?
2. Which stocks (operationalized in indicators) of resilience could be included in a valid and usable model to measure the level of resilience of a society and what is their interrelationship?
3. How could the most promising (core) stocks of resilience be operationalized efficiently and responsibly into measurable indicators, taking into account the requirements such a resilience monitor could meet?
4. In which ways could the values of separate core stocks (i.e. the underlying indicators jointly reflecting the quality of the core stock) be processed into a visual representation, description or number representing the overall level or resilience as well as taking into account the relationships between the underlying data and indicators?
5. To which extent is it necessary and possible, when designing a future instrument, to determine a minimum level of functioning to which a society should bounce back? How is this being done in other countries?

Research design

In order to be able to answer these questions, the research is divided in three phases applying various research methods (see Figure 0-1).

In the first phase we started with a quick scan of national and international literature. This was the basis for a workshop with a large variety of experts aimed at defining the context and the problem space, including an analysis of the concept 'resilience' as well as the question whether a generic or specific approach is preferred.

The second phase was focused on the actual inventory and selection of components and ranking mechanisms of resilience (stocks, capitals, indicators, capacities) and of methods of measuring, modelling, aggregation and weighing, and visualisation.

During this phase we have studied national and international literature to get a good overview of the various components and aspects of resilience and the way these can be structured and organized.

With respect to the international literature, in particular the resilience frameworks of Australia, Canada, the United States of America and the United Kingdom were reviewed.

In order to structure the vast amount of information from the various frameworks in a sensible and comprehensive way, we used the concepts of 'capital' and 'stock'. This approach results directly from our systems approach to resilience, in which the society is regarded as a complex adaptive system. Resilience is a system characteristic used to cope with threats. The system characteristic 'resilience' is composed of various capitals, for instance social, physical and institutional capital. The value of these capitals is determined by the underlying and mutually interdependent stocks of which the status and quality is measured by means of qualitative or quantitative indicators.

Next, we conducted several expert sessions. The aim was, supported by system-dynamics software, to describe the mutual relationships between stocks, the way these stocks can be structured in capitals, and to define an illustrative model of resilience with a limited number of core stocks. The resulting model was subsequently tested on two cases.

The third and final phase was aimed at conducting an external validation of the research findings and at formulating a reflection on a future resilience monitor. The principles and outline of the developed model were validated externally. We presented the results to, and discussed with, several external resilience experts, followed by a workshop in which the results were discussed with a larger group of experts.

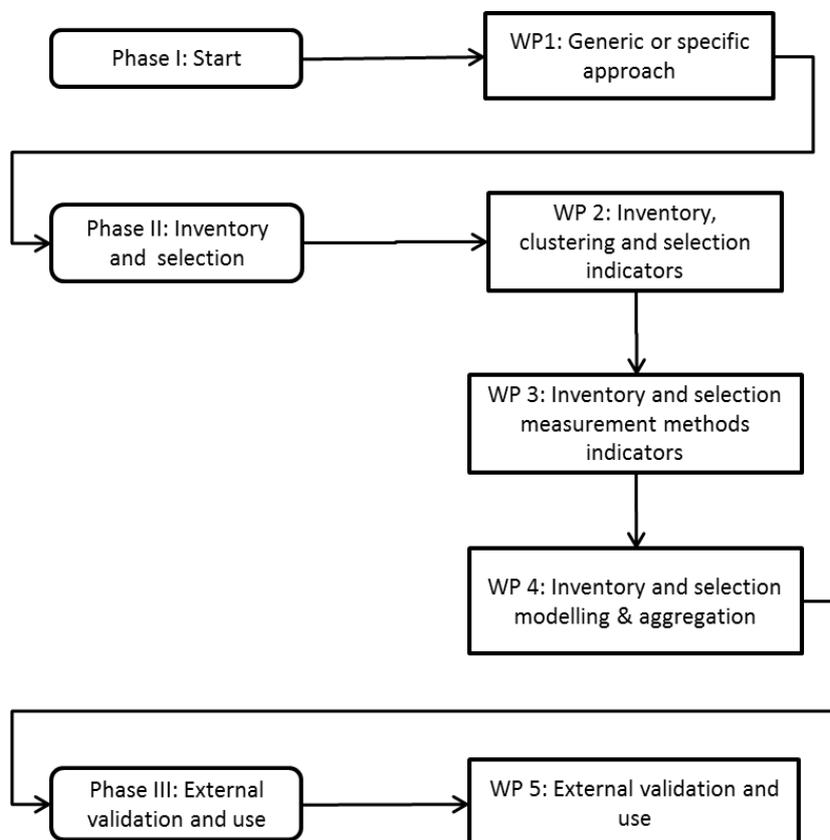


Figure 0-1: Overview of the research approach

Based on the literature research and discussions within the steering committee, the relevance of (and relationships between) various considerations became more apparent, like the advantages and disadvantages of measuring resilience, the purpose of measuring resilience, measuring resilience on a national or regional level, and the level of accuracy and detail of a resilience monitor. It was beyond the scope of this research to formulate a policy recommendation regarding these considerations. However, this study presents an encompassing overview of possibilities and the respective advantages and disadvantages. During the external validation (Phase III) the importance of these consideration was again emphasized. During the first phase of the study, and after consulting he steering committee, an initial preference was given towards several of these considerations and this decision influenced the way the research questions were addressed. Given the preference for a generic, national scope, it appeared not to be possible within the scope of the project to operationalize the corestocks in a clear set of indicators. However, examples of potential types of indicators have been provided. Therefore, these considerations are described in a dedicated chapter (3) of this report.

Definition of resilience

Resistance, resilience and adaptivity

A resilient society is a society in which individuals, groups and communities are able to cope with threats and disturbances resulting from social, economical and physical changes. From the literature it becomes clear that in operationalizing and measuring the concept 'resilience', three aspects are relevant, namely resistance, resilience and adaptivity.

Resistance is the ability of a system to continue functioning when a disturbance occurs, without significantly changing the system. If functions are being affected, resilience is responsible for restoring the system's functioning. Adaptivity is the ability of a system to react to changes in their environment, to adapt and to learn from experiences. This final aspect, the ability to adapt to changing conditions (adaptivity), has been neglected too often. The aim was primarily on restoration with little attention for the dynamic nature of the societal system. Therefore, we use the following definition of resilience: 'Resilience of an individual, community or system is the ability to resist, bounce back and adapt in case of a disturbance of the perceived normal status' (see Figure 0-2).

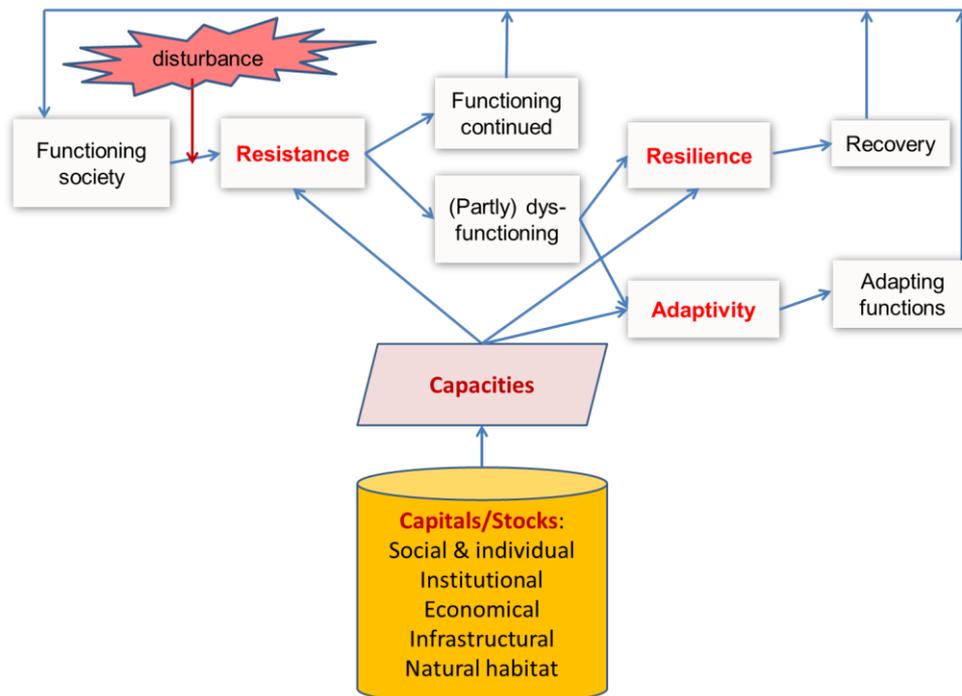


Figure 0-2: Model for resilience

Consideration with respect to measuring resilience

The specific selection of indicators and, related to this, measuring and aggregation are heavily influenced by several considerations. The following considerations were relevant:

1. Advantages and disadvantages of measuring resilience, like completeness and validity as well as complexity and costs involved.
2. The purpose of measuring resilience, like raising awareness with several stakeholders within society, making decisions with respect to large investments and stating policy priorities.
3. The difference of measuring resilience at a national or regional level. Both local and national factors are of relevance, but are weighed differently depending on the level of measurement.
4. Generic or specific. Advantage of a generic approach is, amongst others, that unexpected disturbances are taken into account; a disadvantage is that it is hard to organize and that specific interventions are being ignored. Advantage of a specific approach is, amongst others, that a large amount of information is available and that the selection of interventions is much more clear-cut; a disadvantage is the overwhelming amount of detailed information and that not all risks are taken into account.

Resilience in terms of capitals and stocks

In this research we studied several international frameworks for resilience that are being applied, especially in Australia, Canada, the United States of America and the United Kingdom. An important conclusion of this research is that most frameworks follow an 'all hazard' approach and that the characteristics of a resilient society can be described in terms of capitals, stocks, capacities and critical infrastructures. Most frequently used capitals are social and individual capital, institutional capital, economical capital, infrastructural capital and natural habitat capital. These capitals are divided in stocks (see Table 0-1 and Figure 0-3), and we propose 19 so-called core-stocks. These core-stocks contribute directly to the capacities of the safety and security management chain. Social capital encompasses amongst others 'civic competencies of citizens', institutional capital 'quality of professional response organisations', economical capital 'availability of labour', infrastructural capital 'energy supply', and natural habitat 'eco systemservices'. The value (status, quality) of a stock can be measured with (qualitative and/or quantitative) indicators. As mentioned, it appeared not to be possible within the scope of the project to operationalize the corestocks in a clear set of indicators; however, examples of potential types of indicators have been provided.

Table 0-1: overview of capitals and core-stocks

Institutional capital	Social and individual capital	Natural habitat capital	Infrastructural capital	Economical capital
Quality juridical system	Civic competencies of citizens	Eco-systemservices	Adequate food supply	Quality of economical system
Quality of professional response organisations	Self-reliance of citizens		Functioning of drinking water supply	
Quality public governance			Functioning financial system	
Quality other institutions and businesses			Functioning drainage and processing waste	
			Functioning energy supply	
			Functioning information and	

			communication technology	
			Functioning health care facilities	
			Functioning of transport infrastructure	
			Stock of emergency supplies and shelter	
			Quality physical environment management	
			Quality spatial planning	

Relationships between stocks

To systematically structure the relationships between the stocks, we constructed an illustrative model in which the relationships between the most important stocks, as identified in the literature study, are being described and are related, via capitals, to the capacities in the safety and security management chain (proaction, prevention, preparation, response and recovery).

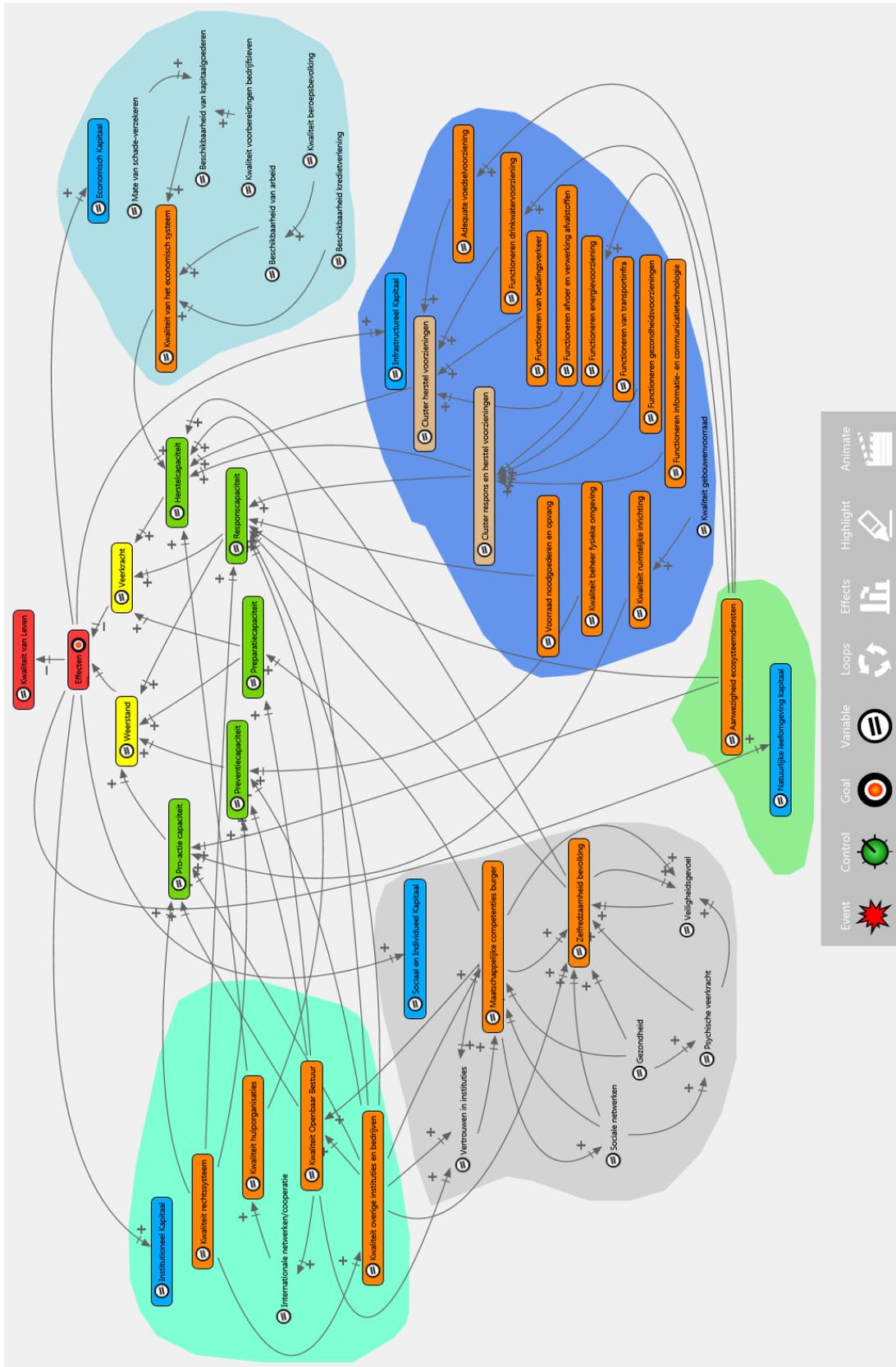


Figure 0-3: The MARVEL model

Testing the outline of the model

To test the outline of the model, two cases were selected: the fireworks explosion in Enschede (2000) and the floodings of 1995. However, from the analysis of both cases it was not possible to test the

entire model because the evaluation reports contained little information to conduct a comprehensive analysis on resilience. In the evaluation reports, emphasis was placed on the performance of professional response organisations, governments, citizens and other organisation during especially the response phase; other relevant aspects in our model, resilience and adaptivity, are neglected. Nevertheless, the case analysis shows a clear relationship between the various stocks. During the fireworks explosion in Enschede, a strong relationship was shown between the juridical system on the one hand, and surveillance and law-enforcement on the other. The 1995 floodings showed a strong collaboration between government, response organisations and citizens during both the response and recovery phase.

Although in these cases much emphasis is placed on institutional capital and social and individual capital, it does not imply that the other capitals and stocks are irrelevant. In other types of crises other capitals and stocks can play a more important role. The relevance of certain capitals and stocks depends on the nature of the disturbance. This would imply that for specific risks, the weighing of stocks, and therefore the resilience score, would be different depending on the nature of the specific threat. This poses an important challenge for designing a method and instrument for measuring the generic resilience of a society taking into account an all-hazards approach.

Modelling and measuring

Modelling, weighing, aggregating, and visualising

To determine what the most suitable approaches are to modelling the level of resilience of the Dutch society, several different modelling methods have been reviewed. These methods have been assessed on the criteria of applicability, maturity, validity, user-friendliness and connection with the National Risk Assessment methodology. The selection of a specific method depends on the importance that is given to each of these assessment criteria. Multi-criteria analysis has a good level of user-friendliness and a reasonable to good validity. A bayesian network or a more complex application of multi-criteria analysis offers a better validity due to the inclusion of the interdependencies between the different stocks and capitals (assuming the quality of the input data is high). However, this requires a much more extensive modelling effort in comparison to a simple application of multi-criteria analysis. A storytelling method or a system-dynamic method (such as the MARVEL method developed by TNO) offers a good qualitative insight in the concept of resilience. The MARVEL method, in addition, offers insight into how a system functions as well as the qualitative effects of interventions (Van Zijderveld, 2007). Agent based modelling has similar or lower scores on all criteria compared to the other modelling methods.

Most of the international frameworks for resilience use a participatory approach aimed at increasing the awareness and achieving consensus on resilience enhancing measures to take, rather than thoroughly measuring resilience. The weighing is – often implicitly – decided upon during participatory sessions and aggregation is usually nothing more than calculating the average scores for each 'capital'.

The choice for a method to visualise results is dependent on the further development of development of a National Resilience Monitor. It is recommended not only to visualise the overall score of resilience but also the values of the underlying stocks, for instance through the presentation of a scorecard. Moreover, it is recommended that the monitor is showing the progress over time of values – both the overall score as well as the underlying scores for capitals/stocks.

Measuring capitals and stocks (indicators)

The degree of resilience is defined by the value (status, quality) of the stocks. These values are determined by indicators: qualitatively or quantitatively measurable entities that provide an indication about the quality/status of a stock. There are different methods to collect the underlying data for an indicator. We distinguish between two main categories of measurement methods: quantitative

methods and qualitative methods. The selection of a specific measurement method depends primarily on the objective, the availability of information (data) and the nature of the available information. Given the objective to develop a quantitative instrument to measure resilience, quantitative methods such as surveys and/or registries are the most obvious choice. For instance, a survey that can be possibly used to substantiate the social capital is the *Permanent Onderzoek Leefsituatie* (POLS). For specific questions about the population (such as age distribution, health, work and income) it is possible to use existing statistics available at CBS (Statistics Netherlands) and for other stocks a range of different registries are relevant for measuring resilience.

External validation

During the third phase of the project the most relevant findings were presented to, and discussed with a range of external experts and intended users of the National Resilience Monitor. During this external validation process, a number of important considerations for the development of a national resilience monitor were emphasised.

The national resilience monitor as a system-dynamic model

A national resilience monitor is ultimately a generic monitor. It aims at measuring the level of resilience of a society ('how resilient are we?'), regardless the type of threat. Due to the complex nature of the concept of resilience it does not suffice to assess all the stocks (and underlying indicators) as independent entities. Therefore, a system-dynamic approach has the best potential to develop a valid approach to measuring resilience.

Developing and validating a comprehensive system-dynamic model for resilience is an ambitious endeavour. Lack of knowledge about some of the components of resilience and more importantly about the interdependencies between the various factors make it difficult to identify the most appropriate measures to enhance the resilience of the entire system, mostly because the essence of resilience is that it is characterised by a high degree of interdependence of its components (Cutter 2013). As such, further research as well as collecting and analysing data is crucial to understand resilience in order to support sensible policy decisions with regard to strengthening resilience.

Method follows objective

Selecting the 'best' approach for measuring resilience is highly dependent on the objectives of the intended instrument. Objectives of a national monitor are to determine how available resources can be efficiently invested to obtain the highest possible degree of national resilience or to assess the results of past policies and interventions. In that case, the instrument should aim at providing insights into the 'controls' that can be exercised to influence the degree of resilience. In other words: where to intervene to achieve the best possible result? Another interpretation of a national monitor would be to compare differences between specific regions or critical societal functions (benchmark) to support investment choices.

National or local

Both local and national factors should be considered when monitoring the level of resilience of the Netherlands. However, to maintain the manageability of a national monitor it is important to limit the scope to a number of areas that are at the core of national resilience (such as healthcare, education, economy, social participation, safety). These core areas should not only include the usual critical infrastructures but also areas that have an important influence on daily life (such as the retail sector). As a matter of fact, measuring societal resilience is about measuring the resilience of all of the essential societal functions. This does not imply that regional or local factors should be disregarded.

Minimum level of resilience

Due to the complex nature of resilience it seems untenable to determine a minimum required level of resilience (or a minimum level of system functioning). After all, resilience is a dynamic concept:

system-dependent, normative and varying in time and place. A much more relevant question is which factors determine the resilience of a system: for instance, how quickly the system can 'bounce back' and/or 'adapt to changing circumstances'. An understanding of the structure of the system is essential to grasp what resilience really means.

Data collection

It is recommended to use as much as possible available datasets and experiences from existing models or instruments, in particular when it comes to local or regional information or results from participatory processes. These insights can contribute to understanding the complex interdependencies between different factors contributing to national resilience. In addition, these experiences can be used to test and validate a national resilience model.

Evaluating resilience

Traditionally, evaluations of disasters and crises are mainly focused on the degree of preparedness to threats and the actual response phase of a crisis. If there is attention for the recovery phase, it is usually limited to the early, short-time recovery phase and the psychosocial support for victims. Resilience, in particular recovery and adaptivity, is typically not addressed in evaluation reports. This is not a surprise since it may take many months or years to conduct an assessment of the success of the recovery phase. In order to obtain a reliable and valid assessment of the quality of interventions aimed at strengthening the capitals and stocks that determine the resilience of a society, it is recommended that future evaluations of disasters and crises explicitly address recovery and adaptivity as well.

Recommendations for developing a resilience monitor

To support the decision whether or not to develop a resilience monitor, this study has provided more insight in the concept of resilience, how it can be measured, and which considerations should be taken into account with respect to selecting methods for data collection, integration, analysis, modelling and visualization. Given the complexity of the concept of resilience and the many choices to be made regarding the design of a resilience monitor, it is recommended to follow a step-by-step approach in developing a valid and accepted instrument. It is imperative that users of the instrument (in this case the NCTV, but possibly other users as well) and researchers work closely together. Experiences with the instrument should be evaluated and implemented carefully, as well as results from other (inter)national research. Moreover, it is important to realize that it is a long-term development process. We have identified several possible steps that could be taken in this process towards developing a comprehensive, national resilience monitor.

Determine the main objective

The selection of the most suitable method for measuring resilience heavily depends on the objective of the intended instrument. A possible objective can be to create or increase the level of awareness amongst different groups of actors in society: this is not the objective of the NCTV. Other objectives can be to support investment decisions and define policy priorities, to take targeted measures for specific threats in a specific region, or to evaluate current and past policies or interventions. Although the NCTV has expressed that the first of these objectives fits best with their intentions they have not yet made an explicit choice. The first step would be to explicitly define the objective. Depending on the objective, the next steps would be to decide on the appropriate level of measuring, methods for data collection, weighing, aggregation of data, modelling, and visualisation of results.

Determining the generic framework

Given the objectives, the next step would be to elaborate and validate the various subsystems (capitals) of the framework. In this step it is essential not to neglect the interconnections between the

various subsystems and factors. It seems logical to start working on those subsystems that are relatively uncontested and for which there is already a substantial amount of data available.

Specific scenarios

Although an all-hazard approach is one of the points of departure for this study, it would be useful to work on specific threat scenarios as well. Understanding the resilience against these specific threats will enhance the reliability and validity of the results. Analysing specific scenarios for specific threats sheds light on the interdependence between various components of the system. This can be followed by testing the model on a more generic level. In taking these steps it is an option to temporarily depart from the system-dynamic approach and to adopt a hierarchical structure of raw data, indicators, capital indexes and ultimately a resilience index. An advantage of this approach is that the most important relations can still be considered, whilst at the same time complexity is being reduced.

Developing the resilience monitor

Given the large amounts of data, connections and dependencies, it seems logical that the resilience monitor would be an ICT-supported instrument. Both the technical aspects of such an instrument as well as the usability need to be developed and tested with great care.

Conducting pilots

We recommend to start conducting pilots at an early stage in order to test the usability of the instrument. These pilots can provide answers to questions about the integration of all required data, the comprehensibility of the visualisations, as well as to which extent the data support the decision-making process.

Maintaining and updating the resilience monitor

When a full version of the resilience monitor has been developed, it is essential to continuously evaluate and update the instrument. Evaluations of national and international crises should be incorporated, keeping in mind that it is important to evaluate not only directly after the crisis but also months and years later to really assess the quality of resilience and adaptivity. Moreover, results of scientific research on resilience need to be incorporated.

Expanding the resilience monitor

The reliability of the resilience monitor will improve when incorporating more comprehensive and varied data. This will enable providing more intelligent support to users, like simulations and decision support tools. Human users will still make the final decisions, but more extensive support can be offered by the system.