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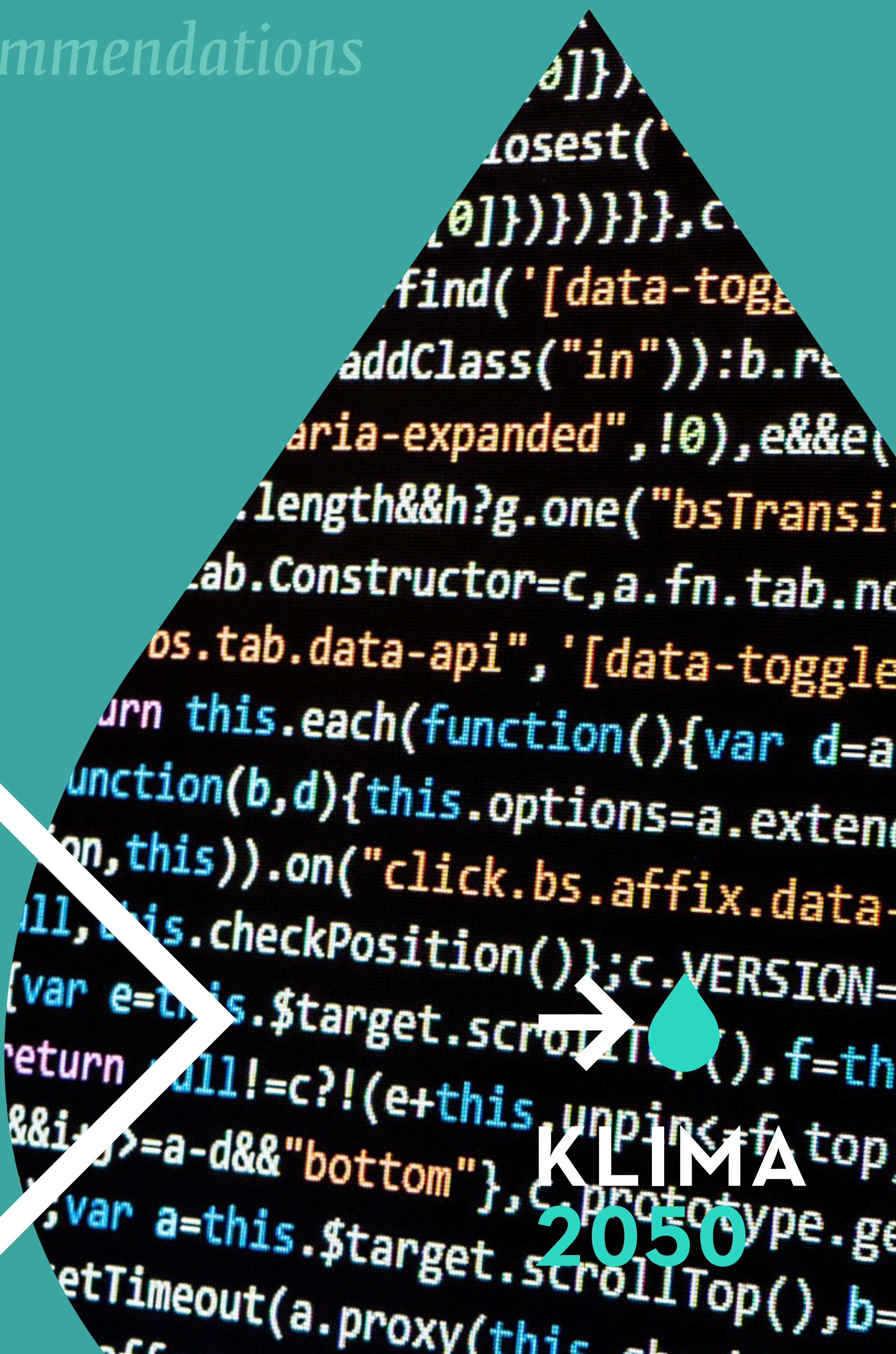
REPORT

STORMWATER-RELATED DATABASES

– *Review and Recommendations*

Nathalie Labonnote



KLIMA 2050

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Stormwater-related databases
– Review and Recommendations
Nathalie Labonnote
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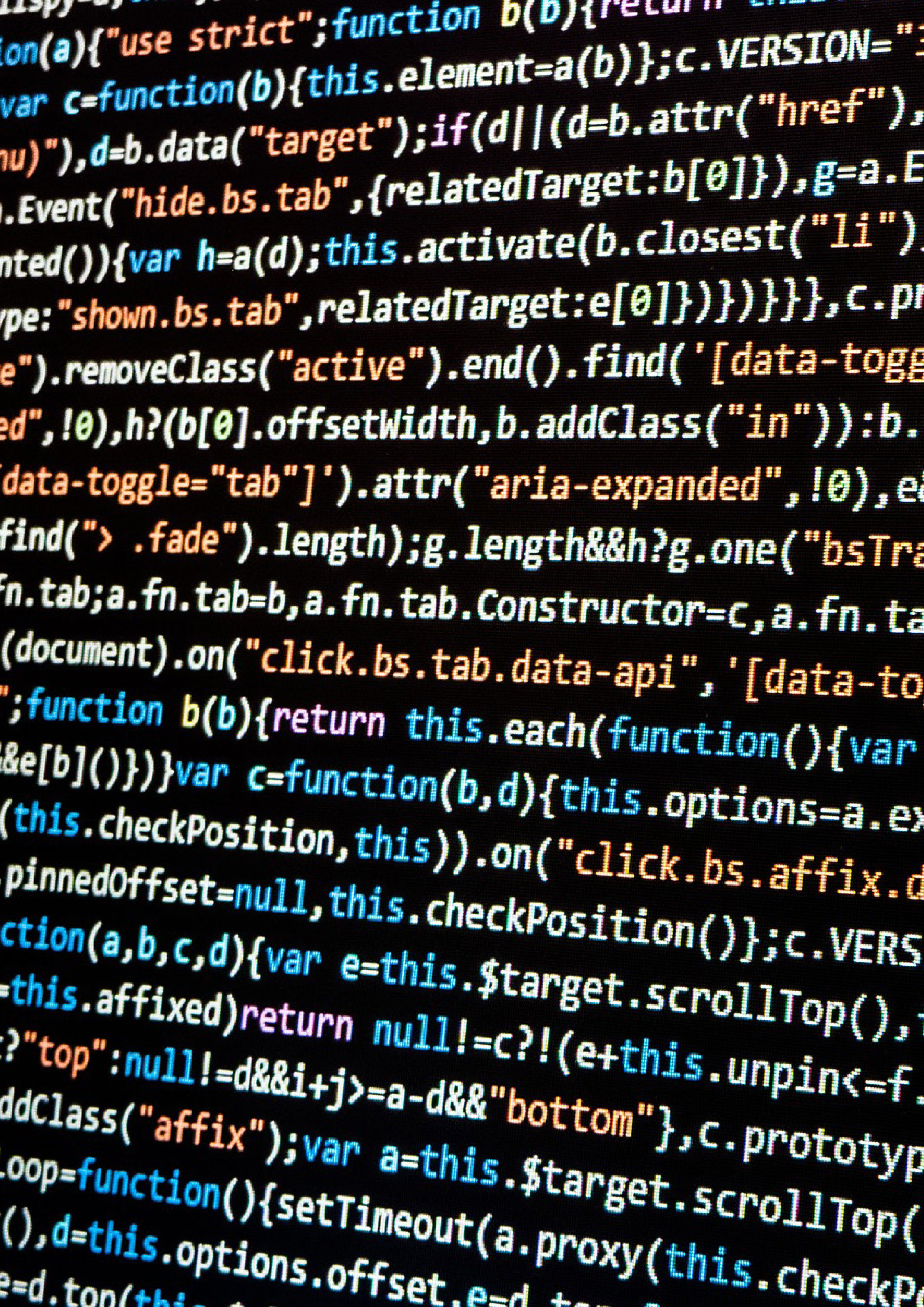

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Preface

Society requires innovation, which will support a resilient and robust stormwater infrastructure, capable of meeting the challenges provided by a changing climate. This implies development of new and innovative principles, products, solutions and processes for better stormwater management. Procedures for flood damage are difficult because liabilities and responsibilities are often ambiguous. The number of urban flooding incidents and damage due to these incidents has increased significantly the last years due to increasing property values of buildings, extended use of buildings (i.e. basements), more deliberate property owners and more intense rainfall.

This report describes the motivations and challenges when organizing information on flooding damage. It also proposes a grid for evaluating the existing databases. The last section is dedicated to establishing guidelines for flooding damage database. Most of this report is based on a review on the state-of-the-art.

Klima 2050 - Risk reduction through climate adaptation of buildings and infrastructure is a Centre for Research-based Innovation (SFI) financed by the Research Council of Norway and the consortium partners. The SFI status enables long-term research in close collaboration with private and public sector, as well as other research partners aiming to strengthen Norway's innovation ability and competitiveness within climate adaptation. The composition of the consortium is vital to being able to reduce the societal risks associated with climate change.

The Centre will strengthen companies' innovation capacity through a focus on long-term research. It is also a clear objective to facilitate close cooperation between R&D-performing companies and prominent research groups. Emphasis will be placed on development of moisture-resilient buildings, stormwater management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision-making processes. Both extreme weather and gradual changes in the climate will be addressed.

The host institution for SFI Klima 2050 is SINTEF, and the Centre is directed in cooperation with NTNU. The other research partners are BI Norwegian Business School, Norwegian Geotechnical Institute (NGI), and Norwegian Meteorological Institute (MET Norway).

The business partners represent important parts of Norwegian building industry; consultants, contractors and producers of construction materials: Skanska Norway, Multiconsult AS, Mesterhus/Unikus, Norgeshus AS, Saint-Gobain Byggevarer AS, Powell, Skjævelandsgruppen and Isola AS. The Centre also includes important public builders and property developers: Statsbygg, Statens vegvesen, Jernbanedirektoratet, Trondheim municipality and Avinor AS. Key actors are also The Norwegian Water Resources and Energy Directorate (NVE), and Finance Norway.

Thanks to all involved experts, partners and colleagues for contributions!

Trondheim, April 2017.

Berit Time
Centre Director
SINTEF Building and Infrastructure

Summary

Floods and stormwater events are the costliest natural catastrophes. Costs are expected to increase due to urbanization and climate change. Mitigation is needed, and is already on-going in certain cases. Different stakeholders with different motivations unfortunately often evaluate vulnerability by using fragmented and incomplete data sources. This report intends to review the different approaches for collecting and analysing data, and to evaluate their usefulness within the proposed framework for a "smart" use of data.

The objectives of this work have been:

- to describe a selection of event-based databases related to floods,
- to review qualitatively and quantitatively a selection of national object-based databases,
- to evaluate the current Norwegian situation and to propose measures for improvement.

This study has shown that data are spread around a heterogeneous community of stakeholders concerned with different motivations, different needs, and different levels of data processing. In general, the needs of the different stakeholders have not been surveyed and defined systematically enough. Regarding international flood databases, there is still a substantial demand for a standardized and systematic collection of flood damage data with clearly defined and documented procedures. Regarding national stormwater-related inventory databases, there is a substantial potential in upgrading from the delivery of passive raw data to the delivery of knowledge-driven decision-support tools.

Further work should aim at:

- Exploiting more efficiently available sources of data and exploring alternative sources of data,
- Achieving a more efficient transformation of data into knowledge via the development of analytical tools that match the identified needs of relevant end-users by efficiently processing several relevant sources of data,
- Providing ergonomic and user-friendly digital solutions to support workers in their daily tasks and to efficiently document the actions within the system, and
- Triggering the implementation of evaluation processes within the national agencies for business purposes, and at a national scale for providing the policymakers with useful knowledge about the societal risks associated with climate changes.

Technical challenges can relatively easily be solved by digitization and its opportunities for improvement of the workflow and for higher quality of data. Organisational challenges must be solved by an end-users-focused approach to identify needs and expectations.

The task WP2.1 intends to be a catalyser within Klima 2050 project for triggering a global data-driven evaluation system to provide policymakers with knowledge on societal risk associated with climate change, and for strengthening national agencies and private companies' innovation capacity for addressing climatic changes.

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1 Contexts

1.1 Stormwater in the general context of the project Klima 2050

1.1.1 Background

Floods defy a common categorization. High tide, storm surge, overflow or breaks of embankments, dam failure, and extreme precipitation with impeded outflow have in common that land is temporarily submerged where this normally doesn't or shouldn't happen [1]. The frequency of, and damage caused by floods is expected to increase because of climate change – increase and change in precipitation and pattern – and because of urban development – unknown changes in land use within the catchment combined with dynamic erosion and transport of particles. There still exist a number of limitations in the understanding of precipitation patterns in a changing climate, and this impairs the design, maintenance, operation and renewal of critical infrastructure and stormwater systems [2].

The modern flood risk management approach acknowledges that floods cannot be stopped from occurring. It places emphasis instead on how to reduce hardship and vulnerability of risk-prone communities. This shift is also backed by the European Union's Directive on the assessment and management of flood risks (EC 2007a [3]). The Directive highlights the need of flood management plans to consider the harmful potential of floods and to identify tangible measures able to reduce exposure and sensitivity to floods, and to improve risk governance. In short, effective mitigation of the negative consequences of floods requires flood risk analyses as a prerequisite [4].

Globally, floods rank among the most serious natural hazards worldwide in terms of economic losses and loss of life. Procedures for flood damage are in general difficult because liabilities and responsibilities are often ambiguous. More specifically, stormwater damage has increased significantly the last years due to increasing property values of buildings, extended use of buildings – i.e. basements –, more deliberate property owners and more intense rainfall. New solutions are therefore needed to cope with intense storms and to reduce the risks to people, buildings and infrastructure [5] (see Figure 1).

Figure 1: Stormwater-induced risks to people, buildings and infrastructure © pixabay.com

1.1.2 Need for an increased knowledge

To help researchers and policy makers assess national progress in reducing vulnerability to flood hazards, reasonably accurate assessments of flood damage are needed [6]. However the actual need of knowledge varies greatly between stakeholders and sometimes between decisions [7]:

- Those who are implementing flood risk management measures may want to consider all benefits and costs measures in their decisions. Since the most important benefit of flood risk management measures is the reduction in flood damages, they may be interested in existing flood damage evaluations in the context of project appraisals.
- National ministries and provincial governments responsible for flood risk management policy must account for tax money spent on flood protection. Consequently, they want to quantify flood damage to demonstrate that government spending for flood risk management schemes is beneficial to the public, and that it contributes to the avoidance of millions of euros of flood damage every year.
- Emergency planners need to identify where the areas critical to flood damage are and hence where emergency action should be concentrated. They also need to identify which areas may have to be sacrificed in order to protect others.
- Governments of a nation hit by a flood event need to know afterwards how serious the flood was, which damages happened and how large the total amount of loss for the nation and the economy was. Such calculations are used to inform policy makers, and may also be used as a basis for the allocation of compensation payments to flood victims.
- Insurance companies are also highly interested in flood damage calculations. However, contrary to the government perspective, insurance companies are not interested in national loss but in insured financial loss referring to their clients. They need flood damage data to assess the flood risk of properties and to specify premium levels for insurances.
- Last but not least private firms and even private house owners (see Figure 2) are also interested in the amount of damages that potential floods events might cause to their property. Based on this information they can judge whether it is worthwhile to take out a flood insurance policy or to bear the costs of private flood protection measures.

Figure 2: Private house owners need an increased knowledge (source unknown)

At least three different levels have therefore different needs for increased knowledge:

- The national level addresses the needs of policy makers. The Norwegian National Government has indeed constituted a committee who had to report on stormwater in 2015. This white paper has been published as an Official Norwegian Report (*Norges Offentlige Utredninger*) with number NOU 2015:16 [8].
- The local level addresses the needs of municipalities e.g. for urban planning issues.
- The individual level addresses the needs of private firms and private owners.

Increased knowledge is needed for implementing measures of different types, among others:

- Prevention and protection [1]:
    - by shedding light on practices that drive vulnerability and risk,
    - by identifying the pathways through which the economic and social hardship is spread beyond the directly affected area,
    - by increasing awareness about what is at stake,
    - by informing in understandable ways about special measures required and restrictions on construction in flood areas.
- Preparedness [1]:
    - by helping to budget resources for development of early warning and alerting systems, and for managing emergencies,
    - by allowing to better tailor the information provided for different communities and groups,
    - by setting up an effective and reliable system of flood forecasting,
    - by rationalizing decision-making to serve the purposes of humanitarian action [9],
- Response [1]:
    - by helping to decide – and legitimize – how much resources need to be deployed to manage properly the emergency situations and constrain the damage and hardship suffered,
- Recovery, mitigation and review [1]:
    - by driving the information collection during and after the emergency,
    - by deciding which investments can most effectively boost the recovery and welfare contributions to most vulnerable groups.

Results of access to such an increased knowledge can be evaluated according to at least three different levels [10]:

- Academic: Improved, transferable methods of forecasting floods and estimating damage,
- Water management practice: Recommendations at a global scale in the form of manuals,
- Local: Support for flood prevention at a local geographical scale.

1.1.3 Definitions

The following definitions are used in this report:

- Adaptation: The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities [11].
- Climate change: A change in the climate that persists for decades or longer, arising from either natural causes or human activity [11].
- Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceed the ability of the affected community or society to cope using its own resources [11].

- Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses [11].
- Flood: temporary covering by water of land not normally covered by water [3].
- Mitigation: The lessening or limitation of the adverse impacts of hazards and related disasters [11].
- Natural hazard: natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage [11].
- Preparedness: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions [11].
- Prevention: The outright avoidance of adverse impacts of hazards and related disasters [11].
- Public awareness: Management activities that address and seek to avoid the development of new or increased disaster risks [11].
- Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions [11].
- Response: The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impact, ensure public safety and meet the basic subsistence needs of the people affected [11].
- Risk: The combination of the probability of an event and its negative consequences [11].
- Risk Assessment: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend [11].
- Risk Management: the systematic approach and practice of managing uncertainty to minimize potential harm and loss [11].
- Stormwater (also referred to as "urban flooding" or "pluvial flood"): when rain overwhelms drainage systems and waterways and makes its way into the basements, backyards, and streets of homes, businesses, and other properties. There are several ways in which stormwater can cause the flooding of a property: overflow from rivers and streams, sewage pipe backup into buildings, seepage through building wall and floors, and the accumulation of stormwater on property and in public rights-of-way [12].
- Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures and systems [11].
- non-Structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular though policies and laws, public awareness raising, training and education [11].
- Urban environment: the region surrounding a city, which usually exhibits a high density of human structures such as houses, commercial buildings, roads, bridges and railways [13].
- Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effect of a hazard [11].

1.2 Data-related contexts

1.2.1 Data-related definitions

Knowledge should ideally be shared and located in a unique repository. This is actually one of the many definitions for a database. In general, databases enable individuals both to explicitly encode their knowledge and to retrieve knowledge they need from other individuals [14]. Perhaps the most famous database in the world is Google, whose core mission is to organize the world's information [15]. The main goal of any database is decision support.

The following general definitions are used in this report:

- Aggregation: A process of searching, gathering and presenting data [16].
- Algorithm: A mathematical formula placed in software that performs an analysis on a set of data [16].
- API: "Application Programing Interface": a set of procedures that allow the creation of applications which access the features / data of an operating system [17].
- Artificial Intelligence: Developing intelligence machines and software that are capable of perceiving the environment and take corresponding action when required, and even learn from those actions [16].
- Big Data: high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation [18].
- Cloud computing: A distributed computing system over a network used for storing data off-premises [16].
- Cloud: a broad term that refers to any Internet-based application or service that is hosted remotely [16].
- Data access: the act or method of viewing or retrieving stored data [16].
- Dashboard: A graphical representation of the analyses performed by the algorithms [16].
- Data aggregation: The act of collecting data from multiple sources for the purpose of reporting or analysis [16].
- Database: a digital collection of data and the structure around which the data are organized. The data are typically entered into and accessed via a database management system [16].
- Database administrator: a person, often certified, who is responsible for supporting and maintaining the integrity of the structure and content of a database [16].
- Database management system: software that collects and provides access to data in a structured format [16].
- Data cleaning: the act of reviewing and revising data to remove duplicate entries, correct misspellings, add missing data, and provide more consistency [16].
- Data collection: any process to captures any type of data [16].
- Data-directed decision making: Using data to support making crucial decisions [16].
- Data integration: The process of combining data from different sources and presenting it in a single view [16].
- Data integrity: The measure of trust an organization has in the accuracy, completeness, timeliness, and validity of the data [16].
- Data mining: The process of deriving patterns or knowledge from large data sets [16].
- Data quality (see Figure 3): The measure of data to determine its worthiness for decision making, planning, or operations [16].
- Data replication: The process of sharing information to ensure consistency between redundant sources [16].
- Data science: A recent term that has multiple definitions, but generally accepted as a discipline that incorporates statistics, data visualization, computer programming, data mining, machine learning, and database engineering to solve complex problems [16].
- Data security: The practice of protecting data from destruction or unauthorized access [16].

- Data source: Any provider of data, for example a database [16].
- Data structure: A specific way of storing and organizing data [16].
- Data visualization: A visual abstraction of data designed for the purpose of deriving meaning or communicating information more effectively [16].
- Document Store Database: A document-oriented database that is especially designed to store, manage and retrieve documents, also known as semi-structured data [16].
- Document management: The practice of tracking and storing electronic documents and scanned images of paper documents [16].
- Internet of Things: Ordinary devices that are connected to the internet at any time anywhere via sensors [16].
- Machine learning: The use of algorithms to allow a computer to analyse data for the purpose of "learning" what action to take when a specific pattern of event occurs [16].
- Metadata: Data about data, i.e. gives information about what the data are about [16].
- Predictive analytics: Using statistical functions on one or more datasets to predict trends or future events [16].
- Predictive modelling: The process of developing a model that will most likely predict a trend or outcome [16].
- Query: Asking for information to answer a certain question [16].
- Query analysis: the process of analysing a search query for the purpose of optimizing it for the best possible result [16].
- Real-time data: Data that is created, processed, stored, analysed and visualized within milliseconds [16].
- Server: A physical or virtual computer that serves requests for a software application and delivers those requests over a network [16].

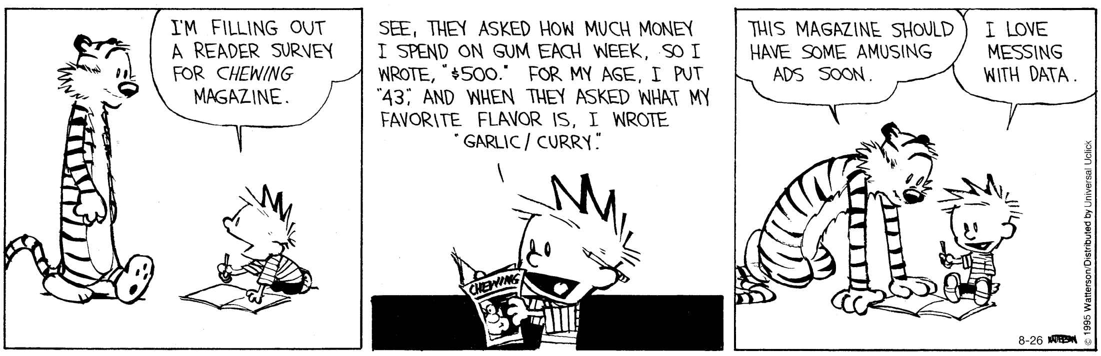

Figure 3: Data quality, CALVIN AND HOBBES © 2015 Watterson. Reprinted with permission of ANDREWS MCMEEL SYNDICATION. All rights reserved.

1.2.2 Data quality

The quality of data is a central question when working with databases. The organisation for data professionals in the UK [19] has defined six best practice definitions as generic data dimensions:

- Completeness: the proportion of stored data against the potential of "100% complete". May be measured by the absence of blank values.
- Uniqueness: no data item will be recorded more than once based upon how that data item is identified. May be measured as the difference between the number of data items as assessed in the "real world" compared to the number of records of data items in the data set.
- Timeliness: the degree to which data represent reality form the required point in time. May be measured as the time difference between when a data item is implemented in the dataset compared to the real time occurrence of the data item.

- Validity: whether or not a data item conforms to the syntax (format, type, range) of its definition. May be measured by comparing between the data and the metadata or documentation for the data item.
- Accuracy (see Figure 4): the degree to which data correctly describe the "real world" object or event being described. May be measured as the degree to which data mirror the characteristics of the real work object(s) it represents.
- Consistency: the absence of difference, when comparing two or more representations of a thing against a definition. May be measured via an analysis of pattern and/or value frequency.

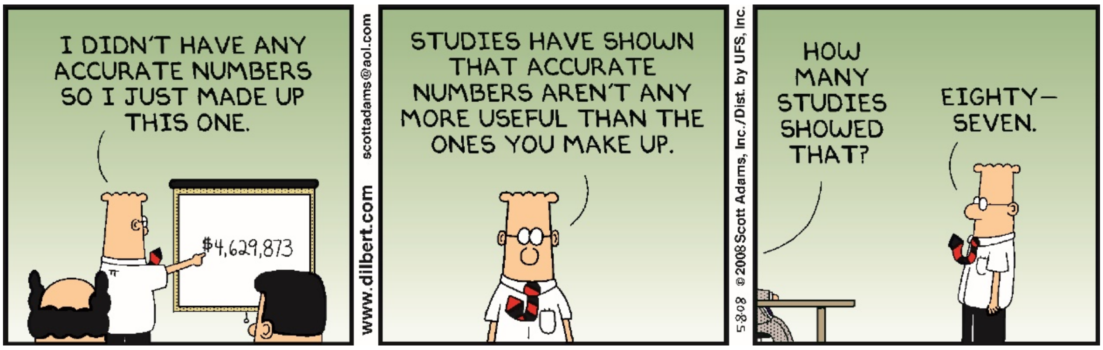

Figure 4: Data accuracy, DILBERT © 2008 Scott Adams. Used By permission of ANDREWS MCMEEL SYNDICATION. All rights reserved.

1.2.3 Challenges for stormwater- and flood-related data

Completeness is most likely the largest challenge met when manipulating stormwater- and flood-related data:

- A lot of flood damage data sets are surveyed by governmental agencies and insurance companies in the framework of loss compensation, but these datasets have to be supplemented with additional information on the hazard impact etc. in order to be useful for damage and risk modelling or planning purposes [20].
- Empirically derived damage models often suffer from a lack of information about damage caused by very extreme events (due to their natural rareness) and hence are not very accurate in estimating the impact of such events [4]. On the other hand, frequent events often do not cause enough damage in a single event to trigger assessment campaigns. Both effects cause bias as the real occurrence of flood damage is not realistically mirrored in the damage data sets [4].
- Potentially the most serious source of error is the lack of systematic, reliable methods for obtaining damage estimates [8, 21]. Staff who collect the estimates have little or no training in damage estimation and rely on diverse sources. Estimation methods used by their sources are unknown, and estimates are usually finalized long after a flood event and are not compared with records of actual damage costs. An overall tendency to underestimate total damage is expected because of incomplete reporting and the omission of some floods.

Accuracy is particularly challenging within the context of estimation of flood-related damages:

- While costs typically refer only to cash pay-outs from insurers and governments, losses encompass a broader set of damages and better portray the true economic impacts of disasters. Losses include direct physical destruction to property, infrastructure, and crops, plus indirect losses that are the consequence of disasters, such as temporary unemployment and lost business [8].

- Information on both direct and indirect losses is lacking. The understanding of indirect losses is even more incomplete since data on uninsured direct losses are limited [8].
- Indirect losses are clearly difficult to identify and measure. However, in large disasters they may be significant and, within the immediately affected regions, potentially greater than the direct losses due to physical destruction, especially in large disasters [22]. For example if a bridge is destroyed by flooding, hurricane, its replacement cost is clearly part of the event's total losses [22]. But should economic losses to local businesses due to the lost bridge be included? What about the extra miles (and the extra cost of gasoline) that people must drive to their homes and businesses? Should the economic gains to a local bridge construction company be counted against the losses? This issue is critical since it has been observed that poor knowledge of the resulting economic losses hinders implementation of effective disaster mitigation policies and emergency response programs [22]. The white paper for stormwater NOU 2015:16 [8] discussed this issue thoroughly, and intended to estimate total cost of damage due to the break of the flooding of the railway in Gudbrandsdalen in May 2013. The direct losses were calculated to be 176 millions Norwegian kroner, whereas the indirect losses were estimated to reach 205 millions Norwegian kroner, more than 50 % of the total losses.
- Due to the limited sources of indirect loss data, statistical models are often used to compile indirect loss estimates. Though these models may help address problems due to a lack of available data, they must become more reliable if they are to be used as guides in setting mitigation and other hazard-related policies [22].
- In addition, it is often impossible to separate damage by flood and that from other storm-related causes [21]. For example, the National Weather Service in the USA labels the full amount as flood damage if heavy rain or river flows are considered the primary cause. Conversely, flood damage may be omitted if the major cause is wind (hurricanes, tornadoes), hail, snow, or ice. These uncertainties can lead to incompatibility with data from other sources.

During and after a disaster, different reasons and varying motivations to assess losses like the support for victims, adjustment of insured losses, scientific loss modelling and planning purposes lead to specific foci in the assessment of losses. This results in incomparable, isolated data sets, hosted in different ways by many organizations, by different stakeholders, for multiple purposes, and at different times. **Consistency** issues arise when trying to integrate data from these isolated datasets.

Timeliness remains a major challenge when establishing a framework for the continuous assessment of flood damage. Damage assessment needs to become independent from occasional interest, temporary resources and assessment campaigns to retrieve an up-to-date data set that describes flood damage representatively.

1.2.4 Usefulness of data

The effective use of data is another dimension that needs to be investigated to check whether or not data achieve the given objective. The organisation for data professionals in the UK [19] identified five crucial questions to measure the usefulness of data:

- Usability of the data: is it understandable, simple, relevant, accessible, maintainable and at the right level of precision?
- Timing issues with the data (beyond timeliness itself): Is it stable yet responsive to legitimate change requests?
- Flexibility of the data: Is it comparable and compatible with other data, does it have useful groupings and classifications? Can it be repurposed, and is it easy to manipulate?

- Confidence in the data: Are Data Governance, Data Protection and Data Security in place? What is the reputation of the data, and is it verified or verifiable?
- Value of the data: Is there a good cost/benefit case for the data? Is it being optimally used? Does it endanger people's safety or privacy or the legal responsibilities of the enterprise? Does it support or contradict the corporate image or the corporate message?

The previous questions may (at least partially) be addressed by considering the data cycle (see Figure 5) that illustrates the theory of "Data-Information-Knowledge continuum" [23]. According to Westfall [24], **data** items are simply "facts" that have been collected in some storable, transferable, or expressible format. Data simply exists and has no significance beyond its existence (in and of itself) [25].

Information is "data in context" [26], for which meaning has been given by way of relational connections [25]. For example [24], a data item stored as the number 53 does not by itself provide us with any usable information. By adding context, e.g. a definition such as "the number of centimetres water has risen"; a timeframe such as "in July 2013"; and relevance such as "after a heavy rain event in Oslo"; that data item is converted to information.

Information in and of itself is not useful until human intelligence is applied to convert it to knowledge through the identification of patterns and trends, relationships, assumptions, and relevance [24]. Information is that water rose up to 53 cm in Oslo after a heavy rain event in July 2013. Knowledge is obtained when comparing this piece of information with the previous water levels (trend) after heavy rain events (relationships), and when it is concluded that a corrective action is needed (assumption) resulting in an improvement of urban drainage systems (relevance). **Knowledge** is eventually the appropriate collection of information such that its intent is to be useful [25].

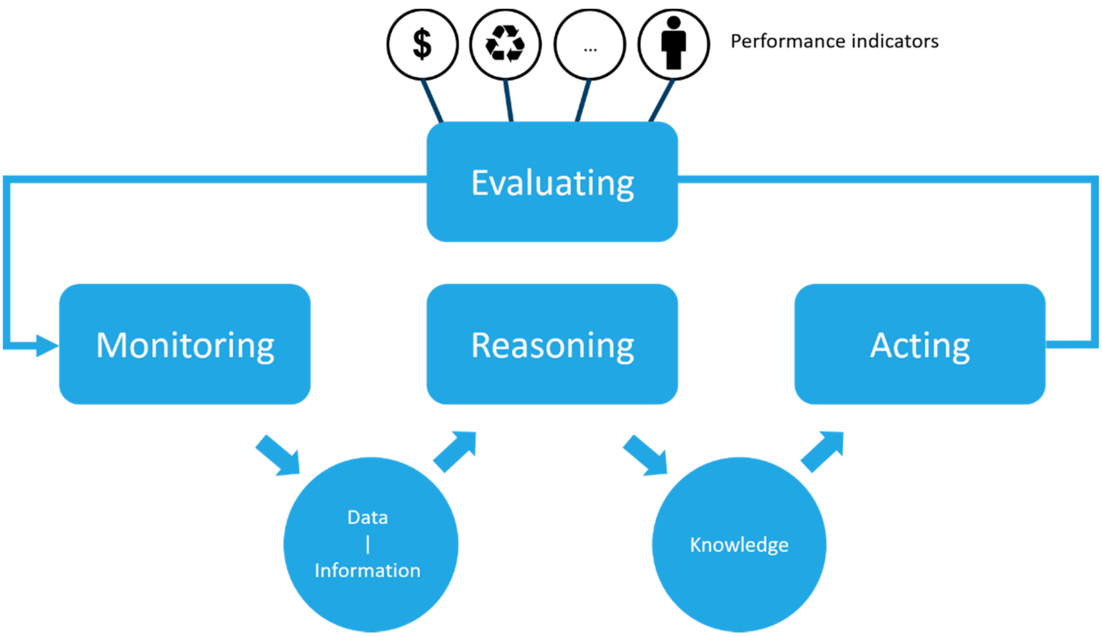

Figure 5: Schematic representation of a smart use of data cycle

Figure 5 shows different data-related processes:

- Monitoring is defined as a short term collection of data and information, which does not take into account outcomes and impact. Data may come from sensor measurements, human observations, or data exchange with other databases. Data may be collected with different time-schedules and different time delays, e.g. real time or once a year for the previous year.

- Reasoning is defined as any data analytic process that enables to transform data into valuable knowledge. In such a process, relevant data are extracted and categorized, and then used to identify behavioural patterns by different techniques, e.g. data mining, forecasting, statistical analysis, optimization, simulation, etc. Reasoning also includes data visualization techniques to help people understand the significance of data by placing it in a visual context.
- Acting is defined as the short-term result of access to new knowledge. End-users are usually expected to take decisions, which can then create specific tasks to be performed by specific persons or specific equipment. The decision may be taken within the reasoning process, as part of generation of new knowledge.
- Evaluating is defined as the process to assess outcomes and long-term impact of previous actions, decision and data collection. The evaluating process is a management tool.

1.3 Motivation and objectives

Floods and stormwater events are the costliest natural catastrophes. Costs are expected to increase due to urbanization and climate change. Mitigation is needed, and is already on-going in certain cases. Different stakeholders with different motivations unfortunately often evaluate vulnerability by using fragmented and incomplete data sources. This report intends to review the different approaches for collecting and analysing data, and to evaluate their usefulness within the proposed framework for a "smart" use of data (see section 1.2.4).

The objectives of this work have been:

- to describe a selection of event-based databases related to floods (see Chapter 2),
- to review qualitatively and quantitatively a selection of national object-based databases (see Chapter 3),
- to evaluate the current Norwegian situation and to propose measures for improvement (see Chapter 4).

2 A selection of flood-related databases

This chapter describes a wide selection of databases that contain flood-related data. Flood-related data are loosely defined as data on events where excessive water or humidity ingress might be assessed as one cause for damage among other potential causes. The different databases are ranked per their geographical extent: Norway (see Figure 6), Europe (see Figure 6), and lastly world (see Figure 7). The following properties are given for each one of the selected relevant flood-related databases:

- Short description of content: Who, what, where, when,
- Motivation for building the database, and
- Availability, user interface, possibility for downloading data.

Figure 6: Flood-related databases in Europe

2.1 NASK / Norway

- In Norway, any building or property insured against fire damage is automatically also insured against natural disasters in accordance with the Natural Disaster Insurance Act. The scheme is administered by the Norwegian Natural Perils Pool [27] where all insurance companies in Norway are members. All individual claims that are covered through natural disaster insurance are registered in the NASK database via the Norwegian Natural Perils Pool. A large event, like a flood or severe storm, tends to result in thousands of individual claims. The NASK database shows either number of claims or the total estimated paid compensations, and is updated quarterly. A short delay in notification of damage to the insurance companies and reporting to the Norwegian Natural Perils Pool may occur.

- NASK database can be used by policyholders to secure claims on natural damage caused by landslides, storms, floods, storm surges, earthquakes and volcanic eruptions.
- The NASK database is accessible from: https://nask.fno.no/default.aspx. Data are displayed in table format, which can be exported to excel.

2.2 VASK / Norway

- The VASK database is dedicated to damages due to water in buildings and uses data from the largest insurance companies in Norway [28]. All major insurance companies in Norway have provided data to VASK from 1 January 2008. Together these companies cover more than 85% of the Norwegian market [29]. Only injuries that are adequately coded are included. The VASK database shows either number of claims or the total estimated paid compensations, and is updated quarterly. A delay between notification of damage to the insurance companies, payment of compensation, and registration into the database may occur. The figures are weighted so that the number of claims and the estimated claims presented in VASK harmonizes with what is presented in the Finans Norges quarter publication "Skadestatistikk for landbasert forsikring" [30]. The damages are coded into three main levels: the affected installation (which corresponds to a rough location for where the damage occurred), the source (which corresponds to a description of what was damaged), and the cause (which corresponds to the primary cause of the damage). Natural disasters, such as floods, are however not directly coded into the database.
- The VASK database intends to make it easier to follow the development of damages due to water.
- The VASK database is accessible from: https://www.fno.no/statistikk/skadeforsikring/vask/. Data are presented in table format, which can be exported to excel.

2.3 The National Database for Buildings Quality / Norway

- A comprehensive review of process-induced building defects investigated by SINTEF Building and Infrastructure in the 10-year period 1993–2002 (2,423 cases registered and described in 2,003 assignment reports) has been undertaken by Lisø et al. [31]. SINTEF Building and Infrastructure's archive contains information on more than 33,000 projects in a wide range of disciplines. The institute has undertaken analyses of building defects for more than 50 years, both on behalf of the construction industry and in comprehensive field investigations. The following key data are registered electronically: client, project number, project leader, report date, age of the building, building address, construction method, keywords and summary. The database is not only dedicated to damages caused by floods, but deals with any process-induced building defects exhibiting excessive humidity.
- The National Database for Building Quality intends to monitor better the development of process-induced building defects.
- Information on these assignments is filed in the institute's central archive, and is registered electronically in the SQL-server database. Data are not publicly accessible.

2.4 The Anticimex Building Statistics report / Norway

- Anticimex is an international service company for both businesses and consumers which operates in the areas of pest control, food safety, building environments, fire protections and insurance. Anticimex's aim is to create a safe and healthy indoor environment through inspections, guarantees and insurance agreements [32]. Anticimex prepared in 2006 a technical report [33] based on statistics calculated from their own inspection database. Inspection reports for all buildings inspected by

Anticimex between 01.01.2003 to 31.12.2005 were taken into account. This represents a total of 8895 reports. The database does not provide any cause for the state of the building inspected, but gives a gross picture of the state of housing in Norway.

- The main motivation for the report was to describe the actual structural condition in Norwegian homes, to educate the individual property owner about what might be important to note, and to give homebuyers a realistic picture of what they can expect when buying a home.
- Data itself is not publicly accessible, but the report is accessible from: http://www.anticimex.com/en/SysSiteAssets/no/boligstatus_2006_storrediagram.pdf

2.5 The SurgeWatch database / UK

- The University of Southampton, the National Oceanography Centre and the British Oceanographic Data Centre have compiled a database of UK coastal flood events and built a website called ‘SurgeWatch’ [34]. Surge Watch provides a systematic UK-wide record of high sea level and coastal flood events over the last 100 years (1915-2014). Using records from the National Tide Gauge Network, with a dataset of exceedance probabilities and meteorological fields, SurgeWatch captures information of 96 storms during this period, the highest sea levels they produced, and the occurrence and severity of coastal flooding.
- The main motivation for the database is to provide a better understanding of coastal flooding to a range of users including, scientists, coastal engineers, managers and planners and concerned citizens [35].
- Data are presented within a timeline featuring all events. The SurgeWatch database is accessible from: http://www.surgewatch.org/. There are no possibilities for exporting data.

2.6 The Swiss flood and landslide damage database / Switzerland

- In Switzerland, floods, debris flows, landslides and rock falls cause damage every year affecting property values, infrastructure, forestry and agriculture. As population and settled areas have increased, the damage potential has also become greater. Since 1972 the Swiss Federal Research Institute WSL has been systematically collecting and analysing this damage on behalf of the Federal Office for the Environment. Damage originating from naturally triggered floods, debris flows, landslides and rock falls have been considered. Damage from avalanches, snow pressure, earthquake, lightening, hail, windstorm and drought is not considered. The corresponding weather conditions are also noted in the database. The database currently exhibits more than 20'000 entries [36]. The estimated direct financial damage as well as fatalities and injured people have been documented using press articles as the main source of information. The database can be analysed in terms of location, extent, causes and the temporal and spatial distribution of the storm events.
- The database intends to act as a source for a broad information basis for hazard assessment [36]. The database intends to provide answers to questions related to the temporal and spatial distribution of damage, natural hazard processes and the corresponding weather conditions [37].
- Damage data are not publicly available but are provided to official institutions on request. The results are published yearly in the Journal "Wasser Energie Luft".

2.7 The HOWAS database / Germany

- Guidelines for standardized assessment of flood damage were drawn up in Elmer's PhD thesis [4] and enabled the development of a flood damage database for Germany: HOWAS 21 via the project MEDIS: Methods for the evaluation of direct and indirect flood losses [10]. HOWAS 21 is a property-specific flood damage database for Germany that was released in 2009. In addition to the monetary damage incurred for residential buildings, furnishings, businesses and other premises, HOWAS 21 contains data on the impact of an event on a property, on the damaged property itself and on damage minimization [10]. Every case of damage is also assigned to an overall flood event and to a data acquisition campaign. The attributes in HOWAS 21 are based on checklists specified for each sector by a multi-stage expert survey. The database was developed in cooperation with the Helmholtz EOS networking platform for natural disasters: NaDiNe [38].

- The main motivation of HOWAS 21 is to gain a better understanding of the occurrence of flood damage and to assess the effectiveness of preventive measures. In addition, a web-based flood damage data acquisition was developed to increase public awareness and to promote the documentation of flood events to improve both flood prevention and flood management.
- The HOWAS 21 database used to be accessible from: http://nadine.helmholtz-eos.de/, but this is unfortunately not the case anymore.

2.8 The National Flood Data Archive / Ireland

- Over 50 different stakeholder organizations, including governmental and local authorities, national organizations, insurance companies and members of the public were consulted by the Office of Public Works so they could provide a range of information about past flood events. This information includes engineers' reports, letters, articles, minutes of meetings, photographs, eye-witness accounts and documents. All the flood information gathered was catalogued, reviewed, classified and made digitally available into one collection, the National Flood Data Archive.
- The main motivation for the National Flood Data Archive was to develop historic flood hazard maps by gathering as much information as possible on flooding throughout the country from any organizations. The targeted use was to identify areas at risk of flooding and to make decisions about land use and development. The targeted end-users were planners and general public.
- The National Flood Data Archive is accessible from: http://www.floods.ie/View/Default.aspx. The user can download reports, but cannot export data. The user interface is provided by ESBI Computing[1].

2.9 The AVI project / Italy

- The AVI database collects more than 18 000 data items on landslides and floods. More than 300 people, divided into 15 research teams and two support groups, worked for one year on the AVI project. Twenty-two journals were systematically searched for the period 1918-1990, 350000 newspaper issues were screened, and 39953 articles were collected. About 150 experts on mass movement and floods were interviewed and 1482 published and unpublished technical and scientific reports were reviewed. The results of the AVI project represent the most comprehensive archiving of landslides and floods ever prepared in Italy. The type and quality of the information collected and the methodologies and techniques used to make the inventory are discussed. Possible applications and future developments are also presented [39].
- The AVI project was commissioned by the Minister of Civil Protection to the National Group for Prevention of Hydrogeologic Hazards to complete an inventory of areas historically affected by landslides and floods in Italy. The project goal was to distribute historical information.
- The AVI database is accessible from: http://avi.gndci.cnr.it/en/archivi/frane_en.htm. Data can be downloaded as Microsoft Access files. More data can be downloaded within the website for hydrogeological catastrophes: http://sici.irpi.cnr.it/.

[1] www.esbic.ie

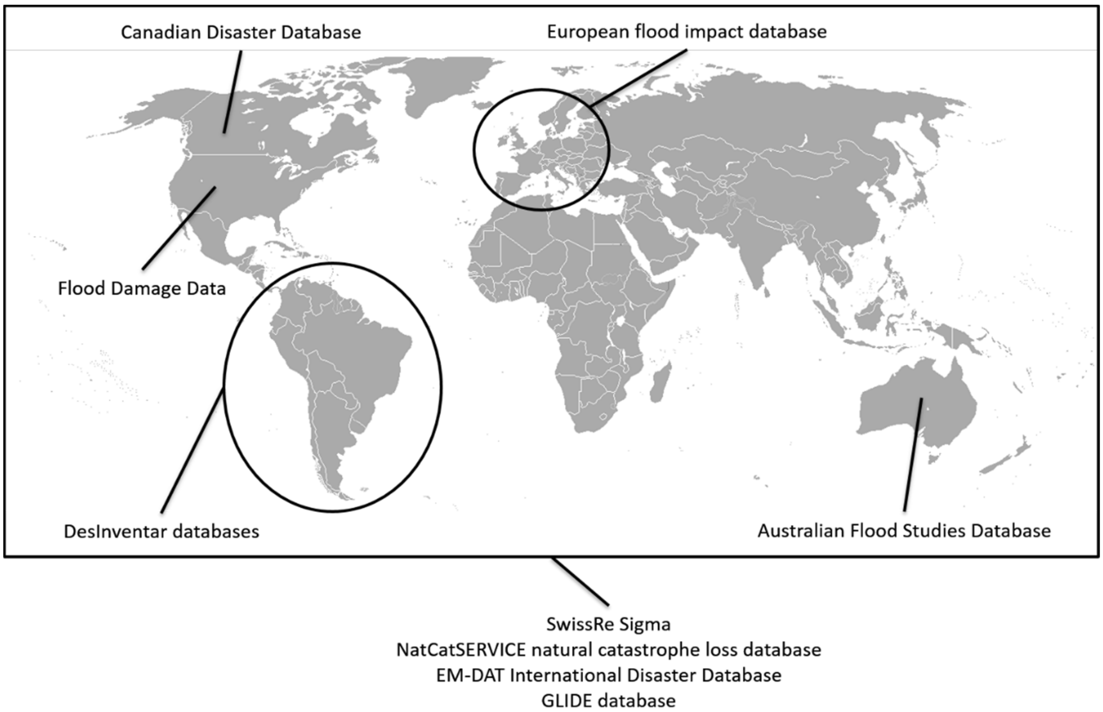

Figure 7: Flood-related databases in the world

2.10 The (potential) European flood impact database / Europa

- Over the recent years, global databases have been harmonized, although some differences remain in respect of certain characteristics e.g. threshold levels, specific methodologies for data re-cording, etc. Since 2011, the concept of an European Flood Impact Database has been explored as a joint initiative of the European Environment Agency and the Joint Research Centre, in collaboration with the Centre for Research on the Epidemiology of Disasters and the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation [1]. The initiative is being followed within the EU project INUNDO [40]. INUNDO fills the geospatial information gap missing in today's risk models and facilitates the impact assessment during and after large flood events. Such users are global players and could eventually help INUNDO expand to markets on other continents.
- Europe's coverage of the EM-DAT database (see section 2.17) is insufficient for detecting the trends of flood losses or guiding the EU disaster risk mitigation and climate change adaptation efforts. In addition, the above databases are less suitable for analysing the impacts of smaller events or for analyses at the sub national level. Additionally, the linkage between global databases and additional information from local, regional and national levels is currently rather poor. Improving knowledge about the intensity, magnitude and impacts of *significant flood events* in Europe is important as a principle of good governance, smart regulation and better law making. The proposed European Flood Impact Database will help to better understand the pattern of vulnerability across the regions and sectors, and to choose the most suitable (cost efficient, equitable) risk mitigation and climate adaptation measures. Besides, a European Flood Impact Database would enable new information services that are likely to lead to a greater awareness of and preparedness for flood risk. INUNDO intends to provide accurate, current and historical flood spatial information for risk modelling to help (re-)insurance companies improve their existing risk assessment processes. The objective of INUNDO is to create, validate, update, organise, license, and provide access to geospatial flood disaster information based on Earth Observations, meteorological data, and social media for the insurance industry to enhance their risk modelling and

reduce their expenses. Target market is insurance companies and related businesses developing and using natural hazard models. INUNDO is expected to sell business-to-business information to enhance risk models, to allow tailored premiums, and eventually to reduce losses for insurances as well as exposed citizens.

- To the knowledge of the authors, no database is publicly available yet.

2.11 The Canadian Disaster Database / Canada

- The Canadian Disaster Database [41] contains detailed disaster information on more than 1000 natural, technological and conflict events (excluding war) that have happened since 1900 nationally or abroad and that have directly affected Canadians. The database tracks "significant disaster events" which conform to the Emergency Management Framework for Canada definition of a "disaster" [42]. In addition, the registered events must meet one or more of the following criteria:
    - 10 or more people killed
    - 100 or more people affected/injured/infected/evacuated or homeless
    - an appeal for national/international assistance
    - historical significance
    - significant damage/interruption of normal processes such that the community affected cannot recover on its own

  The database describes where and when a disaster occurred, the number of injuries, evacuations, and fatalities, as well as a rough estimate of the costs. As much as possible, it contains primary data that is valid, current and supported by reliable and traceable sources, including federal institutions, provincial/territorial governments, non-governmental organizations and media sources. Data are updated and reviewed on a semi-annual basis.
- The main motivation for such a database is to determine whether disaster costs have increased or decreased over time, or whether preventative/mitigative measures have helped to lower the cost of disasters.
- The Canadian Disaster Database is accessible from: http://cdd.publicsafety.gc.ca/srchpg-eng.aspx. A geospatial mapping component enables users to define their search within a spatially-defined area. It also displays query results charted across a map. Geospatial disaster data can be exported through KML or GeoRSS feeds. Data can be downloaded into report formats.

2.12 The Flood Damage Data / USA

- The National Weather Service (NWS) is the only organization that has maintained a reasonably consistent long-term record of flood damage throughout the U.S. [6]. The NWS damage estimates do not represent an accurate accounting of actual costs, nor do they include all of the losses that might be attributable to flooding. Rather, they are rough estimates of direct physical damage to property, crops, and public infrastructure. Downton et al. [21] reviewed and evaluated NWS flood damage data sets by examining archived information, interviewing people who collect the data, identifying sources of error and inconsistency, and performing error analyses. Corrections were made in the estimates only when changes could be clearly justified based on published sources or information in NWS files. Flood damage is based on the United States, for the period 1926 – 2003.
- Objectives of this study were:
    - to assemble a national database of historical flood damage based on NWS damage estimates, making it as complete and consistent as possible
    - to describe what the estimates represent
    - to evaluate the accuracy and consistency of the estimates, and
    - to develop guidelines for use of the data and make it widely available to users.

- The Flood Damage Data are accessible from: http://www.flooddamagedata.org/national.html. Data can be saved as a text file or as an excel file.

2.13 The Australian Flood Studies Database / Australia

- The Australian Flood Studies Database [43] was developed in 2003–2004, was made available online by Geoscience Australia in 2006, and was finally developped as a web-based tool in 2010.The tool allows registered stakeholders to add information on new studies remotely, to edit existing information, and to upload attachments to the database via the internet. State and territory governments have assumed responsibility for updating the database and are now working with local government and relevant agencies to facilitate this.
- The database's goal is to provide metadata on Australian flood studies and information on flood risk.
- The Australian Floods Studies Database is accessible from: http://data.gov.au/dataset/australian-flood-studies-database-a-freely-available-national-catalogue. Data are publicly provided via the website data.gov.au. In theory data can also be visualized on the map-based tool: http://www.nationalmap.gov.au/.

2.14 The DesInventar databases / Latin America

- Until the mid-1990's, systematic information about the occurrence of daily disasters of small and medium impact was not available in Latin America nor in the Andean Sub-region. From 1994, the creation of a common conceptual and methodological framework was begun by groups of researchers, academicians, and institutional actors linked to the Network of Social Studies in the Prevention of Disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina - LA RED). These groups conceptualized a system of acquisition, consultation and display of information about disasters of small, medium and greater impact, based on pre-existing data, newspaper sources and institutional reports in nine countries in Latin America. The developed conceptualization, methodology and software tool is called Disaster Inventory System - DesInventar (Sistema de Inventario de Desastres) [44]. DesInventar is a conceptual and methodological tool for the construction of databases of loss, damage, or effects caused by emergencies or disasters. It includes:
    - Methodology comprising definitions and help in the management of data,
    - Database with the following high-level categories: geography, event, cause, basic effects and additional effects,
    - Software for input into the database, and
    - Software for consultation of data (not limited to a predefined number of consultations) with selection options for search criteria.
- The development of DesInventar, with its conception that makes visible disasters from a local scale e.g. town or equivalent, is intended to facilitate dialogue for risk management between actors, institutions, sectors, provincial and national governments. LA RED also developed a methodology [45] with the intention of providing the diverse actors involved in activities for the prevention and mitigation of disasters with greater capacity for the gathering, processing, analysis and homogeneous representation of disasters.
- The DesIventar databases are accessible from: http://online.desinventar.org/ and http://www.desinventar.org/en/database . Data are displayed in a table format, and can be exported to excel.

2.15 SwissRe Sigma / World

- Swiss Reinsurance Company maintains the Sigma database, a global, limited-access, natural – excluding drought – and man-made disasters database. Events are recorded from 1970 to the present. There are approximately 7,000 entries in the database with

300 new entries per year probably due to the more and more stringent inclusion criteria. For the reporting year 2015, the lower loss thresholds were set as follows:
  - Casualties:
    - 20 deaths;
    - 50 injured;
    - 2000 homeless;
  - or insured losses of at least:
    - US$ 19.7 million (Maritime disasters),
    - US$ 39.3 million (Aviation),
    - US$ 48.8 million (all other losses);
  - or total losses in excess of US$ 97.7 million.

Disasters are recorded on an event entry basis and recorded information includes dead, missing, injured, and homeless along with detailed accounting of insured and uninsured damages. This sigma study is based on the direct premium volume of insurance companies, regardless of whether they are privately- or state-owned. Premiums paid to state social insurers are not included. Life and non-life premium volume in 147 countries is examined [46].
- The Sigma Explorer database intends "to be a unique tool for anyone with an interest in the insurance risk business"[2] and to provide industry-related information readily and graphically available for all.
- The Sigma Explorer database is accessible from: http://www.sigma-explorer.com/ . Data are visualized with time-line trends. Only visualizations can be exported, not data itself.

2.16 The NatCatSERVICE natural catastrophe loss database / World

- Comprising some 30,000 data records, NatCatSERVICE is the most comprehensive natural catastrophe loss database in the world. This unique archive of natural hazards has developed into the world's most comprehensive database of natural catastrophes, going all the way back to the eruption of Mount Vesuvius in AD 79. Approximately 1,000 events are recorded and analyzed every year. Munich Re receives its loss data from more than 60 offices worldwide and good relations with clients in over 150 countries. National and international insurance associations additionally provide reliable data in the form of notified claims and detailed reports of the loss events. Systematic evaluation of daily press reports, from local to international levels, rounds off the range of sources.
- The information collated can be used to document and perform risk and trend analyses on the extent and intensity of individual natural hazard events in various parts of the world. Originally developed for the insurance industry, NatCatSERVICE is now also used by scientific and institutional facilities and media [47].
- The database itself is not publicly accessible but a selection of analyses is accessible from: https://www.munichre.com/touch/naturalhazards/en/natcatservice/annual-statistics/index.html.

2.17 The EM-DAT International Disaster Database / World

- Since 1988 the Centre for Research on the Epidemiology of Disasters has been maintaining an Emergency Events Database EM-DAT. EM-DAT was created with the initial support of the World Health Organization and the Belgian Government [9]. EM-DAT contains essential core data on the occurrence and effects of over 18000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations,

2 http://www.swissre.com/reinsurance/insurers/sigma_explorer_the_data_you_need_at_your_fingertips.html

insurance companies, research institutes and press agencies. EM-DAT distinguishes two generic categories for disasters: natural and technological. The natural disaster category is divided into five sub-groups, which in turn cover 15 disaster types and more than 30 sub-types. The technological disaster category is divided into three sub-groups which in turn cover 15 disaster types. For a disaster to be entered into the database at least one of the following criteria must be fulfilled:
  - 10 or more people reported killed, or
  - 100 or more people reported affected, or
  - declaration of a state of emergency, or
  - call for international assistance.
- Development and relief agencies have long recognized the crucial role played by data and information in mitigating the impacts of disasters on vulnerable populations. Systematic collection and analysis of these data provide invaluable information to governments and agencies in charge of relief and recovery activities. They are also crucial in the integration of health components into development and poverty alleviation programmes. EM-DAT is intended to provide an objective basis for vulnerability assessment and rational decision-making in disaster situations. For example, it helps policymakers identify the disaster types that are most common in a given country and that have had significant historical impacts on human populations. In addition to providing information on the human impact of disasters – such as the number of people killed, injured or affected – EM-DAT provides disaster-related economic damage estimates and disaster-specific international contributions.
- The EM-DAT International Disaster Database is accessible from: http://www.emdat.be/database . Results can be saved under a csv format.

2.18 The GLIDE database / World

- The Asian Disaster Reduction Center (ADRC) proposed a globally common unique ID code for disasters. This idea was shared and promoted by a number of international organizations including the Centre for Research on the Epidemiology of Disasters in Belgium, the Office for the Coordination of Humanitarian Affairs, ReliefWeb, the Field Coordination Support Section, the United Nations International Strategy for Disaster Reduction, the United Nations Development Programme, the World Meteorological Organization, the International Federation of Red Cross, the Office of U.S. Foreign Disaster Assistance, the Food and Agriculture Organization, La Red and the World Bank. The idea was jointly launched as a new initiative "GLIDE" [48]. The components of a GLIDE number include: two letters to identify the disaster type e.g. "EQ" means earthquake; the year of the disaster; a six-digit, sequential disaster number; and the three-letter ISO code for country of occurrence. The GLIDE number for West-India Earthquake in India is for example: EQ-2001-000033-IND.
- Accessing disaster information can be a time-consuming and laborious task. Not only is data scattered but frequently identification of the disaster can be confusing in countries with many disaster events. The GLIDE database intends to address both of these issues.
- ReliefWeb, La Red and ADRC have prepared a specific website to promote GLIDE: http://www.glidenumber.net.

2.19 Partial conclusions

This non-exhaustive selection of databases demonstrates the diversity of motivations and targeted end-users. Most of the databases intend to improve flood risk assessment for all involved stakeholders, without really focusing on one target group. Some of the most frequently cited applications and end-users include:

- Spatial planning for planners,
- Insurance-related applications for policyholders,

- Insurance-related business applications for insurance companies,
- Building-related issues for current and future house owners,
- Building-related issues for stakeholders within the construction industry,
- Flood science for scientists and engineers
- Flood management issues for policy makers, and
- Public awareness issues for policy makers.

More general topics include flood prevention, risk mitigation and climate adaptation, but again without mentioning explicitly the end-users. Only once, the database own goal is clearly defined as facilitating the dialog between all involved stakeholders.

The early identification of end-users should be a governing specification when building a database, since in general, quality of data should only be assessed in regards to its suitability for the intended uses. In a perfect world, database builders would gather all requirements and then craft a database design and applications to match them [49]. However, this seems to be seldom the case. Among some interesting methodological approaches, Elmer [20] questioned experts about their information needs for flood damage analysis, and performed the survey by applying a Delphi-survey approach [20]. The selected experts represented university institutes and major research institutions, reinsurers and insurance companies, governmental agencies as well as agencies from flood-prone municipalities and leading engineering consultants. The complete findings are described by Thieken et al. [50, 51].

Substantial variations are observed within the methods for distributing data, information, or knowledge. Data are more often delivered, sometimes together with pieces of information. Information is usually provided within a map-based format. Knowledge itself is very rarely provided, except under the form of reports most likely addressing the needs of previous customers. Whether or not information or knowledge should be provided instead of data appears to remain an open question, and depends on the capacity – and willingness – for mapping the accurate needs of- and accurate type of end-users.

The best way to deliver publicly available data appears to rely on governmental platforms such as data.gov.au for Australia or data.norge.no for Norway. Distributing data – which can be private or public – via such platforms is to recommend for practical reasons: all data are available from one and unique location, and quality reasons: such platforms usually maintain high requirements regarding documentation.

Final recommendations for addressing these issues are given in Chapter 4.

3 Stormwater-related inventory databases: a Norwegian overview

In this report, "inventory databases" are defined as a general concept for both object- and event- based databases. Object-based databases include databases used by infrastructure owners to map all their belongings. Event-based databases include databases used by infrastructure owners to plan and perform operational procedures.

3.1 Methodology

The following criteria were used in order to select relevant inventory databases:

- inventory database should provide a record for a selection of objects or events, and
- at least part of the registered objects should be either related to stormwater systems or potentially exposed to damages due to stormwater, or
- at least part of the registered events should be related to causes or consequences of stormwater events.

The following methodology has been used:

- The databases properties were collected under different general categories (see Figure 8), that can address event-based, object-based, and possibly "hybrid" databases ,
- A questionnaire was prepared based on these categories,
- The first part of the questionnaire was based on factual questions, and was answered and returned by all relevant partners, and
- The second part of the questionnaire – based on personal opinions of those who register data, those who process data, and those who use data – was filled out during face-to-face interviews with a selection of employees from the relevant partners.

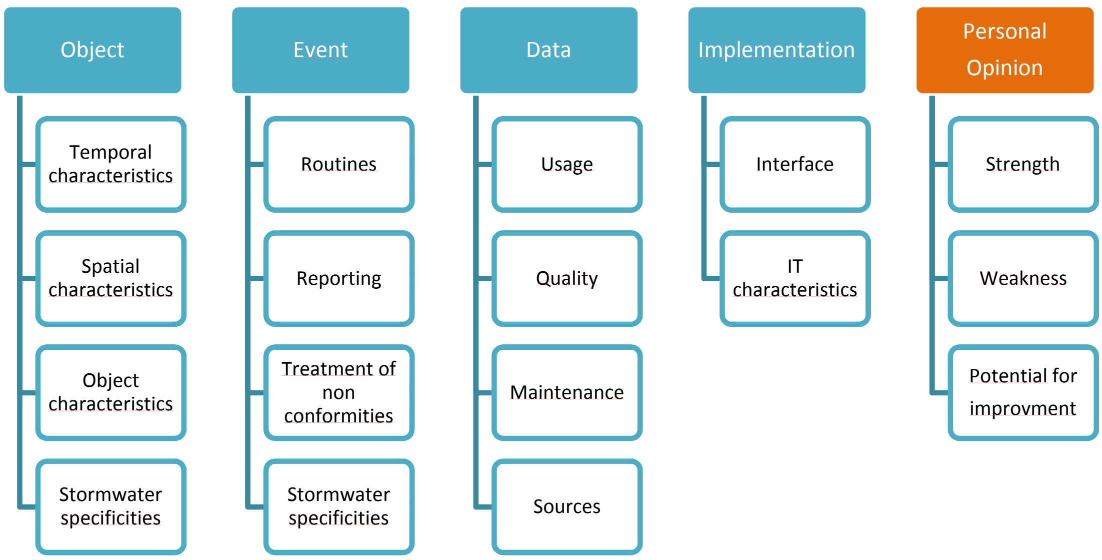

Figure 8: Structure of the questionnaire

3.2 The case of the Norwegian Public Road Administration (SVV)

3.2.1 General description

The Norwegian Public Road Administration (Statens Vegvesen = SVV) is currently developing a new National Road Database (Nasjonal Vegdatabank = NVDB). The database stores information about all state, municipal and private roads in Norway, and part of it is publicly accessible from: www.vegvesen.no/vegkart.

NVDB's purpose is to establish an information system that secures optimal management, optimal maintenance and optimal development of the national roads. In addition, NVDB maintains an effective information system for the road-owner and the road-users about the traffic and incidents on the road network.

Main goals are reported as:

- To store correct data with the right quality,
- To provide both internal and external users with a better user interface and easier access to important data, with better possibilities for different presentations and analyses,
- To use standard report tools,
- To establish a new data model for the road network,
- To work within a common feature catalogue, and
- To use standard GIS tools on the market.

3.2.2 Objects

All objects – also identified as "features" – of relevance to the NVDB are defined and described[3] in a standardized manner, and are reported in the Feature Catalogue which is publicly available[4]. There are approximately 400 different types of features that include items owned or maintained by SVV or items that are of interest to the SVV's operations and maintenance departments. All objects have a unique ID, and the first of them was registered in 1970. They are all referenced with GPS coordinates and according to road number and the distance from the start of the road. In total 206 000 km of road are registered.

The most important characteristics of the feature catalogue are:

- Easy definition and maintenance features for all purposes,
- Simple and comprehensible machine-readable base code,
- Features that be grouped, compared, and combined, and
- Definitions and base code that apply for all participants and technical systems within the area of road and traffic data.

3.2.3 Events

In general no events are registered in NVDB. However, more abstract concepts, such as incidents, injuries, road conditions, and queuing conditions, are included in the Feature Catalogue, together with "regular" objects.
In general, SVV is not responsible for operations onto features: SVV local offices work with local contractors dedicated to specific areas / road sections, who are responsible for inspection and maintenance. Collaboration between SVV and contractors is based on yearly reports that are collected within other databases (see section 3.2.7 for more details). In addition, more specific events can be found within other databases e.g. real-time images from web-cameras.

3.2.4 Stormwater specificities

Specific features related to stormwater include among others:

- Pond/ Basins / Reservoir: arrangement / unit for storing water. For example, in connection with the tunnels.
- River / stream, closed: river or stream that is closed in connection with road construction.
- Trench/ditch/swale, open: scarp terrain to divert water. Part of the road dewatering. Also referred to as "channel".

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[3] http://labs.vegdata.no/nvdb-datakatalog/
[4] http://tfprod1.sintef.no/datakatalog/

- Hydrant: Object that can be used to connect hose systems associated with fire or washing of streets / areas.
- Plastic drainage: Laid in the road edge to cut off the water inflow into the road.
- Manhole: Drainage construction, used for easy access to equipment/connections or as a basin.
- Closed pipe trenches: buried pipes or crushed stone string. Used primarily in connection with drainage of roads, but can also contain other types of pipes.
- Spillway: Ditch/culvert leading the water from top cutting down to manhole / culvert.
- Stormwater trench/swale/drain: Construction leading stormwater along the road to the closed drainage system or ditch.
- Pump: A device for pumping water.
- Pump station: Place where it is installed one or more pumps to pump away the drainage / stormwater.
- Screen: used to protect ditches, pipe/culvert entrances etc.
- Pipe: pipe leading liquid (exempt from public access).
- Subdrain / culvert: pipes for water passage across the road (if desirable across adjacent exit) with a maximum aperture 2.5 meters. Subdrain / culvert have open inlet and / or outlet. Subdrain / culvert may have inlet and outlet structures as manholes and support shield.
- Stormwater systems: system that collects drainage water and stormwater before discharge to the recipient.

Some properties available for these stormwater-related features include (but are not limited to): maintenance responsible, construction year, normal water depth, geometric properties, soil conditions, presence of heating cables, owner, producer, area of use, connection method, etc. An example of such a tree-structure for a culvert object is given in Figure 9.

3.2.5 Data use

Different user groups have access to different parts of the NVDB. NVDB is mostly publicly available, but some parts are available only to authorized users, divided in external and internal user groups. Internal users work in the Norwegian Public Road Administration. External users can be governmental agencies and local authorities, county authorities, municipalities, the police, the National Bureau of Statistics, the Norwegian Mapping Authority, transport companies, consultants, and research organizations. Only a small part of user groups has permission to register data.

The NVDB is used among others activities for:

- Road planning and design
- Road maintenance and operation
- Environmental tasks
- Pollution from traffic (dust and noise)
- Landscape planning
- Traffic safety work
- Statistics about traffic accidents

Only one institution within SVV is responsible and liable for the contents. The following principles are promoted:

- A feature is defined in a manner for all technical areas and fields of expertise to regard the feature as theirs. E.g. the feature “sign” is only defined once, but the managers for the technical areas of sign maintenance and of traffic signs will only be presented with sign characteristics relevant to their field of expertise.

- All systems and users gain instant and unrestricted access to the current feature catalogue. The users relate only to the latest version of the feature catalogue.
- All qualified technical divisions have the right to propose modifications and to comment on the feature catalogue contents.

In order to define features efficiently, the number of features needs to be kept to a minimum.

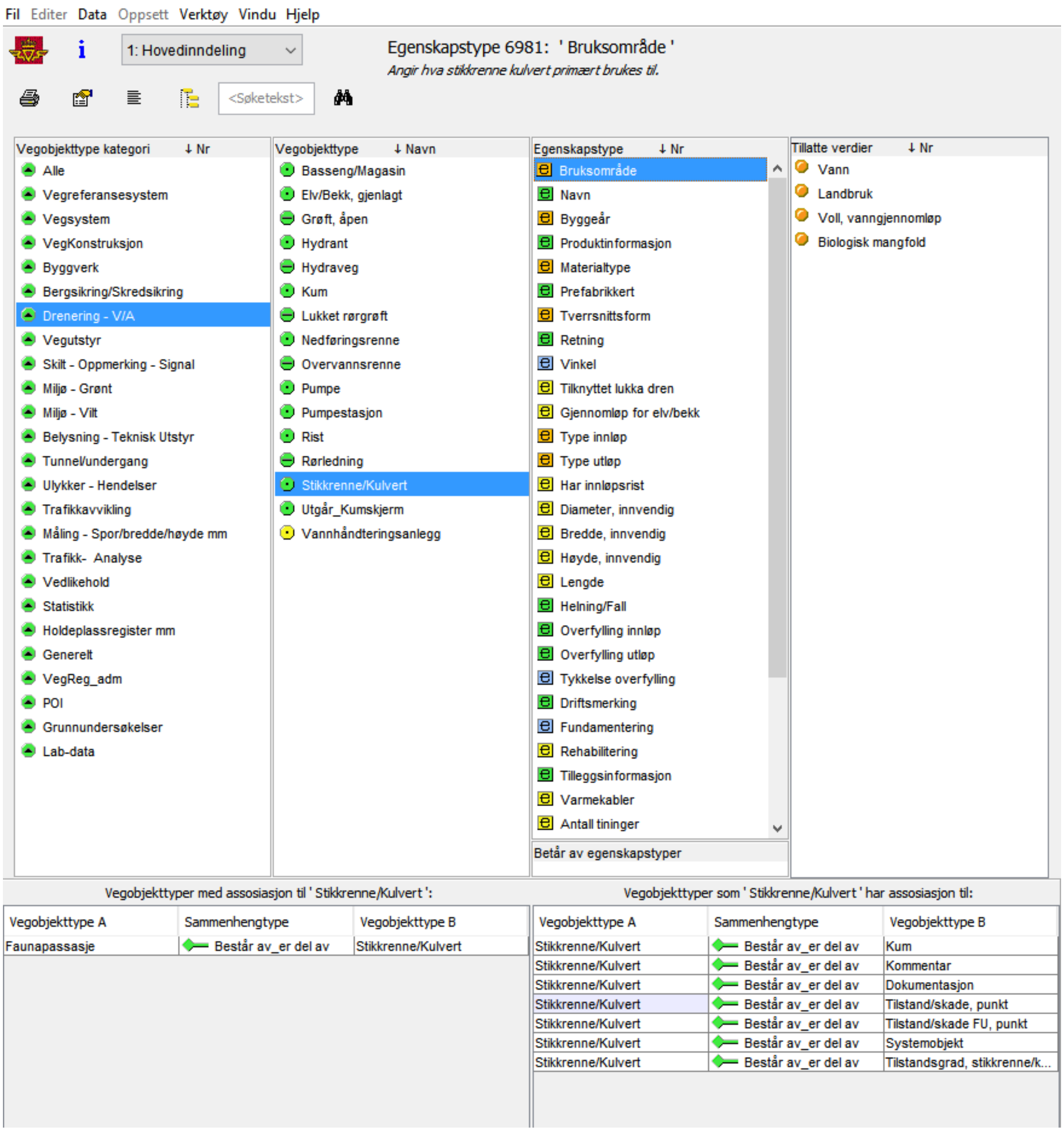

Figure 9: Tree-structure related to culvert object-type.

3.2.6 Implementation

The object-relational database management system Oracle is the underlying programming foundation of the NVDB. Geographical information is standardized according to the reference standard ISO/TC 211. Both the geographic information systems ArcGIS and GIS/LINE utilize the NVDB's Application Programming Interface (API) when using the database.

The NVDB's API enables new individual clients and/or other programming software products, e.g. a large number of municipalities computer systems, to employ the NVDB in a simplified way. All server/client communication is carried out via the HTTP protocol. This protocol is identical to the one used for downloading web pages in i.e. Internet Explorer. In this case, however, the striking difference is that all data are to appear within structures and thus require a Client API to be downloaded. The Client API offers functions for downloading and extracting data from the NVDB server in order to update local sets of data subjected to client modification, to expand on or restrict sets of data, and to update modifications made in NVDB set of data. Normally, all working procedures start by specifying technical data and geographical areas being selected via a standard selection dialogue called query builder.

3.2.7 Interactions with other internal or external systems

SVV local offices use NVDB mainly as an information system and also interacts with other systems on a daily basis. These other systems include:

- ELRAPP is a system for electronic reporting and following-up of the different duties and responsibilities of tasks related to operation- and maintenance contracts towards SVV. Contractors have to send a specific form in case of damage. Cause and pictures should in principle be documented. In case of acute events, SVV local offices usually get a phone call from SVV central offices. In some cases a report in NVDB goes directly to the relevant SVV local office. The same notification also alerts the contractor.
- VegROS is a mapping of geographic locations / road segments where an event could cause long-term break in navigability. VegROS points are available in NVDB (see Figure 11), but are used only for emergency by SVV local offices.
- VegCIM is a Crisis Information Management software product that was implemented in SVV in 2007. It is used by SVV local offices only in case of emergency.
- xGeo is a tool used by experts for preparedness, monitoring and warning of flood, landslides and avalanches (see section 3.4.6).
- SeNorge.no is an open portal on the Internet that shows daily updated maps of snow, weather and water conditions and climate in Norway (see section 3.4.6).
- The classical version of www.yr.no is used when needed, but no specific meteorological bulletin is used. In theory, the contractor should check the weather forecast him/herself.
- A network of cameras is available to SVV local offices, however without image analysis solutions. SVV local offices use cameras mostly to assess road conditions when necessary and to provide evidence on lack of plowing in case of dispute / complains.

3.2.8 Identified challenges

All identified challenges are classified under the main categories of "monitoring", "reasoning", "acting", and "evaluating", according to the concepts defined in Figure 5, in addition to the general issues of collaboration and adoption of digital solutions.

- <u>Adoption of digital solutions</u>
  - Lack of updated "status" indicator: SVV has 5-year contracts with different contractors for different areas / road sections. The contract consists in a list of objects the contractor should maintain. The contractor inspects all the objects he is responsible for once or – at best – twice a year. Status of the object is then updated; damages, if any, are identified.
  - The process itself is time-consuming and imprecise. The contractor delivers a hand-written document that refers to all objects. An example can be seen in Figure 10. This means that:
    - the report is not automatically implemented into the digital database,
    - there is no instantaneous connection between the "status" property in the database and the reality, not even at the time of inspection,
    - there is no digital procedure for SVV local offices to get help for prioritizing necessary maintenance with respect to available budget and time constraint, and
    - transfer of hand-written inspection data to digital database is not a priority in itself and is seldom performed.

- Operational routines are normally not documented in NVDB.

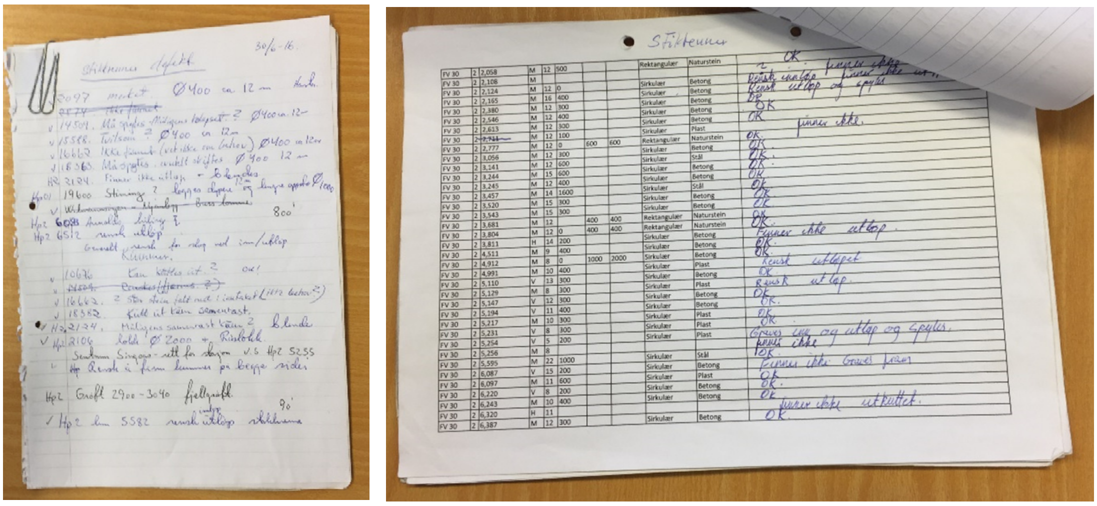

Figure 10: Hand-written reporting from contractors to SVV local offices

- Quality-assurance of inspection is not optimal: There are no specific procedures for inspection, and most of them rely on personal knowledge or competence. The most usual case is a simple visual inspection, without any mandatory measurements. This is mainly due to lack of time: contractors may have to handle up to 5000 culvert in their "area of responsibility" and have no time to perform advanced inspection on all objects at short intervals of time. The lack of documented procedures also raises a quality assurance issue: contractors may sometimes report even status or conditions that are not always true. A double inspection by SVV local offices would result in a much higher working load and would anyway not improve the workflow.

- Monitoring:
  - No vulnerability information is available to support decision-making process.
  - No structured information is stored regarding potential vulnerability of areas.
  - In case evaluation is needed, e.g. for prioritizing work, this is based on personal and/or local knowledge.
- Reasoning: Impact of climate change on daily activities: Climate changes are taken into account when deciding to replace objects related to water managements system. Rule of thumb is to replace old objects by new over-dimensioned objects. This applies for example to culverts. More complex models – such as hydrology calculations – are used for supporting the decision-making process only when planning to build new road sections.
- Evaluating: SVV local offices main task is to ensure that third parties come forward. In addition, they monitor contractors on a daily basis. They have budgetary responsibility for operation and maintenance within their area. The budget is however low and necessitates therefore a clear prioritization of the most critical items. In case budget is found insufficient by SVV local offices, request on extension of budget is evaluated as difficult to forward to SVV central offices.
- Collaboration: SVV local offices have little interaction with BaneNor, except at a very local level, when individuals are willing to do so. This was for example the case for the Soknedal-slide in 2012, where SVV and BaneNor conducted joint meetings and inspections.

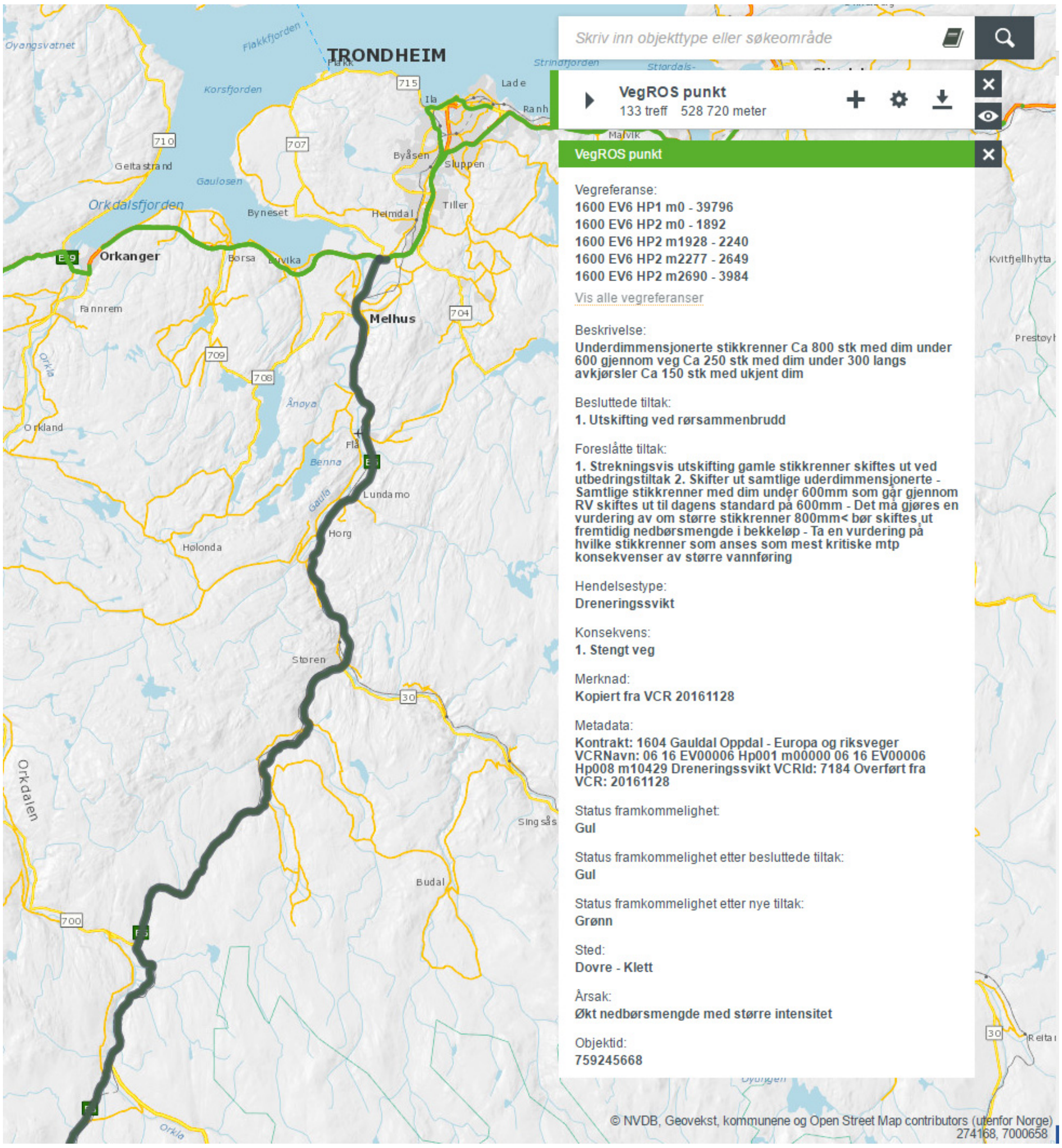

Figure 11: VegROS points related to underdimensionned culverts because of increased rainfalls with greater intensity

3.3 The case of the Norwegian governmental agency for railway services (BN)

3.3.1 General description

The Norwegian governmental agency for railway services (Bane Nord = BN) main task is to provide Norway's train companies with a safe and efficient transport system. BN plans, constructs and maintains the railway network, including railway stations and terminals. BN is also responsible for day-to-day traffic management and for providing traffic information to passengers at all railway stations in Norway. BN operates in a range of specialist fields such as electrical engineering, construction, telecommunications, social planning, scheduling and traffic management.

Maximo BaneData was established in 2004 and contains a database and several tools for management and administration of maintenance. The purpose of registering infrastructure objects in BaneData is to be able to plan, conduct and report on maintenance performed out in the field in an efficient way. Data about the condition of the objects are used by the management to prioritize maintenance resources in the short and long term.

The benefits of the Mobile BaneData solution are BN's ability:

- to distribute automatically generated working orders to technicians out in the field, based on technical regulations related to each type of object, and
- to provide an easy-to-use tool that accommodates well the constraint of limited access to the rail network, and that supports in an efficient way the following actions: plan, control, repair, and report.

3.3.2 Objects

BaneData covers more than 870 000 objects – and events – from about 1996. All objects – or events – are geographically located both via GPS coordinates and within the local coordinates of railways. This means that an object should be registered together with the side of the train track, as well as the distance from the beginning of the line, e.g. from Oslo, Trondheim or Narvik. Resolution of such distances is about one meter.

Objects are grouped into main categories: superstructure, substructure, bridge, catenary system, low voltage systems, signs, objects on stations, electric traction power supply, control command and signalling, and telecommunications[5]. Example of substructure objects are: culvert, drainage, tunnel, bridges etc.

For each object a description of the work is given, as well as some indicators[6]:

- Number that relates to the specific chapter in the Technical Regulations book the work routine is answering to,
- Type of working routine: periodic visual control, periodic measurement, periodic functional testing, continuous control/measurement, periodic overhaul or replacement,
- Maintenance interval: generally 1, 6, 12, 24 or 120 months, and
- Priority ranking.

3.3.3 Events

BaneData sends up to 2.5 millions working orders automatically according to the established technical regulations at BN. BaneData is updated continuously, however the system is not reacting to extraordinary events, although this is technically feasible. Extraordinary inspections may be conducted only in case of damages on the infrastructure. Several sensors are used for active monitoring of the railways, e.g. acoustic sensors on each train that register error messages. Several alert systems are implemented together with colour ranking depending on emergency, e.g. to detect ice on rails.

Inspection reports are registered under each inspected object and are partially indexed with keywords. They follow a fixed template while allowing free text. They are kept internal, and are not sent to any other external database. In case a deviation is registered, a new working order is automatically generated and categorized as urgent or "schedulable". The deviation is registered with the following characteristics: cause, effect and direct damages. Indirect damages are not registered. Analyses to find out the specific cause of a given deviation are carried out by external experts only in case of serious events.

The new working order is only warning on the need to take appropriate measures. The final decision is taken "individually" by the local responsible, with the help of weather services HALO and alerts on flood and landslides from NVE (see Section 3.3.7). Analyses of deviations may be conducted but seldom are.

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[5] https://trv.jbv.no/ga/

[6] https://trv.jbv.no/ga/beskrivelse.html

3.3.4 Stormwater specificities

Objects which are specially related to stormwater include closed / open drainage systems, manholes, and culverts. For example, culvert inspection routine is to be performed every year and consists in two distinct activities[7]:

- Ensure that the culvert has sufficient capacity, that it does not remain blocked nor that it has ice problems. Inspection period should be according to local climate and terrain conditions.
- Ensure that culverts are not damaged or show leakage at the inlet, outlet or in the gutter.
- Characterise the culvert structural conditions with a specific code for planning maintenance routines, which can be either "acute corrective" or "deferred corrective".

Deviations specific to stormwater events include for example: damaged object, flooded object, or non-functioning object.

3.3.5 Data

Mainly BN workers, state controllers, group leaders, and the rail responsible ("BaneSjef") use data. Access to data is critical for owners of infrastructure for performing daily inspection routine work: about 800-900 BN workers use the mobile version of BaneDate each day. The iPad support solution has proven to be efficient for allowing quick and safe work. BaneData is used as a registering tool for inspection results, but also as a source of documentation for performing correct reparations or for finding correct location of objects.

Access to data might be restricted depending on decisions from the local rail responsible ("BaneSjef"). Those owning infrastructure have in general the authorisation to modify/implement data, either directly or via the mobile version. Everyone having access to Banenettet has access to the reporting tool BaneData Innsyn.

In general, external users may have access to BaneData but they should send an official request to BN.

3.3.6 Implementation

IT solution for BaneData is a mix of Maximo / Excel / Microsoft Project / Agentry. Maximo is the IBM solution for database and analyses, and was presented as the best software in the world for such applications. BaneData itself is developed and maintained by three developers within BN, and beneficiates from the work of external programmers. BaneData is also available in a mobile version for use of field agents during inspections.

It is possible to search the content of BaneData with requests, as well as get a monthly report on some characteristics, after request. Analyses are used for example for preparation of monthly forecast, but there is no tool for automatic generation of trends for example.

3.3.7 Interactions with other internal or external systems

- BaneData Innsyn is a reporting tool that collects all reports related to an object or to a specific part of the rail network. Suppliers have access to BaneData Innsyn.
- An online map (Jernbaneverkets kartvsining[8]) is publicly available and displays data from several sources, among them data from BaneData, slide events and flood events from NVE, and property information.

[7] https://trv.jbv.no/ga/Generiske%20arbeidsrutiner%20Underbygning.pdf

[8] https://customapps2.geodataonline.no/JBV_HTML5_27_norsk/Index.html?viewerConfigUri=https://customapps2.geodataonline.no/Geocortex/Essentials/JBV/REST/sites/Innsynslsning_46_Prod/viewers/Innsynslsning-Prod/virtualdirectory/Resources/Config/Default/Desktop.json.js

- DOP-UT registers activities within the maintenance plan. It is updated yearly and contains risk analyses.
- ProArc is an electronic database that mainly contains technical drawings and reports. It is still in use today.
- TekDok is a project to collect all documentation related to each object under a unique digital location. This means that ProArc contents should be accessible from BaneData. This requires substantial efforts in digitization of documents.
- Halo[9] is the Meteorological Institute[10] weather service for government agencies and businesses. The service is similar to yr.no and provides location-based weather forecasts but it is designed specifically for businesses' needs. Examples include turbulence warning for aircrafts or calculation of how oil spill moves in the ocean. Halo is regularly updated with improvements based on users' feedback.

3.3.8 Identified challenges

All identified challenges are classified under the main categories of "monitoring", "reasoning", "acting", and "evaluating", according to the concepts defined in Figure 5, in addition to the general issues of collaboration and adoption of digital solutions.

- Reasoning:
  - Today, the equipment is dimensioned for flood with a return period of 200 years. Adaptation to climate change of the rail network is mainly performed via over-dimensioning culverts to account for increased occurrence of extreme rain events. The distribution and prioritization of budget itself is based on facts and reported needs, but there is no automatic analysis tool from BaneData that support such decisions.
  - There is no automatic decision when a deviation (or a warning) is registered (or received). The deviation message might come automatically – e.g. from landslides sensors – but the decisions are to be taken by the assigned security guard on duty at the time the incident occurs. There are different security guards with different responsibility areas:
    - The weather security guard is receiving automatic warning messages issued by NVE and Halo, but such messages are not automatically implemented in BaneData. Their impact is dependant on the decision of the weather guard.
    - The readiness guard is responsible for performing real-time analyses and for issuing a colour-based emergency level to BN staff:
      - Yellow: be careful and aware of potential danger,
      - Orange: enforce reduced speed and more frequent inspections, and
      - Red: close the rail network.
- Evaluating:
  - Risk analyses are performed at management levels with a limited top-down dissemination.
  - In general, it seems that BaneData is used for both knowledge management purposes and as a tool for performing on-site routine work. The activities linked to reasoning and evaluation seem however little investigated, restricted to central management level, and very little disseminated to operational levels.

[9] https://halo.met.no/faces/Halo-brukerveiledning.pdf
[10] www.met.no

- Collaboration:
  - There is an increased collaboration with NVE, but little collaboration with other governmental agencies such as SVV. It is however likely that SVV is also facing similar challenges in emergencies, and it is likely that readiness and preparedness would gain in efficiency if collaboration were enforced. Among other opportunities, it would be interesting to compare real-time emergency levels and risk-based maps from the two governmental agencies.
  - At a non-management level, the NIFS project was unknown to most of the interviewed persons. The lack of top-down communication may be a reason why collaboration with other partners / governmental agencies has not been much developed up to now.

3.4 The case of the Norwegian Resources and Energy Directorate (NVE)

3.4.1 General description

NVE’s mandate is to ensure an integrated and environmentally sound management of the country's water resources. NVE is responsible for the national flood and landslides warning service and for the 24/7 emergency line for flood and landslide situations. In addition, the directorate bears the overall responsibility for maintaining national power supplies. NVE administers a comprehensive flood management system that includes guidelines and expert guidance in land use planning; planning and financial assistance for building physical flood protection works such as levees and embankments; a flood warning system that maps programs for flood inundation and quick clay slides; and an emergency preparedness system. The Hydrology Department at NVE has more than 80 positions and is responsible for collecting, storing and analysing data. The Landslides, Flood and River Management Department has more than 120 positions, and is responsible for the managing of watersheds regarding floods and landslides.

NVE currently owns two event-based databases: one related to landslides, and one "historical database" related to flood. The historical flood database covers floods from over 660 years, and is mainly based on historical documents such as parish registers. 771 events are registered. The historical database [52] is however not publicly available, not adapted to modern data format and is not searchable, which makes it difficult to use it for analyses.

NVE owns and maintains the national hydrological database called HYDRA II. HYDRA II contains time series data for about 400 000 station-years, with a considerable number of stations exceeding 100 years of continuous observations. The data base is continuously, usually every hour, automatically updated with data from a large network of gauging stations.

NVE is now planning the creation and implementation of a new modern database for flood and stormwater events in Norway. The focus will be set on geomorphological information of floods and stormwater events. Damages and costs will not be registered in a detailed way, unless their inclusion adds relevant knowledge to the hydrological events themselves. The foreseen scope of end-users is large and include municipalities and management units. The project team is composed of a coordinator, designers and developers who work together with a reference group consisting of NVE end-users, e.g. scientists, advisors, and officers.

This whole section is dedicated to the foreseen specifications of the new modern flood and stormwater database.

3.4.2 Measurements and observations

NVE does not own any infrastructure objects, and does not issue work orders. Data in HYDRA II consists mostly in measurements from sensors, observations and measurements from NVE staff, observations and measurements from external persons, e.g. via the app regObs (see Section 3.4.6), and data exchange with other databases, e.g. www.met.no (see

Section 3.4.6). The water-related parameters currently collected by the Hydrology Department cover the land-phase of the water cycle, among other:

- Water levels and discharge,
- Water temperature,
- Ice on lakes and rivers,
- Sediment transport,
- Snow,
- Glaciers, and
- Soil moisture and groundwater.

Within the new flood database, all measurements and observations performed by NVE staff connected to high-flood events shall refer to a specific procedure issued within a well-defined framework. Typical reports will include fixed templates together with some free-text areas.

The following properties are likely to be registered:

- ID number, which will be either automatically generated, either taken from other existing databases,
- Watercourse number / stretch of river / river name / watersheds, that shall be searchable by text requests – e.g. by using names – or by manually choosing an area on a map,
- Location, such as place names, municipality, county, coordinates, that shall be searchable by text requests – e.g. by using names – or by manually choosing an area on a map,
- Date and time,
- Duration,
- Measuring stations, with the possibility to dynamically link data to and from other databases systems such as xGeo (see Section 3.4.6),
- Water level and water flow: dynamic data link from other database systems, among others fields measurements from HYDRA II (see Section 3.4.6) together with date, time and measurement method,
- Notions about damages and pictures from regObs (see Section 3.4.6),
- Weather conditions: dynamic link with www.met.no (see Section 3.4.6),
- Warnings issued by other systems within NVE (see Section 3.4.6),
- All measures carried out by NVE, including urgent measures, safety measures, and measures carried out by external stakeholders,
- Amount of damages, or number of fatalities, and
- Other type of "free data" such as pictures – e.g. simple picture, aerial picture, satellite picture – or free text, or media coverage.

Both raw data and analyses results – under the form of customized reports – shall be provided. Once data are registered, analyses shall be performed to determine the following properties:

- flood type,
- cause of flood,
- cause of damages / injuries,
- recurrence period, etc.

3.4.3 Stormwater specificities

This white paper on stormwater [8] recommended that NVE takes the responsibility for stormwater, and even if this has not been passed yet, full collection of stormwater data shall be implemented in the future flood database. Measurements and observations related to stormwater events shall follow the same scheme as floods (see section 3.4.2).

3.4.4 Data

The new database shall follow a crowd-sourcing model where anyone, e.g. land and property owners, shall in principle register and describe events that occurred on his/her property. Other sources of data include NVE staff and their own observations and measurements, in addition to exchange of data with other relevant databases such as the ones owned or maintained by other national agencies, local authorities, etc.
However only "super-users" from NVE shall be able to edit and control registrations, and to collect observations exhibiting similar spatial-temporal characteristics under a unique flood-event ID number.
The different user-groups shall be attributed specific quality control procedures, and their performance shall be monitored statistically, in order to customize the new database to users' needs in a continuous process.

3.4.5 Implementation

Format of data shall allow efficient data exchange with other internal databases, e.g. landslides database, and shall be compatible with external databases systems already in use.

Any data item shall be registered with GPS coordinates. The format and detailing levels are not decided yet, but end-users shall be able to look for specific geographical areas of interest. An API platform shall be made available to support end-users requests. Among other types of data, it will be possible to download geographical data[11] with different map format for future GIS applications.

In addition to collection and storage of raw data – likely to be used for research purposes – NVE also contributes to the development of tools, usually under the form of software products, in order to answer the internal – and sometimes external – needs for knowledge. Analyses and assessments provided by NVE include: station network design and operation, measurement and observation technology, basic and advanced data processing, hydrological database management, environmental impact assessments, and hydrological analyses in general. Development of tailored-made software products is in general limited to NVE's own internal needs. The needs are first expressed by employees, then reported by leaders, and finally prioritized, depending on NVE's strategy.

3.4.6 Interactions with other internal or external systems

NVE owns and maintains a large number of databases dedicated to different targeted end-users. A selection of such databases is described in the following. They represent therefore interactions with other internal systems.

- NVE's national hydrological database system called "Hydra II"[12] plays a key part for research and development activities. This database is meant to support NVE's staff needs for information, and is in general open for use by registered external users. More than 100 external users are registered via a system of abonnement and can be proposed training if needed. Observations, experiments and modelling are key components, while the effect of climate change is a key research topic. Recently, research related to natural disasters and extremes has become a priority, and includes studies of floods, droughts, avalanches and landslides in a present and future climate.

- xGeo[13] is an expert tool owned and maintained by NVE. It is used for preparedness, monitoring and forecasting of floods, landslides and avalanches. It gives access to map- and time- based collated data from stations and models with events and field

[11] http://nedlasting.nve.no/gis/
[12] https://www.nve.no/hydrologi/hydrologiske-data/historiske-data/data-i-hydra-ii-databasen/
[13] www.xgeo.no

observations. xGeo is accessible to everyone and contains many types of data: both historical observations and model simulations, as well as forecasts, risk indices, and real-time data. The tool itself collects information from different databases, and include among other properties:

- timeline: 8 daily values + forecast + past values. The user can actually choose number of days back and forth,
- available weather data (from www.met.no), both forecast and past observations, for temperature, rain and snow,
- available warnings issued by NVE regarding flood, landslides, avalanches, storm, etc,
- Choice of specific areas: steeper than 30°, over forest line, mountain shadow, etc,
- Choice of specific infrastructure: roads, rails, hydropower infrastructure, watercourses, ski resorts, etc,
- Real-time data such as webcameras,
- Results of analyses issued by NVE such as: evaluated avalanche risk, snow stability, and
- Events registered by NVE.

- SeNorge[14] is the "non-expert" version of xGeo. SeNorge is a daily updated map-based tool which displays, among other properties:
  - Snow map for Norway, with among other properties: snowfall, fresh snow, ski conditions, snow melt, snow depth and deviation from norm,
  - Water map of Norway, with among other properties: water saturation in the soil, and amounts of water coming from rain and snowmelt,
  - Weather map for Norway, with among other properties: precipitations and temperature (daily and weekly), and deviations from the norm,
  - Map of climate and climate scenarios for Norway, with among other properties: normal and future scenarios for precipitations, temperature, snow and runoff,
  - Geographic information on terrain, such as steepness of slopes.

- regObs[15] is a registration application for natural hazard-related observations from NVE's observers and employees, SVV and the public. Data are used by NVE, but are also available to anyone who want to make their own assessments via NVE tools such as xGeo and SeNorge. Data can be registered for snow, water, landslides and ice. regObs is also available as an app for IOS and Android. A complete description of regObs is given in [53].

- Iskart[16] collects and displays data mainly related to ice covering lakes:
  - Timeline: some real-time data – some of it coming from sensors such as lake temperature, water flow and water level – together with past values and visualisation over days or years,
  - Observations: can be evaluations from the shore, or real measurements on specific locations over the lake,
  - Evaluation of dangerous lakes,
  - Some webcameras which focus on rivers or lakes,
  - Accidents related to icy lakes, either on foot or with motorized vehicles, and
  - Problems related to icy lakes, which can be categorized according to "flood", ice, landslide or others.

[14] www.senorge.no
[15] www.regobs.no
[16] www.iskart.no

- Varsom[17] is designed to provide avalanche warnings, flood warnings, landslides warnings and icemelting warnings together with important information related to alerts. Varsom.no is open to other types of natural hazards and events.

- Sildre[18] displays hydrological real time data for Norway. This is not a map-based service. This includes:
    - Water flow,
    - Water and ground water level,
    - Water, groundwater and air temperature, and
    - Snow-water equivalence.

3.4.7 Identified challenges
All identified challenges are classified under the main categories of "monitoring", "reasoning", "acting", and "evaluating", according to the concepts defined in Figure 5, in addition to the general issues of collaboration and adoption of digital solutions.

There are no "identified" challenges per today since the database is not yet implemented. However, there are still several open questions related to the scope of the database:
- Will the topics of vulnerability and risk be treated? And to which analysis level?
- Will damage and cost be treated? To which analysis level?

Answer to these questions depends on the scope of end-users, and on the business model that is foreseen by NVE (see Section 4.5).

3.5 The case of Trondheim municipality services (TK)

3.5.1 General description
Most of the reported facts about Gemini are reproduced from Holte [54].Trondheim municipality services use Gemini VA's systems for the management and documentation of the water and wastewater network. The water and wastewater services of Trondheim municipality are composed of two departments: the operational municipal services and the technical municipal services. They employ 85 persons and 20 persons, respectively.

Gemini VA is a software suite[19] developed and sold by Powel AS, and is currently used by about 300 Norwegian municipalities. Powel AS, headquartered in Trondheim, Norway, delivers business-critical software solutions and related services specifically designed to help energy companies and public utilities to improve daily operational processes and service quality.

The main purpose of the software is to keep a good record of the structural assets of a utility e.g. pipes, valves, manholes, pumping stations, and of the maintenance history on each asset. The software is a system of databases with an advanced descriptive presentation and registration manager [54].

Key features of Gemini VA include:
- Water and sewer system documented with standard features,
- A separate diary for all events relating to the different component of the network,
- Possibility to introduce web based properties and events,
- Separate module for work routines that can communicate with a field device, and
- Ability to extract statistics on properties and events from specific locations.

[17] www.varsom.no
[18] http://sildre.nve.no/
[19] http://www.powel.com/no/bransjer/kommunalteknikk/va-vann-og-avlop/

3.5.2 Objects

Gemini VA features three main registration areas: network information, diary, and planned activity. The network information includes mainly structural information on the different assets, e.g. construction year, diameter, material. Gemini VA's database is built up by several different databases and queries, and with links to other databases controlled by the municipality. The network is registered by nodes with coordinates where pipes are links between these nodes. The nodes consist of manholes, pumping stations, valves, service connections, etc, and links consist of all pipes, inclusive tunnels. An example of registered data is given in Figure 12.

3.5.3 Events

The diary registration area keeps the record of the completed work orders and other occurrences on the network, e.g. breaks, flushing, leaks, inspections. The diary part of Gemini VA is an important feature for making condition assessment and evaluating the performance of the network for future rehabilitation planning. Most of the diary information is readable for statistics and automatic reports.

The planned activity registration area keeps the record of the date and description on the known future activities, e.g. flushing program, inspection program. Work orders are all registered with date, and marked with a status: completed (green) or not completed (red). The program also preserves the historical diary registrations, by registering this as "historical". The planned activity feature is more interesting for operations than for rehabilitation.

3.5.4 Stormwater specificities

Stormwater events are registered within the diary registration feature. The number of recorded stormwater events has been unusually higher in 2001, 2007 and 2014. In general, some dozens of events are registered each year, evenly distributed within the municipal and private pipe networks. When stormwater events occur on private properties, the owner is responsible for solving the problem and making sure it is not expanding to other private properties.

3.5.5 Data

Data from Gemini is mainly used from TK water and wastewater services, for operational purposes. In some few cases, urban planning services are using the database, but only data linked to flooding roads and pipe network map.
Data might be open to external users for technical purposes, but TK has to be careful about data that could induce a decreased value of property, in addition to privacy issues.

Few data come automatically from real-time sensors located at six stations located around Trondheim, such as error messages and precipitation measurements. Most of event-related data comes from inhabitants (see Section 3.5.7), which are then used as "sensors".

Simple statistical data are extracted each year, such as number of events and distribution of events per category (water, road, wastewater) and are used by management levels.

3.5.6 Implementation

In general, TK buys IT services externally.

The Gemini software is not a GIS software, but it includes powerful GIS functions for visualization and analysis. The GIS interface can export both shape and .inp (hydraulic models) files. There are four important types of information sources in Gemini: field layer, map layers, control file and theme map. The field layer is made up of nodes, links and text. The map layer is a raster picture in the background that indicates where the network is located. Control file aims at easing the use of the map functions. The theme map's goal is to promote the information that is in focus, e.g. number of breaks or renovation types, by construction year or by material.

Gemini Portal is a mobile, simplified online version of Gemini VA. With Gemini Portal, the user has access to the VA data from tablet in the field, and can check and update information directly. Queries in Gemini VA can be submitted for statistical purposes or for providing other valuable information about the network.

LINE	INFORMATION RECORDED	NODE (INCL. PUMPING STATION)	INFORMATION RECORDED	OWERFLOWS	INFORMATION RECORDED	CONNECTION POINT	INFORMATION RECORDED
TOTAL ID	125688	TOTAL ID	132831	TOTAL ID	99	TOTAL ID	58637
BELONG TO NET TYPE	99,93 %	STATION	0,28 %	CATEGORY	68,69 %	LSID	100 %
RESPONSIBLE	99,98 %	FCODE	100,00 %	CONTROL	4,04 %	TYPE	100 %
OWNER	99,99 %	FUNC	89,81 %	CONTROL DIM	42,42 %	OWNER	87 %
STATUS	99,99 %	TYPE	51,16 %	WASTEWATER MEDIUM	-	YEAR	78 %
STREET CODE	93,06 %	OWNER	93,53 %	WASTEWATER MAX	-	DATE REGISTERED	100 %
LENGTH	100,00 %	STATUS	99,85 %	STORMWATER NORMAL	-	DATE CHANGED	8 %
FLOW DIRECTION	9,03 %	YEAR	73,36 %	EXCESS STORMWATER	-	DISTANCE	84 %
RISC	0,01 %	RISC	-	STORMWATER TO TP MAX	6,06 %		
REGISTRY DATE	99,99 %	COUNTY	48,25 %	STORMWATER MAX	-		
CHANGE DATE	81,45 %	STREET CODE	47,90 %	STORMWATER START	-		
MATERIAL	37,42 %	HOUSE ADDRESS	10,59 %	OUTLET HEIGHT	33,33 %		
DIM	44,02 %	LOCATION	23,26 %	WEIR HEIGHT	33,33 %		
YEAR	93,18 %	ACCESSIBLE	0,00 %	FLOODING CONDITION	-		
FORM	2,12 %	SHAPE OF OBJECT	21,87 %	SHUTTER	5,05 %		
DIM VERTICAL	0,17 %	WIDTH OF OBJECT	0,05 %	POLLUTANT CONTROL	9,09 %		
JOINT TYPE	30,04 %	LENGTH OF OBJECT	0,02 %	DISCHARGE TO	80,81 %		
PROD STANDARD	18,61 %	BUILDING STYLE	21,33 %	RESIPIENT	82,83 %		
REINFORCEMNT	18,25 %	CONE	0,13 %	PE	82,83 %		
STD DIM RATIO	0,10 %	MIDDLE DECK	0,01 %	CATCHMENT AREA IMPERMEABLE	-		
RINGSTIFFNESS	0,29 %	DATE REGISTERED	98 %	CATCHMENT AREA TOTAL	-		
PROTECT INTERNAL	2,71 %	DATE CHANGED	65 %				
PROTECT EXTERNAL	2,77 %	PUMP CAPASITY	-				
NOM PRESSURE	0,56 %	PUMP POWER	-				
PRESSURE CLASS	0,07 %	WELL_MAX_LEVEL	0 %				
RENOVATION METHOD	0,57 %	WELL_MIN_LEVEL	0 %				
OLD MATERIAL	0,57 %	WELL_VOLUME	0 %				
OLD DIM	0,57 %	WELL_UNITS	0 %				
OLD FORM	0,00 %						
OLD DIM VERTICAL	-						
OLD YEAR	0,57 %						
GROUND SURFACE	29,32 %						
EXTERIOR MASS	3,99 %						
SONE	55,54 %						

Figure 12: Registered data in Gemini (taken from [54])

3.5.7 Interactions with other internal or external systems

Another software from Powel used by the municipalities in Norway is Gemini Message ("Gemini Melding"). This software product takes care of the communication with the customers and deals with the complaints. The information can help the municipalities setting priorities on different rehabilitation projects based on the number of complaints.

Gemini Message is primarily used by the Customer Service for Trondheim Municipality. The department is composed of 10 persons who process requests and messages from Trondheim inhabitants' phone calls. The service[20] is open from 08:00 to 15:30 during weekdays. For emergencies outside working hours, Trondheim inhabitants have to contact the emergency guard by telephone for immediate answer / assistance.
Other methods for notifying an error[21] to Trondheim municipality include a net-based service[22] provided by Gemini Message Web (see Figure 13). The simple "search" function gives access to previously registered error messages via the platform, within a given period and complying with selected keywords.

The operator who receives the notice by phone takes decision about who is responsible and sends the message further. In case of emergency, a follow-up with a telephone call is performed. The follow-up of enquiries is a main task in itself: about 10-15 enquiries are received per day for closed drains, and 3-5 enquiries are received per week for other water-related issues. Net-based messages are directly implemented into Gemini Message system and are directly distributed to the relevant service, e.g. road or water.

Trondheim Municipality also uses a net-based warning service[23] to inform inhabitants about important events (such as water leakages and water closure).

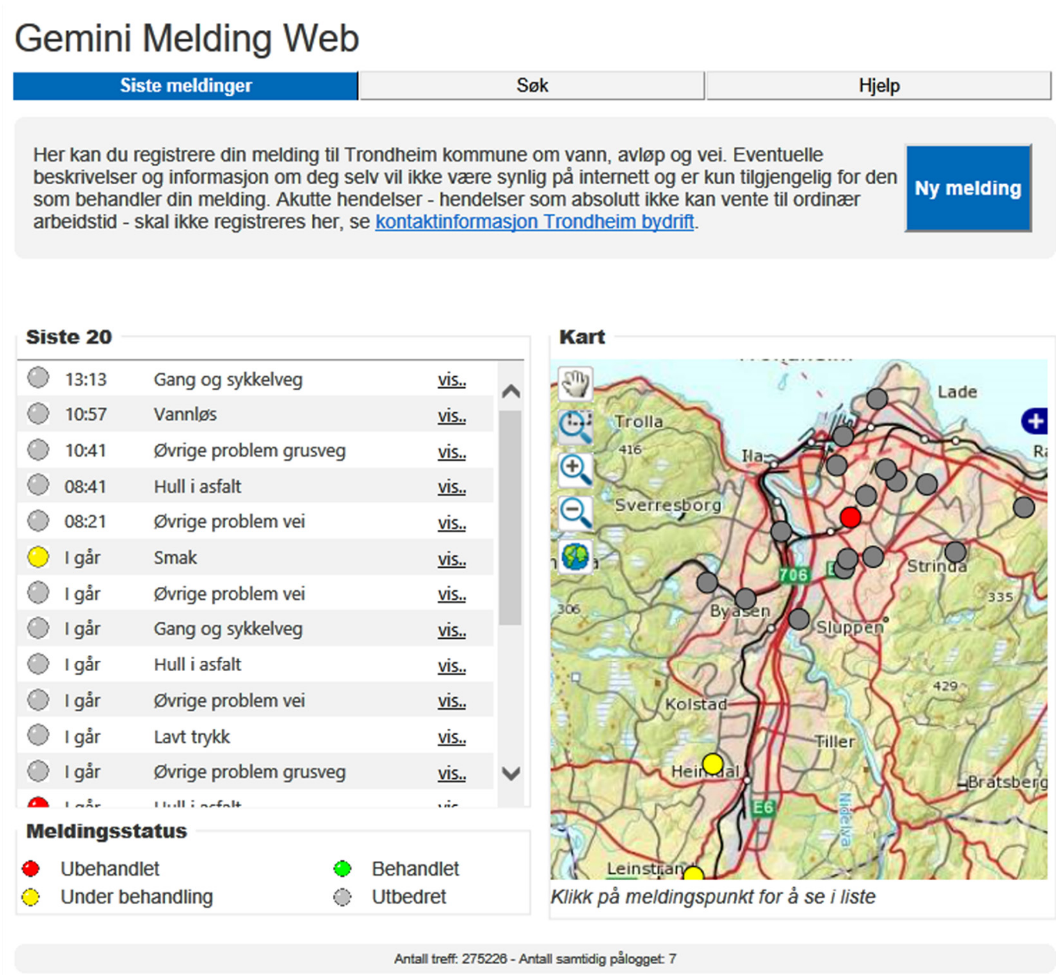

Figure 13: Screenshot[24] from Trondheim Error message service

[20] https://www.trondheim.kommune.no/content/1117713554/Kontaktinfo-Bydrift-vann-og-avlop
[21] https://www.trondheim.kommune.no/meld-inn-feil/
[22] http://feilmelding.trondheim.kommune.no/GmiWeb.Meld/Default.htm
[23] https://secure.ums.no/varsling365/

3.5.8 Identified challenges

All identified challenges are classified under the main categories of "monitoring", "reasoning", "acting", and "evaluating", according to the concepts defined in Figure 5, in addition to the general issues of collaboration and adoption of digital solutions.

A complete evaluation of Gemini software suite has been performed by Holte [54] and Ugarelli [55] in 2010, and a selection of their main conclusions is repeated below:

- Monitoring:
  - No cost data are available in the software, which makes cost-benefit analyses impossible.
  - All life cycle cost data should be included as primary input data in order to enable a preventive strategy (cheaper on the long term).
  - Gemini should include statistical information from other assets of the network, not only pipes and manhole.
  - Gemini needs more interoperability for possible use of input from other software products / databases.
  - Real-time data could be implemented and saved as diary features on the assets.
  - Extended data should be open to at least certain categories of external users, for example to municipalities lacking historical information, so they are still able to take data-based decisions.
  - Data validation should be more robust, with validation scripts to detect non-valid data, in order to prevent misleading statistics / reports.
  - Flooding data should include cause of flooding together with weather conditions.
  - Measures taken after a flooding event should be recorded in Gemini database, and should be classified as either temporary or permanent.

- Reasoning:
  - Risk of failure feature is not developed enough: it should include societal cost, environmental cost, construction cost, rehabilitation cost, repair cost, and should not be limited to damage and compensation cost.
  - In general, automatic reports could be issued every sixth month on diverse aspects of the network, e.g. current failure rates, updated service life, economic information.
  - Gemini message should be more automated. Prioritization of tasks could also beneficiate from optimization algorithms, depending on the number / location of available operators, gravity of the incident etc.

- Evaluating:
  - Gemini could either be upgraded to become a decision support system, or could at least provide inputs to an (external) decision support system by integrating necessary data.
  - Gemini should provide more support for decision-making by aggregating data and providing the user with cost for rehabilitating and risk for non-rehabilitating.
  - Gemini should give the user data-supported suggestions on when to rehabilitate, when to repair, and when to replace. Gemini should allow for a Capital Investment Plan feature in order to help the utility to develop a long-term funding strategy.
  - Gemini Message should give an effortless digital track of all events, that can again be used for optimizing allocation of budget, resources etc.

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[24] feilmelding.trondheim.kommune.no/GmiWeb.Meld/Default.htm

From interviews with end-users, the following challenges were identified:

- Adoption of digital solutions:
    - Phone errors messages are received "manually", and are then entered into the system after a first human decision, which is sometimes deemed as "difficult".
    - Few people are using the existing net-based tool for informing Trondheim municipality about errors. The service is probably not advertised enough, and its net-based user interface may not be customized to the current needs, e.g. relying mostly on "app" via mobile phones.

- Monitoring: Lack of relevant data for stormwater events:
    - Very few sensors are used. Measurements are usually performed manually according to well-defined sampling procedures, and the registration of events is usually triggered by Trondheim inhabitants' observations.
    - Information on flooding of basements is not usually distributed from individuals to the municipality services. Municipality services get the information from insurance companies later, depending on the gravity of events. In case of a large compensation, the request from insurance companies goes directly to the Norwegian Natural Perils Pool .
    - Even when municipality services know about a stormwater event, data are not complete enough for them to perform analyses. They need for example the height of water ingress, which is seldom recorded. Having access to this type of specific data requires a large amount of efforts, for example ringing inhabitants.
    - Trondheim municipality was part of a pilot project [56] in collaboration with Finance Norway, whose goal was to provide access to insurance data to municipalities in order to improve their preparedness to nature disasters and to future, more extreme, climate. However, the provided data were not specific enough, particularly when it comes to the cause of water-induced damages.

- Monitoring: Missing or incomplete economic data:
    - There is no obligation for Trondheim's inhabitants to inform TK about the cost of a water-induced damage. In case the damage is due to a 20-year period storm rain event, TK is legally responsible and is contacted by insurance companies for paying compensation.
    - In best case, the only cost which is known is the cost of paid compensation by TK, which does not correspond to any real damage cost estimation.
    - All other costs are not registered in Gemini VA.

- Monitoring: Lack of relevant data in general:
    - Gemini database covers only municipal pipe network and about 60 % of private pipe network. In addition, there is no updated information about other governmental agencies such as SVV and JBV, although a collaboration is seen as beneficial.
    - Pressure line and water level are recognized as important information for TK together with a terrain model that shows flood roads and drainage lines. Validation of models and analyses is also crucial.
    - There is no automatic relationship provided between recorded events and meteorological conditions.

- Monitoring: Little need for real-time data with focus on warning systems:
    - Such real-time data are difficult to implement.

- TK services have very few possibilities "to act preventively" in case a warning of extreme rain event is issued. The whole pipe network is not adapted to such real-time control.
- Being part of a project to use radar data for getting a more precise spatial prediction of precipitation data[25] is therefore not addressing the direct needs of TK services.

- Evaluating: Decision support system is not optimally used:
  - Gemini VA database is in theory used for registering pipe inspection data (about 40 km per year). Prioritization of investment is then based on classification criteria. The classification does not come automatically, and correct data has to be requested through the database.
  - In reality, about 20 % of investment is decided on the basis of other "external" projects, such as the construction of new roads for which the whole pipe network has to be changed. For some projects, the process is early enough to plan such investment, however, the real cost is known often very late.
  - In general, the capacity to optimally use – increasingly available – data was compared to an "art", particularly for generating status analyses and meaningful statistics.
  - However, the interviewed users were sceptical to the usefulness of decision support systems. A significant need for knowing what is behind such algorithms was expressed, together with a significant doubt about "black-box" systems.

3.6 Summary

The main features of all identified sources of data are summarized in Table 1. It is interesting to note that the main databases owned or maintained by the national agencies serve different needs of different end-users:

- SVV uses its database (NVDB) as a complete display for providing different types of information to its employees,
- BN uses its database (BaneData) to efficiently document and follow-up all maintenance routines for its employees,
- NVE uses its database for informing the general public about past events and future forecasts related to natural hazards,
- TK uses its database (based on Gemini software product) to efficiently distribute tasks to its employees and to collect reports.

[25] RegnByge 3M: http://web.rosim.no/regnbyge3m/index.php/partnere/

Table 1: Short overview of data sources available in Norway

Name	Availability	Map-based	API	Main Motivation	Specific goals	End user	Main developer (contributors)	Web-reference
BaneData	On-request	Yes	Yes	Active documentation system	To send automatically working orders.	BN	BN	None
				Reporting tool	To provide an easy-to-use tool that accommodates well the constraint of limited access to the rail network, and that supports in an efficient way the following actions: control, repair, and report.			
Jernbaneverkets kartvisning	Open and On-request	Yes	No		To provide most of available information within BaneData together with warnings from NVE.	external	BN (NVE)	https://customapps2.geodataonline.no/Jernbaneverket_HTML5Viewer/
Dop-Ut	On-request	No	No	Documentation system	To collect activities within the maintenance plan together with risk analyses.	BN	BN	None
Pro-Arc	On-request	No	No	Documentation system	To collect technical drawings and reports.	BN	BN	None
TekDok	On-request	No	No	Documentation system	To collect all documentation related to each object under a unique digital location	BN	BN	None
Vegkart	Open and On-request	Yes	yes	Data & information display	To support optimal management, maintenance and development of the national roads.	SVV	SVV	www.vegvesen.no/vegkart/vegkart/ https://www.vegvesen.no/nvdb/apidokumentasjon/
					To display effective information system about traffic and incidents on the road network.	Road-owner Road users		
xGeo	Open	Yes	Yes	Data & Information display	To support preparedness, monitoring and warning of flood, landslides and avalanches.	External experts	NVE	www.xgeo.no
regObs	Open	Yes	Yes	Registration tool	To register observations related to snow, flood, ice and landslides.	General Public	NVE	www.regobs.no http://api.nve.no/
IsKart	Open	Yes	Yes	Data & information display	To display information related to ice covered lakes.	General public	NVE	www.iskart.no
Varsom	Open		Yes	Data & information display	To provide warnings for avalanche, floods, landslides, and icemelting.	General public	NVE	www.varsom.no http://api.nve.no/
SeNorge	Open	Yes	Yes	Data & information display	To display daily updated maps of snow, weather, water conditions and climate.	General public	NVE (met.no)	www.senorge.no
Sildre	Open	No	No	Data & information display	To display hydrological real time data.	General public	NVE	http://sildre.nve.no/

Name	**Availability**	**Map-based**	**API**	**Main Motivation**	**Specific goals**	**End user**	**Main developer (contributors)**	**Web-reference**
ELRAPP	Internal	No	No	Documentation system	To support and document electronic reporting & following-up. To document tasks related to operation- and maintenance contracts	SVV	SVV	None
Hydra II	Open		yes	Data & information display	To collect observations, experiments and modelling related to hydrological topics.	General public	NVE	https://www.nve.no/hydrologi/hydrologiske-data/historiske-data/data-i-hydra-ii-databasen/bruk-av-hydra-ii/ http://api.nve.no/
Gemini Trondheim	On-request	Yes	?	Data & information display	To keep a good record of the structural assets of a utility and the maintenance history on each asset.	TK	TK	None
Gemini Message	Open	Yes	No	Registration tool	To register observations and complaints from customers to the municipality.	General Public		None
Future NVE database	Open	Yes	Yes	Analytic tool	To provide geomorphological information of floods and stormwater events.	Municipalities Other stakeholders NVE	NVE	Not implemented yet

4 Suggestions for further work

4.1 Further work related to the "monitoring" pillar in the data cycle

Data sources have been shown to be either scarce or not exploited in an efficient way. The potential of alternative sources of data has to be investigated, together with development of new solutions for a more efficient exploitation of already existing sources of data.

- "Manual" inspections have been deemed as costly and demanding in terms of required staff over large geographical areas and following a frequent inspection schedule. In some cases there were no specific procedures nor any quality system to control the inspection procedures. Digitization of reports was in some cases not achieved, which led to additional workload and additional potential sources of errors. The development of relevant **sensors** can instead prove to be a rather efficient way to increase amount and quality of data. Sensors can automatically send relevant data each day, each week, or at relevant inspection intervals. This also enables further data processing to transform data into knowledge. A typical example of such sensor solutions are inexpensive web cameras whose images can be treated automatically by image analyses software products. A typical application would be to continuously detect blocked culverts.
- All technologies related to the "**Internet-of-Things**"(IoT) represent potential additional sources of data whose relevance should be investigated in a systematic way. IoT shall be able to incorporate transparently and seamlessly a large number of different and heterogeneous end systems, while providing open access to selected subsets of data for the development of a plethora of digital services [57]. The realization of an IoT network, together with the required backend network services and devices, still lacks an established best practice because of its novelty and complexity. In addition to the technical difficulties, the adoption of the IoT paradigm is also hindered by the lack of a clear and widely accepted business model that can attract investments to promote the deployment of these technologies [57]. Technical, societal, and business studies are therefore needed to fully map the potential of IoT within the scope of this report. Security aspects must also be investigated to ensure a robust internet infrastructure to avoid e.g. cyber-attacks[26].
- The **participation of citizens** to smart cities-like purposes is getting more and more interest. The development of dedicated and easy-to-use "apps", together as the application of game-design elements and game principles in non-game contexts – coined as "gamification" – is an efficient way to enhance the involvement and contribution of citizens to mitigation of climate changes within an urban environment. At the same time, by creating such redundant low-cost sources of data, data is likely to come with a higher quality. Further studies are however necessary to improve ergonomics of such "app" solutions, to map the real interest of citizens for such collaborative solutions, to understand how to entice citizens into providing data – e.g. via incentives – and to promote efficiently such solutions via marketing. The main motivation should be to develop and deliver scientifically-relevant and at the same time popular "app" solutions.
- It is essential that collected data items are registered together with their location. Location should imperatively be coded under both a readable street address / place name and GPS coordinates for ensuring correct understanding from human users, and efficiency from machine-controlled algorithms. A research project from The Western Norway Research Institute [56], together with Finance Norway and some other local and regional authorities, assessed the potential and preconditions for strengthening the prevention of climate-related natural hazards through assessing the usefulness of access to the damages data of insurance companies. The project

[26] STOP-IT project: stop-it-project.eu (website will be launched in autumn 2017)

showed that municipalities had very limited competence with geocoding, and that in many cases, quality of data had to be reviewed manually before geocoding data. Studies to select available and relevant **geocoding – and reverse geocoding – tools** are necessary to enhance the quality and usefulness of collected data.

- Geocoding and reverse geocoding have raised potential **privacy concerns**, especially regarding the ability to reverse engineer street addresses from published static maps[27]. By digitizing published maps it is possible to georeference them by overlaying with other spatial layers and then extract point locations which can be used to identify individuals or reverse geocoded to obtain a street address of the individual. The Western Norway Research Institute [56] and Finance Norway underlined the potential effect on sale value of properties. Societal studies should be performed to evaluate the risks associated to making such information available to the general public, and to propose appropriate measures.
- Data should ideally be open and datasets should be collected under a **common and secure platform**. Open data is expected to contribute to the following positive developments: efficiency and innovation, industrial development, democratization, and transparency. Governmentally maintained platforms such as data.norge.no[28] are ideal candidates for such purposes. However, issues such as handling of business sensitive information (see Figure 14), treatment of classified information, and treatment of data with third-party copyright still must be investigated.

Figure 14: Business-sensitive data, DILBERT © 2010 Scott Adams. Used By permission of ANDREWS MCMEEL SYNDICATION. All rights reserved.

4.2 Further work related to the "reasoning" pillar in the data cycle

Transformation of data into knowledge has been shown to be performed with limited efficiency, sometimes because of unclear needs, sometimes because of technical limitations. Solutions do exist for other types of applications, and the potential of their transfer to climate mitigation purposes should be investigated.

- Passive use of data has often been observed. Although most of the databases were used as powerful and robust dashboards containing and displaying a substantial amount of information, the **development of analytic tools** to enhance an active use of data to support decision-making processes appeared as limited. Analytics is a well-developed field whose technical implementation is relatively easy if precise specifications are given.
- The need of mapping relevant groups of end-users and their corresponding needs is therefore crucial for the customized development of relevant analytic tools. **Standard procedures for mapping end-user needs** and their corresponding technical specifications should be defined. Typical cases could be defined for recurrent end-users' needs, e.g. urban planning departments in municipalities.

[27] https://en.wikipedia.org/wiki/Reverse_geocoding
[28] https://data.norge.no/om

Development of a catalogue of standard needs of typical end-user groups could be achieved via large-scale interview series led by social scientists.

- Depending on the actual needs, data from several databases may be required for supporting the development of customized analytic tools. Although the possibility of a unique gigantic database that would collect all data sounds tempting at first, its realization is highly hypothetic and would require time-consuming commitments from each database owner. A more relevant solution is to use **APIs** for selecting and exchanging data in an "automatic" and structured way, depending on the relevant needs. Implementation of efficient APIs is therefore required for all databases.
- APIs are the technical solution to select and use data originating from different sources, but their presence is not enough to guaranty an efficient integration of data sources afterwards. A common terminology must be ensured so that different data sources can communicate between each other, and can eventually be integrated within the same analytic tool. The best-known technical solution to the problem is represented by the **development of ontologies**. An ontology is a controlled, logically structured representation of the world (more usually part of it) that is both human and machine readable [58]. De Wrachien et al. [59] give the following definition for ontologies: "ontologies provide a mechanism to share knowledge by using a common vocabulary; they allow semantic labelling, exchanging and reusing knowledge; they can be also used to establish a communication protocol". Its formal background makes possible the semantic, logic and formal descriptions without additional tools. Ontologies have been originally used in genetics but have recently spread to fields such as knowledge engineering, artificial intelligence and computer science, language processing, knowledge representation, cooperative information systems, ecommerce, bioinformatics, database design and integration, smart integration of information, information retrieval and knowledge management [59]. Ontologies have also been developed for the specific field of natural disasters, for example in the framework of the EU project "INFRARISK" [60] whose main goal was to evaluate the risks associated with multiple infrastructure networks for various hazards (see Figure 15 and Figure 16). Other attempts include studies from De Wrachien et al. [59], Scheuer et al. [61], Kuziemsky et al. [62], and the European project "Disaster 2.0" [63].

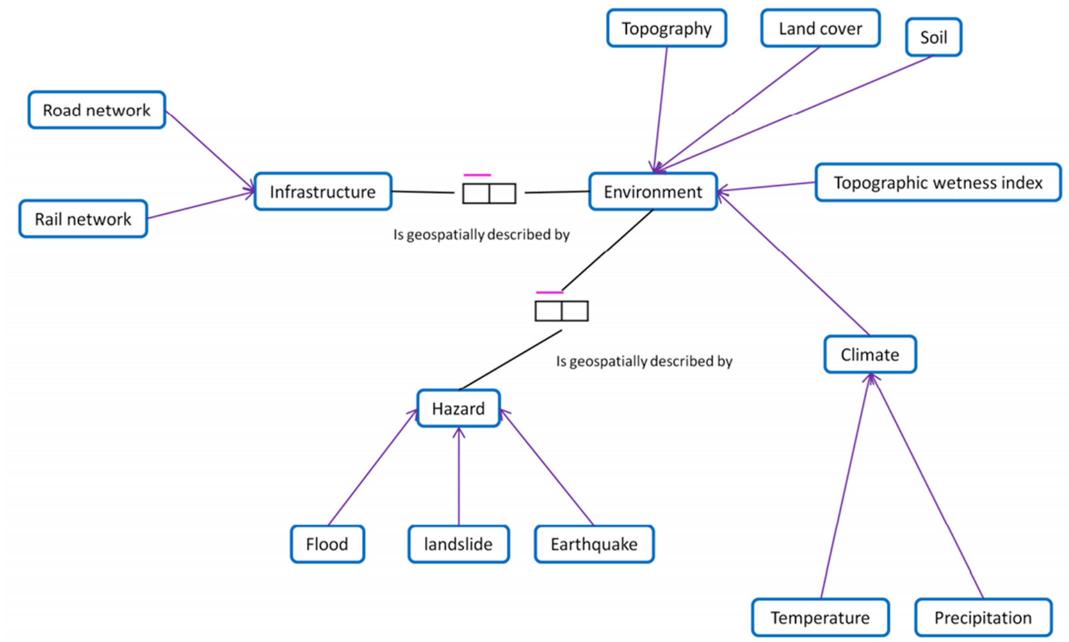

Figure 15: General ontology from the INFRARISK project [60]

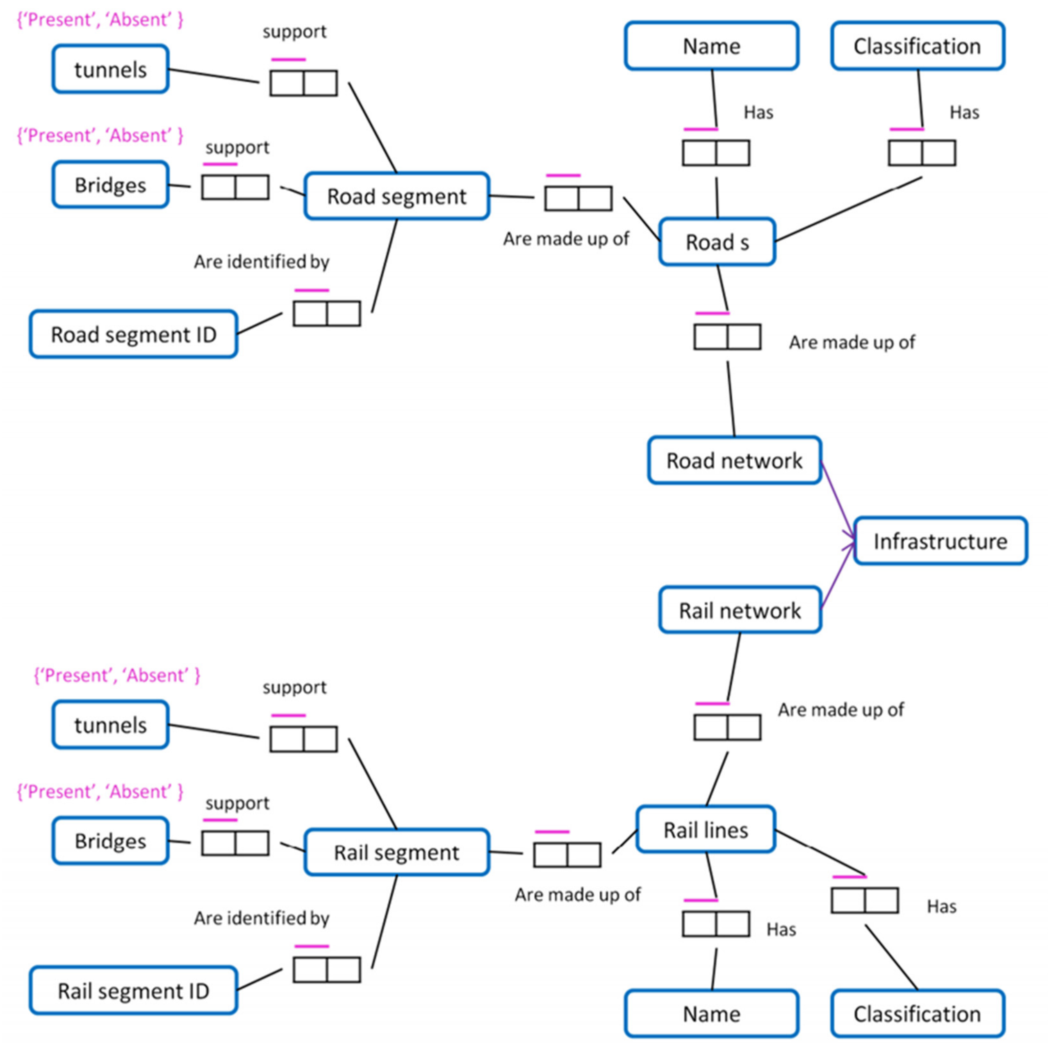

Figure 16: More detailed part of "Infrastructure" ontology developed within the INFRARISK project [60]

4.3 Further work related to the "acting" pillar in the data cycle

"Acting" in the field requires ergonomic and user-friendly digital solutions to support workers in their daily missions and to efficiently – and mistake-free – document the actions within the system.

- It is almost mandatory that the provided tools are **digital**, so that there is a direct data flow from workers to the system. This saves time and increases data quality by limiting the occurrence of errors. A digital inspection framework is also an efficient way to develop – and enforce – procedures.
- **Ergonomics** and graphical-user-interface (GUI) are important features of any tool designed to support workers (see Figure 17). The limited adoption of tools by workers is often due to bad design and this penalizes efficiency of the whole data flow. Studies to improve ergonomics and GUI design are therefore needed to ensure good adoption of the tools by the workers.
- The use of map-based tools has been observed to be widely spread among all national agencies. Map-based tools rely mostly on the development of **Geographical Information System (GIS)** solutions that integrate, store, edit, analyze, share, and display geographic information. GIS applications allow users to create interactive and customized queries, to analyse spatial information, to edit data in maps, and to

present the results of all these operations [64]. The use of map-based tools should not be limited to the "acting" part and should enable a wider adoption of GIS benefits, which include [65]:

- cost savings to optimize e.g. maintenance schedule,
- better decision making about location e.g. route selection and evacuation planning,
- improved communication: GIS-based maps and visualizations are a type of universal language that improves communication between different teams, disciplines, professional fields, organization, and the public,
- better record-keeping e.g. for maintaining authoritative records,
- the development of a new management approach: managing geographically, meaning understanding what is happening and what will happen in geographic space.

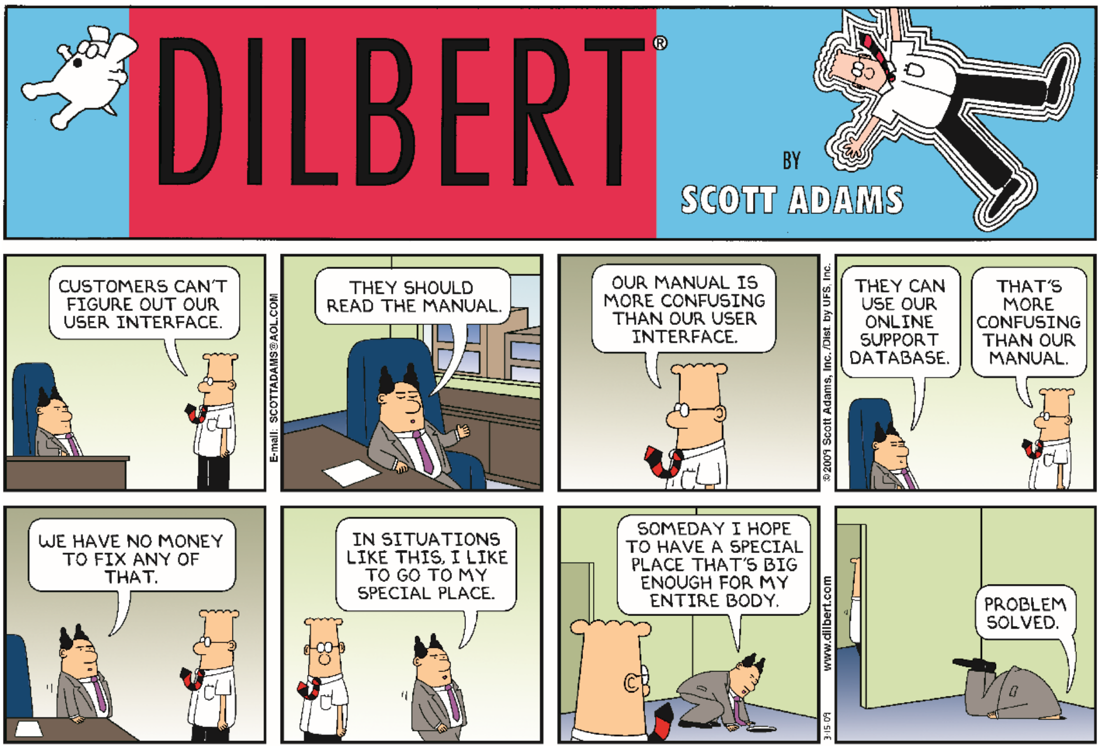

Figure 17: Ergonomics and user-interface are important features, DILBERT © 2009 Scott Adams. Used By permission of ANDREWS MCMEEL SYNDICATION. All rights reserved.

4.4 Further work related to the "evaluating" pillar in the data cycle

The evaluating part is the last one within the data cycle, and is also the most important for enabling improvement at a system scale. However, this is also the aspect which has been observed to be the least implemented within the national agencies, most probably because it requires all digital connections to be implemented upstream.

- An efficient evaluating process is based on the assumptions that the whole data cycle is continuously digital, that workflows are efficiently designed, and that analytical tools are appropriate to management purposes. The main challenge lies in using dataflows for **business purposes** whereas they have been originally designed to serve operational purposes. Important properties such as costs, which are not needed for supporting operational tasks, need therefore to be added within the dataflow. This requires e.g. the database solution to be flexible enough for authorising inclusion of new properties and/or new categories. Responsibilities also need to be precisely defined regarding evaluation tasks, reporting tasks, and final decision-

making process. Both technical and organisational studies are needed to provide guidance to organizations for implementation of an efficient evaluating process.
- An efficient evaluating process is based on the definition of **relevant performance indicators**. Such indicators must be mapped and defined by the management system itself, and it is likely that each organization would have a different set of performance indicators depending on its specific business model. However, business studies could help the management systems in such a task by publishing guidelines, sets of best practice, and potential common structure for performance indicators.
- From a purely technical side, the management system needs to be provided with knowledge, which is probably most efficiently displayed under the form of a dashboard featuring the current values of relevant performance indicators, together with forecast values for the next periods and benchmark values against own tracked record from previous periods. Forecast and benchmarked performance are key insight tools that requires process modelling of activities. Studies involving **business process modelling** would benefit to organizations for increasing quality and/or reducing costs.
- In addition to evaluating the performance of organizations with respect to their core business, it would be interesting **to evaluate the societal risk associated with climate changes at a national level**. This ambitious goal requires all digital connections in all systems from all organizations to be implemented upstream, and all previously identified possibilities for further work to be completed. It is also likely that, although some historical data exist, the delivery of the first relevant results would necessitate several years of monitoring. However, implementation of such an overall evaluation system would provide policymakers precious knowledge for evaluating and eventually adapting their policy.

4.5 Opportunities for innovation

The challenges have been shown to lie in multiple fragmented data sources together with processing tools that do not provide sufficient and/or relevant knowledge to end-users. There is therefore an obvious need for providing more adapted tools both for triggering efficient actions and for improving knowledge-driven decisions. The following proposed methodology is not specific to stormwater issues, and can be applied to other climatic issues e.g. landslides.

The premises for enabling innovation are the following:

- Data must be as open as possible. This requires:
  - Definition of appropriate rules for data ownership,
  - Definition of appropriate procedures for guaranteeing privacy, and
  - Definition of appropriate procedures for guaranteeing security.
- Quality of data must be as high as possible. This requires:
  - Definition of appropriate procedures and performance indicators for evaluating data quality, and
  - Enforcement of public availability of these performance indicators, together with the dataset.
- Data must be as accessible as possible. This requires:
  - Implementation of API or similar IT solutions for efficient data exchange
- Data must be as standardized as possible. This requires:
  - Definition of appropriate ontology schemes, and
  - Implementation of these schemes for all datasets / databases.

Innovation lies in the development of relevant tools for giving relevant stakeholders relevant knowledge from relevant data sources. The following steps, in this order, must be respected:

1- Select a homogeneous group of end-users.
2- Map their needs, both related to knowledge and to user-interface.

3- Select the relevant data sources available via datanorge.no, or any other governmental platform for hosting data.
4- Identify the gap between data availability and data needs, if any.
5- Program the relevant algorithms.
6- Provide a customized tool to the group of end-users.

Business models may vary depending on who is providing and who is paying for development of such a tool:

- Data owners may develop proprietary tools for external customers to exploit their own data.
- End-users may develop themselves, internally, the tools they need.
- External IT companies may develop specific tools for individual customers, or may sell targeted customers generic tools depending on the market opportunities.

In any case market analyses must be performed to evaluate customers' preferences for actual and potential products and services.

4.6 Potential synergies with other projects, possibly collaborative pilot projects

The cooperation established between NVE, SVV and BaneNOR in the program "Natural Hazards, infrastructure, floods and landslides" (**NIFS**), has laid a good foundation for the national strategy. The program was implemented in the period 2012-2015. Many results from NIFS are ready for implementation in the national agencies, but there also is a need for more concrete projects and initiatives.

The collaborative effort between **Finance Norway**, several insurance companies, the Western Norway Research Institute, the Department of Geography at the Norwegian University of Science and Technology, and ten pilot municipalities to assess the usefulness of access to damage data of insurance companies [56] has resulted in a comprehensive report describing the challenges and opportunities encountered during the pilot project. It is expected that the conclusions of the report serve as a basis for triggering the creation of follow-up projects – as spin-off projects from Klima 2050 – together with selected municipalities.

NatureFareForum was established in 2016 to achieve the national strategy for flood and landslide through coordination between several national agencies and some external stakeholders. The overall aim of NatureFareForum is to improve society's ability to manage risks related to natural hazards and to keep damages at an acceptable level by achieving better coordination and collaboration. The main objectives include:

- better resources,
- better quality services,
- greater awareness and understanding across areas of responsibility, and
- better and easier access to information.

The last point related to information and access to it is especially relevant to Klima 2050 project, and fits particularly well within the work performed in WP2.1.

The **Sendai Framework for Risk Disaster Reduction**[29] is a 15-year, voluntary, non-binding agreement which recognizes that the State has the primary role to reduce disaster risk. The Sendai Framework also states that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders. As one of the states that endorsed the Sendai Framework, Norway agreed to work for a reduction of damages until 2030. The seven global targets are the following:

[29] http://www.unisdr.org/we/coordinate/sendai-framework

- Reduce mortality caused by disasters,
- Reduce the number of people affected by disasters,
- Reduce direct economic losses,
- Reduce damage to critical infrastructure and disruption of basic services,
- Promote strategies for disaster prevention,
- Promote international cooperation, and
- Promote early warning systems and risk information.

The four priorities for action are the following:

- Understanding disaster risk,
- Strengthening disaster risk governance to manage disaster risk,
- Investing in disaster risk reduction for resilience, and
- Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

It is expected that the establishment of the NatureFareForum initiative will contribute to achieving the Sendai Framework Agreement goals and targets. This may also be the motivation for developing collaborative spin-off projects from Klima2050 main platform.

NVE is developing a **new Norwegian flood database** including historical flood information as well as information on new floods. The database will be based on flood events where each event is assumed to be caused by the same meteorological conditions within a geographically defined area. Section 3.4 gives more details about the specifications for this new database at the time of writing this report. A collaboration between Klima 2050 and NVE on this specific task, e.g. to develop complete specifications for the new database, perfectly fits within the scope of Klima 2050 project.

5 Conclusion

The task WP2.1 within Klima 2050 project mapped and reviewed the different databases related to floods and/or stormwater events. The review has shown that data are spread around a heterogeneous community of stakeholders concerned with different motivations, different needs, and different levels of data processing. In general, the needs of the different stakeholders have not been surveyed and defined systematically enough, while no widely perceived international norm for the management of a damage database has been proposed in the literature [37]. Regarding international flood databases, there is still a substantial demand [4] for a standardized and systematic collection of flood damage data with clearly defined and documented procedures. Regarding national stormwater-related inventory databases, there is a substantial potential in upgrading from the delivery of passive raw data to the delivery of knowledge-driven decision-support tools.

Further work should aim at:

- Exploiting more efficiently available sources of data and exploring alternative sources of data,
- Achieving a more efficient transformation of data into knowledge via the development of analytical tools that match the identified needs of relevant end-users by efficiently processing several relevant sources of data (see Figure 18),
- Providing ergonomic and user-friendly digital solutions to support workers in their daily tasks and to efficiently document the actions within the system, and
- Triggering the implementation of evaluations processes within the national agencies for business purposes, and at a national scale for providing the policymakers with useful knowledge about the societal risks associated with climate changes.

Technical challenges can relatively easily be solved by digitization and its opportunities for improvement of the workflow and for higher quality of data. Organisational challenges must be solved by an end-users-focused approach to identify needs and expectations.

The task WP2.1 intends to be a catalyser within Klima2050 project for triggering a global data-driven evaluation system to provide policymakers with knowledge on societal risk associated with climate change, and for strengthening national agencies and private companies' innovation capacity for addressing climatic changes.

Figure 18: Need of knowledge for decision-making, CALVIN AND HOBBES © 1993 Watterson. Reprinted with permission of ANDREWS MCMEEL SYNDICATION. All rights reserved.

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