The STIG – A new SDI assessment method. *

B. Nushi[1], B. Van Loenen[2], J. Crompvoets[3]

[1,2] TU Delft, Delft, The Netherlands, b.nushi@tudelft.nl ; b.vanloenen@tudelft.nl

[3] KU Leuven, Leuven, Belgium, joep.crompvoets@soc.kuleuven.be

Abstract

To stimulate the Spatial Data Infrastructures (SDI) development effectively and efficiently, it is key to assess the progress and benefits of the SDI. Currently, several SDI assessment methods exist. However, these are still in an infant stage and none of these appear to meet the requirements of practitioners. As a result, SDI decision makers are still without any guidance on the performance of their SDI. In the financial sector stress testing is commonly used to assess the sustainability and success of the system. This work presents an early stage of a longer research activity by introducing the subject, underlying concepts and proposing a projection of an assessment method from FI to SDI. While this work already identifies a key scenario to begin with, concrete realisations remain part of the future work. Based on a review of the nature and concept of the SDI and Financial Infrastructure (FI) we conclude that the stress test methodology is likely to be an appealing alternative way of assessing SDIs. The Multi-factor Stress tests (Hypothetical and a Non-systematic Subjective scenario model) are most promising as a basis for SDI assessment. A first draft of the Stress Test for Infrastructure of Geographic information is presented: the STIG.

Keywords: SDI, Stress test, Financial sector, STIG.

DOI: 10.2902/1725-0463.2015.10.art3

1. INTRODUCTION

The development of Spatial Data Infrastructures (SDIs) remains to require major investments. Worldwide around €120 million is spent each year on the management of online portals providing access to geo-information alone (Crompvoets, 2006). The investment requirements for an Infrastructure for Spatial Information in the European Community (INSPIRE) was estimated to vary from €202 to €273 million each year for each European Member State (INSPIRE, 2003). Given this expenditure and society's interest in the effective and efficient use of public funds, it is very important that these SDI services and initiatives are assessed on their effectiveness and efficiency.

Driven by different goals and interests, researchers have developed and applied several SDI assessment methods over the past decade. These assessment methods concentrate on one of the aspects of an SDI (such as cadastres, organisational aspects), are restricted by one region, describe SDI development in only a few countries, or are still conceptual in nature, leaving SDI practitioners with no support or guidance on the performance of their SDI.

In other domains, stress testing is an accepted way of assessing the functionality of a system. The objective of a stress test is to understand the sensitivity of the portfolio to changes in various risk factors.

Our work assesses the extent to which stress test methodologies can be supportive to developing a new SDI assessment method that can provide the required information on the performance of SDIs.

The characteristics of SDIs and Financial Infrastructures (FI) are central to the presented work. If we can assume that FIs have comparable key components as SDIs and are, similar to SDIs, complex, multi-faceted, dynamic and constantly evolving (Grus et al., 2007), then the assessment methodology applied to FIs may also work for the assessment for an SDI. Assuming that the systems of SDI and FI may have a similar level of complexity also their assessment methods may be similar.

This paper aims to develop a theoretical framework of stress testing for infrastructures of geographic information and presents the lessons learned from an implementation of the stress test in FIs. The research on this paper stands on an on-going PhD research project on the development of a sound foundation for an academic theoretical framework for the STIG, Stress Test for Infrastructure of Geographic information.

The remainder of this paper is structured as follows. In Section 2, the theory behind the SDI and SDI assessment is portrayed while the FI is presented in Section 3.

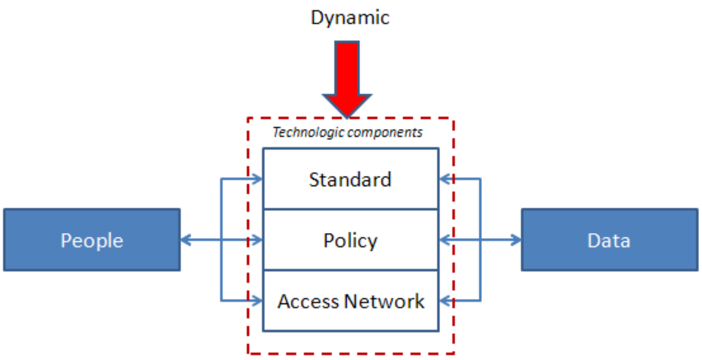
The theory behind the stress testing and the implementation of the stress testing is explained in Section 4. Finally, the argumentation on the suitability of stress testing for SDI assessment and the description of the framework of the stress test in SDIs, STIG 1.0, can be found in Section 5. This paper ends with a conclusion and further research in Section 6.

2. SDI AND SDI ASSESSMENT THEORY

An SDI may be defined as a framework continuously facilitating the efficient and effective generation, dissemination and use of needed geographic information within a community or between communities (Van Loenen, 2006). Rajabifard et al. (2002) argue that an SDI is an infrastructure intended to create an environment that will enable a wide variety of users to access, retrieve and disseminate geographic information in an easy and secure way. According to Rajabifard et al. (2002), SDIs allow for the sharing of data enabling users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with generation and maintenance of data and their integration with other datasets. An SDI is also an integrated, multi-leveled hierarchy of interconnected SDIs based on collaboration and partnerships among different stakeholders (Rajabifard et al., 2002). Many countries have developed SDIs to better manage and utilize their geographic information assets by taking a perspective that starts at a local level and proceeds through regional, national levels to the global level. Rajabifard et al. (2002) suggest that different categories of components can be formed based on the different nature of their interactions within the SDI framework. Considering the important and fundamental role between people and data as one category, the second can be considered the access network, policy and standards – the main technological components. The nature of the second category is very dynamic due to the rapidity with which technology develops and the need for mediation of rights, restrictions and responsibilities between people and data change (Rajabifard et al., 2002).

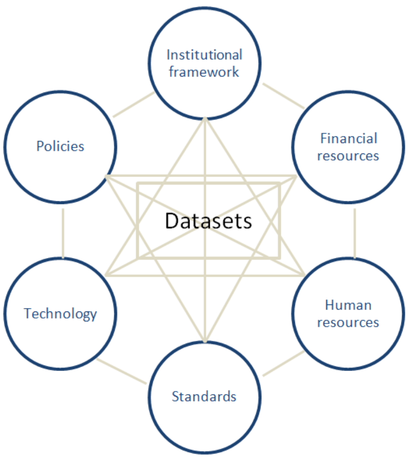
An SDI encompasses the policies, access networks and data handling facilities (based on the available technologies), standards and human resources necessary for the effective collection, management, access, delivery and utilization of geographic information for a specific jurisdiction or community (see Figure 1).

Figure 1: SDI Components (Rajabifard et al., 2002)



Access mechanism, network mechanism and response time were also identified as three main factors with respect to accessing networks. With respect to data, scale and resolution, content, capture (tools and mechanisms), access and analysis tools, database management and metadata were identified as important factors. This suggests that an integrated SDI cannot be composed of geographic information, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks. From this perspective, anyone (e.g. data users through to producers) wishing to access datasets must make use of the technological components. According to Van Loenen (2006), the SDI includes the following components: Datasets, Institutional framework, Technology, Standards, Financial resources, and Human resources (Figure 2).

Figure 2 – SDI Components (Van Loenen, 2006)



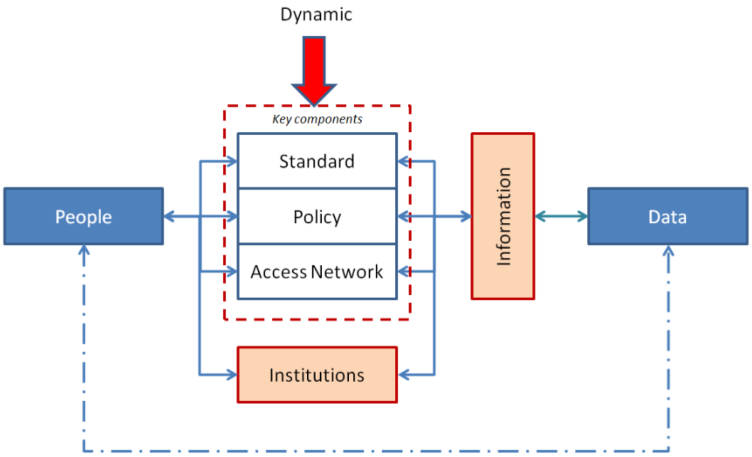
Van Loenen (2006) distinguishes two categories of datasets: framework datasets and thematic datasets. Framework datasets are commonly used as a base dataset for thematic mapping. Specific thematic datasets are added to the framework dataset. The collection, maintenance, dissemination and use of geographic information is organized by institutions and maybe is the most important aspect of an SDI. The coordination of SDI development and leadership at a national level through the institutional framework are prerequisites for the establishment and further development of an SDI (Van Loenen, 2006). Van Loenen further argues that policies do exist at every level of SDI development and at each level they are likely to reflect the needs of a specific community. As a result, the policies of countries in a same level of a geographic information infrastructure (GII) development may differ from, or even conflict with, each other. According to the author (Van Loenen, 2006), technology has allowed us to start thinking about the SDI concept. Technology allows us to collect information in a digital form, distributing it very quickly at almost no costs. The technology component is closely linked with the existence of standards (both in software and hardware). Additionally he states that one of most important aspect of information sharing and integration is standardization. Dataset and technology specifications should adhere to standards in order to assure the integration of information. About the availability of the financial resources Van Loenen argues that this is a critical condition for the development of an SDI. Building awareness and commitment among the stakeholders that control funding resources is very important. Awareness will lead to short term financial support and commitment to continuing sustainable funding. Regarding the last SDI component Van Loenen believes that human resources are a natural element of the SDI. In a process-based SDI strategy, human resources typically exist of experts involved in coordinating the SDI, bringing the information producers and user together, and promoting the concept within and outside the SDI sector.

2.1. New SDI Model

Taking in account the recent technological developments we believe that Rajabifard's SDI model of people accessing data through SDI has to evolve. Having considered the core components of SDIs by Rajabifard et al. (2002) and Van Loenen (2006) we are considering the *access network, policy* and *standards* as the key SDI components. According to this view, users (people) wishing to access data must utilize the key components. In some cases an SDI user may access information as well as data. The processes have become increasingly transparent to data users, as more and more access is required to a simplified form of data (Information) rather than in its raw data form. The shift to this new presented SDI model of information access and use will require institutional mechanisms (Institutions) to support the availability and access to data through the information and technologies components.

The new modified SDI model with the two new components (institution and information) is presented in Figure 3.

Figure 3: New SDI Model & Components



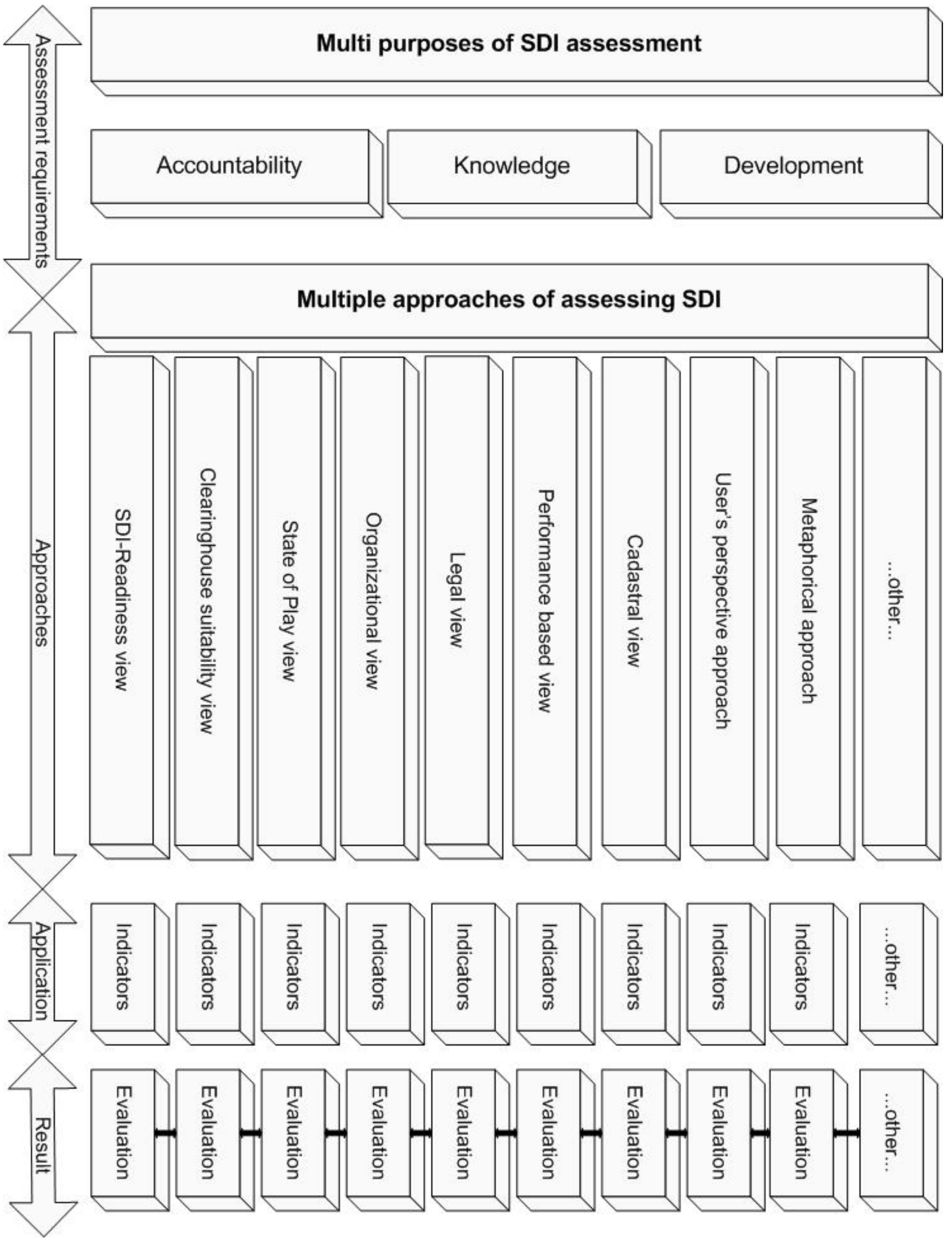
This new model will be implemented as a reference point in further research towards the new SDI assessment method.

2.2. SDI Assessment Methods

Most SDI researchers of the last decade have tried several SDI assessment methods. Some authors focused on the description of the SDI themselves (Onsrud, 1998; Masser, 1999; Vandenbroucke and Janssen, 2008) while others paid more attention to the methodology (Steudler et al., 2003, Delgado-Fernandez et al., 2005; Kok and Van Loenen, 2005; Van Loenen, 2006; Rodriguez-Pabon, 2005; Grus et al., 2007).

Grus et al. (2007) introduced the multi-view framework to assess SDIs (Figure 4). This framework acknowledges the difficult task of assessing SDIs due to their complex, multi-faceted, dynamic and constantly evolving nature, unclear objectives and poor knowledge about the implications of the current SDI-use and current demands. According to Grus et al. (2007) the essence of the multi view framework is that it accepts the multiple facets of an SDI and therefore accepts its complexity in terms of multiple definitions. Grus et al. (2007) explains that the framework is a combination of several SDI assessment approaches varying from assessing the organizational aspects of an SDI to SDI clearinghouse that focus on different aspects of the SDI (Figure 4).

Figure 4: Multi-view SDI Assessment Framework (Grus et al., 2007)



Each approach uses several indicators to measure specific SDI aspects and treats SDIs from a different perspective but none of them assesses the robustness of SDIs. This collection of indicators could potentially be used to create an assessment approach to measure the realization of specific SDI goals (Grus et al., 2007). The multi-view SDI assessment framework can also be applied in a purpose driven way. For example, an SDI practitioner who is interested in an assessment of a specific SDI aspect can select those assessment approaches that fit best his/her purpose of the assessment. Nushi et al. (2012) attempted to mutually implement a blend of three assessment methods (SDI readiness Index by Delgado-Fernandez et al., 2005; INSPIRE State of Play by Vandenbroucke and Janssen, 2008 and the Maturity Matrix by Kok and Van Loenen, 2005) to assess the status of SDI implementation of Kosovo. This research showed that the developed *blended assessment* method has significant shortcomings: the blended method was not useful for the practitioners; gathering objective input was very difficult; results of the assessment are biased and can be influenced and the monitoring and reproduction of the results is difficult.

Based on this overview of the SDI assessment landscape, there is a need for a new SDI assessment method, which is more extensive, comprehensive, user-oriented, demand-driven, diverse and closely tied to explicit targets. The assessment methods applied to financial systems may be an option for the SDI assessment. Therefore the next section identifies and defines the main components that typically constitute a financial system.

3. FINANCIAL SYSTEM

A financial system consists of *institutional units* and markets that interact, typically in a complex manner, for the purpose of mobilizing funds for investment, and providing facilities, including payment systems, for the financing of commercial activity (IMF, 2006). According to the International Monetary Fund (IMF) an institutional unit is an entity, such as a household, corporation, government agency, and so on, that is capable, in its own right, of owning assets, incurring liabilities, and engaging in economic activities and in transactions with other entities. The role of financial institutions within the system is primarily to intermediate between those that provide funds and those that need funds and typically involves transforming and managing risk. It can be assumed that financial markets provide a forum within which financial claims can be traded under established rules of conduct, and can facilitate the management and transformation of risk.

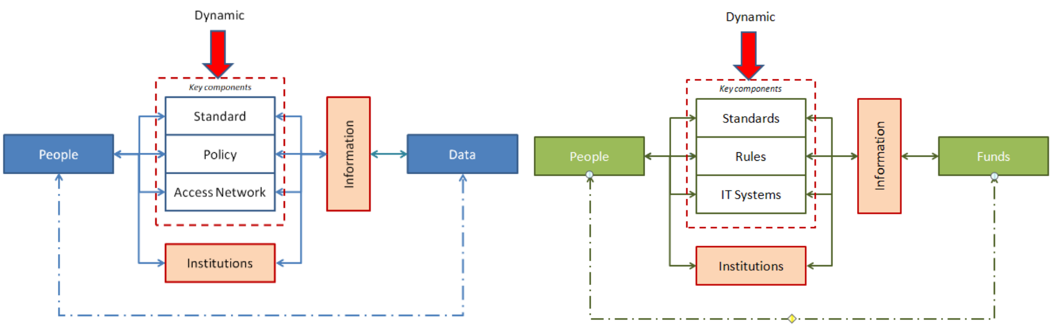
3.1. Financial Infrastructure

Financial Infrastructure (FI) is a core part of all financial systems. Financial Infrastructure, broadly defined, comprises the underlying foundation for a country's financial system. It includes all *institutions, information, technologies, rules and standards* that enable financial intermediation (IFC, 2009). These key components are vital to facilitating greater access to finance, improving transparency and governance, as well as safeguarding financial stability in global financial markets. Poor financial infrastructure in many developing countries is a considerable constraint upon financial institutions to expand their offering of financial services to the population and the economy (Worldbank, 2011). The quality of financial infrastructure determines the efficiency of intermediation, the ability of lenders to evaluate risk and of borrowers to obtain credit, insurance and other financial products at competitive terms (IFC, 2009). Credit bureaus, collateral registries, and payment, remittance and securities settlement systems are all vital parts of a country's financial infrastructure (IFC, 2009). When financial infrastructure is available, efficient and reliable, the cost of financial intermediation decreases. Financial products and services become accessible to greater numbers of citizens and lenders and investors have greater confidence in their ability to evaluate and guard against risk (IFC, 2009). Bossone et al. (2003) find that in environments with a weak FI, banks and other financial institutions are declining some of their roles such as information gathering, monitoring and contract enforcement. As FI develops it promotes financial market growth and competition which leads to more efficient capital allocation and more options for consumers. Serres et al. (2006) use data from business expansion to demonstrate the relationship between elements of FI and financial development and growth. They also include legal and regulatory variables related to contract enforcement and bankruptcy, as well as measures of investor protection or corporate governance in their analysis. Serres et al. (2006) took a similar approach to Rajan and Zingales (1998) and evaluated whether firms that depend more on external finance are more prevalent in countries with better financial infrastructure. Their findings indicate that FI significantly impacts both value-added and productivity growth by increasing finance for these firms. Most countries with mature FI have depositories for securities immobilization, whereas for countries with less mature FI is this not the case. Wealthier countries with more developed capital markets also tend to have one depository for all types of securities, have shorter settlement cycles and are more likely to have a real-time interface with the payment system. Stern and Feldman (2004) argue that there seems to be a perception in financial sector that if a large banking organization were to get in trouble, the government would, under most circumstances, intervene to prevent its failure. This possibility of a government bailout is commonly referred to as the "too-big-to-fail" policy. The idea behind this belief is that, in general, policymakers will be inclined to bail out institutions which are considered to be of "systemic" importance; that is, institutions whose potential failure could threaten the stability of the entire FI. Based on this "too-big-to-fail" argument, we can introduce future hypothesis about the importance of a balanced system: *A balanced system can benefit from mutual balance of components. No dominant component relative to others is desirable.*

3.2. Relation Between FI and SDI

FIs like SDIs have a significant role in economic development and stability of a country or a system. The key components enabling FIs and SDIs to perform are similar (FI: standards, rules, IT systems and SDI: standards, policy, access networks). For this research we will apply the following definition of a financial infrastructure: '*The underlying foundation for the financial system including the institutions, information, technologies and rules and standards which enable financial intermediation*' (IFC, 2009). While viewing the core components of FI we suggest that components (similar to SDIs) can be formed based on the different nature of their interactions within the FI framework. The fundamental role between people and funds (information) as one category while as second category can be considered the main technological components like Standards, Rules and IT systems (together with the institutions which are facilitating the whole process). This implies that an integrated FI cannot be composed of funds and users alone, but instead involves other important issues regarding financial intermediation. To be able to compare a FI with an SDI we used the new SDI model represented in Figure 3 and adapted with the key elements of the FI (Figure 5).

Figure 5: SDI and FI Components



The core elements of a FI are similar to an SDI because both infrastructures have many different providers (institutions) involved, a vast amount of different users, use a range of the technological systems, there is a need for interaction between all stakeholders while each of them has its own agenda (interest), standards and rules are necessary and the strength of the infrastructure depends on the coherence of the individual parts. Additionally stress testing is very often used to assess complex financial systems or parts of it.

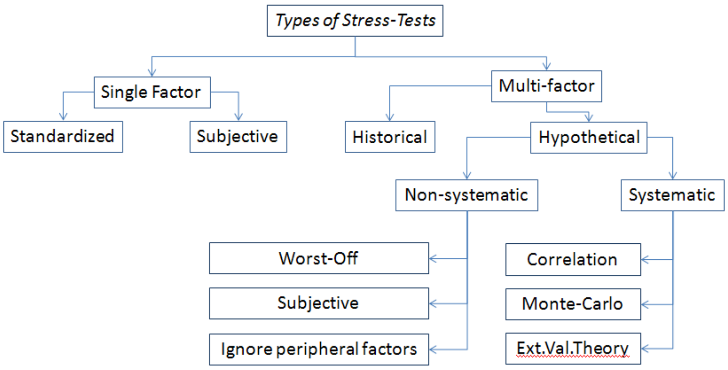
4. STRESS TESTING

Reliability engineers often test items under expected stress or even under accelerated stress in order to determine the operating life of the item or to determine modes of failure. Stress testing is to be compared with load testing although no clear boundary exists when an activity ceases to be a load test and becomes a stress test. Load testing is the process of putting demand on a system or device and measuring its response. Load testing is performed to determine a system's behavior under both normal and anticipated peak load conditions. It helps to identify the maximum operating capacity of an application as well as any bottlenecks and determine which element is causing degradation. Stress testing is when the load placed on the system is raised beyond normal usage patterns, in order to test the system's response at unusually high or peak loads.

4.1. Types of Stress Testing

There are essentially two types of stress tests: single factor and multifactor stress tests (MAS, 2003). As the name implies, only one risk factor is stressed in single-factor stress tests while several risk factors (if not all) are stressed in multi-factor stress tests. The different types of stress tests are shown in Figure 6.

Figure 6: Types of Stress tests (Adapted from MAS, 2003)



We discuss each of the different Stress tests briefly below.

4.1.1. Single Factor Stress tests

Single factor shocks are appropriate at the desk or frontline level when an expert would like to know the consequence of a large move in a single risk factor. However, when assessing exposure to stress events, a single factor shock is rarely appropriate and would probably suffer from implausibility because when a stressful event occurs; seldom does it affect one factor alone (MAS, 2003). Standardized single factor stress tests have been issued by various organizations and can be adopted off-the-shelf. Few examples of standardized single shock stress tests are: standardized yield curve shift, steepening and flattening of the yield curves by standardized moves, increase and decrease in equity index values by standardized % etc. The advantage of using standardized stress-tests is that they are easily understood and have ready acceptability among users. However, the problem with standardized stress-tests is that they sometimes lose their relevance (MAS, 2003). Often these tests have been 'out stressed' by subsequent episodes of extreme moves in the market. Subjective single factor stress tests can also subjectively stress test any factor shock as well as its magnitude. This is the practice of many banks. When factors are chosen subjectively, a risk manager should try to ensure that the magnitude of shock of each factor is plausible and relevant to the portfolio (MAS, 2003).

4.1.2. Multi-factor Stress Tests

Stressing one stress factor at a time may be appropriate at the desk level but single factor shocks by themselves, are not sufficient for a comprehensive stress testing program because actual stress events seldom affect one risk factor alone. Multi-factor stress tests involve stressing several risk factors at the same time. There are two main streams of multiple-factor stress testing: historical and hypothetical stress testing.

4.1.3. Historical Stress Testing

Historical stress testing can be conducted by revaluing portfolios using values of risk factors that existed during historical stress events. Historical stress events have been occurring so often in the recent past that risk managers are likely to find at least a few episodes that are relevant to their portfolios. The challenge in using historical scenarios is to choose a scenario that is appropriate for the portfolio. An argument against historical scenarios is that since no crisis has resembled any of its predecessors, there is no point in conducting such tests, since they will most probably never occur again (MAS, 2003).

4.1.4. Hypothetical Stress Testing

Risk managers can also construct hypothetical scenarios when no historical scenarios match the special features of their portfolios or when they want to stress new combinations of risk factors. When several risk factors are stressed at the same time, care must be taken to ensure that no relevant risk factor is omitted and that the shocks applied to combinations of risk factors, collectively make sense and are plausible. Hypothetical scenarios can be constructed systematically or non-systematically.

<u>Systematic scenarios</u>

A systematic search for stress scenarios tries to ensure that all relevant risk factors are appropriately changed in an economically consistent manner. Several new methodologies are being developed to construct scenarios systematically. Risk managers can assess these methodologies and adopt those that they think are most appropriate for their portfolios. Some systematic scenarios building techniques are described below.

Kupiec (1998) has introduced a Correlation Matrix methodology where a few risk factors (which play major roles) are stressed and all the other peripheral factors are adjusted using historical volatilities and correlations. The stress losses calculated using this method have the benefit of introducing an element of probability into stress-testing. However, several studies including Longin and Solnick (1999) have pointed out that correlations break down during crisis periods, which means that use of historical volatilities and correlations to adjust peripheral factors may not be appropriate except under special conditions. In the methodologies that we have seen so far, a stress-test is first constructed and the stress loss is then calculated.

A different approach is to specify a threshold stress loss and then examine the scenarios that could cause losses in excess of the threshold. Breuer and Krenn (2000) use the Monte Carlo simulation to first calculate portfolio values in different scenarios and then identify those scenarios that result in losses greater than a certain threshold. The scenarios where the threshold is exceeded can then be examined to determine what movements in risk factors caused the extreme losses and then appropriate risk mitigation can be performed.

The last methodology for systematically constructing scenarios is called Extreme Value Theory (EVT). Models that use variance-covariance methods assume that the probability distribution of portfolio changes is well approximated by a normal distribution. However, it has been found that actual returns distributions display a higher level of probability for extreme events than that supposed by the normal distribution. According to Longin (1999), this is the reason why the actual distributions are said to have 'fat tails'. EVT is a theory that models these fat tails and Longin (1999) explains how one might apply EVT to stress testing. All the above methods, as pointed out in Schachter (2000), in some way incorporate historical data into the stress test. This may make the stress-test lose plausibility because it is probable that in an actual stressful event, the risk factors will not behave as they did in the past. Nevertheless, as argued by Kupiec (1998), stress scenarios that use historical volatilities and correlations are more plausible than scenarios that ignore these correlations altogether.

Non-systematic scenarios

One of the methods of the non-systematic stress tests is 'Worst-off' Scenarios. This is a common method used to construct a hypothetical scenario. It combines the most adverse movements in different risk factors, at a certain time interval and then revaluates the portfolio using these adverse movements. This method completely ignores the correlation between risk factors and will most likely lead to implausible scenarios that are often of little relevance. However, this is one of the more common scenario building methods (often adopted by the financial sector). Another method is using Subjective Scenarios. In a subjective search for scenarios, risk factors are first chosen and then stressed on the basis of expert inputs including users, producers, data owners, management, consultants etc. (MAS, 2003). The main problem with this approach is that despite the best efforts of experts, such subjective stress tests may omit some risk factors or miss specify the correlation (MAS, 2003). There could be hundreds of risk factors and it is quite impossible to subjectively configure a correlation matrix for them.

This last method uses a technique that ignores peripheral risk factors. Some institutions conduct stress tests by changing a few risk factors and leaving all the other relevant risk factors unchanged. Such Stress tests are likely to be unreliable and are similar to the 'worst-off' scenarios. The only difference is that in this case the risk manager chooses the magnitude of change in the stress factors whereas for worst-case scenarios the magnitude is the same as the worst historical change in a given time interval.

4.2. Implementations of Stress Testing

The term "stress" may have a more specific meaning in certain fields. In materials science, fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. This can be typically seen as a standardized single factor stress testing method. In software testing, a system stress test refers to tests that put a greater emphasis on robustness, availability, and error handling under a heavy load, rather than on what would be considered correct behaviour under normal circumstances. Software testing uses also typically standardized Single factor stress testing method. The Cardiac stress test is a test used in medicine and cardiology to measure the heart's ability to respond to external stress in a controlled clinical environment (ATS/ACCP, 2003). Cardiac testing also implements standardized single factor stress testing method. The Nuclear power reactors stress test is based on a common methodology and assesses both natural and man-made hazards (i.e. effects of airplane crashes and terrorist attacks). Nuclear power plant testing clearly implements the historical multi-factor stress testing method.

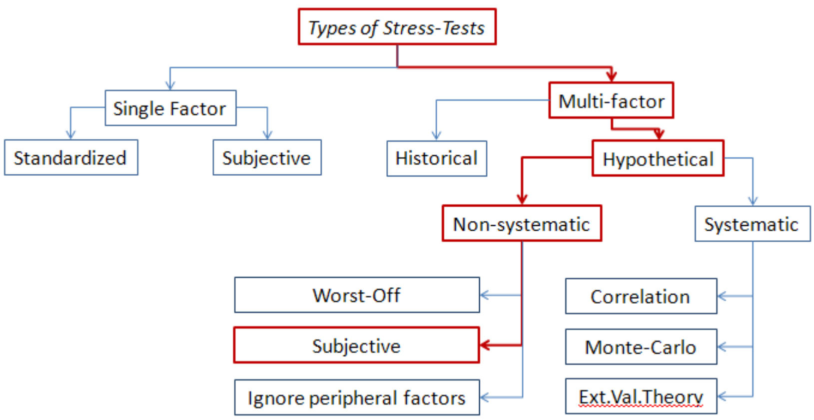
4.3. Stress Testing in Financial Infrastructure

Stressful events occurred recently with alarming regularity and their impact is still severe. In the recent years there have been several stress events, some examples of which are the Gulf War, the Asian Crisis, destabilization of Balkans, the terrorist attacks of September 11th, the Arabic spring and most recently the political tensions in Ukraine. These events have had an impact on the stability of FIs. Stress testing has played an important role as a systematic methodology to financial institutions to help prepare for such financial crises caused by these stressful events. Stress testing of a FI is a form of testing that is used to determine the stability of a given system or entity (IMF, 2006). It involves testing beyond normal operational capacity, often to a breaking point, in order to observe the results. Reasons for performing the stress test can include: determining breaking points or safe usage limits; confirming intended specifications are being met; determining modes of failure (how exactly a system fails); testing stable operation of a system outside standard usage (IMF, 2006).

The Bank for International Settlement (BIS) committee on the global financial system (BCGFS, 2000) defines 'Stress testing' of a FI as '*a generic term describing various techniques used by financial firms to gauge their potential vulnerability to exceptional but plausible events*'.

Financial risk is defined as the uncertainty of returns from a portfolio. Credit Risk, which is one of the most important financial risks, is defined as the risk of loss that arises when an obligor to a contract, fails to perform its obligations under the contract or when its ability to perform such obligations is impaired. The uncertainty of returns from a portfolio is directly or indirectly influenced by numerous variables, which are called risk factors. For example, the prime rate is one of the risk factors that influence the value of a loan or bond portfolio. Even a simple loan portfolio made up of a few loans, is likely to be influenced by numerous risk factors. One of the risk manager's primary objectives is to measure the influence of each risk factor on the volatility of portfolio returns and to manage the composition of the portfolio so that the volatility of the portfolio's returns is reduced. Further, the risk manager must also measure the influence of the risk factors on each other (MAS, 2003). As presented in Figure 7 the most used scenario building methods in FI are worst-off and subjective non-systematic methods.

Figure 7: Stress tests method for FIs (Adapted from MAS, 2003)



Disentangling the effects of multiple risk factors and quantifying the influence of each is a fairly complicated undertaking. There is a distinct difference in the behaviour of risk factors during normal business conditions and during stressful conditions such as financial crises. In ordinary business conditions the behaviour of risk factors is relatively easy to predict because their behaviour does not significantly change in the short to medium term. Therefore, future behaviour can be predicted, to an extent, from past performance. However, during stressful conditions, the behaviour of risk factors becomes far more unpredictable and past behaviour offers little help in predicting the future. This is why risk managers are well-advised to adopt a two-pronged approach to risk management, where on the one hand they use various qualitative and quantitative techniques to measure risk in ordinary business conditions; while on the other hand, they use stress tests to quantify likely losses under stress conditions (MAS, 2003).

Based on this we can conclude that the most used scenario building methods in FI are worst-off and subjective non-systematic methods.

4.4. The Basel Core Principles

The Core Principles for Effective Banking Supervision (The Basel Core Principles) are the *de facto* minimum standard for sound prudential regulation and supervision of banks and banking systems (BIS, 2012). Originally issued by the Basel Committee on Banking Supervision in 1997, countries use the Core Principles as a benchmark for assessing the quality of their supervisory systems and for identifying future work to achieve a baseline level of sound supervisory practices (BIS, 2012). In the context of the Financial Sector Assessment Program (FSAP), the International Monetary Fund (IMF) and the World Bank uses the Core Principles to assess the effectiveness of countries' banking supervisory systems and practices (BIS, 2012).

The Core Principles define 29 principles that are needed for a supervisory system to be effective. Those principles are broadly categorized into two groups: the first group (principles 1 to 13) focus on powers, responsibilities and functions of supervisors, while the second group (principles 14 to 29) focus on prudential regulations and requirements for banks (BIS, 2012). Table 1 presents 29 Basel core principles.

Table 1: The Basel Core Principles

Nr	Principle
1	Responsibilities, objectives and powers
2	Independence, accountability, resourcing and legal protection for supervisors
3	Cooperation and collaboration
4	Permissible activities
5	Licensing criteria
6	Transfer of significant ownership
7	Major acquisitions
8	Supervisory approach
9	Supervisory techniques and tools
10	Supervisory reporting
11	Corrective and sanctioning powers of supervisors
12	Consolidated supervision

13	Home-host relationships
14	Corporate governance
15	Risk management process
16	Capital adequacy
17	Credit risk
18	Problem assets, provisions, and reserves
19	Concentration risk and large exposure limits
20	Transactions with related parties
21	Country and transfer risks
22	Market risk
23	Interest rate risk in the banking book
24	Liquidity risk
25	Operational risk
26	Internal control and audit
27	Financial reporting and external audit
28	Disclosure and transparency
29	Abuse of financial services

To assess compliance with a Core Principle, this methodology proposes a set of essential and additional assessment criteria for each Core Principle (BIS, 2012). By default, for the purposes of grading, the essential criteria are the only elements on which to gauge full compliance with a Core Principle. The additional criteria are suggested best practices for countries with an existing bank infrastructure that wish to further improve. Going forward, countries will have the following three assessment options:

1. Unless the country explicitly opts for any other option, compliance with the Core Principles will be assessed and graded only with reference to the essential criteria;
2. A country may voluntarily choose to be assessed against the additional criteria, in order to identify areas in which it could enhance its regulation and supervision further and benefit from assessors' commentary on how it could be achieved. However, compliance with the Core Principles will still be graded only with reference to the essential criteria; or
3. To accommodate countries that further seek to attain best supervisory practices, a country may voluntarily choose to be assessed and graded against the additional criteria, in addition to the essential criteria.

To explain the whole process we are taking an example of one principle in this case principle 22: *Market risk*. The definition of the principle 22 is: "*The supervisor determines that banks have an adequate market risk management process that takes into account their risk appetite, risk profile, and market and macroeconomic conditions and the risk of a significant deterioration in market liquidity. This includes* *prudent policies and processes to identify measure, evaluate, monitor, report and control or mitigate market risks on a timely basis".* The essential criteria are:

1. Laws, regulations or the supervisor require banks to have appropriate market risk management processes that provide a comprehensive bank-wide view of market risk exposure. The supervisor determines that these processes are consistent with the risk appetite, risk profile, systemic importance and capital strength of the bank. Furthermore, they must take into account: market and macroeconomic conditions, the risk of a significant deterioration in market liquidity and clear articulation of the roles and responsibilities for identification, measuring, monitoring and control of market risk.
2. The supervisor determines that bank strategies, policies and processes for the management of market risk have been approved by the banks' Boards and that the Boards oversee management in a way that ensures that these policies and processes are implemented effectively and fully integrated into the banks' overall risk management process.
3. The supervisor determines that the bank's policies and processes establish an appropriate and properly controlled market risk environment including:

a. effective information systems for accurate and timely identification, aggregation, monitoring and reporting of market risk exposure to the bank's Board and senior management;
b. appropriate market risk limits consistent with the bank's risk appetite, risk profile and capital strength, and with the management's ability to manage market risk and which are understood by, and regularly communicated to, relevant staff;
c. exception tracking and reporting processes that ensure prompt action at the appropriate level of the bank's senior management or Board, where necessary;
d. effective controls around the use of models to identify and measure market risk, and set limits; and
e. sound policies and processes for allocation of exposures to the trading book.

4. The supervisor determines that there are systems and controls to ensure that banks marked-to-market positions are revalued frequently. The supervisor also determines that all transactions are captured on a timely basis and that the valuation process uses consistent and prudent practices and reliable market data verified by a function independent of the relevant risk-taking business units (or, in the absence of market prices, internal or industry-accepted models). To the extent that the bank relies on modelling for the purposes of valuation, the bank is required to ensure that the model is validated by a function independent of the relevant risk-taking businesses units. The supervisor requires banks to establish and maintain policies and processes for considering valuation adjustments for positions that otherwise cannot be prudently valued, including concentrated, less liquid and stale positions.

5. The supervisor determines that banks hold appropriate levels of capital against unexpected losses and make appropriate valuation adjustments for uncertainties in determining the fair value of assets and liabilities.
6. The supervisor requires banks to include market risk exposure into their stress testing programs for risk management purposes.

Grading is not an exact science and the Core Principles can be met in different ways. The assessment criteria should not be seen as a checklist approach to compliance but as a qualitative exercise. Compliance with some criteria may be more critical for effectiveness of supervision, depending on the situation and circumstances in a given jurisdiction (BIS, 2012). Hence, the number of criteria complied with is not always an indication of the overall compliance rating for any given Principle. Emphasis should be placed on the commentary that should accompany each Principle grading, rather than on the grading itself. The primary goal of the exercise is not to apply a “grade” but rather to focus authorities on areas needing attention in order to set the stage for improvements and develop a plan of action that prioritizes the improvements needed to achieve full compliance with the Core Principles (BIS, 2012). For assessments of the Core Principles the following four-grade scale will be used: compliant (C), largely compliant (LC), materially non-compliant (MNC) and non-compliant (NC). A “not applicable” (NA) grading can be used under certain circumstances where the supervisors are aware of the phenomenon and would be capable of taking action, but realistically there is no chance that the activities will grow sufficiently in volume to pose a risk. A brief description of grading and their applicability:

- Compliant – A country will be considered compliant with a Principle when all essential criteria applicable for this country are met without any significant deficiencies.
- Largely compliant – A country will be considered largely compliant with a Principle whenever only minor shortcomings are observed that do not raise any concerns about the authority’s ability and clear intent to achieve full compliance with the Principle within a prescribed period of time.
- Materially non-compliant – A country will be considered materially non-compliant with a Principle whenever there are severe shortcomings, despite the existence of formal rules, regulations and procedures, and there is evidence that supervision has clearly not been effective, that practical implementation is weak, or that the shortcomings are sufficient to raise doubts about the authority’s ability to achieve compliance.
- Non-compliant – A country will be considered non-compliant with a Principle whenever there has been no substantive implementation of the Principle, several essential criteria are not complied with or supervision is manifestly ineffective.

A stress test could be seen as a 'disaster exercise' for the systemic banks or the entire FI. Systemic banks are banks that may not actually become insolvent because of their size. Should that happen, then it would constitute a direct risk to the financial system as a whole.

Possible scenario can be outlined based on these events: sudden fall of the real-estate prices, rising of the unemployment, the economy is stagnating, collapse of the financial markets or even countries cannot repay their debts. Banks should have at least 8% financial buffers reserved for these events so that national governments do not have to get involved in rescuing the banks by paying the financial buffers. The banks have to keep after the stress test more than 5.5% of their capital as a buffer. If a bank fails the stress test, it means that the capital buffers should be supplemented. A bank can supplement the capital buffers itself by trading certain organisational activities or by raising funds on the capital market. If this is insufficient, governments will get involved.

5. DEVELOPING STRESS TESTING FOR SDI ASSESSMENT

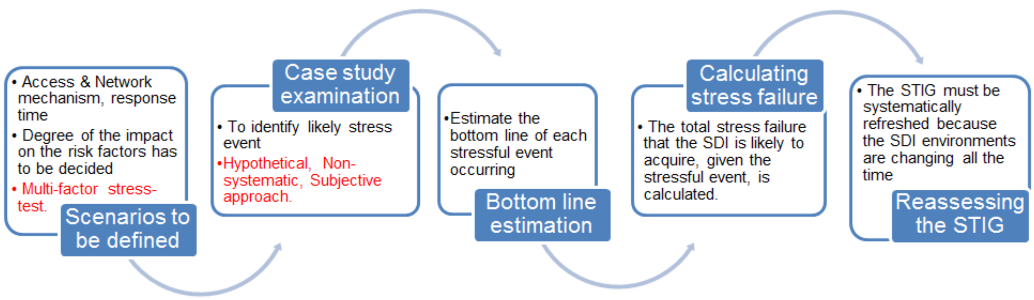
In section 3 we have found indications that justify research into the application of stress testing of a FI to the assessment of SDIs. Stress testing means choosing scenarios that are exceptional and plausible, and then putting them to a valuation model. The problem is that choosing stress test scenarios is, in its very nature, subjective. This makes an external review of a stress testing method extremely difficult (MAS, 2003).

The SDI stress testing could alert SDI organizations to adverse unexpected outcomes related to a variety of risks and provides an indication of how much useful data might be accessed in the times of large risk impact. While stress tests provide an indication of the appropriate level of SDI necessary to endure deteriorating disaster conditions, an SDI structure alternatively may employ other actions to help mitigate increasing levels of risk. Stress testing as an SDI assessment method once implemented in the decision making process, can effectively increase the SDI system robustness. When implementing stress testing, challenges remain in modelling the interaction of different risk factors and their impacts; integrating stress testing at different levels; and how to make stress tests workable, realistic and timely. Having examined the various types of risk factors and methods to construct stress tests in section 4, we have chosen the Multi-factor Stress tests and among them the Hypothetical and a Non-systematic Subjective scenario model as often used in FI as the fundament for the STIG framework. This method first chooses and then stresses risk factors on the basis of expert inputs including users, producers, data owners, management, consultants etc. SDI practitioners can construct hypothetical scenarios when no historical scenarios match the special features of their situation or when they want to stress new combinations of risk factors.

Multi-factor shocks are appropriate when an SDI expert would like to know the consequences of large moves in a risk factor on the SDI. When several risk factors are stressed at the same time, care must be taken to ensure that no relevant risk factor is omitted and that the shocks applied to combinations of risk factors, collectively make sense and are plausible. The multi-factor approach being subjective stress-test may exclude some risk factors or misspecification of the correlation regardless of the best efforts by experts. Also due to the large number of risk factors it is quite unfeasible to subjectively configure a correlation matrix.

Nevertheless, multi-factor tests can be used to investigate the sensitivity of an SDI to specific factors and to help identify and correct potential stress points. Therefore we suggest below the procedure for constructing a sound framework for The STIG model as represented in Figure 8.

Figure 8: The STIG Framework



Sections 5.1 and 5.2 explain the steps that are required to establish the suggested framework. Section 5.3 addresses the scenario and related case study examination in more detail, while the estimation of the bottom line and the calculation of the stress failure are further discussed in Section 5.4. The suggested STIG framework will be reassessed after a first complete implementation, which is part of our future work (see also Section 6).

5.1. The Process Towards the STIG Framework

The process of implementing the STIG starts with the assessment of compliance. As a result, the STIG will allow the SDI authority to initiate a strategy to improve the SDI where necessary. The process towards the STIG framework consists of eight development steps:

1. *Translating Basel principles to the SDI context.* An assessment needs to be made about the applicability of the Basel Core Principles to the SDI context.
2. *Determining per SDI Core principle the assessment criteria and scores.* Here, the assessment criteria per SDI Core principle and the scoring options will be developed.
3. *Defining scenarios.* The scenarios have to be defined for each factor and the degree of the impact on the risk factors has to be decided.
4. *Case study examination.* A case study will be conducted to identify likely stress events such as an industrial or nuclear disaster. The primary objective of STIG should be the identification of the nature and extent of any weaknesses in SDI compliance with individual Core SDI Principles, which will be defined in next phase of this research based on the Basel Core Principles.
5. *Assessing compliance with a Core SDI Principle*. To assess compliance with a Core SDI Principle, the STIG framework will also identify a set of essential and additional assessment criteria for each Core SDI Principle.
6. *Determining bottom line estimation.* The STIG will be used to value the impact of a stress event on the SDI. The STIG assessment experts have to go through the statements of each factor and using their expertise, and estimate the bottom line of each stressful event occurring.
7. C*alculating the stress factor.* Once the new bottom line for each factor has been estimated, the total stress failure, that the SDI is likely to acquire given the stressful event, is calculated.
8. *Reassessing the STIG.* The STIG must be refreshed systematically because the SDI environments are changing all the time. The STIG should be reviewed at least annually, if the portfolio or the environment changes significantly.

5.2. Translating Basel Principles to the SDI Context

The core principles may not all be applicable to the SDI context. For example, the principle 7 “Major acquisitions” addresses major acquisitions or investments by a bank, against prescribed criteria, including the establishment of cross-border operations, and confirming that corporate affiliations or structures do not expose the bank to undue risks or hinder effective supervision. In an SDI context such issues are unlikely to exist. Other principles, such as Principle 1 “Responsibilities, objectives and powers” addresses the operational independence, transparent processes, sound governance, adequate resources and accountability. This principle is very relevant in an SDI context. Therefore, we maintain this principle in the first STIG draft. Table 2 shows the principles, which we assess at this moment to be relevant to the SDI context.

Table 2: The Basel Core Principles: Applicability to SDI Context (draft)

Nr	Principle
1	***Responsibilities, objectives and powers***
2	***Independence, accountability, resourcing and legal protection for supervisors***
3	***Cooperation and collaboration***
4	Permissible activities
5	***Licensing criteria***
6	Transfer of significant ownership
7	Major acquisitions
8	Supervisory approach
9	***Supervisory techniques and tools***
10	***Supervisory reporting***
11	Corrective and sanctioning powers of supervisors
12	Consolidated supervision
13	Home-host relationships
14	***Corporate governance***
15	***Risk management process***
16	***Capital adequacy***
17	Credit risk
18	***Problem assets, provisions, and reserves***
19	***Concentration risk and large exposure limits***
20	Transactions with related parties
21	***Country and transfer risks***
22	***Market risk***
23	Interest rate risk in the banking book
24	***Liquidity risk***
25	***Operational risk***
26	***Internal control and audit***
27	Financial reporting and external audit
28	***Disclosure ad transparency***
29	Abuse of financial services

** Principles likely to be implemented in STIG are emphasized in* ***bold***

Step 2, determining the assessment criteria and score scenario per SDI Core principle, will build on the criteria developed in the Core Principles framework. We will start with these selected principles likely to be implemented in STIG and gradually tailor-make them by defining the criteria's and values for SDI.

5.3. Scenario Definition and Case Study Examination

An example of a case study we may use is around the disaster at a chemical plant in Moerdijk, the Netherlands. This case study is carefully selected to assess the Dutch SDI as a first test of The STIG Assessment method. To predict similar results in means of a literal replication (Yin, 1994), we would apply the STIG method to assess the Dutch SDI from another perspective like Water management, Defence, and Urban Planning by using the same Moerdijk disaster scenario.

The blast and fire completely destroyed the Chemie-Pack plant near the port of Rotterdam in January 2011. The fire started in the early afternoon sending a towering plume of thick smoke into the air and causing several powerful blasts, apparently as storage tanks exploded. The incident led to commotion about whether a cloud of smoke that crossed part of the country contained harmful substances and whether proper safety measures had been observed. A large area around Rotterdam was affected as the plume of potentially toxic smoke moved across several urban areas. Local authorities told residents to stay indoors. Authorities also closed off the nearby highway to traffic and warned local farmers to move livestock indoors so they did not eat soot (harmful black powder resulting from the incomplete combustion of hydrocarbons) falling from the smoke plume. Residents in parts of nearby cities were also warned to keep windows and doors shut, and boat traffic on the nearby waterway was halted.

Figure 9: Scenario Fire in Moerdijk and Disaster Zone Around Rotterdam.

These kinds of disasters can have a large impact on the society. Therefore the required information should be provided fast to the disaster managers and the emergency response team. It concerns information about the extent of the toxic plume, about who is present in the direct area of the disaster area and who needs to be evacuated, how these people will be informed and evacuated, via which routes and with what transportation means they can be evacuated, which transportation networks exist and can be used and where are the traffic jams due to hysteric population.

5.4. Bottom Line Estimation and Stress Factor Calculation

In the bottom line estimation the impact of a stress event on the SDI is determined. The STIG assessment experts have to go through the statements of each factor and using their expertise, and estimate the bottom line of the Moerdijk event. The experts may conclude that for Principle 1 the responsibilities were not clearly determined and therefore this principle scores a non-compliant. This will be done for all SDI Core Principles. Once the new bottom line for each factor has been estimated, the total stress failure of the SDI for the Moerdijk event is calculated.

6. CONCLUSION AND FURTHER RESEARCH

In this paper we assessed the extent to which stress test methodologies can be supportive to developing a new SDI assessment method that can provide the required information on the performance of SDIs.

Based on a review of the Spatial Data Infrastructure (SDI) and Financial Infrastructure (FI) we conclude that the stress test methodology is a promising approach for assessing SDIs.

In the next phase of this research the Core SDI Principles will be defined based on the Basel Core Principles. Additionally, a set of essential and additional assessment criteria for each Core SDI Principle will be defined.

From all the examined types of risk factors and methods to construct FI stress tests, the Multi-factor Stress tests (Hypothetical and a Non-systematic Subjective scenario model) are most promising as a basis for SDI assessment. This hypothetical scenario first chooses and then stresses risk factors on the basis of expert inputs including users, producers, data owners, management, consultants etc. SDI practitioners can construct hypothetical scenarios when no historical scenarios match the special features of their situation or when they want to stress new combinations of risk factors.

Stress testing as an SDI assessment method once implemented in the decision making process, can effectively increase system robustness of an SDI. When implementing stress testing, challenges remain in modelling the interaction of different risk factors and their impacts. Such things as: integrating stress testing at different levels and making stress tests workable, realistic and timely remain complicated. These issues will be addressed in the research further developing the Stress Test for Infrastructure of Geographic information: the STIG.

7. REFERENCES

ATS/ACCP - American Thoracic Society (ATS) and the American College of Chest Physicians (ACCP) (2003). ATS/ACCP statement on cardiopulmonary exercise testing, *American Journal of Respiratory and Critical Care Medicine, Volume* 167, pp 211–277, at https://www.thoracic.org/statements/resources/pfet/cardioexercise.pdf [accessed 1 September 2015].

BIS - Bank for International Settlements (2012). Core Principles for Effective Banking Supervision, Basel Committee on Banking Supervision, ISBN 92-9197-146-4, at http://www.bis.org/publ/bcbs230.pdf [accessed 1 September 2015].

BCGFS - BIS Committee on the Global Financial System (2000). Stress Testing by large Financial Institutions: Current Practice and Aggregation Issues, Bank for International Settlements, Committee on Global financial System, Basel, Switserland, pp 2, at http://www.bis.org/publ/cgfs14.htm [accessed 1 September 2015].

Bossone B., Mahajan S. and Zahir, F. (2003). Financial Infrastructure, Group Interests, and Capital Accumulation - Theory, Evidence, and Policy, IMF working paper WP/03/24, at https://www.imf.org/external/pubs/ft/wp/2003/wp0324.pdf [accessed 1 September 2015].

Breuer, T. and Krenn, G. (2000). Identifying Stress-test Scenarios, Working paper, Oesterrehische National Bank, Vienna, at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.27.118&rep=rep1&type=pdf [accessed 1 September 2015].

Crompvoets, J. W. H. C. (2006). National spatial data clearinghouses: worldwide development and impact, Doctoral dissertation, WUR Wageningen University and Research Centre.

Delgado-Fernández, T., Lance, K., Buck, M. and Onsrud, H. J. (2005). Assessing SDI readiness index, Proceedings From the Pharaohs to Geoinformatics, FIG Working Week 2005 and 8th International Conference on Global Spatial Data Infrastructure, April, Egypt at http://www.researchgate.net/publication/237259846_Assessing_an_SDI_Readiness_Index [accessed 1 September 2015].

Grus, L., Crompvoets, J., and Bregt, A. (2007). Multi-view SDI Assessment Framework, International Journal of Spatial Data Infrastructures Research 2007(2): pp 33-53, at http://ijsdir.jrc.ec.europa.eu/index.php/ijsdir [accessed 1 September 2015].

IFC - International Finance Corporation (2009). *Financial Infrastructure Report*, A joint report of World Bank and IFC, Washington D.C.: The World Bank, at http://siteresources.worldbank.org/FINANCIALSECTOR/Resources/282044-1252596846652/FinancialInfrastructureReport.pdf [accessed 1 September 2015].

IMF - International Monetary Fund (2006), Financial Soundness Indicators: Compilation Guide, Washington D.C., at http://www.imf.org/external/pubs/ft/fsi/guide/2006/ [accessed 1 September 2015].

INSPIRE (Craglia, M.) (2003). Contribution to the extended impact assessment of INSPIRE, at http://inspire.jrc.ec.europa.eu/reports/fds_report_sept2003.pdf [accessed 1 September 2015].

Kok, B. and Van Loenen, B. (2005). How to assess the success of National Spatial Data Infrastructures? Computers, Environment and Urban Systems 29: pp 699-717, at http://www.ngdi.gov.ng/Ngdi%20papers/Kok_van%20Loenen.pdf [accessed 1 September 2015].

Kupiec, P.H. (1998). Stress-testing in a value at risk framework, The Journal of Derivatives 6(1): pp 7-24.

Longin, F. and Solnick, B. (1999). Correlation Structure on international equity markets during extremely volatile periods, Working Paper, Groupe HEC, at SRN: http://ssrn.com/abstract=147848 [accessed 1 September 2015].

MAS (2003). Technical Paper on Credit Stress-Testing, MAS Information Paper 01 – 2003 (March), Specialist Risk Supervision Department, Monetary Authority of Singapore, Singapore, at http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan011700.pdf [accessed 1 September 2015].

Masser, I. (1999). All shapes and sizes: The first generation of national spatial data infrastructures, International Journal of Geographical Information Science 13(1): 67–84, at http://www.researchgate.net/publication/233965710_All_shapes_and_sizes_The_first_generation_of_national_spatial_data_infrastructures [accessed 1 September 2015].

Nushi, B., Van Loenen, B., Besemer, J., and Crompvoets, J. (2012). "Multi-view SDI assessment of Kosovo (2007-2010) - Developing a solid base to support SDI strategy development", In Rajabifard, A. and D. Coleman (Eds.) *Spatially Enabling Government, Industry of Citiziens: Research and Development Perspectives.* Needham, USA: GSDI Association Press, pp.

253-275, at http://repository.tudelft.nl/view/ir/uuid:534a405b-5063-454d-b043-335cd5270884/ [accessed 1 September 2015].

Onsrud, H. J. (1998). Compiled Responses by Questions for Selected Questions. Survey of national and regional spatial data infrastructure activity around the globe. Global Spatial Data Infrastructure, at http://www.spatial.maine.edu/~onsrud/GSDI.htm, [accessed 1 September 2015].

Rajabifard, A., Feeney, M.-E. F. and Williamson, I. P. (2002). Future directions for SDI development, International Journal of Applied Earth Observation and Geoinformation 4 (1): 11-22, at https://minerva-access.unimelb.edu.au/bitstream/handle/11343/33974/66333_00001254_02_ITC_Journal_2002.pdf?sequence=1 [accessed 1 September 2015].

Rajan, R. and Zingales, L. (1998). Financial Dependence and Growth, Chicago: University of Chicago & NBER, at http://faculty.chicagobooth.edu/raghuram.rajan/research/papers/growth.pdf [accessed 1 September 2015].

Rodriguez-Pabon, O. (2005). Cadre theorique pour l'evaluation des infrastructures dínformation geospatiale. Centre de recherché en geomatique, Departement des sciences geomatiques. These de doctorat, University of Laval, Canada. (in French).

Serres A., Kobayakawa S., Sløk T. and Vartia, L. (2006). *Regulation of financial systems and economic growth in OECD countries: An empirical Analysis*, OECD Economic Studies No. 43, 2006/2, at http://www.oecd.org/eco/growth/40505986.pdf [accessed 1 September 2015].

Schachter, B. (2000). Stringent Stress-tests, Risk Magazine, No. 12, Special Report on Enterprise-Wide Risk Management: pp 22–S24.

Steudler, D., Rajabifard, A. and Williamson, I. (2003). Developing Evaluation and Performance Indicators for SDI, in Williamson, I., Rajabifard, A., and M.-E.F. Feeney, (Eds.) Developing Spatial Data Infrastructures: From Concept to reality. London: Taylor & Francis, pp. 193-210.

Stern, G.H. and Feldman R.J. (2004). Too Big to Fail: The Hazards of Bank Bailouts, Washington, D.C.: Brookings Institution Press, at https://www.minneapolisfed.org/publications/the-region/too-big-to-fail-the-hazards-of-bank-bailouts-20080501 [accessed 1 September 2015].

World Bank (2011). *General principles for credit reporting*, Washington D.C., at http://documents.worldbank.org/curated/en/2011/09/16426885/general-principles-credit-reporting [accessed 1 September 2015].

Van Loenen, B. (2006). Developing geographic information infrastructures; The role of information policies, Dissertation, Delft University of Technology. Delft: DUP Science, at http://repository.tudelft.nl/view/ir/uuid:6781e9dd-1468-4b31-bf88-ee1fbfffe4a1/ [accessed 1 September 2015].

Vandenbroucke, D., Janssen, K., and Van Orshoven, J. (2008). INSPIRE State of Play. Development of the NSDI in 32 European countries between 2002 and 2007. In Tenth International Conference for Spatial Data Infrastructure St. Augustine, Trinidad February (pp. 25-29), at http://www.researchgate.net/publication/229016344_INSPIRE_State_of_Play._Development_of_the_NSDI_in_32_European_countries_between_2002_and_2007 [accessed 1 September 2015].

Yin, R.K. (1994). Case Study Research: Design and Methods, London: Sage Publication.