Assessment of Industrial Asset Values at Risk

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ABSTRACT

In the event of natural disasters and extreme events like storms, floods and earthquakes, not only people, residential buildings and infrastructure, but also industry can be seriously affected. Direct losses to installations as well as indirect losses e.g. interruption of production can cause severe damage to companies and the economy as a whole. For a comparative and quantitative risk assessment and as a prerequisite for emergency planning and crisis management (e.g. planning of mitigation measures), a financial appraisal of industrial assets at risk is needed. This paper presents the reference installation approach which is a methodology that allows a consistent and transparent assessment of individual industrial asset values. In this bottom up approach due to the consideration of the heterogeneity of various industrial sectors, the obtained results can be depicted for a detailed spatial distribution and on a high degree of accuracy.

Keywords

Natural hazards, risk assessment, economic impact, industrial asset estimation.

INTRODUCTION

Emergency situations can differ in many ways, for instance according to their causes and the dimension of their impact. Yet, they share the characteristic of sudden onset and the necessity for a coherent and effective emergency management (Geldermann et al., 2007). By natural disasters like storms, floods and earthquakes, not only people and residential buildings, but also industry can be harmed seriously. In industry, risk management is related to the environment (IPPC Directive, 1996), to major accident hazards (Seveso II Directive, 1996), and to occupational health and safety (ATEX Directive, 1994). From an economic view, modern industries can be affected by a natural disaster in two different ways. Firstly, direct losses due to physical damage to buildings and industrial installations have to be regarded. In general, manufacturing facilities show a different vulnerability according to their construction type and the type of the extreme event (flood, storm, earthquake). Additionally, industry may be affected by indirect losses. Indirect losses merge all losses which are not directly caused by the damaging effect of the extreme event, e.g. losses due to the interruption of the production, reduced investments or subsequent charging on costs of remediation measures which can sum up to enormous amounts.

For an effective assessment of direct losses in industry, the values of the industrial assets at risk need to be estimated and geographic information of industrial assets must be sampled. In order to estimate actual losses in industry, the spatial distribution of the assessed values at risk can be intersected with the spread of different hazard scenarios. At present, mainly macroeconomic approaches for industrial asset estimation are applied (Kleist et al., 2006; Grünthal et al., 2006; Meyer, 2005; Hofstede and Hamann, 2000). Key objective of this study is the elaboration of a quantitative bottom up method for the estimation of direct monetary losses of vulnerable industrial assets starting from the process level of industrial production. The estimation of direct monetary losses of industrial assets and possible damage within the whole supply chain allows for the evaluation of adequate expenses for risk mitigation and could be used to support decisions in companies and different responsible administration levels.

In this paper, after a description of the purposes and aims of industrial asset estimation research and an overview of the current data situation in Germany, a review of existing approaches is given. In the next part, a bottom up approach for asset estimation is described: the Reference Installation Approach (RIA). Finally the economic assessment is followed by the description of the procedure for asset estimation in a test region in southern Germany. The work presented in this paper is part of the "Center for Disaster Management and Risk Reduction Technology", CEDIM.

PURPOSES AND OBJECTIVES OF ASSET ESTIMATION

In risk management, the term risk is usually defined as the probability that a given loss will occur (Crichton, 1999; Kaplan and Garrick, 1981). In engineering and technical risk assessments, direct tangible losses are chosen as risk indicators. Therefore, risk analysis combines three elements: hazard, vulnerability (in terms of susceptibility of the affected element) and exposure of assets (Crichton, 1999). For a quantitative risk assessment and for an effective loss assessment, values of elements at risk have to be determined on a disaggregated scale to intersect them with different hazard scenarios, commonly modeled on an explicit raster (Thieken et al., 2006; Kleist et al., 2006). Knowledge about the spatial distribution of both, industrial asset values and the potential threat of different hazards can be used for spatial planning in future. For instance, this can be considered for site selection problems when planning new industrial installations. Different risks (risk due to earthquakes, storms and floods) can be compared on a common database of potentially exposed assets (Grünthal et al., 2006).

Ex ante risk assessment

The estimation of industrial asset values as part of the total loss potential is an important input for planning and relieve decisions in industrial crisis management as for instance, acceptable expenses for risk mitigation measures could be judged. Furthermore, through industrial asset estimation exceptionally vulnerable points of the supply chain are identified showing points where a broad and consistent planning of emergency management and provisions is fundamental. To provide an effective local emergency management it is crucial that required emergency appliances and resources are available in appropriate places. On the one hand, depots for emergency appliances should not be placed in potentially endangered areas, but on the other hand the distance to vulnerable objects (e.g. chemical industries close to rivers) should be as short as possible in order to avoid long transport times in case of an emergency (Fiedrich, 2004; Fiedrich, 1999).

Ex post risk assessment

A quantitative industrial risk assessment facilitates financial risk management not only in mitigation and emergency planning, but also in insurance considerations (Kleist et al., 2006). Direct insurers as well as reinsurers need a reliable financial appraisal of exposed assets in order to estimate the amount of losses caused by a potential disaster. In Germany, in the early phase after a disaster, the local administration of an affected district has to announce the amount of estimated losses to the federal government in order to get emergency aid. Therefore, an area – wide estimation of loss potential – including industrial assets – is needed. Moreover, the state is interested in knowing the expected shortfall in tax revenue due to the damage event and the subsequent interruptions of production. A further benefit of the estimation of industrial assets is the fostered dialogue between different stakeholders, providing the opportunity for the development of new strategies for reducing losses from future disasters and a better risk communication (Renn, 2001).

AVAILABLE DATA AND STATISTICS

For the estimation of industrial asset values at risk, data on the existing industries and production assets are necessary. In Germany, data on the gross stock of fixed assets ("Bruttoanlagevermögen BAV") is available only at the level of federal states, which is too inaccurate for a detailed appraisal of industrial loss potential.

Census data on industry are provided by (INFAS GEOdaten GmbH, 2002). These data contain information about the number of enterprises for 148 sectors on a community level. Furthermore, the enterprises are classified into three categories according to their respective size (measured in number of employees). One major drawback of this data set is the assumption of a homogenous distribution of assets throughout a community, which is not suitable for a detailed estimation of the loss potential of industrial assets.

Detailed data for production processes and assets can be taken from CORINAIR inventory (CORe INventory of AIR emissions). This data set is provided by the UNECE/EMEP Task Force on Emissions Inventories and Projections and is the only emission inventory available on a cross-national level. The data are differentiated depending on country, emission source, used fuel, processes and technologies and the spatial distribution is presented on community and administrative district level. The inventory comprises data listed in the current versions of the Selected Nomenclature on Air Pollution (SNAP95) on three aggregation levels: main emission sources (sectors, SNAP level 1), sub sectors (processes, SNAP level 2) and activities (SNAP level 3) (Geldermann and Rentz, 2004).

EXISTING APPROACHES

Currently there is no standardised methodology for the estimation of direct losses in buildings, industrial assets and infrastructure (Dutta et al., 2001). Numerous studies for loss estimation presented in literature differ in the level of detail and can be classified into micro, meso and macro scale approaches (Hofstede and Hamann, 2000). Mostly, macro or meso scale top down appraisal methods are used (Meyer and Messner, 2006). However, only a few bottom up approaches can be found in literature (Penning-Rowsell et al., 2005).

Top down approaches

All described top down approaches use national economic data. These approaches are suited for a rough and area wide assumption of industrial assets, but as they assume a uniform distribution of valuables over the whole considered area they are often inaccurate and do not consider the heterogeneity of the various industrial sectors. To overcome the loss in accuracy, an adjustment of data is necessary (Hofstede and Hamann, 2000). For instance, this could be achieved by combining a top down approach (e.g. the "Relation-approach", see below) with a micro scale bottom up approach such as the RIA presented in this paper.

Within CEDIM, one approach for industrial asset estimation based on macroeconomic statistical data called "Relation-approach" has been elaborated. Here, values of industrial assets on the community level are calculated by means of data on gross stock of fixed assets on the federal state level, data on employees and companies ("Beschäftigten- und Betriebstättenzähler, Bundesagentur für Arbeit") and a data set of (INFAS GEOdaten GmbH, 2002). Underlying the rationale that a company with a higher number of employees has a higher value of assets, in the first calculation step for each size category a gross stock of fixed assets is determined allocating the gross stock of fixed assets of the federal state on the sum of the number of companies listed in the INFAS data. In a second calculation step the industrial assets are estimated for each community. Therefore, the gross stock of fixed assets per size category is multiplied by the respective number of enterprises of the size class in the community. A similar method for the estimation of loss potential of industrial assets in various sectors due to storm surges is described by Meyer (2005). Even though there are sophisticated approaches for value assessment of private housing (Kleist et al., 2006; Grünthal et al., 2006) these methods can-not be transferred to industrial asset estimation The reason is that the industrial sectors are very heterogeneous compared to the private housing sector.

Bottom up approaches

Compared to the above described top down approaches, bottom up approaches yield to more accurate results as they consider the heterogeneity of installations in different industrial sectors. Since these approaches start the estimation of industrial asset values from an object level, results can be presented in any desired spatial distribution. Besides these advantages of bottom up methods it must be emphasised that these methods need high effort in data acquisition and data maintenance. This might be the reason why only few bottom up approaches are used as for instance, the methodology developed by (Penning-Rowsell et al., 2005) which provides a differentiated estimation of non residential assets and is used in the UK.

THE REFERENCE INSTALLATION APPROACH

The RIA was originally developed as a support for the preparation of the new "multi-pollutant and multi-effects" protocol of the UN/ECE (Rentz et al., 1999b; Rentz et al., 1999c). It allows a consistent and transparent assessment of techno-economic properties of primary and secondary emission reduction options/techniques. This concept has been applied for the elaboration of a comprehensive data base covering the pollutants VOC (40 sectors represented by about 160 reference installations) and NOx (seven sectors represented by about 130 reference installations) (Nunge, 2001; Geldermann et al., 2000; Rentz et al., 1999a).

This Approach is now transferred and applied to the evaluation of the monetary value of industrial assets at risk. In order to obtain an exact prediction of the potential losses due to extreme natural events, knowing the value of industrial assets at risk is essential. Thus, the RIA starts the financial appraisal of industrial assets on a process level. Furthermore, for an actual loss estimation in case of natural hazards it is indispensable to be able to asses vulnerability and the susceptibility to interruptions of single industrial assets. Due to the variety and heterogeneity of industrial assets, each single installation in each sector cannot be assessed; thus, categories of installations have been defined, each category being represented by a reference installation. All installations assigned to one category, have similar values and show a similar vulnerability to storm, flood and earthquakes. The investments of these reference installations are obtained from literature, branch experts and representatives of industrial associations. For a comprehensive and transparent documentation of these data, a relational data base is established. It is based on a classification of emission sources following the CORINAIR nomenclature (European Topic Centre on Air Emissions, 1997) and is complemented by further subdivisions allowing the representation of the lowest aggregation level corresponding to the reference installations. In the following paragraphs, the RIA is explained in more detail, as well as the economic characterisation of industrial assets and financial impacts of disasters on industrial production, in order to derive conclusions and recommendations for industrial risk management.

Definition of Reference Installations

Within all industrial sectors, asset values have to be determined on the installation or process level. Such an assessment highly depends on specific characteristics of single installations, since for most of the sectors, significant differences do exist between installations with regard to size or capacity and processes in use. However, due to a multitude of individual assets within a sector and the number of considered sectors, it is impossible to consider and assess each individual installation in each single sector. The solution to this problem involves the assignment of individual installations to defined categories of installations, each category being represented by a "reference installation". The definition of a reference installation is performed according to the following criteria:

- all installations which can be assigned to a certain reference installation, have a similar monetary value;
- all installations which are assigned to one reference installation show similar vulnerability to flood, storm and earthquakes.

Thus, the characteristics of the reference installation can be considered as representative values for all concerned installations. A selection of parameters used for the definition of reference installations is given in Table 1.

For the purpose of determining relevant parameters of production and transformation processes, flow-sheets can be elaborated and used for the considered sectors (Rentz et al., 1999c).

Sector	Parameters	Range
Glass production	• sector • type of glass • type of furnace • production capacity • fuel: natural gas	• flat glass, container glass, ... • clear glass, tint glass, ... • cross-fired furnace with regenerative preheating, ... • 1 - 600 Mg/d • heavy fuel oil, natural gas, ...
Cement production	• type of process • production capacity	• wet process, dry process, ... • 500 - 5000 Mg cement clinker/a
Wood coating	• sector • application equipment • production capacity	• furniture coating, flat wood interior panel coating • conventional / HVLP / airless / electrostatic spraying, roll coating, dipping, … • 65000 – 4000000 m²/a (wood surface to be coated)

Table 1. Parameters and their ranges for the definition of reference installations in selected sectors

All production and transformation processes are documented according to the Selected Nomenclature on Air Pollution (SNAP95). By means of this nomenclature the production processes are differentiated on three aggregation levels (Geldermann, 2006):

- SNAP 1 level is equivalent to 11 main emission sources on the highest aggregation level (sectors), *e.g. SNAP 04: petroleum industry*
- SNAP 2 level consists of 80 sub sectors and is described with a four-digit code, *e.g. SNAP 04 01: processes in petroleum industry*
- SNAP 4 level characterizes the lowest level with a six-digit code, comprising more than 400 activities, *e.g. SNAP 04 01 0: petroleum product processing*

This taxonomy enables a clear identification of reference installations by means of extending the SNAP Code with two-digit code and three vulnerability codes representing the reference installation (dependent on the size of the installation) and the vulnerability of these references installations to natural hazards respectively (cf. Figure 1).

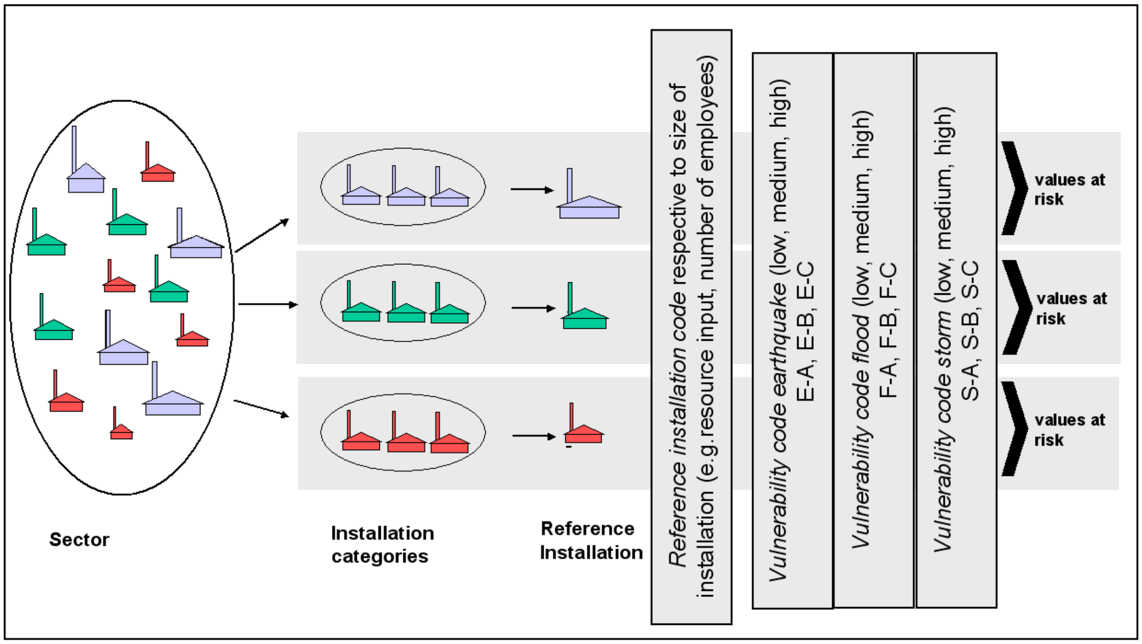

Figure 1. Generation of Reference Installation Categories

ECONOMIC CHARACTERISATION OF INDUSTRIAL INSTALLATIONS

As mentioned in previous sections, modern industry can be harmed by direct losses and indirect losses in the event of a natural disaster. As an initial step for the assessment of economic consequences of a natural disaster for each reference installation, the costs of production processes need to be known. The definition of cost includes the proper designation of notions (e. g. investments, operating costs, costs of emission reduction measures) and the compilation of relevant cost components. The following formula comprises all relevant cost items as investment induced costs (first sum) and as operating costs (Verein Deutscher Ingenieure, 2000):

(1) $$C = \sum_{j \in J} \alpha_j (I + \Delta I_j) + \sum_{i \in I} \dot{m}_i \cdot u_{ci} + p \cdot u_p + c_o + c_{od} - r_s$$

with:

α_j Rate for the calculation of the investment depending cost item j (e. g. rate of depreciation, capital costs, repair and maintenance, etc.) [1/yr]

C Annual costs [€/yr]

c_o Other costs. Cost items which have not been included in the above mentioned terms or the assignment of which is not reasonable or not usual. [€/yr]

c_{od} Included costs in other departments e.g. changes of revenues of the production process, due to changes of product quality and product composition [€/yr]

I Investment [€]

ΔI_j Correction of investment depending on cost item j (e. g. determining depreciation, the investment has to be reduced by the expenditure for land) [€]

$\dot{m}_i$ Consumption of item i; e. g. [m^3 process water/ yr]

p Personnel requirement [persons]

r_s Revenues from the recovery of by-products resulting from pollution control [€/yr]

u_{ci} Unit cost assigned to consumption of item i; e. g. [€/m^3]

u_p Unit cost of personnel [€/(person yr)]

Investment induced costs as well as production costs are affected by many different factors. These are explained in more detail in the subsequent sections.

Assessment of Investments

For an estimation of direct losses, total capital investments at risk must be assessed. Total capital investments are defined as the sum of all occurring expenses to supply the necessary plant and manufacturing facilities (fixed capital investment) plus the expenses required as working capital for operation of the facilities. Fixed capital investments, amounting to 80 - 90% to total capital investments, is influenced by direct and indirect cost factors (Peters et al., 2003). Direct costs cover the expenses for the purchased equipment, equipment installations, instrumentation and controls, piping, yard improvements and service facilities. Cost for Engineering and supervision, construction and contractor's fees are designated as the non-manufacturing fixed-capital investments or indirect costs. The assessment of working capital, defined as raw materials and finished products in stock and semi finished products in process of being manufactured, is not to be neglected for the estimation of actual loss potential in industries amounting to 10 - 20 percent of the total investment at risk. In chemical industries for instance, the raw materials inventory included in working capital usually amounts to a one-month supply of raw material and finished or semi finished products have a value which is approximately equal to the total manufacturing costs for one month's production (Peters et al., 2003).

Investment assessments can for instance be accomplished using summary methods. One such a method often used in Germany, is the application of cost indexes e.g. "Kölbel-Schulze-Index" (Schulze, 1980). By means of these indexes, average values of fixed capital investments based on capacity units available at a past date are updated to cost data that are representative of conditions at a later time. Alternatively, factor methods affording a more detailed approximation of capital investment can be used (Hirsch and Glazier, 1960; Lang, 1948).

In all these approaches the assessment of investment needs for purchased equipment (as one part of total investments) play a central role. These equipment values can be calculated using, standard price diagrams, prices per unit weight, experience data form experts, site surveys, publications on equipment prices or offers from suppliers and producers. The exact determination of monetary values of installations is described more detailed in the section "Exemplar application of the RIA to a selected test region". In general, values of industrial assets are comprised as market prices. Depending on the point of reference they can be expressed as constant prices (prices of one single reference year), purchase prices or replacement prices. As replacement prices represent best the actual value of the installation, in many studies replacement prices are used for the assessment of assets (Meyer, 2005). Furthermore, a valuation method which takes into account the obsolescence within time of industrial assets is needed. However, there are few studies which calculate direct damages by considering full replacement of assets, thus showing the expense needed for the abatement of the damage. But taking full replacement costs, leads to an over estimation of loss potential, because advanced investments are included. For these reasons calculating direct economic costs by average remaining values, which account for the obsolescence of assets by means of depreciation seems to be more appropriate (Parker and Green, 1987).

Assessment of Operating Costs

In Industry, losses due to lost production during the interruption of production processes constitute the major part of indirect losses caused by natural disasters. It can be assumed that the damage caused by an interruption of production processes in a firm equals the value added it would normally produce in that period of time (de Nooij et al., 2003). For quantifying the lost production and thus monetarising the indirect effects, the operating cost of the normal production in the time equal to the interruption period must be assessed.

The considered cost components are determined in relation to the parameters defining the reference installation. Different components must be considered for the determination of operating costs of reference installations. The determination of annual operating costs is based on two categories of cost components:

- cost items related to direct consumption, including utilities consumption (material, energy, etc.), replacement of components, waste disposal and effluent treatment, personnel costs, and possibly other cost items;
- cost items depending on the investments (insurance premiums, taxes, maintenance and repair, and administration costs).

Beside these consequences due to lost production, it should be taken into consideration that industries may be affected by the rising cost in general, which may occur if a whole region is strucked by a natural disaster. For instance, the price of raw materials may rise considerably because of the local shortage due to damaged infrastructures and the involved critical transport situation. Furthermore, additional costs arise after an extreme event because firms need extra labor input which they may compensate with overwork bonuses. Moreover, firms have to bring up additional expenses e.g. remediation and disposal costs. All these extra cost stirred up by indirect damages of extreme events can be of a very high amount and set off serious economic losses in industry.

EXEMPLAR APPLICATION OF THE REFERENCE INSTALLATION APPROACH TO A SELECTED TEST REGION

The presented approach for industrial asset estimation is utilised in a test region. Test region is the *Mittlerer Neckar*, a highly industrialised area in the federal state of Baden-Wuerttemberg, stretching along the river Neckar and one of the most earthquake prone areas in Germany (Tayagunov et al., 2006). About 30% of the value added of Baden-Württemberg are produced in this region. The most important sectors are the sectors of automotive engineering, mechanical engineering, electrical engineering, IT and media as well as publishing . Not only large installations, but also many small and medium sized enterprises, especially in the sectors of mechanical and electrical engineering are resident in the chosen test region. In a first step, typical reference installations are classified and the value as well as the vulnerabilities of these installations are determined. Therefore, site surveys and expert interviews will be carried out in a large number of firms in different industrial sectors. The census of firms tends to provide results about the following main topics :

1. Value and age of the installations
2. Size of the installations
3. Location of the installations inside the buildings
4. Value of services installed (e.g. lifts, air conditioning, control equipment)
5. Value of raw materials, work in progress and products stored
6. Location of raw materials, work in progress and products stored
7. Vulnerability assessment of installations
8. Former losses due to natural disasters

After the classification of reference installations and the assessment of their monetary values, all installations sited in the test region are assigned to the reference installations according to their size and vulnerability. In a last calculation step, the total value of industrial assets at risk in the whole test region can be estimated by summing up the estimated values of all installations. In order to demonstrate the degree of accuracy, the estimated values of industrial assets in the test region will be finally compared with data resulting from other methods e.g. the “Relation-approach” (top down approach) which was presented in the previous sections.

CONCLUSIONS

Natural disasters can cause direct and indirect losses in modern industries. To provide a consistent decision making in crisis management, e.g. planning mitigation measures, structuring of insurance protection and planning emergency management, quantifying these losses is essential. For an estimation of direct losses, the presented RIA allows a consistent and transparent assessment of individual industrial asset values. This method, starting on the process level, has a high degree in accuracy because the high heterogeneity of industrial sectors is taken into account. The results can be presented on a detailed spatial distribution. This is one major benefit of the assessment method, because natural disasters are events mostly confined to a local spread. Knowledge about the spatial distribution of both, industrial asset values and the potential threat of different hazards is an important finding and can be used for spatial planning in future. It should be noted, however, that data collection for assessing individual reference installations is time consuming and extensive as site surveys and expert interviews must be carried out. Estimating the vulnerability to natural disasters of different assets is not easy and generalization is indispensable. Nevertheless, the reference installation approach, after having sampled a sufficient database of values and vulnerability data of reference installations, can be used for a spacious and transparent estimation of industrial assets at risk. Additionally it can be used for the validation and adaptation of top down approaches (e.g. "Relation-approach"). Though these methods need fewer data (mostly statistical or census data) and facilitate fast wide-area assessments, they often are inaccurate on a more regional level and do not consider the high heterogeneity of industrial sectors and the proper installations. Future works should focus on the improvement and sophistication of vulnerability assessment of installations due to different types of extreme events. Furthermore, effects of indirect losses to industries must be analyzed in more detail. Especially, there is a lack of methods for assessing and modeling domino effects, which can spread through highly linked supply chains of industrial production.

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