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# ANP Disruption Simulation for Supply Chains due to Macro Risks

Hella Abidi

Matthias Klumpp

Institute for Logistics and Service Management (ild)

FOM University of Applied Sciences

Leimkugelstraße 6

D-45141 Essen, Germany

E-Mail: hella.abidi@fom-ild.de – Phone: +49 201 81 004 991

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ABSTRACT: Supply chain risk management becomes important for researchers and practitioners. Therefore this research paper aims to develop a risk controlling measurement system by applying a soft operation research method, analytical network process, for a global supply chain in case of disruption by an environmental risk such as a natural disaster. In 2010 for example the volcanic ash disruption in Iceland caused a high damage along supply chains because over two days no flights were possible within Europe. The second big disaster which led to an interruption of supply chains was 2011 in Japan where many manufacturers were affected because of the interconnection of many supply chains by structural and geographic aspects.

KEYWORDS: Supply chain risk management, analytical network process, natural disasters, global supply chain.

# 1. Introduction

Over the last years different branches, in particular automotive branch, were confronted to increase their competition from their counterpart in the U.S. and Asian countries. This pressure leads the companies to improve quality, to reduce product development and manufacturing time as well as development and manufacturing costs. Furthermore the economic and financial crisis of 2009 led to an increased effort to outsource their manufacturing activities and to find suppliers who can insure production of products with high quality to lower costs (Kumar 2009). Further rapid technology development, contracting out, global markets, product dynamic, service complexity, reducing supplier and inventory practices are aspects behind commonplace complex and interlinked business environment (Deleris and Erhun 2005; Glickman  and White 2006). The European in particular German companies outsource their activities to other Asian and Eastern European countries who dispose of cheap and skilled labour and who offer an enormous reduction of costs. Minahan confirmed that by global supply chain cost savings of 10% to 40% can be achieved (Minahan 1996; Schiele et al. 2011; Frear et al. 1992). The main objective of global supply chain is profit maximization (Nelson and Toledano 1979) and balance between efficiency and effectiveness (Mentzer and Firman 1994). The company strategy such as global supply chain is afflicted with risks such as linguistic and cultural deficits and customs regulations (Cho and Kang 2001; Schniederjans and Zuckweiler 2004), transportation delays, logistics service differences (Cho and Kang 2001). All these risks can be counteracting with measurement even if these measurement increases the costs. But risk factors like natural disasters such as floods, earthquakes, hurricanes, fires, and tornadoes are significant and these are random events. A natural disaster can disrupt a global supply chain in few seconds after an outbreak (Canbolat et al. 2008;

Manuj and Mentzer 2008), e.g. volcanic outbreak in Iceland and Earthquake in Japan in 2011 or hurricane Kathrina in 2005 (Munichre 2011; Manuj and Mentzer 2008).

Since 1970 the total number of natural and technological disasters increased six-times (Schulz 2009).

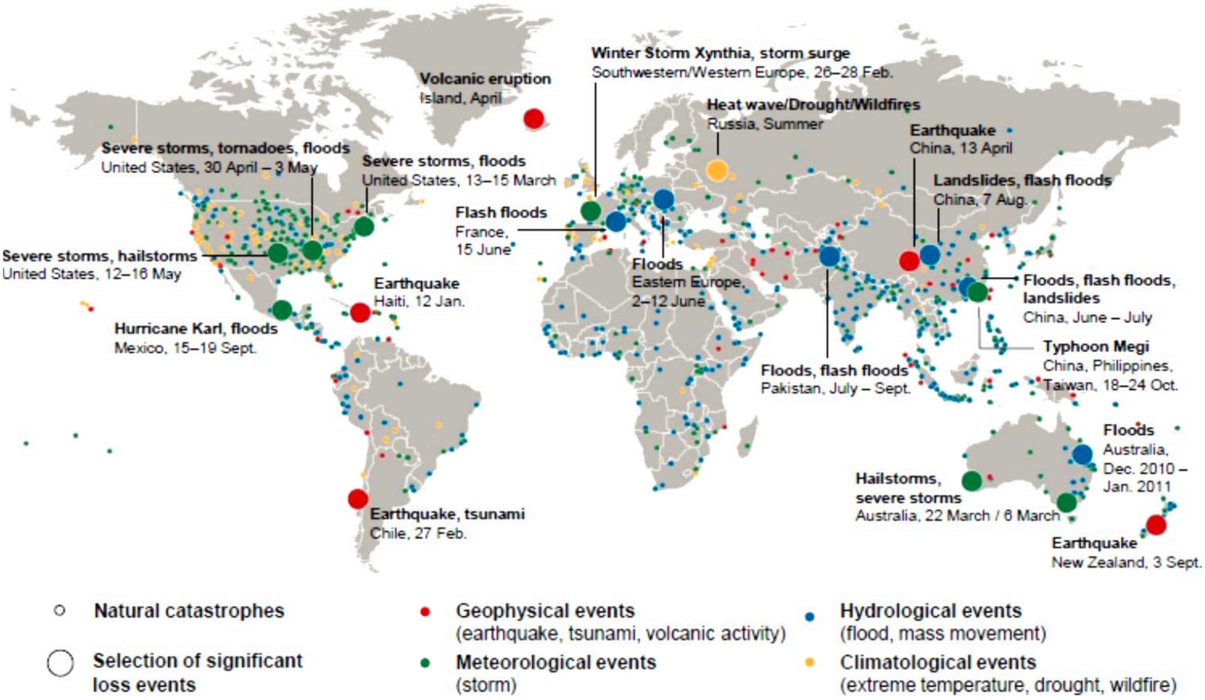



**Figure 1: Worldmap of natural disasters 2010**

Source: Munich RE 2011, retrieved 16.10.2011

Furthermore Thomas and Kopczak expect a steadily increase of natural disasters the next fifty years because of destruction of urbanization and the range of HIV/AIDS diseases in developing nations and destruction of the environment (Thomas and Kopczak 2005). In 2010, 960 events occur overall damages of US$ 150 bn and 295,000 fatalities (Munich RE 2011).

The most significant natural disasters of 2010 are the earthquake and tsunami in Chile (overall damage US$ 30,000 m and 520 fatalities), the earthquake in Haiti (overall damage US$ 8,000 m and 222,570 fatalities), the flood in Pakistan (overall damage US$ 9,500 m and 1,760 fatalities) and the winter storm in Europe (overall damage

US$ 6,100 m and 65 fatalities) (Munich RE 2011; EM-DAT 2011). The above figure shows a world map with the natural disasters of 2010 and underlines the significance of a necessity of an integration of supply chain risk management. These macro risks increase the importance of supply chain risk management (Busher et al. 2007), the significance of mitigation of risks and costs (BVL 2011), the handling of prevention of risks, risk sharing and risk acceptance (Kersten et al. 2008).

## 2. Literature Review

In 2002, Christopher et al. criticized that there are only few research contributions regarding supply chain vulnerabilities and the awareness for the subject supply chain risk management is meagre (Christopher et al. 2002). By now this is changing by a slow progress of academic and practical effort which is done.

In the segment of supply chain risk management 120 contributions were identified by Ghadge et al. in a period of 2000 until 2010 (Ghadge et al. 2011). A radical increase in the number of publications in supply chain risk management was determined in 2004. A reason for this increase results from the 09/11 attack. Then this attack disrupted many supply chains (Chopra and Sodhi 2004; Sheffi 2005). A further significant increase was determined in 2009. This would be a sign of the financial crisis of 2008/2009. The Analysis of Ghadge et al. shows that two thirds of research publications was supported by the USA with 46.66% of all journals and UK with 15.8% of all journals. This is due to the fact that USA and UK unlike to central European countries have outsourced the most activities, therefore they are more interested and their supply chains are more vulnerable than the ones from other countries (Ghadge et al. 2011). The literature review considers macro risks as one of various risk factors such as bankruptcy etc. and discusses in general serious consequences for a supply chain. Exemplary Johnson (2001) made a deep insight regarding supply chain risk management in the toy industry. Steele and Court (1996) and Zsidisin et al. (2000) worked out the assessment of supply risk. Zsidisin (2003) illustrated the supply characteristics that have a high impact on perceptions of supply risk and classified supply risk sources. Peck (2005) and Juttner (2005) developed supply chain vulnerability. Smeltzer and Siferd (1998) involved risk management and considered proactive supply management practices. Sanders and Manfredo (2002) have proposed estimations of the weakness of risks on material flow by applying a value-at-risk method. Supply chain vulnerability was primarily recommended by Svensson (2002). Chapell and Peck (2006) developed risk management situations for the military supply chain by applying six-sigma method. Manuj and Mentzer (2008) developed a risk management and mitigation model for global supply chain. Manuj et al. (2009) developed an eight step model for the design, assessment and application of logistics and supply chain simulation model. Kleindorfer and van Wassenhove (2003) investigated on supply demand coordination risk and analyzed disruption risk management in global supply chains.

In general the major of literature deals with management of disruption risks in global supply chain networks by considering supply chain risk management cycle: Identification risk factors and the sources of risk, determination the measurement, estimation the potential consequences and risk mitigation and control.

This research paper is unique in the scientific context. Based on the literature review no similarity with other research publications was found. This new approach seeks to show an accurate linking between macro risk factors and their consequences on a supply chain. For example when Japan was attracted by earthquake as risk factor or consequence was not contract risk or liquidity risk, the main risk factor was an impact on demand supply or inventory management. The increasing number of macro risks the supply chain management is confronted with different amendments of supply chain risk management and making adjustments.

## 3. Impact of macro risks on a supply chain and their management

The management of risks in the contemporary business environment is becoming more and more challenging (Christopher and Lee 2004). The reasons are various such as (Stefonovic et al. 2009):

- Globalization of markets
- Uncertainties in demand and supply
- Short life cycles of products and shot time to market
- Financial instability (e.g. financial crisis 2009)
- Modern technologies and e-business (e-commerce, e-purchasing)
- Trend to outsource activities
- Pull instead of push strategies

All these simplify the vulnerability of a business environment by risks. Then risks are defined from Rowe as a potential for unwanted negative consequences to arise from an event or activity (Rowe 1980) or Waters describes that "there are risks in a supply chain when unexpected events might disrupt the flow of materials on their journey from initial suppliers through to final customers" (Waters 2011). Zsidisin defines it as "the potential occurrence of an incident or failure to seize opportunities with inbound supply in which its outcomes result in a financial loss for the firm." (Zsidisin 2005). In a study of BCI in 2010 300 companies taking part . More than 70% of those suffered a supply disruptions, 50% of those have had experience with more than one disruption. It is not avoidable when clearly increases of micro risks and in particular macro risk such as natural disasters can be noticed which becomes commonplace (Kerner and Lynch 2011).

All these argue for a sustainable supply chain risk management. But at first moment a risk management seems to be as an additional work for companies and manager as well as losses (Manuj and Sahin 2009). Supply chain disruptions cause a sales fall of 7%, a down of an operating income of 42% and a fall of return on assets of 35% and an announcement of supply chain disruptions causes a shareholder return between 7 and 8% (Hendricks and Singhal 2005). In the depth sight, it is to recognize that risk management brings profits which make the companies more efficient (Waters 2011). Supply chain risk consists of two different types: (a) Internal risks or micro risks such as financial risks, late deliveries, out of stock, unfortunate forecast, poor information and communication etc. (b) External risks or macro risks such as disease, earthquake, storm, flood, heat wave, price rise, crime, problem with supplier, bankruptcy of trading partner etc. (Siebrandt 2011).

Following figure presents exemplary an interrupted supply chain due to macro risks.

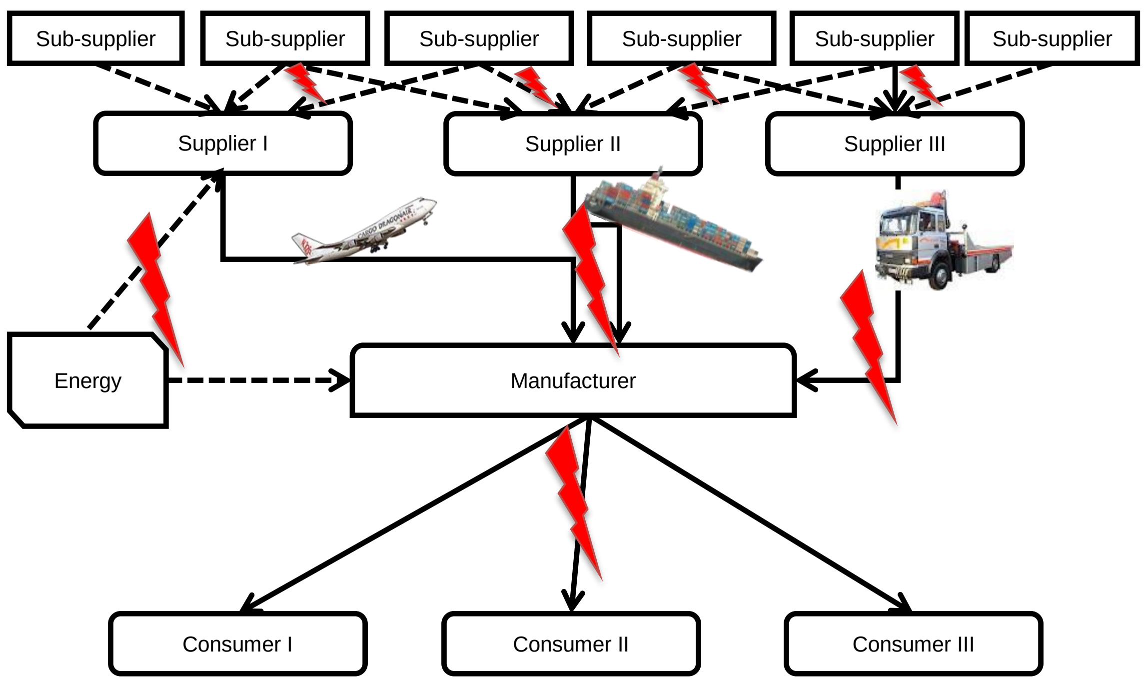



**Figure 2: Interrupted global supply chain**

Macro risks are unpredictable and as clarified above can disrupt a holistic network and cause high costs for companies and unintended consequence for collaborating global partner relationships. The modern business environment may reckon that the supply chain is characterized by volatility and further it can expect the natural disaster as a permanent risk and feature of the commonplace economy.

Dramatic collapse of a supply chain due to macro risks such as natural disasters argues to verify the strategic, tactical and operational level of a supply chain and to address all efforts to manage in efficient way. The three levels in detail are as followed (Kumar 2009):

I) Strategic level: If the available supply chain is aligned to the risk management objectives?

II) Tactical level: Are all potential risks due to macro risk events well known and does the supply chain management dispose of contingency plans and are they prepared when these disasters occurred?

III) Operational level: If the time is known when the prepared contingency plan can be deployed and if the users are able to learn from the experience and to improve their reflexes for future events?

In literature there are various perceptions how to execute risk assessment, risk management and risk mitigation in a global supply chain and these are common. Risk management should be a continuous and developing process which runs throughout the organizations strategy and the implementation of that strategy. “It should address methodically all risks surrounding the organizations activities past, present and in particular, future. It must be integrated into the culture of the organization with an effective policy and a program, led by the most senior management. It must translate the strategy into tactical and operational objectives, assigning responsibility throughout the organization with each manager and employee responsible for the management of risk as part of their job description. It supports accountability, performance measurement and reward, thus promoting operational efficiency at all levels" (IRM/AIRMIC/ALARM, 2002).

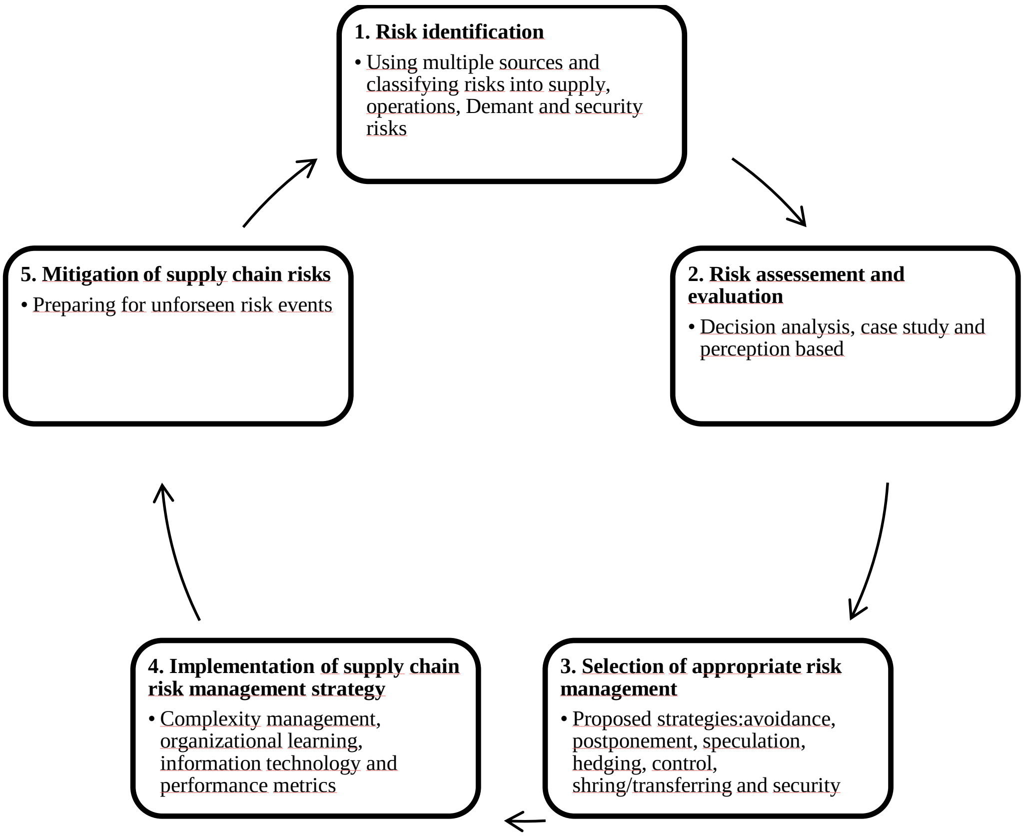



**Figure 3: Five Step process for global supply chain risk management and mitigation**

Source: Manuj and Mentzer (2008), p. 137

Detailed conceptualization of supply chain risk management by considering macro risks such as natural disasters can be obtained of chapter 4.5.

# 4. Application of Analytical Network Process

## 4.1 Analytical network process

To achieve substantial results an accurate multi-criteria decision analysis (MCDM) has to be researched. Then MCDM solves decision problems which includes multiple and conflicting purposes (Arbel and Vargas 1992). "MCDM is a term to describe a subfield in operations research and management sciences." (Schniederjans 1995). In the operations research discipline there are a variety of MCDM methods e.g. aggregated indices randomization method (AIRM) (Hovanov et al. 2007), analytic hierarchy process (AHP) (Saaty 1978), analytic network process (ANP) (Saaty 1990), data envelopment analysis (DEA) (Charnes et a. 1978), elimination et choix traduisant la realité (ELECTRE) (Figueira et al. 2005), measuring attractiveness by a categorical based evaluation technique (MACBETH) (Bana e Costa et al. 2002) and multi-attribute utility theory (MAUT) (Posavac, Carey 1989). In the logistics sector there are two well-known methods and useful methods to solve decision problems and which consider multiple objectives:[1] Analytical network process and data envelopment analysis. In this research paper the authors use method analytical network process (Saaty 1990; Saaty 1996) as a soft research. Then by using the analytical network process the relevant criteria for a controlling measurement on a strategic, tactical and operational level will be identified which is the basis for supply chain risk controlling measurement matrix. An analytical network process disruption simulation for a supply chain due to vulnerability provides a key concept which outlines the need for a holistic approach to manage and structure supply chain risk management and resilience.

Analytical network process (ANP) (Saaty 2001; Meade and Sarkis 1998; Sarkis 2000; Sarkis and Sundarraj 2002) was designed and shaped by Saaty 1990 (Saaty 1990). Analytical network process is an extension of the analytical hierarchy process (Saaty 2004). Analytical hierarchy process (Saaty 1980) solves multiple criteria problems in a hierarchical structure. In contrast Analytical network process solve also multiple criteria problems but in a network structure.

Analytical network process is a decision-supporting method which integrates qualitative and quantitative data for prioritizing alternatives when multiple criteria

[1] Sometimes tradeoff between the objectives

have to be considered or to evaluate complex multiple criteria alternatives (Saaty 2001).

Analytical network process provides a more generalized model than analytical hierarchy process without making assumptions about the independency of the criteria at different levels of the hierarchy and also of the criteria within a level (Saaty 2001). Performance measurement metrics cannot be expressed by a structured hierarchy. Therefore the development of performance measurement metrics requires a method where all the components of each figure are interconnected to each other (Lo Liu and Tsai 2004). "Analytical network process allows for more complex interrelationships among the decision levels and attributes. […] Interdependencies may be represented by two way arrows (or arcs) among levels, or if within the same level of analysis, a looped arc. The directions of the arcs signify dependence, arcs emanate from an attribute to other attributes that may influence it." (Meade and Sarkis 1998). In line with Saaty predetermined basic criteria of analytical network process are as follows (Saaty and Özdemir 2005; Lo Liu and Tsai 2004; Saaty 2004):

I) After the description of the decision problem the system that includes objectives, criteria, their objectives, actors and outcomes will be decomposed into many groups. This is the base to form the network structure.

II) Within the comparison matrices, each component will be assumed that it takes inner and outer interdependence.

III) A component in each hierarchy is able to use some or all components of the previous components as the basis to conduct the evaluating operation.

IV) It is able to change the absolute and numerical scales into the ratio scale despite the fact that conduct the comparing assessment.

V) After conducting the pair or pair-wise comparison, it is able to use the positive reciprocal matrices to handle the follow-up process.

VI) The preference relations conform to transitivity i.e. if A is better than B, and B is better than C, then A is better than C, but also the useful step of components can be obtained by the weighting principle.

VII) Every element that showed in the hierarchical framework, no matter if it is advantageous degree is small or not, it will be regarded as relating to the whole evaluation framework but the independence of non-check hierarchical structure.

## 4.2 Method of ANP

To adapt results for analytical network process disruption simulation for supply chains due to macro risks following nine steps were applied (Saaty 2001; Saaty 1996; Peters, Zelewski 2008; Sevkli et al. 2008; Tsai et al. 2007; Shyur 2006; Jharkharia, Shankar 2007; Thakkar et al. 2005; Meade, Sarkis 1998; Peters 2008):

1) Model design and problem formulation: In the first place the main subject has to be determined and has to be put in broad context which includes goals and outcomes.
2) Identification of clusters and nodes: In this research paper the analytical network process structure as well as the goals, criteria and alternatives are based on a literature review. In this proposed analytical network process model the goals are named clusters which include three different risk classes because the classification is crucial in the decision making and depends on the remaining criteria: Risk class 1 poses a major risk with an impact on a supply chain of with a frequency of > 2,0, risk class 2 means relevant with an impact on a supply chain with a frequency of > 1,0 > and risk class 3 can be seen as irrelevant with an impact on a supply chain of < 0, 5 (Schatz et al. 2010). The determinants such as disasters which are

categorized in 4 groups (CRED 2010; Munich RE 2011) present the upper level in this analytical network process structure.

The nodes or criteria are named risk factors which are based on a literature review and can be adapted from following table.

| **Type of Risk** | **Reference** | **Type of Risk** | **Reference** |
|---|---|---|---|
| Price increase | Moder (2008) | Currency decrease | Moder (2008); Kersten et al. (2008); Chopra and Sodhi (2004) |
| Quality | Zsidin and Ellram (2003); Chopra and Sodhi (2004); Moder (2008); Kersten el at. (2008) | Inventory management | Cho and Kang (2001); Chopra and Sodhi (2004); Zsidisin and Ellram (2003) |
| Demand uncertainty | Moder (2008 | Information management | Moder (2008); Zsidisin and Ellram (2003) |
| Supplier capacity | Kersten et al. (2008); Chopra and Sodhi (2004); Zsidin and Ellram (2003) | Liquidity crisis | Moder (2008); Kersten et al. (2008) |
| Transportation delay | Chopra and Sodhi (2004); Birou and Fawcett (1993); Cho and Kang (2001) | Global sourcing | Moder (2008) |
| Single sourcing | Moder (2008) | Contract risks | Moder (2008); Kersten et al. (2008) |
| Cycle time | Zsidin and Ellram (2003); | Trade regulation | Schniederjans and Zuckweiler (2004) |
| Bankruptcy | Moder (2008) | Cultural and language deficit | Schniederjans and Zuckweiler (2004); Moder (2008) |
| Supplier dependence | Moder (2008); Kersten et al. (2008); | Economy risk | Moder (2008); Kersten et al. (2008 |
| Process change | Kersten et al. (2008); Moder (2008) | Customs regulation | Cho and Kang (2001) |

**Table 1: Risk factors for analytical network process structure**

3) Development of an ANP structure: Referring to above table and step 2 an ANP structure for this research paper is developed as shown in following figure:

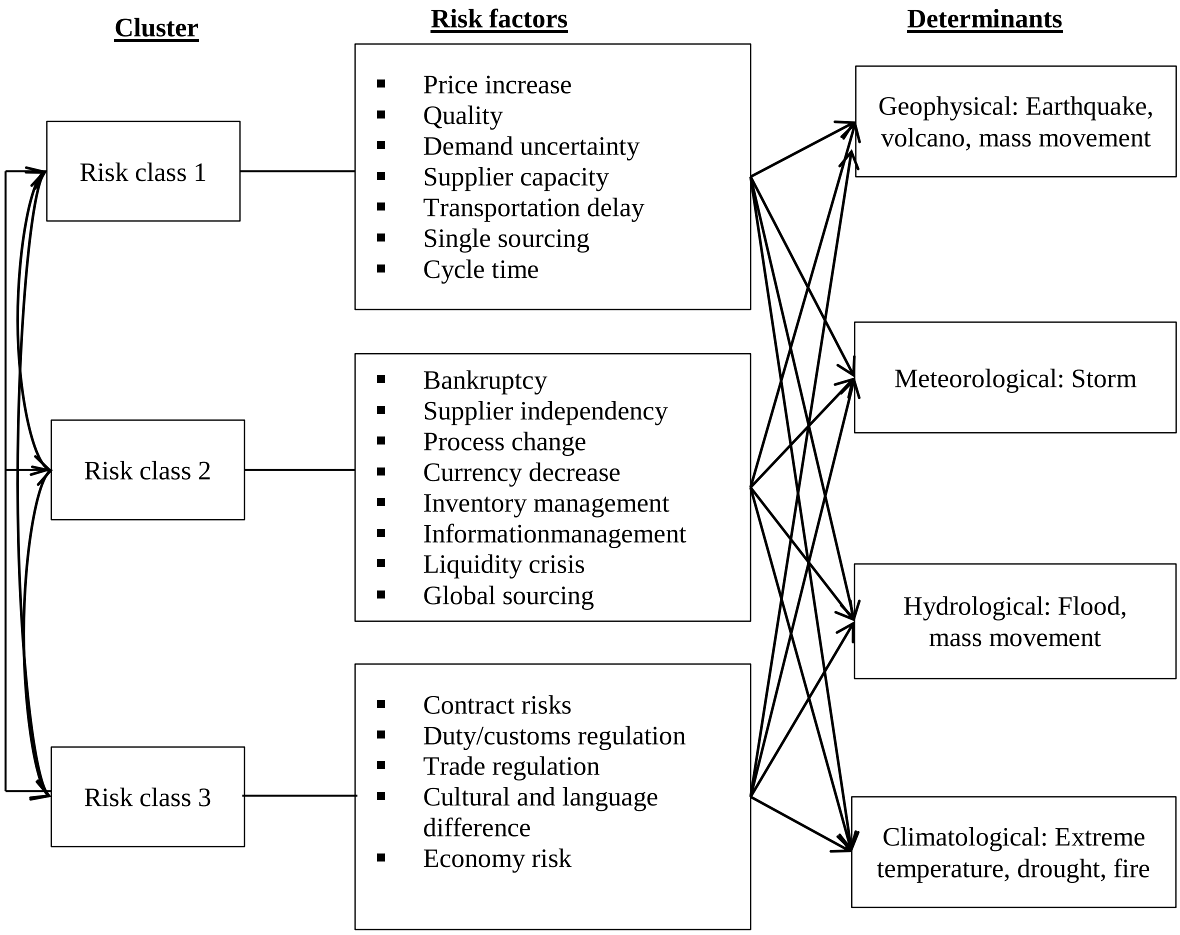



**Figure 4: Analytical network process structure**

4) Pairwise comparison matrix: After a development of an analytical network process structure a pairwise comparison matrix can be established and formed of manifold judgment of risk factors and determinants. For the analytical network process application a fundamental scale of 1-9 (Saaty 2001) has to be used. Analytical network process derives relative weightings based on this measurement scale (Saaty 2001) as presented in the following table.

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two activities contribute equally to the objective |
| 2 | Weak | …between Equal and moderate |
| 3 | Moderate importance | Experience and judgment slightly favour one activity over another |
| 4 | Moderate plus | …between Moderate Strong |
| 5 | Strong importance | Experience and judgment strongly over another; its dominance demonstrated in practice |
| 6 | Strong plus | …between strong and very strong |
| 7 | Very strong | An activity is favoured very strongly over another ; it´s dominance demonstrated in practice |
| 8 | Very, very strong | …between very strong and Extreme |
| 9 | Extreme importance | The evidence favouring one activity over another is of the highest possible order of affirmation |

**Table 2: Fundamental Scale for making judgment**

Source: Saaty (2001)

The pairwise matrix is shown in following equation (1). The element $a_{ij}$ of matrix A is the relative importance of the $i^{th}$ criteria risk factors to the $j^{th}$ determinants.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1/n} \\ {}^{1}/_{a_{12}} & 1 & a_{23} & a_{2n} \\ \dots & {}^{1}/_{a_{23}} & \dots & \dots \\ {}^{1}/_{a_{1n}} & {}^{1}/_{a_{2n}} & \dots & 1 \end{bmatrix} \qquad (1)$$

5) Calculation of the eigenvector and eigenvalue: $\lambda_{max}$ (maximum eigenvalue) and $w_i$ (eigenvector) have to be calculated to estimate a relative weight of the decisive elements. The comparison matrix allows comparing the priority of elements by using equation 2. Equation 2 shows the computation of eigenvalues and eigenvectors

$$A.w = \lambda_{max}.w \qquad (2)$$

Subsequently, the $\lambda_{max}$ calculation is to get the new matrix W by multiplying matrix A with $w_i$, and then the $\lambda_{max}$ can be gained by averaging the value. These are presented in equation 3 and equation 4.

$$\begin{bmatrix} 1 & a_{12} & \cdots & a_{1/n} \\ 1/a_{12} & 1 & a_{23} & a_{2n} \\ \cdots & 1/a_{23} & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} . \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} = \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix} \quad (3)$$

$$\lambda_{max} = \frac{1}{n}\left( W_1/w_1 + W_2/w_2 + \cdots/\cdots + W_n/w_n \right) \quad (4)$$

Furthermore the consistency value *C.R.* of the comparison matrix has to be calculated. *C.R.* supports by decision making, if the judgment and preferences of the experts has to be revised. The consistency value can be calculated as follows:

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

In the denominator of Equation 5 $R.I.$ presents a random index. This was randomly determined of a reciprocal matrix and is an average of a consistency index. The values for a random index are fixed by Saaty (Saaty 2001) and can be adopted from following table.

| *n* | *R.I.* | *N* | *R.I.* |
|---|---|---|---|
| 2 | 0.00 | 9 | 1.45 |
| 3 | 0.52 | 10 | 1.49 |
| 4 | 0.89 | 11 | 1.51 |
| 5 | 1.11 | 12 | 1.54 |
| 6 | 1.25 | 13 | 1.56 |
| 7 | 1.35 | 14 | 1.57 |
| 8 | 1.40 | 15 | 1.58 |

**Table 3: Random index table**

Sources: Saaty (2000); Saaty (2004)

When *C.R.* $\leq 0.1$ no correction of judgment and preferences is needed, that means the consistency is satisfied. Further applies, the larger the inconsistency of the comparison matrix is, the larger is the value of consistency *C.R.*

6) Supermatrix formulation: By the application of supermatrix, interdependencies that are among the elements of a system can be resolved. It is a subdivided matrix where each sub-matrix presents a set of relationships between and within the clusters or components in as system.

7) Weighted supermatrix formulation: Equation (1) is an unweighted supermatrix. Then the cumulative of the column vectors of a supermatrix, as can be noticed, is not equivalent to 1. For transforming in a weighted supermatrix, which can be denoted, $W$a convergence has to be made. This explicit procedure ensures an adaption of a long-term stable set of weights. That means the sum of each column has to be 1. The supermatrix has to be raised to the power $2^{k+1}$, where k is an randomly large number and a weighted supermatrix is transformed.

8) Selection of a harmless macro risk determinant: the best alternative with a low impact on a supply chain depends on the desirability index as presented in Equation (6) referring to Meade and Sarkis (1999).

$$D_{ia} = \sum_{j=1}^{J} \sum_{k=1}^{K_{ja}} P_{ja} A_{kja}^{D} A_{kja}^{I} S_{ikja} \qquad (6)$$

$D_{ia}$= desirability index indicate the alternative *i* and the determinant *a*

$P_{ja}$= indicate the relative importance of dimension *j* influencing the determinant *a*

$A_{kja}^{D}$= indicate the relative importance of risk factor *k* influencing the determinant *a* in the dimension *j* for *D* (dependent relationship)

$A_{kja}^{I}$= indicate the stabilized importance weight of risk factor *k* in the dimension *j* and determinant a for *I* (interdependent relationship)

$S_{ikja}$= indicate relative impact of alternative *i* on risk factor *k* of dimension *j* for determinant *a;* $K_{ja}$ is the index set of risk factors of dimension *j* of determinant *a* and *J* is the index set for dimension *j*.

9) Till step 8 the formulation and results which were achieved concern for the compatibility determinants. Similar analysis for the remained determinant has to be conducted by formulation and calculating *OWI*. *OWI* is the sum of the normalized desirability indices ($D_{ia}$) and the relative importance weight of the determinants ($C_a$). Finally the sum of *OWI* values must be equal to 1. The following equation demonstrates *OWI*.

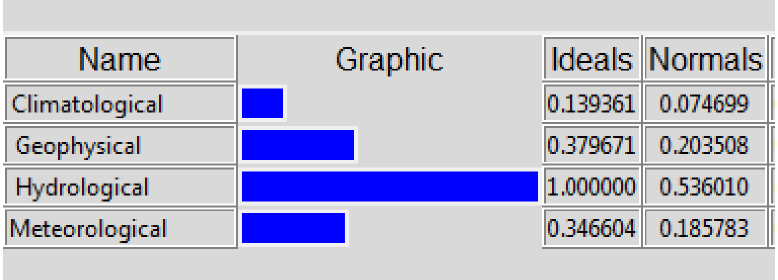
$$OWI_i = \sum D_{ia} C_a \qquad (7)$$

### 4.3 Results

In this chapter the results of analytical network process which were calculated by using the software super decisions software will be presented. The following figure shows the analytical network process structure according to figure 2.


**Figure 5: Analytical network process structure by applying software super decisions**

The following diagram presents the classification of the determinants macro risks. From the year 1900-2011, 1385 climatological events, 1464 geophysical, 3432 meteorological events and 4512 hydrological disasters occurred worldwide (CRED 2012).



| Name | Graphic | Ideals | Normals |
|---|---|---|---|
| Climatological | | 0.139361 | 0.074699 |
| Geophysical | | 0.379671 | 0.203508 |
| Hydrological | | 1.000000 | 0.536010 |
| Meteorological | | 0.346604 | 0.185783 |

**Figure 6: Priorities of determinants macro risks**

| Cluster/Node | | 1Cluster | | | 3Determinants | | | |
|---|---|---|---|---|---|---|---|---|
| | | Risk class 1 | Risk class 2 | Risk class 3 | Climatological | Geophysical | Hydrological | Meteorological |
| 1Cluster | Risk class 1 | 0.673811 | 0.664839 | 0.673811 | 0.66484 | 0.59363 | 0.63010 | 0.59363 |
| | Risk class 2 | 0.225535 | 0.244929 | 0.225535 | 0.24493 | 0.24931 | 0.21844 | 0.24931 |
| | Risk class 3 | 0.10065 | 0.09023 | 0.10065 | 0.09023 | 0.15706 | 0.15146 | 0.15706 |
| 2Risk factors | Bankruptcy | 0.01275 | 0.01412 | 0.01512 | 0.01255 | 0.00887 | 0.00752 | 0.00814 |
| | Contract risk | 0.01166 | 0.01600 | 0.01388 | 0.01342 | 0.01122 | 0.00920 | 0.00929 |
| | Cultural and language difference | 0.01234 | 0.02134 | 0.01905 | 0.01844 | 0.01171 | 0.01223 | 0.00815 |
| | Currency decrease | 0.01491 | 0.01950 | 0.01895 | 0.01859 | 0.01529 | 0.01311 | 0.01135 |
| | Customs regulation | 0.01835 | 0.02517 | 0.02489 | 0.02125 | 0.01555 | 0.01792 | 0.01246 |
| | Cycle time | 0.02266 | 0.02795 | 0.03116 | 0.02428 | 0.01699 | 0.01860 | 0.01441 |
| | Demand uncertainty | 0.03179 | 0.02407 | 0.03016 | 0.02881 | 0.02335 | 0.02162 | 0.01829 |
| | Economy risk | 0.03262 | 0.02860 | 0.00000 | 0.03412 | 0.02859 | 0.02839 | 0.02260 |
| | Global risk | 0.03063 | 0.03530 | 0.04327 | 0.03814 | 0.02069 | 0.01912 | 0.02051 |
| | Information management | 0.03340 | 0.03624 | 0.04616 | 0.03882 | 0.03044 | 0.02983 | 0.02942 |
| | Inventory management | 0.03730 | 0.04780 | 0.05099 | 0.04793 | 0.03596 | 0.03551 | 0.03172 |
| | Liquidity crisis | 0.04665 | 0.04303 | 0.04984 | 0.04871 | 0.04422 | 0.04067 | 0.03835 |
| | Price increase | 0.06066 | 0.04688 | 0.04693 | 0.05833 | 0.05546 | 0.05159 | 0.05237 |
| | Process change | 0.05926 | 0.06219 | 0.06391 | 0.06037 | 0.06803 | 0.05208 | 0.05583 |
| | Quality | 0.05406 | 0.07504 | 0.06962 | 0.07263 | 0.06891 | 0.05862 | 0.06409 |
| | Single sourcing | 0.15456 | 0.07289 | 0.05674 | 0.06246 | 0.09350 | 0.09170 | 0.09455 |
| | Supplier capacity | 0.10677 | 0.08248 | 0.07103 | 0.07554 | 0.11438 | 0.11357 | 0.10345 |
| | Supplier interpendency | 0.11137 | 0.08553 | 0.07667 | 0.07866 | 0.11663 | 0.12373 | 0.13362 |
| | Trade regulation | 0.05983 | 0.10972 | 0.12999 | 0.10945 | 0.08703 | 0.11391 | 0.10851 |
| | Transportation delay | 0.08843 | 0.12613 | 0.14164 | 0.13750 | 0.13319 | 0.14108 | 0.16291 |
| 3Determinats | Climatological | 0.05475 | 0.05308 | 0.43305 | 0.06952 | 0.07692 | 0.06255 | 0.07899 |
| | Geophysical | 0.24831 | 0.18241 | 0.30850 | 0.25528 | 0.21931 | 0.16462 | 0.23697 |
| | Hydrological | 0.53719 | 0.24915 | 0.16452 | 0.52429 | 0.57164 | 0.56294 | 0.54724 |
| | Meteorological | 0.15975 | 0.51536 | 0.09393 | 0.15091 | 0.13214 | 0.20989 | 0.13681 |

**Table 4: Unweighted supermatrix**

| Cluster/Node | | 1Cluster | | | 3Determinants | | | |
|---|---|---|---|---|---|---|---|---|
| | | Risk class 1 | Risk class 2 | Risk class 3 | Climatological | Geophysical | Hydrological | Meteorological |
| 1Cluster | Risk class 1 | 0.22405 | 0.22107 | 0.22405 | 0.07513 | 0.06708 | 0.07120 | 0.06708 |
| | Risk class 2 | 0.07499 | 0.08144 | 0.07499 | 0.02768 | 0.02817 | 0.02468 | 0.02817 |
| | Risk class 3 | 0.03347 | 0.03000 | 0.03347 | 0.01020 | 0.01775 | 0.01711 | 0.01775 |
| 2Risk factors | Bankruptcy | 0.00178 | 0.00197 | 0.00211 | 0.00295 | 0.00209 | 0.00177 | 0.00191 |
| | Contract risk | 0.00163 | 0.00224 | 0.00194 | 0.00315 | 0.00264 | 0.00216 | 0.00218 |
| | Cultural and language difference | 0.00172 | 0.00298 | 0.00266 | 0.00433 | 0.00275 | 0.00288 | 0.00192 |
| | Currency decrease | 0.00208 | 0.00272 | 0.00265 | 0.00437 | 0.00360 | 0.00308 | 0.00267 |
| | Customs regulation | 0.00256 | 0.00351 | 0.00348 | 0.00499 | 0.00365 | 0.00421 | 0.00293 |
| | Cycle time | 0.00316 | 0.00390 | 0.00435 | 0.00571 | 0.00399 | 0.00437 | 0.00339 |
| | Demand uncertainty | 0.00444 | 0.00336 | 0.00421 | 0.00677 | 0.00549 | 0.00508 | 0.00430 |
| | Economy risk | 0.00456 | 0.00399 | 0.00000 | 0.00802 | 0.00672 | 0.00667 | 0.00531 |
| | Global risk | 0.00428 | 0.00493 | 0.00604 | 0.00897 | 0.00486 | 0.00449 | 0.00482 |
| | Information management | 0.00466 | 0.00506 | 0.00645 | 0.00912 | 0.00715 | 0.00701 | 0.00692 |
| | Inventory management | 0.00521 | 0.00668 | 0.00712 | 0.01127 | 0.00845 | 0.00835 | 0.00746 |
| | Liquidity crisis | 0.00651 | 0.00601 | 0.00696 | 0.01145 | 0.01040 | 0.00956 | 0.00901 |
| | Price increase | 0.00847 | 0.00655 | 0.00655 | 0.01371 | 0.01304 | 0.01213 | 0.01231 |
| | Process change | 0.00827 | 0.00869 | 0.00893 | 0.01419 | 0.01599 | 0.01224 | 0.01312 |
| | Quality | 0.00755 | 0.01048 | 0.00972 | 0.01707 | 0.01620 | 0.01378 | 0.01507 |
| | Single sourcing | 0.02158 | 0.01018 | 0.00792 | 0.01468 | 0.02198 | 0.02156 | 0.02223 |
| | Supplier capacity | 0.01491 | 0.01152 | 0.00992 | 0.01776 | 0.02689 | 0.02670 | 0.02432 |
| | Supplier inderpendency | 0.01555 | 0.01194 | 0.01071 | 0.01849 | 0.02741 | 0.02908 | 0.03141 |
| | Trade regulation | 0.00836 | 0.01532 | 0.01815 | 0.02573 | 0.02046 | 0.02678 | 0.02551 |
| | Transportation delay | 0.01235 | 0.01761 | 0.01978 | 0.03232 | 0.03131 | 0.03316 | 0.03830 |
| 3Determinats | Climatological | 0.02890 | 0.02802 | 0.22858 | 0.04532 | 0.05014 | 0.04077 | 0.05149 |
| | Geophysical | 0.28355 | 0.13151 | 0.08684 | 0.16643 | 0.14297 | 0.10732 | 0.15449 |
| | Hydrological | 0.28355 | 0.13151 | 0.08684 | 0.34180 | 0.37267 | 0.36700 | 0.35676 |
| | Meteorological | 0.08432 | 0.27203 | 0.04958 | 0.09838 | 0.08614 | 0.13683 | 0.08919 |

**Table 5: Weighted supermatrix**

Referring to figure 4 and the weighted supermatrix the macro risks as well as risk factors can be classified in risk classes which is presented in following table.

| **Risk class 1** | **Risk class 2** | **Risk class 3** |
|---|---|---|
| Relevance category: critical – endangered company value | Relevance category: normal-influenced company value | Relevance category: small – influenced company value |
| Feature: likelihood >50-75% | Feature: likelihood >26-50% | Feature: likelihood >10-25% |
| **Determinants** | | |
| Geophysical<br>Hydrological | Meteorological | Climatological |
| **Risk factors** | | |
| Economy risk | Cultural and language difference | Cycle time |
| Liquidity crisis | Currency decrease | Global risk |
| Liquidity crisis | Customs regulation | Information management |
| Price increase | Information management | Inventory management |
| Process change | Inventory management | Liquidity crisis |
| Quality | Quality | Quality |
| Single sourcing | Transportation delay | Trade regulation |
| Supplier capacity | | Transportation delay |
| Supplier inderpendency | | |
| Transportation delay | | |

**Table 6: Classification of macro risks as well as risk factors in risk classes**

The classification of risk factors to each macro disaster and to each risk class is to criticize. Then every company has to verify individually company structure, supply network, location of supply chain partner on the globe and if the location of the supply chain partner in the country which can be affected fast by macro risks. For example risk factor information management is essential for every supply chain and can not only classified to climatological events or can be seen as a risk class 3 with a slow impact of a supply chain partner. Based on the analytical network process results the main critical supply chain risk factor is calculated: single sourcing, supplier independency, supplier capacity, quality and transportation delay which are classified to hydrological (flood) and geophysical (earthquake). These have a high impact and influence company value as well as turnover in a supply chain as shown in the beginning of the year 2011. March 2011, Japan was affected by tsunami and earthquake; this caused a high damage of many supply chains of the automotive industry. The supply chain network partner has to procure automotive parts from other supplier or to stop production. All these mean high costs for company and threat the labour market in particular in the automotive industry. Therefore the supply chain of different industries has to recognize that macro risks are not only risk factors there are specific risk determinants where the supply chains have to establish an adapted contingency plan for each macro risk.

In this research paper first approach of classification risk factors to each macro risk event by showing the impact on supply chain can be seen as a satisfied result and is helpful for strategic decision by organizing and issuing a supply chain risk plan. The analytical network process is an applicable measurement system for supply chain and can be seen as base for building supply chain resilience.

## 4.4 Managerial insight

This research paper presented the preliminary part of the research conducted to develop a framework for assisting risk control in global supply chain which can be disrupted and are vulnerable due to macro risks such as natural disasters by application analytical network process approach. Referring to this research risk mitigation and control has to be classified in two groups, proactive and reactive, because not all macro risks are similar and cause high damage. Because of the increasing number of natural disasters the global supply chain has to verify their chain and to take measurement how they can reduce vulnerability and to build supply chain resilience.

## 4.5 Concept of supply chain risk management due macro risk

Based on the analysis of analytical network process following figure has been issued. Risk supply chain management due to macro risks such as natural disasters has to subdivide into two groups: Proactive and reactive supply chain risk management. This concept supports the strategic, tactical and operational level of companies in their decision and their activities before and after an occurrence of natural disaster. The analytical network process shows that the type of natural disasters is not inherent but if the natural disaster can be categorized in sudden or slow onset.

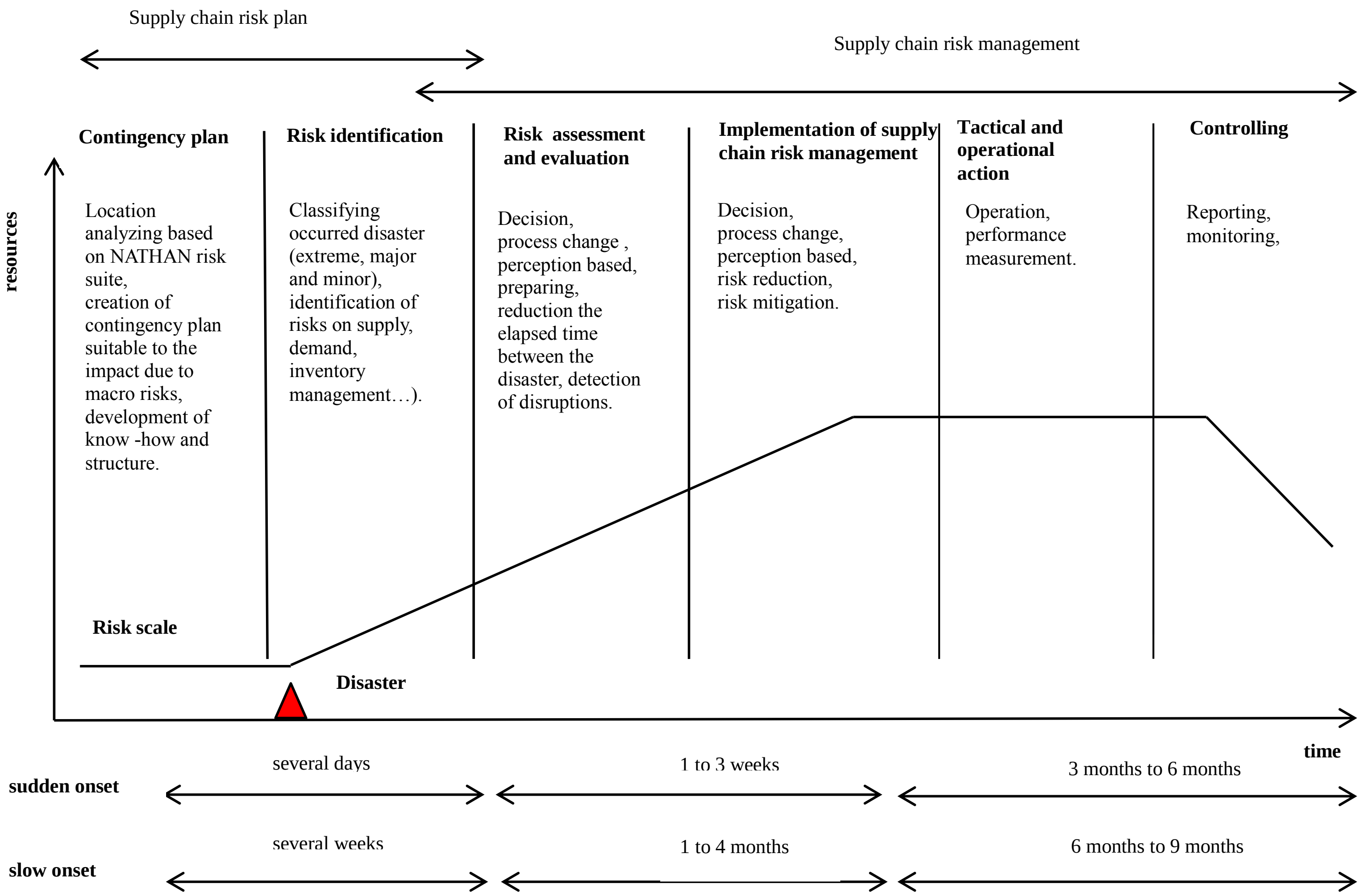



**Figure 7: Supply chain risk management process**

Taking action in such case is dependent. Exemplary slow onset disaster can be drought, till the disaster break out the management of companies has more time to take action and to analyse their location, supplier relationship, contract, process inventory, and demand management than when flood or earthquake break out, they have to act fast and they should have a more detailed contingency plan. Furthermore not all risk factors shown in figure 5 are essential and concern macro risks such as natural disasters. Summarized this concept highlight that slow onset disasters require a proactive supply chain risk management and sudden onset disasters require more reactive supply chain risk management because missing resources such as time, employees and money.

## 5. Conclusion and Future Development

This research contribution showed that improved risk assessment and measurement instruments are needed and feasible for a future professional supply management. As risk especially from global disasters increase, agility and flexibility of supply chains have to increase too, and research can contribute especially in the measurement and information management part regarding supply chain risks.

Furthermore the presented research results show a method as well as a process blueprint for supply chain risk management systems in global corporations. With the example of natural disasters outlined, this can be transferred to other risk areas (political, economic, geographical) and therefore be useful beyond the actually presented specific risk assessments.

Further research has to establish for example how feasible the presented draft weightings (ANP) are and if a larger group of experts may sustain these distributions for global business practice. Therefore many researchers on different continents are urged to check and enlarge these results in order to provide a broad basis for further discussions and business practice implementation.

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