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Impacts of extreme weather in supply chains

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Abstract—There are many phenomena which confirm the fact of climate change. Two kinds of responses are mentioned often to this fact: 1. Actions by which this process can be interrupted or slowed down. 2. Accepting the fact of changes and finding adaptive strategies.

Authors present a research which aimed to increase the responsiveness of supply chains for the climate change – especially extreme weather. Secondary and primary investigation were carried out, and the nominal group technique was used to discover, group and assess the potential threats.

Results so far pointed out that both physical and control processes are involved in extreme whether consequences. Findings give good bases for a substantial risk analysis for any disaster coming from the climate change or other reasons.

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Key-words: Climate change, disaster management in supply chains, extreme weather.

1. Introduction

Extreme weather event might cause wide range of problems in everyday life. While there is a debate on the fact of climate change (*Nordhaus*, 2013) and its possible source, there is no doubt that being ready for unexpected weather evens is not a bad decision. There are studies which deal with the source and implications of extreme weather.

Stott et al. (2004), in their pioneering study, concluded that human influence more than doubled the likelihood of the heat wave occurring. An

OECD study (*Agrawala et al*., 2011) discovered that while companies are generally aware of the physical implications of climate change, few include it into their risk management system.

From this point of view, there are two possible strategies:

1. To reduce the climate change effects – mostly emission – in order to slow down or to turn back the negative trend. We have to be aware that outcomes of corrective and preventive actions will show up in middle or long time horizon.

2. To learn to live with climate change at least on middle range and to do our best to adapt to the situation.

Weather sensitive sectors such as agriculture, horticulture, food industries are involved mostly. *Thorpe* and *Fennel* (2012) present three case studies from coffee, cotton, and sesame oil business. Since supply is vital in wide area of society and life, it is important to examine the implications of climate change. The effects can have influence in direct and indirect ways.

Present youngsters are the most involved in the consequences of climate change. In the State of the Union speech, President Obama urged Congress "to get together, pursue a bipartisan, market-based solution to climate change, like the one John McCain and Joe Lieberman worked on together a few years ago." In his second inauguration speech (January, 2013), the president said: "We will respond to the threat of climate change, knowing that failure to do so would betray our children and future generations. Some may still deny the overwhelming judgment of science, but none can avoid the devastating impact of raging fires, and crippling drought, and more powerful storms."

The topic is especially relevant in Hungary, since we faced some extreme weather events recently, such as extreme temperature, excessive rainfall, flooding, and spring snowstorms.

Recognizing this and the fact that certain aspects of climate change issues are inevitable, University of Pannonia defined a project to carry out research on consequences of climate change, especially weather phenomena issues. Economics, agriculture, engineering, and social science researchers work in the project supported by the EU and the Hungarian government.

Inside economics, the main analyzed areas are: macroeconomics, regional development, tourism, health sector, and supply chains. Part of the research is a literature review, such as we introduced above. The other part is primary research, in first stage mostly forecast.

First we tried to discover a wide set of implications. The method we have used is the nominal group technique.

In our research we asked master level students – who are in supply chain related programs – about their judgments on the possible consequences of climate change, especially extreme weather.

2. Literature review

The main research question was to learn the opinion of next generation about weather change implications in supply chains.

According to *International Energy Agency* (2013), it is possible that global warming will be more than two degrees Celsius. Above this limit the climate could become unstable. This will affect production and transport processes as well. *Carey* (2011) suggests that extreme weather events have become more common in recent years.

Czifra, et al. (2013) argue that climate change affects competitiveness.

According to IPCC's annual report (*Trenberth*, 1999), Hungary is acutely vulnerable. Based on this forecast climate change will turn the weather towards extreme events. The temperature will be higher than it is now, and we can expect stormy winters with more fall (*Czifra, et al.*, 2013).

In Hungary one of the main supply related implications will be the deterioration of transport infrastructure. Extreme weather phenomena such as storm, flooding, high temperature, lots of fall will cause damages in transport infrastructure. *Hunyadi* (2010) gives examples for possible damages of road infrastructure. *Gáspár* (2003, 2004) has set up road durability requirements. He suggests that the requirement pyramid (*Fig. 1*) will change in the future as a respond to climate change.

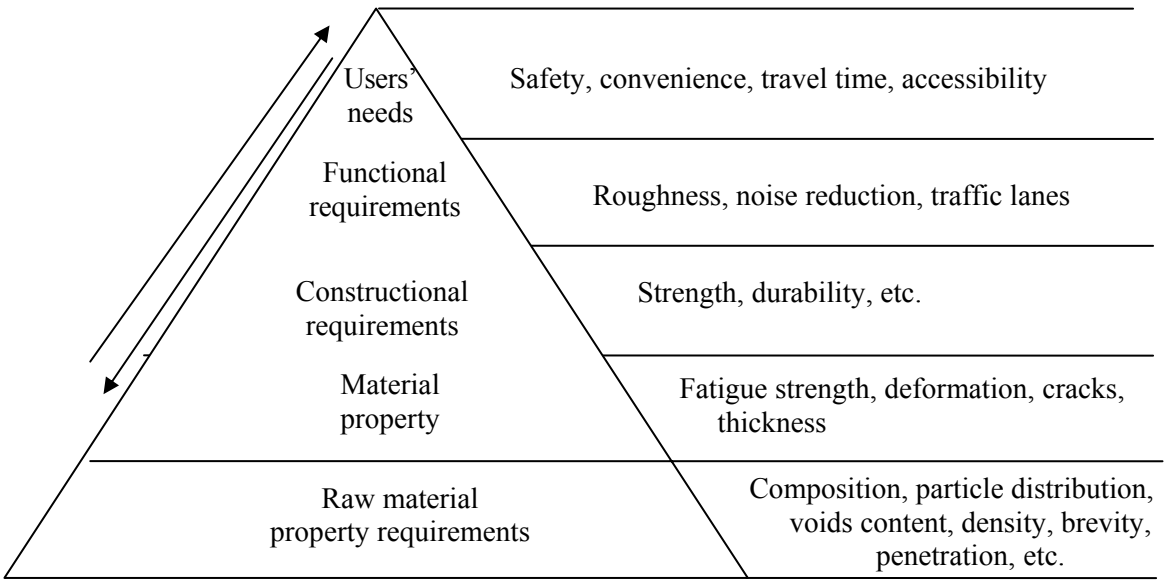

Fig. 1. Surface performance requirement related pyramid of requirements (*Gáspár*, 2003)

Hunyadi (2010) argues planting vegetation near the roads which have larger tolerance limits, in order to take consideration the effects of climate change in advance. *Gáspár* (2003) suggests life cycle design:"life cycle design includes both design methods and their phases which take into consideration economic issues, cultural integration and ecological aspects".

In addition to the environmental impacts on supply chains, there is an other important factor: restructuring of customer needs. Production infrastructure and distribution networks have to adjust to them (*Czifra et al*, 2013).

Caldwell et al. (2013) and others (*Thrope* and *Fennel*, 2012) examined the potential impacts of climate change to freight transport. *Table 1* summarizes the direct and indirect effects of meteorological factors on terrestial traffic safety.

Jüttner et al. (2003) give an overview of the potential research areas.

Table 1. Effects of weather on surface traffic safety (*Vissy* and *Bátyi*, 1998)

Surface conditions (road, rail)	**Direct effects**		**Indirect effects**	
	Visibility	**Loading**	**Biometeorological effects (front effects)**	
Snowing	Fog	Wind	Accident prevention	Health and safety
Snowdrift	Heavy rainfall	Heavy rainfall		
Temperature				

There are relatively small number of researches on the opinion of the future generation, however, *Revesz* and *Shahabian* (2010) evaluate opportunities for intergenerational discounting, which are often conflated in the literature. They have found that the existing justifications do not support the prevalent approach of discounting benefits to future generations at the rate of return in financial markets and, more generally, that discounting cannot substitute for a moral theory setting forth our obligations to future generations.

3. Research methodology and results

As previous studies from literature show, implications of climate changes include wide areas of supply chains. We can say that the whole society is involved in the climate change, partly due to the effects in supply chains. There are different ways to discover opinions on the topic.

Zaltman et al. (1982) and *Yin* (1994) used discovery oriented, practitioner-based approach, with semi-structured interviews.

The nominal group technique (NGT) is a group-based problem solving or decision making method (*Delbecq* and *VandeVen*, 1971, 1975; *VandeVen* and *Delbecq*, 1974). It combines the amenities of the un/low structured brainstorming and formal voting. We have followed the next steps:

1. Introduction and explanation: We welcomed the participants, who were master students in logistics, management, MBA and industrial engineering. We provided the question in written form on the top of an A4 format page: *What are the impacts of extreme weather to the operation of supply chains?* We have raised participants' attention to the importance of the question.

2. Silent generation of ideas: We asked participants to put down possible answers to the paper. Since any interaction is prohibited, in this phase we asked them not to consult or discuss their ideas with others. This stage lasted 10 minutes. In this stage, we repressed not only negative but useful positive interactions also. We allowed them in next steps.

3. Sharing ideas: We invited participants to read their ideas they have written on the paper. If they ran out of idea, they could 'pass'. If they have new idea – generated by others – they can join again. They can further develop others' ideas. We recorded each idea into a spreadsheet using the same words as participants formulated their ideas. (They were asked to use not more than 3 words to compose their idea.)

   The round robin process continued until all ideas have been presented. Since this phase supports only positive interaction, they could hear each other but were not allowed to comment others' ideas.

4. Discussion: Participants were invited to seek verbal explanation or further details about any of the ideas that others have produced that may not be clear to them. Anybody could ask, comment, interpret, explain any ideas on the screen. New ideas were generated, others were combined, extended or deleted (when they are proved to be equal with others: they called duplicates). There are two dangers in this stage (based on our more than 30 years NGT experiences):

   — Drawing together ideas might result so-called 'super idea' which will get lots of votes but is not concrete at all, thus, it can not be made real. Sometimes 'super idea' and some of its parts exist simultaneously.

   — There will be similar good ideas, which will compete again each other and share votes. In this way, each of them gets little weight and will drop out.

   It is important for the facilitator to keep good balance in the weight of ideas. Such aspects are complexity, extent, related hierarchy level of ideas. In this stage, we have received the list of possible effects in *Table 2*.

Table 2. List of potential effects after group discussion

1	Product damage
2	Communication problems in the EDI
3	Damage of factories
4	Routes are cancelled
5	Extreme work conditions
6	Other modal transport are forced
7	Cost, time, and resource losses
8	Low water-sailing ban
9	Increased preparations in the case of FMCG products
10	Huge storm - closed airports
11	Increased transport (supply) uncertainty
12	Additional storage costs
13	Appreciation of reliability models due to increased uncertainty
14	Increased number of risk factors
15	Increased costs of mining, excavating raw materials
16	Increased transport time requirement
17	Companies that fall out of the supply chains
18	Electric grid dropouts complicate storing
19	Necessity of work reorganization
20	Increased mental and physical load of labour
21	Higher vulnerability of electronic products, lower humidity during winter
22	Loss of goodwill due to delays and damages
23	Lack of agricultural products
24	Physical delivery becomes impossible
25	Difficult traffic conditions due to flooding
26	Development of resistant packaging
27	Railway comes to the fore
28	Coming out supply chain issues
29	Profile change is necessary (products)
30	Maintaining higher inventory
31	Accidents
32	Maintaining crisis staff
33	Alternative supply seeking
34	Further company social responsibilities
35	More pressure on co-operation, collaboration
36	Earthquake abyss engulfes the company
37	Daily 8-hour work period may be fragmented
38	Increasing number of non-forecasted transport errors
39	Closer relocation of supply chain players
40	Introduction of stricter limitations
41	Establishing specialized warehouses
42	Conflicts between partners
43	Consumer needs can not be satisfied
44	Material flow slows
45	More dense distribution points, necessity for warehouses
46	Shutdown due to state of emergency
47	Appreciation of taking out insurance
48	Good condition tires can not be calculated
49	Market rankings change
50	Development of vehicles
51	Needs assessment difficulties
52	IT equipment damage
53	Stress
54	Longer delivery lead times
55	Shipments over Arctic can not be solved
56	Decentralized inventory management
57	Necessity of rationalization
58	Increased energy consumption
59	Appreciation of meteorological information
60	Weakening of political stability
61	Growing importance of forecasts
62	Obstruction in mining
63	Rails freezing
64	Shifted seasonality
65	Appreciation of products with longer warranty period
66	Chain problems accumulate
67	Increasing weight of security/safety technology
68	Need for special storage conditions
69	Changes in priorities within the company
70	Co-operation with the army
71	Importance of loading and fastening technology
72	Rail deformation

5. Ranking: In this session there were little, spontaneous and informal interaction between participants. They were busy with their voting papers and selecting the most preferred ideas.
   First they were asked to select the 5 most important effects from the list of 72. Then they ranked them. The ranking order was: 1 – 5 – 2 – 4 – 3 where 5 was the grade of the most important, 1 is the grade of least important one.
   Finally, the grade points were summarized for all effects in the list of 72 ideas. *Table 3* shows the final ranks of the effects.
   Then we summarized the grade points.

Table 3. The final ranks

Rank	Potential effects	Score
1.	Increased transport (supply) uncertainty	22
2.	Cost, time and resource losses	21
3.	Routes are cancelled	15
4.	Damage of factories	12
5.	Accidents	11
6-7.	Appreciation of reliability models due to increased uncertainty	10
6-7.	Maintaining crisis staff	10

4. Conclusions

Looking at the list we can conclude, that students have a realistic judgment on possible consequences of climate change, especially effects of extreme weather. It is especially important in Hungary where the frequency of extreme weather events is increasing, however, to put it cynically, they are tending to become not extreme ones.

We did not asked the participants about the ‘to do’s, it will be the part of further research. Based on their case studies *Thorpe* and *Fennel* (2012), using an EOCD study, suggest five possible actions:

1. Raise awareness and understanding of adaptation within the business: companies need to make more effort to understand and evaluate the potential physical impacts.

2. Ask producers about current climate trends and impacts: talking to producers directly, risks must be assessed.

3. Build longer-term and more stable relationships with suppliers: where markets are more stable, producers are empowered to invest for the future.

4. Support community development and environmental sustainability: climate resilient products, technologies, new forms of organizations and co-operations, managing social issues, new markets need to be supported.

5. Work through existing institutions, including governments.

Our other researches on modeling the implications (*Kovács et al*., 2014) confirm this complex approach.

We are planning to get further information from the national disaster management system. This research will include the evaluation of extreme weather related cases such as snowstorm and flooding.

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