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Global Climate Change & Maritime Logistics

Rainer Müller[a]*, Matthias Dreyer[b], Esther Hoffmann[c],
Patrick Schöpflin[c], Nils Meyer-Larsen[b]

[a]*ISL Institute of Shipping Economics and Logistics, Universitätsallee 11-13, 28359 Bremen, Germany*
[a]*ISL Institute of Shipping Economics and Logistics, Barkhausenstrasse 2, 27568 Bremerhaven, Germany*
[a]*IÖW Institute for Ecological Economy Research, Potsdamer Str. 105, 10785 Berlin, Germany*

Abstract

The global climate change already has adverse effects on maritime intermodal door-2-door supply chains. Extreme weather events, like heavy rainfall, inland river floods and heatwaves already have direct effects on the maritime industry in the Federal State of Bremen in Germany. Besides these direct effects, an event, which happens upstream in the global supply chain, can lead to indirect consequences for Bremen. Besides these extreme weather events, which already occur, also the long-term effects of global climate change – such as sea-level rise, temperature rise, changes in precipitation patterns, and the increase in the frequency and intensity of these extreme weather events – have to be analysed for a proper supply chain risk management. This paper gives insight into the current situation on supply chain risks caused by global climate change. These results were retrieved from interviews and one workshop with participants in the maritime logistics domain.

Keywords: Supply chain risk management, maritime logistics, global climate change, extreme weather events

* Corresponding author. Tel.: +49 471 30 98 38-65;
E-mail address: rmueller@isl.org

1. Introduction

The port of Bremerhaven is the second largest port in Germany and belongs to the Federal State of Bremen. Global climate change affects Bremen directly and indirectly. Extreme weather events, like heavy rainfall, inland river floods and heatwaves already have direct effects on the maritime industry in Bremen. Besides these direct effects, an event, which occurs upstream in the global supply chain, can lead to indirect consequences for Bremen, situated at the end of the chain. For instance, in 2017, the most imported good in Bremerhaven was coffee, which is imported mainly from Brazil, Vietnam and Honduras. According to the Notre Dame Global Adaptation Index (ND-GAIN) that presents the vulnerability of countries to climate change Vietnam and Honduras are among the endangered countries in terms of climate change impacts (Chen (2015)). Thus, disturbances at the source could affect the import flows to Bremen.
Besides these extreme weather events, which already affect maritime logistics, also the long-term effects of the global climate change have to be considered (Rupik and Samui (2018)). In detail, increase in the frequency and intensity of extreme weather events as well as the impacts of sea-level rise plus the change of precipitation and temperature have to be analysed for a proper supply chain risk management. Therefore, in 2017 the project "BREsilient – Resilient Future City of Bremen" was started to increase the resilience against the impact of global climate change (BREsilient (2019)). One of the work packages aims at the development of adaptation measures against these impacts for the maritime logistics domain. As a first step, this paper gives insight into the current situation on supply chain risks caused by global climate change. These results were retrieved from literature review as well as interviews with different companies of the maritime logistics domain.

2. Methodology

To analyse risks caused by extreme weather events as well as long-term effects of global climate change, the following methodology was defined. First, a literature review for the field of extreme weather events and global climate change in maritime logistics was carried out. Secondly, import trade flows to the port of Bremen and Bremerhaven were analysed to identify imported goods that are endangered by climate change. Later, a questionnaire for a semi-structured interview was created featuring experiences of extreme weather events and expectations for climate change until 2050. Next, different interviewees were identified to cover (i) different parts of logistics in Bremen/Bremerhaven and (ii) importers and companies importing and processing vulnerable goods. Next, the interviews were carried out, and the statements were analysed. Finally, a workshop has been carried out to assess the risks behind the events identified in the interviews.

3. Literature review

Kovács and Pató (2014) describe two main strategies to tackle global climate change. First, to reduce the harmful trend emissions have to be reduced. The outcome of this strategy would materialize in the middle or long time horizon. Second, corresponding adaption measures have to be developed to deal with the effects of climate change on the middle range. McKinnon and Kreie (2010) conclude that the response to climate change must be 'twin-pronged'. Besides the implementation of mitigation measures also adaption measures to a warmer climate have to be implemented. This paper focuses on the identification and analysis of the effects of global climate change. Consequently, it offers a basis for the development of adaption measures.

Supply chain disruptions can have a significant impact on the value creation of companies. In a survey of 550 companies in over 60 countries on the resilience of supply chains conducted by the Business Continuity Institute in 2011, productivity loss was the most frequently mentioned consequence of supply chain disruptions (49%), followed by increased labour costs (38%). In third place of the most frequently cited were loss of profits, complaints from customers and service disruption with 32% each (Business Continuity Institute (2011)). The most commonly mentioned reason for those supply chain disruptions are adverse weather events (51%) (Business Continuity Institute (2011)). According to Munich Re (2018), which has been researching natural hazard loss events for 40 years (NatCatService), the variability in the number of natural loss events between individual years is significant. However, the average trend curve of global natural catastrophes has risen by a factor of three in the last 35 years (Hoeppe (2016)). Weather-related events mainly cause the increase, as the number of earthquakes, tsunamis or volcanic eruptions has remained roughly the same (Hoeppe (2016)). Figure 1 shows the number of weather-related events from 1998 to 2017. Natural catastrophes caused by geophysical

changes such as tsunamis or earthquakes are not included in the figure.

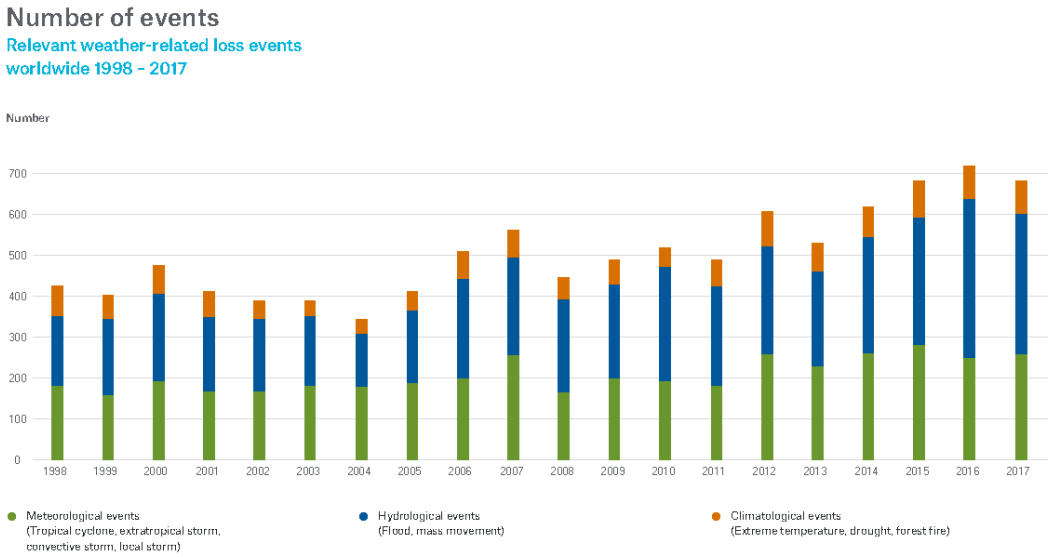

Fig. 1 Number of extreme weather events 1998-2017; Source: Munich Re (2018)

There are many examples of interruptions of supply chains due to weather-related events. For instance, Toyota had to interrupt production for 42 days in 2011, representing a loss of 37% of operating profit, due to a heavy flood in Thailand which affected Thai suppliers (Masahiko and Lall (2015)). Regarding the question of how German companies are generally influenced by climate change the Institute of German Business (IW Future Panel) conducted a survey among German companies in 2011. The study concluded that "German companies today are primarily not directly affected at home and abroad, i.e. by natural-physical climate impacts, but indirectly". Only 15% of the companies stated that they currently see themselves affected by direct negative consequences. Companies in the logistics sector have a higher perception of affectedness: 21% of logistics companies see themselves currently affected and for 2030 already 33% estimate that they will be directly negatively affected by climate change (Mahammad et. al (2013)). The authors concluded that considering direct and indirect impacts of climate change the logistics sector is the most negatively affected industry (Mahammad et. al (2013)).

For supply chains of imported goods, the vulnerability to climate change impacts of the country of origin influences the supply chain's overall vulnerability to a large degree. To measure the general vulnerability of countries to climate change impacts the use of indices is widely spread. ND-GAIN is an index that presents the vulnerability of countries to climate change. The index is published by Notre Dame University in the USA and has been published annually for 181 countries since 1995. The index consists of indicators for vulnerability and willingness to adapt to which we will only consider vulnerability due to the focus on climate change risks. For vulnerability, indicators on exposure, sensitivity and adaptive capacity are included for the sectors of water, food, health, habitat, ecosystems and infrastructure. The exposure indicators are forward-looking and reflect the projected change. The index uses the IPCC scenario RCP4.5 to calculate climate-related changes. This scenario assumes a temperature increase of 2.6°C by 2100 compared with the value of 1986-2005 (Chen (2015)).

In terms of import value, the most important import products for Bremen are foodstuffs and processed industrial goods such as motor vehicle and aircraft parts (DeStatis, Statistisches Bundesamt (2017)). With 10,000 employees and over 250 companies, the food and stimulant industry is the second most important employer in the manufacturing industry of Bremen and thus of high importance for the city. In particular, the product groups of coffee, fish & seafood and fruit & vegetables are imported into Bremen in large quantities. Some of them come from climate-vulnerable countries (cf. Table 1).

Table 1. Vulnerability to climate change of import goods to Bremen

Vulnerability: high / medium to high / low to medium / low

Product group (Import value)	Exporting country	Import value Bremen (in 1,000 €)	Ranking ND-GAIN
Coffee (1.3 bil. €)	Brazil	401.317	54
	Vietnam	179.285	119
	Honduras	120.222	113
	Colombia	73.361	61
	Ethiopia	71.072	159
Fish & seafood (740 mio. €)	Norway	116.202	2
	China	109.257	66
	USA	90.799	22
	Denmark	80.782	25
	Poland	52.671	16
Fruit & vegetables (350 mio. €)	Costa Rica	83.560	66
	Turkey	44.364	21
	Colombia	34.980	61
	Netherlands	29.667	32
	France	22.725	6

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4. Impact of Global Climate Change on Maritime Logistics

In this chapter, the results of the interviews which were enhanced by a workshop are presented. In total, 12 interviews were carried out. Questions of the semi-structured interview covered the following topics:

- Type of extreme weather events which already occurred
- Impact of these events on operations
- Expectations on the global climate change for 2050 and its impact

The results of the interviews were presented and analysed on a workshop. During the workshop, a working group with 20 participants focused mainly on the maritime logistics domain and analysed the results of the interviews. The goal of the discussion group was to (i) identify further events and (ii) to assess the probability and consequences of the events.

4.1. Type of extreme weather events

Figure 2 shows the number of interviewees who were already affected by which type of extreme weather event. Besides it also shows the usual duration of such an interruption in operation caused by such an event.

Storm and heatwave were mentioned often, and the impact of such an event is quite long on operations. Also, heavy rain and salt spray were reported quite often.

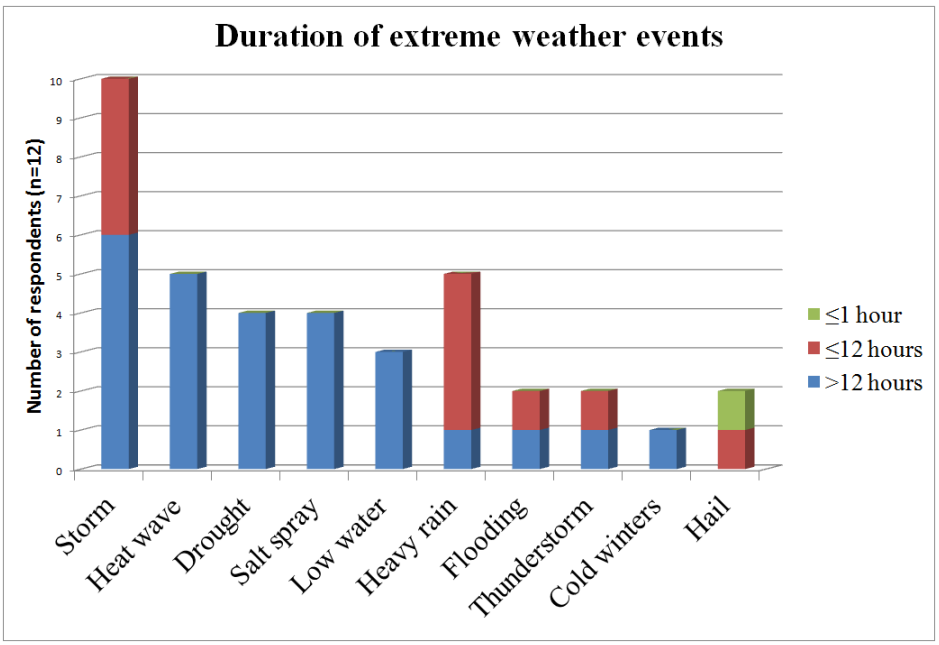

Fig. 2 Duration of effects by extreme weather event

4.2. Impact of extreme weather events on operation

Figure 3 shows the effects of extreme events that respondents have already experienced. Most interviewees experienced transport delays which were caused by the non-usability of transport routes. Also damaged company's infrastructure, damaged buildings and damaged vehicles were often reported. In addition, overloading of the sewer system due to heavy rainfall and unbearable heat at the workplace were mentioned.

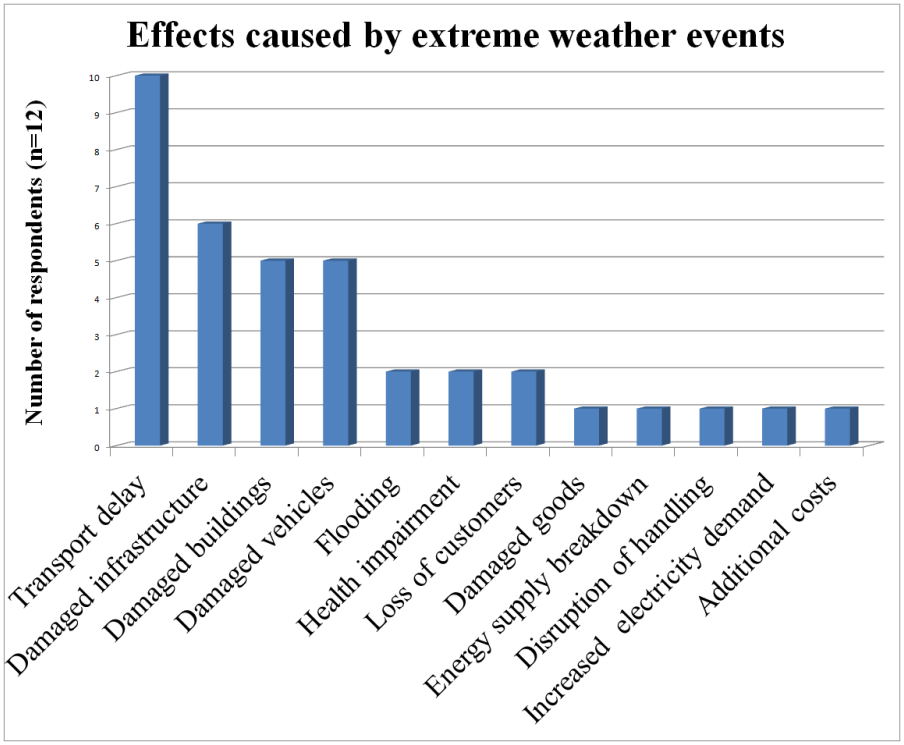

Fig. 3 Effects caused by extreme weather events

In the following section, the most important findings on experienced extreme weather events from the interviews and the workshop are clustered according to different sectors in the maritime industry:

4.2.1. Ports and vessels

During heatwaves, the cabins of straddle carriers can be unbearably hot, which can lead to health impairment of the drivers. Heat could also weaken the asphalt on the port's premises, especially near buildings.
Strong winds in combination with high tides, can hinder port operations. During heavy storms, the port captain has to stop services in the whole port. Moreover, vessels can be delayed due to adverse weather conditions.
In the field of port infrastructure, it was reported that bad weather conditions could delay construction processes.
For automobile terminals, it was reported that flooding and hail can lead to damaged vehicles.

4.2.2. Inland waterway transport

The river Rhine is often affected by low waters. Consequently, depending on the draft, some vessels cannot sail and shipping lines have higher costs for alternative transports. Besides low waters in summer also high water levels in spring hamper this transport mode.

4.2.3. Rail transport

With roughly 700 arrivals and departures per week, the port of Bremerhaven heavily relies on its rail connection. Any disturbances of this mode of transport can lead to significant problems in port operations. In the past, rail services were disrupted by trees and branches fallen on overhead wiring. Also, bush fire can lead to severe disruptions. Also, heat could lead to track distortions.
Salt spray is another incident which is unique for the region: Due to a storm on the sea, seawater is swirled up, taken by the wind and the salt covers insulators of the overhead wiring. Severe interruptions in rail services are the consequences. In 2018, the rail service between Bremen and Bremerhaven was cancelled for several days due to salt spray.
Health impairment due to heat is a problem which primarily affects shunters. Another aspect is maintenance on tracks, which has to stop at temperatures of 56°C of the tracks. Also, welding is forbidden if there is a risk of fire. These restrictions can hinder maintenance and can have an impact on operations. Due to these incidents, some customers already switched to other transports modes to avoid delays and cancellations.
Also, extreme weather events which took place in neighbour countries can have an indirect impact on the port of Bremerhaven. Trains are delayed or do not arrive at the port at all.

4.2.4. Road transport

In 2018 the highway between Bremen and Bremerhaven was temporarily closed because of a sandstorm. Roads could be damaged due to blow-ups which can occur during heatwaves. Strong winds on bridges can lead to restrictions on the usage. Storms can lead to fallen trees on roads leading to road closures. Another incident type is caused by heavy rainfall, which can lead to flooded streets and damaged infrastructures.

4.2.5. Manufacturing and warehousing

Storms in South- or West-Germany can lead to shortages in resources for production in Bremen. As a result, the stop of production is a possible consequence, especially for just-in-time processes. Manufacturing processes can also be affected directly: Lacquer processes cannot be carried out in more extended periods with high temperatures and low humidity. In the field of warehousing, it was reported that high temperatures for more extended periods could hamper the cooling process in cold stores.

4.3. Expectations on the global climate change until 2050

Most respondents expect an increase in the number of different event types until 2050. The interviewees expect especially an increase in storm and heatwave events. According to the respondents also drought, heavy rain and hail are event types which are expected to occur more often in future. The interviewees also mentioned that they assume that the sea level will rise which would also harm the maritime logistics domain.

4.4. Risk assessment

During the working group in the workshop, the participants had to assess the probability and consequences of all effects generated by extreme weather events. In the assessment, it can be seen that the evaluation of the participants shows a low degree of dispersion and that hardly any outliers were set. Figure 4 presents the findings of the assessment of the working group. When analysing the results, it became obvious that the effects "Inland waterway transport: Restriction (High/low water)", "Railway: Line closure (Fallen trees, storm / bush fire)" and "Container terminal: Interruption of handling (Storm)" were assessed with an increased risk. The effect "Unbearable heat at workplace" has the highest probability. The effect with the highest damage is "Inland waterway transport: Restriction (High/low water)". Furthermore, it was found that all effects based on the event "heat" were also assessed with a relatively high risk.

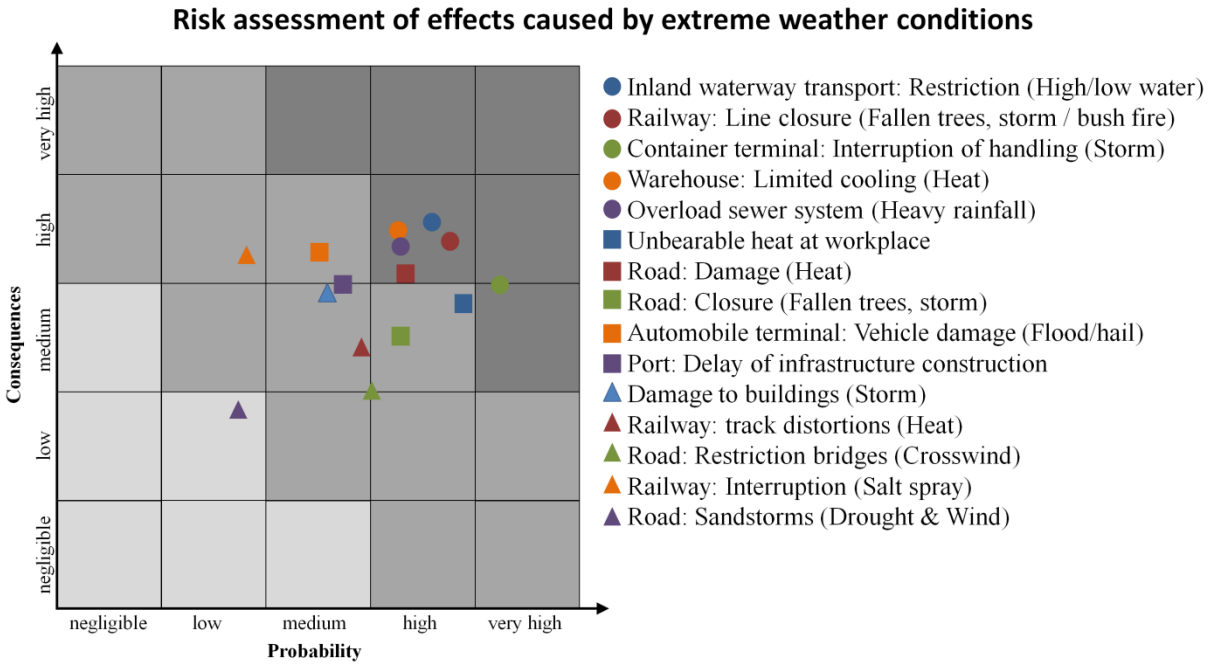

Fig. 4 Risk assessment of effects caused by extreme weather conditions

5. Adaption measures

Corresponding adaption measures have to be developed and implemented, to cope with the effects of global climate change. The described findings in 4.2 and especial the assessment in 4.4 offers a sound basis for a proper prioritization of risks which should be mitigated. The development of such adaption measures is not the scope of this paper. However, for the development process of adaption measures, possible adverse effects of these measures have to be taken into account. For example, to reduce the probability of fallen trees on overhead wiring and tracks, tree-free zones could be established. On the one hand, a tree-free zone would lower the likelihood of fallen trees. On the other hand, increased vulnerability to heat and temperature could be an adverse consequence of this measure (Lindgren et al. (2009)).
Also, first adaption measures have been identified during the workshop like emergency plans and the creation of networks to increase the resilience of the supply chain.
Future research should be carried out to develop proper adaption measures to cope with the effects of global climate change.

6. Conclusion

Insights into the current situation on supply chain risks caused by global climate change are presented in this paper. The effects of extreme weather events on different sectors of the maritime logistics are described. Also, first insights on the long term effects of global climate change are discussed. The overall results clearly show

that the global climate change already has negative impacts on maritime logistics. The results from this paper indicate which risks in this domain have to be tackled for a proper supply chain risk management.
Experiences of practitioners in the field of extreme weather events and global climate change and their consequences on maritime logistics are presented. Existing research in the field of the assessment of the impact of global climate change on maritime logistics is quite limited. This paper helps to close a gap in an area with limited existing research and also indicates space for future research tasks. First insights on the risks, effects and expectations regarding the development until 2050 in this domain are given. However, the mitigation of these risks is not addressed in this paper in detail. Consequently, future research should focus on the development of adaption measures to cope with the effects of this risk type.

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