Extreme weather impacts on European networks of transport
Grant Nr 233919
Co-funded by the European Commission under the 7th Framework Programme, Transport, Horizontal activities

D4.4 (working memo):
Costs and consequences of extreme weather on European freight and logistics industries and supply chains

Project: EWENT
Document Number and Title: D4.4 (working memo): Costs and consequences of extreme weather on European freight and logistics industries and supply chains
Work-Package: WP4
Deliverable Type: Working memo
Contractual Date of Delivery: M15
Actual Date of Delivery: M28
Author/Responsible(s): Johanna Ludvigsen and Ronny Klæboe, TÖI
Contributors: VTT: Marko Nokkala, Anna-Maija Hietajärvi, Pekka Leviäkangas and Kalle Oiva
CYMET: Spyros Athanasatos, Silas Michaelides and Matheos Papadakis

Approval of this report: By the consortium
Summary of this report: EWENT, WP4, extreme weather, freight, logistics, road, rail, maritime, inland waterways, transport system, EU
Keyword List: EWENT, WP4, extreme weather, freight, logistics, road, rail, maritime, inland waterways, transport system, EU
Dissemination level: Public
## Version history

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Status</th>
<th>Author (Partner)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>09.05.2011</td>
<td>1st draft</td>
<td>Marko Nokkala (VTT)</td>
<td>Outline</td>
</tr>
<tr>
<td>0.2</td>
<td>13.05.2011</td>
<td>2nd draft</td>
<td>Marko Nokkala (VTT)</td>
<td>Outline proposal</td>
</tr>
<tr>
<td>0.3</td>
<td>30.05.2011</td>
<td>3rd draft</td>
<td>Johanna Ludvigsen (TÖI)</td>
<td>Content inputs: literature review, case studies and international survey reports, modelling of weather-induced flow breakdowns and vehicle travel diversions due to landslide and inundation of underground tunnel in Norway, and modelling of monetary costs and odds for freight train delays attributed to bad weather on Finnish network during 2008-2010.</td>
</tr>
<tr>
<td>0.4</td>
<td>30.11.2011</td>
<td>4th draft</td>
<td>Johanna Ludvigsen (TÖI)</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>14.12.2011</td>
<td>5th draft</td>
<td>Johanna Ludvigsen and Ronny Klæboe (TÖI)</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>29.3.-2.4. 2011</td>
<td>Final draft</td>
<td>Pekka Leviäkangas, Anna-Maija Hietajärvi and Kalle Oiva (VTT) Spyros Athanasatos (CY-MET)</td>
<td>Editorial work, sum-up, Finnish survey details, Limassol port case</td>
</tr>
</tbody>
</table>
Distribution list

European Commission Ioana-Olga Adamescu
EWENT partners E-mail list
EWENT Consultative Board E-mail list
Website http://ewent.vtt.fi
VR-Group Ltd

“Interested parties”

This publication has been produced with the assistance of the European Union. The contents of this publication are the sole responsibility of EWENT Consortium and can in no way be taken to reflect the views of the European Union.

Special thanks are extended to VR Group for data provision
Abstract

Results from Deliverable 4.4 indicate a high level of vulnerability that transport operators, logistics suppliers, shippers and consignors are exposed to due to weather hazards and these adversities’ negative consequences on companies’ level of service, equipment functionality, costs of operations and costs of cargo dispatch. In addition, it was also empirically established that industrial firms in many countries suffered severe and prolonged economic damage in the aftermath of natural disasters. The same pertained to supply chains, especially those spanning over several country territories, and/or continents. Generally, ruptures in supply chain operations attributed to bad weather and/or natural disasters were harmful for all collaborating parties. Yet, the magnitude of damage depended on where in the supply chain structure a given company was located, and also, how the target supply chain was organised. On few occasions, supply chain disruptions could even render advantages to some firms, when the ensuing shortage of materials and goods increased the demand for their products and/or service. Besides, many companies interviewed, especially in rail freight business suffered from reputation damage and loss of customer trust which jeopardised the long-term business prospects.

It has also been established that many of the companies affected were not adequately prepared to avert and/or neutralise the negative weather impacts. The analysis of measures used to contain the scope of adversity revealed that the affected parties improvised their way out of crisis rather than drawing on a priori preparedness assets and/or rehearsed risk management skills. Results from an international survey of how the companies in transport, logistics and infrastructure provision sectors dealt with repercussions of extreme weather over the last five years has also disclosed that business people did not have a good grasp of linkages between the probability of these events and the risks of business damage. Only very few respondents run catalogues over the risk categories they have recently encountered and/or registered additional expenses due to weather-related harms. Therefore, they could not perform the risk tolerance appraisal and take decisions on which risk prevention and/or mitigation strategies to employ. Even when companies recognised the need for commensurable proactive actions to mitigate the weather hazards, still the resources apportioned to this goal were meagre. Generally, keeping reserves in the form of standby manpower, buffer stocks and/or idle equipment was considered unwise. On the contrary, many vital business operations (such as maintenance) were outsourced while rolling stock leased from banks and/or equipment renting companies on time-limited contracts. These business models were justified by the needs for lean production regime and removal of physical assets from the firms’ balance sheet. The negative consequence of these dispositions such as delayed responses and longer delivery times for critical components under emergency conditions have apparently not been factored in.

Analyses of interactions between bad weather conditions and punctuality of freight trains arrivals on Finnish network have established that cargo delivery tardiness during 2008-2010 was more frequent during the autumn and winter months, with higher tonnage of cargo delayed per freight train run and higher values of time lost due to weather-inflicted delivery lateness as compared to other seasons. 60% of delays in all delays registered in Finnish freight train traffic during the same period of time could be attributed to bad weather. Modelling of co-variation between weather and train delays disclosed that a combination of low temperature and heavy snowfalls pose significant threats to rail freight punctuality.
# Table of contents

1. Introduction ........................................................................................................... 8

2. Impacts of extreme weather on supply chains ..................................................... 10
   2.1. General overview ............................................................................................ 10
   2.2. Vulnerability of road freight transport .......................................................... 12
       2.2.1. Demand considerations ............................................................................. 12
       2.2.2. Supply side issues .................................................................................... 14
   2.3. Values of time for on-time arrivals and arrival tardiness in freight road transport .... 16
   2.4. Long-term impacts of transport disruptions on logistics channels ..................... 26
   2.5. Vulnerability of freight transport customers ................................................... 28

3. Preparedness - building in transport, logistics and manufacturing industries ........... 34
   3.1. Structuring the challenge .............................................................................. 34
   3.2. Managerial attitudes towards risks of natural hazards ..................................... 35

4. Case studies and an international survey .................................................................. 39
   4.1. Adverse weather impacts on road freight transport in Great Britain in 2010 .......... 39
   4.2. Vulnerability of rail freight operators to winter and flood disruptions ............... 41
   4.3. International survey of freight and logistics companies .................................... 47
   4.4. Port case: Limassol, Cyprus .......................................................................... 49
   4.5. Summary and conclusions on case studies and surveys .................................... 54

5. Modelling of weather-induced freight flow breakdowns ......................................... 57
   5.1. Applicability of values of time in freight transport to loss of supply chain robustness due to flow breakdown ................................................................. 57
   5.2. Simulation of flow breakdowns ....................................................................... 58
   5.3. Consequences of HGV traffic breakdowns .................................................... 59
   5.4. Assessing impacts of transport system meltdowns on HGV traffic – two simulations based on empirical cases ................................................................. 60
       5.4.1. Blockage of motorway connecting Sweden with Norway by a landslide ........ 60
       5.4.2. Oslo-fjord-tunnel shut-down accident ..................................................... 62
       5.4.3. Summary and conclusions on simulations ................................................ 64

6. Quantitative model: linkages between freight train delays and bad weather in Finland over 2008-2010 ........................................................................... 65
   6.1. Values of time lost and tonnage of rail goods delayed due to bad weather .......... 65
   6.2. Assessing proportion of weather-related train delays in all delays during 2008-2010 ................................................................. 68
   6.3. Modelling of linkages between train delays and weather indicators ................. 70
       6.3.1. Challenges When Analysing the Aggregate Data .................................... 70
       6.3.2. Data preparation: initial transformations ................................................ 71
       6.3.3. Odds for delays as a function of adverse weather conditions ................... 72
       6.3.4. Freight trains’ delays as a function of weather parameters ....................... 75
       6.3.5. Summary and conclusions on the Finnish rail freight modelling case .......... 78
List of Figures

Figure 1. Flow of goods and information within a traditional supply chain structure .......................... 26
Figure 2. Flow of goods and information within the vendor managed inventory supply chain... 27
Figure 3. Factors affecting the scope, the content and duration of extreme weather impacts on
transport, logistics and manufacturing companies, and chances of recovery................................. 34
Figure 4. Landslide location which blocked the Swedish motorway connection (E6) to Norway 61
Figure 5. Map of Oslo-fjor-tunnel connecting Vestfold and Østfold Counties in Norway .......... 63
Figure 6. Delayed freight train arrivals by monthly average temperatures in Finland 2008 - 2010
................................................................. 73
Figure 7. Delayed freight trains by month, Finland 2008-2010 ....................................................... 74

List of Tables

Table 1. Valuations of delay time, arrival time spread (VSP) and schedule delay (VSH)
expressed as pence per minute, end-2000 prices; t ratios in brackets................................. 19
Table 2. Values of time for goods transport in the Netherlands (€) ................................................. 21
Table 3. Values of time, on-time arrivals, arrival variability, values of delay and average weight
of shipments in domestic road transport in Norway in 2009...................................................... 22
Table 4. Values of time, on-time arrival, arrival variability and values of delay, and the average
shipment weights carried by own-account and third party hauliers in Norway .......................... 23
Table 5. Values of time, on-time arrival, arrival variability and delay assigned by third party
hauliers (stratified by operation types) ....................................................................................... 23
Table 6. Values of time, on-time arrival, arrival variability and values of delay, and the average
shipment weights carried by own-account hauliers in Norway (disaggregated by operation
types) ........................................................................................................................................... 24
Table 7. Values of time, on-time arrival, arrival variability and delays, and the average shipment
weights carried by third party hauliers in Norway; stratified by customer types ................. 24
Table 8. Values of time, on-time arrival, arrival variability, values of delays, and weights of
average shipment carried by three segments of third party hauliers in Norway (disaggregated
by service types) ......................................................................................................................... 25
Table 9. 2011 BDO risk-factors reported by technology businesses in the US ....................... 38
Table 10. Respondents in Survey on Extreme Weather Impacts (2011) ................................. 47
Table 11. Port of Limassol equipment inventory ........................................................................ 50
Table 12. Discomfort recorded for port of Limassol, 2009 ......................................................... 53
Table 13. Extreme weather events and their impact on loading and unloading of bulk cargo and
containers ........................................................................................................................................ 54
Table 14. Unit tonne values of commodities carried on Finnish rail network in 2008............ 67
Table 15. Values of time lost due to weather-related freight train delays in Finland for 2008-
2010, 1000 € ................................................................................................................................. 67
Table 16. Volume of cargo tonnes which arrived delayed due to bad weather in Finland,
 tonnes/train, 2008-2010 ............................................................................................................... 67
Table 17. Estimated parameters of univariate regression model explaining the proportion of freight train delays related to bad weather in occurrence of all delays ........................................ 69
Table 18. The goodness of fit for the univariate regression model ........................................... 70
Table 19. Estimated Parameters for a Regression Model Explaining the Log Odds for Freight Train Delays .................................................................................................................. 75
Table 20. Estimated parameters for a regression model explaining the duration of freight trains’ delays.......................................................................................................................... 76
Table 21. Estimated parameters of a regression model explaining the duration of train delays 77
Table 22. Estimated parameters for a regression model explaining the duration of train delays 77
1. Introduction

The EWENT project’s WP2 has estimated the likelihoods of frequency and magnitude that extreme weather phenomena may acquire in the long-term and affect future functioning of transport modes and transport infrastructure in climatically different European regions.

Deliverable D4.4 reviewed the state of knowledge on impacts that extreme weather imposed on freight transport suppliers, logistics operators, shippers and consignors in merchandising and manufacturing industries. By exploring the nature of harms that these parties experienced due to weather hazards and the negative impacts that these events exerted on the quality of service and operational robustness, this work identified several vulnerability areas, the needs for preparedness building and managerial skills for adversity management. Based on these inputs five empirical studies were carried out and results reported.

This deliverable is composed of six thematic segments with conclusions at the end. We open with a review of literature exploring the extreme weather impacts on supply chains operators followed by more specific research studies which have investigated and assessed:

1) Vulnerability of road freight transport to extreme weather-related flow breakdowns,
2) Values of time assigned by road hauliers, shippers and consignees to random variability in arrivals, delivery tardiness and travel time savings in different countries,
3) The long-term impacts of transport disruptions on operations of logistics channels, and
4) Vulnerability of freight transport customers to natural hazards and managerial requirements for preparedness against future disruptions, and
5) The traffic consequences of temporal decrease in road fluidity and/or blockage, and the different modes of motorists’ adaptations.

Subsequently, preparedness-building in freight transport, logistics and manufacturing industries is discussed followed by a review of managerial attitudes towards risks of natural disasters. Thirdly, several case studies are reported which illustrate how road hauliers in Great Britain and railway operators in continental Europe fought to re-establish the normal operations conditions after being struck by extremely harsh winter and flooding in 2010, and how these events affected the long-term business prospects of these parties.

The fourth segment summarises results from an international survey which assessed the types of damage that extreme weather brought upon the freight transport companies over the last five years, the ways the affected parties responded to these adversities and the needs for long-term preparedness-building.

The fifth section reports results from modelling of monetary impacts that two natural disasters, a landslide blockage of an important road artery connecting Sweden with Norway has imposed on heavy goods vehicles (HGV) travel over a three month period, and a closure of under-the-sea-road-tunnel caused by inundation that has brought about reassignment of HGV traffic to lateral roads and a ferry connection for reaching the Oslo city. The simulation used the national goods model as modelling platform and showed that increases in operations costs due to HGVs detouring over longer distances varied considerably depending on which adaptation strategy the road hauliers, logistics service providers and/or shippers have opted for.
Finally, the sixth section presents results from three statistical analyses. The first involved assessments of value of time lost and the tonnage of goods delayed in rail freight traffic due to bad weather in Finland during 2008-2010. The second reports results from modelling of a proportion of weather-related delays in all freight train delays registered in Finland for 2008-2010. The third reveals results from modelling of linkages between occurrences and duration of freight trains delays and bad weather events in Finland for 2008-2010.

The deliverable closes with conclusions and summing up the results.
2. Impacts of extreme weather on supply chains

2.1. General overview

Extreme weather events may threaten individual companies, their personnel, and collaborative arrangements such as supply chains. Managerial literature indicates that there is no one best way for overcoming negative impacts of these occurrences. One reason for that is that such events fall into high-impact/low probability risk category and therefore there is a scarcity of historical data needed for devising universally effective prevention, containment and mitigation tools. Another reason is that such low-frequency incidents are hard to predict and avert making it difficult to justify why resources should be devoted to proactively manage this type of risk. If a risk never materialises, the expenses incurred on risk assessment and management are hard to justify to company leadership and/or shareholders (Zsidisin et al. 2004).¹

Yet empirical evidence indicates that weather-induced disasters tend to occur more frequently and with an increase in the severity of damage. In relation thereto, the report on “Performance Measures for Freight Transportation” (Transportation Research Board 2011) clearly states that the above approach is reminiscent of “sub-optimisation” in managerial decision making where the focus is inordinately upon achieving narrow, easily and immediately justified sub-goals to the detriment of broader organisational objectives such as long-term operational continuity and resilience against unexpected risks.

In this connection a question arises: why some organisations cope far better than others with both the prospects and the impacts of weather-induced adversities?

The organisations in focus do not have a common secret formula or even many of the same processes for dealing with weather-generated risk, but share one critical trait: resilience. Conceptually resilience is an anti-thesis of vulnerability which Svensson (2002) defined as

“…unexpected deviations from the norm and their negative consequences”.

Mathematically vulnerability may be measured in terms of “risk”, a combination of a likelihood of an event and its potential severity (Sheffi. 2001; 2005). The notion of organisational resilience entails functional and structural preparedness. Functional resilience implies that a given functional entity is capable to efficiently and effectively deal with a range of adversities and recover from negative impacts by drawing on internal resources. On the other hand, structural resilience is an organisational ability to absorb and/or withstand external risks and/or perturbations thanks to built-in robustness without adjustments in the overall system function, adaptation or recovery (Bundschuh et al. 2003; Holmgren. 2007; Lai et al. 2002.

The first well known European study of supply chain disruption and the level of professional knowledge on supply chain vulnerabilities were carried out by Cranfield University in 2003. This investigation has established that 1) supply chains were quite vulnerable to weather-inflicted disruptions, 2) awareness of disruption threats was poor among supply chain managers, 3) little knowledge existed on damages the supply chain operations may suffer from weather disasters

¹ As Qiang et al. (2009) have shown in numerical modeling of changes in supply chain risk level invoked by transport disruptions, this statement indicates that manufacturers, retailers and transport carriers within a given supply network place zero weights on disruption risks (page 108).
in short-and-medium terms and, 4) the industry was lacking best practice for systematic reduction of supply chain risks generated by natural hazards.

In parallel with Cranfield University, researchers at the Massachusetts Institute of Technology and other academic institutions in the US investigated multiple cases of supply chain disruptions caused by natural disasters in order to assess how the different preparedness measures such as flexibility, redundancy, back-up and collaboration with strategic stakeholders helped managers to contain damage, recover losses and resume manufacturing and supply operations (Knemeyer et al. 2003; Rice and Caniato 2003; Shefi 2005).

One interesting finding that these studies uncovered was that despite usually negative short-term impacts, sometimes weather hazards have unlocked opportunities for success. Yet the type and the magnitude of positive consequences depended not only on duration of time that followed a given disruption but also on the topology and climatic conditions of the territory a given supply chain run through, the type of disaster and the level of target’s preparedness, and finally, which echelon the affected company occupied within a supply chain structure.

In relation thereto, Dacy and Kunreuther (1969) have shown that GDP often has increased in medium-term following the large-scale natural disasters due to re-building of losses of capital and durable goods (equipment, infrastructure and inventory). Also it has been established that higher frequencies of climatic disasters were correlated with higher rates of human capital accumulation, increases in total factor productivity and economic growth which came from reconstruction and re-placement of damaged property and assets (Toya and Skidmore 2002).

There is no doubt that supply chain disruptions are costly. Thus in order to prevent, mitigate and neutralise negative consequences of chain disruptions one needs to understand how an abrupt cessation of goods movement and/or stoppage of material flows may affect not only the focal transport operator but also other segments in supply chain structure (Hendriks and Shinghal 2005). This was demonstrated by Hurricane Katrina in 2005, which in addition to considerable human and material losses inflicted on American society, has also disrupted 10% -15% of gasoline supply within the entire country (Canadian Competition Bureau 2006). A more recent example is the earthquake in Japan which in March 2011 damaged several plants producing microchips and other electronic components for equipment manufacturers in the US and Taiwan. This contagion has spread to Europe causing transient shortages of smart phones, tablets and other high-tech consumer electronics (Financial Time of April 23rd 2011). As summarised by Shefi (2005) on page 74, one of the main characteristics of disruptions in large-scale supply networks is the “high-level transmission between vulnerabilities stemming from large systems’ inter-connectivity”.

---

2 According to HIS e-Supply Inventory Market Brief published on July 18th, 2011 semiconductor inventory levels at chip suppliers worldwide rose for the seventh consecutive month in a row in the second quarter of 2011, as the industry rebuilt the depleted stockpiles and prepares for expected increase in demand later this year. Inventories throughout the electronics supply chain during the first quarter 2011 rose for all sectors except for computer manufacturers. Therefore, HIS commented, semiconductor inventories were likely to continue rising throughout 2011. The consultancy went to say that the Japan earthquake in March had a minimal effect on the electronics supply chain, given that inventories have been built up during the prior two quarters. In, it believed that the wide spread disruption was prevented by supplies at hand, and the repair and restart of production facilities and agile moves among manufacturers to shift production from Japan to other countries (http://www.transportintelligence.com/content/industry-sector/high-tech/).
Yet, the risks caused by weather-related disruptions in Europe are surprisingly scarcely addressed by supply chain management literature (Kleindorfer and Saad 2005). Even worse, the consequences that extreme weather events exerted on freight transport operations in Europe received hardly any attention from researchers in this field (Wilson 2007).

One reason could be that as compared to disruptions paralysing manufacturing plants and/or warehouses which result in large supply shortages, a rupture in movement of goods within a supply pipeline may be potentially less contagious because it halts only transfer of merchandise and/or materials. The uniqueness of transportation disruption consists thus in that although the goods in transit have been stopped, the remaining supply network operations may still function undisturbed.

As observed by Gunipero and Eltantawy (2004) as well as Adegoke and Gopalakrishnan (2009), this is very far from being true. Transport interruption is a risk that can quickly cripple the entire supply chain because in addition to halting the flow movement, stoppages in materials and/or goods transfer spread quickly to upstream and/or downstream supply chain segments causing stock outs, inventory depletion, production downtimes, unsatisfied customer orders, information distortion and/or stoppages in goods transit.

### 2.2. Vulnerability of road freight transport

Haphazard goods arrivals caused by disruptions in road freight vehicle journeys and material flows invoke immediate, substantial and negative consequences on transport operators, logistics service providers, shippers and manufacturers. Results from the study performed by Fowkes et al. (2004) on why the freight transport industry values journey time reliability so high have showed that supply breakdowns and delivery delays:

1) Increase the overall journey times with fixed departure times
2) Increase spreads (or range) in arrival times for a fixed departure times
3) Delay schedules by requiring that departure times were effectively put back
4) Disturb inventory levels at upstream and downstream supply segments jeopardising manufacturing operations and inbound and outbound material movements.

Interviews with transport managers on the nature of flows they have been moving and the needs for supply reliability revealed that in many instances effective operations depended on a high level of certainty as to the expected arrival times of freight vehicles either for loading and unloading. On further investigation, additional reasons for time certainty emerged. These reasons have been divided into two broad groups – those related to the nature of demand for freight transport, and those concerned with supply side issue.

#### 2.2.1. Demand considerations

**Goods characteristics**

---

3 Although a disruption in transportation will certainly delay the arrival of goods at destination, a distinction is made here between a transportation disruption and a transportation delay which fall into two different risk categories. Because of larger element of surprise and lower preparedness level, Chopra and Sodhi (2009) maintained that risk drivers for a delay are much smaller than those of disruptions which may last longer and hit several supply segments simultaneously. This distinction was also useful for determining the conditions of supply network robustness and development of strategies targeting disruptions caused by natural hazards.
Some goods deteriorate as regards the value at destination if their transit time exceeds certain time limits. This pertains to perishable goods with shelf-time of only few days or hours whose utility may suffer from delivery tardiness. Some other goods such as fresh food and drinks may deteriorate in terms of “looks” if they stay longer in transit. Finally, some solid, powder and fluid chemicals carried in tankers may “settle” and/or change consistency after prolonged transit. Still some other materials can become hazardous due to chemical reactions released by longer time lapses between departures and arrivals and/or motions under transit. Still some other types of liquids may solidify in tank containers making discharge more difficult and/or expensive. In addition, some other types of cargo such as newspapers lose their inherent value composed of time-constrained information newness. As reported later, cargo’s consistency can also change as a consequence of longer than allowed exposure to adverse atmospheric conditions such as very low or high temperatures.

**Just-in-time delivery requirements**

Transport operators who deliver goods under just-in-time quality regime do typically carry components to manufacturing or assembly plants or materials needed for processing industries. In some cases, these operations may need time-precise deliveries of several loads per day. Since the continuity of these production processes can easily be jeopardised in the event of late arrivals, delivery times of just-in-time consignments are usually very precisely specified. Disruptions of flow movements with the consequent arrival delays impose thus legal and financial penalties on transport operators, consignors and manufacturers. Some high-value retailers which deal with medical and/or healthcare articles usually require just-in-time delivery not only because of the risks of material decay or utility spoilage, but because of high costs of inventory and low stocks held at medical depots.

**Quick response demands**

Transport operators who handle deliveries of food, drinks or other high-value manufactured goods into retail trade segments often operate on orders from:

- Manufacturers or other suppliers delivering directly to individual retail outlets
- Manufacturers or other suppliers delivering into regional delivery centres (RDCs). Some of these “Quick response” deliveries of goods with little or no inventory stock are also being held by secondary distribution outlets and retailers.
- Logistics operators working under dedicated contracts for major retailers responsible for deliveries of consolidated loads from RDCs to individual retailer outlets
- Logistics operators contractually hired by shipping lines to perform overland transfer of large volumes of overseas and/or international cargo between European gateway ports and national and/or regional distribution hubs.

Since all four types of delivery are very time sensitive, retail deliveries to RDCs are often “booked in” for unloading at an agreed time. Extreme time sensitivity allows only for small windows of variability to be built around the booked supply time with high statutory penalties for late arrivals. In this context, lengthy supply time disruptions caused by weather hazards disintegrate the entire pipeline inventory and may disturb stock availability at, at least, two upstream supply chain echelons: wholesalers and retailers.

Another case where the supply network disruption may be quite critical arises from quite a common practice where consignor sends vary late notice of the precise content of orders. For
example, a retailer may transmit the order electronically at midnight, for delivery at RDC by mid-morning. In such cases the time available to a supplier to undertake order processing, picking of goods, checking loading, documentation and dispatch may be very tight, placing considerable strain on warehousing and transport operations. Again abrupt punctuation of material flow between manufacturing plant and/or warehouse and a RDC may result in stock out and/or production downtime.

**Port arrivals and railway departure deadlines**

Deadlines imposed by ships’ discharge schedules and/or freight trains departures exert strong pressures on journey timeliness. If there is a low level of predictability of arrival times at ports and/or railway terminals, vehicles must be scheduled earlier to provide a reasonable degree of certainty for achieving the preferred sailing and/or utilising the capacity booked on a given train departure. Prolonged pick-up or discharge waiting times idle the vehicles and drivers causing additional outlays for transport companies and logistics operators. On the other hand, disruptions in vehicle travel time and late vehicle arrivals at ports and/or railway terminals may lead to high storage costs if load trans-shipment misses the vessel sailing date and/or wagon discharge schedule.

**Hub and spoke operations**

All express shipments and parcel consignments are by their nature time-sensitive. That is why operators in this freight service segment use “hub and spoke” networks. National depots collect parcels and/or other urgent consignments during the afternoon for evening shipments to a central “hub”. All sortation at the hub must be carried out within very narrow time window so that vehicles can return to their home depots loaded with parcels destined to their region or country hubs (depending on the scope of operations) within the tightly scheduled time. Unpredictable arrival times at hubs will reduce efficiency of hub operations and may delay the sortation process forcing the vehicles to depart late for return journey. Further delays on that journey will cause late deliveries to consignees and possible refunds to customers under the terms of customer guarantees.

Similarly, traffic stoppages at sortation hubs will cause downtime in parcel processing and disrupt schedules of deliveries to final customers. Consequently the rupture in parcel transportation and other time sensitive consignments will disturb not only the hub operations but also deliveries to final customers.

Freight transport companies working for global parcel operators may also experience that disruptions at regional hubs and delays in outbound vehicle departures may cause them to arrive late at airports from where the consolidated loads are shipped to inter-continental and/or overseas destinations. The most severely impacted by these delays will be network operators guaranteeing the overnight delivery schedules, and transport operators responsible for timely feeder of parcel consignments into long-haul intermodal chains.

**2.2.2. Supply side issues**

The key issue on the supply side is that (regardless of the nature of the freight moved) disruptions in journey times and processes will affect efficiency of transport and logistics operations, harming sing ability to meet statutory obligations and the long-term business relationships. Several examples of these impacts are listed below.
Two-way loading

Patterns of transport planning and capacity utilisation reveal that in many cases load collections and deliveries are performed for the same industrial clients, e.g., outbound product distribution may be linked to inbound transport of materials or components. Further in many other cases, transport hauliers will accept, consolidate and deliver freight of several shippers and/or consignors in less-than-truck-load traffic in order to reduce the amount of empty running and risk of idle capacity on vehicles’ round trips. Needless to say, efficiency of load consolidation process and on-on-time delivery requires high level of journey predictability, especially when the return and/or the subsequent lot of shipments have to be collected within a narrow time window.

Consolidation of deliveries

As mentioned, transport operators consolidate deliveries in order to improve fleet efficiency and to maintain certain geographical market coverage. Consequently, by utilising one vehicle for dispatches of several consignments to both DRCs and retailer outlets, one specific transport supplier may service multiple manufacturers and/or wholesalers. This will facilitate the efficiency of large primary distribution vehicles performing trunk haul but also reduce the freight supply costs for shippers and/or manufacturers. Faced with possibility of less certain journey times, transport operators and/or forwarder companies may lose ability to consolidate for two reasons. First, they may miss their booked unloading times at the second or subsequent calls jeopardising thus service quality to customers. Secondly, delays on such schedules may cause problems with driving time regulations, raising prospect of expensive double manning.

Driving hours’ implications

Greater journey variability may have driver cost implications. In majority of cases, delivery schedules are being calculated on the basis of an effective utilisation of driver’s working shift. Delayed journey starts, longer travel times and/or greater journey time delays due to weather-induced stoppages may increase personnel costs by imposing needs for additional drivers. Since all transport operators are bound to adhere to working time regulation, disruption of transportation may also cause direct financial disadvantages due to reduced scope for using drivers for other work at the end of driving day and/or assigning drivers to vehicles trips on other lanes. Delays in vehicle arrivals may also disrupt driver exchanges en route. In many cases, vehicle moving in opposite directions are scheduled to exchange drivers at a convenient point in time. Obviously, the scope for this efficiency gains will be considerably reduced if travel times become more variable making vehicles unavailable for subsequent trips. In the latter case, a delay in one of the vehicle’s arrival time will also delay scheduling and routing for other vehicles.

Scope of round the clock operations

In many cases vehicle fleet equipment at freight transport companies, who offer traction for long-haul primary and secondary domestic and/or international distribution, is utilised round the clock but with day-time schedules differing from the night-time work. One example of multiple utilisations of traction units is assignment of tractors during the day-time to towing smaller trailers suited for urban deliveries. The same tractors will be used with larger trailers on over-night inter-depot trunking operations. A delayed return of a tractor to the depot either in late afternoon or early morning will disrupt the vehicle utilisation schedule disturbing the next assignments. A disruption in tractor work continuity may thus cause shortage of vehicle load carrying capacity and/or produce idle vehicle capacity.
Parcel carriers also tend to use vehicles day and night. Drawbar combination vehicles are highly efficient for the night-time operations to and from sortation hubs. During daytime, the trailer could be detached and the resulting rigid vehicle can undertake collection and/or delivery work. By disturbing vehicle movement en route, weather hazards will delay arrivals and departures and lead to shortage of traction units as well as load carrying devices such as trailers, containers and flat cars for day and night assignments. These consequences will be more severe when equipment is either rented or leased out from specialty companies who charge demurrage for withholding containers and other load carrying devices beyond the statutory time window.

**Order management and warehousing regimes**

Since scheduling of transport operations is tightly connected to order processing, warehousing and manufacturing, unexpected variability in vehicle journey times and/or an abrupt punctuation of goods flows can hinder timely completion of several logistics chain operations. Extended journey times and other causes enforcing earlier departures, tardy arrivals and sudden ruptures of freight movement place greater pressures on already tight order processing, picking, loading, checking and dispatching deadlines. Occurrence of even small irregularities in these goods handling schedules would require additional shifts at warehouses and/or logistics service depots so that delays could be internalised by extending order executed cycles according to delivery contracts. Otherwise transport operators may be liable for delay penalties, risk higher transaction costs and even loss of transport contracts.

In summary, the continued raise in transport factor costs (e.g. fuel, drivers’ personnel expenditures, road usage fees and environmental taxes) forced many sectors in road transport industry to operations within quite narrow time margins and applying tight vehicle and drivers schedules for attainment of operational efficiencies and survive in increasingly more competitive market. Critically, many of these strategies depend on high level of certainty as to the journey times on local and trunk road networks as well as international lanes.

### 2.3. Values of time for on-time arrivals and arrival tardiness in freight road transport

Recognising high importance that consignors, shippers and transport operators assign to predictability of vehicles’ travel time and long-term consistency in consignment arrivals, below three studies are reviewed which assessed the values of time for on-time and delayed deliveries by different modes of transport.

The first is the already mentioned work by Fowkes et al. (2004), the second the study of values of time and reliability in freight transport performed for Netherland by de Jong et al. (2004), while the third the national value of time assessment done for Norway by Halse et al. (2010).

Fowkes et al. (2004) hypothesized that values assigned by shippers and transport operators to different types of consignment would vary and that just-in-time (JIT) and quick response (QR) operators may attach higher values to arrival predictability. They have also surmised that consignors using third party logistics suppliers may be having lower valuation of travel time predictability than own-account hauliers or third party hauliers. Shippers with parallel rail alternatives might also be less concerned about delays than shippers who run low-inventory operations and are highly dependent on reliable transport for maintaining in-house stocks at minimum safety level.
To verify these expectations in quantitative manner, an Adaptive Stated Preference experiment was conducted. The experiment investigated the values assigned to the three different types of delays:

- Delay time (DT) (i.e. an increase in free flow of time for a given departure time)
- An increase in the spread (SP) of arrival times
- A schedule delay (SH) in initial departure time.

For DT, respondents were asked for the departure time (T) for the movement in question, and the earliest possible arrival time (EA) if everything went according to schedule, DT was a difference (EA - T). Respondents were then asked by what time the 98 per cent of deliveries could be expected to arrive. This was denoted as A98 (unless it was within 10 minutes of EA, in which case the 10-minute difference was forced). The difference between A98 and EA was called "spread" (SP).

Having determined when the load movement actually departed, some delays were then imposed on departure times. These were related to schedule delays as they involved inability to depart at the preferred time. Such delays might arise if planned road works were either to block the journey or cause so much delay, that it was not worthy starting out until the road blockage was removed or if vehicle was waiting for the congestion to end.

The dependent variable measured by this experiment was cost (C) expressed as percentage of the current cost (of freight rate). There were four cost options. Alternative (1) resembled the current position (base option) regarding typical flow travelling over 282 kilometres, but at twice the baseline freight rate which was given a rating of 100. The respondents were asked to give ratings to three other alternatives which had one attribute worse than alternative 1 (the base option). Table below presents results from statistical analyses for the entire sample and also for various classes of survey respondents. Good t ratios obtained indicated that reductions in all three types of delays were significantly positively valued.

The results for the sample of 40 shipments showed that the value of delay time (VoD) had the highest estimate of 10.7£ /min followed by the value of spread of journey time (VSP) 0.85 £ /min, and then schedule delay (VSH) 0.66 £ /min. The average distance for shipment delivery was over 281 kilometres and the average cost per kilometre was just over 1£. Standard errors of difference were 7-9 pence/min, so the gap between the adjacent values was about two standard errors.

As shown in Table 1, the valuations of three types of delays varied considerably between the disaggregated classes of respondents. The valuations differed between own account operators and third party with third party valuations being dissimilar between the shipper and the haulier. The values to the shipper were low, reflecting an interest in the cost of the load, but no interest in what happens to the lorry or driver. Hauliers were found to have higher values, particularly for spread, where uncertainty of arrival time was highly detrimental to vehicle/driver efficiency. Own account transport operators were less worried about the spread than the third party hauliers but more worried about journey time and schedule delay.
This may reflect shorter distance recorded in own account trips which may mean that shorter delays may cause more disruption than in movements over longer distances performed by third party hauliers. The next disaggregation into primary and secondary distribution has shown that distribution movements were costing much more per kilometre and their valuations were also much greater. When disaggregation between JIT/QR and other consignments was undertaken, it was found that valuations were much higher for JIT/QR although this time the per kilometre freight rate was lower for JIT/QR than for other deliveries.

Type of vehicle used had little impact on valuations, though it was noticed that articulated vehicles were used for longer distance journey. With respect to journey distance, the disaggregation of journeys into less and more than 250 kilometres revealed that long distance journeys had higher values of delay time but lower values of spread reflecting lower odds for arrival tardiness. This echoes the earlier observation that an absolute amount of uncertainty is more disruptive for shorter as opposed to longer journey, and therefore shuttle operations may require extra vehicle in the circuit.

With respect to commodities moved, chemicals were travelling an average distance but at a cost greatly above the average, presumably reflecting the specialist equipment involved and the lack of opportunity to obtain suitable return loads (avoiding contamination of tank containers). They had higher valuation. Grocery flows, on the other hand, were carried longer than average, slightly more cheaply than average and had lower than average valuations.

Flows where rail was a remote possibility were longer than average and had lower valuations than average. Only one fifth of flows involved night-time movement. These were found to have high valuations suggesting that once a decision to operate at night is taken, any form of delay is greatly avoided.

However, results from analyses of values per load were not very conclusive as high value loads produced very low values of delay time, zero value of spread and low value of schedule delay. These findings contradict received knowledge that high value goods are more time sensitive and therefore command higher delay valuations. In search for an explanation behind this finding, some Norwegian road hauliers were contacted. The opinions obtained indicate that in some cases shippers or consignees may value delayed or lengthened delivery times higher than more speedy alternatives because they may reduce the risk of consignment loss and/or damage.
Table 1. Valuations of delay time, arrival time spread (VSP) and schedule delay (VSH) expressed as pence per minute, end-2000 prices; t ratios in brackets
(Source: Fowkes et al. 2004)

<table>
<thead>
<tr>
<th>Operation type</th>
<th>N</th>
<th>Cost (£)</th>
<th>Distance (km)</th>
<th>VDT (p/min)</th>
<th>VSP (p/min)</th>
<th>VSH (p/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole sample</td>
<td>40</td>
<td>285.8</td>
<td>281.6</td>
<td>107.1</td>
<td>85.3</td>
<td>65.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(15.7)</td>
<td>(13.7)</td>
<td>(26.3)</td>
</tr>
<tr>
<td>Own account</td>
<td>11</td>
<td>227.3</td>
<td>237.2</td>
<td>169.3</td>
<td>89.5</td>
<td>126.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(15.4)</td>
<td>(10.0)</td>
<td>(25.0)</td>
</tr>
<tr>
<td>Third party (Haulier interviewed)</td>
<td>19</td>
<td>298.2</td>
<td>286.8</td>
<td>155.1</td>
<td>167.6</td>
<td>86.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(9.2)</td>
<td>(8.3)</td>
<td>(15.7)</td>
</tr>
<tr>
<td>Third party (Shipper interviewed)</td>
<td>10</td>
<td>326.8</td>
<td>320.6</td>
<td>37.2</td>
<td>61.5</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3.7)</td>
<td>(6.5)</td>
<td>(9.3)</td>
</tr>
<tr>
<td>Distribution</td>
<td>25</td>
<td>310.2</td>
<td>281</td>
<td>183.6</td>
<td>128.7</td>
<td>104.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(14.4)</td>
<td>(13.0)</td>
<td>(26.3)</td>
</tr>
<tr>
<td>Not distribution</td>
<td>15</td>
<td>245.3</td>
<td>282.7</td>
<td>76.2</td>
<td>56.9</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(9.5)</td>
<td>(7.1)</td>
<td>(15.7)</td>
</tr>
<tr>
<td>JIT/QR</td>
<td>27</td>
<td>277.9</td>
<td>279.1</td>
<td>128.6</td>
<td>101.8</td>
<td>75.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(15.6)</td>
<td>(13.7)</td>
<td>(26.3)</td>
</tr>
<tr>
<td>Not JIT/QR</td>
<td>13</td>
<td>302.4</td>
<td>286.8</td>
<td>61.0</td>
<td>46.8</td>
<td>35.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5.1)</td>
<td>(4.1)</td>
<td>(7.2)</td>
</tr>
<tr>
<td>Distance greater than 250 km</td>
<td>26</td>
<td>343.2</td>
<td>361.7</td>
<td>125.0</td>
<td>74.5</td>
<td>74.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(12.9)</td>
<td>(7.9)</td>
<td>(19.8)</td>
</tr>
<tr>
<td>Chemicals, chem. products, paint</td>
<td>8</td>
<td>397.3</td>
<td>285.0</td>
<td>224.7</td>
<td>126.6</td>
<td>94.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(6.1)</td>
<td>(6.5)</td>
<td>(10.0)</td>
</tr>
<tr>
<td>Food drink, grocery</td>
<td>15</td>
<td>288.7</td>
<td>298.0</td>
<td>90.9</td>
<td>77.5</td>
<td>48.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(11.6)</td>
<td>(10.6)</td>
<td>(15.6)</td>
</tr>
<tr>
<td>Other commodities</td>
<td>17</td>
<td>230.9</td>
<td>265.6</td>
<td>145.7</td>
<td>93.3</td>
<td>97.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(9.8)</td>
<td>(6.2)</td>
<td>(20.9)</td>
</tr>
<tr>
<td>Rail possible</td>
<td>13</td>
<td>301.4</td>
<td>300.5</td>
<td>77.9</td>
<td>60.4</td>
<td>56.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(6.4)</td>
<td>(5.2)</td>
<td>(12.2)</td>
</tr>
<tr>
<td>Rail not possible</td>
<td>27</td>
<td>278.3</td>
<td>272.6</td>
<td>120.5</td>
<td>96.2</td>
<td>69.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(14.6)</td>
<td>(12.9)</td>
<td>(23.5)</td>
</tr>
<tr>
<td>Daytime movement only</td>
<td>32</td>
<td>283.7</td>
<td>268.2</td>
<td>97.3</td>
<td>72.0</td>
<td>61.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(14.0)</td>
<td>(10.6)</td>
<td>(15.7)</td>
</tr>
<tr>
<td>Some night-time movement</td>
<td>8</td>
<td>294.7</td>
<td>325.5</td>
<td>413.5</td>
<td>159.0</td>
<td>173.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(10.7)</td>
<td>(10.0)</td>
<td>(13.7)</td>
</tr>
</tbody>
</table>

The Dutch study used the stated and the revealed preference (SP and RP) methods to collect data enabling to assess the values assigned by shippers to the total value of on-time deliveries and/or consignment delays. The VoT were related to average transit times (between origin and destination) ranging between 1 and 2 vehicle travel hours.

Values of time constituted additional appraisal factors which were added to the basic factor costs incurred in production of transport.
The latter encompassed:

- Fixed costs (depreciation, vehicle taxes, interest and insurance)
- Variable costs (repairs, maintenance, tires, fuel)
- Labour costs (driver wages, social security premiums, travel and subsistence costs)
- Specific transport costs (materials, inspections, licenses, port fees, etc.)
- General company costs (overheads covering wages of auxiliary personnel, housing, ICT, etc.).

The following exploratory variables were used in VoT calculations:

1) Service providers’ demographics (location, status: own account transport or third party haulier, fleet of vehicles operated, sidings and modal split)
2) Attributes of a typical shipment 1 (origin, destination, weight, value, handling, transport costs, time reliability, damage frequency).
3) RP determinant of transport choice of typical shipment 1 including attributes of available but not chosen alternative modes (if respondent did not know the alternatives, default attribute values were suggested)
4) A within-mode SP experiment for a typical consignment 1 to be shipped by two alternatives but by the same mode presented to shipper or carrier
5) A between mode experiment for shipment of a typical consignment 1 (but only when respondent indicated that alternative modes, i.e., by road, rail, inland waterways, sea and air transport were available)
6) Questions about typical shipment 2
7) Determinants of RP choices and attribute values for typical shipment 2.

The following SP attributes were modified in experiments to assess changes in value baselines

- Transport costs for shippers who used third party hauliers
- Transport time (door-to-door)
- Percentage of shipments not delivered on time (or within specific time window)
- Probability of damage
- Frequency of service on a given lane.

Values of times attained through these assessments for shipments of different commodities are shown in Table 2.
Table 2. Values of time for goods transport in the Netherlands (€)  
(Source: De Jong et al. 2004)

<table>
<thead>
<tr>
<th>Shipments</th>
<th>VoT for a shipment (€/h)</th>
<th>VoT for a shipment tonne (€/tn/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-value raw materials and semi-finished goods</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>High-value raw materials and semi-finished goods</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Final products (with value depreciation due to longer transit time)</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Final products (without value depreciation)</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Containerised cargo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total road transport</td>
<td>38</td>
<td>5.28</td>
</tr>
<tr>
<td>Rail (train load)</td>
<td>918</td>
<td>0.96</td>
</tr>
<tr>
<td>Inland waterways (barge)</td>
<td>74</td>
<td>0.046</td>
</tr>
<tr>
<td>Maritime transport (short and deep sea vessel)</td>
<td>73</td>
<td>0.016</td>
</tr>
<tr>
<td>Air transport (full airplane shipment)</td>
<td>7,935</td>
<td>132.24</td>
</tr>
</tbody>
</table>

Subsequently, values of reliability loss have been assessed. The following monetary valuations were estimated by modelling losses in baseline reliability with 10% of shipments not delivered on time.

- 1.01 € for road shipment of low-value raw materials and semi-finished goods
- 1.31 € for road shipment of high-value raw materials and semi-finished goods
- 2.67 € for road shipment of perishable final products
- 2.51 € for road shipment of non-perishable final products
- 2.85 € for road transport of 20 ft. containers
- 1.77 € for all road shipments
- 898.98 € for a train load
- 62.53 € for inland waterway barge
- 930.60 € for a ship in short and deep sea transfer
- 15,429.36 € per airplane freight load.

The 2004 trade-off ratios between reliability and costs for road transport were between 0.14 and 0.38 (depending on the commodity consignment delayed). This means that an increase in the percentage of delayed shipments from 10% to 11% was equivalent to 1.4%–3.8% of transport costs depending on commodity category which arrived late.

The time valuation study for Norway applied the stated preference method (SP) only to assess the willingness to pay by own account transport operators, third party transport hauliers and industrial shippers who hired transport providers for shorter/longer transit times, variable arrival times, and avoidance of delays or too early delivery.

Despite the fact that the target population included all shippers and transport providers in Norway, all types of goods carried and transport modes used, the majority (87%) of domestic shipment sample on which calculations were based was carried by road. Therefore, the table below presents the values of time and valuations of travel time consistency for road shipments only.
Table 3. Values of time, on-time arrivals, arrival variability, values of delay and average weight of shipments in domestic road transport in Norway in 2009
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Sample</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shippers (N= 395)</td>
<td>Own account hauliers (N=112)</td>
<td>Third party hauliers (N= 107)</td>
</tr>
<tr>
<td>Value of time</td>
<td>58</td>
<td>331</td>
<td>444</td>
</tr>
<tr>
<td>NOK/h, (€/h)</td>
<td>(7.44)</td>
<td>(42.44)</td>
<td>(57.0)</td>
</tr>
<tr>
<td>Confidence interval for value of time</td>
<td>43-73</td>
<td>272-389</td>
<td>347-541</td>
</tr>
<tr>
<td>Value of expected transport time</td>
<td>101</td>
<td>370</td>
<td>435</td>
</tr>
<tr>
<td>NOK/h, (€/h)</td>
<td>(13.0)</td>
<td>(47.43)</td>
<td>(55.77)</td>
</tr>
<tr>
<td>Value of arrival variability</td>
<td>69</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>NOK/h, (€/h) standard deviation</td>
<td>(8.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of delay</td>
<td>398</td>
<td>1 360</td>
<td>1 012</td>
</tr>
<tr>
<td>NOK/h, (€/h)</td>
<td>(51.0)</td>
<td>(174.36)</td>
<td>(129.74)</td>
</tr>
<tr>
<td>Approximate average weight of shipment</td>
<td>3.8 tn</td>
<td>3.6 tn</td>
<td>12 tn</td>
</tr>
</tbody>
</table>

Table 3 above indicates that both the own-account and the third-party hauliers assigned much higher values to shipments’ on-time arrivals and delays as compared to shippers. This finding is consistent with indication of VoT disparities established by the UK study.

The following table presents the outcomes from analyses of disaggregated samples of respondents and their operations to compare the results for Norway with those from the UK. The goal was to find commonalities which despite different analytical methods and numerical results may create baseline for extrapolation of weather-inflicted disruptions on freight transport operators to third countries.

The average distances for cargo moved by shippers in Norway were 324.3 km, by third party hauliers 348.2 km and by own-account hauliers 112.8 kilometres.

---

4 Because of large methodological differences between the UK and the Dutch VoT in freight transport studies, no commonalities between the latter and the Norwegian results was sought.
Table 4. Values of time, on-time arrival, arrival variability and values of delay, and the average shipment weights carried by own-account and third party hauliers in Norway
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Type of transport operator</th>
<th>Own account hauliers (N=112)</th>
<th>Third party hauliers (N=107)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of time (VoT) NOK/h (€/h)</td>
<td></td>
<td>331</td>
<td>444</td>
</tr>
<tr>
<td>Confidence interval for VoT</td>
<td></td>
<td>272-389</td>
<td>347-541</td>
</tr>
<tr>
<td>Value of expected transport time NOK/h (€/h)</td>
<td></td>
<td>370</td>
<td>436</td>
</tr>
<tr>
<td>Value of arrival variability standard deviation</td>
<td>Not significant</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>Value of delay NOK/h (€/h)</td>
<td></td>
<td>1,360</td>
<td>1,012</td>
</tr>
<tr>
<td>Approximate average weight of shipment 3.6 tn</td>
<td></td>
<td>12 tn</td>
<td></td>
</tr>
</tbody>
</table>

Values of time (NOK/hour) assigned by own-account hauliers to on-time arrivals were lower than those of the third party carriers, while delay valuation was higher. The lower value of delay assigned by the third party carriers may stem from the higher time buffers built in the load pick up and cargo consolidation planning, making these trips less sensitive to arrival lateness.

Table 5. Values of time, on-time arrival, arrival variability and delay assigned by third party hauliers (stratified by operation types)
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Primary distribution (N=34)</th>
<th>Long-haulage domestic transport (N=50)</th>
<th>Long-haulage international transport (N=18)</th>
<th>Shuttle between warehouse and terminal (N=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of time (VoT) NOK/h (€/h)</td>
<td>643</td>
<td>632</td>
<td>252</td>
<td>715</td>
</tr>
<tr>
<td>Confidence interval for VoT</td>
<td>551-735</td>
<td>477-787</td>
<td>186-319</td>
<td>421.0065</td>
</tr>
<tr>
<td>Value of expected transport time NOK/h (€/h)</td>
<td>Not significant</td>
<td>314</td>
<td>228</td>
<td>Not significant</td>
</tr>
<tr>
<td>Value of arrival variability NOK/h (€/h)</td>
<td>Not significant</td>
<td>Not significant</td>
<td>208 (26.67)</td>
<td>Not significant</td>
</tr>
<tr>
<td>Value of delay NOK/h (€/h)</td>
<td>Not significant</td>
<td>798</td>
<td>718</td>
<td>Not significant</td>
</tr>
<tr>
<td>Approximate average weight of shipment 8.1 tn</td>
<td>25.0 tn</td>
<td>11.3 tn</td>
<td>13.5 tn</td>
<td></td>
</tr>
</tbody>
</table>

The informative value of Table 5 is quite limited due to the small size of the sub-sample. However, the highest value of time assigned by the third party transport carriers to goods shuttled between terminals and warehouses confirms that this operation is scheduled within very narrow time windows. Value assigned to on-time arrivals and delays to domestic long-haulage shipments were higher than for international transport.
Table 6. Values of time, on-time arrival, arrival variability and values of delay, and the average shipment weights carried by own-account hauliers in Norway (disaggregated by operation types)
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Own-account truck hauliers by operation types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary distribution (N=79)</td>
</tr>
<tr>
<td>Value of time (VoT)</td>
<td>366 (50.0)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Confidence interval for VoT</td>
<td>297-435</td>
</tr>
<tr>
<td>Value of expected transport time</td>
<td>549 (70.38)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Value of arrival variability</td>
<td>Not significant</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Value of delay</td>
<td>1 062 (136.15)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Approximate average weight of shipment</td>
<td>2.9 tn</td>
</tr>
</tbody>
</table>

The most important conclusion from the above table is that own-account hauliers do typically carry smaller shipments in primary distribution with highest value of time. The high level of punctuality required from the smallest shipments was confirmed by the highest value of delay. This result corresponds with the outcomes from the UK study.

Table 7. Values of time, on-time arrival, arrival variability and delays, and the average shipment weights carried by third party hauliers in Norway; stratified by customer types
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Third party hauliers per customer segment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industrial shippers (N=71)</td>
</tr>
<tr>
<td>Value of time (VoT)</td>
<td>387 (49.6)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Confidence interval for VoT</td>
<td>292-482</td>
</tr>
<tr>
<td>Value of expected transport time</td>
<td>254 (32.56)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Value of arrival variability</td>
<td>Not significant</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Value of delay</td>
<td>1 005 (128.85)</td>
</tr>
<tr>
<td>NOK/h, (£/h)</td>
<td></td>
</tr>
<tr>
<td>Approximate average weight of shipment</td>
<td>26.6 tn</td>
</tr>
</tbody>
</table>
Despite the small sub-sample, disaggregation of the third party hauliers by types of customer served not unexpectedly revealed that the highest values of time and delay were attached to shipments commissioned by retailers, followed by supplies to industry (Table 7). This outcome is also in line with results from the UK study.

In order to assess how the values of time and valuations of on-time arrivals and delays varied among the third party transport carriers, this sub-sample was disaggregated into firms which in addition to freight haulage also performed as forwarders, consolidators and freight brokers and then compared to appraisal levels assigned by the pure road freight hauliers. The results are shown in the following table.

Table 8. Values of time, on-time arrival, arrival variability, values of delays, and weights of average shipment carried by three segments of third party hauliers in Norway (disaggregated by service types)
(Source: Halse et al. 2010)

<table>
<thead>
<tr>
<th>Value items</th>
<th>Forwarder, load consolidator, freight agent (N=40)</th>
<th>Pure truck and lorry operator (N=58)</th>
<th>Parcel operator (N=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of time (VoT)</td>
<td>376 (48.21)</td>
<td>572 (73.33)</td>
<td>906 (116.15)</td>
</tr>
<tr>
<td>Confidence interval for VoT</td>
<td>261-492</td>
<td>280-765</td>
<td>314-1.498</td>
</tr>
<tr>
<td>Value of expected transport time</td>
<td>580 (74.35)</td>
<td>400 (51.28)</td>
<td>Not significant</td>
</tr>
<tr>
<td>Value of arrival variability</td>
<td>Not significant</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>Value of delay</td>
<td>1217 (156.02)</td>
<td>1434 (183.85)</td>
<td>Not significant</td>
</tr>
<tr>
<td>Approximate average weight of shipment</td>
<td>10.4 tn</td>
<td>14.4 tn</td>
<td>3.6 tn</td>
</tr>
</tbody>
</table>

Not surprisingly, the highest values of arrival lateness were assigned by pure road transport operators whose main business consists in delivering goods on-time. It was unfortunate that the values of time assigned to highly time sensitive parcels could not be estimated and checked against valuations of delay for the same cargo category.

The review of the three national studies of VoT in freight transport revealed the different methodological approaches and, as a consequence, highly variable end results. However, some parallels could be deduced from the UK and Norwegian studies as regards the high levels of values of time assigned to short trips by own-account hauliers, and high time values attached to shipments commissioned by retailers and industrial shippers whose inventories may be quickly depleted by the lack of reliable delivery time. It was also shown that transport operators (both from the own-account and third party haulier sectors) assigned higher values to on-time arrivals than shippers. The reason may be that delivering goods on time represents the main line of the-
se parties’ business, the main source of revenues and operational efficiencies, and consequently, a rationale for their market presence.

However, one has also to remember that the numerical values of time calculated by these studies are a product of national socio-economic differences which separate the three focal countries as regards the wage levels, the laws regulating collective bargaining and labour agreements, the overtime compensations, the technical conditions of traction equipment, the mode split in freight carriage, the level of taxes, the physical topography of transport networks, and finally, the structure of freight transport industry. Because of these idiosyncrasies, applications of these estimates to third countries should be done with utmost caution.

Besides, since the above valuations pertained to small variability intervals in freight travel and arrival accuracy, below we review two studies which analysed the impacts that long-term transport disruptions imposed on robustness of logistics channels.

2.4. Long-term impacts of transport disruptions on logistics channels

The consequences of long-term transport disruptions have been studied by Wilson (2007). She simulated the effects of goods flow stoppages between two echelons of supply chains with two organisational patterns; the first was a traditional formation while the second a vendor managed inventory system (VMI).

![Figure 1. Flow of goods and information within a traditional supply chain structure](Source: Wilson 2007)

The traditional supply chain (depicted above in Figure 1) was composed of one retailer, one warehouse, one tier 1 supplier (of subassemblies converted into final goods), one tier 2 supplier (converting the incoming raw materials into subassemblies), and one raw material supplier. Within this organisational structure the raw material suppliers based their shipment decisions on order information received from the tier 2-supplier only. In contrast to that, a warehouse within the vendor managed inventory (VMI) system became a distribution centre which did not receive the customer demand information (see figure below) because number of items to be shipped to the warehouse was based on customer demand conveyed directly to tiers 1 supplier. In VMI both the tier 1 and the retailer received customer information. The tier 2 supplier, however, received order from the tier 1 supplier, and did not have access to customer demand information. Yet, the raw material supplier received orders from the tier 2 supplier only, and was not aware
of the final customer demand. Therefore, the upstream portion of VMI supply chain behaved as a traditional supply chain.

For both supply structures the processing and the transit times were set to 6 days.

Wilson mapped the changes in flow of order information, order traffic, the subsequent fluctuations in actual and desired inventory levels, and the amount of goods in transit (pipeline inventory) that prevailed between and at each echelon in both supply chain systems before and shortly after the transport flow was halted. The simulated transport interruptions ruptured four types of collaborative linkages within both supply chain structures: between the Retailer and the Warehouse, between the Warehouse and the Tier 1 supplier, between the Tier 1 supplier and the Tier 2 Supplier and between the Tier 2 Supplier and the Raw Material Supplier. To compare the scope of severity these disruptions imposed on each supply chain system, changes in the following performance indicators have been measured: the amount of unfilled customer orders, the maximum amount of goods in transit, and the maximum and the average inventory levels.

The most negative impacts occurred when transport was severed between the Tier 1 Supplier and Warehouse, particularly in a traditional supply chain because this formation experienced the greatest fluctuation of inventory and the highest increase in goods in transit to their facilities. This finding had implications for the relative location of the Tier 1 Suppliers and the Warehouses they served: to reduce the consequences of transport disruption, efforts should be made to identify alternative routes, alternative modes of transportation, and alternative suppliers who do not share the same route, and/or use the same transhipment facilities between Warehouses. If a disruption could be anticipated, improvement of supply chain security was especially needed when shipments crossed several national borders.

Further, adoption of vendor managed inventory (VMI) structure could also help because customer demand information and the Retailer and warehouse inventory positions were shared there with the Tier 1 Supplier. Still the amount of unfilled orders was approximately the same there as in the traditional supply organisation. For both structures the implementation of the above contingency plans was very costly and could not be realised before the risk of disruption was relatively predictable. Still another mitigation strategy amounted to carrying of additional inventory or having a reserve supplier which could add inventory on permanent basis, and
thereby increase the safety stocks or build-up a buffer needed to counteract an impending transport stoppage. But this measure undermined the principle of lean operations and unless the additional costs of carrying safety inventory were to be borne across the entire supply chains, the upstream chain suppliers would not have any incentive to build up their buffers.

2.5. Vulnerability of freight transport customers

In order to assess the impacts that industrial operators experienced in the aftermath of extreme weather events, Hendricks and Singhal (2005) analysed 800 instances of supply chain disruptions experienced by firms whose stocks were publicly traded. They found out that the companies that suffered supply chain disruptions experienced share price returns 33% to 40% lower than the entire industry and the general market benchmark. Furthermore, share price volatility was 13.5% higher in these companies in the year following a disruption than in the prior year. Based on their findings it was evident that only well-prepared companies could effectively cope with supply chain disruptions (Xia et al. 2011).

Wagner and Bode (2006) assessed opinions of business executives in Germany regarding factors that influenced the supply chain vulnerability and established that demand-side risks were related to single customer dependence while supply-side risks were associated with single supplier dependence, single sourcing and sourcing through global supply networks.

A seminal study that Altaý and Ramirez performed in 2010 on the “Impacts of Disasters on Firms in Different Sectors: Implications for Supply Chains” corroborated the above findings but also produced new knowledge on the scale of damage that the different disaster categories inflicted on multiple industries. This work was unique because it assessed the consequences that four types of natural hazard imposed on financial performance of 150 000 firm-years of companies operating in extracting, manufacturing, wholesale and retail industries in 53 countries registered in Worldscope data base over 1990-2004. By uncovering the different damage categories that earthquakes, floods, and windstorms exerted on firms’ economic performance, disaster-specific mitigation and neutralisation strategies were subsequently devised.

Drawing on an impressive body of literature, the authors conjectured that natural disasters impose financial losses, reduction in product and service quality, loss of information and market reputation (good will), from which firms do not recover quickly (Gardner and Cooper 2003; Gasseberet et al. 2006; Wagner and Bode 2006; Xu and Beamon 2006). These financial casualties spill over to operating incomes, leverage levels and returns on sales and assets, which take quite some time to recuperate. Still, in medium-term some companies may experience some positive financial outcomes depending on the type of disaster they have been exposed to and the industry sector they operate in.

Using these empirical results, Altaý and Ramirez devised three hypotheses which they tested empirically:

H1: Financial leverage of firms should increase shortly after a catastrophic event.

---

5 For the sake of analytical robustness the largest countries in EM-DAT data base sample - the United States, Brazil, China, Canada, Russia, India and G8 members have been excluded from estimations of weather hazard impacts.

6 Financial Leverage was defined as the ratio of total debt to total assets reported at the end each year in local currency over 1990-2004.
H2: A firm’s total asset turnover (TAT) may decrease in response to a disaster.\(^7\)

H3: If re-construction efforts increase the local production activity, it could be expected that disaster damage may be positively correlated with firms’ operational cash flow (OCF). Thus firms’ OCF may increase in response to natural disasters.\(^8\)

To assess these impacts, the authors measured the post-disaster changes in the level of leverage, total asset turnover (TAT), and operational cash flows (OCF) of companies operating in mineral extracting, manufacturing, wholesale and retailer sectors. Proposition testing utilised the following methodological insights:

1) Using the number of people affected as a proxy for the scope of damage of labour productivity was not adequate because the damage inflicted on infrastructure could be more critical for maintaining operational continuity in a given sector even if productivity remained unchanged.

2) Raw figures of damage do render cross-country comparisons meaningless because they, among others, do not account for differences in purchasing power parity (PPP). The resultant biases will make countries with high population numbers more likely to exhibit higher numbers of people affected. In a similar fashion, developed countries with more valuable assets and infrastructure will be more likely to exhibit higher monetary damages as compared to poorer countries.

3) Therefore, the measurement of variables has been normalised to make cross-country comparisons of disaster impacts meaningful.

4) The concept “people affected” could be misleading because it could room a wide variety of cases where some people might just needed water, food and temporary shelter while others might have required hospital treatment. A solid theoretical framework was thus needed so that one did not give the same weights to these two groups of affected individuals and confused frequency disaster counts with yearly aggregates of scope of damage or the number of people affected, consequently over-or-under evaluating the true impacts.

To avoid the above caveats and to capture the real impacts of weather-related disasters, Altay and Ramirez (2010) devised a composite measure of disaster damage and used it as an independent variable in regression models:

\[
\text{Composite} = [(0.25 \times \text{aff/pop}) + (0.25 \times \text{k/pop}) + (0.25 \times \text{count}) + (0.25 \times \text{dam/gdp})].
\]

The measure’s particular components were denoting:
- \text{aff/pop} - the ratio of number of people affected over population of the country,

\(^7\) TAT, total asset turnover was composed of ratio of total sales to total assets over 1990-2004 and measured the firms’ financial efficiency by showing how many Euros were generated by each unit of assets.

\(^8\) Operational Cash Flow is a ratio of cash from operation activities to total assets recorded at the end of each year in local currency over the period 1990-2004.
- \( k/pop \) - the number of people killed over the population count - the frequency of events within one year, and
- \( dam/gdp \) - the ratio of disaster damage over GDP.

Higher values of component variables indicated that the disaster had a bigger impact on a given country.

As mentioned, regression models which measured the impacts that weather disasters exerted on firms in the four above sectors used three firm-level performance indicators: financial leverage, OCF and TAT. The assumption was that changes in these indicators will become manifest within one year after a given natural hazard had occurred as compared to indicator levels from years not affected. To verify the above, an ordinary least squares (OLS) regression model with White (1980) robust errors was run of the following three forms:

\[
OP_{Cashflow_{ict}} = \alpha + \beta_1 Extract_{ict} + \beta_2 Manufacturing_{ict} + \beta_3 Whole_{ict} + \beta_4 Retail_{ict} + \Gamma Firm_{ict} + \phi Country_{ict} + \epsilon_{ict}
\]

\[
Leverage_{ict} = \alpha + \beta_1 Extract_{ict} + \beta_2 Manufacturing_{ict} + \beta_3 Whole_{ict} + \beta_4 Retail_{ict} + \Gamma Firm_{ict} + \phi Country_{ict} + \epsilon_{ict}
\]

\[
TAT_{ict} = \alpha + \beta_1 Extract_{ict} + \beta_2 Manufacturing_{ict} + \beta_3 Whole_{ict} + \beta_4 Retail_{ict} + \Gamma Firm_{ict} + \phi Country_{ict} + \epsilon_{ict}
\]

where the subscript \( ict \) referred to firm \( i \), in country \( c \), and in year \( t \).

Disaster data were compiled from EM_DAT (http://www.emdat.be), a database maintained by the Centre for Research on the Epidemiology of Disasters at Catholic University of Louvain Belgium and Disaster Data Base Project at University of Richmond in the US.

The four industry sectors, extraction of raw materials, manufacturing, wholesale and retail sectors functioned as the main exploratory variables. Each one represented the product of disaster damage proxy (\( dam/gdp \), \( aff/pop \) or the composite measure) times a dummy variable that took the value of 1 for the firm-year observations belonging to a specific sector. For example, extract took a value of 0 if a firm was within this sector but the firm’s country has not suffered from any of disaster damages in this particular year. Extract would also take the value of 0 if the firm belonged to another sector. Finally, the extract took the value 1 of the damage proxy only if the firm belonged to a sector and the country where the damage was reported to happen in that year.

Included in every regression were also the “firm and country” variables that represented firm- and country-level controls, respectively. Firm-specific controls included growth opportunities, size, non-debt tax shields, business risk, cash holding and tangibility of assets. Country-level controls included growth opportunities, GDP, and GDP per capita.
controls included GDP per capita, relative size of the banking system, country risk and the corruption level.

Additionally dummy variables for every year and for every two-digit Standard Industry Classification (SIC) code were also included. It was noted that there could be delay between the time a disaster has struck and the time its impact have been reflected in firms’ performance. For this reason 1-year-lagged-value of the main variables were created and the model was estimated using them. The estimation of equations was performed by comparing disaster firm-year observations (regardless of the country where the disaster took place) against baseline from disaster-free years.

The analyses revealed that all four sectors suffered from decrease in OCF after being struck by weather disasters. The impact of disasters on firms’ leverage was visible from positive and time persistent correlation between the increases in total liabilities in the aftermath of disaster damage for all sectors with an exception of extraction industry. Results on TAT differed between the sectors although a general finding was that firms became less efficient at managing their assets after being hit by a disaster. Analyses of monetary and composite proxies showed that coefficients for firms in wholesale and retail sectors were negative and significant, while those for people proxy were not significant. Further exploration revealed however, that sales in disaster years were generally higher than sales in disaster-free years. Thus, the decrease in asset turnover was related to increase in the asset side. This finding suggests that besides investing in repairs, the firms in wholesale and retail sectors have also invested in building inventories because inventories in disaster years were much higher than otherwise.

Next, the study investigated whether the different types of catastrophic events, i.e. earthquakes, floods and windstorms differed as regards the types of impacts they have inflicted on firms’ financial indicators. The results revealed that firms’ operational cash flows in all sectors were negatively correlated with earthquake damages. This was substantiated by a finding that the latter have not only disrupted operations and damaged infrastructure, but also affected people.

However, the impacts of windstorms on firms OCF showed positive. This might have been caused by the facts that windstorms were more predictable than earthquakes, hence allowed for more preparations. Since the aftermath of windstorms might increase the demand for certain goods and services, they might have also increased sales especially when inventories were increased in expectation for an impending hazard. In the same fashion, floods showed also to exert positive impacts on all sectors’ OCF most probably because floods were also somehow predictable and thus allowed firms to increase emergency stocks before they happened.

Analyses of impacts caused by earthquakes revealed a positive correlation between firms’ financial leverage and the lagged-values of resultant damages, confirming that leverage is a financial condition that firms cannot alter quickly. On the other hand, damages from windstorms and floods showed to be positively correlated with firms’ leverage levels indicating that after-disaster increases in demand for firms’ goods and services might have prompted companies to take up commercial loans to increase buffer stocks or production output.

Finally, the impacts inflicted by windstorms on firms’ asset turnover were positive increasing the assets efficiency of companies in manufacturing, wholesale and retail sectors, but not an extrac-
tion industry. However, these results differed for floods because firms in manufacturing sector increased their TAT, while those in wholesale and retail showed a decline.

These results hold important managerial message; the disasters affected the four industry sectors in different manners. This implies that vulnerability reducing and resilience improving actions should become a supply chain-wide practice. However, given the differences in impacts that the different disaster categories inflicted on firms’ financial performance, all-hazards mitigation strategies may not to be effective, and therefore should be replaced by measures and actions tailored for specific disaster types.

In contrast to the above comprehensive exploration of disasters’ medium-term impacts, a research by Oke and Gopalakrishnan (2009) on “Managing Disruptions in Supply Chains: A Case Study of a Retail Supply Chain” focused on internal and external risks that retail chain operators are vulnerable to and managerial requirements for effective mitigation and/or neutralisation of different risks.

In line with previous studies, the risks invoked by extreme weather were defined as low probability – high impacts hazards. Using different categories of disaster impacts and risk combat strategies, the authors distinguished between the damages afflicted on individual supply chain operators and on entire supply chain organisation. Weather-induced hazards that typically affect individual supply chain operators, such as transport companies, disrupt the service demand and service supply through cessation of flow movements, fleet and infrastructure damages, and jeopardised working schedules and vehicle routing. Diminished production base, infrastructure shutdowns and manpower shortage generate negative contagion to firms’ operations and financial results (Koetse and Rietveld 2009).

Yet, the hazards that affect the entire supply chains are much more harmful because in addition to all the above harms, they also punctuate the flows of intra-channel information. Cessation of information on customer and/or shipment orders may typically lead to high inventory fluctuations, production downtimes and supply shortages.

However, managerial requirements for mitigation and/or pre-emptive efforts in both cases are the same. Preparedness building requires costly production capacity reserves, additional suppliers and additional ICT installations combined with higher inventory buffers and reserve sourcing outlets for increased supply chain robustness. Therefore, considering the high capital costs of preparedness building, the authors maintain that effective mitigation strategies must incorporate both the managerial ability to predict the disruption likelihood and the scope of the likely damage (Cochran 2009). Further, because the severities inflicted by windstorms, snowstorms and floods may differ with targets’ location, market territory, resource endowment and knowledge of prior occurrences, these variables may 1) provide basis for different risk perceptions, and 2) underlay adoption of different contingency and abatement plans, consequently commanding reliance on different counter-measures, strategies and actions.

As a result, it is the managerial ability to properly assess the risk of damage, its range and the content that in the final end will affect the magnitude of prevention, preparedness and remediation. Approximation of these hazards will define the resources that the targets will be willing and/or able to set aside a priori in order to fend off the negative consequences of future disas-
ters. Thus, the authors' argument that understanding the risk probability alone will not suffice for identifying the levels of companies’ exposure, the areas of disaster vulnerability, and the effective prevention is worthy of acceptance.

This knowledge complements the work of Altay and Ramirez on different categories of medium-term damage that the natural disasters inflicted on manufacturing and logistics companies in 53 countries.
3. Preparedness-building in transport, logistics and manufacturing industries

3.1. Structuring the challenge

Figure 3 summarises in schematic manner the relationship between the magnitude of business exposure to weather hazards, the sensitivity to weather-related risks, the needs for preparedness and chances for quick recovery. The two latter factors will determine the firms’ vulnerability areas and response capability, and consequently, the types of negative impacts which companies in transport, logistics and manufacturing industries may experience in the short, medium and long-term.

![Diagram showing the relationship between extreme weather events, structural and functional preparedness, response capacity, and recovery](image)

*Figure 3. Factors affecting the scope, the content and duration of extreme weather impacts on transport, logistics and manufacturing companies, and chances of recovery*

The diagram suggests that the magnitude of negative impacts and the speed of recovery may depend on two types of internal capabilities. First, the awareness of prior extreme weather events and/or the risks of impending hazards may urge the company managers to boost the structural and functional preparedness. Higher preparedness level might increase the targets resilience and crisis management ability.

The first stage in this process may involve development of business continuity plan followed by the regular updates of its parameters. Such a scheme will detail the infrastructure and operations areas that are critical for keeping the company in functional modus. By identifying people, production assets and supporting systems which, when jeopardised, will stop the business from running, the responsible managers may assess the criticality of specific assets, the needs for physical reserves and the standby manpower. However, one may need to recognise that the risk perceptions and the expectations of negative impacts may vary not only between the functional departments but also between the individual managers who may harbour the different experience from previous risk exposures and crisis management cases.

Therefore, in ensuring that senior decision makers get an accurate, timely and independent overview of the “ground truth” they need to independently verify the information provided by lower echelons. Beyond that, some senior leaders can make a point in soliciting multiple assessments in order to get a broader risk composition picture, and increase the framework of checks and balances for more comprehensive risk recognition and prevention.

When the functional departments do not have the authority to influence the company’s risk management strategy, an integration mechanism is needed to consolidate the partial risk as-
sessments through one organisational vulnerability decision-making board. Next, the board shall make judgements regarding the sources and the types of risks that may threaten the company’s functionality, and consequently, set aside resources and solutions to be deployed in crisis situations. Parallel with resource assignment, a secondary communication support and commando centre for managing operations affected by crisis eruption will need to be established.

To fortify the above solutions, one can also conclude an arrangement with third party equipment providers and/or business partners to dispatch back-up and/or support in case of disaster. However, reliance on external assistance will always exacerbate the level of potential risk. Sub-contractors may be located far from the target company’s headquarters and/or the main service provision areas. Besides, supplier contracts typically limit the type and amount of information that can be shared. In addition, in many cases sub-contracting agreements impose penalties for delays – thus giving subcontractors an extra incentive to withhold troubling information (for fear of becoming the messenger of bad news or in hope that another subcontractor may be forced to communicate first).

Regular review meetings with subcontractors and/or suppliers will not suffice; it will take many in-depth communication sessions between the latter and senior leadership of a target company to get a broader picture of impending hazards (seen from the external stakeholders’ vantage points) and arrive at decisions as to how to deal with them through internal and externally provided solutions.

Second, while companies may not always be in position to limit their exposure to extreme weather hazards, they may still control the levels of reactive sensitivity through crisis preparation skills and in-built structural resilience. Higher sensitivity will reveal lower internal resilience. More vulnerable companies will also be more susceptible to damage from weather-related adversities. Hence, the higher the level of a company’s vulnerability, the more damage it may encounter, and the more time and efforts it will require to recover from weather-induced harms.

3.2. Managerial attitudes towards risks of natural hazards

In this context one interesting question arises: Why the business firms affected by the above weather disasters were not better prepared to pre-empt or counter-act the negative impacts?

On a global level a survey that McKinsey Global Research Institute performed in 2007 among 2 192 business executives of large manufacturing and service companies (with revenues greater than 1$ billion) that operated in Europe, both Americas and Asia-Pacific region may provide some explanation. The survey questioned business executives about importance that climate change and the higher likelihood of weather disasters may impose on their companies and the long-term business prospects. The report published in McKinsey Quarterly December 2007 issue finds that all business people viewed climatic issues as important for their companies, seeing both opportunity and risks.

60% of respondents from a range of industries (some 40% of whom were evenly split between finance and manufacturing, with another 8% in energy, transport, or mining) communicated that

---

10 Within the sample of 2 192 executives polled around the world, 27% were CEOs or other C–level business leadership functionaries.
the climate change was an important issue considered within their companies’ overall strategy. Further, nearly 70% of respondents saw the subject as important for managing their corporate reputation and brand image and over half of them said that they deemed climate change important for future product development, investment planning, and purchasing and supply management. Above one third of survey participants disclosed that their companies already place more emphasis on climate change than on most other global trends.

Relatively few companies, however, appeared to be translating importance they attached to climate change into corporate actions. 44% of business leaders polled admitted that climate change is not a significant item on their agendas. Further, many reported that their companies considered climate change only occasionally at best when managing corporate reputation and brands, developing new products, or dealing with environmental aspects. More than one third of global executives said that their companies seldom or never factor climate change into their companies’ overall strategies. Yet, when asked how well their companies do take climate change into consideration in strategy, more than half answered that this issue is well and/or somewhat well taken care of. Moreover, a majority of business leaders surveyed regarded climate change as strategically relevant and important to consider in many of their key decisions. 60% of those operating in developed Asia, China and Europe admitted that this issue is somewhat or very important for their companies’ managing the environmental consequences, development of new lines of business, and market expansion.

Executives were relatively optimistic when anticipating business prospects that climate change could bring about. About one-third viewed climate change as representing an equal balance of opportunities and risks which was more than the amount of those who saw the subject as either preponderance of risk or of opportunity. Whole 61% of respondents perceived the climate change issues and the corresponding risk of natural disasters as having positive long-term effect on their profits if managed well. Those corporate decision makers, who took climatic changes into account when planning for their companies’ future indicated that factors that influenced them to do so incorporated needs to protect corporate reputation, respond to media attention to climatic issues and/or natural disasters and customer preferences.

When asked to rank the nine factors that have caused their companies to take climate change seriously and include into strategic priorities, over 50% of respondents put emphasis on corporate reputation. Interestingly, threats to physical assets, reliability of business operations and ability to serve customers in uninterrupted fashion received the least attention, i.e., scored as the last item in terms of percentage points assigned among the nine externally and internally imposed risk factors.

Given considerable uncertainty related to climate change regulations, it was noteworthy that more than 80% of executives expected some form of climate change regulations to come to their companies’ home country within five years. However, few respondents were willing to commit their companies to respond to new regulations in geographical areas where they operated.

When confronted with long-term damages to companies’ economic and market positions that natural and extreme weather disasters brought upon them, one may ask why these executives did not reflect more realistic assessments of risks that these phenomena do already inflict on
their operations, personnel, infrastructure, and subsequently, brand reputation and business prospects.

One explanation could be competitive pressures and ubiquitous search for higher operational efficiency and lower capital costs that companies all over the world pursue with increasing vigour. The well-known managerial terms such as “lean production” and “tightly coupled” supply chain systems with high intra-channel efficiency, visibility and “just-in-time” manufacturing and supply regimes reveal that there is not much preference for operational slack, “wasteful reserves” or doubling of sourcing and/or manufacturing outlets.

Pursuit of financial effectiveness makes those reserves in production capacity, capital assets and sourcing duplications which constitute the core of preparedness measures are deliberately avoided as they show on the companies’ balance sheets and become hard-to-justify costs to board-members and/or shareholders. As a result they reduce operating profit margins and returns on total capital assets. The results from the McKinsey survey indicate that business leaders from all-over the world are more occupied with managing public perception of possible problems rather than counteracting the impending environmental risks. One may thus surmise that building of preparedness against natural disasters and the accompanying decisions on reserve holdings might not come from the industry itself, but rather from two other sources: more stringent government regulation and customer pressures.

Admittedly, business leaders have many other and more compelling challenges to deal with on daily basis in addition to natural disasters. This was very aptly summarised in 21st Supply Chain newsletter’s June 2011 edition: “natural disasters are not the only risks in town”. In addition, the Virtual Strategy Magazine (http://www.virtual-strategy.com/2011/05/10) which recently published the results from the BDO study (http://www.bdo.com) of risk factors most frequently cited in the tax filling reports by one hundred largest publicly traded US technology companies indicate how the natural hazards fare in relation to other business risk categories. Table 9 provided a summary of these results.

---

11 BDO Seidman, LLP is the US professional service firm providing assurance, tax, financial advisory and accounting services to a wide range of publicly traded and privately held companies. The company’s international arm, BDO International Limited serves multinational clients through global network of 1138 offices in 115 countries.
Table 9. 2011 BDO risk-factors reported by technology businesses in the US

<p>| Risk |</p>
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Frequency Cited</th>
<th>%Change from 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Competition and consolidation in technical sector; pricing pressure</td>
<td>97%</td>
</tr>
<tr>
<td>2</td>
<td>General economic concerns</td>
<td>96%</td>
</tr>
<tr>
<td>3</td>
<td>Federal, state and local regulations</td>
<td>96%</td>
</tr>
<tr>
<td>4</td>
<td>Failure to properly execute corporate strategy</td>
<td>93%</td>
</tr>
<tr>
<td>5</td>
<td>Failure to develop or market new products or services</td>
<td>88%</td>
</tr>
<tr>
<td>6</td>
<td>Legal proceedings</td>
<td>86%</td>
</tr>
<tr>
<td>7</td>
<td>Domestic and foreign supplier/vendor concerns, supply chain issues</td>
<td>86%</td>
</tr>
<tr>
<td>8</td>
<td>Management of current and future M&amp;A or divestitures</td>
<td>85%</td>
</tr>
<tr>
<td>9</td>
<td>Threats to international operations</td>
<td>85%</td>
</tr>
<tr>
<td>10</td>
<td>Predicting customer demand and interest, innovation</td>
<td>85%</td>
</tr>
<tr>
<td>11</td>
<td>Ability to retain or attract key personnel</td>
<td>82%</td>
</tr>
<tr>
<td>12</td>
<td>Natural disasters, wars, conflicts and terrorist attacks</td>
<td>81%</td>
</tr>
<tr>
<td>13</td>
<td>Intellectual property infringement</td>
<td>79%</td>
</tr>
<tr>
<td>14</td>
<td>Equipment failure and product liability</td>
<td>75%</td>
</tr>
<tr>
<td>15</td>
<td>Cyclical revenue and stock fluctuations</td>
<td>70%</td>
</tr>
<tr>
<td>16</td>
<td>Inability to acquire capital and financing</td>
<td>68%</td>
</tr>
<tr>
<td>17</td>
<td>Inability to maintain operational infrastructure and system</td>
<td>68%</td>
</tr>
<tr>
<td>18</td>
<td>Labour concerns</td>
<td>61%</td>
</tr>
<tr>
<td>19</td>
<td>Credit or financial risk of customers, vendors or suppliers</td>
<td>61%</td>
</tr>
<tr>
<td>20</td>
<td>Accounting and internal control compliance</td>
<td>58%</td>
</tr>
</tbody>
</table>

The list reveals that the risk connected to natural disasters ranked as number 12 among the most frequently cited risk factors. However, one may expect that supplier/vendor concerns (#7) as well as natural disasters (#12) may gain in prominence after the Japanese earthquake of 2011. The odds are high because as already shown in the table the percentage increase in this risk factor’s prominence between 2009 and 2010 reached 47.
4. Case studies and an international survey

4.1. Adverse weather impacts on road freight transport in Great Britain in 2010

The case study below reveals the impacts that severe winter weather exerted on road transport operators and public road administrators in Great Britain in 2010. The material derives from a survey that the Freight Transport Association (FTA) conducted in January 2011 among more than five thousands of its members as regards the immediate causes of traffic stoppages and damage they suffered due to two spells of heavy snowfall and icing of road surface in January and December 2010. The goal of this investigation was to provide the national Highway Agency with documentation on the chain of events explaining the technical causes of traffic breakdowns, vehicle incidents and accidents, road closures and supply chain ruptures. Based on this knowledge, several strategies improving serviceability of all roads in the UK and preventing the stock outs of critical commodities, such as medicines, heating oil and LPG have been devised (http://www.publications.parliament.uk/pa/cm211011).

One interesting observation is that the most immediate mitigation measure proposed here was to extend the current met-advisory service (limited so far to information on the current wind strength and wind strength forecasts) to also include the occurrence of snowfalls and their impacts on the quality of road surface and traffic flow capacity on the main running carriageways. The FTA proposed that the Highways Authorities should monitor the most exposed parts of road network and the critical key junctions in order to identify the “hot spots” prone to causing traffic disruptions and flow stoppages. Based on that, the alerts should be issued on impending curtailment of network capacity and throughput blocks.

In order to allow the operators to adjust their vehicle travel schedules, alerts for overnight operations were proposed to be issued by lunchtime and those for early morning departures, by the end of the previous working day. Another remedy envisioned was a temporal relaxation of the EU’s Drivers’ Hours Rules and Working Time Regulation by the Department for Transport which should allow transport operators to re-adjust the schedules and re-assign the goods traffic to diminished network capacity.

It is also interesting to observe that when asked whether Great Britain should not increase the general level of preparedness to improve resilience against future spells of harsh winter weather, the Highway Agency officials remarked that resources and measures available in countries more prone to heavy snowfall and freezing temperatures provide no guidance to what economically or technically is sensible for the UK (Chapman and Andersson 2010).
Early winter spells of extremely low temperatures, heavy snowfall and lack of preparedness at the Highways Agency as main causes of infrastructure closures, road blocks, traffic breakdowns and disruptions to regional trade flows in Great Britain in 2010

Traffic and cargo supply disruptions experienced in December 2010 as compared to January 2010

Disruptions caused by snowfall and icing of road surface in December 2010 were more acute, more widespread and more enduring than severe winter weather in January 2010. As a consequence longer stretches of motorways, trunk and local roads in England, Wales and Scotland remained closed for several days. Road gritting on large stretches of trunk roads was poor because the Highway Agency lacked people and equipment (though not salt) at the early stage of winter season. Besides, many short stretches of roads connecting depots to motorways and trunk road network were snow clogged because of poor prioritisation by local authorities of gritting tasks. After the local roads frequently used by HGVs were opened and finally gritted, their recovery was slow as the snow had compacted to ice during long periods of freezing temperature. The result was congestion, accumulation of idle time and arrival delays for all road users. As a result, the Scottish Government introduced short ban on all HGVs’ travelling on trunk roads during the most severe weather spells in order to release carriageway capacity to private commuters.

Impacts on freight transport operators and HGVs traffic

Poor ploughing and the lack of appropriate gritting left snow and ice on the roads. Driving on slippery surface caused loss of drive axle traction, jack-knifing incidents and loss of control on numerous vehicles: many HGVs skidded on driving lanes blocking motorways and/or trunk roads and causing even longer queues.

Breakdown of flow movement and cargo supply

Large amounts of snow deposits on exposed stretches of roads compacted into ice especially on uphill and downhill segments, causing loss of vehicle traction over long distances. This condition was further exacerbated by the lack of proper equipment; only seven per cent of the five thousand five hundred fifty five FTA members who responded to the survey had winter tyres mounted on their vehicles. Reason was that winter tyres cost 20 per cent more than all-season tyres. Besides, in Great Britain there is no legislation imposing usage of winter tyres. So, the operators who do not use winter tyres explained that the high fitting costs (downtime for swapping tyres over, storage costs of tyres not in use and greater tyre wear rates) hindered them from using this specialty equipment.

Impacts on logistics operators

Delivery schedules and consignment arrivals at points of consumption by business, retailers and consumers were severely shattered. Operators build resilience into trip planning to accommodate regularly encountered journey time unreliability and seasonal changes in network performance did not absorb the delays encountered. The following supply chains suffered the most from flow breakdowns: drugs, distribution of road salt, animal feed from manufacturers to farms, distribution of de-icer products to airports, movement of heating oil and LPG, and distribution of bulk milk in tankers and fresh food and drinks.

Crisis abatement measures

On the most exposed trunk road stretch, the Highway Agency used convoys of ploughs and salting vehicles to clear the thoroughfare for HGVs. The Department for Transport relaxed the EU Drivers’ Hours Rules and Working Time Regulation to allow FTA operators to catch up with deliveries. The government considered, but not yet commissioned the usage of agriculture machinery for snow clearing when dedicated equipment was overstretched.
4.2. Vulnerability of rail freight operators to winter and flood disruptions

The four case studies that follow illustrate how the rail freight companies, rail infrastructure providers and logistics operators in four European countries were hit by and dealt with operational disruptions that the harsh winter weather and floods brought upon them in 2010. This evidence illustrates the instantaneous relationship between the extreme weather and the operators’ responsive behaviours.

It shows that neither of the parties affected was adequately prepared to avert and/or neutralise all negative consequences. Efforts used to contain the impacts of infrastructure shutdowns and transport breakdowns reveal that the affected parties improvised their way out of crisis rather than drew on the priori preparedness and/or systemic risk management skills.

One interesting finding is that although all rail freight companies studied function in northern Europe where harsh winter weather is quite common, still none of them anticipated the extraordinarily cold spells which in 2010 brought their operations and infrastructure to a standstill. Because of railways’ specific position in logistics network, disruptions in rail cargo operations produced a chain of contagion which quickly spread to other supply segments. However, the railways bore the major brunt of weather-inflicted damage because they could not substitute rail freight transfer by alternative modes (as did shippers and forwarding companies).

Adding to the complexity was the fact that being the government-owned utilities, rail infrastructure operators, were not liable for direct business losses and other disutilities that infrastructure shutdowns imposed on rail undertakings, cargo owners and logistics operators. As a consequence, in addition to sharp spikes in operations and manpower costs, railways have also suffered from loss of customers, reputation and diminished business prospects in the intermodal freight market.

The cases make it readily visible that infrastructure closures rendered the railways’ crisis management futile and underscore the fact that the continuity of rail traffic and the reliability of cargo delivery are heavily dependent on infrastructure functionality. In order to avert the risk of stock outs and/or supply shortages at wholesale and retailer outlets, the logistics service suppliers moved cargo away from rail to road transfer.

These examples are instructive. On the one hand they reveal that mobilisation of ad hoc damage containment tactics showed effective at dealing with the unfolding course of disaster events. On the other hand, however, the lack of back-up systems and preventive resources magnified the scope of damage and the costs of adversity abatement. The crisis response behaviour revealed that all managers strove to alleviate the most immediate impacts in their own operations area rather than improving the overall operational robustness of the entire chain. Constrained by the rolling stock damage, infrastructure shutdowns and shortage of vital components destroyed by extremely harsh exploitation conditions, the targets turned to in-house human resources because this type of assets was easily available and effective at quelling the enfolding crisis.

Although all railway operators deployed extraordinary resources, they still could not stop the aftershocks spreading beyond their boundaries to upstream and downstream chain segments.
All these findings underscore the needs for a more systematic approach to risk assessment and strong leadership capable of dealing with risks at all supply chain segments through both resilience building and level-headed handling of enrolling crises.

In this context one interesting question arises: Why were all the affected business parties so badly prepared to tackle the extreme weather events despite being well accustomed to the harsh north European winter climate?

Evidently, one reason is that both the private and the state-owned freight railway companies avoid keeping larger stock of locomotives, wagons, spare-parts and reserve components as a result of their wide-spread adoption of lean production methods, along with demand uncertainty. As the price of multisystem locomotives reaches these days in Europe 3 million € while multifunctional specialty rail wagons require at least 0.5 million €, hardly any small rail undertaking or rail logistics service company has financial capacity to keep proprietary equipment and/or spare parts buffers on its balance sheet. Market uncertainty evidenced by seasonal and corridor-dependent spikes and slopes in demand for freight transfer makes that many new entrants neither own locomotives nor wagons, basing their entire service provision on time-limited lease contracts with specialty rolling stock and traction companies. This is also fortified by many countries’ depreciation rules in the tax code legislation where lower tax rates are charged on asset-free service providers.

As a rule, service, maintenance and repairs of rolling stocks, traction and IT equipment are also outsourced to external contractors. As it is widely admitted in managerial literature and practice, outsourcing may reduce the current costs of service provision but in return will also reduce the levels of operational robustness and output security due to delayed responses and/or longer delivery times for emergency items. As it is evidenced below, this way of doing business became quite expensive under the weather-induced crises.
Situational awareness and operational agility at dealing with extreme weather impacts - an interview with Chief Operating Officer at CTL Logistics of Warsaw, Poland, on how his company dealt with natural disasters in 2010

Q1: How did you deal with track line and infrastructure closures caused by harsh winter 2010?

It may sound quite strange, but during winter 2010 we have actually experienced less infrastructure shutdowns, less traffic stoppages and less partial network closures than we usually do. Reason was much lower volumes of traffic moving on the Polish rail network due to the lingering economic crisis and the consequent reduction of freight flows in Poland.

Q2: How did you protect your personnel, rolling stock and other assets whose effectiveness was threatened by cold, snow falls, flood, and infrastructure damage?

Heavy (wet) snow falls was a nuisance because they broke catenaries and fell trees along the track lines that blocked the network pathways. In addition, freezing fog glazed the catenaries and broke pantographs on several locos. Surprisingly, cold in the range of minus 15 Celsius and below did not inflict much harm on locos technical fitness, but temperature in the range of -1 /+ 1 Celcius combined with high humidity level caused shortcuts in locos’ electrical wiring. We protected our locos from freezing by keeping engines on empty runs before and after each journey. As a result, our loco drivers had to put extra working hours in emergency shifts, but this did not cause any worker complaints or labour conflicts. Organisationally, the entire operation went very smoothly and we did not lose any loco.

However, another serious disruption of our operations cycle was caused by frozen bulk cargo, especially coal. Frozen coal was extremely difficult to discharge especially at stations lacking de-freezing equipment. Yet, our clients were aware of this problem. They had sufficient inventories, which, however, were also frozen. Whatever delays it caused, these were not used by our clients as legal basis for penalties or compensation claims.

The flood disaster in spring 2010 has shutdown considerable swathes of Polish rail network. In May 2010 our company lost 600 000 PLN worth contracts for cargo transfer because of track damage and/or blocked connection to clients’ sidings. However, PKP PLK, the Polish Infrastructure Manager, kept us very well informed about the network conditions and provided guidance on detours through alternative track paths. In one case, high water flowing through the area where our rail shunting depot was located almost tipped over the walls threatening to overflow locomotives, railcars, fork-lifts and hoisting cranes. So, within four working hours we have evacuated the entire station to a safer site; our team was very flexible and efficient; it moved all equipment with high speed and within very narrow time window.

Q3: How were your timetables disrupted and what measures did you use to restore the consignment punctuality?

Actually, we mainly operate with individual client-adjusted timetables, which was possible in 2010 due to much lesser freight traffic as compared to volumes in times before crisis. This operations pattern renders more degrees of freedom by allowing us to adjust the departure and arrival times exactly to customer demands. Therefore, we were not much affected by cancellations of timetables and path-allocations. Our operational flexibility was the main asset that helped us to absorb the consequences of and to deal with these disruptions. Today, all these happenings seem as if they have taken place in a distance past. Now-a-day we’re facing and dealing with quite new and different types of challenges. We have realised however, that we need more operational flexibility in our system to be able to combat similar adversities in the future.
Situational awareness and operational flexibility at dealing with extreme harsh winter 2010 - an interview with
Chief Operating Officer at ERS Railways BV in Rotterdam, the Netherlands

Q1: How did your company respond to infrastructure closures, rolling stock breakdowns and shipment stoppages during winter 2010?

Since we operate in several European countries we had to deal with different intensity, different bad-weather events and different types of impacts. In Switzerland we had to stop all our rail container traffic for one week in January 2010 because the track line was blocked by unusually heavy snow falls. However, information about infrastructure shutdown reached us in advance so we were able to re-position our locos, flatcars and containers, and reduce the costs of standstill. Our customers were duly informed about this Force Majeur so nobody troubled us with penalties or compensation demands. After one week time our operations resumed. To do away with container backlog we increased the volumes of daily traffic. After just three working days we returned to normal operations status.

In Sweden the situation was different because there several of our trains were trapped by snow falls blocking connections between the feeder tracks and trunk line and could not return to the main operations depot after discharge of container loads at customer sidings. Besides, persistent low temperature of -20°C damaged rubber linings on our flatcars’ brake cables making the vehicles idle. This forced us to stay put until the cables have been replaced. The operation took quite many man-hours.

Q2: How high was the cost of extraordinary equipment repairs and train standstill, and how did you cover these outlays?

The costs were pretty high. They have been partially covered by our insurance and partially had to be absorbed internally. However, the highest cost was not caused by technical damages and/or the equipment idle time but by manpower overtime needed for keeping our locos running non-stop. But these are business risks which we are used to face and deal with anyway.

Q3: Did you learn any lessons from grappling with these adversities?

That we should have been better prepared; had more internal reserves in production system to be able to draw on our own emergency assets and reduce external reliance. However, we did not have much influence over infrastructure shutdowns. Recently, we have discussed with the Swedish Rail Infrastructure Administration what harms the network shutdowns and reduced network serviceability inflicted on our operations. We have presented them with bill representing our losses accruing from infrastructure closures. The Swedish people have launched a full-blown investigation into factors causing infrastructure downtime which, we hope may improve infrastructure security next winter. Still, we expect more harsh winters to come, and with that more infrastructure closures. We will simply need to live with that and be better prepared.

Q4 How much business did you lose because of traffic disruptions?

We did not lose any customers because we fulfilled all our contracts, though some consignments were seriously delayed. However, I am afraid that some prospective customers were put off by a fear that railway is not as reliable cargo supplier as road transport. It takes four-five years for a customer to re-design its distribution system from road to rail and I would think they will be even more cautious now than in the past before they consider rail. But I know also that road operators have struggled to meet consignment schedules last winter. So, it is impossible to say; time will show.

Q5 How are you going to cover the extraordinary costs and losses on you balance sheet?

Through higher revenues from new and hopefully more profitable contracts. That's how we usually survive.
Poor infrastructure conditions and lack of robust dispatch system - two reasons for container traffic disruptions during harsh winter 2010

– an interview with Strategy Director at Cargo Net, Oslo, Norway

Q3: How did the harsh winter 2010 affect your operations and service quality?

A broader picture is that Cargo Net is one of the few rail operators in Europe which managed to carry over 70 p.c. of consumer goods transported between the major cities in Norway. DB-Schenker and other international logistics operators are our important clients which means we operate in high-value high-time-sensitive container segment. This high market share was achieved through gradual improvement of our service punctuality which, after two years of persistent efforts reached 90 p.c. in 2010 (within 15 minute-time-window from the scheduled arrival time). Our supply reliability convinced clients they can safely move their cargo by rail. In many cases our clients went to their own customers, i.e., shippers and consignees to convince them they could rely on rail intermodal not only because it was more environmentally friendly but also because it was more cost-effective and equally reliable as road haulage. The 2010 winter weather brought about a rare combination of unusually heavy snow falls and low temperatures. This resulted in a range of infrastructure shutdowns and rolling stock breakages. First, Infrastructure Managers lacked enough snow ploughs to keep all tracks and interchanges snow free. Second, low temperature caused that wheels on some of our flatcars went to pieces. These disruptions reduced our flatcar fleet and supply reliability to 60p.c. meaning that considerable number of containers was not delivered on time. Our customers were aghast; they had to re-structure their supply operations towards road haulage. Further, we had to renew our spare wheel stock immediately and that showed difficult. As a consequence of this but also because of heavy ice accumulation on track surface, the deceleration time and the braking distance for wagons have increased. As a result, we were forced to run fewer and shorter trains. Yet despite fewer trains we had to increase the manpower at terminal because of technical emergencies. More people had to step in so that we did not breach the working time regulation. As a consequence we faced two adversary impacts at one time: our operational costs skyrocketed while the volumes of cargo along with customers’ trust plummeted.

Q2: How did you cope with these adversities?

To reduce the risks of stock out and unfilled orders at distribution centres, we had to re-position our resources. This required higher operational back-up and closer collaboration with Infrastructure Managers. However, our hands were tied: our trains were stopped by infrastructure shutdowns. Our customers demanded compensations for unfilled supply orders. Therefore, we started discussions with the Ministry of Transport and Communications who owns rail infrastructure in Norway to grant us rights to charge infrastructure provider with penalties for track closures and/or paying lower user charges after several track paths were out of service and delayed our freight trains’ arrival times. Still, paying considerable delay compensations was not the biggest harm to us. We consider that the loss of traffic which our clients re-located to road transport and the loss of our customers’ trust in our ability to supply on time are much more serious setbacks that threaten our business’ future.

Q3: How do you plan to resolve these issues?

This experience has humbled us. We have to regain the customers’ trust by making our freight dispatch system more robust. That means that several elements of our command and control system have to be re-engineered while collaboration with infrastructure provider reinforced. However, before we re-launch a more reliable container dispatch system we need a guarantee from Infrastructure Managers as regards higher standards of network reliability. And that’s the critical area on which we are working right now.
Mixed taskforces at combat of harsh weather impacts during winter 2010
– an interview with Managing Director of The Swedish Train Operators Association, Stockholm

Q1: Did you observe any impacts of long-term climate change on your members’ operations?
I can confirm that over the last five years rail operations in Sweden have been more frequently disrupted by floods which damaged large swathes of rail infrastructure. As a consequence, both the passenger and freight traffic on the affected track segments had to be either phased out and/or re-routed to alternative transport modes not only because of the needs for comprehensive network repairs but also because of reinforcement of track subsurface and construction of new and more advanced drainage systems. Completion of some of these projects took not only weeks but months. Some works will linger over many years.

Q2: How did you tackle the impacts of extremely harsh winter 2010?
During winter 2010 the south-western Sweden was affected by unusually low temperatures and heavy snowfalls which begun in December 2009 and lasted until March 2010. During this period the volume of rail cargo in Sweden was reduced by entire 20 percent. We have been taken aback by a combination of low freezing temperatures and heavy snow storms. Strong winds formed clouds of light snow which stuck to wagon undercarriage, immobilised vehicle movement and blocked track lines between Halsberg terminal and main Swedish harbours. The Halsberg marshalling terminal which is a centre of Sweden’s rail freight operations was closed for 14 days. This shutdown alone cost between 200 and 250 million SEK. This amount has been further attenuated by phasing out of 20 rail shuttles between Halsberg and Gothenburg and re-location of large cargo volumes to road haulage. Interestingly, our operations in northern Sweden went mainly unaffected.

Snow accumulated under flatcars and undercarriages has dramatically amplified vehicle weights causing the wheel axles to break. We had no buffer stocks of spare wheels or additional personnel capable of replacing broken units on short notice. So, we had to sign new agreements with repair workshops. The smallest rail operators have of course suffered the most because of resource scarcity. In addition, wagon brakes system also failed on slippery track surface.

Further, many tonnes of temperature-sensitive goods has frozen while still in wagons because of delays in transshipment to truck. But all-in-all, the total amount of cargo damaged was relatively small as compared to the tonnage salvaged and delivered safely.

Q3: How did you fight these adversities?
Shippers, rail operators and Trafikverket formed task forces to jointly combat these adversities. To be effective, our decisions had to be based on real-time information. Trafikverket fed us with information about impending and/or imposed infrastructure closures, lines open for detour and serviceability of the remaining network. To facilitate the most critical consignments, our clients handed us a list of most urgent shipments along with goods’ physical conditions (i.e. tolerance for cold and transit time). These data helped Trafikkverket to re-assign traffic demands to considerably downsized network capacity through priority rules which discerned between train categories 1) that had to be given green light immediately, 2) had to be re-scheduled to new time windows and new track paths over the next 12 hours, and 3) that could be kept at sidings or marshalling yards longer than 12 hours. Eventually we got the most critical tonnage of international cargo traffic out and moving.

Q4 Did you learn any lessons?
Trafikverket has beefed up its security standards for winter. Our members increased the spare parts buffers and staff reserves because they have realised that better preparedness will improve their crisis management capacity. However, infrastructure still remains a big impediment because the repairs and upgrade projects will not be completed within just one-year.
4.3. **International survey of freight and logistics companies**

An international survey was carried out to collect data on impacts that extreme weather over the last five years has exerted on operations and financial performance of logistics, freight transport companies and infrastructure providers in four European countries and measures undertaken to mitigate and/or avert weather-induced risks and/or negative consequences. The respondent sample is described in Table 10 below.

**Table 10. Respondents in Survey on Extreme Weather Impacts (2011)**

<table>
<thead>
<tr>
<th>Company’s Service Provision</th>
<th>Austria</th>
<th>Finland</th>
<th>Norway</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport by Sea</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Transport by Road</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Transport by Rail</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air freight</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Intermodal/Multimodal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inland Waterways</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistics/Forwarding</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Rail Infrastructure Provider</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Road Infrastructure Provider</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Inland Waterway Infrastructure Provider</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>14</td>
</tr>
</tbody>
</table>

All respondents (so far from Finland, Norway and Austria) indicated that the quality of their service, and consequently the ability to serve customers has been affected by weather-induced disruptions which occurred over the last five years. The most adverse weather events involved heavy snow falls/storms, accumulation of ice on roads and rail networks, unusually persistent spells of low temperature, and floods and draughts. All together, these events have temporarily jeopardized the focal firms’ ability to upheld the usual operations standards and meet customer demands. Although some informants worried that delivery tardiness has damaged their reputation as reliable service supplier, still majority maintained that their customers understood the force majeure nature of weather-related adversities and did not charge the statutory penalties. All logistics and transport companies maintained the need for well-functioning and reliable infrastructure as a condition for their own supply robustness, especially during winter.

Some logistics suppliers mentioned that the quality of their service suffered due to road closures, vehicle accidents, infrastructure shutdowns, and breakdowns of rail freight traffic. Informants from Austria also mentioned draught and floods which damaged the inland waterway port infrastructure and hampered navigation at Danube One global logistics operator mentioned cargo and HGV damage, but also delivery delays and occasional disruptions. These occurrences brought cargo (and occasionally also passenger) transfer to a standstill, and postponed consignment arrivals and/or load pickups.

One respondent performing logistics on behalf of fish farming estate in an outskirt district of western Norway mentioned eight HGV accidents which happened during the three winter months in 2011 which were caused by poor gritting of road surface and slippery carriageway on steep and winding uphill road. Each accident blocked both lanes of the driveway for at least 4-5 hours before the truck salvage equipment was dispatched and traffic resumed. Since there is no other lateral road linking this industrial estate with the trunk road network, all fish farming and
fish processing companies remained cut off for at least 48 hours from other parts of the country and the regional airport from where they airship salmon to Asia and the US. As a consequence, the fish processing companies without cold storage suffered financial losses in the magnitude of 1.5 million NOK because of deterioration in fish quality and loss of the pre-paid airfreight bookings.

Still, the number of locations without lateral road connections is quite low even in scarcely populated western Norway, so the most common adjustment that HGV drivers undertake when the main road is blocked is to drive over detour (see the model simulation of trucker adaptation to road blockage later in this report).

Yet despite all these negative consequences, almost none of the survey participant have registered monetary values of extra expenses which the bad weather imposed upon them. One exception was a global provider of express and parcel shipments from Norway who revealed that the weather-induced traffic breakdowns and delivery delays in 2011 added 10% or 3 million Euros to the company’s operating costs. One road infrastructure provider in Finland who did not want to reveal the scale of additional outlays due to the nature of its business admitted however, that the weather-induced losses were quite “significant”. Yet, the majority of transport and logistics operators pointed out that the short-term impacts such as consignment delays did not impose many long-term bearings on companies’ financial conditions or market standing.

Majority of transport and logistics operators expected that the frequency and severity of extreme weather events may increase in the future, while few others did not believe so. Although all respondents found 2010 - 2011 winters exceptionally harsh as compared to the “standard” Nordic severity expectation (due to much heavier snowfalls, more ice on roads and rail tracks, and protracted periods of cold temperature), still they did not define these occurrences as high-impact threats to their business.

Yet, some preparations have been made; buffer stocks of specialty equipment such as wheel chains preventing vehicle skidding on icy uphill roads have been increased. Some interviewees said that their companies improved communication with drivers to secure real-time information on road traffic conditions. However, logistics integrators emphasized that they do not take responsibility for HGV driving; this task has been out-sourced to truckers who need to do their best to arrive on time in any weather. Some logistics and inland port operators mentioned flexible budgeting in order to reserve resources for extra-ordinary events and/or these events’ consequences like purchases of specialty equipment. One global logistics supplier indicated that weather-related risks are included into its regular risk assessment procedures performed at all operations sites worldwide. In addition environmental management system is in place to monitor development in environmental conditions at multiple locations; the company has also installed emergency generators to be prepared for unexpected energy supply shutdowns.

High uncertainty related to whether the risks imposed by bad weather will materialize, affect the respondents’ business, and whether the resultant damage will result in financial losses was perceived as the biggest impediment to preparedness-building. Many respondents maintained that they did not have sufficient knowledge as to what kind of weather threats may come about in the future, so it was impossible to be prepared for these unknowns. Under these circumstances, all informants considered that preparedness-building was too expensive: keeping manpower
standby, buffer stocks and/or idle equipment were neither strategically nor operationally wise. Yet, all business managers required higher preparedness from private and public infrastructure providers and quoted unsatisfactory performance on the part of these organizations as a reason for their own woes. Some large companies with global scope of operations established in-house teams who offered internal advice on resilience-building and management of business risks related to environmental hazards. Some even mentioned infusion of some slack in the structure of supply chains in order to be able to deal with unexpected disruptions. Besides, many informants expected better information from authorities, met-services, sector organizations, and professional associations they belonged to as regards the impending weather-related risks and the modes of risk management (Fabrikant 2009).

The Finnish survey's more detailed report is in the appendix.

4.4. Port case: Limassol, Cyprus

General characteristics and infrastructure

The Limassol Port is situated on the northwest coast of Akrotiri Bay on the outskirts of the country's second main city in terms of population and economic significance. It is the largest port in Cyprus, serving most of the island's seaborne cargo and passenger traffic. It handles two thirds of the total container traffic locally generated and trans-shipment as well as the entire volume of grain imports. Similarly, over 90% of the country's passenger traffic is presently served by this port. The port is comprised of two harbours and two anchorages. The commercial harbour is the largest, and is capable of handling vessels up to 820 ft size for berthing in 45 ft of water. Berthing is unrestricted, but the harbour is very busy and berthing space may not be available. It is entered through an approach channel which is 49 ft deep and 492 ft wide between the ends of two breakwaters. A fleet landing is established on the north end of the inner harbour at the North Quay. Port working hours are 0600 - 2400 local time (L). As a container port, Limassol provides two terminals with six gantry cranes and a total annual capacity of 600 000 TEUs. (Source: Limassol Port Authority).

The port's new container terminal with a draft of 14 meters along the quay is a part of the first phase of the Limassol Port's development plan scheduled to be completed by the year 2010. Limassol Port has acquired recently two new tug boats in order to assist the handling of increasing number of bigger vessels. Additional improvements of facilities at Limassol Port include the expansion of the storage capacity of its grain silo, the construction of a significant number of dolphin berths on the south part of the basin, the upgrading of the western multi-purpose quay into a post panamax vessel facility as well as the extension of the passenger terminal. In addition to being a major container trans-shipment centre in the Eastern Mediterranean, Limassol is also an important cruise liner hub for mini excursions in the region as well as a main stopover point for international liners cruising in the area.

The Port of Limassol has two container terminals: The East Container Terminal with an annual capacity of 150 000 TEU’s per year and the West Container Terminal with an annual capacity of 450 000 TEU’s per year; combined they provide an estimated capacity of 600 000 TEU’s per year, (actual traffic during 2010 was 348 358 TEU’s), serviced by 6 gantry cranes (2 Post Panamax and 4 Panamax type) and their “unit of efficiency” is moves per hour; how many containers they are able to load/unload. Post Panamax type cranes are capable of an average 40
moves per hour (35-45 moves per hour) while Panamax cranes are capable of an average of 25 moves per hour (20-30 moves per hour).

Considering berthing space, the East Container Terminal has a length of 480m, water depth of 11m and no special characteristics, while the West Container Terminal has a length of 620m, a depth of 16m and a ro-ro Ramp 50m wide. The stalking yard is 200 000 sq.m. for each terminal, with 29 reefer installations and 4 000 slots for East Terminal and 5 000 slots for West Terminal. The container freight station is 37 600 sq. m. and transfer and stalking equipment (servicing both terminals) is shown in table below.

Table 11. Port of Limassol equipment inventory
(Source: Limassol Port Authority).

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transtainers</td>
<td>4 (40 t.)</td>
</tr>
<tr>
<td>Stradle Carrier</td>
<td>7 (35 t.)</td>
</tr>
<tr>
<td>Top Loaders for empties</td>
<td>5 (30 t.)</td>
</tr>
<tr>
<td>Forklifts (Hyster)</td>
<td>4 (44 t.)</td>
</tr>
<tr>
<td>Tug Masters</td>
<td>20</td>
</tr>
<tr>
<td>Trailers (8 wheel units)</td>
<td>80</td>
</tr>
</tbody>
</table>

In our analysis, we will consider a ship of 4 000 TEUs served by one Post Panamax Crane. As previously mentioned, such a crane has an average move per crane per hour of 40, which means it can unload 800 TEUs per day (a day’s shift is 20 hours long, but if asked, 24 hours can be provided), meaning it needs 5 days to unload said cargo, totalling 100 hours. This is under normal day conditions.

In order to assess the economic cost of extreme weather events on the port of Limassol, one must take note of the general rules considering prevailing weather events all year round and how these affect the various stages of operations. For the Limassol port, the prevailing weather conditions are as follows:

General characteristics of the Harbor as Haven

- The New (commercial) Port of Limassol is a relatively safe port under all weather conditions. Caution is advised during strong easterly winds and waves for ships anchoring, arriving or departing.
- Because of the orientation of the entrance, the new harbour offers good protection from waves from all directions. The older harbour is well protected, but small boats may have problems entering during strong easterly winds. During such situations small boats should still be able to enter the commercial harbour.
- The anchorages are exposed to winds and waves from northeast clockwise to southwest. Waves may reach 13 ft in the anchorages. Heavy swell generated by persistent (2-3 day duration) easterly winds may last up to 10 hours after the wind ceases.
- A typical winter storm lasts 2-3 days and can cause 7-8 ft waves.
- When westerly winds occur, moving anchorage to 1 nautical mile south and west of port breakwater will reduce the fetch for waves for smoother small boat operations.
- Vessels can anchor in an anchorage area located east extending to the southwest of the new harbour entrance. Also, vessels can use the anchorage located about 1/2 n mi southeast of the smaller harbour. The anchorages are very congested, however. Hold-
ing in the anchorages is good on a bottom of mud and sand. No anchor dragging has been reported in over 20 years for vessels with good ground tackle, even in winds of gale force. If conditions in the anchorages are severe, Episcopi Bay on the west side of the Akrotiri Peninsula provides good shelter from easterly wind and swell.

**Visibility**
- Visibility is mainly good or very good throughout the year. Fog or poor visibility occurs 3 - 4 times a year usually confined to early morning in spring.
- Fog occurs when the air is humid and there is little wind. Visibility is reduced to near zero starting around 0600L. Port operations may be interrupted but the fog usually clears by 0830L, 1000L at the latest.
- Southeast desert winds bring dust to the area, but normally is not a problem.

**Currents and tides**
- Tides are negligible at Limassol; currents are wind driven and are typically not a problem.

**Hazardous Weather Conditions**

**Spring**

Weather during March and the first part of April is similar to that of winter, but spring is noted for periods of unsettled winter-type weather associated with increased occurrences of desert depressions (North African cyclones); otherwise spring weather is much like summer weather.

Limassol experiences precipitation on an average of 7 days during March, 4 days during April, and 3 days during May. The port of Limassol experiences fog 3-4 times during the spring season. Fog may reduce the visibility to near zero at dawn, but it usually clears by 0830L, 1000L at the latest.

Warm southeast desert winds (Scirocco) occur most frequently during March - April. These winds can last 1-2 days. Extreme anomalous radar and radio propagation are likely because of strong low level inversions.

Desert depressions (North African cyclones) develop over the desert region south of the Atlas Mountains, and are more likely to occur during spring than any other month. These systems usually move northeastward upon reaching the Tunisia/Gulf of Gabes region, but may continue moving eastward just south of the North African coast. Since various tracks are possible, it can be very difficult to forecast when and if a desert depression will affect the eastern Mediterranean. Of special concern to the forecaster in the eastern Mediterranean are the desert depressions that move eastward just south of the North African coast during spring. These systems are hard to track because of the scarcity of timely surface data over North Africa. If the depressions deepen, they are likely to move northeastward. If a desert depression moves out over the water, warm, southeast to southwest desert winds become the primary weather phenomenon associated with it.

The Cyprus depression develops in the lee of the Taurus Mountains of Turkey in the general region from the Gulf of Antalya to Cyprus. These cyclones usually become most intense from November through April, so they are most likely to affect the weather at Limassol during the first part of the spring season.
Summer

Summer is characterized by settled and dry weather with persistent daytime westerly winds. This is due to the monsoonal effect where a heat trough over southern Asia extends westward over Turkey. Higher pressure persists over the relatively cooler sea surface of the Mediterranean.

Precipitation statistics indicate that rainfall is unlikely during the summer. Records for Limassol show that precipitation occurs on an average of one day in June, zero days in July and August, and only one day during September.

Local authorities at Limassol identified a daytime, moderate, westerly wind, known as Bouentes by some mariners. The wind is a result of cyclonic flow over the Cypriot coastline from a mesoscale thermal low near the island center, formed from daytime heating. The salt lake, west of the port, would provide reduced friction region thus keeping the wind strong as it passes over the peninsula. The prevailing winds sometimes reach near gale force (Beaufort 5-7, 8-17 m/s) in the afternoon making boat work uncomfortable. If winds are prevalent by 1000L, moderate winds can be expected in the afternoon.

Autumn

The autumn season in the Mediterranean area is short, usually lasting only for the month of October. It is characterized by an abrupt change from the relatively subdued summer weather to the unsettled weather of winter. By the end of the month, the extratropical storm track has moved southward from its summertime location over Europe, and extratropical storms again transit the Mediterranean region. The threat of strong northeast to southeast winds increases as the month progresses.

Precipitation frequency starts to increase by the end of the month. Records for Limassol indicate that rain can be expected on an average of 3 days during the month of October.

Winter

During the winter season the Eurasian land mass north of the eastern Mediterranean Sea is very cold in comparison to the sea surface temperature near Cyprus. Upper level westerlies are often found over the Mediterranean during this period, resulting in cyclonic activity, unsettled weather and strong winds.

Local port authorities state the most common hazardous weather condition during the winter season is a combination of easterly winds (Levante) and waves and that 23 days of stormy weather/easterly winds can be expected per winter. A typical winter storm lasts 2-3 days and winds could reach gale force. A specific cause is anticyclonic flow from a high pressure over Turkey and low pressure to the south near Egypt. The resultant pressure gradient brings northeast to southeast winds to the Cyprus area.

In an average year, Limassol receives rain on 6 days in November, 13 days in December, 14 days in January, and 12 days in February. Thunderstorms are primarily a winter time occurrence. Waterspouts are occasionally observed to the west and south, and sometimes move on
shore near Limassol. Heavy rain is likely near frontal boundaries and along topographical barriers. Such barriers would likely include the mountains north of Limassol.

The Cyprus depression develops in the lee of the Taurus Mountains of Turkey in the general region from the Gulf of Antalya to Cyprus. These cyclones usually become most intense from November through April. Weather conditions to the west of a Cyprus depression are typical for the classic case of cold air moving over relatively warm water, i.e., strong-to-gale-force, squally winds with heavy showers. Near gale to gale force southwest winds can occur ahead of a cold front from depressions moving east from Crete.

**Sum-up**

Winds over 7 Beaufort will ensure a stop in the unloading operation, while winds in the scale from 5-7 Beaufort will create difficulties and slow down work. The records for the Port of Limassol during 2009 show that a total of 224 episodes of 5-7 Beaufort were recorded, whereas only one over 7 Beaufort episode was recorded during the period.

Heavy rain and fog will impede or stop operation altogether due to poor visibility. Considering rain, there were 35 episodes during 2009 where rain exceeded 2.5mm, of which only 10 exceed 10mm/hour and for fog, there are no records but it is safe to assume that these do not exceed 3-4 episodes per year.

Excessive heat during summer months, combined with high humidity will also ensure in a stop in the unloading operations, while high heat will also slow down work and productivity. During 2009, in Limassol’s port, the discomfort recorded due to excessive heat and humidity is as shown in table below.

<table>
<thead>
<tr>
<th>Time</th>
<th>Discomfort episodes</th>
<th>Severe discomfort episodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0600</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>0900</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>1200</td>
<td>62</td>
<td>21</td>
</tr>
<tr>
<td>1500</td>
<td>55</td>
<td>12</td>
</tr>
</tbody>
</table>

It is important to note that measurements of discomfort (based on the combination of temperature and humidity) are confined to daytime hours. There are no records of high humidity or discomfort for night-time.

According to the Cyprus Port Authority, the most common weather events that create problems are rain, winds, excessive heat and fog (following table). All things considered, one cannot say that extreme weather events are considered a serious problem in Limassol Port. They do, however, create hindrances (especially heat and wind) although these are minor, as reported by Limassol Port Authority. Weather conditions that can stop loading/unloading are confined to 10 events for rain, 1 event for wind, 4 events for fog and 50 events for heat discomfort. The duration of these is, however, unknown; heat discomfort can be estimated as 2 hours per episode, and fog as 3 hours per episode. Rain and wind, however, are much more elusive: Duration of
wind gusts and intense rain are difficult to estimate, especially since the decision of how these affect the port lies with the Port Authority.

Table 13. Extreme weather events and their impact on loading and unloading of bulk cargo and containers

<table>
<thead>
<tr>
<th>Weather event</th>
<th>Containers</th>
<th>Bulk Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>Restricts visibility and thus leads to delays. In case of heavy rain, all loading/unloading stops</td>
<td>Loading/unloading stops for the duration of the event</td>
</tr>
<tr>
<td>Wind (&gt;7 Beaufort)</td>
<td>Affects cranes and personnel and thus leads to delays</td>
<td>Affects cranes, cargo and personnel - leads to delays</td>
</tr>
<tr>
<td>Fog</td>
<td>Restricts visibility - leads to delays</td>
<td>Restricts visibility - leads to delays</td>
</tr>
<tr>
<td>Heat</td>
<td>Affects personnel - leads to delays. If combination of heat and humidity is prohibitive, all operations stop</td>
<td>Affects personnel and may lead to delays. If combination of heat and humidity is prohibitive, all operations stop</td>
</tr>
</tbody>
</table>

Considering the economic cost of such hindrances is difficult: there is no countable loss since stop operations are compensated with extra stuff and longer working hours. There is not a serious problem of congestion within the port for extreme weather events to intensify and Limassol Port Authority claims that such costs are negligible. Also, traffic fluctuations are of extreme importance: it is quite different to have a stop operation when port traffic is high and quite another matter entirely when port traffic is low.

However, the effect of extreme weather events on Limassol Port might intensify in the future. The fact that weather events, especially extreme heat, seems to appear more frequently might elevate the “insignificant problem” status of such events to “considerable problem” one. Limassol Port can shrug off such problems for now because it does not face an immediate congestion problem; a case not shared by most European Ports, especially busy ones. Since weather events do affect the whole chain of operations and especially loading and unloading cargo, preventative measures must be addresses. Something that does not constitute a problem at present does not mean that it will not be one in the future.

4.5. Summary and conclusions on case studies and surveys

The above attitudes indicate that business people in transport, logistics and infrastructure provision and management sectors did not have a good grasp of linkages between the probability of extreme weather and the risk of company damage. Despite the fact that many transport and logistics managers mentioned they regularly check the met-reports and weather forecasts in order to update the routing rosters for vehicles, semitrailers and rail wagons especially when weather was bad, still they all expected more assistance from authorities in dealings with weather impacts. Therefore, they could not carry out the risk tolerance appraisal and take decisions as to which preventive and risk mitigation strategies to employ. In the absence of understanding of their own risk tolerance threshold, they removed extreme weather hazards from strategic decision-agenda (Tang 2006).

The transport infrastructure providers admitted that the serviceability of road and rail networks has suffered considerably due to bad weather conditions over the last five years. However, maintaining the infrastructure functionality under the prolonged spells of heavy snowfalls and
high ice deposits on carriageways (and sailing tracks) would require more frequent snow clearing and more gritting. Higher costs of securing infrastructure serviceability under these circumstances would require higher budgetary allocations from government. This, however, was not feasible under the current economic conditions.

Also the case of Limassol port underlines the obvious weather prone risks and due to climatological differences and not surprisingly different weather phenomena arose forth, such as heat, which caused mainly productivity losses and increase of working accident risks. But as with other cases, few practical measures could be pointed out how to mitigate these risks, as these risks were not considered as a major source of operations impacting hazards.

These findings corroborate the results from March and Shapira’s (1987) study of managers’ attitudes towards risk in general, which have also established that

- Managers were quite insensitive to estimates of the probabilities of possible outcomes
- Managers tended to focus on critical performance targets which affected the way they managed the risk, and
- Managers made a sharp distinction between risk-taking and gambling

The first finding can be explained by the fact that managers do not trust, do not understand, or simply do not use the precise probability estimates. This is consistent with investigations performed by other researchers (Kunreuther 1976 and Fishhoff et al. 1981).

Since managers are insensitive to probability estimates, managers are more likely to define risk in terms of magnitude of loss such as “maximum exposure” or “worst case” instead of the scale of anticipated losses. The second conclusion is based on the observation that the quality of managerial accomplishments is measured by a set of performance targets. These metrics cause that managers become more risk averse (or risk prone) when their performance is above (or below) certain targets. Finally, the third conclusion is based on the fact that companies tend to reward managers for “good outcomes” but not necessarily for making “good decisions”. The more fragmented and specialised the service and operations chains become, the more focus is put on each actors’ own slot in the value chain and the less there are holistic approaches. The contractual structures and incentives are likely to follow this line.

Furthermore, several authors (Closs and McGarrel 2004; Rice and Caniato 2003; and Zsidisin et al. 2004) explored the managers’ attitudes towards managing the risk of supply chain disruption through several case studies and concluded that

1) Most companies recognized the importance of risk assessment programmes and used different methods, ranging from formal quantitative models to informal qualitative plans, to assess supply chain risks. However companies apportioned little time and resources to mitigation of supply chain risks, not to mention weather risks.

2) Due to few data points, good estimates of probability of occurrence of any particular disruption and the measurements of exact impacts of different disaster types are difficult to obtain. This makes it difficult to perform cost/benefit analysis and/or assess the degradation in returns on assets damaged in order to justify to the company’s leadership and/or shareholders the necessity of risk reduction programmes and holding of contingency-reducing assets.
3) Firms tend to underestimate the risk of disruption in the absence of an accurate supply chain risk assessment. As a consequence, many managers tend to ignore the possible impacts of unlikely events. This may explain why so few firms take commensurable actions to mitigate supply chains risks in proactive manner. As aptly summarized by Repenning and Sterman (2001), firms rarely invest in improvement programmes in proactive manner because “nobody gets credit for fixing problems that never occurred”.12

---

12 The latest World Economic Forums Global Agenda Council which took place on October 12th in Abu Dhabi, UAE recognized at last the critical issue of Supply Chain Risk. The Logistic and Supply Chain Council, chaired by Professor Alan McKinnon form University of Edinburgh admitted that modern integrated supply chains are complex, global and lean. This, in some respects, became a double edged sword. It has meant that when supply chains are working well, inventory is minimized whilst customer service improves. However, it has also left them vulnerable to external “shocks” and in recent years, their fragility has been exposed. Although individual natural disasters happen only rarely, the chances of weather-related chain disruptions occur more frequently. The risk does not stop here. Given the present economic environment, it is not far from imaginable that the air and shipping sectors may suffer some sort of meltdown in the not-so-distant-future. Identifying these risks, mitigating them as well as developing a robust response is one of the key projects in which the Logistics and Supply Chain Agenda Council is involved in 2011/2012. Only by highlighting the impact of these risks will manufacturers and retailers start to fully realize the exposure of their business.
5. Modelling of weather-induced freight flow breakdowns

5.1. Applicability of values of time in freight transport to loss of supply chain robustness due to flow breakdown

As observed, the above valuations by transport operators and shippers of variability and consistency in goods travel times and arrivals are confined to small time deviations (within one hour and/few minutes against the scheduled arrivals/departures) caused by random disturbances. In relation thereto, Bates et al. (2002) have aptly observed that these valuations do not apply to predictable variation arising from the varying levels of demand by time of day, day of week and the seasonal effects which are incorporated into vehicle fleet scheduling, warehousing and inventory planning and production cycle management.

Further, since extreme weather events may cause flow breakdowns, vehicle incidents and accidents, load sheds and infrastructure shutdowns, they also lead to temporary reductions in carriageways and/or rail network capacity. By so doing, they produce unpredictable variation in journey times and consignment arrivals. As shown, weather-inflicted disruptions in goods movement and/or infrastructure throughput reduction generate derived impacts which increase supply variance within the entire logistics chain organisation, with harmful impacts on particular segments.

Supply variance affects 1) transaction costs (due to disturbance in freight handling, transshipment timing, vehicle routing and transit time calculation) for transport operators, 2) stability of manufacturing processes and inventories in stock and in transit at production plants, and 3) the overall operational robustness of distribution and retail outlets. Unfortunately, these outcomes have not yet been subjected to systematic financial and/or economic appraisal studies. As a consequence, application of values of time assigned to random freight travel variations to weather-inflicted disruptions should be done with utmost caution.

Research conducted by Bates et al. (2002) as well as by Copley et al. (2002) has established that impacts of medium-term unpredictable variability in road freight travel time caused by bad weather should take into account the formation of queues because such weather events reduce the road capacity causing traffic streams to exceed available carriageway on a transient basis. As a result flow velocity is reduced and traffic brought to a standstill. Depending on the incident duration, some traffic participants may opt for detours in order to avoid/diminish the waiting time on main artery.

Heavy snowfalls may also immobilise trains on rail networks and/or sidings causing train queues and rail traffic stoppages. In this context it is more proper to speak of value of freight travel time loss due to unexpected lengthening of vehicle travel time, delays in consignment arrivals and additional expenses for transport operator, shippers and/or consignees (Zamparinin and Raggiani 2007).
5.2. Simulation of flow breakdowns

However, the simple queuing theory (Daganzo 2002) does not address the full complexities of traffic behaviour on motorways and highways following breakdowns of freight vehicle travel on particular stretches of motorways. In addition to aggregate traffic behaviour under the condition of flow breakdown following weather events, there are also merging and weaving issues, particularly when motorways converge. The problem is extremely complex, especially for merge situations where one movement may dominate. According to Bates et al. (2002) similar flow breakdown issues would arise with reference to diverges, for example, when capacity problems on the diverging slip road lead to a tailback on the main carriageways.

In order thus to explore and assess the first and second-range of traffic reactions to flow breakdowns along some European corridors, a micro-simulation of different disruption cases may be useful. Such simulation may model the different traffic breakdown incidents, patterns of traffic-redistribution (diversions), magnitude of disruptions in vehicle travel time, the resultant increases in vehicle travel costs and other expenses, and finally, impacts on shippers and consignees. Starting from a baseline of undisturbed/scheduled freight movement along the corridors studied, this method may identify the weather-related cases when flows were severed and traffic reassigned. Simulation of time and values lost due to traffic diversion to alternative routes on upstream carriageways may then be extrapolated to more numerous similar cases.

Consultations with freight transport managers and researchers working on freight travel appraisal, plus findings from case studies on weather-induced harms indicate that for the first approximation of weather-induced additional value of freight travel time loss a factor cost method maybe used (Zamparinin and Reggiani 2007). Odgaard et al. (2005) mentioned the following key expenditure posts as directly affected by flow breakdowns and changes in vehicle routing and running time:

- higher vehicle operating costs due to longer travel time (fuel, maintenance, tyres, vehicle taxes, insurance and material value depreciation)
- higher drivers wages (including overtime and employment of additional drivers due to overruns of drivers’ hours rules and working time regulations)
- loss of overheads due to vehicle idle time.

Depending on circumstances, the following extraordinary outlays may also be incurred by transport operators, shippers and consignees:

- higher expenditures due to disruption in original fleet assignment schedule and needs for additional vehicles
- vehicles repairs (in case of damage) and/or vehicle salvage costs
- depreciation of goods in transit and/or
- production breakdown at manufacturing plants and/or
- stock-outs at distribution centres and/or retailer outlets.

The last two items are optional because not all freight flow stoppages lead to depletion of material inventories at manufacturing and/or storage facilities.

Reduction of intrinsic utility of goods in transit and/or under warehousing due to longer transit and/or storage is well known, particularly in wholesaler and retailer industry. As a result, the interest rates of 30% or even 40% are often imposed on inventory in pipeline to account for the
risk of losses caused by spoilage, physical decay, en-route damage, pilferage, obsolesce, and load shedding caused by road accidents.

In addition, calculation of these costs needs also take into account the commodity category, and where in the supply chain structure the flow has been ruptured; whether the disruption affected the freight traffic moving between logistics hubs, manufacturing plants, distribution centres or retail outlets and the length of arrival delay. One can expect that the busiest flows such as those being under requirements for JIT Instant Delivery (particularly in parcel delivery segments) and Quick Response regime will have the highest values of time lost.

Finally, one needs also to keep in mind that almost 50% of all freight transport vehicles in Europe travel without paid load or with less cargo than their permissible load-carrying capacity allows. This implies that the values of time lost should be adjusted by the ratio of empty and/or partially utilised vehicle/ trips vs. trips with full vehicle utilisation. The same applies to load carrying units hauled by railways on return trips, particularly chemical tank containers and reefer containers.

5.3. **Consequences of HGV traffic breakdowns**

Taking stock of the above one may summarise that the variability in freight travel time arises from three main sources:

1) Random effects which cause small delays/spreads between departure, transit and arrival times captured by values of time. small penalties for tardiness and time saving gains

2) Variations in journey time between different time periods, days, seasons, caused by different traffic conditions, including *known and anticipated factors*, such as long-term road-works captured by transport planning, storage, warehousing, and inventory and production management regimes, and

3) Variations in travel time at specific points of time caused by *unexpected* traffic breakdowns caused by extreme weather events which invoke temporal infrastructure shutdowns, vehicle incidents/accidents and traffic stoppages. These incidents reduce temporarily the carriageway capacity, flow velocity, and bring traffic to a halt inciting (some) drivers to divert to alternative/parallel routes.

Since variations in travel time classified under 3) are unpredictable for individual journeys, the value of freight travel lost due to this type disruption is not yet assessed through transport economic evaluation method.

Ahuja et al. (2002) have observed that since travel time variability caused by unpredictable incidents increases the standard deviation of journey times, the calculations of time lost should be link-additive in order to comprise the whole journey impacts. Therefore, delays on individual should be accumulated to assess the whole journey impact. Thus the disutilities caused by weather-related incidents or the severity of delays should reflect: a) consignment delays due to incidents, and b) unexpected lengthening of travel time for vehicles and goods caused by these incidents.

Further, the length of delays caused by incidents will be determined by:

- the incident rate of occurrence during given period of time
- the total number of vehicles using a given carriageway (inbound and outbound traffic)
- the amount of “spare capacity” on a given lane at a given point in time
- the number of lanes available along a given corridor
- the number of blocks and the capacity reduction on the main running carriageway and the remaining lanes
- the “build up duration” of the incident. That is the length of time between the incident occurring and the carriageway being cleared
- the amount of traffic diverting in response to the incident.

The lane blockage effects and the build-up duration on motorways caused by adverse weather conditions may vary further depending on the scope. With respect to that one may discern between:

a) Single lane incidents which blocks only one strip of the running carriageway which usually have medium average build-up duration a low carriageway blockage effect
b) Multi-lane incidents which block more than one lane of the running carriageway for a given duration (these are relatively infrequent with long average build-up duration and a medium carriageway blocking effect)
c) Vehicle breakdowns when vehicle suffers a mechanical and/or other failure and obstructs the running carriageway like those caused by slippery road surface (these have relatively short build-up duration, but in some cases may block more than just one lane)
d) Connected to the above could be accidents caused by spillage when shedding of a vehicle’s load on the running carriageway blocks the lane (these are relatively infrequent but result in very long build-up durations and the highest carriageway obstruction effect).

When tailbacks from an incident reach an upstream junction some drivers may divert to alternative routes. The total amount of this diversion will depend on the availability and attractiveness of alternative routes, the flow on the main carriageway and the proportion of capacity reduction, the duration of the incident, and the average and maximum delay per vehicle by the incident.

5.4. Assessing impacts of transport system meltdowns on HGV traffic – two simulations based on empirical cases

In order to assess the mechanisms through which the natural disasters disrupted the freight flow movements, diverted traffic flows and brought negative tangible impacts upon transport and logistics operators, two model simulations were performed:

1) landslide blockage of motorway connecting Sweden with Norway
2) shutdown of Oslo-fjord-tunnel, an important regional under-the-sea-road artery connecting Østfold and Vestfold counties in southern Norway caused by inundation. The tunnel provided a fast-link thoroughfare for commuters and freight truckers dispatching goods to and from Oslo and to/from Norway.

5.4.1. Blockage of motorway connecting Sweden with Norway by a landslide

Landslide incident description
The landslide in question occurred at 02 a.m. on December 12th 2005. A-400-metres-wide-swath of loose rocks, stones and soil fell on the E-6 motorway near Munkholm (a small residential area in Swedish city of Uddevalla in Västra Götaland county) blocking a 300-metre-long stretch of the roadway crossing Munkdal. A rescue operation started immediately, but apart
from infrastructure damage no other harms were recorded. The first landslide was followed by a series of smaller rock falls, without however causing any serious damage.

![Figure 4. Landslide location which blocked the Swedish motorway connection (E6) to Norway](image)

The accident location is shown on the map above. The affected stretch of the motorway, which is an important artery for freight carriage between Sweden and Norway, remained closed from December 12th 2005 until March 15th 2006, i.e. over three months. The same landslide also demolished the rail track running in parallel to the roadway bringing the train traffic to a standstill and causing all goods and passenger transport to be moved by road detour.

To bypass the affected road segment, the Swedish Public Road Administration imposed a 55-kilometre-long-detour through Bäckefors and Dals-ED on all motorised vehicles. Merging of the detour flows with the E-6 motorway was moved northward to the place called Skee. The detour affected between 20 000 and 25 000 commercial vehicles (with a length of 5.6-7.8 metres and larger), which on average crisscrossed this motorway segment in both directions during the three month period.

**Costs of HGVs’ travel reassignment due to landslide**

To monetise the impacts the road blockage at Munkedal imposed on road hauliers, logistics operators and/or forwarders ferrying goods to and from Norway, the Norwegian national goods model, which also incorporates the Norwegian HGVs variable cost module was applied as modelling platform. This module uses 5.5 NOK (0.79 €) as an average variable cost per one kilometre driven by a HGV in Norway or 500 NOK (71.5€) per one driving hour. As regards the consequences of road blockage, two travel reassignment scenarios were tested, and impacts on vehicles’ operations costs, values of time lost and adaptations made by road hauliers, logistics operators and/or forwarding agents estimated.
Scenario 1: All HGVs detour through Bäckefors and Dals-ED
The HGV traffic counts at Svinesund station (the Swedish-Norwegian border crossing) indicate that about 700 000 trucks (of 7.8 to 19 metre length) travelled every year over the period 2008-2010 on this road segment. When commercial vehicles with the length ranging between 5.6 - 7.6 metres are added up, the number raises to almost 800 000 HGVs. Considering that the HGV traffic on this route is unevenly distributed throughout the year, the 55 km-detour has redirected 20 000 – 25 000 commercial vehicles to a bypass during the road closure. Assuming that each HGV travels at 70 km/h, the bypass travel time added about 47 minutes to the duration of original one-way-trip. Given that no changes in vehicle routing were imposed by road hauliers during this period, the 55 km-longer detour and 47 minute-longer-one-way-trip increased the vehicle operations costs and the value of time lost by 126 mill. NOK or 18 mill. €.

Scenario 2: Some traffic is reassigned to other routes; 20% of shipments are moved by sea, rail and ferry, while some other loads are consolidated to reduce the trip numbers
Runs of the Norwegian national goods model shows that 7.7 million tonnes goods were ferried by road over E6 highway crossing Munkedal each year during 2008 - 2010. Assuming that an average payload carried by vehicles longer than 5.6 metres (including empty backhauls) was 12 tonnes, the number of HGVs crossing this road segment was estimated at 640 000 and 650 000 trucks per year, or 16 000 - 20 000 units during the three-months of detour (because of non-linear traffic distribution over the last twelve months. and also within each month during the three-month-period). Taking the above into account, the additional travel costs caused by imposition of 55-km-long-detour and valuation of travel time lost were estimated at 25 million NOK or 3.6 million €.

This amount is considerably lower than the one calculated above. Four different types of adaptation behaviours contributed to this difference. First, not all vehicles crossing the Swedish-Norwegian border at Svinesund drive along the E6-highway passing Munkedal. Second, a twelve-tonne-payload per a HGV means full utilisation of vehicle’s load carrying capacity which not always is achievable, especially on back hauls. When payload is lower, then the number of vehicles needed to transfer the same goods volume must be higher. Third, when faced with considerable increase in vehicle operation costs due to detour, several shippers and/or logistics service suppliers have transferred 20% of consignments to sea carriage, rail freight and/or ferry transport which charge lower tonne/km rates. Fourth, shippers, consignors and/or logistics operators have consolidated consignments into larger shipments to run fewer trips, and thereby reduce the value of time lost due to detour and the costs of longer drive.

5.4.2. Oslo-fjord-tunnel shut-down accident
This seven-kilometre-long under-the-sea tunnel was closed by the Norwegian Directorate of Public Highways at 14:00 hours on March 29th 2011 because of inundation. The rescue team evacuated 30 motorists who were trapped in the tunnel; 11 people were hospitalised because of respiratory problems and other injuries. Since March 29th 2011 the thoroughfare is under refurbishment and remains closed for all motorised traffic. Because the tunnel provided fast-link-connection for road freight supplies to/from Oslo and also out of the country, all HGV travel is now diverted to detour via E18, and then ferry connection for crossing the Oslo-fjord.
Figure 5. Map of Oslo-fjord-tunnel connecting Vestfold and Østfold Counties in Norway

The traffic count station at the tunnel entrance has been established in 2008. Altogether 364,000 heavy distribution vehicles have passed through the tunnel out of which 296,000 were trucks of 7.6-metre-length and larger. The reassignment to alternative arteries imposed a 25 - 26 kilometre detour adding about eleven minutes to one-way-trip. Monetisation of consequences of tunnel closure was assessed by running three vehicle travel reassignment scenarios and estimating impacts on vehicles’ operations costs, value of time lost and adaptations undertaken by shippers and/or logistics intermediaries.

Scenario 1: All HGVs drive through Oslo

As mentioned, the detour travel via Oslo took about 25 km. However, the trip could last more than just eleven minutes because of bad road standard and speed limits on the lane. In case of traffic build-ups and queues which reduce the vehicle velocity, the trip time could have been doubled or even tripled. However, since traffic standstills do not happen regularly, they were not included in the scenarios modelled.

Runs of national goods model estimated that driving over a 25 km-long detour (lasting approximately 11 minutes) will add roughly 226 NOK (30.3 €) to the variable costs of one-way-trip. When aggregated at annual basis, the detour will hike the operational costs for all 5.6 meter-long-vehicles by 82 million NOK (11.7 million €) and by 67 million NOK (9.6 million €) for all HGVs longer than 7.6 metres. However, with only eleven minutes longer trip, the value of time lost was negligible.

Scenario 2: Some domestic cargo is trans-loaded to maritime or rail carriage while import-export goods are shipped by Sandefjord-Strømstad ferry

A long-lasting tunnel-traffic-ban may force some logistics operators and forwarders to redistribute 10% - 20% of domestic road cargo to much cheaper maritime and/or rail carriage. In a similar vein, large chunks of international goods to/from Norway could be loaded onto ferry sailing between Sandefjord and Strømstad and then moved by truck or rail down to European continent. Alternatively, some forwarders may consolidate road consignments into larger shipments to reduce the number of vehicle trips and the costs of longer travel. Assuming that these ad-
justments have indeed took place, an increase in vehicle operations costs and the value of time lost due to the E18 detour over Oslo will be reduced to 13.1 million NOK (1.87 million €) on an annual basis.

Scenario 3: Higher utilisation of vehicle load carrying capacity

The national goods model estimates that 23.5 million tonnes of cargo passed annually through the Oslo-tunnel in 2009. Assuming that this tonnage is ferried by 364 000 HGVs with an average pay load per truck of 6.5 tonnes (including the back haul). This value is quite low for heavy-duty distribution vehicles, indicating that the model may underestimate the number of trucks driving through the tunnel. As a result, the third scenario assumes that all HGVs still detour via Oslo, but that the average pay load on a round trip has increased to 8.5 tonnes. This adaptation strategy shall reduce the extra costs induced by the detour and the value of time lost to 33 million NOK (4.7 million €).

5.4.3. Summary and conclusions on simulations

In order to monetise the impacts that the two types of natural disasters, the landslide blockage of an important road artery connecting Sweden and Norway and the inundation of an under-the-sea-tunnel providing passage under the Oslo-fjord to Vestfol and Østfold counties in southern Norway, a national Norwegian logistics model was used as modelling platform. Together, five scenarios were run to assess the consequences that the above events imposed on vehicles’ operational costs, value of time lost, and adaptation strategies the road hauliers, shippers and logistic intermediaries undertook to reduce the scope of negative consequences.

The results show that traffic disruptions and travel diversion may have different monetary impacts depending on which adaptation strategies road hauliers, logistics service providers, shipper and/or forwarders choose to cope with these events. Monetary upshots were high reducing the vehicles’ operational profitability and capacity utilisation. It was indicated that the most costly adaptation was to drive over detour which increased both, the trip length and the costs of travel. The less costly strategy was to redistribute the consignments to cheaper modes of transport, although this might require more efforts and/or time.

However, the results of this modelling exercise should be interpreted with caution. The operational costs on which the model based its estimation of extra outlays caused by vehicle diversions reflect the Norwegian standards. The fact is that large volumes of goods entering Norway by road are carried by foreign truckers, whose operations, depending on the home country, may have quite different cost structure. The calculation presented above will not apply to these parties.
6. Quantitative model: linkages between freight train delays and bad weather in Finland over 2008-2010

This section provides results from statistical analyses of
- the values of time lost and the tonnage of goods delayed due to bad weather
- the proportion of delays in freight train arrivals attributed to bad weather as compared to all delays registered by VR-Group and the Finnish Transport Agency
- the linkages between the odds for duration of freight train delays and aggregate weather indicators depicting weather over the Finnish rail freight system. The indicators comprised the mean monthly temperatures and precipitation averages measured at a number of measurement stations all over Finland averaged monthly as regards the depth of snow cover, the amounts of snowfalls, and the minimum and maximum temperature levels.

The data for the below analyses was provided by the courtesy of VR Group Ltd. and the Finnish Meteorological Institute. As mentioned, the data comprised two sets of aggregated monthly values. The first included the freight trains delays (inclusive of those related to bad-weather) and the number of freight trains operated on Finnish network over 2008-2010. The second involved the monthly levels of temperatures and precipitation, and number of days in a given month, with specific temperature and precipitation levels during 2008-2010.

6.1. Values of time lost and tonnage of rail goods delayed due to bad weather

The data from VR show that in 2010, 35.8 million tonnes of goods were carried by 116 446 freight trains in Finland. The number of freight trains operated in 2009 was 112 607 while in 2008 it was 138 138. To calculate the value of time lost and the delayed tonnage per one train, the total amount of goods ferried in 2009 was estimated to be 35.5 million tonnes and 43.6 million tonnes in 2008. 60% of commodities carried by rail were “the products of the forest industry: wood, paper, chemical pulp and board”. The rest of the pay load consisted mainly of steel, products of mining industry (e.g. ores), chemicals, and containerised goods. The latter were moved in transit traffic and carried mix cargo.
Table 14 below presents unit tonne values of rail commodities in Finland.

Taking stock of the above, the average values per tonne of goods carried were calculated assuming that the forest industry products belonged to crude material group 3 in the table. Considering that the forest industry cargo comprised 60% of goods shipped, its unit value was 278 €/per tonne. The remaining 40% of the cargo was distributed throughout the different commodity categories as follows:

- 10% were steel products valued at 870 €/tonne (calculated as average for commodity groups 3 and 8)
- 10% were ores valued at 278 €/tonne (group 3)
- 10% were chemicals valued at 1,406 €/tonne (group 6)
- 10% were containers valued at 6,049 €/tonne (calculated as average for commodity groups 9 and 11).
Table 14. Unit tonne values of commodities carried on Finnish rail network in 2008  
(Source: VR)

<table>
<thead>
<tr>
<th>Commodity groups</th>
<th>EUR/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Food and live animals</td>
<td>1 388</td>
</tr>
<tr>
<td>2. Beverages and tobacco</td>
<td>3 700</td>
</tr>
<tr>
<td>3. Crude materials, inedible, except fuels</td>
<td>278</td>
</tr>
<tr>
<td>4. Mineral fuels. Lubricants and related materials (coal, coke and briquettes)</td>
<td>185</td>
</tr>
<tr>
<td>5. Animal and vegetable oils, fats and waxes</td>
<td>1 184</td>
</tr>
<tr>
<td>6. Chemicals and related products, n.e.s.</td>
<td>1 406</td>
</tr>
<tr>
<td>7. Paper, paperboard and articles</td>
<td>1 388</td>
</tr>
<tr>
<td>8. Manufactured goods of metals</td>
<td>1 462</td>
</tr>
<tr>
<td>9. Manufactured miscellaneous goods (not classified elsewhere)</td>
<td>2 479</td>
</tr>
<tr>
<td>10. Machinery and transport equipment</td>
<td>11 655</td>
</tr>
<tr>
<td>11. Miscellaneous manufactured articles</td>
<td>9 620</td>
</tr>
<tr>
<td>12. Apparatus, equipment and instruments</td>
<td>25 346</td>
</tr>
<tr>
<td>13. Petroleum, petroleum products</td>
<td>380</td>
</tr>
</tbody>
</table>

In order to assess the value of time lost due to weather-related train delays, the rail tonnage from 2008, 2009 and 2010 was divided by the number of trains operated each year. This value was then multiplied by the values of €/tonne for the different commodity categories to estimate the value of goods carried by one train. From the punctuality data provided by VR we knew that the arrival reliability in 2008 was 90 % while the univariate regression analysis has established that 60% of all delays could be ascribed to bad weather (see below). Delay per train was then assessed by multiplying these, i.e.

$$0.1 \times 0.6 \times \text{value of goods carried in the train}$$

Taking these factors into account the following values of time lost per freight train were calculated (Table 15).

Table 15. Values of time lost due to weather-related freight train delays in Finland for 2008-2010, 1000 €

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>17.9</td>
<td>24.7</td>
<td>25.6</td>
<td>23.4</td>
<td>22.6</td>
<td>22.6</td>
<td>17.6</td>
<td>20.0</td>
<td>30.8</td>
<td>29.7</td>
<td>29.0</td>
<td>18.1</td>
</tr>
<tr>
<td>2009</td>
<td>18.9</td>
<td>18.4</td>
<td>17.3</td>
<td>15.7</td>
<td>15.7</td>
<td>28.4</td>
<td>17.1</td>
<td>16.9</td>
<td>22.5</td>
<td>28.8</td>
<td>27.0</td>
<td>39.6</td>
</tr>
<tr>
<td>2010</td>
<td>42.2</td>
<td>56.1</td>
<td>32.3</td>
<td>38.9</td>
<td>40.8</td>
<td>29.5</td>
<td>22.3</td>
<td>23.8</td>
<td>23.6</td>
<td>34.0</td>
<td>35.9</td>
<td>52.3</td>
</tr>
</tbody>
</table>

In addition, the cargo tonnage per train delayed due to bad weather or weather-related technical problems was also calculated (Table 16).

Table 16. Volume of cargo tonnes which arrived delayed due to bad weather in Finland, tonnes/train, 2008-2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>17.4</td>
<td>24.0</td>
<td>24.9</td>
<td>22.7</td>
<td>22.0</td>
<td>22.0</td>
<td>17.1</td>
<td>19.5</td>
<td>30.0</td>
<td>28.9</td>
<td>28.9</td>
<td>17.6</td>
</tr>
<tr>
<td>2009</td>
<td>18.4</td>
<td>17.9</td>
<td>16.8</td>
<td>15.3</td>
<td>15.3</td>
<td>27.7</td>
<td>16.7</td>
<td>16.5</td>
<td>21.9</td>
<td>21.9</td>
<td>28.0</td>
<td>38.6</td>
</tr>
<tr>
<td>2010</td>
<td>41.2</td>
<td>54.6</td>
<td>31.5</td>
<td>37.9</td>
<td>39.7</td>
<td>28.7</td>
<td>21.7</td>
<td>23.2</td>
<td>23.0</td>
<td>23.0</td>
<td>33.1</td>
<td>51.0</td>
</tr>
</tbody>
</table>
Inspection of tables above indicates that the higher the tonnage of goods delayed per train, the higher the value of time lost due to bad weather. One can also observe that the highest values of time lost were registered in the late autumn and winter months, although the delays occurred all-year-long. Admittedly, these values are only indicative, as they do not take into account the seasonal variations in the amount and the structure of goods carried. Finally, in the absence of calculated “values of time” attributed to on-time arrivals and/or arrival-tardiness for rail goods in Finland, a proxy of unit values of goods per tonne carried (€/tonne) were used. A comparison of values of time with values of goods carried by rail in Norway in the same commodity categories supports a supposition that the above calculation has probably elevated the values of time lost in Finland by at least 10%. However, faced with the lack of daily delay counts and the value of time inputs, the method applied here was the only feasible solution for this case.

6.2. Assessing proportion of weather-related train delays in all delays during 2008-2010

In order to find out what was the proportion of delays related to bad weather in all freight train delays in Finland during 2008 - 2010, an Anova regression analysis was performed. The results in tables below (Table 17,
Table 18) indicate that weather-related delays accounted for 60% of variation in all delays. However, the model’s goodness of fit was not very high (9.6%) indicating that many other factors contributed to train delays in addition to bad weather. All results were statistically significant.

Table 17. Estimated parameters of univariate regression model explaining the proportion of freight train delays related to bad weather in occurrence of all delays

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R Square</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Change</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.858a</td>
<td>.736</td>
<td>.598</td>
<td>.032543</td>
<td>.736</td>
<td>5.343</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant). The number of days with snowfalls over 5 mm. The number of days with temperature 32 centigrade. The number of days with min 20 cm of snow depth. The average number of days at with t < minus 20 centigrade at measurement station. The number of days in a month with 50 mm snowfalls or more. The number of days with min 10 cm of snow depth. The average number of days with med t < 0 centigrade at measurement station. The average number of days with temperature of 25 centigrade. The number of days with snowfalls over 1. The number of days with temperature minus 20 centigrade. The average number of days with t < minus 7 centigrade at measuring station. The average temperature in Finland in a month.

b. Dependent variable: punctuality
Table 18. The goodness of fit for the univariate regression model

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>.071</td>
<td>12</td>
<td>.006</td>
<td>5.343</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>.025</td>
<td>23</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.096</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Predictors: (Constant). The number of days with snowfalls over 5 mm. The number of days with temperature 32 centigrade. The number of days with min 20 cm of snow depth. The average number of days with \( t < \) minus 20 centigrade at measurement station. The number of days in a month with 50 mm snowfalls or more. The number of days with min 10 cm of snow depth. The average number of days with med \( t < 0 \) centigrade at measurement station. The average number of days with temperature of 25 centigrade. The average number of days with \( t < \) minus 7 centigrade at measuring station. The average temperature in Finland in a month.

b. Dependent variable: punctuality

6.3. Modelling of linkages between train delays and weather indicators

6.3.1. Challenges When Analysing the Aggregate Data

The monthly aggregated weather and delay indicators provided by VR and FMI posed a challenge to statistical linking of freight train arrival delays with actual and/or area-specific weather conditions. The reason was that these indicators depicted the Finnish weather as national averages and confounded weather differences between the different days of the month with weather conditions prevailing over northern, coastal, inland and southern regions. Since some of the indicators were specific for the areas surrounding the measurement stations, a change in an indicator value could have been ascribed to (at least) two mechanisms. The first could simply be a worsening of weather conditions at the given measurement station, while the second, a change in a number of measurement stations that satisfied a given selection criteria.

Similarly, the freight train delay records represented monthly averages for the period 2008 - 2010. Given the above, it was not possible to assign specific weather data to a given transport corridor or to delays occurring along this corridor per train trip, per day of train operations or per train operations hour.

The average temperatures of different Finnish regions may differ sharply which means that not only temperature differs during a given time period between the different regions, but also that seasonal changes occur in a time lagged fashion. This implies that the monthly temperature and precipitation averages do not distinguish between the different areas as regards when the weather is most severe there.

Addition to data file with lagged weather indicators

The analyses were initially run on monthly data set consisting of 36 data records from 2008 - 2010. Each record contained information on punctuality of freight train arrivals, the number and duration of delays attributed to the different reasons, and the aggregate indicators of the weather conditions in Finland during a given month.
However, it is well known that adapting to rapid changes can be more challenging than to chronic conditions (Xia et al. 2011). Changing weather conditions can come as a surprise, and pose a challenge with respect to punctuality of train arrivals. Therefore, to capture the shifts in indicator values, one-month-lagged values were calculated and added to the data set representing the independent variables.

Analysing whether changes in weather conditions contributed to delays beyond these depicted by monthly indicators was in general not meaningful, given the data quality and the purpose of this study. Therefore only changes in the number of days with a given snow depth from one month to another were calculated. The change in the number of days with a given snow cover served here as a proxy for snow accumulation during a given month. We have assumed that it was rather the accumulation of snow than the numbers of days with a given snow cover that could obstruct train punctuality. The number of days with a given depth of snow indicator could simply signify that the measurements were undertaken at the end of the winter season. Analyses using information on the changes in snow depth included 35 observations only since data on the snow cover in December 2007 were missing.

It would of course be desirable to have the direct measurements of the amount of snow or the average depth of snow before calculating the differences in snow cover and not the number of days with a given snow condition. As observed, an increase in the number of days with a given snow depth could in some instances reflect at which point in time the measurements were undertaken within a given season, and not that the actual depth of snow has changed. Still, since we were using an aggregate indicator, we got a little bit of both elements, and thus had a somewhat weak indicator of worsening of snow depth conditions.

6.3.2. Data preparation: initial transformations

**Dependent variable**

As established earlier, punctuality was inversely related to adverse weather. To make the interpretation of the regression model results easier we decided to study delays defined as a proportion of the trips that were delayed. A worsening of weather conditions, and an increase in indicators signifying harsh weather occurrence became thus related to a positive increase in the proportion of delays. The negative parameter estimates on the other hand signified that the relationship was opposite to what it was expected.

Generally, it is a bad idea to blindly use linear regression on a dependent variable in the form of proportion. It is well known from studies of disaggregate data that such relationships often are non-linear and S-shaped. Predicted values from an estimated linear regression model can easily result in a prediction of negative probabilities (below 0% delay) or more than 100% delay occurrence which of course is meaningless.

The standard treatment when analysing a dependent variable in the form of a probability or a proportion, is to perform a non-linear logit transformation by taking a natural logarithm of the odds for a delay (Hosmer & Lemeshow, 1989). By so doing, one can establish a linear regression model linking the transformed dependent variable to the independent variables. This is an equivalent of running a grouped regression model (Agresti & Natarajan, 2001, Long, 1997).
\[
\ln \left( \frac{\text{delays}}{1 - \text{delays}} \right) = C + b_1 X_1 + \ldots + b_n X_n
\]

Using this logit transformation of the dependent variable means that by powering the estimated parameter value, one obtains an estimate of the odds ratio associated with the independent variable increasing by one unit. That is: \(e^{b_1}\) indicates how much the odds for a delay increases when the associated variable \(X_1\) increases by one unit \(X_{\text{new}} = X_1 + 1\) while the other variables remain constant.

**Choice of independent variables**

The temperature indicators (or a number of days below a given temperature) were overlapping. In the analytical work, these values were transformed so that it would be possible to analyse the probability of a delay and the resulting duration of the delay as a function of each separate temperature interval. However, the original coding system was upheld in the result presentation with an exception of the change in snow cover where a non-overlapping version was used. Instead of the depth of snow exceeding 10 cm, a depth of snow exceeding 10 cm but not more than 20 cm was used.

**6.3.3. Odds for delays as a function of adverse weather conditions**

**Precipitation**

No relationship between days with high precipitation and the odds of freight trains delays could be established. Potential delays may have occurred but not be detected due to a simultaneous reduction in other types of delays. High temperatures are typical for summer months when one might expect fewer commuter trains on the network and fewer slot allocation conflicts with freight traffic.

Days with higher precipitation occurred in the month of June/July 2009 and 2010 and August/September 2010. A more relevant variable for predicting delays attributed to minor or major flooding could perhaps be a combination of ground soakage index at a given location, the size and the form of catchment area and the amount of precipitation. Here it would also be helpful to analyse disaggregated data on the number of trains cancelled or delayed scheduled to travel through the affected area.

Since the number of data points was so small, there was a significant danger of over-fitting the regression models. As a consequence, the indicator of heavy precipitation was kept out of the subsequent analyses.
**Impacts of high temperatures**

No specific impact of high temperatures on freight train delays could be discerned. As we know, rail lines can buckle under heat conditions. However, the size of the delays could be difficult to disentangle from reduction in other delays and number of stretches where the buckling occurred. The risk of buckling depends not only on the temperature on the track, but the quality of track metal alloy. The impact could thus vary with the age of the tracks, and the quality of maintenance on the different lines. One would also expect that direction of local wind, wind strength, humidity and the topography of terrain that the track cuts through might be the tear-and-wear agents in addition to high temperatures. The high temperature indicators were therefore removed from the subsequent models. Had there been a larger number of data points, this decision might have been different, but with the limited data set the danger of over fitting was of genuine concern.

**Selection of temperature indicators**

Several measures of temperature, among these the mean temperatures in Finland during a given month were provided. However, it was quite obvious that delays were not a linear function of temperature despite the fact that when it becomes quite cold trains arrive delayed (Figure 6).

![Figure 6. Delayed freight train arrivals by monthly average temperatures in Finland 2008 - 2010](image)

Inclusion of mean temperatures into a regression model in addition to indicators of low temperatures could easily prove to be one independent indicator too much. Having several strongly correlated independent variables could create models with parameter estimates contributing to explaining random variations rather than to systematic components of a relationship between low temperatures and train delays. Therefore, the monthly average temperature for Finland were removed from the equations and instead, indicators of cold conditions i.e., the number of days below -7°C and -20°C were used.
Handling of extraordinary delays from March to May 2010

After inclusion of the independent variable as the number of days with cold temperatures, the amount of snowfalls, and the depth of snow cover, the fit statistics indicated that the explanatory factors in the model were not explaining well the variation in train delays during the 36 month studied period from 2008 to 2010.

An inspection of a simple clustered bar chart showing delays per month over 2008-2010 indicated that the reason for the models’ ill-fitting could lie in the unexpected large delays during the relatively warm period from March to May 2010 (Figure 7).

![Figure 7. Delayed freight trains by month, Finland 2008-2010](image)

VR, the national rail operator informed us that delays during these two months could be attributed to after-effects of winter-damages inflicted on rail infrastructure, which led to imposition of temporal speed limits for trains.

In addition, some operations days could be lost due to industrial action in the transport sector which took place in March 2010. However, it is not clear how important the industrial action was for the number of delays, since delays are measured by time lags between the actual and the scheduled arrivals and during the strike no trips were scheduled. Delays caused by the subsequent train back-logs and the needs to catch-up with delayed rail consignments could still be substantial. Whereas the strike started at the beginning of March and lasted 16 days, it could have had time-lagged effects on punctuality of trains in April and May. To capture the effect of March delays with lagged impacts until May 2010, a dummy variable “Lagged/other” that was 1
for each of the three months affected and zero otherwise was constructed. It was to neutralise the lagged effects of the previous months' infrastructure damage/maintenance needs as well as impacts of non-weather-related event (industrial action).

6.3.4. Freight trains' delays as a function of weather parameters
Since several of the independent variables contained temperature measurements in one form or another and data on snowfalls and snow depth which were a function of below-zero temperatures, it was necessary to choose which factors to use. Given the small data set, and the exploratory nature of the study, this decision could not have been solely based on statistical records. In this context, insights from expert judgements presented in case studies on weather conditions which severely threatened rail traffic punctuality in Poland, Sweden, Norway and Switzerland and led to operations shutdown in addition to conclusions from discussions with VR and FMI were used. Taking the above into consideration, a limited set of explanatory weather variables were included into analyses which results are presented below. The included variables explained 62% of variation in the reported train delays (see Table 19 below for individual parameter estimates).

Table 19. Estimated Parameters for a Regression Model Explaining the Log Odds for Freight Train Delays

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>-2.047</td>
<td>.055</td>
<td>-37.485</td>
</tr>
<tr>
<td></td>
<td>Lagged/other</td>
<td>.557</td>
<td>.154</td>
<td>.404</td>
</tr>
<tr>
<td></td>
<td>t &lt; -7</td>
<td>.027</td>
<td>.006</td>
<td>.510</td>
</tr>
<tr>
<td></td>
<td>Change snow depth 10-20 cm from month before</td>
<td>.083</td>
<td>.022</td>
<td>.428</td>
</tr>
</tbody>
</table>

Explanatory factors: a dummy variable composed of the mean number of days with temperatures below -7 Celcius and the change from one month to the next in the number of days with a snow depth of 10-20 cm.

The constant term of the regression model captures the log odds of a delay that cannot directly be attributed to the explanatory factors in the model. The odds for freight train delays were obtained by calculating \( e^C = 13\% \), which translates into an approximately 12% probability of delay. The compound lagged effects of damage to the infrastructure caused by 2010 harsh winter and (possibly) industrial action in March 2010 have increased the odds of delays by 75% calculated by multiplying the odds associated with the fixed values of the other variables by \( e^{0.557} = 1.77 \) or approx. 175%. A unit increase in the number of days with 10-20 cm of snow cover from one month to the next has raised the odds for freight train delays by about 8%. In the same way, each additional day of temperature below -7 Celcius increased the odds for a train delay by about 3%. The increases in odds were calculated "ceteris paribus", i.e. under the condition that the values of the remaining variables were unchanged.
However, when one wants to assess not only a partial impact, but an overall impact associated with changes in given factor, one should keep in mind that the independent variables were correlated. This means that when for example moving from one month to the next, all weather-related explanatory factors might change in concert. Thus, when one wants to obtain an estimate of the overall increase in probability of train delays caused by changes in e.g. temperature level, it is necessary to also include the expected values of changes in snow cover into the analytical models that usually are associated with a given temperature level.

The subsequent models analysed the duration of delays associated with a given delay code. The three linear ordinary regression models below describe the duration of train delays as a function of only a few independent variables indicating changes in weather conditions. Several weather-related delay codes were initially inserted into the regression models, but the results were simplified for showing only the relationship between the delays and the variables that were significant and also, where the models made good sense. Good sense meant here that they were in accordance with the qualitative study containing the experts’ judgments of delay-causing factors on freight train arrivals, and these factors’ combined impacts on punctuality.

**Delays in train arrivals attributed to fog, bad weather and leaves on the track (code “I1”)**

One additional mean day in the number of days as compared to previous month with 10-20 cm snow cover was extracted as the only significant explanatory factor. The model including this variable “change in snow cover” explained 65% of variation in freight train delays. A unit increase in the average number of days with snow cover between 10 and 20 cm from one month to the next contributed to 629 minutes or 10 ½ hours in duration of train delays linked to the above weather condition (Table 20).

<table>
<thead>
<tr>
<th>Coefficients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 (Constant)</td>
</tr>
<tr>
<td>Change #days with snow depth 10-20 cm from month before</td>
</tr>
</tbody>
</table>

*a. Dependent Variable: I1_min

Explanatory factor: the change from one month to the next in the number of days with a snow depth of 10-20 cm.

**Freight train delays attributed to snow barriers (code “I2”)**

The number of days with snowfalls over 5 mm explained 77% of the variation in train delays attributed to snow barriers. This implies that each additional mean day with heavy snowing may contribute to an additional train delay of 19 ½ hours.


Table 21. Estimated parameters of a regression model explaining the duration of train delays

<table>
<thead>
<tr>
<th>Coefficients&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>145.578</td>
<td>191.669</td>
</tr>
<tr>
<td>&gt; 5 mm snow</td>
<td>1167.453</td>
<td>110.137</td>
</tr>
</tbody>
</table>

<sup>a</sup> Dependent Variable: I2_min

Explanatory factor: number of days with snowfalls above 5 mm/24h.

Freight train delays due to faults at switch stations (code P3)

A unit increase in the mean number of days with more than 5 mm snowfalls contributed to an additional 342 minutes in freight trains delays or nearly 6 hours extra delay. Each additional day with temperature -20 Celcius or below may increase the duration of train delays by 193 minutes or roughly 3 hours and 15 minutes. This regression model explained 80% of the variation in duration of train delays attributed to faults in track switches.

Table 22. Estimated parameters for a regression model explaining the duration of train delays

<table>
<thead>
<tr>
<th>Coefficients&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>2 (Constant)</td>
<td>278.496</td>
<td>67.035</td>
</tr>
<tr>
<td>&gt; 5 mm snow</td>
<td>342.039</td>
<td>45.914</td>
</tr>
<tr>
<td>Days mean t &lt; -20</td>
<td>195.313</td>
<td>62.834</td>
</tr>
</tbody>
</table>

<sup>a</sup> Dependent Variable: P3_min

Explanatory factors: the mean number of days with temperatures below -20 Celcius and the mean number of days with more than 5 mm snowfalls.

Delays due to other weather–related codes

No explanatory models could be established for codes S1.2.4 and P1.
6.3.5. Summary and conclusions on the Finnish rail freight modelling case

The results from the three above statistical analyses have shown

- The € values of time lost due to weather-related train delays in Finland calculated on monthly basis for a period 2008 - 2010

- The monthly tonnage of rail cargo that arrived delayed per train and was attributed to bad weather during 2008 - 2010

- The proportion of freight train delays attributed to bad weather as compared to all train delays over 2008 - 2010

- The linkages between the monthly weather indicators and the occurrence and duration of freight train delays over 2008 - 2010.

The monthly values of time lost due to weather-related freight train delays over 2008 - 2010 were correlated with the tonnage of goods which also arrived late. Not surprising, both values were higher during the late autumn and winter months, indicating that as the weather became more harsh, the number and duration of delays has also increased, amplifying the value of time lost and the number of overdue shipments.

The runs of a univariate ANOVA regression model revealed that about 60% (59.8%) of all arrival tardiness could be attributed to bad weather and/or weather-related technical damages of the network.

Assessment of statistically valid linkages between bad weather and occurrence and duration of freight train delays was difficult due to small data set and aggregation of weather and delay observations as monthly averages. For establishing the odds for delays, a dependent variable was converted into log odds through non-linear logit transformation. This allowed the odds for the occurrence of a delay to be calculated. As regards the independent variable, the monthly changes in the number of days with a given snow depth and snowfalls combined with occurrence of negative temperatures were used as model parameters. This model explained 62% of variation in the occurrence of the reported train delays. Afterwards, three linear regression models were run to assess the strength of statistical co-variation between the monthly changes in the number of days with snow depth of 10 - 20 cm, the different categories of bad weather and/or weather-related damages, and the duration of freight trains delays.

The three models explained, respectively, 65%, 77% and 80% of variation in duration of freight train delays. It also appeared that train delays attributed to snow barriers (code I2) were the most severe punctuality impediments as these might have contributed to additional 19 ½ hours of train delay.

The results from the above analyses indicate that, statistically, it was quite difficult to establish clear causal relationships between bad weather and occurrences of freight train delays and/or a contribution of bad-weather-induced technical problems to exact delay duration. This does not, however, imply that such relationship could not be detected with better quality of both, met-data,
the train delay counts, and generally better understanding of interactions between the weather conditions and the reliability parameters of freight rail traffic.

Therefore, one conclusion derived from the above work consists in an acknowledgement that these types of analyses need more than a simple collating of the existing information without regard of the content of task at hand. Rather, an interactive and continuous dialogue between the met-professionals, rail infrastructure managers and traffic supervisors is required. Such interactions where the output of the met-models and the delay monitoring routines are shaped/tweaked to provide a better match between values of indicators depicting the weather and operations conditions is highly recommended. It would improve the scope and the quality of data on climatic impacts on train operations in general and punctuality in particular.

Future work on improving the understanding for how the different classes of adverse weather indicators may affect train delays could involve five steps proposed below.

To assess the impact that the various weather conditions may exert on train punctuality, and devise models discerning between the effects of low temperatures, wind, icing, snowfalls, and snow accumulation, more detailed data are needed. To attain this goal, rail practitioners need to assess in detail how the different categories/combinations of bad weather conditions affect the reliability of train traffic. In research on weather impacts on humans, a compound indicator “chill-factor” which strong wind, low temperature and precipitation levels conjointly exert on human body is often used. Could a similar “chill factor” that capture impacts of low temperatures, precipitation and infrastructure exposure to natural events be constructed in order to measure the strength of threats affecting the security of rail operations? Could track clogging by leaves, icing of switch stations, snow accumulation on rail car undercarriages or other traffic-adverse impacts be captured through construction of more comprehensive indicators? Will a change in snow depth from one hour to the next, one day to the next or one month to the next provide the best time frame with respect to defining what the elements of adverse conditions affecting the freight train punctuality?

Further, these insights may need to be discussed with met-experts and people with topographic knowledge of rail infrastructure in a given area in order to establish which combinations of snowfalls and temperature levels may become critical for infrastructure serviceability and continuity of traffic operations.

A second step would consist in obtaining indicators of these composites (e.g., the snowfalls, the wind strength and temperature levels that collectively lead to accumulation of snow deposits under rail cars’ undercarriages). Further, this information may be stratified by the different geographical areas predicting how the above weather conditions may affect traffic on particular network lines/corridors crossing the specific territories.

The third step would be to code the different delay causes more precisely to better link them with specific weather conditions. The data on different classes of weather developed at the primary stage could be used here. Since the analyses reported above indicate immediate/acute, mediated, and time-lagged types of weather impacts on train delays, indicators of short-term or lasting damages need to be developed and linked to the different categories of weather events.
The fourth step would involve making sure that sufficiently large data are available for determining the relationships between more detailed model parameters. Ideally, data representing the varying weather conditions on particular network stretches would be desired. In this manner, the need for long time series of observation might be somewhat, but not entirely reduced. Inter-temporal differences are not the same as inter-regional conditions during the same time-period. However, with data on both inter-temporal and inter-regional differences available, the partial impacts of the various weather indicators, the interaction effects, it could possibly be established whether the composite weather indicators from primary steps are more useful for explaining a given cause of delays than just single indicators. Finally, the fifth step will consist in data analyses by applying multivariate regression and/or structural equation models capable to assess how the train delays could be linked to the various weather components separately and in combination.

As suggested, a dialogue between the met-scientists, behavioural researchers and the rail managers whose daily experience from coping with weather-related and other types of train punctuality threats will provide insights into and guidance for data definitions, data processing, and designing of analytical models and, finally formulation of empirically validated findings is highly recommended.

Since the subject of this type of study requires not only the application of standard outputs from weather and climatology and rail operations indicators, a need for conjoint efforts into this cross-disciplinary field of research has emerged.
7. Summaries and conclusions

So... what are the unit costs?

Based on the previous analyses of literature, empirical cases and interviews it is apparent that we cannot draw a single figure to even roughly approximate the costs of extreme weather induced supply chain interruptions and meltdowns since the costs vary by

- mode of transport: road, rail, waterborne, airborne
- actor in the value chain: shipper, 3rd party, operator, etc.
- type of good and commodity: bulk, containers, high/low value, time sensitive/insensitive, etc.
- structure of the supply chain: length, complexity, contractual architecture, etc.
- type context and delivery: vendor managed inventories, just-in-time, and so forth
- options for corrective actions, such as alternative routing and mode shift
- type of time characteristics: transport time, delay time, time variance, etc.
- type of research method: market values, stated preference values, historical costs, etc.

This means that whatever estimates are given, the estimates are dependent on the above dimensions and contexts.

Three notable studies give estimates for value of delay time and for our purpose from different parts of Europe, are carried out in different countries and come from chronologically different period.

Table 20. The comparison of three studies on values of time in freight and logistics

<table>
<thead>
<tr>
<th>Study, year</th>
<th>Country</th>
<th>Mode</th>
<th>Value of time</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fowkes, 2004</td>
<td>UK</td>
<td>Road</td>
<td>107</td>
<td>pence / minute / vehicle</td>
<td>Based on the whole sample (N=40) with different actors who had varying delay time value preferences; value of delay</td>
</tr>
<tr>
<td>De Jong et al., 2004</td>
<td>Netherlands</td>
<td>Containerised cargo</td>
<td>42</td>
<td>€ / shipment / h</td>
<td>Based on the values stated and revealed by shippers; value of transport time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road</td>
<td>38</td>
<td>€ / shipment / h</td>
<td>5.28 € / tonne / h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rail</td>
<td>918</td>
<td>€ / shipment / h</td>
<td>0.96 € / tonne / h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IWT</td>
<td>74</td>
<td>€ / shipment / h</td>
<td>0.046 € / tonne / h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short and deep sea</td>
<td>73</td>
<td>€ / shipment / h</td>
<td>0.016 € / tonne / h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air</td>
<td>7 935</td>
<td>€ / shipment / h</td>
<td>132 € / tonne / h</td>
</tr>
<tr>
<td>Halse et al., 2010</td>
<td>Norway</td>
<td>Road</td>
<td>13.4</td>
<td>€ / tonne / h</td>
<td>Value of delay for shippers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48.4</td>
<td>Value of delay for own account hauliers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.96</td>
<td>Value of time for shippers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11.8</td>
<td>Value of time for own account hauliers</td>
<td></td>
</tr>
</tbody>
</table>

It is noteworthy that the most recent study gives lower values for time for shippers whilst having a sample of at least as high-price-level country as the former studies and with a six year difference lowering the real value of money.

The figures received from the Norwegian study are the most recent and somewhat lower than from the earlier studies. Hence, applying those would probably keep the results on the safer
side and there would be no need to adjust for the inflation to be considered up-to-date (2012)\textsuperscript{13}, particularly as the indices do not necessarily reflect equally well the market context in different countries, which is volatile in itself, and as they might not capture transport markets' idiosyncratic features. The Dutch study we could use to adjust for the modal differences since it was the only one of the three that covered all modes under research. The relative ratios for all modes are in the below table (road, shippers = 1.00) as well as the real cost estimates using the Norwegian values and adjusted values when taking into account the price level difference between Norway and European Union member states (EU27=100.0, NO=147.3 in 2012; Eurostat).

### Table 21. Relative, real and adjusted cost estimates for values of time and delay

<table>
<thead>
<tr>
<th>Mode</th>
<th>Relative cost estimates, unit / tonne / h</th>
<th>Real cost estimates, € / tonne / h</th>
<th>Price level adjusted costs for EU27, € / tonne / h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shippers'</td>
<td>Hauliers'</td>
<td>Shippers'</td>
</tr>
<tr>
<td>Road</td>
<td>Time</td>
<td>1.00</td>
<td>6.02</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>6.84</td>
<td>24.7</td>
</tr>
<tr>
<td>Rail</td>
<td>Time</td>
<td>0.182</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>1.24</td>
<td>x</td>
</tr>
<tr>
<td>IWT</td>
<td>Time</td>
<td>0.0087</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>0.059</td>
<td>x</td>
</tr>
<tr>
<td>Short sea</td>
<td>Time</td>
<td>0.0030</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>0.021</td>
<td>x</td>
</tr>
<tr>
<td>Airborne</td>
<td>Time</td>
<td>25.0</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Delay</td>
<td>171</td>
<td>x</td>
</tr>
</tbody>
</table>

The rightmost values can be used for EU27 proxies when assessing European shippers' costs for freight delivery delays.

**Costs… or increased cash flows?**

The studies on extreme weather events and natural disasters on firms' financial performance seems to hold two truths:

1. on firm level, the share prices and hence the shareholders' returns were significantly lower for companies which had experienced the extreme events
2. on industry level, the impact on companies' cash flows seems to be positive after experiencing the extreme events, such as windstorms and floods.

This leads to a reasonably clear conclusion based on those findings. The extreme events seem to increase demand to the extent that on industry level the results are economically positive for the companies. Yet at firm level the losses are explicit and paid by the owners in the form of reduced shareholder wealth. This result appeals to the logical mind, however, and are easy to accept.

**What are the managers thinking?**

To sum up the impression on prior studies, the cases and interviews and the survey carried out in Austria, Finland and Norway, the direction of the conclusions is relatively clear. Managers throughout the logistics and freight industry are well aware of extreme events potential impacts on their business and reputation, but the tools and means to mitigate the impacts are limited. The industry leaders and managers are prioritising different things than weather, which in the end is an “act of God”, not something that they can influence through their business skills. They

---

\textsuperscript{13} Two years' difference is insignificant thinking of the inflation adjustment for two good reasons. First, all other assumptions' error margins clearly outweigh two years' inflation adjustment. Secondly, the inflation in the euro-zone has been practically non-existing for the last couple of years because of the financial distress caused by debt crisis.
expect and hope, however, that infrastructure managers improve their performance to have pathways available even during or at least soon after extreme weather phenomena.

It would be a grave misinterpretation to consider that freight and logistics business managers do not care or are not prepared for extreme events. The simple fact is that these issues are not too high on their agenda. One obvious reason for this behaviour could be that such preparations are not included in their management contracts – *it is shareholder value that matters, not necessarily smooth and uninterrupted operations*. One can with good reason to question whether these issues should be also on industry managers’ agenda or whether they should be included in the management and performance contracts of public sector executives, namely infrastructure managers. If neither side is assuming responsibility, there will be little preparedness-building outside climate change conference rooms.

*Also modern lean production thinking with little slack in reserves (capital, people, equipment) and inventories gives little room for preparedness-building. The more overall efficiency requirements are placed on business and public organisations, the less room there will be for preparing for extreme events, at least on operational level.* On strategic level, the situation could be different, but this aspect was not covered in this analysis. *Placement of production facilities, choosing of global logistics corridors and strategic hubs, the contractual architectures chosen for supply chains, ownership of inventories, and similar decisions are examples of strategic choices where the preparation for extreme events can factually take place.* These are, of course, the decisions made by the very highest levels of corporations.

The logistics and freight managers are also expecting and hoping to have more concrete help and advice from met-service organisations. Sharing the knowledge publicly between countries which have to tackle extreme events was considered a helpful option as well in order to prepare plans for extreme events. There is perhaps a weak signal, that there would be a slight increase in the willingness-to-pay for more advanced and tailored services. However, it is likely that even the industry is not too well aware what their exact needs could be, as the issue is not given a priority consideration.

**What types of events seem to be on the table?**

Probably based on the fact that this analysis on extreme weather impacts on transport supply chains and logistics was clearly focused in Northern European contexts, the winter phenomena, mainly precipitation of snow, came strongly forth. As the climate seems to be getting warmer, there might less preparedness-building for these phenomena and hence the impacts could be even more radical than what they are today. Nobody is likely to be willing to bear the costs of preparedness for such phenomena that are considered to be reducing in frequency and perhaps also in intensity.

**Is there value for adaptive strategies?**

For individual events, the Swedish motorway blocked by landslide resulted in value of time loss of several million euros (18 M€) when the heavy goods vehicles had to take an alternative route. Shippers and operators were obviously the ones to bear most of the immediate costs. What was interesting that when simulated, adaptive strategies to utilise alternative modes of transport the costs of the event would have been significantly lower (3 M€). This could well imply one very important conclusion:
the more intermodal our transport system will be, the more flexible it will be to respond breakdowns of single mode or single links of the system, and hence reduce the time value losses of shippers, operators and all affected supply chain actors.

The simulation exercise regarding the flooding of Oslo tunnel in Norway produced similar results. Even if the simulated results are hypothetical and should be interpreted with caution, the general implication is clear, and again, making sense.

Is quantitative modelling possible to associate weather phenomena and consequences on logistics chains?

The analysis on Finnish freight train punctuality and surrounding weather conditions showed that the answer is yes – it is possible. It goes without saying that this type of modelling requires first all skills to do it and secondly a good deal of reliable historical data. The first criterion is of course to be noted, but not an obstacle of any sort, but the latter one can be a true challenge in some European countries.

The results of the modelling exercise were evident. Cold days (below -20°C) and snow falls (≥5 mm) explained the majority of winter time freight train delays and when these phenomena are known – as they usually are – with reasonable certainty a few days beforehand, preparations can take place – if seen worthwhile. Even when the knowledge is there it does not necessarily mean that it will be taken into practice unless the benefits are explicit, measurable and concrete. For example, if freight operators’ customers are not willing to pay for an increased reliability and there is no competition pressure to add the value to the customers, there is little reason to take measures.

Yet the modelling exercise was significant and will set a benchmark how similar studies for different modes and different weather phenomena in question can be carried out. There are typical weather phenomena for each country and climatological zone which are worth analysing. Winter phenomena in Finland are obvious and heat waves are not, and the latter was considered but still not taken further. In southern Italy the situation is vice versa.

Needless to say, both transport and meteorological / climatological scientists need to join forces to successfully do such research.
8. References


Appendix: Finnish survey details

All interviews were carried out in June 2011.

Destia, interview of the manager of the winter maintenance management centre

Destia is a Finnish infrastructure and construction service company and is categorised as a private infrastructure provider. Dealing with weather events is Destia’s daily job, but extreme weather events also affect them. During the years 2010-2011 the winters have been really snowy. There has been a lot of snow on the roads and what has been extraordinary is that the snow has not melted away between the snow storms. Slush and zero-temperature weathers have been missing. A positive effect of this has been less slippery road conditions. The manager is also responsible for the building sector where snow has also brought many problems. Winter has started very early and this meant that projects have been delayed. Another effect has been that projects could not be presented and being handed over to the customers because the buildings were covered by snow, and customers could not see the result before the spring. Harms have been serious in short-term but not in the long-term.

The manager thought that the secondary impacts of extreme weather events are minor and that they are marginally negative for both for their partner or customer and themselves. For example, if a truck is stuck on the snow and blocks the way from snowploughs by causing car jams, the situation gets worse also to Destia - but this is not a big thing.

Destia’s ability to serve customers, their reputation and finance are affected marginally negative in the short- and long-term. Destia’s work, after all, is to be prepared for weather events; so the impacts cannot be that strong. Of course the extreme conditions during the last two years (not typical in Finland) have changed the situation a bit.

The financial costs due to extreme weather events have not been as substantial big as people may think. The amount of snow left on the ground is considerable and this has affected the project economy but, at the same time, money has been saved due to minor slippery conditions and e.g. less salting of the roads. The money saved from the slippery conditions has gone to transporting and ploughing the snow. But the total budget has been pretty much the same as in a normal year. All the costs are short-term costs, not long-term costs at all.

The manager noted that there are justifiable risks to their business right now but the level of financial and organisational risks posed to their business will not change in the future. Destia has taken some precautions against financial, operational, and market-related risks: ploughing routes have been re-planned and e.g. some extra snowploughs and trucks are being invested. Quality plans have also been specified.

The risks caused by extreme weather events are crucial to Destia’s business partners, collaborators and clients. One such Destia’s customer is a traffic agency which has promised its own customers (e.g. transport operators) a certain transportation speed level. If operators cannot move in a planned schedule because of e.g. bad road conditions, that adds to costs for the customers.

The fact that preparation is too expensive is the biggest barrier in increasing preparedness against extreme weather risks. Also lack of support from industry and/or national authorities is considered a crucial factor. These two factors are pretty much about the same thing. Authorities are the customer and they have bought the service from Destia and the price is the most important thing when choosing the operator. There is not really any flexibility, no money to divert on abnormal situations.

Relevant knowledge is already available but it requires time and effort to acquire. This is especially true in the building sector; in the maintenance sector the information level is better. The local meteorological service is the first organisation Destia would contact for advice and support against impacts of extreme weather events. National infrastructure providers and industry colleagues are also important organisations in giving advice. Financial support is the best possible way to give support. Knowledge of other preparedness measures geographic information systems and information in general could all be useful in helping to increase resilience. The manager felt that clients are the most important party in giving support. Government and the insurance sector should also be involved. Web-sites with tested measures could come in handy.

Finnish Transport Agency, interview of a railway expert

Rail transportation has been affected by severe snow storms during the years 2010 and 2011 and the effects have been dramatic with serious long-term harms (many months). The infrastructure provider felt that the effects have been as seriously negative for themselves as for their partners and customers. They feel that the area of their business being most affected is their reputation: the immediate and long-run impacts have been dramatically negative. Snow storms have affected so many people and delays and waiting are always considered very negative. Extreme weather events have also an impact on the infrastructure and its general condition. The traffic agency felt that the investments in infrastructure are currently insufficient.

Extreme weather events mean longer working days for the workers of the traffic agency. The way from home to work and back home becomes more time-consuming, but the duration of the work day remains the same. What comes to the expenses and financial costs due to the extreme weather events, the immediate costs are multiple compared to the normal situation. The maintenance and energy costs are higher than normal – for example, cleaning the tracks from snow and heating the electric systems. The interviewee could not give any exact information about these costs. Long-term costs are thought to extend to about a month from when the event occurred.
The interviewee could not say if any justifiable risks to their business exist. The level of financial and organisational risks posed to their business by extreme weather events is not expected to change. The traffic agency has taken some precautions against future financial, operational, and market-related risks; they have composed a list of actions for the cases of extreme weather events. Anyhow, the most important way to prepare is by increasing the resources when the weather conditions get worse. The interviewee thought that the risks caused by extreme weather events are reasonably important to their business partners, collaborators and clients.

The interviewee of the traffic agency felt that the most important barriers for increasing preparedness against extreme weather risks are the facts that preparation is too expensive and support from external stakeholders is missing. Other crucial factors are lack of information on event occurrence and risk level, lack of appropriate skills in the organisation and lack of organisational flexibility.

There seems to be enough information and the knowledge of future extreme weather trends in Finland would be certainly helpful but for the fact that defining these trends is time consuming and results are not easily acquired. The local Meteorological Services is the first place that the Traffic Agency would contact when wanting some advice and support against impacts of extreme weather. The second place would be other European Meteorological services. Also, the European Environmental Agency would be a possible place to contact.

Financial support is considered the best kind of support against extreme weather events. Geographic information systems could also be helpful, right after the previously mentioned financial support. Information about how to increase resilience and knowledge of other’s preparedness are also thought as possible types of support. The best way to deliver such support is via national governments and via met-services. Web sites with testes measures could be useful.

Port of Oulu, port service and stevedoring company, interview of the production manager
Herman Andersson Ltd. offers a complete range of port services – from ships’ agency to stevedoring and to forwarding. Interviewee categorized Herman as a logistics supplier. The extreme weather events that Herman Andersson confronts are usually during winter-time: cold and ice. However, heavy storms can also have an effect during the other seasons of the year. Harms are usually short-term. For example, storms can break a buildings doors and ceilings. Cold seasons last usually only a few days. Interviewee thought that the extreme weather events have an extreme negative effect on them and their partners. For example, during a cold season, a ship can get stuck in the ice for many days, resulting in the late arrival of the ship to the terminal to be unloaded. This causes extra waiting time for the operator and leads to new arrangements (e.g. work overtime, full inventories). However, the problem is more severe for the shipping company than for Herman Andersson because the shipping company is the one responsible for transporting its shipment to its customer within a certain time. Herman Andersson does the extra work required and can get a compensation for that.

Herman Andersson’s premises are affected marginally negative due to extreme weather events. E.g. doors and ceilings can be broken. Their production assets are affected more severely to a considerable negative effect. During the cold season the machinery is constantly working under pressure. Herman Andersson does not have any cold limits for workers – they work as long as the machinery is operational. Also the ability to serve customers is marginally affected. Cold can delay unloading e.g. due to frozen doors on the ship. Herman Andersson’s people, on the other hand, are more severely affected (considerably negative). People are prone to cold’s negative effects because they are working outside. During the very cold seasons Herman Andersson gets some extra workers in order to provide limited cold exposure to his workers (and make some of them able to get warm indoors). This arrangement brings extra labour costs to Herman Andersson. Sometimes, during heavy storms, it is possible that telecommunication masts fall and information systems stop working; thus, extreme weather events have also effect on their logistics. All these impacts, however, are short-term impacts. Extreme weather needs to be taken into account in designing and building the premises in order to build them durable enough, which is more a long-term impact.

The immediate costs due to extreme weather events are caused by four reasons. First, overtime work and extra men increase salary costs. Second, if the ship arrives late, this causes waiting costs for Herman Andersson. Third, Herman Andersson buys some work from subcontractors, for example crane services, and in problematic situations, Herman Andersson needs to pay for subcontractor extras due to extreme weather conditions. Fourth, cold can break the machinery, which leads to maintenance and repair costs. There aren’t really any long term costs.

There may be justifiable risks to Herman Andersson’s business in long-term but not immediately. For example, if the Finnish Government decides that no more ice breakers are needed and winters get colder, it is possible that routes to Oulu cannot be kept open the whole year. If ships cannot come to Oulu because of the ice, they go somewhere else. Anyhow, interviewee did not believe that the level of financial and organisational risks posed to their business will change. Herman Andersson has not taken any precautions against future financial, operational, and market-related risks. The risks caused by extreme weather events are very important to Finnish companies. If the shipments cannot be transported (for example for a week), the effects on the Finnish companies is significant.

The major barrier for increasing the preparedness against extreme weather events is the uncertainty about how the business will be affected. It is hard to prepare if you don’t know about what you exactly are preparing for. Preparation is also too expensive and the support from industry and/or national authorities is missing. One way to improve the preparedness could be to build a covered dock, but due to the fact that the dock is property of harbour, support and action from the port is also needed. Political support is also of essence.

Herman Andersson felt that good information about storms and ice situations is provided. They have a real time information system about rain clouds and they can e.g. schedule the day based on this information. Of course, the system could always be fancier, but currently it seems to work well. The situation has improved a lot during the last 10 years. When in need of extreme weather advice and support, they would first contact the local meteorological services; insur-
ance brokers come second since the former would be helpful when preparing to the weather event, but the latter would be helpful after the weather event has occurred. Other possible organisations to contact would be national infrastructure providers, European meteorological services and industry colleagues. The best kind of support would be the knowledge of others’ preparedness measures and information about how to increase resilience. Also financial support would be desirable. Insurance companies and business/industry associations would be the best organisations to deliver support and give information. Partners, collaborators & clients and the government are also considered possible supporters. Web site with tested measures might be the best possible format to give said support, since people use the internet a lot, and they might seek information just for the interest of it. All kinds of workshops are also considered good options, but the participation to the workshops may be low, because people usually think that extreme weather events are not that big a problem.

VR Transpoint, interview of the rail freight traffic manager
VR Transpoint is a Finnish state-owned rail and road transport company. Extreme weather events are crucial for the company; especially during the winters in 2010-2011 when the amount of snow has exceeded all the expectations. And usually storms are a risky factor for VR. Trees fall on tracks, thunderstorms are bad for electrical apparatus, and snow storms block the tracks in winter-time. Also cold can freeze electrical machines. These are usually serious harms in short-term but not in long-term. Harms last usually maximum for 2-3 weeks. Harms are seriously negative for VR and their partners. Positive thing is that harms can usually be fixed fast.

Areas, which have been affected by extreme weather events, are their production assets (tracks), their ability to serve customers, their reputation, and vital public infrastructure inside their premises. The immediate impacts are considerably negative, but long-run impacts only marginally negative. But the interviewee mentioned that it seems that the amount of strong weather events is increasing, and this brings uncertainty to VR’s action.

Interviewee mentioned that it is still usual to people to think that VR takes care of tracks, but it is the Agency who is responsible for maintaining the tracks. But this misconception affects also VR’s reputation.

Extreme weather events increase also VR’s financial costs, especially in short-term. They have to pay compensation for the damage for customers and arrange substitutive rides, e.g. bus rides. This financial cost information is not public. Heavy thunder storms can also break railway yards, which cause extra costs. The Agency is responsible for the cost of repairing the tracks. Long-term financial costs effect no more than for 2-3 weeks.

There are justifiable risks to VR’s business all the time; thunderstorms in summertime and snowstorms in winter. Interviewee doesn’t think that the financial and organisational risk posed to their business will change during the following years. Anyhow, he feels that the risk will increase for traffic agency. There are pressures for traffic agency, for example to cut down trees close to rail tracks. Interviewee could not say if any precautions have been taken against future financial, operational, and market-related risks. Extreme weather events are crucial what comes to the risks they pose to VR’s business partners, collaborators, and clients. For example thunderstorms have caused sudden need to shut down the pulp factory, which can be dangerous.

The most important obstacle for increasing preparedness against extreme weather risks is the cost of the preparation. There is also uncertainty about how the business will actually be affected. Also support from external stakeholders would help in preparations.

Interviewee thought that the available information is helpful but it is difficult to access and it is usually available at that time, when there is not possible to do anything. It is difficult to be prepared for storms – you just know that storm is coming and some harms because of that. The National Infrastructure provider would be the first organisation to contact for advice and support against impacts of extreme weather impacts. Second important organisation is local met services, which already now give support. Business partners are also thought as appropriate organisations for giving advice.

The financial support is the best possible way to give support in increasing resilience against weather events. Knowledge of others’ preparedness measures is also considered as an important way to give support. It would be good to know how it is prepared in other parts of the world, where the extreme weather events are more dramatic.

Support should come via National Governments - governments should budget more money on preparing against the weather events. Support via met-services is also crucial, and it is working already now. Anyhow, it would be better if the prediction of the events was improved. Interviewee thought that dedicated sector workshops would be a good way to get support. Workshops should include authorities and companies that are affected by weather events.

TNT Finland, interview of the depot manager
TNT is a multinational express delivery services company. They consider themselves as an air and road transport company. TNT has been affected especially during the years 2010 and 2011 by heavy snow storms and cold/frost. Pack ice has been difficult in sea traffic. Ashes (not really a weather event) have affected air traffic – one week in 2010. Snow is the most severe and typical cause for extra arrangements. Interviewee felt that extreme weather events cause serious short-term harms but not long-term. For example if the flight to a destination is normally once a day, due to a delay the flight is automatically delayed at least for one day. Sometimes this does not matter but sometimes it is really crucial to get the shipment to its destination on a specific day/hour. One day delay is typical. Effects are marginally negative for both partner/customer and TNT. Interviewee did not see any difference between those.

Extreme weather events affect TNT’s ability to serve their customers. Usually customers understand if there has been for example snow storm and that this can cause some delays. The immediate impacts are considerably negative, espe-
cially concerning critical shipments, which should be delivered on time. This can affect TNT’s reputation. But interviewee did not think any long-run impacts exist.

The main consequences for TNT are time delays. They have not studied what are the immediate and long—term financial costs due to extreme weather events. It was considered to be impossible to calculate.

There is a justifiable risk related to extreme weather event in foreseeable future. By saying this, interviewee meant that winter-times are always a bit risky. The level of financial and organisational risks posed to TNT’s business will not change – it is the same year after year. TNT has not taken any precautions against future financial, operational, and market-related risks. Interviewee felt that the risks caused by extreme weather events are very important for TNT, its business partners, collaborators, and clients.

Significant barrier to TNT increasing preparedness against extreme weather risks is the uncertainty about how their business will be affected. It is hard to know what the actual effects to their business are.

TNT is happy with the current level, quality, and speed of information about extreme weather events. Media and their own organisation can provide enough information. Interviewee did not think he would contact any of the organisations for advice and support against impacts of extreme weather. Weather events just come and you cannot really do anything with that. Anyhow, it would be good to know how other companies prepare for extreme weather events (benchmarking). Partners, collaborators, and clients would be the best way to get the support on this matter. Dedicated sector workshops were considered useful.

Summary of Finnish interviews

This is a summary composed of both operators and infrastructure administrators ‘interviews, presented here and part of the information was also utilised in the context of the freight. All the interviewees feel that extreme weather events do have an impact on their operations, but such hazards are usually regarded as serious in the short-term, without long-term effects. Also the financial costs come from the immediate costs. Of course, some of the respondents were worried about their reputation, which might result in long-term costs. However no attempt to approach this issue has been made.

Four out of five respondents felt that extreme weather events have affected their ability to serve customers. Although the impacts haven’t been dramatic, it remains an important factor for companies. One interviewee mentioned that customers understand that there may be delays due to bad weather. This might be so if these are occasional and infrequent delays; however if delays due to bad weather become more frequent and end up being the rule rather than the exception, customers might revise their stance and the “bad weather” excuse might not be sufficient anymore.

The traffic agency feels that both immediate and long-term impacts of the weather events are dramatic and strongly negative. They are especially worried about their reputation: and it seems that this worry is justified. Many interviewees mentioned the important role of the traffic agency in e.g. maintaining the public infrastructure and giving support and advice against impacts of extreme weather events on their businesses. Especially VR and Destia emphasised the important role of the Finnish Transport Agency as the infrastructure manager.

None of the interviewees could give any exact information, in terms of monetary valuation of the financial impact since this kind of information is either not available or is not considered public. One respondent said that it is impossible to calculate the costs but besides this, the company did not seem to take extreme weather events as a big threat anyway. They felt that weather is what it is, and you learn to live with it. Usually the costs seemed to be short-term costs. The traffic agency mentioned that the costs are multiplied, which indicates that they confront the biggest impacts among the interviewees.

Every interviewee thought that the level of financial and organisational risks posed to their business will not change. Although many respondents mentioned that the last two winters have been extraordinary cold, this does not seem to have affected the way companies consider extreme weather events as a risk to them. Some actions for preparations have been taken, but it is possible that companies still think that maybe next year there won’t be any snow and the preparation is in vain. This idea is also supported by the answers received about the most significant barriers in increasing the preparedness against extreme weather events. Uncertainty about how the business will be affected was chosen in three out of five interviews as the most important or second important barrier.

Four out of five respondents mentioned that “preparation is too expensive” and this is the biggest or second most important barrier in increasing the preparedness against weather risks. The first thing to do when preparing for the extreme weather events seems to be to increase the resources; extra manpower, more snowploughs, etc. This naturally creates extra costs. Lack of support from external stakeholders, industry or authorities was also mentioned as a significant barrier in increasing the preparedness against extreme weather events. This statement along with “preparation is too expensive” relate at least at some point to costs. Support from authorities, especially, is usually regarded to be financial support. Public operators seem to demand better support from the government by increasing their budgets. This again indicates that preparing for the extreme weather events adds financial costs for the organisations.

All the respondents thought that the current level of information and knowledge about impacts of extreme weather is quite good. Two out of five responders said that they are very happy about the current situation and the rest of the interviewees believe that information does exist, but it is difficult to access or it requires time and effort. It seems that if the company operates in prescheduled timetables (like VR), the information about the coming extreme weather events is not that meaningful as it is for example to a logistics operator. For example, Herman Andersson makes their daily load-
ing/unloading schedules with the help of weather forecasts. Weather information is also crucial to road maintenance (Destia).

Interviewees were reasonably unanimous about the best options in increasing the resilience against weather events. Financial support and knowledge of others’ preparedness were regarded as the best ways to increase resilience. Companies are interested in finding out how companies from other countries are prepared for weather events. Also workshops were considered as an interesting way to get support, but there is a risk that the participation to the workshops may be low. The participation could be possible only if extreme weather events are perceived as a real risk for the company. Web sites with tested measures and benchmarking information may be a better way to support companies. They are easily accessed and people may look for information just for their own interest.