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Estimation of disruption risk exposure in supply chains

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Abstract: The purpose of the paper is to provide more knowledge on how to estimate disruption risk exposure in the supply chain by developing a conceptual estimation model. The purpose is also to shortly illustrate and discuss by help of a case the possibilities to adapt this theoretical model for use in everyday practice.

The developed model, which links disruption risk to disruption source, covers all flow-related disruption risks in the total supply chain from natural resources to delivered final product, seen from the angle of an individual focal unit in the supply chain. The model classifies the risk exposure into 15 different risk exposure boxes, of which 12 have 'expected result impact' and three have 'known result impact', providing a total negative result impact.

The positioning of the model against other theoretical models revealed that the developed model presents a more complete and partly new structure for estimation of disruption risk exposure.

Keywords: business continuity; business continuity management; BCM; business continuity planning; conceptual model; disruptions; disruption risk exposure; disruption source; resilience; risk estimation; risk exposure; risk handling; supply chain; supply chain flow; supply chain management; supply chain risk management; SCRM.

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1 Introduction

1.1 Background

This paper deals with risk exposure estimation. It focuses on the potential disruption risk linked to a certain disruption source in the supply chain flow, where disruption is defined as an interruption in the continuity of the normal supply chain flow with an expected negative result impact (NRI). In cases where there is a disruption risk preventive actions, like taking an insurance or keeping a buffer stock, to mitigate the consequences of a potential disruption are often taken. The 'costs' for those preventive actions will exist even if there never is any disruption. From a pre-event risk management perspective they are essential also to consider and estimate since the balancing of pre- and post-event handling is one of the key issues of a risk manager.

A number of *trends,* like globalisation, outsourcing, leanness, single sourcing, and agility, have affected the supply chain risk situation. All these trends (and others as well) tend to *make the supply chain more vulnerable.* In recent years, a number of supply chain disruptions have occurred that have had *severe consequences* (see, e.g., Sheffi, 2005). Disruptions in one link of the chain could easily spread to other links in the chain (domino effects). In some situations the negative economic consequences also tend to grow for each link, infusing *escalating domino effects* [Jüttner et al., (2003), p.198]. In combination with the often limited liability for the individual link, companies further down the supply chain can be much more severely hit than where the initial disruption took place. Researchers and practitioners realise the existence of a new risk situation in supply chains (Jüttner et al., 2003; Kajüter, 2003). This has raised interest in finding new ways of handling those risks and thus creating more resilient and robust supply chains (Peck et al., 2003).

The risk management process, according to International Electrotechnical Commission (IEC, 1995), can be divided into three phases: risk analysis, risk evaluation and risk reduction/control, with two or three steps in each phase. The risk analysis phase has the following three steps; system border, hazard identification, and risk estimation. In this paper, the focus is on the last step. To be able to better manage the risks in the future we need to know where the present hazards are and estimate them – we need a risk 'picture'. And the more complete – the better. At the same time we want it to be simple.

As can be seen in the literature review in Section 2, existing theoretical risk estimation models tend to restrict themselves to just some links in the chain or just some kind of disruptions. There is thus a need for models that can include all disruption risks in the total supply chain.

1.2 Paper purpose and structure

The *purpose* of this paper is to contribute to the general knowledge about how to manage disruption risks in the supply chain flow by developing *a general aggregate theoretical risk exposure estimation model* that includes all disruption risks in the supply chain flow seen from the perspective of a focal unit in the supply chain.

The paper is structured as follows. Based on existing theories, especially a risk definition by Kaplan and Garrick (1981) and a supply chain structure proposed by Sheffi (2005), and a step-wise analysis of the problem situation, a conceptual estimation model will be developed. The practical usability in general of the theoretical model will then be discussed, and the application of the model exemplified and illustrated through a real case – Brämhults, a Swedish juice producer who used to produce and sell fresh juice but changed over to pasteurised juice a couple of years ago. The originality of the model is determined through positioning against some other research models within the area. Finally research contributions and managerial implications are summarised.

2 Literature review

One research area that deals with supply chain risk issues is *business continuity management (BCM)*. BCM focuses on how an organisation, after a serious interruption, will be able to be 'back in business' again as quickly and smoothly as possible (Hiles and Barnes, 2001). BCM thus includes all kinds of organisational activity and all kinds of interruptions. Another research area is *supply chain risk management (SCRM)*, which is the intersection of supply chain management and risk management (see, e.g., Zsidisin and Ritchie, 2008). Focus is here on the supply chain flow and the threats of the continuity of this flow. Both research areas can be seen as parts of the more general area *Enterprise Risk Management* which deals with all enterprise-related risks (COSO, 2004).

Generic models can be useful to create a common frame of reference that facilitates analysis of the present situation and the search for novel solutions. Within supply chain management, one such model is SCOR, which is a reference model for supply chain operations. Its five basic processes are plan, source, make, deliver, and return. Each process is carefully defined, as well as their internal relations. This makes the SCOR model a candidate for "*.... a powerful tool in the hands of management*" (Supply Chain Council, 2009). The focus of the SCOR model is not primarily on risks, but for each of the five processes it emphasises the supply chain risk aspects as important to consider and manage.

When it comes to research contributions specifically dealing with supply chain disruption risks we find a multitude of approaches. In one end of the spectra we find contributions looking for disruption risks in one supply chain direction only (Svensson, 2000) or looking in both directions but just one tier deep (Svensson, 2001). In the other end of the spectra we find studies of the total supply chain (Peck et al., 2003; Gaudenzi, 2005; Kleindorfer and Saad, 2005). Some researchers do not delimit themselves to disruption risks alone, but include supply chain risks in general (Johnson, 2001; Lindroth and Norrman, 2001; Kleindorfer and Van Wassenhove, 2004) while others also want to include opportunities (Norrman and Jansson, 2004; Asbjörnslett and Rasmussen, 2005).

3 Developing the theoretical risk exposure estimation model

Based on the identification of three different categories of disruption source and five different approaches for handling risks, this section develops step by step a risk exposure estimation model for disruption risks in the supply chain flow. The model classifies the risk exposure into 15 different risk exposure boxes, of which 12 have 'expected result impact' and three boxes have 'known result impact', that can be summarised into a total NRI.

3.1 Model setting

3.1.1 Starting points

In many cases where the focal unit is producing more than one product, the focal unit is a 'member' of several different supply chains where each supply chain is based on a certain product or product group. One has to be chosen. Since one and the same product can be using different supply chain alternatives, e.g., the product can be distributed through several parallel principally different distribution channels, it may also be necessary to specify the supply chain under consideration. So when we talk about 'a focal unit perspective' we actually mean from the perspective of a certain focal unit *and* a certain focal product *and* a certain focal supply chain.

There are a number of different flows in the supply chain, like product flow, information flow and financial flow. Our focus will be on the product flow, where *product* is defined as *something one gets paid to deliver.* It could be a physical product, a service or a mixture of both. All events that could lead to a disruption in the supply chain product flow are included *regardless of their origin and character*.

A *result* is that which someone or something, such as an organisation or a company, wants to reach. It is up to the user of the model to specify what kind of result dimension he or she wants to choose, and thus what is meant by *result impact (RI)*.

The time perspective is a *pre-period time perspective (ex ante)* where *period* is the chosen time period for the project in question, e.g., the coming 12 months. The ex ante perspective means that we try to act before something happens. Focus is not on actual disruptions but on *disruption risk exposure*. Disruption risk exposure means that there is a possibility that an event with a NRI will happen. *It is supposed* that if the NRI is considered too high then *there is always the opportunity of closing down the supply chain*. Then there will be no NRI anymore, but we will of course at the same time lose the opportunities that were linked to the supply chain in question.

Disruption is defined as a potential interruption in the continuity of the supply chain flow with an expected NRI compared to the normal supply chain flow situation. A normal product flow creates a normal result. An impact is then a change in this normal result. When we imagine the RI, we suppose that if an event happens, normal suitable actions, belonging to earlier chosen strategies, will be taken to deal with the consequences.

If the focal unit had not been subject to any disruption risk exposure, its estimated future result would have been of a certain size. But now, since the focal unit is exposed to certain disruption risks, the estimated future result is less favourable. The difference can be regarded as the *total NRI from the disruption risk exposure.* Through risk management one tries to minimise this difference.

3.1.2 Supply chain disruption sources

Johnson (2001) was one of the first to stress the importance of including both the supply side and the demand side when looking at supply chain risks. Sheffi (2005, p.28) suggests, from the perspective of a focal company/unit, a division of the supply chain into three different parts: the *inbound* or supply side, the internal processes or *conversion* part, and the *outbound* or customer-facing side. This division into three will be used here, but the parts will be somewhat renamed, namely: *supply side*, *production* and *demand side*. They can be identified in a supply chain product flow going from *natural resources* to *end market*. These three parts of the supply chain will be used here for structuring the disruptions into three different types of *disruption sources*: within the supply side, within the focal unit, and within the supply side.

3.1.3 Handling approaches to risk exposure

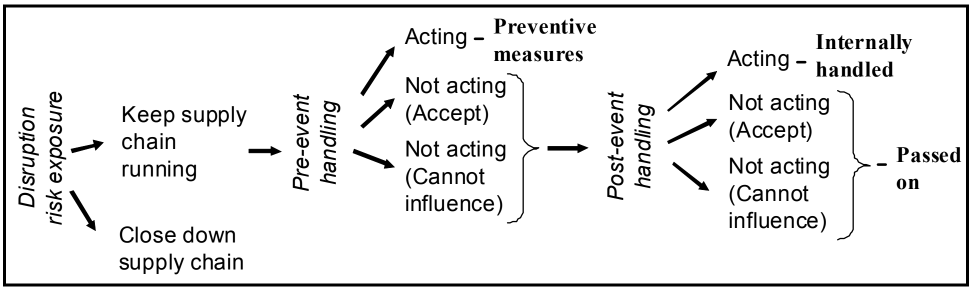
It was supposed in Section 3.1.1 that the alternative of closing down the supply chain always exists and if we do that, then of course the risk will be totally eliminated. But if we choose to let the supply chain keep running, then we are exposed to certain disruption risks. The disruption risk exposure in itself does not cause any ‘costs’. The RI is *the result of the use of different risk handling activities* where doing nothing, i.e., passing on the disruption to another link, is regarded as a risk handling action. The activities could take place pre-event and post-event.

P*re-event handling* could mean that actions are taken, like buying new insurance or building up a buffer stock, to mitigate the risk. One could also choose not to act, because that is seen as more favourable than acting (we simply accept the risk as it is). But not acting could also follow from a situation where the risk cannot be influenced once we have decided to keep the supply chain running. In both cases the disruption is sent on to post-event handling.

Post-event handling means taking actions like working overtime or temporarily buying from another supplier. There are two basic approaches for the focal unit to handle a disruption that has taken place: to handle the disruption within the focal unit, or to let the disruption out of the focal unit by passing it on. Disruptions are passed on for two different reasons. One is that the NRI of the disruption will be lower if passed on than if handled internally (accepting). The other reason is that it has to be passed on because it cannot be handled internally. The latter will also be seen as risk handling, since we have supposed that the alternative of closing down the supply chain exists.

Pre-event handling in the form of actions will be called *preventive measures*. Post-event handling in the form of actions will be called *internally handled*, and in the form of not acting, *passed on*. There exist in other words three different basic approaches to handling risk exposure: preventive measures, internally handled, and passed on. In the individual situation one, two or all three approaches to risk handling can be applied.

Figure 1 Disruption risk exposure and risk handling approaches



3.2 Expected NRI

Acting after the disruption has happened can cause 'costs'. Those costs will be called 'expected NRI', since we do not know if the disruption is going to occur or not, but we can estimate its 'costs' by employing a likelihood.

The concept *risk* gets a meaning only when the situation has been specified. Risk is defined by Kaplan and Garrick (1981, pp.12–13) in a precise way, *given a certain situation*, as *'a complete set of triplets'* where *the individual triplet* <S, L, C> is the answer to the three questions: What can happen? (Scenario, S), How likely is it that it will happen? (Likelihood, L), and if it does happen, what are the consequences? (Consequences, C). The expected consequence of a specific scenario S is L*C where L is here specified as the probability that the scenario will happen during a specified period of time.

3.2.1 The individual triplet

3.2.1.1 Risk scenario description

A risk scenario can basically be described as a chain of events starting with an initiating event and terminating with an end state. Between those there are one or more mid states and, in complex scenario situations, there will be a number of mid states (Kaplan, 1997).

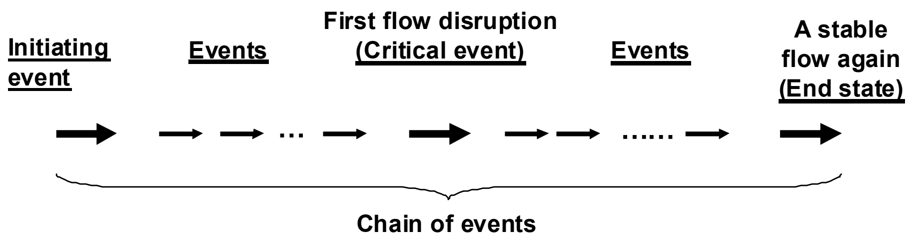
Often, we have a special interest in one of those mid states, and that intermediate state will here be called *'critical event'* (others often call it '*top event*').

As soon as we apply the risk scenario model in a certain context, a number of specifications are necessary. We might need to specify initial event, critical event and end state. We might for instance only be interested in fires in private houses (critical event) caused by a short circuit in old electrical systems (initial event), and our interest ends when the fire has been extinguished (end state).

In the model, the critical event is specified as "*a supply chain product flow disruption, which constitutes the first disruption in a scenario*". What characterises the 'end state' also has to be defined, and the definition chosen here is when we are "*back to a stable flow again*". Consequently, there is a stable flow, something happens (initiating event) that starts a chain of events, including a critical event (first product flow disruption), that ends when we are back to a stable flow again (End state).

An initiating event could be of any kind – such as a machine break-down, a bankruptcy, a flooding, a wild strike, a fire, a flu, or a rumour on the consumer market that the product is poisoned – that might lead to a product flow disruption.

Figure 2 Illustration of a scenario with a critical event in the model setting



3.2.1.2 Supply chain disruption source and post-event handling approach

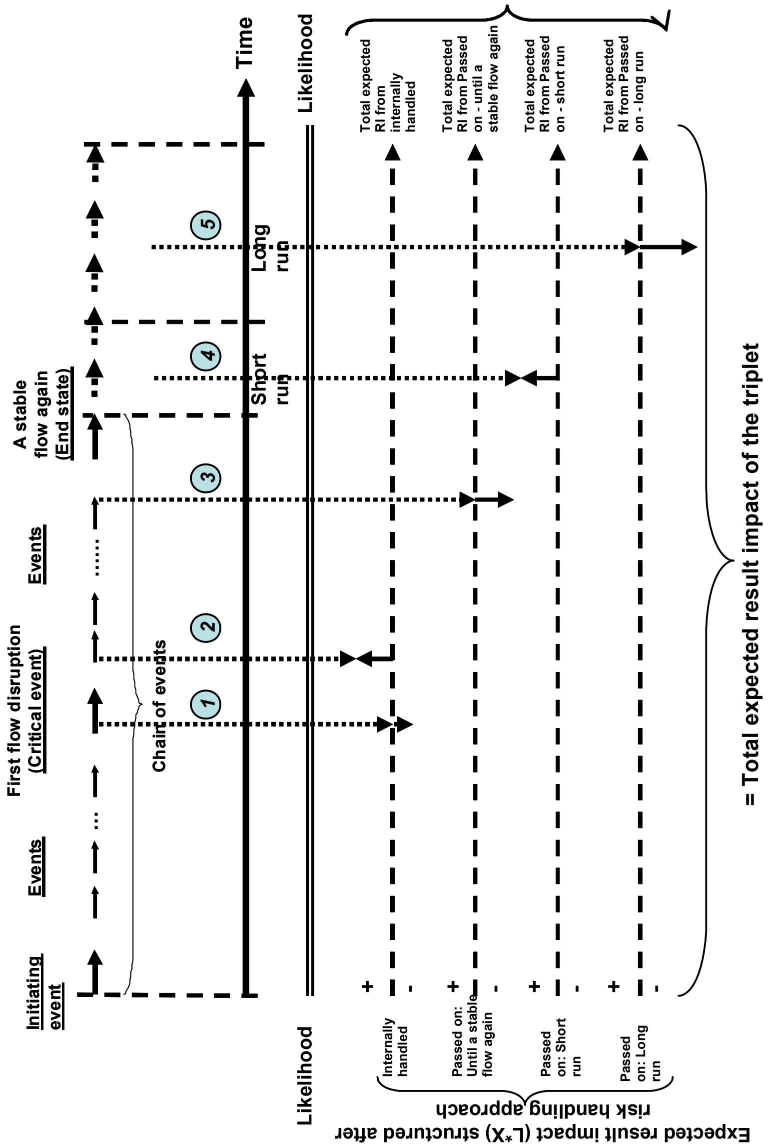
The consequences of a disruption can often spread over long periods, unfold over time from local to widespread, and may change character over time. Those aspects seem to be especially relevant for the disruptions passed on to market. It is therefore suitable to split up the market reactions into several periods of time. The following three periods of time are chosen: from critical event (disruption) until *back to a stable flow*, from stable flow until *short run* effects have materialised, and from that point in time until *long run* effects have materialised. *Short run* is also called market patience, and another term for *long run* is market confidence. Consequently there are now *four approaches to post-event risk handling*: internally handled, passed on-until back to a stable flow, passed on-short run, and passed on-long run. If we combine those four with the three different *disruption sources* identified in Section 3.1.2 we will get twelve possible combinations.

3.2.1.3 The individual triplet linked to risk handling and RI

A scenario is *one* chain of events. Each scenario is assigned a particular likelihood (L). Each scenario can further belong to just one disruption source.

It is possible, based on the chain of events in a scenario, to identify those events which have a RI, specify the impact and sum up all the RI into a “total expected result impact from the specific triplet”. A scenario might include one or several of the risk handling approaches. Some of them may, in the specific situation, have an expected *positive* RI while others have a negative.

Figure 3 The individual triplet linked to risk handling approach and RI (see online version for colours)



Illustrative example of a single triplet (Figure 3): suppose that the company A-PRODUCTS Limited produces and sells the product A with a certain profit. Suppose that the initiating event is a breakdown of a machine at a first tier supplier of the critical component X and that there is a four-week disruption in deliveries from the supplier. Suppose also that the likelihood for this chain of events (scenario) to happen during a year is 1/100 and that the company has a one week buffer stock of component X.

1 The company manages to buy a one-week supply of component X from another supplier but at a higher price. No more components can be bought on the spot market.
2 Since there are no deliveries of component X from our usual supplier for four weeks, we will not have to pay them during this period.
3 Of the four-week disruption, two weeks will be passed on and we will lose sale revenues for those two weeks.
4 When deliveries start arriving, the company can start producing again. In the short run (market patience) our customers, because of the two-week disruption in deliveries, will buy somewhat more from us than usual.
5 In the long run (market confidence), though, we will lose sale because the market no longer regards us as an equally reliable supplier as before the disruption.

The illustrative example can be complemented by monetary values.

Table 1 The illustrative example A-PRODUCTS with monetary values

Event	*Risk handling approach*	*Result impact in monetary value*
1	Buying components at a higher price on the spot market	–130
2	No supplier payment for four weeks	+300
3	Lost sale for two weeks	–320
4	Extra sale in the short run	+250
5	Lost sale in the long run	–500
	Total result impact	*= –400*
	Likelihood	1/100
	Total expected result impact	*–4*

3.2.2 Risk as the complete set of triplets for a certain disruption

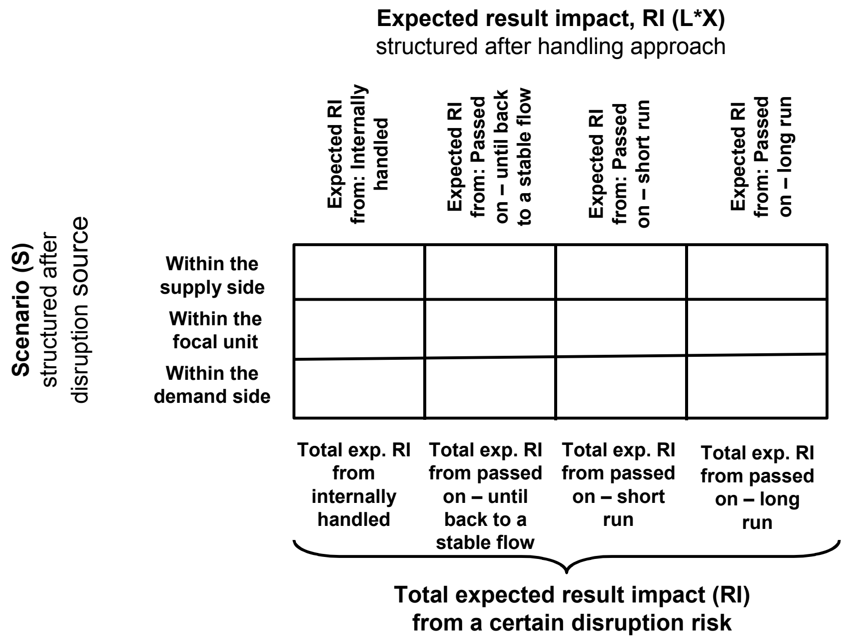
Suppose that a closer look at the *A-PRODUCTS example* reveal that the consequences will be different depending on what time of the year the machine break-down takes place. Actually three different scenario alternatives can be identified. The company closes each year down for summer vacations during the month of June. The figures presented above in Table 1 are quite representative for the first five and half months of the year. Most of the sale is though concentrated to the last five months of the year and a machine break down during this period would be much worse and result in an expected NRI of 20. On the other hand would a machine break down during the two weeks just before vacations actually have a small positive RI of 2. Taking all this into consideration we can calculate the annual disruption risk linked to the disruption source "a breakdown of a machine at the first tier supplier of the critical component X" as the expected RI:

$$-4*5.5/11+2*0.5/11-20*5/11=-2+0.41-9.09=-10.68$$

3.2.3 The total disruption risk

The expected RI of any disruption risk can be distributed among 12 boxes depending on disruption source and risk handling approach.

Figure 4 Model for distributing the expected RI from a certain disruption risk on disruption sources and handling approaches



Our interest, however, is not primarily in the risk linked to one individual disruption but to all disruption risks. This can be reached by systematically going through all potential initiating events and the expected RIs from their scenarios.

3.3 Known RI

A company's awareness that it is exposed to certain disruption risks in the supply chain product flow often prompts it to take some preventive measures, like buying insurance, having multiple suppliers, creating a certain overcapacity in production or (as was the case in the illustrative example) building up a buffer stock of components. Acting in advance by taking preventive measures causes NRI. This must also be included in the model. Those 'costs' will be called 'known result impact' since we know that they will occur regardless of whether there turns out to be a disruption or not. Each preventive measure can be linked to one or more of the three disruption sources – within the supply side, within the focal unit, and within the supply side, as identified in Section 3.1.2.

Table 2 Disruption risk exposure estimation model

Disruption source	*Known RI from preventive measures*	*Expected result impact (RI)*				
		Expected RI from internally handled disruptions	*Expected RI from passed on disruptions*			
			Until back to a stable flow	*In the short run (market patience)*	*In the long run (market confidence)*	
Initiating event within supply side						Total negative RI from scenarios initiated within supply side
Initiating event within focal unit						Total negative RI from scenarios initiated within focal unit
Initiating event within demand side						Total negative RI from scenarios initiated within demand side
		Total expected RI from internally handled	Total expected RI from passed on; until back to a stable flow	Total expected RI from passed on; in the short run	Total expected RI from passed on; in the long run	
	Total known RI	*Total expected RI*				*Total negative RI*

Note: Abbreviation: RI = result impact

3.4 The disruption risk exposure estimation model

If we sum up known NRI and expected NRI, we will get the *total NRI from the disruption risk exposure.*

The issue of 'expected result impact' was treated in Section 3.2, and in Section 3.3 'known result impact' was dealt with. Both types of RI were structured according to the three different types of disruption sources identified in Section 3.1.2.

This gives us the following model for estimation of the disruption risk exposure (Table 2).

With the help of this model, in theory all product flow-related disruption exposure risks in the total supply chain, seen from the point of view of the focal unit, can be estimated and presented as a risk 'picture' with 15 different 'risk boxes' which are structured after risk source and risk-handling way. They can be summed up in different ways.

4 Application of the theoretical model in practice

First some general reflections on the possibilities to apply the theoretical model, that was developed in the previous chapter, in practice. Then a live case giving a concrete example of how the model can be applied in practice is presented.

4.1 Some reflections on the practical application of the model

4.1.1 Situation specification

When applying the model we need to specify a number of factors like; focal company, focal product, supply chain, and RI. For instance is in the Brämhults case discussed below; focal company – Brämhults, focal product – fresh orange juice, supply chain – from orange producer to orange juice drinking consumer, and RI – business profit impact.

4.1.2 Data access and accuracy

In theory it is easy to simply assume that we have access to all relevant information and that the quality of this information is ideal. *In practice* this is often not the case. Data might be impossible to access or the cost of collecting it very high. But from a practical perspective, complete and perfect information is often not necessary. According to Borge (2001, p.27) "*most real-life risk problems of any importance have to be simplified to be solved. The best risk managers are those that can simplify without sacrificing the essentials*." One possibility to simplify is to only consider *critical risks*, i.e., disruption risks that might have a considerable NRI. Another possibility is to only use *a limited set of risk levels*. In the Brämhults case only critical events are considered and only five different risk levels are used.

4.1.3 User-friendly

Another aspect is that models that are complicated and therefore hard to understand and use will often never be used at all in practice. The model presented here has a number of possibilities for simplification and the basic structure of the theoretical model is quite un-complicated and does the estimation of the disruption risk exposure in a logical, systematic and aggregated way, all which makes the model easy to understand and use.

4.2 An illustration: the model applied on Brämhults juice

As an illustration of how the model might be used, it is applied to Brämhults juice before and after the installation of a pasteuriser.

4.2.1 Brämhults before the installation of a pasteuriser

The situation described below is the one that existed before the installation of the pasteuriser in May 2005.

4.2.1.1 Some company facts

The company is situated in Sweden, has just one production unit, and a turnover of about 20 million Euro. It has about 100 employees, most of who are employed within sales and distribution. The company produces freshly squeezed juices that do not contain any preservatives, and is very keen on keeping a high and even quality of their products.

4.2.1.2 The supply chain

- *Natural resources*: Natural resources are here mainly the land and the soil producing the citrus fruits.
- *Supply side*: The fruits are mainly bought from traders, and to some extent directly from producers located both within and outside Europe. The freight is paid by the supplier, and the transport is also arranged by the supplier. For a number of reasons the quality of the fruit can change in an unforeseeable way. One factor is changing weather conditions, which can affect the accessibility and the quality of the fruits.
- *Production*: The production process consists of five different steps; arrival control, squeezing, mixing, bottling and picking. The company has on its premises a small stock of fresh oranges and other citrus fruits covering a couple of days' need. The juice is squeezed during nighttimes and chilled and distributed early in the morning. Production is customer driven, and no stock of finished products exists. This means that everything that is produced during the night has already been sold and will be distributed during the day.
- *Demand side:* The company sells its products in Denmark, Finland, Norway and Sweden. The fresh juice is delivered to the different stores and their refrigerated display cabinets by Brämhults' own refrigerated trucks driven by their own drivers (except on the Finnish market, where distribution is bought from a third party). The products have to be kept cool during the whole chain from production to consumption, because the juices are not pasteurised, which means that they might contain bacteria that could easily multiply if the temperature rises too much. If the juices are kept at the right low temperature, between zero and 5 degrees, they are guaranteed to stay fresh for ten days. Within this period of time, the bottles should be distributed to the shop, stored at the shop, bought by an end customer, brought to the home of the end customer, stored again and finally consumed. This is the main

reason why the company only sells its products in geographically nearby markets (i.e. the Scandinavian countries).

- *End market*: End customers are mainly the different individual consumers (private households) that buy the juice in the shop, but there are also a few big customers (e.g., an airport) that get the juice directly delivered to them.

4.2.1.3 Potential risk sources

Changing weather conditions like heat, cold or an unusually dry period can drastically reduce the supply of citrus fruits, and so can natural disasters like flooding and hurricanes. Wrong deliveries and late arrivals could also cause problems. The fact that the bottle is unique and single sourced is another risk source. There is only a small buffer stock of packages and an almost non-existent one of citrus fruits. Moreover, there is just one production unit with one production line. A disruption in production could not be mitigated by buffer stocks of finished products, since there are none at the factory and only a limited stock of juice covering a couple of days' demand at the shops. If Brämhults juice is not on the shelf, there is a risk that the customer will buy a competitor's product instead – and like it.

The risk of spoiled juice is a special case. Not only will the quality of the product be affected if it is mistreated, but there are also contamination risks, meaning that people actually could get sick, although the risk is very small. If a shipment containing bad fruit is not discovered on arrival, it might enter production and cause contamination problems because the juice is not pasteurised. But the major problem is the cold chain, which has to be maintained from production throughout the whole distribution. There are a number of risk sources. One is that the shops may not pick up the delivered juice immediately and place it in refrigerated display cabinets. Another risk source is that the temperature may be too high in the refrigerated display cabinets in the shops. Yet another is that customers may regret buying the product while they are still in the shop and just put it back on an ordinary shelf or leave it at the cashier's counter. Then it might occasionally take some time before the juice is put back in the refrigerated cabinet. Spoiled products might thus be on the shelves in the shops and be bought by customers.

There are also a number of risk sources after the product has been sold in the shop: too high temperature during the end customer's (consumer's) transport from the shop to the refrigerator in his/her home, too high temperature in the end customer's refrigerator or in another place where the customer leaves the juice for a period of time, e.g., on the kitchen table.

The customer's personal experience of the spoiled juice means that s/he might hesitate to buy the product in the future even if s/he likes it. Information about spoiled juice from external sources like newspapers or television might also mean that customers feel apprehensive about buying the product in the future even if they have not had any problem with bad juices themselves.

4.2.1.4 Risk management activities

Brämhults tries to buy all their fruit from certified producers. They also have specific routines for the arrival check of the fresh fruits, e.g., visual control of the fresh fruit and returning those fruits that do not live up to the required quality level, or occasionally taking a sample of the fruit and sending it to a test laboratory for analysis.

In production, Brämhults has specific routines for sorting away those fruits that do not live up to the required quality level. There are also specific routines for cleaning the machines (but no central clean-up function). There are also certain routines for handling customer complaints that can provide indications of quality problems in production.

On the demand side, there is direct distribution from factory to the individual shop with Brämhults' own trucks driven by their own drivers. There are also routines for the drivers to check the quality of the products on the shop shelves and, finally, routines for picking up and taking back bad products belonging to batches that do not live up to the quality standard.

4.2.1.5 Risk levels

NRI has been specified as negative business profit impact. The risk levels have been set in a repeated dialogue with company representatives. Below are the arguments for setting the different risk levels presented in summary.

Two major individual risk sources have been identified. One is spoiled juice, which if it reaches the end customer can lead to a disruption in demand in the short run. But it could also have severe long-term effects on market confidence. The other is the unique bottle, which is characteristic of Brämhults juice. Single sourcing in combination with a limited buffer stock of bottles and a long start-up time if the production facilities for the bottle are damaged can make it necessary to bottle the juice in standard packages for some period of time. The problem, however, is that the customer might not recognise the product.

Table 3 Brämhults; risk exposure levels before the pasteuriser

Disruption source:	*Known BPI from preventive measures*	*Expected business profit impact (BPI)*			
		Expected BPI from internally handled disruptions	*Expected BPI from passed on disruptions*		
			Until back to a stable flow	*In the short run (market patience)*	*In the long run (market confidence)*
Initiating event within supply side	Low	Very low	Medium	High	Very high
Initiating event within focal unit	Very low	Very low	Low	Medium	High
Initiating event within demand side	Low	Very low	Medium	High	Very high
		Total expected BPI from internally handled	Total expected BPI from passed on; until back to a stable flow	Total expected BPI from passed on; in the short run	Total expected BPI from passed on; in the long run
	Total known BPI	*Total expected BPI*			

Notes: Abbreviation: BPI = business profit impact
Risk exposure levels; very low, low, medium, high, very high and not estimated.

There are few preventive risk-handling actions, and consequently the known business profit impacts are *low*. Since the juice is fresh, the possibilities to handle a disruption internally are nearly non-existent, and therefore the business profit impacts are *very low*. Accordingly, almost all disruptions have to be passed on, and this is where the main expected negative business profit impacts will be found. Since there are several other fruit juice brands on the market, customers will change over, some of them permanently, to another brand if Brämhults juice is not on the shelf – the risk level for market patience is therefore *high*. Finally if end customers consume spoiled juice for one reason or another and they get sick, then that could totally destroy the market's confidence in the Brämhults brand for a long period of time. The risk level for market confidence is therefore set to be *very high*.

4.2.2 Brämhults after the installation of a pasteuriser

A pasteuriser is a machine in which (in this case) the juice is heated to 70–72°C for about 30 seconds, thereby eliminating many of the micro-organisms that might contaminate the product.

The description and analysis below is based on the situation in August 2006 – about 15 months after the installation of the pasteuriser in May 2005. Table 4 presents the estimated risk exposure levels after the installation of the pasteuriser. The estimations before the installation are given within brackets if changed. Also in this situation the risk levels have been set in a repeated dialogue with company representatives.

Table 4 Brämhults: Risk exposure levels after the pasteuriser

Disruption source:	*Known BPI from preventive measures*	*Expected business profit impact (BPI)*			
		Expected BPI from internally handled disruptions	*Expected BPI from passed on disruptions*		
			Until back to a stable flow	*In the short run (market patience)*	*In the long run (market confidence)*
Initiating event within supply side	Medium (low)	Very low	Low (medium)	Medium (high)	Medium (very high)
Initiating event within focal unit	Medium (very low)	Very low	Low	Low (medium)	Medium (high)
Initiating event within demand side	Very low (low)	Very low	Low (medium)	Medium (high)	Medium (very high)
		Total expected BPI from internally handled	Total expected BPI from passed on; until back to a stable flow	Total expected BPI from passed on; in the short run	Total expected BPI from passed on; in the long run
	Total known BPI	*Total expected BPI*			

Notes: Before within brackets if changed.
Abbreviation: BPI = business profit impact
Risk exposure levels; very low, low, medium, high, very high and not estimated.

The investment in a pasteuriser is mainly to be seen as a risk handling action – a preventive measure. The known business profit impacts are therefore now *medium* for two of the three disruption sources. The business profit impacts for internally handled disruptions are still *very low.* Almost all the business profit impacts that are linked to passed-on disruptions have decreased and are now *low* for 'until back to a stable flow' and about *medium* for the rest. The main reason for not lowering them even more is that the risks linked to the unique bottle are unchanged.

The analysis showed that there was an increase in two of the three 'known business profit impact boxes' and a decrease in the third one. There was also a decrease in eight of the 'expected business profit impact boxes', and the remaining four were unchanged. It is especially interesting that the three risks boxes linked to market confidence, which before were high or very high, were now all medium. There has also been a change towards comparatively *more known* business profit impacts and *fewer expected* business profit impacts.

5 Conclusions

The importance of having a supply chain risk perspective and including the whole supply chain from nature to market is often stressed in journal papers and other literature, but few examples of such models exist – at least when it comes to supply chain flow disruption risks. The risk exposure estimation model developed in this paper addresses the whole supply chain from nature to market. The model is a *holistic* and *generic model* for estimating disruption risks in the supply chain product flow that helps to treat such risk issues *in a structured and systematic way*. It is a model based on the setting of a focal unit employing a supply chain perspective. It can be used in a number of different ways.

The research contributions presented in Section 2 that have most similarities with the risk estimation model developed here are Peck et al. (2003), Norrman and Jansson (2004), Gaudenzi (2005), and Kleindorfer and Saad (2005).

Peck et al. (2003) cover the whole supply chain with the help of four risks, since the fifth risk is the supply chain environment. For each of the risks, the factors affecting it and how the risk can be handled are discussed. No attempt to quantify the risks is made. Norrman and Jansson (2004) discuss the risk management work at Ericsson. Mapping is done for a number of links upstream and partly also downstream. The company works with the identification of individual risks and tries to grasp their business value impact (BVI). To simplify the analysis, BVI is split into four categories: severe, major, minor and negligible – each category representing a certain economic interval. Also the probabilities are judged with the help of a limited number of classes. Individual major risks are thus categorised according to impact and probability, but no attempt is made to summarise risk values or to cover all risks. Gaudenzi (2005) stresses the identification of a focal unit as the starting point of risk analysis. The focus is on the handing over (transfer) point and the fulfilment of the perfect order. Different deviance possibilities of the perfect order are discussed, and different risk handling methods presented. Methods for partial quantification are also discussed. Kleindorfer and Saad (2005), finally, present ten different principles for efficient management of disruption risks in supply chains. No attempt is made to quantify the risks.

The risk estimation model developed in this paper is an aggregate model that explicitly includes all product flow-related disruption risks in the total supply chain, which none of the above models do. The *theoretical* model developed is thus a model that presents a more complete estimation and a partly new structure for estimation of the disruption risk exposure. *In practice*, information in most situations is far from complete and perfect, but the model may nevertheless be interesting, because from an action perspective one wants only as much information of an acceptable quality that will allow action. It is in practice also important that the model is easy to learn and apply, and this model does the estimation of the disruption risk exposure in a way, which makes it easy to understand and use. The model includes both pre- and post-event handling, and can therefore assist in finding a better *balance* between proactive and reactive risk handling actions – which is an important management issue.

Finally the application of the model on the Brämhults case provides an *illustration* of how the model might be used in practice for identifying, structuring and estimating the supply chain disruption risks and presenting an overall picture of the risk exposure situation.

The original basis for this paper is a doctoral thesis by Paulsson (2007) and a research report by Paulsson and Nilsson (2008).

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