

2 Phenomena of Disruptions in Supply Chains

2.1 Introduction to the Section

The research process in social sciences firstly requires the specification of the research subject and the development of a conceptual system (e.g. Chmielewicz 1979; Hill, Fehlbaum & Ulrich 1994; Kromrey 2009). This includes according to Kromrey (2009) a specification of terms by a semantic and a dimensional analysis, the elaboration of the status of research related to these terms, as well as related to potential causal relations. Therefore, in section 2, a deeper understanding of disruptions in general and supply chain disruptions in particular shall be provided. Based on the understanding to be developed, the focus will be narrowed down afterwards to the identification and analysis of causes of disruptions in food supply chains. How these research objectives will be pursued is depicted in the following paragraphs.

Firstly, the term “disruption” has to be specified and distinguished from similar concepts, to concretize the research focus. Therefore, section 2.2 creates first of all the terminological basis by a semantic analysis. Section 2.2.1 aims at the specification of the understanding of disruptions, which currently still diverges considerably not only regarding content, but also regarding terms used. Because of this variation, not only the term “disruption” will be analyzed, but also the term “rupture”, as both terms find application in the literature and partly are used to describe the same phenomena. Based on the semantic analysis of the terms rupture and disruptions in research disciplines such as medicine, physics, and sociology, the understanding and terminology used in the rest of this thesis is chosen, to avoid confusion with similar constructs from other disciplines. Apart from the specifying the understanding of disruptions based on the research discipline, in section 2.2.2, the focus is narrowed down to the actual research field. The status-quo of research concerned with disruptions in supply chains is illustrated, to provide an overview on already existing insights on causal relationships, as well as on common understandings of disruptions in this context. Thereby, not only encountered definitions will be depicted and compared, but also their conformity with requirements of philosophy of science analyzed, to assess their suitability and explanatory power for the purpose of this thesis. Based on the previous considerations, section 2.2.3 develops an own understanding and definition of disruptions in supply chains. Thereby, quality criteria of philosophy of science will be considered as well as the previously illustrated definitions, to increase its explanatory power as well as convenience for purpose. Therewith, assertiveness of the definition as demanded by Chmielewicz (1979) shall be increased.

However, before being able to develop hypotheses on causal relations, the semantic analysis of disruptions has to be followed by a dimensional analysis, to understand the construct in its entirety (Kromrey 2009). Therefore, the construct disruption is decomposed into its elements and related dimensions, which can then be used to build typologies of disruptions, to facilitate the deduction of hypotheses (Hill, Fehlbaum & Ulrich 1994). Current literature on disruptions in supply chains identified or mentions implicitly different dimensions of reality, which are

part of disruptions. For the empirical analysis of disruptions it is important, which dimensions are involved, to what extent these dimensions can be grouped, or whether they need consideration by choosing specific indicators (Kromrey 2009). Therefore, the dimensional analysis and construction of typologies is the purpose of section 2.3.

To this purpose, section 2.3.1 will provide the dimensional analysis of supply chain disruptions. Therewith relevant dimensions of reality shall be illustrated, the construct decomposed, and causal connections between dimensions identified. Section 2.3.2 will assess already existing typologies of disruptions encountered in the literature review. Such typologies may help to describe conditions for the validity of stipulated hypotheses in a shortened form (Hill, Fehlbaum & Ulrich 1994). Based on the deficits of typologies of disruptions encountered in the literature, in section 2.3.3, a terminological decomposition of supply chain disruptions will be executed, which aims at a complete and comprehensive decomposition of the construct. Based on the hitherto developed understanding of disruptions, their semantic content, dimensional characteristics and causal relations, a systematic classification will be developed, which is conceptual and multidimensional in nature. In order to identify and measure empirically occurring disruptions with statistical analyses however, quantitative indicators have to be attributed to the different theoretical categories (Bailey 1994). Therefore, this conceptual classification has to be integrated in a tool for the systematic operationalization of indicators and measurement of disruptions.

This tool will be developed in section 2.4 and serves as a starting point for the identification and development of indicators for disruptions in food supply chains. Section 2.4.1 provides the logical basis, on which the tool can be developed under consideration of the definition and prevalent dimensions of disruptions. At the end of this section, a framework will be offered, which allows for a systematic deduction of indicators for disruptions in food supply chains. How these indicators can be developed is part of section 2.4.2. In this section, specifications will be made based on the terminological decomposition of disruptions from section 2.3.3, for the deduction and prioritization of indicators. Therewith, the abstract phenomenon is already concretized, but still lacks rules for operationalization, which is done in section 2.4.3. In order to increase its general usability, a guideline for the deduction of indicators and measures will be developed. At the end of this section, a scoring model will be provided which may help to analyze disruptions in food supply chains.

However, before starting the analysis, the status-quo of research on causal explanations of disruptions in supply chains has to be depicted, to avoid redundancies and facilitate the concretization of the research question. Therefore, section 2.5 is concerned with depicting the status-quo of research on potential causal relationships of disruptions. To this purpose, section 2.5.1 will depict firstly the status of research on causes and effects of disruptions in supply chains, to identify already empirically tested causes of disruptions for the use in subsequent investigations, and to avoid redundancies. Therewith, the preliminary understanding of causes of disruptions shall be enhanced, assumptions on causal relationships reconsidered, and the

research gap outlined. The research field will be further concretized in section 2.5.2. Therefore, an overview on characteristics of food supply chains in general, as well as on challenges reported in the literature will be provided, to identify potential starting points of analysis. Furthermore, the objective is thereby to deepen the understanding in the context of this thesis, as well as its practical relevancy. This end is further pursued in section 2.5.3, which will highlight potential causes of disruptions in food supply chains. Based on a content analysis of the status-quo of research in food supply chains, insights will be grouped schematically into different aspects of supply chains, to identify core areas of potential causes. Therewith, starting points for the development of hypotheses on causes of disruptions shall be provided.

Finally, section 2.5 summarizes the findings of section 2, giving a short overview on tasks and results of each section. Based on these terminological and conceptual results, section 3 can then start to pursue the analytical objectives of this thesis.

2.2 Deficits in Understandings and Definitions of Disruptions

2.2.1 Untangling “Ruptures” and “Disruptions”

The purpose of this section is to provide an overview on use of the terms disruptions and ruptures in general. Therewith, a better understanding of the phenomenon and its theoretical context shall be achieved, which is indispensable for a subsequent empirical testing of hypotheses (Kromrey 2009). The reason why both terms will be investigated is that with reference to cold chains, industrial associations as well as official authorities¹² use the expression “cold chain *rupture*”, whereas in the general supply chain literature, the term “supply chain *disruption*” is used (see section 2.2.2). Since this thesis will focus on the intersection between both research fields, both terms will be included to avoid the omission of important aspects.

For the collection of relevant literature, the database Business Source Premier by EBSCO has been chosen, since it is used in business-related industries and research in such fields as marketing, finance, management, accounting and economics and offers more than 2,300 journals, of which 1,100 are peer-reviewed (Oulanov 2008). In order to assure that the papers considered dispose a certain quality, only those papers were considered, which were published in academic peer-reviewed journals.

The search for the term “rupture” yielded 296 results, whereas for “disruption”, 1,405 results were found. For the review of the terms in general, the first 150¹³ search results on each term have been assessed regarding the understanding and contextual embeddedness of the phenomenon. Additionally, for the review of disruptions and ruptures in a supply chain management context, the database Google Scholar has been used to double check and extent the results obtained in Business Source Premier. Out of the 1,405 results on disruptions in Business

¹² E.g. Cool Chain Association (www.coolchain.org) or reports in the European Commission’s database RASFF (http://ec.europa.eu/food/food/rapidalert/index_en.htm).

¹³ This threshold assures that at least 10% of the publications encountered have been included in the general overview on the terms.

Source Premier, 113 dealt with the phenomenon in a supply chain context and were therefore assessed in detail. In Google Scholar, 84 additional papers were identified of which 60 were included in the review after deletion of duplicates. An overview on the findings will be provided in the next paragraphs, as well as in sections 2.2.2 and 2.5.1.

The first time when the term “disruption” in Business Source Premier was mentioned dates back to 1938, when it was used to describe *family disintegration* processes. Mowrer (1938) understands a disruption as being the climax of a conflict between family members, when a drastic change becomes inevitable, such as a divorce. Furthermore, he notes that up to the point of a disruption, even though existing, the conflict might be ignored. In the following years, the term has been repeatedly used to describe *social disintegration*, either in the contexts of communities, or families (Elliott 1941), societies as a whole (Buckley 1958), or habits and status (Holt 1940). Thereby, the discontinuous character of disruptions has been highlighted, with conflicts or changes evolving over time up to the point of no return.

The abstract nature of disruptions is also highlighted in other application fields. For example, in *psychology* it often means the disturbance of a train of thought or of the execution of a task by background noises or irrelevant speech, which has been a widely studied phenomenon (e.g. Banbury & Berry 1998; Larsen & Baddeley 2003; Bridges & Jones 1996; Jones, Macken & Mosdell 1997; MaCken et al. 1999). Instead of disrupting the link between two or more different elements however, these disruptions take place internally in a human being. Thus, the disruption occurs in cognitive processes caused by some external stimuli.

In the area of *ecology*, a disruption is concerned with pollution and depletion of natural resources, which lead to considerable changes of the environment (e.g. Embrey, Remais & Hess 2012; Driesen & Popp 2010; Leontief 1977). Again, the lack of some kind of resources is stressed, which is caused by complex interactions of multiple and diverse reasons. The cause and its effect may thereby be temporally and spatially apart, so that it might not be clear what caused the observed negative effect.

A variety of applications can be found in fields of study concerned with economics and management. For instance, “disruption” describes the introduction of an innovative technology in the market, which leads to substantial adjustments of this market (e.g. Cochran, Patz & Rowe 1978; Ash & Smith-Daniels 2004). Lam et al. (2010, p. 128) for instance define market disruptions as “*major events occurring in the market that threaten customer–brand relationships*”. However, not in every case, such a disruption is necessarily understood as something negative, but also as a creative process, an entrepreneurial ability, and as the start of something new (Vedres & Stark 2010). Therewith, a disruption is understood as an important and necessary event to foster evolution of markets and becomes similar to the creative destruction that is at the core of the theory of economic development by Schumpeter (1947). Nevertheless, it implies substantial adaptation and re-alignment of strategies and production plans to a new situation and may result in concurrency (Cochran, Patz & Rowe 1978) or competitive advantage (Vedres & Stark 2010).

In *international trade*, the use of the term is related to the termination of supply of critical resources (e.g. petrol, copper, etc.) between states or regions (e.g. Glick & Taylor 2010; Lindsey 1989; Dean 1995), which can again be linked to the depletion of resources in ecology. However, in this case, not only commercial interests play a role, but also political factors (Glick & Taylor 2010), whereby the termination of supply is not seen as the final effect, but as a side effect or as a mean to achieve another ultimate goal. Thereby, the complexity and need for contextual interpretation of disruptions is stressed.

Closely related to international trade is the topic field of *finance*, where a disruption is for example understood as periodic misalignments of price and income, stressing its potentially repeated occurrence (Nourse 1960). Its unintended nature is additionally stressed by Williamson (1945), who uses the term to describe economic crises in the United States caused by bank failures and lacking governmental control of banks. He stresses thereby the complexity and multi-causality of what he terms “*serious disruption of economic affairs*” (Williamson 1945, p. 217). These two examples understand disruptions as a temporal lack of purchasing power, either by increase of prices or loss of capital due to multiple causes and their complex interactions.¹⁴

One last example stems from the literature on construction claims (e.g. Ibbs & Liu 2005; Norfleet 2005; Braimah & Ndekugri 2006). Here, disruption claims occur, if during the construction process, the plans are changed by the customer, so that the constructor has to change the planned workflow, which results in additional costs. Frequently, those costs are substantially higher than the directly change-related costs, difficult to estimate and to trace for external parties. In this context, “disruption” is understood similarly to “ripple effects”, “knock-on impacts”, “secondary effects”, “impact on unchanged work”, and “lost productivity” (Cooper, Reichelt & Moore 2004, p. 1). Again, the difficulty to identify causes for a disruption becomes obvious, as well as the limited control over its inducing events, and its process characteristics.

In summary of the literature depicted above, a disruption seems to involve multiple causes, which cannot necessarily be identified as such, as firstly, their complex interaction causes the disruption, and/or secondly, they occur at remote places, and/or thirdly with a considerable time span in between. This highlights the abstract nature of disruptions, as well as the need for at least two elements, which are involved in some kind of relationship. Additionally, a disruption and its causes might only be observable ex-post. Furthermore, the causes might not be in control of those experiencing the disruption, which is in the majority of cases a negative and substantial effect. The question arising is now, whether the term “rupture” is similarly used, which is analyzed next.

¹⁴ A similar understanding can be found for example in Hall (1997), Moskow (2000), Elifoglu, Fitzsimons & Lange (2010), and Sufian & Habibullah (2012).

In comparison to the term “disruption”, the first mentioning of the term “rupture” in the literature provided by Business Source Premier was later, namely in 1953. Also this term is applied in an abstract context, namely discontinuity of evolutionary processes (Geiger 1953). The author argues that any event is always embedded in a multitude of causes on the one hand and being a cause itself for future events on the other hand. Additionally, it is used in relation with economic structure, to describe the growing inadequacy of a traditional market organization to new requirements, (Lodge 1966) or the end of an economic union between two countries (Moes 1966). Comparing the two terms, it can be noted that both terms are used in similar contexts (social and economic ones), and describe the same type of events. Thus, it seems as if their meaning coincides. However, later on the meanings of both terms begin to differentiate more.

“Rupture” is used frequently in *medicine*, where it describes the bursting of a structure, such as an aneurysm (e.g. Chien et al. 2008; Helderma et al. 2008; Neugebauer et al. 2009). Again, the term is used to describe a negative outcome, but yet its occurrence can be predicted more easily, as the existence of the aneurysm can be taken as an indicator.

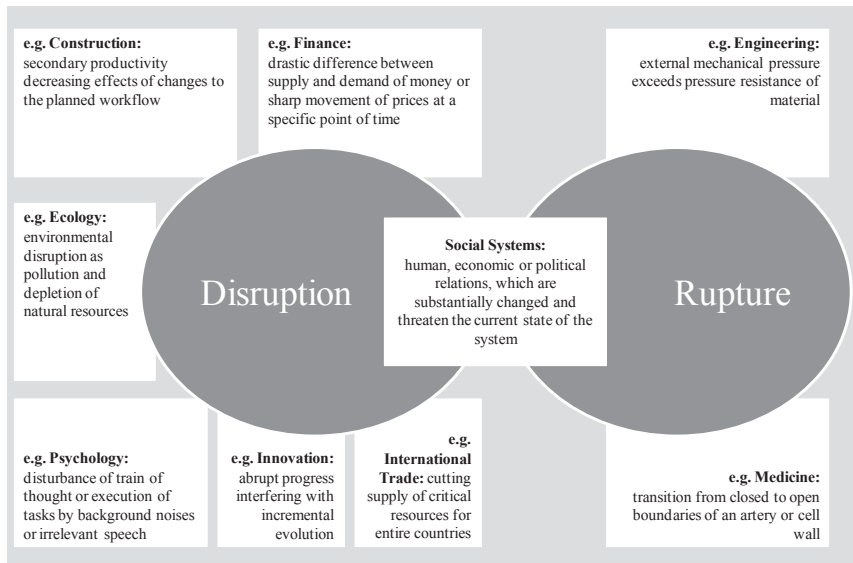
Another prominent application of the term is in *mechanics*, where it is used to describe how a material bursts under the influence of mechanical pressure (e.g. Yang Zhang & Zhiming Yu 2011; Gupta, Yan & Feng 2011; Olorunnisola, Pitman & Mansfield-William 2005). Many papers have been written on the “modulus of rupture” (MOR), which seems to be an established term on its own (e.g. Mao, Shi & Steele 2011; Yafang Yin et al. 2011; Dian-Qing Yang, Xiang-Ming Wang & Hui Wan 2010; Juwan Jin & Chunping Dai 2010; Hegazy & Aref 2010). To test the elasticity of materials, they are exposed to static bending till the point of rupture of the material (Ayarkwa, Hirashima & Sasaki 2001). In contrast to the hitherto developed understanding of disruptions, such ruptures are thus purposefully induced under controlled conditions and their causes can be identified and quantified.

Nevertheless, also in sociology the term is still frequently used, when certain historically grown social structures are substantially changed (e.g. Palazuelos & García 2008; Waldheim & Berger 2008; Young 2002). However, in the case of ruptures, the structural perspective seems to play a larger role than the process-related perspective.

Comparing the use of both terms, a “rupture”, at least in its application in medicine and mechanics, seems to be more an observable event at a determined point in time, where by force and external pressure, a structure is changed in such a way that it cannot return to its previous form. The causal relationships as well as the effects seem to be clearer, with fewer directly influencing parameters. The specification of these parameters can be measured more easily, as for example the amount of force necessary to break lumber (e.g. Cheng Piao & Groom 2010; Lebow, Lebow & Nelson 2010). However, when the term is used in sociological contexts, these characteristics do not apply anymore and it becomes more similar to the use of “disruption”.

The following figure shall illustrate the perceived similarities and differences between the use of the two terms and their meanings.

Figure 6: Interpretations of disruption and rupture based on the literature review



In sum of the first and second part of the literature review, a complete separation of the two terms is not possible, since the term “rupture” as used in sociology seems to imply the same as “disruption”. The reason why in the case of cold chains the term “rupture” prevails at least in some parts of the literature, could be that a cold chain rupture is observable and measurable (e.g. by temperature tags), which makes it more tangible than a “disruption” in social systems. Furthermore, a cold chain rupture involves the exchange of cold and warm air, which is subject to the laws of thermodynamics. These laws are closely associated with statistical mechanics (e.g. Ramsey 1956; Lubliner 1972; Curado & Tsallis 1991), which in turn, and as illustrated above, refer to “ruptures” when something is broken instead of “disruptions”.

However, whereas in cold chains the term is used, the two databases revealed no mentioning of the term “rupture” in the context of the literature on supply chains or production systems in general. Since both terms are used interchangeably in certain contexts, and since cold chains can be seen as a specific type of supply chains, a cold chain rupture is therefore understood as being one special case of supply chain disruptions. Therefore, the following paragraphs will only focus on disruptions of supply chains and production systems.

2.2.2 Contextual Shortcomings of Definitions of Disruptions

According to Kromrey (2009), the research process starts in general with the clarification of the research context, which contains the identification of already existing suitable definitions, relevant dimensions of the reality for the research question, and potential further differentiations of dimensions. Therefore, the literature on disruptions in supply chains and production systems was assessed regarding existing definitions, dimensions of disruptions, and approaches to classify disruptions.

First of all, the contributions to the research on disruptions of supply chains and production systems revealed a scarcity of definitions of disruptions. In total, 173 papers were identified, which deal with disruptions in a supply chain or production system context. Of those, 160 papers did not provide any definition of disruptions. This scarcity of definitions can be partly attributed to the fact that not all of the papers encountered put a focus on disruptions, but mentioned it as a side issue. However, even the majority of papers dealing primarily with disruptions did not provide a definition (e.g. Kleindorfer & Saad 2005; Qi, Shen & Snyder 2009; Schaefer et al. 2005; Ratick, Meacham & Aoyama 2008). A reason could be that there exists a general consistency on what a disruption means. If this would be the case, all definitions encountered should be very similar. Overall, thirteen publications outlined an understanding of the term (e.g. Craighead et al. 2007; Gaonkar & Viswanadham 2004; Wagner & Bode 2008), which have to be evaluated regarding their ability to describe and specify the phenomenon of disruptions.

As Chmielewicz (1979) explains, the purpose of a definition is to describe and specify the phenomena encountered, in order to allow for the development of theories and the discussion of research results to be based on a common understanding. If different terms are used for the same phenomenon, the comprehensibility of the results is imperilled and may lead to wrong conclusions. Therefore, he advocates for evaluating definitions based on certain quality criteria.

Criteria to evaluate the quality of definitions are according to Chmielewicz (1979, pp. 59–64):

- usefulness (1)
- unambiguousness (2)
- preciseness (3)
- non-redundancy (4)

These criteria can be used to determine, whether a definition fulfils the basic scientific requirements and shall therefore also be used here to evaluate the definitions encountered in the literature. The criterion of *usefulness* means that the definition has to be suitable for the purpose of research (Chmielewicz 1979). Considering that the purpose of this thesis is to causally explain the occurrence of disruptions in supply chains and production systems, it shall be assessed, whether the definition explains, **what** a supply chain disruption is.

Unambiguousness implies according to Chmielewicz (1979) that the term defined (i.e. definiendum) cannot be used to describe different things and vice versa. For example, Hendricks & Singhal (2005a) use the term “glitches”, whereas in Hendricks & Singhal (2005b) the same phenomenon is called “disruptions”, to circumscribe a firm’s inability to match supply and demand. This ambiguousness could lead for instance to significant ascertainment errors, if the phenomenon is not adequately explained (Kromrey 2009).

According to Chmielewicz (1979), *preciseness* of a definition is primarily a matter of discretion, since every definition includes further terms, which would require a definition themselves. However, to avoid confusion and reliance on basic non-defined terms, the attempt should be to use terms, which specify the definiendum instead of keeping the definition at the surface. This also implies the avoidance of abstract and vague terms to define the term in question. In this context, Kornmeier (2007) suggests the use of technical terms, if possible.

Finally, *non-redundancy* implies that the definiendum is not repeated in the definiens (Chmielewicz 1979). For example, if risk would be defined by risky behaviour, no further insights into the meaning of risk would be gained, since the term remains unexplained by this repetition. An overview on the definitions of disruptions encountered, and their assessment according to the quality criteria, can be found in Table 1.

Table 1: Definitions of disruptions and assessment for this thesis

Source	Definition	Breached Criteria
Albino, Garavelli & Okogbaa 1998	"any event that causes variations in the expected behaviour of a production system" (p. 3057)	3: no clear identification of disruptions possible
Rosenberger et al. 2002	"an event that prohibits an airline from operating as scheduled" (p. 357)	1: reduction of focus on airline industry excludes other areas
Gaonkar & Viswanadham 2004	"occurs when the structure of the supply chain system is radically transformed, through the non-availability of certain production, warehousing and distribution facilities or transportation options due to unexpected events caused by human or natural factors" (p. 2700)	3: by naming kinds of causes others might be excluded
Hendricks & Singhal 2005b	"a firm's inability to match demand and supply" (p. 35)	3: separation of disruptions from other issues impossible
Wagner & Bode 2006	"an unintended, untoward situation, which leads to supply chain risk" (p. 303)	3: risk exists before something occurs ¹⁵
Dorndorf et al. 2007	"a situation, in which one or more activities in one or more key areas [...] have deviated from the resource plan. Subsequent activities in the affected lines of work either cannot start on time, or can start on time, but only after controller intervention" (p. 94)	1: reduction of focus on airline industry excludes other areas
Craighead et al. 2007	"unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain and, as a consequence, expose firms within the supply chain to operational and financial risks." (p. 132)	2: goods and materials are overlapping 3: normal is an elastic term 4: repetition of disrupt
Wagner & Bode 2008	"the combination of (1) an unintended, anomalous triggering event that materializes somewhere in the supply chain or its environment, and (2) a consequential situation which significantly threatens normal business operations of the firms in the supply chain" (p. 309)	3: significance and normal business operations are elastic terms, making separation difficult
Berman, Krass & Menezes 2009	"periodic failures, rendering them [<i>service facilities</i>] temporarily unable to provide service" (p. 845)	1: focus on service facilities excludes other areas
Parmar et al. 2010	"During this entire process of transforming specifications to finished deliverables, things often do not go as planned. This is what is commonly referred to as an exception or a disruption [...]" (p. 3803)	3: specification of „things“ is lacking 3: specification of extent of deviation from plan is lacking
Yang & Yang 2010	"a failure at a supplier facility that results in the inability of the purchasing company to meet its customers' demands" (p. 1906)	3: only failures at suppliers considered
Cole 2010	"the unprotected losses for an activity" (p. 255)	2: only consideration of unprotected losses 1,3: not precise enough for purpose

¹⁵ Risk can be defined as "the chance, in quantitative terms, of a defined hazard occurring" Parkinson (1992, p. 4).

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Pharmaceuticals

Brenner, V.

2015, XVI, 323 p. 54 illus., Softcover

ISBN: 978-3-658-08661-9