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Postponement in supply chain risk management: a complexity perspective

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Postponement in supply chain risk management: a complexity perspective

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Abstract While the poor response implications of supply are often not elaborated on in literature, postponement has recently been mentioned as a useful tool for managing supply risk and disruptions. To interpret this in a more complete manner, this paper has attempted to explore the role of postponement in supply chain risk management from a complexity perspective. After a review of the relevant literature, it first draws insights emerging from normal accident theory that addresses the system characteristics of catastrophic accidents and applies them to supply chain disruptions. This is followed by the utilisation of normal accident theory to explain the role of postponement in supply chain risk management. Building on this, this paper also investigates the complexity implications of some commonly recommended measures to mitigate supply chain disruptions. In certain circumstances, the introduction of those measures may add to the complexity of a system and thus become inherently infeasible. The paper concludes with a summary and some suggestions for further research.

Keywords: Postponement; Risk management; Supply chain management; Complexity; Normal accident theory

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Abstract While the poor response implications of supply are often not elaborated on in literature, postponement has recently been mentioned as a useful tool for managing supply risk and disruptions. To interpret this in a more complete manner, this paper has attempted to explore the role of postponement in supply chain risk management from a complexity perspective. After a review of the relevant literature, it first draws insights emerging from normal accident theory that addresses the system characteristics of catastrophic accidents and applies them to supply chain disruptions. This is followed by the utilisation of normal accident theory to explain the role of postponement in supply chain risk management. Building on this, this paper also investigates the complexity implications of some commonly recommended measures to mitigate supply chain disruptions. In certain circumstances, the introduction of those measures may add to the complexity of a system and thus become inherently infeasible. The paper concludes with a summary and some suggestions for further research.

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1. Introduction

With outsourcing and off-shoring increasing the geographical dispersion of supply chains, there has been increased attention focused on the risks from supply chain disruptions. For example, while global configurations of their supply chains provide access to cheap labour, raw materials and markets in emerging economies, companies face the challenges in maintaining continuity of supply through longer and more variable lead times, and greater delivery uncertainty (Prater *et al.*, 2001). Meeting these challenges can be further compounded by the nature of doing business today (i.e. the mutual dependencies of companies arising from inter-organisational networking). A failure of any one element in a supply chain causes disruptions for potentially all partnering companies upstream and downstream. The need for heightened awareness of supply chain risk management has also been driven by the increased scrutiny by insurance cover providers (McGillivray, 2000; Norrman and Jansson, 2004). A trade-off must thus be made between the efficiency and robustness of the supply chain. This results in an additional consideration of product design, production and distribution strategies, and the development of partnership relations with suppliers and customers (Chopra and Sodhi, 2004; Tang, 2006a). Much has been written regarding a wide range of ideas and techniques to identify, analyse, accommodate and minimise the effects of supply chain disruptions. However, implementing such strategies as adding buffer, building flexibility and adopting coordination mechanisms is a costly endeavour (Prater *et al.*, 2001; da Silveira, 2006). Some of those resultant costs could be passed along to consumers, but in many cases the market is too competitive to raise prices. Also, in certain circumstances, the introduction of some measures that mitigate supply chain disruptions may add to the complexity of a system and thus become inherently infeasible. In this research, we attempt to make a theoretical contribution by understanding how postponement can be used as a strategy to mitigate supply chain disruptions from a complexity perspective.

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Postponement is about delaying processing or distributing activities (e.g. as to the form and/or the place of goods) until precise customer order information becomes available. For example, by postponing the final mixing of paint colours till the customer orders arrive, retail outlets achieve savings in transport and inventory costs by sorting products in large lots and in undifferentiated states. A key facilitating mechanism in the implementation of postponement is the emerging realisation of the importance of a more customer-oriented view of operations. We choose this particular supply chain strategy in this study for a number of reasons: (1) Postponement becomes increasingly valuable as the proportion of off-shore components in the final products increases (Manuj and Mentzer, 2008). In this scenario, numerous links interconnecting a wide network of companies are prone to disruptions, breakdowns, macroeconomic and political changes and disasters leading to higher risks and making risk management difficult. (2). Postponement is often implemented in connection with just in time practices, which are among the most frequently mentioned supply chain strategies with high risk exposure implications (Juttner, 2005). (3). While the poor response implications of supply are often not elaborated on in the postponement literature, postponement has recently been mentioned as a useful tool for managing supply disruptions (Sheffi, 2001; Lee, 2004; Tang, 2006 a & b). While there are other risks in a supply chain, this paper focuses mainly on the inbound supply risk as Rice *et al.* (2003) point out that managers are less concerned for outbound flows than inbound flows in supply chain disruption. For example, a disruption in transport for inbound materials will more likely result in additional disruption in supply, whereas a disruption in outbound product flow is less likely to have an affect on internal operations. Supply risk in this study is defined as the potential occurrence of an unexpected event associated with inbound supply from individual supplier failure in which its outcomes result in the inability of the purchasing company to meet its customers' demands (Zsidisin, 2003). The rest of this paper is developed as follows: Section 2 presents a review of the relevant literature. Section 3 draws insights from normal accident theory to explain the role of postponement in supply chain risk management. Section 4 investigates the complexity implications of some commonly recommended measures to mitigate supply chain disruptions. Section 5 concludes the paper with a summary and some suggestions for future research.

2. Literature Review

This section reviews three streams of literature including supply chain risk management, a complexity perspective in supply chains, and postponement.

2.1 Supply Chain Risk Management

Supply chain risk may be the outcome of unexpected variations such as capacity constraints, machine breakdowns, uncertain yields, quality problems, a fire or even natural disasters occurring in a supplier facility (Blackhurst *et al.*, 2005). The impact of such disruptions can be significant. A fire in a facility in New Mexico that supplied vital chips to Ericsson resulted in a loss of \$2.34 billion for Ericsson's mobile phone division. To respond to supply chain disruptions, two basic approaches are recommended: adding redundancy and building flexibility (Sheffi, 2001; Chopra and Sodhi, 2004). Adding redundancy involves maintaining excess resources such as inventory and capacity. Putting this in a supply chain context, Lee (2004) states that the best supply chains identify changes in the environment, and develop contingent networks by having more than one supply chain structure in place. While protecting against disruptions, excess resources can be costly. Flexibility can be achieved through the use of a multi-skilled workforce, versatile equipments, and the development of closer relationships with suppliers and customers to accommodate last minute changes. It also plays a facilitating role in

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3 the coordination process and provides a unique ability to help companies to manage the high
4 levels of environmental and operating uncertainty inherent in supply chain operations (Manuj
5 and Mentzer, 2008). Other suggestions include using sourcing strategies, shifting demand to
6 different products, developing a strategic stock, and monitoring and controlling their suppliers
7 through the use of pre-contract audits and supplier certification schemes (Zsidisin *et al.*, 2004;
8 Tang, 2006 a &b).
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11 In the literature, the term “resilience” is also borrowed from other disciplines to characterise an
12 organisation’s capability to recover to the original operating status before a disruption. In
13 addition, keeping track on signals that may indicate disruptions helps companies to better
14 prepare themselves to prevent, control and mitigate supply disruptions. This often involves
15 supply chain integration and coordination programmes to provide accurate and early information
16 for managing risk such as sharing information related to risk with supply chain partners (Juttner,
17 2005). Finally, recent years have witnessed that there has been an increasing emphasis on the
18 simultaneous and coordinated design of product, production process and supply chain (Fine *et al.*,
19 2005). Implicit here is the ability of product design to reduce the likelihood of supply risk (Khan
20 *et al.*, 2008). For example, the nature of relationships between customers, manufacturers and
21 suppliers is often established early in the product design process. This significantly impacts the
22 sourcing arrangements. Designing products so that product variety is pursued through component
23 and interface standardisation allows a company to build a strong and flexible web of sources to
24 reduce supply risk.
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29 *2.2 A Complexity Perspective in Supply Chains*

30 It has long been emphasised in the organisation theory literature that a company’s structure and
31 management process must grow increasingly complex to respond to a complex environment
32 (Anderson, 1999). To respond to today’s environmental complexity such as the increasing
33 product proliferation, outsourcing and globalisation, organisational systems have become
34 increasingly complex. For example, as companies and their supply chains expand globally,
35 management of processes across different cultures, technical standards, regulatory requirements
36 and geographic distances becomes more complex. Reducing complexity enables companies to
37 streamline their processes, eliminate waste and ultimately improve the overall performance
38 (Khurana, 1999; Wilding, 1998; Vachon and Klassen, 2002). The complexity experienced in a
39 supply chain also increases the vulnerability to disruptions (Wilding, 1998; Choi and Krause,
40 2006). When the level of complexity is uncontrolled, organisation systems are less predictable
41 (Manuj and Mentzer, 2008). Reducing complexity has thus been considered as a strategic goal
42 for operations (Frizelle and Woodcock, 1995).
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47 When addressing the issue of supply chain risks, a complexity perspective has recently
48 appeared to provide a more holistic picture. For example, much has written in the supply chain
49 literature regarding whether a single or multiple sourcing strategy can be used as a risk
50 mitigation strategy. While it in general may reduce administrative and transaction costs e.g. by
51 concentrating greater purchase volumes with fewer suppliers, a single sourcing strategy leads to
52 the over-dependence on one single supply source, thus exposing great vulnerability to negative
53 events that may occur at the supplier’s plants. Multiple suppliers have thus been viewed as a
54 means of mitigating supply risk, but this implies that more efforts are require to co-ordinate the
55 supply base (Vachon and Klassen, 2002). On the other hand, single sourcing facilitates the
56 building of long-term relationships with suppliers which in turn facilitates effectively managing
57 supply risk. From a complexity perspective, in addition to the number of elements, the level of
58 coupling among differentiated elements within a system also affects the level of complexity
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3 (Dooley, 2001). In line with this, Choi and Krause (2006) argue that, as the number of suppliers
4 increases, we should also consider the level of inter-relationships among suppliers in a supply
5 base, another factor contributing to the complexity of a supply chain. With a low level of inter-
6 relationships among suppliers it would be difficult for one supplier to step in for another
7 supplier in case of an unexpected event. That is, the low level of inter-relationships would be
8 associated with a high risk. By contrast, as the inter-relationships increase, the risk mitigation
9 strategies could be implemented more readily and thus the level of risk would decrease.
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12 2.3 Postponement

14 Over time, postponement applications have encompassed the whole supply chain from product
15 design and development, to manufacturing and on to final distribution of products. For the
16 purpose of this research, we review the postponement literature from a risk management
17 perspective. Postponement was introduced as a marketing strategy to reduce risk and uncertainty
18 costs relating to highly changeable demands by delaying the creation of time, place, form and
19 possession utilities. One extreme example is that companies do not even finalise product design
20 or start the full manufacturing cycle until after the necessary number of pre-orders from
21 interested customers has been garnered (Ogawa and Piller, 2006). Product designs may thus be
22 altered not only to quickly respond to sudden changes in demand, but to address supply issues
23 including unanticipated changes from suppliers early in the product cycle. That is, postponement
24 may give the opportunity to change the configuration of one product at the last possible moment
25 in case of disruptions in supply of a component. When a lightning bolt caused a fire at its radio-
26 frequency chip supplier's factory, Nokia quickly redesigned the chips so that they could be
27 sourced from other locations. With the design change, Nokia was able to meet its production
28 target despite the fact that the fire disabled the original supplier's factory for more than a month
29 (Lee and Wolfe, 2003).
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34 Bucklin (1965) originally viewed postponement as an opportunity to shift the risk of owing
35 goods from a buyer (or supplier) in a distribution channel to the supplier (or buyer), involving
36 the delay of the forward movement of inventory. Extending this to a supply chain,
37 postponement could shift the risk to the most appropriate player in the supply chain to reduce
38 the overall risk (Hallikas *et al.*, 2004). In practice, this has been facilitated by a trend in a
39 postponement initiative towards the use of third-party providers for final customised activities
40 (Yang and Burns, 2003). With postponement, Hewlett Packard (HP) centralises its manufacture
41 of the basic printers to one facility in Holland that supplies all of Europe and North Africa
42 (Prater *et al.*, 2001). The company outsources its transport and distribution to Fraure Machette
43 (FM), a French company. FM also customises the goods once an order has been received by
44 packaging the printer along with the appropriate set of add-on components which differ
45 regionally (e.g. the power supply and manuals). With such an outsourcing strategy, HP reduces
46 its supply chain risk exposure (i.e. transport uncertainty within in Europe) as well. In this case,
47 FM willingly accepts the uncertain demand for transport, as transport is its core capability and
48 the company has ways of dealing with problems.
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53 It has been well established that forecasts at the component level are more accurate than those at
54 the finished product level. Risk is thus pooled under a manufacturing postponement strategy
55 where demand is aggregate for all variations of the undifferentiated products. Logistics
56 postponement is another example of risk pooling by geographical aggregation. It is about
57 delaying changes in inventory locations until the final market destination and/or customer
58 requirement is known and so avoiding shipments that become unnecessary or inappropriate as
59 demand changes. Furthermore, postponement can also reduce risks inherent with possible major
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3 changes in customer needs, technologies and competitor's action, by alleviating the need to make
4 some decisions prior to the availability of adequate information. Delaying activities in time
5 enables companies to learn from the behaviour of the demand and other environmental factors
6 (Aviv and Federgruen, 2001). In capacity planning, Fisher *et al.* (1994) view postponement as a
7 risk-based sequencing strategy whereby low-risk activities employ speculative capacity and
8 higher-risk activities are postponed until additional market information has been available. Lee
9 (1998) proposes pull postponement to increase the knowledge of the contents of customer orders
10 instead of a commitment to early production.
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14 In summary, much has been written in the literature regarding a wide range of ideas and
15 techniques to identify, analyse, accommodate and minimise the effects of supply chain
16 disruptions and risk. However, implementing such strategies as adding buffer, building
17 flexibility and adopting coordination mechanisms is a costly endeavour (Prater *et al.*, 2001; da
18 Silveira, 2006). Furthermore, the issue of complexity should also be taken into account when
19 assessing the various tools available to manage supply chain risk. By applying the complexity
20 literature, we attempt to provide a new lens to examine supply chain disruption mitigation
21 initiatives. Specifically, we will examine postponement strategies. While the current
22 postponement literature has largely focused on a desire to manage risk from the market side, the
23 success of postponement in coping with demand risk often comes at the hidden expense of
24 increased supply risk. For example, production postponement has made companies increasingly
25 reliant on the existence of a reliable and efficient supply network of raw materials and
26 components (Feitzinger and Lee, 1997). A recent questionnaire survey (across the food,
27 clothing, electronics and automotive industries) by Yang *et al.* (2005) also finds that one of the
28 most significant barriers to postponement was supplier delivery performance. Surprisingly,
29 while the poor response implications of supply are often not further elaborated on in the
30 postponement literature, postponement has recently been mentioned as a useful tool for
31 managing supply risk and disruption (Sheffi, 2001; Lee, 2004; Tang, 2006 a & b).
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36 **3. A Complexity Perspective of Postponement in Supply Chain Disruptions**

37 To examine the complexity aspect of postponement and its impact on supply chain risk
38 management, we draw insights emerging from the theoretical principles in normal accident
39 theory (NAT), where accidents in complex systems are presumed to be "normal" or inevitable.
40 NAT was originally developed to explain why marine transport is less prone to accidents than
41 other systems like nuclear plants. However, this organisational theory has wider implications for
42 understanding the structural characteristics of a system and then analysing the propensity of the
43 system accidents and failures. In the recent supply chain management literature, Wagner and
44 Bode (2006) suggest that NAT supports the presumption that modern supply chain management
45 initiatives amplify the fragility of supply chains. They also call for future research on "the
46 identification of further underlying factors (that drive supply chain vulnerability) by exploiting
47 theories that yield exploratory power on supply chain vulnerability such as normal accident
48 theory...". NAT states that organisations may be prone to accidents under conditions of high
49 interactive complexity and tight coupling (Perrow, 1999a). Here an accident is defined as a
50 failure in a subsystem or system that damages more than one unit and in doing so disrupts the
51 ongoing output of the system (Perrow, 1999a). Coupling refers to the level of slack or buffer
52 within the system while interactive complexity refers to the way that parts within a system are
53 connected and interact (Sagan, 1993). According to NAT, the likelihood of accidents can be
54 reduced by making structural changes to reduce interactive complexity, or reduce tight coupling
55 (Perrow, 1999a). However, Perrow (1999b) points out that doing both at the same time will most
56 likely make the system inefficient. Therefore, here we only consider the following two options
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3 companies are faced with to mitigate against disruptions: reduce tight coupling while remaining
4 complex, or reduce interactive complexity while remaining tight coupling. Finally, NAT warns
5 against the potential negative consequences of adding redundancy to a system such as increasing
6 interactive complexity (Sagan, 1993; Perrow, 1999 a & b).
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9 *3.1 Complexity, Coupling and Supply Chain Disruptions*

10 Before applying NAT to the complexity dimension of postponement, we first relate the main
11 elements in NAT to supply chain disruptions. Following the definition of supply risk we
12 adopted in the introductory section, a supply chain disruption is referred to as a failure at a
13 supplier facility that results in the inability of the purchasing company to meet its customers'
14 demands. Addressed in NAT are two elements that are also fundamental to supply chain risk
15 management: interactive complexity and coupling. Tight coupling implies that there is little
16 slack or buffer within the system or it is not possible to delay processing, while loose coupling
17 refers to excess slack, buffers or time (Perrow, 1999a). Within the supply chain risk literature,
18 tight coupling is particularly relevant in today's marketplaces, where the widespread adoption
19 of time-based and customer-driven strategies has enabled companies to become more
20 responsive to customer demand with less inventory and lower cost. These strategies help avoid
21 the risk of stock obsolescence or stock out inherent in the current business trends of expanding
22 product variety, rapid technological development, shortening product life cycles and
23 increasingly demanding customers. However, this could also lead supply chains to become
24 more vulnerable to disruptions. With just in time production, for example, there often tends to
25 be very little inventory existing to hedge against potential disruptions in supply. Therefore, the
26 supply chain literature supports the notion that there is a positive relationship between tight
27 coupling and the likelihood of experiencing a supply chain disruption.
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33 In NAT, interactive complexity is evaluated according to the number of elements within a
34 system and the inter-relatedness of the elements. Similarly, there are three well established
35 related dimensions of complexity in the supply chain literature to measure interactive
36 complexity: product complexity, process complexity and interconnection complexity (e.g. Kotha
37 and Orne, 1989; Khurana, 1999). Product complexity is defined by the number of parts and
38 components needed to produce a product (Clark and Fujimoto, 1991). It can be reduced when
39 there are fewer components, fewer processes, fewer states as well as fewer variations of states.
40 Fewer numbers of components and options of these components reduce the number of potential
41 interactions that may exist between parts (Khurana, 1999). In order to manage process
42 complexity, it is often required to decompose the job into a small number of non-dependent tasks
43 or activities. The interconnection level refers to the interaction level of various parts and process
44 operations (Kotha and Orne, 1989). As the number of process steps increases, the number of
45 potential interactions also increases. As noted with tight coupling, there is also agreement in the
46 supply chain literature regarding a positive relationship between interactive complexity and the
47 likelihood of experiencing a supply chain disruption particularly in an international setting
48 (Wilding, 1998; Prater et al., 2001).
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53 When there is a high degree of complexity, even small seemingly independent failures can
54 interact in unexpected ways that can not be anticipated by process designers nor understood by
55 operators (Marley, 2006). If a highly complex system has no or little slack between stages, the
56 inevitable failures will intensify uncontrollably causing a serious accident (Perrow, 1999a). As
57 noted before, the likelihood of accidents in NAT can be reduced by making structural changes to
58 reduce tight coupling while remaining complex, or reduce interactive complexity while
59 remaining tight coupling. Although increasing the level of slack may be logical in high risk
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3 systems, today's market often rewards companies who tightly couple their operations (i.e.
4 reducing slack) (Marley, 2006). There are many situations where it is not economically feasible
5 to build up excess inventory or capacity. Adding slack may also have a complexity implication,
6 which will be investigated in Section 4. Using NAT, here we posit that, to be less prone to
7 supply chain disruptions under conditions of tight coupling, companies can decrease the level of
8 interactive complexity (as a supply chain risk mitigation strategy). This has not been addressed
9 in the current supply chain management literature
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12 13 *3.2 Application of NAT in Postponement*

14 To view postponement from a complexity perspective, the starting premise of this section is that
15 companies pursuing postponement can often be viewed as complex organisational systems. For
16 example, their production and delivery systems are generally characterised by a very high
17 proliferation of individual items, either in input components and subassemblies or finished goods.
18 The complexity induced by the increasing product proliferation has been considered a primary
19 driver for adopting a postponement strategy. Product proliferation increases the level of
20 complexity present in a production system, such as forecasting, product purchasing and
21 production scheduling (e.g. Kotteaku *et al.*, 1995; Fisher *et al.*, 1997). Part of the postponement
22 principle is to seek an undifferentiated status by delaying volume, weight, value adding
23 operations or final customisation. In addition to the reduced inventory costs and lower logistics
24 costs, postponement involves a decreasing complexity at the end product level as final products
25 are not manufactured and held until a customer order arrives. More importantly, postponement
26 suggests that the stage at which a product variation occurs should be delayed towards the end of
27 process thus minimising the level of the variety-induced complexity. If a product variation
28 occurs closer to the end of the production process, it will significantly reduce upstream
29 complexity involved with sourcing, manufacturing and transport such as reducing the number of
30 parts and suppliers to manage. By contrast, if the variation is introduced in the early phase of
31 production, it may require performing a greater number of subsequent operations, increasing the
32 complexity downstream processes (Prasad, 1998).
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38 We now turn our attention to the use of NAT to explain the role of postponement in mitigating
39 supply chain disruptions. In NAT, tight coupling is characterised by little or no slack in the
40 system. Literature on postponement has well documented that the adoption of postponement
41 leads to a reduction in the slack and buffers. This is attributed both to shorter forecast cycles and
42 shifting inventory upstream to a less expensive generic state (Yang *et al.*, 2004). Companies that
43 adopt postponement principles are also committed to meeting the needs of their customers in an
44 efficient way. This often involves examining the way that work is currently done and then
45 identifying how best to develop the sequences of process steps, aiming for the effective
46 allocation of resources within the system. The rationale of this is to intentionally delay the
47 execution of a task instead of starting it with incomplete or unreliable information input. In this
48 way, postponement places a conscious emphasis on the reduction of slack resources that do not
49 serve the customer. This also implies that postponement embodies customer driven practices that
50 make and deliver products only to the actual customer demand. To achieve this, postponement
51 calls for the direct use of the exact demand signal connecting key functions such as production,
52 logistics and marketing, which is suggested by Roberts (1990) to alleviate the complexity within
53 the organisation.
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57 As companies seek to mitigate against disruptions, they often reduce interactive complexity (i.e.
58 product, production and interconnection complexities) by using common, standard and modular
59 products and processes, all of which are also embraced in postponement to delay the point at
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3 which product variations assume their unique identities. For example, the development of a
4 modular product structure implies manufacturing a variety of end products on the basis of only
5 few, generic modules or platforms. In the modular product architecture, components are
6 interchangeable, loosely coupled and upgradeable, and interfaces are standardised. Therefore,
7 they can be developed and optimised independently, thereby greatly decreasing the overall inter-
8 dependence among components and cutting down on the coordination costs. Developing the
9 ability to shift business operations elsewhere when a disruption occurs often involves using
10 interchangeable and generic parts in many products, and standard business operations (Martha
11 and Subbakrishna, 2002; Lee and Wolfe, 2003). Interconnection complexity can also be dealt
12 with through the use of modularity in organisation which allows companies to break their
13 hierarchies down into components that can be fluidly recombined in a variety of configurations
14 in response to unexpected events. Extending to a supply chain, modularity also permits
15 substitution of different versions of functional components (e.g. specialised companies) to be
16 fluidly recombined in a variety of supply chain configurations to quickly adapt to changing
17 environments (Voordijk *et al.*, 2006).
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22 To summarise, companies practicing postponement achieve tight coupling concomitantly with a
23 reduction in interactive complexity. Tight coupling, as defined by NAT, is the essence of
24 postponement, which has a significant cost impact. The ideas embodied in postponement can
25 also decrease interactive complexity. Postponement initiatives include standard/modular design,
26 operational efficiency, and improved information exchange with suppliers and customers. Each
27 of these elements suggests simplification of processes and operations. In addition, companies
28 adopting postponement can also achieve responsiveness to changing requirements through
29 reducing the level of complexity in their systems (da Silveira, 2006). The tight coupling and
30 decreased complexity aspects embodied in postponement are exemplified by the example of Dell.
31 Under a postponement strategy, Dell sells directly to consumers via the internet and telephone
32 (i.e. direct order taking from customers). It delays purchasing its own subsystems and
33 components until demand has actually occurred. In fact, Dell holds only a few days' worth of
34 inventory. This enables Dell to realise lower costs for parts due to its reduced exposure to the
35 pattern of declining components prices and final goods prices, which have characterised the
36 computer industry. In addition, to catch up with the latest technological trends in computer
37 components, computing manufacturers need to offer new product lines very often. If the supply
38 chain is full of conventional products, then either new products have to wait or conventional
39 products are offered at give-away prices. Therefore, postponement also allows Dell to quickly
40 introduce new product lines as they are unencumbered by final goods inventories. However, this
41 appears to make Dell more exposed to supply disruptions and the resultant sudden component
42 price increases. Not surprisingly, investors associated Dell with lower profitability after the 1999
43 Taiwan earthquake, which disrupted the world-wide supply of memory chips (Papadakis, 2003).
44 Largely neglected here is an understanding of how reduced interactive complexity (concomitant
45 with tight coupling) in postponement can serve to protect the company against supply disruptions.
46 Dell actually improved its earnings in 1999 by 41% over the previous year even when such a
47 supply disruption occurred (Papadakis, 2003).
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54 4. Discussion

55 By drawing on insights from NAT, we have attempted to explain how postponement serves to
56 avoid supply chain disruptions. In doing so, we have brought to light many practices embraced
57 in postponement which can reduce interactive complexity. When explaining postponement as a
58 supply chain risk mitigation strategy, the current supply chain literature tends to only look at its
59 elements of commonality, standardisation and modularity in products and processes, i.e.
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3 broadening the base of supply and increasing inventory pooling with other sites (Lee and Wolfe,
4 2003). We argue that, by understanding how postponement overcomes the complexity present a
5 system, we can interpret the role of postponement in supply chain risk management in a more
6 complete manner.
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9 In the supply chain literature, such strategies as standard and modular design (embraced in
10 postponement to reduce interactive complexity) are often considered to reduce the inventory or
11 capacity levels (resulting in high tight coupling). This raises the issue of the interaction between
12 coupling and interactive complexity, which has been introduced in NAT. Here we examine two
13 commonly discussed supply chain risk mitigation strategies - adding redundancy and building
14 flexibility. Reducing the tight coupling to protect a system against disruptions may involve
15 adding slack or buffers. While recognising the added costs associated with providing additional
16 capacity and resources, the supply chain management literature ignores the potential resultant
17 increase in the complexity. Adding redundancy may induce the high level of interactive
18 complexity by increasing the number of potential interactions between parts of the systems
19 (Sagan, 1993). Excess resources also provide false security into the safety of a system, and small
20 problems or failures thus become less visible. Similarly, the supply chain management literature
21 also acknowledges that flexibility comes at a cost and is not necessary in all cases (Manuj and
22 Mentzer, 2008). However, increasing flexibility is also likely to exacerbate the complexity of the
23 system (Marley, 2006). In a flexible system, process flows become more complicated, adding
24 ambiguity to the pathways for products to travel as flexibility results in multiple options for
25 decision variables. It can be expected that adding redundancy and building flexibility may
26 increase complexity to a point that will increase the supply chain risk exposure.
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32 Based on the above discussion, it can be argued that, before seeking to add redundancy or
33 flexibility to protect themselves against disruptions, companies should examine the degree of
34 complexity that they are adding through these protective measures. This is also supported by
35 Prater et al. (2001), who point out that, even if some innovative management practices are called
36 for, complexity inherent in the organisation of international supply chains may make the
37 realisation of them impossible. Using case studies, they demonstrate that some companies
38 operating in global environments have been forced to limit agility of their supply chain since the
39 introduction of factors that increase agility would increase complexity of management.
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42 **5. Conclusion**

43 We have attempted to explore the role of postponement in supply chain risk management from a
44 complexity perspective. To achieve this, we draw insights from NAT that addresses the system
45 characteristics of catastrophic accidents and apply them to supply chain disruptions. NAT
46 supports the notion that companies can mitigate supply chain disruptions by altering their levels
47 of coupling and interactive complexity. When it is not economically feasible to reduce tight
48 coupling, companies are encouraged to simplify their systems to protect them against disruptions.
49 We also suggest that companies should examine the complexity of their supply chains prior to
50 adopting commonly recommended supply chain risk mitigation strategies. In certain
51 circumstances, the introduction of those strategies may add to the complexity of a system and
52 thus become inherently infeasible. Further research may need to focus on the implications of
53 complexity on performance metrics, when assessing the degree of complexity in supply chains
54 and the ability of their organisations to ameliorate the complexity.
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