Supply chain failure: the effects of short term quick fixes

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Abstract
Supply chain failure occurs when a supplier fails to provide the level of quality and/or delivery performance originally specified. The literature focuses on failure avoidance and approaches to de-risk a supply chain. Here we focus on how supply chain actors respond to, and manage failure when it occurs. In particular, we examine the tendency to engage in short-term quick fixes rather than addressing the root causes of failure. Based on an extensive empirical study in the gas turbine industry, we capture the effects of short-term quick fixes. We use causal loop diagrams to show why supply chain failure may persist.

Keywords: Persistent Failure, Supply Chain Management, System Dynamics

Introduction
The literature on supply chain failure focuses on two broad streams. The first stream examines events that are out of the control of the supply chain such as natural disasters or civil unrest (e.g. Natarajarathinam et al., 2009). Such significant events may be anticipated to some degree but generally are very difficult to predict. The second stream concerns failure in operations within the supply chain such as failures to produce components to the required specification (e.g. Craighead et al., 2004). These types of failures may potentially be identified and dealt with by manufacturers (e.g. Power and Terziovski, 2007). However, in this work we are concerned with a different scenario: understanding what happens when an organisation can identify and observe supply chain failure happening but seems incapable of preventing the failure from recurring. Such persistent supply chain failure occurs when a supplier consistently fails to provide the level of quality and/or delivery performance originally expected or specified in an agreed contract. It can seriously harm an organisation's ability to successfully produce and deliver its products, potentially resulting in harm to its reputation and its ability to secure repeat business. Here, we investigate and analyse such persistent supply chain failure. Specifically, we examine and analyse how supply chain failure cycles emerge in the gas turbine industry, a typical example of a long lead time industry producing complex, highly engineered products characterised by a prime (or lead) company outsourcing critical sub-systems and sub-assemblies to first tier suppliers.

Manufacturing organisations tend to be reactive to supply failures as such events typically have immediate or imminent negative effects on their own planned operations and thus their ability to supply their own customers. This can induce a 'quick fix' response mentality at the supplier and/or the prime organisation to ensure that supply is maintained somehow. Lack of resources, lack of time, and the nature of the relationship between the prime and the supplier may militate against undertaking a fundamental analysis to identify the root causes of failure and develop appropriate and effective remedial actions that are sustainable over time. We focus on the role of such quick fixes that seek to mitigate supply chain failure. We develop causal loop diagrams based on primary empirical research to capture the effects of such short-term quick fixes on supply chain failure. The findings show how failure to address root causes may ultimately lead to the persistence of failure.

The study adds to knowledge in the supply chain management literature by showing how seeking to mitigate supply chain failure by conducting short-term quick fixes ultimately feeds back to result in reduced supplier performance. The causal loop models developed here can help practitioners to identify the circumstances that lead to a reduction in performance and the mitigating actions that may reduce or eliminate the recurrence of failure.

Literature Review

Supply chain failures are often associated with quality issues. Within the supply chain quality management literature studies have examined whether stringent approaches to quality within an organisation can lead to improved supply chain performance or reduce the likelihood of disruptions in supply (Ebrahimi and Sadeghi, 2013). Further studies have sought to measure the effect that poor quality has on a prime manufacturer's performance (Yeung, 2008). Flynn and Flynn (2008) sought to identify whether the existence of a quality management function within an organisation improved supply chain management performance. The literature challenges the notion that the existence of a well-established quality control certification process held by a prospective first tier supplier guarantees that the supplier has control over their processes and procedures. Studies suggest that it is often the case that they do not (Diaye et al., 2014). Certification may be necessary and valuable but is in general not sufficient to guarantee uninterrupted supply at a desired level of quality.

Morrison (2015) investigated the effect of 'workarounds' carried out by organisations to limit disruption caused by product quality issues. These are short term 'quick fixes' conducted by manufacturers to essentially circumvent their own quality management systems in order to resolve problems more expediently (Morrison, 2015). The research identified that this could happen due to a lack of available resources needed to quickly mitigate failures. An early study conducted by Repenning and Sterman (2001) found that despite a number of tools and techniques available to organisations giving guidance on how to improve product quality there had been little improvement in the ability of organisations to incorporate these innovations into their daily activities (Repenning and Sterman 2001).

Supplier development initiatives have been examined in detail in the literature. By persevering with such initiatives, buying organisations are much more likely to experience an improvement in supply chain performance over the long term (Williams, 2007). However, Arroyo-López et al. (2012) identified that a major issue with supplier development initiatives is the tendency for buying organisations to abandon them too early in the process if implementations do not result in an immediate improvement. Their research also identified how initiatives that take longer to complete may prove to

be less successful. This is dependent on whether the initiatives have been intentionally implemented to mitigate against short-term failure or whether they are undertaken to improve strategic suppliers over a longer period of time (Watts and Hahn 1993; Krause and Ellram, 1997).

Previous studies have sought to identify the characteristics of supply chains in relation to frequency of disruption. Bode and Wagner (2015) found a positive relationship among organisations with higher complexity in skills and knowledge, hierarchical levels and geographical spread with the frequency of supply chain disruptions. Essentially, the greater the size of the organisations that operate within a supply chain then the greater the complexity, which in turn increases the risk of supply chain disruptions.

There is recognition that achieving improvements in quality performance throughout the supply chain is resource intensive and time consuming for all organisations, hence the extensive literature and studies on supplier selection processes (González et al., 2004). Although the supply chain quality and risk literature is substantial, the issue of how organizations react to supply chain failure has received much less attention. The tendency of organizations to adopt short-term quick fixes and the mechanisms by which these may affect supply chain failure over a longer term has not been addressed in the previous literature.

Research approach, design, and methods

The research was motivated by the need to understand in detail the factors influencing the effects of short-term quick fixes on persistent supply chain failure and to seek to identify the inter-relationships and interactions between such factors. The work has been conducted on organisations operating within the gas turbine industry. A prime manufacturer and a number of its first tier suppliers were investigated for the study. The aim was to obtain dyadic perspectives to enhance the richness of the research in the context of the literature on supply chain failure. The methodology encompassed study design, research instrument and protocol design, data collection, data analyses and modelling, followed by validation of the findings. Five first tier suppliers participated in the study. They were chosen on the basis of their importance to the prime and that they had at various points in the previous five years been associated with persistent failure in supplying to the prime. Twenty one detailed interviews were conducted in total. All of the interviews were conducted on site at either the suppliers' or the prime's manufacturing facilities, as appropriate. It should be noted that due to the sensitivity of the issues being investigated (i.e. perceptions of supply chain failures and their causes) this was not an easy activity to carry out as all participating suppliers continued to conduct business with the prime at the time of the study. The study was conducted in three stages as explained below.

Research Stage 1: Exploratory Phase and Data Collection with interviews

Research Phase one was split into two stages - (1) semi-structured interviews conducted with participants from first tier suppliers, and (2) a repeat process with participants from the prime's global purchasing and supply chain management divisions. The interview questions developed were driven by the research questions and were informed by the supply chain management literature from a range of relevant topics (e.g. supplier development, relationship management, information and communication). Prior to commencing the interviews at the suppliers and the prime manufacturer, protocol documents were developed to give the process the required structure and rigour and to enable the best possible opportunities to obtain rich data, as well as to provide

protection for all interview participants in terms of confidentiality. Pilot interviews were also conducted. All interviews were recorded and subsequently transcribed before the analysis phase.

Stage 1 (interviews with suppliers) concentrated on identifying linkages with themes from the literature review. Stage 2 (interviews with the prime, i.e., the buyer) focused on strengthening the exploratory phase findings by assessing opinions from the other side of the relationship dyad. This allowed the perspectives of the customer and the supplier to analysed and considered in the context of the literature.

Research Phase 2: Analysis

Research phase 2 was conducted by first adopting an axial coding technique (Yin 2009) as a way to analyse the interview data. This was carried out to identify emergent trends and themes. The aim was to identify both consistencies and differences in responses to the interview questions from both sides of the dyad. It was hoped that consensus to answers of the interview questions would provide richness to the data. The issues and themes that emerged were also considered with regard to the literature.

System Dynamics was adopted as the method to capture, model, and illustrate the findings from the research. More specifically the focus is on causal loop diagramming, which is a method to visualise relationships between variables within complex systems and is particularly useful in an organisational context (Moorcroft, 2009). Causal loop diagrams highlight positive (reinforcing) or negative (balancing) feedback loops between key variables (Groesser and Schaffernicht, 2012). Variables represent elements of the current state of the system. Loops or linkages depict the actions that change the current state over time (Ford, 2010). Positive feedback loops represent a cycle of relationships between variables that accentuate the effect being examined as the loop is re-enacted over time. Negative feedback loops reduce the effect but still have an impact on overall system behaviour (Anderson et al., 2012). In this research causal loop diagrams are used to illustrate the effects of short term quick fixes on supply chain failure.

An important aspect of using causal loop diagrams is to identify and categorise the key variables in the system and their linkages with each other (Repenning and Sterman, 2001). Strong emergent themes from an empirical study such as interviews provide a basis for variables to be identified to initiate the causal loop diagram process (Sterman 2000). Causal loop diagrams were constructed for this study using the following process:

- Consistently quoted responses were formulated as variables and placed into categories covered by the most pertinent literature domains, e.g. supply chain quality management, risk and contingency management.
- The key variables related to short-term quick fixes, failure and recovery activities by all of the research participants were identified.
- Mental modelling, which is a technique utilised for System Dynamics modelling (Groesser and Schaffernicht, 2012), was then adopted to create causal loop diagrams for each theme based on the judgement of the researcher.
- Using the interview responses as a guide, the established variables were then linked to other variables based on causality, i.e. variables that create an effect on a process either positively or negatively when linked together (Moorcroft 2009).

Research Phase 3: – Validation.
This phase aimed to test and validate the causal loop models including the variables identified, their linkages, and the interactions they show. Validation of the causal loop diagrams was carried out by conducting workshops involving participants from the study as well as others new to the study. The validation process further informed our understanding of the management of supply chain failure and how response processes are enacted.

Findings

The unit of analysis for this study is a prime manufacturer and a failing first tier supplier. Analysis of the outputs from the data collection and model formulation activities has led to the creation of causal loop diagrams entitled 'Short Term Quick Fix' (See figure 1) and 'Recovery Activity' (See figure 2). They are relevant to the literatures on Quality Management, Supplier Development and Performance Management. We illustrate and describe these processes here.

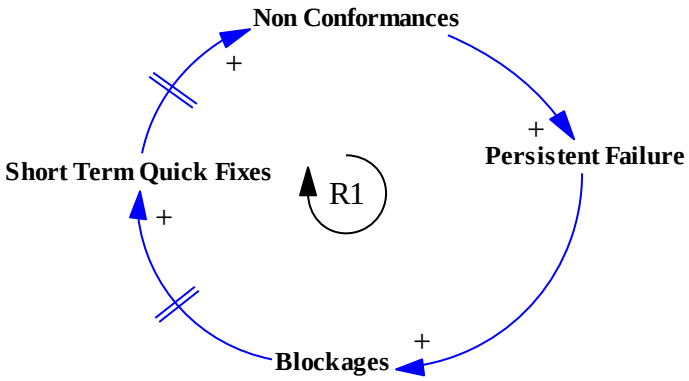

Figure 1 –The Short Term Quick Fix Loop

The interview findings indicate that failure persistence is influenced by the fact that the prime has no option but to accept the first tier supplier's poor performance because of the prime's lack of alternative supply options. Therefore, to reduce the risk of causing disruption, the prime either (1) conducts short-term quick fixes to keep production moving, or (2) takes steps to reduce the amount of non – conforming product being delivered by the first tier supplier, which means committing resources to identify the root cause of the persistent failure. Blockages occur when components stop production because they are either late being delivered or do not meet the required specification. Starting with the 'Blockages' variable, the linkages illustrate that the longer a blockage lasts then the greater is the temptation or perceived need to conduct 'short term quick fixes' by the prime and the first tier supplier in order to reduce the number of non–conformances and allow production to continue or resume. This is demonstrated by the arrow linking the blockage variable with the 'Short Term Quick Fix' variable. The time delay mark placed between the two variables highlights how this can happen over a period of time as the loop has a reinforcing effect. The empirical evidence indicates that this effect does not occur immediately, as noted in earlier work (Repenning and Sterman, 2001). These activities become self-reinforcing (as denoted by R1 in the causal loop diagram) because the initial effects of short-term quick fixes can

temporarily resolve problems, which is an attractive and convenient course of action for the prime (Foster et al., 2011). However, rather than reducing non–conformances, which are components supplied by the first tier supplier that do not meet the required specification as contractually agreed, the evidence indicates that increasing short-term quick fixes has a reinforcing effect that increases non–conformances. The loop becomes a vicious cycle (Sterman, 2000), causing failure to increase until production has to be halted. Should effective action not be taken then the loop continually reinforces until the prime and supplier are continually adopting short-term quick fixes but the first tier supplier continues to fail (Groesser and Schaffernicht, 2012). The factors that influence these variables were regularly cited during the interviews as potential causes of failure. It was also found that the factors that drive failure to persist reinforce to further increase the number of blockages experienced by the prime as a result of further non–conformances being captured because the short term quick fixes being deployed by the prime have not eliminated the causes at source, i.e. at the first tier supplier.

A possible end effect of the cycle is that the prime manufacturer has to divert resources to the first tier supplier in order to identify the root cause of the problem so that non-conformances are minimised and to reduce the need to conduct short-term quick fixes (Wagner 2010). It was frequently mentioned by interviewees from the prime manufacturer that some first tier suppliers consistently struggled with (1) understanding the prime's product and/or manufacturing requirements, and (2) achieving the correct specifications for components on a consistent basis (Nagati and Rebolledo 2013). Further findings from the empirical research found that the prime manufacturer regularly conducted supplier improvement activities to improve performance of a first tier supplier by increasing understanding of specifications and reducing non-conformances. However, Arroyo-López et al., (2012) identified that a major issue with improvement activities is the tendency for buying organisations to abandon them too early in the process if implementations do not result in an immediate improvement.

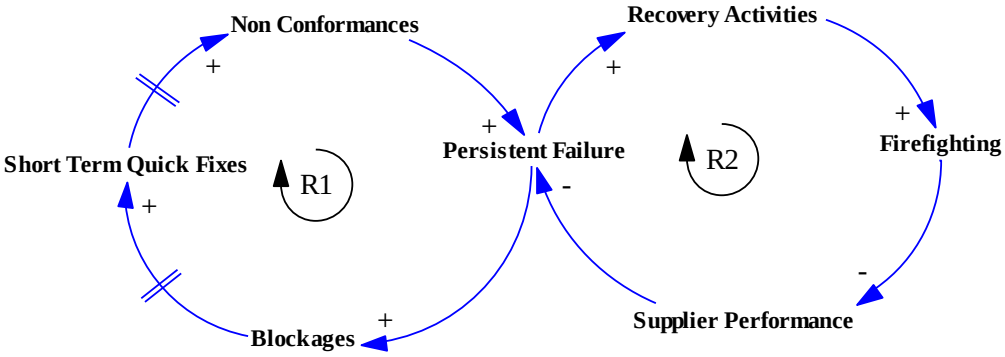

Figure 2 – Recovery Activity Loop

In order to mitigate against persistent failure, recovery activities are often hastily put in place by the prime organisation as captured in the 'Recovery Activity Loop' (see Figure 2). The recovery activity loop emerged from the analysis of data from interviewees from the prime explain how failures were prioritised and managed by the prime. Once persistent failures reached a position where failure to supply to the prime's end customer is identified as a major risk by senior management, then the prime is

obligated by their customer to act. Alleviating non–conformances by constantly conducting short-term quick fixes eventually becomes unsustainable resulting in reduced performance. The 'Persistent Failure' variable increases the need to trigger 'Recovery Activities', which are activities or initiatives conducted by the prime to help a first tier supplier recover from failure. The prime identifies and deploys a series of recovery activities with the affected first tier supplier. These activities are differentiated from short-term quick fixes because they involve assembling a team of quality engineers to manage the failure through to recovery. Greater focus on the supplier is stimulated by senior management from various functions in the prime becoming involved in the process.

The additional requirements on the prime manufacturer to conduct recovery activities has the effect of increasing 'Firefighting' because the prime is under pressure to solve problems with the first tier supplier in a short period of time. This is further exacerbated in complex supply chains that operate across a wide geographic range, which is in line with the findings of Bode and Wagner (2015) on how greater supply chain complexity increases the risk of supply chain failure. Increased firefighting leads to a reduction in 'Supplier Performance' because management behaviour intensifies towards the first tier supplier when persistent failure occurs. The effect of delivery delays can result in the supply chain being in a constant state of 'catch up' in order to fulfil the prime's build line schedules. When firefighting activities are intensified resources are focused towards mitigating the existing failure rather than planning and delivering future requirements. The principal reason is that the efforts of the supplier are concentrated on the recovery initiative. This has the effect of delaying current or future deliveries whilst the cause of current non–conformances is investigated. Improvement in the supplier performance variable will ultimately have the effect of reducing the risk of persistent failure because the first tier supplier is performing to the level of quality and delivery performance that has been stipulated by the prime. However, the overall impact of this loop is that it further increases persistent failure each time the it feeds back. Both loops have been identified as having a reinforcing effect causing failure to persist. The short-term quick fix loop can quickly develop into a vicious cycle, which is exacerbated by the recovery loop as the prime and supplier struggle to reduce non–conformances quickly enough to prevent persistent failure.

Quality failures cannot be tolerated in the gas turbine industry because of safety issues. If a prime manufacturer cannot readily guarantee process stability and full product conformance from a first tier supplier then they have a duty to act. As a consequence, both the short-term quick fix and recovery activity loops are strongly influenced by the requirement to adhere to the prime's quality management system (Barouch and Ponsignon, 2016). Both loops portray the effect that conducting short term quick fixes has on increasing the risk of persistent failure eventually leading to reduced supplier performance. The occurrence of these effects are not exclusive to either the prime or the supplier – they lie in the nature of the relationships and interactions between both parties.

Research and managerial implications

The literature focuses mainly on failure avoidance and putting in place approaches to de-risk a chain. The literature focuses on understanding quality management practices and concepts, providing descriptions of how they seek to prevent failure from happening in the first instance (Robinson and Molhotra, 2005). There is only a limited literature on organisational responses to supply chain failure. In particular, there is very little literature that analyses the long term effects on supplier performance of favouring

short-term quick fixes instead of establishing the root cause of non–conformances. Morrison (2015) did however recently conduct research aimed at establishing why organisations carried out 'workarounds' in order to quickly fix problems, which is reflected in the effects captured in the short-term quick fixes loop depicted here that shows how short-term quick fixes reduce blockages. The research found that workarounds happen due to the lack of available resources needed to quickly mitigate failures. The model we present shows two effects occurring. First, there is an immediate response to failure in the form of quick fixes but which fail to identify and correct underlying problems and thus allow failure to persist. Second, prolonged failure by the supplier results in an organisational response by the prime, which places the supplier under a high level of scrutiny and pressure to resolve the underlying problem but which has the effect of diverting the supplier's resources to address the specific problem and ultimately resulting in continued failure. These two effects interact and combine to allow failure to persist.

The interaction between the persistent failure and recovery activity variable is to an extent supported by the literature. Some research has investigated how organisations aim to mitigate against instances of failures. The literature highlights how factors such as senior management involvement and the alignment of strategic goals between buyers and suppliers are important for success in supplier development initiatives leading to recovery from poor performance (Humphreys and Chan, 2004). Findings from our empirical research add to the literature by identifying and highlighting the importance of managing recovery activities in an appropriate way. Efficient and effective methods need to be deployed in initiating mitigation activities with a failing first tier supplier, taking into account the benefits that can be derived. This includes carefully deciding on the intensity of the effort and minimising the potential for firefighting activities to occur. When failures start to persist, the pressure that is applied on managers responsible for a supply chain engenders a tendency to favour quick fixes or workarounds in order to reduce current disruption (Morrison 2015). However, short-term resolution of problems may not be sustainable. Developing 'short term quick fixes' to solve a problem in order to quickly alleviate blockages is likely eventually to feedback and allow failure to persist. These observations are important for managers at both the prime and at first tier suppliers. As the long term effects of short term quick fixes build up over time, it becomes increasingly difficult to identify the root cause of failure resulting in non–conformances becoming expensive and time consuming to resolve. A strong message reflected by the loops is that managers need to avoid resorting to short-term solutions for failures and concentrate on identifying the root cause and developing problem resolutions that are both effective and sustainable. Otherwise, the failure is likely to become persistent.

A key purpose for the development of each loop was to create a visualisation tool and methodology that could be used by businesses and by purchasing and / or supply chain professionals to help mitigate failure by reducing the need to conduct short term quick fixes and focus efforts to establish the root cause of the failure. Each loop pinpoints interactions between key variables that link and eventually reinforce to cause supply chain failures to persist if not treated effectively and expediently. The loops also demonstrate how causal loops feedback to cause vicious cycles that if not mitigated effectively can result in serious disruption. The core message communicated by model is that the prime needs to recognise the emergence of a persistent failure scenario and use the loops to (1) help identify and focus on reducing non–conformances by identifying the root cause of failure, and (2) develop recovery strategies to mitigate

against long term failures and avoid short term thinking and reactive strategies as they can combine to create unfavourable situations in the long term if not managed correctly.

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