

Creating Supply Chain Resilience Through Agile Six Sigma

By **Professor Martin Christopher & Christine Rutherford**

Today's global supply chains are, in effect, highly complex networks. They are increasingly vulnerable to disruption which can have significant impact on profitability and shareholder value. Recent research at Cranfield School of Management has highlighted where the sources of risk in supply chains might lie and how that risk might be mitigated and managed by the application of 'Six Sigma' philosophies and procedures.

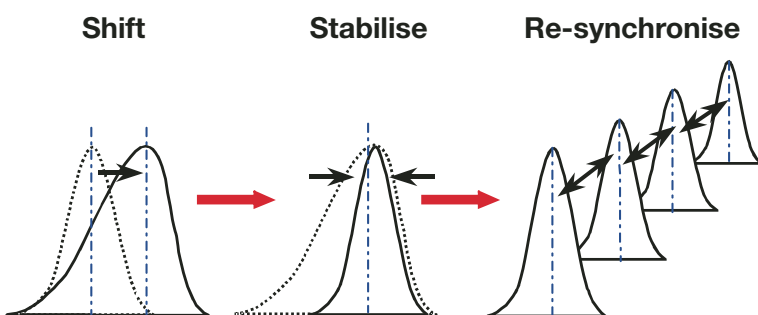


Fig 1. The Responsiveness of Robust Supply Chain Processes

As Supply Chain networks increase in complexity as a result of market volatility, outsourcing, globalisation and single point sourcing, so too has the risk of disruption. Networks are becoming more vulnerable as supply chains become longer and leaner. Cost-reduction and efficiency are now key business goals and, as a result, networks become increasingly vulnerable to events that previously may have caused only minor local disruptions.

Whilst the continued search for efficiency improvements is essential in a fiercely competitive marketplace, the challenge is to find ways in which vulnerability can be contained and managed. Recent research (1) has highlighted how the risk of supply chain disruption has grown and how great the consequences of that disruption might be. Whilst there are many obvious sources of risk external to the supply chain e.g. terrorist attacks, floods, earthquakes and the like, it is our contention that a growing source of risk lies within the supply chain itself and that, once recognised, that risk can be mitigated or even removed.

Since supply chains comprise the linked processes of the different entities in a network, it is appropriate to focus on ways in which process risk can be managed.

ROBUST VERSUS RESILIENT

Central to the debate on process risk are the notions of robustness and resilience. Instinctively we would argue that a risk management strategy should aim to create and maintain a supply chain that is both robust and resilient. But what exactly does this mean? Often used interchangeably, in the context of supply chains 'robust' and 'resilient' have quite different meanings. Based on dictionary definitions 'robust' is understood to mean 'strong, and sturdy: constitutionally healthy'. Thus a robust process might reasonably be expected to produce consistent results with very little variation in output; i.e. a healthy reliable process. The design and maintenance of robust processes makes good business sense and the popular tenets of lean thinking drive us in this direction. However, how resilient is a supply chain comprising a network of robust processes? Resilience is the 'ability of a system to return to its original (or desired) state after being disturbed'. In the context of business today, a resilient supply chain must also be adaptable, as the desired state may be different from the original. 'Robust' processes may be strong but they are not by definition adaptable, hence a supply chain of robust processes is not necessarily going to be resilient.

Table 1. provides a comparison between the

TABLE 1: THE CHARACTERISTICS OF ROBUST AND RESILIENT SUPPLY CHAINS

ROBUST SUPPLY CHAINS	RESILIENT SUPPLY CHAINS
'Lean thinking' central to supply chain strategy	Risk management central to supply chain strategy
A culture of quality awareness	A culture of risk and quality awareness
Internal quality control	Internal and external risk management
Responsive to reasonable variation in input	Responsive and capable of sustained response to sudden and significant shift in input
Supply chain velocity	Supply chain acceleration & deceleration
Low inventory levels throughout with strategic safety stocks	
Spare capacity minimised throughout	Critical path spare capacity in manufacturing, storage space and process capability
Lean processes	Mix of Lean and Agile processes
Efficient processes	Effective processes
Strong	Scalable/Adaptable
Processes are stable and under control	
Non-value adding activities and processes removed	
Supply chain output variability is minimised	

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characteristics we might expect to find in robust and resilient supply chains. Although they share a number of characteristics such as stable processes and low inventory levels, the key difference between the two is in their ability to respond to variations in input.

A robust supply chain can deal with reasonable variability in input whilst maintaining good control over output variability. A resilient supply chain is certainly robust, but it offers much more; as well as being responsive to predictable input variability it is also able to respond to a sudden and unexpected shift in the level and variability of input. As such we would expect a resilient supply chain to be adaptable and scalable, and able to sustain a response indefinitely.

Consistent with this definition of a resilient supply chain is an appreciation that our robust processes must also be responsive i.e. able to shift, stabilise and re-synchronise in a reasonable timeframe (2). A model of robust process responsiveness reflecting this requirement is given in **Figure 1**. Here shift refers to a step change in process throughput; once the desired throughput

has been achieved then the process is stabilised and brought back under control (variability is squeezed out until the desired capability is reached). Finally interfacing processes must be re-synchronised at the new level of throughput.

Clearly our ability to carry this through will depend on the degree of visibility and control we have over our processes as well as the timely availability of spare process capacity. A fundamental first step toward achieving this is to bring critical path processes under control.

PROCESS CONTROL

Conventional approaches to quality management were typically based upon 'inspection'. In other words, a sample of the output of a process would be taken on a periodic basis and if non-standard outputs were detected then remedial action would be taken. Not surprisingly, inspection-based quality management has proved to be less than satisfactory. Often non-conforming items would 'slip through the net' and, in any case, inspection is 'after the event'. Today, our thinking on quality



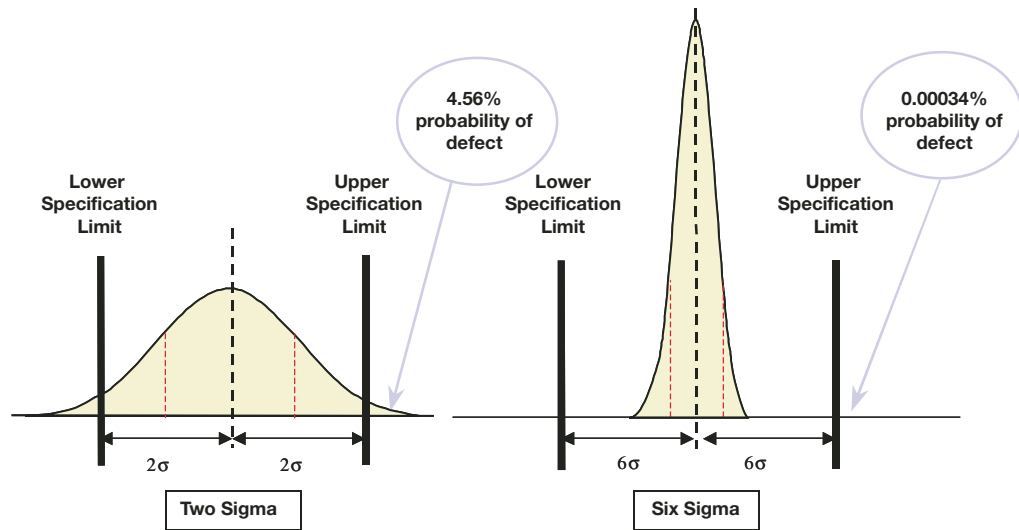


Fig 2. The Difference Between a Two Sigma and a Six Sigma Process

WHILST SIX SIGMA PERFORMANCE MAY BE UNATTAINABLE IN MANY CASES, IT IS USED AS A TARGET.

management has changed. Now the recognition is that we seek consistency in the quality of the output then the only way to achieve this it to ensure that the process that produces those outputs is under control.

Thus process control becomes the means by which variation in output is reduced. Variation in any process is the problem. If everything in life or in business was totally constant or even predictable, then there would be few problems. The challenges arise because of variations. Hence it follows that if variation can be reduced then the consistency (and, by definition, the reliability) of the output can almost be guaranteed.

THE SIX SIGMA WAY

The Six Sigma route to quality control emerged in the 1980s as Motorola searched for a robust quantitative approach that would drive variability out of their manufacturing processes and thus guarantee the reliability of their products. The term Six Sigma is largely symbolic, referring to a methodology and a culture for continuous quality improvement, as well as referring to the statistical goal, Six Sigma. The term 'Sigma' (σ) is used in statistics to measure variation from the mean; in a business context the higher the value of sigma the more capable is the process of delivering an output within customer specifications. Figure 2 illustrates the difference between two processes; one with a low capability and the other with Six Sigma capability.

The Six Sigma goal, (which in many cases is an aspirational one) is to squeeze out process variability until the process produces just 3.4 defects per million activities or 'opportunities'; this reduces waste and hence saves money whilst improving customer satisfaction. But Six Sigma is more than just a statistical measure it is 'a comprehensive and flexible system for achieving, sustaining and maximising business success.'⁽²⁾ Whilst Six Sigma performance may be unattainable

THE FIVE-STAGE DMAIC CYCLE

- Define:** What is it we are seeking to improve?
- Measure:** What is the current capability of the process? What averages, what variability in process output is evident?
- Analyse:** Map the process, use cause and effect analysis (Ishikawa) and prioritise for action.
- Improve:** Re-engineer the process, simplify.
- Control:** Improve visibility of the process. Use statistical process control and monitor performance.

in many cases, it is used as a target – sometimes referred to as ‘more of a journey towards continuous improvement than a destination’ (3).

Six Sigma is a data-driven, continuous-improvement methodology that seeks to bring processes under control and to improve process capability. The methodology itself follows the five-stage DMAIC cycle.

Six Sigma tools and techniques enable the proper execution of the DMAIC cycle and ensure that decisions are based on hard quantitative evidence.

SIX SIGMA SUPPLY CHAINS

Evidence of the spread of Six Sigma practice beyond the factory gates into the wider supply chain has emerged over the last ten years. Most notably Ford has created Customer-Driven Six Sigma (4), an approach that touches every function at Ford from manufacturing to marketing and sales. Al Ver, Ford’s vice president of manufacturing and engineering, makes it quite clear that “Six Sigma is not simply something else we do, it’s the way we must execute everything we do”

In one Six Sigma project, Ford analysts measured inventory levels at one of their plants during production hours and found that levels varied by 20% over a month. With further investigation they discovered one of the major causes of inventory fluctuation was inefficient and inconsistent unloading of parts at the plant docks. Taking steps to improve dock utilisation and thus driving out process variability led to annual savings of more than \$3.7 million due to inventory reduction, reduced overtime for unscheduled materials handling and other savings.

Unlike many manufacturing processes, supply chain processes are often measured against time (e.g. on time deliveries, picking rates, etc), as opposed to some physical dimension or quantity (e.g. picking accuracy, product tolerances, etc). If we apply Six Sigma techniques to squeeze out variability in time, lead-times become more reliable and safety stock levels can be reduced. Furthermore, lead-times across multiple activities or processes can be compressed thus improving overall responsiveness to customer requirements whilst reducing costs through reduced levels of cycle stock.

It would appear that Six Sigma offers a route to creating more robust supply chain processes that reduce the risk of non-conformance and hence produce a more reliable and consistent output. In a ‘steady state world’ this degree of ‘resilience’ would suffice, but faced with unpredictable events our supply chain processes also need to be agile and

responsive. The key lies with Six Sigma process control; if organisations have control over their supply chain processes they are then in a good position to control a shift in output as required to counteract or respond to disruptive events that threaten supply chain continuity. But to achieve and sustain the shift we also need spare process capacity.

LEAN SIX SIGMA

The power of integrating Lean and Six Sigma principles is quite dramatic. Their complementary objectives, tools and techniques create a synergetic effect that drives out waste in all its guises. Lean thinking takes care of waste across all processes and focuses on speed, whereas Six Sigma focuses on eliminating defects and driving out process variability (5). Through applying these ideas simultaneously, organisations can improve customer satisfaction, increase process speed and quality of product and service, whilst reducing cost and invested capital.

Honeywell, for example, integrated Lean practice with a Six Sigma approach and formed Six Sigma Plus. Now many of their improvement projects include aspects of both variation reduction and waste elimination. In one particular project at a chemical plant in Europe, the company succeeded in doubling the production capacity and reducing manufacturing costs by 50% (6). Honeywell estimate that Six Sigma Plus has saved the company \$3.5 billion since 1995.

However, the danger of Lean Six Sigma is that ‘leaning down’ all the way and realising all the cost savings has the potential to make a supply chain vulnerable to unpredicted events because there is no slack to fall back on.

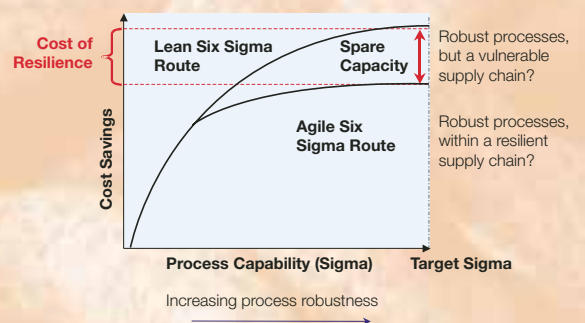


Fig 3. The Agile Six Sigma Route: Putting Spare Capacity into High Risk Critical Path Processes

AGILE SIX SIGMA

Traditionally supply chains hold buffers of safety stocks and spare capacity in the form of warehouse



THROUGH AN 'AGILE SIX SIGMA' APPROACH, SUPPLY CHAINS CAN REDUCE INTERNAL SOURCES OF RISK WHILST IMPROVING SUPPLY CHAIN EFFICIENCY AND EFFECTIVENESS

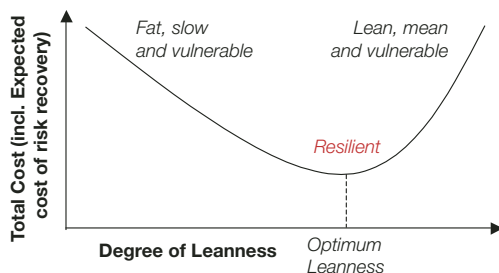


Fig 4. Finding the Optimal Level of 'leanness'

space to deal with variability in demand and supply. But in the event of a sudden unpredicted shift in input or a significant increase in variability these first line defences (which may have been weakened under lean efficiency drives) are soon consumed and the supply chain falters as processes fail to cope with the change in throughput required. The second line of defence needed to deal with such events is an ability to create the required process capacity. For example, spare capacity in the picking process might be in the form of a contract for short notice agency staff brought in to deal with an increase in throughput.

But this additional capacity needs funding; we propose that a proportion of the savings generated from a Lean Six Sigma efficiency programme should be re-invested in risk mitigation solutions that enable process responsiveness. In other words, aim for Lean Six Sigma process performance but do not be tempted to lean-down too far. The Agile Six Sigma route (Figure 3) leads to a resilient supply chain of robust Six Sigma processes with spare process capacity where it is needed most along the critical path.



THE COST OF RISK RECOVERY

If cost remains the priority driver then organisations may arrive at a lean but vulnerable solution. To avoid 'leaning down too far' the expected cost of risk recovery should be added into the total cost equation so that an optimum level of leanness can be identified. This expected cost is a function of the probability of the risk occurring and the cost of recovery from the consequences of the risk. For example, increasing the delivery frequency of raw



materials and thus reducing the inventory requirement may reduce the total combined cost of inventory and inbound transportation, but it will increase the risk of not meeting customer demand in the event of a supply failure. Adding the expected cost of risk recovery into the equation will shift the optimum away from a totally lean solution. In this example the organisation may decide to hold back some inventory to reduce the impact of the risk or improve their supplier relations to reduce the probability of the risk occurring. This notion of an optimal level of leanness, one stop short of a totally lean solution, is depicted in **Figure 4**.

Certainly the additional costs associated with risk abatement will be significant, but our contention is, that through an Agile Six Sigma approach, supply chains can reduce internal sources of risk whilst improving supply chain efficiency and effectiveness.

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Martin Christopher is Professor of Marketing and Logistics at Cranfield School of Management. He can be contacted at m.g.christopher@cranfield.ac.uk

Christine Rutherford's area of specialisation at the Cranfield School of Management includes logistics modelling, forecasting and inventory management. She can be contacted at christine.rutherford@cranfield.ac.uk

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