SPEEDING UP THE PROGRESS CURVE TOWARDS EFFECTIVE SUPPLY CHAIN MANAGEMENT

Denis R. Towill, Paul Childerhouse and Stephen M. Disney

Abstract
Although much has been written on supply chain practice, there is still a wide variation in present day performance between apparently similar value streams, dating back decades if not centuries. This paper introduces a supply chain "health check" procedure successfully applied in the European automotive sector and presents the results for the analysis of 20 trans-European value streams covering a wide range of first and second tier suppliers. The health check procedure is activated via a Quick Scan Methodology (QSM) requiring execution by a multi-disciplinary team working on-site. The degree of integration within the value chain is estimated by the QS Team using the Uncertainty Circle concept which apportions observed uncertainties in the Product Delivery Process (PDP) according to source. In our experience the four major contributors are the Demand Side: Supply Side: Value Added Process Side: and Systems Controls. The results clearly demonstrate a well-trodden and hence proven route for value stream performance improvement. They also identify value chain exemplars, and many areas of best practice but most importantly they provide a list of actions focussed at improving the performance of individual value streams. Properly applied, re-engineering programmes based on these trigger points will speed up the progress curve towards effective supply chain management.

Key Words: Supply Chain Management, Uncertainty Circle; Best Practice; Supply Chain Integration; Supply Chain Diagnostics; Trigger Points

1. Introduction

The concept of the "Seamless Supply Chain" (SSC) was recently proposed by Towill (1997a) as an idealised target state for supply chain operations. The aim here is enable an environment in which all "players" think and act as one entity in order to maximise the performance of the total system. SSC implies the lean synchronous arrival of materials coupled with minimum wastage, minimum lead times, and minimum reasonable inventory. In turn this requires a minimum entropy (maximum certainty) scenario despite the volatile behaviour of the marketplace.

It is our experience that the SSC may only be reasonably targeted if there is streamlined feedforward and feedback information flow coupled with optimal decision making. Yet despite the wide availability of techniques such as EDI, flexible manufacturing, automated warehousing, and rapid logistics, poor supply chain design performance is regrettably still the norm according to Fisher (1997). He highlights the poor matching of supply chain design to the product needs as a major contributor to this situation. Given the long history of supply chain operations Fisher's conclusions may appear surprising, but are in line with other informed opinion, for example, Towill (1997b). Much of this ineffectiveness is due to the adversarial nature of traditional supply chains (Handfield and Nichols, 1999).

As we reach the next millennium, it appears reasonable to introduce the problem to be addressed in this paper by inviting readers to answer the seven questions on supply chain development shown on Table 1. Detailed answers, some of which may seem very surprising at first sight, are given in Appendix I. What is so amazing, given the performance of the Venice ***arsenalotti*** supply chain way back in 1574, is to realise that in the late 1990's only a few percent of modern day value streams appear to be effective. However, as we shall see later, there are diverse reasons for this state of affairs. In the same way as Fisher (1997) has suggested that supply chain design needs to be matched to the product, our view is that to achieve maximum impact, re-engineering must also be matched to individual value stream requirements. This is definitely an area where one solution ***does not*** fit all! (Shewchuk, 1998).

Supply chains and value streams are of course closely related and in some ways the words are interchangeable. The supply chain has been defined by Christopher (1992) as a network of organisations that are involved through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer. Thus a supply chain consists of a number of businesses through which information concerning demand flows upstream from the marketplace and ultimatel to the raw material supplier. Material flows downstream, ending up as the particular physical product satisfying end-customer neexs. The value stream takes a focussed view of the supply chain, and is defined by Womack and Jones (1996) as the set of all specific actions required to bring a particular good or service to market. This paper specifically addresses the current state of the Product Delivery Process (PDP) for value streams in the European automotive sector.

2. Contribution of the Present Paper

For the purpose of the present paper the automotive industry supply chain has already been well described elsewhere and need not be repeated here (Womack, Jones, and Roos (1990)). The dominant player is usually the Original Equipment Manufacturer (OEM) i.e. the car assembler. Despite much publicity, frenzied activity, and benchmarking since Womack, Jones and Roos (1990) was published relatively little seems to have happened in the intervening years to actually improve automotive supply chain performance (Oliver and Delbridge (1998), Mason-Jones and Towill (1998)). But it is our view that making sweeping generalisations do not help individual "players" improve their performance in a lasting and meaningful way. Hence the design of our Supply Chain 2001^{+} health check which assesses specific strengths and weaknesses of individual value chains, identifies best practice, and clearly pinpoints what they must do to close the gap to achieve world class standards. This must include matching the design of the value stream to the specific product again emphasising the fact that one plan of action does not fit all (Gattorna and Walters 1996).

Q1	How long did it take the Venice ***arsenalotti*** to build a warship in the year 1574?
Q2	When and where was Value Stream Management invented?
Q3	When did the Retail Sector first exploit Value Stream Management?
Q4	What manufacturing principle was exploited in UK delivery of Spitfire fighter planes during World War II?
Q5	When and where were the Principles of Material Flow Control first published?
Q6	When were the nine simplification rules inherent in Japanese manufacture first published in the Western Literature?
Q7	In the year 1995, what percentage of supply chains were thought to be effective?

TABLE I. Seven Interesting Questions on the History of Supply Chain Management

The Supply Chain 2001^{+} project was conceived in order to provide the UK automotive sector "players" with material flow Decision Support Systems (DSS) appropriate to their needs. It is expressly aimed at assisting "players" (especially second and third tier suppliers) close the gap between their present performance and the Seamless Supply Chain. The target set here takes account of the likely changes in configuration and operation of supply chains as predicted for the early years of the next millennium. The DSS utilises a four vertical level framework from business strategy to shop floor activities, Towill, Childerhouse, and Disney (1999a). Individual improvements so far pinpointed during the Supply Chain 2001^{+} Project and in some cases already implemented in industry include reduction in transportation and central warehouse stock holding costs (Level 1); reduction in demand amplification and supplier capacity variance (Level 2); batch size reduction and capacity improvements (Level 3); and labour utilisation improvements in operating the Nagare line (Level 4).

We shall begin by reviewing the rules (established via both theory and practice) for smooth material flow, which is recognised as the basis for lean production (Womack and Jones, 1996). This is followed by describing a Reference Framework for managing change across a spectrum of supply chain scenarios ranging from "traditional" to "seamless". Our "Quick Scan" Health Check is then outlined, together with codified results obtained from an analysis of twenty European automotive supply chains. A gap analysis based on the Euclidean Norm then identifies "exemplar" value chains, and those exhibiting much good practice. Additionally there are also significant weaknesses highlighted which enable us to pinpoint specific areas of improvement recommended for the re-engineering of individual value chains.

3. Characteristics of Good Material Flow

It is our industrial experience (shared by many others, as discussed in Towill 1997b) that smooth well controlled material flow lies at the heart of best SCM design and practice. By identifying the shortfall in smooth material flow we are able to highlight those areas most in need of re-engineering to obtain significant performance improvement. To this end the set of twelve rules shown in Table II has been devised. Together these rules point the way forward to smoothing material flow throughout the chain. They are an amalgam of the principles of planning and execution of good flow control. Included in the set are the "best practice" lessons learned from value stream clustering (Burbidge, 1989) simplified manufacturing control (Schonberger, 1982), and system dynamics (Wilkner et al, 1991). The philosophy associated with the twelve rules is transparent: design material flow problems out of the system, rather than build them in thereby needing complex controls.

As a consequence of properly implementing good material flow control systems, it is found that ***all*** important business metrics are simultaneously improved. There is no downside to be traded against the enhanced bottom line. This is clearly evident from the results shown in Table III which compares business performance before and after re-engineering material flow systems. The exemplar company is a UK automotive tubular assembly supplier and the particular methodology used to enable the twelve material flow rules to be implemented is Production Flow Analysis (PFA) (Burbidge and Halsall, 1994). PFA seeks to simultaneously cluster products into effective groups so combining economies of scope with economies of scale. It also eliminates flow back tracking, operates on the "pull" principle, and seeks to implement Single Minute Exchange of Dies (SMED) wherever possible.

Lean thinking is defined as re-engineering the value chain to eliminate waste (Womack and Jones, 1996). However the ***practice*** of eliminating waste in a value chain closely follows the twelve rules of Table II. This similarity between lean thinking and good material flow control has indeed been noted by Womack and Jones (p 320). Of consequential importance is the realisation that Burbidge, still active in the highly successful application of PFA in European industry in the early 1990's, was associated with "lean production" of Spitfires during World War II, and first published the principles of PFA as far back as 1961. Thus one man spanned many of the later events questioned in Table I. It is therefore not surprising that he frequently expressed frustration at the general lack of progress by UK plc in achieving universally high standards of good material flow (Burbidge, 1995). In particular he highlighted the effective use of materials in wartime construction as contrasting with "fat" supply chains which became the norm again during peacetime.

RULE 1	Only make products which can be quickly despatched and invoiced to customers
RULE 2	Only make in one time bucket those components needed for assembly in the next period
RULE 3	Streamline material flow and minimise throughput time, i.e. compress all lead times.
RULE 4	Use the shortest planning period, i.e. the smallest run quantity which can be managed efficiently
RULE 5	Only take deliveries from suppliers in small batches as and when needed for processing or assembly.
RULE 6	Synchronise "Time Buckets" throughout the supply chain.
RULE 7	Form natural clusters of products and design processes appropriate to each value stream.
RULE 8	Eliminate all uncertainties in all processes.
RULE 9	Understand, document, simplify and only then optimise (UDSO) the supply chain.
RULE 10	Streamline and make highly visible all information flows throughout the chain.
RULE 11	Use only proved simple but robust Decision Support Systems
RULE 12	The operational target is to enable the seamless supply chain i.e. all players "think and act as one".

TABLE II. Twelve Proven Rules for Simplifying Material Flow (Towill, 11)

PERFORMANCE METRIC	JUNE 1991 (Before Re-engineering)	MARCH 1993 (After Re-engineering)
Throughput time	4 weeks	4 days
Set-up time	50 mins	15 mins
Production Runs p.a.	12	52
Rejections/Millions Parts	200	80
Overdue Orders/week	120	30
Sales p.a.	£m6.0	£m8.0
Return on Investment	15.6%	19.4%

TABLE III. Improved Bottom-Line Performance Obtained Via Streamlined Material Flow of Automotive Tubular Products Manufacture (Burbidge and Halsall, 15)

4. SCM Diffusion Dynamics – Slow and Painful, or Playing Catch-up?

Against the background of the apparently long history of "good" (but isolated and often transient) examples dating back to at least 1574 must be set the despair of pioneers such as Jack Burbidge. But as with most growth curves the diffusion dynamics of good SCM are themselves extremely fuzzy with a curious mixture of good and bad practice. Figure 1 illustrates the point, based only on recent and present events (Towill, 3). Here we speculate on the future from what is a very sparse data set. This requires an assessment of the shape of the learning curve, the rate of progress, and the final target level (Towill, 1990). However, we would reasonably expect to see improvement measured in terms of the customary "S-curve" but with a range of possible outcomes. However even the most optimistic asymptote is likely to have a final conversion rate to streamlined material flow of no more than 75% due to some companies forever refusing to change and struggling to get by without getting down to basics and analysing and streamlining their value streams.

But there may be much worse news still to come. Firstly, a pessimistic estimate of the asymptotic conversion rate to best practice could be as low as 25%. Furthermore, and even more worrying is the extended lead-time before effective re-engineering is achieved. This may be due to a mixture of poor planning, the low number of starts attempted; early failures abandoned; or good progression following by regression. What is blindingly obvious is that nearly 40 years after the principles of material flow control were published in the UK by Jack Burbidge, there is still so much scope for innovation in Lean

Production, as typified by the application reviewed by Bicheno and Sullivan (1999). This suggests that whether or not the transition need be slow and painful, there is still much emphasis on playing catch-up. But the gap between best and worst is widening fast, as at the top end companies compete successfully in the electronic shopping era (Kare-Silver, 2000).

5. Codifying the Health of Supply Chains

It is clear that there is a considerable need to assess and rapidly codify the health of supply chains. As Lord Kelvin remarked, "it is not possible to control a process without measuring it". Similarly we cannot improve it without controlling it. Hence our approach is firstly to measure where our particular value stream is presently positioned relative to the SSC. Secondly, our measurement system must also clearly indicate the actions required to close the gap, which are applicable to a specific value stream rather than yield general advice which may receive only scant attention.

Our approach, which follows immediately from the good material flow rules of Table II, is to assess the perceived levels of uncertainty induced within the supply chain. The starting point is the principle that regardless of the position of a business within the value stream, the PDP uncertainty problem may be simplified and put into the generic format of Figure 2 (Mason-Jones and Towill 1998). The objective is then to audit the supply chain by codifying the uncertainties arising from the four major sources shown in Figure 2.

Here a single echelon PDP is shown with our Value-Added Process (which may be composed of many individual tasks) directed by the System Controls. We respond to our immediate customer (the "Demand" side). In turn our stocks are replenished with materials, components, and sub-assemblies by various vendors (the "Supply" side). Our considered view is that reducing uncertainty is achieved by understanding and tackling the root causes inherent in each of the four areas in Figure 2 and especially by studying the various flows across each interface. Hence in this paper we shall take a holistic approach to Supply Chain Management (SCM) based on this generic model. By relating the QS output to the generic model via radar plots which represent the various sources of uncertainty (the Uncertainty Circle) we shall demonstrate a simple visual display of the health of our supply chains.

Codification is undertaken via the "Quick Scan" (QS) Diagnostic Procedure developed by the Cardiff LSDG team in collaboration with their research partners (Lewis, Naim, Wardle and Williams, 1998). To satisfy time and company access requirements the QS is completed within a two-week period, including feedback sessions to management. The key to the approach is the formation of a multi-disciplinary team incorporating researchers, site engineers and managers, and experts from the industrial partners. The latter are responsible for supply chain competency development and implementation. QS utilises the well-honed techniques of questionnaire analysis, process mapping, semi-structured interviews, analysis of company documentation and modelling from numerical data. The process-mapping phase is of prime importance, as this enables flows to be determined across internal supply chains and interfaces with both customers and suppliers. This procedure includes the identification of both value-added and non-value added processes along the value stream.

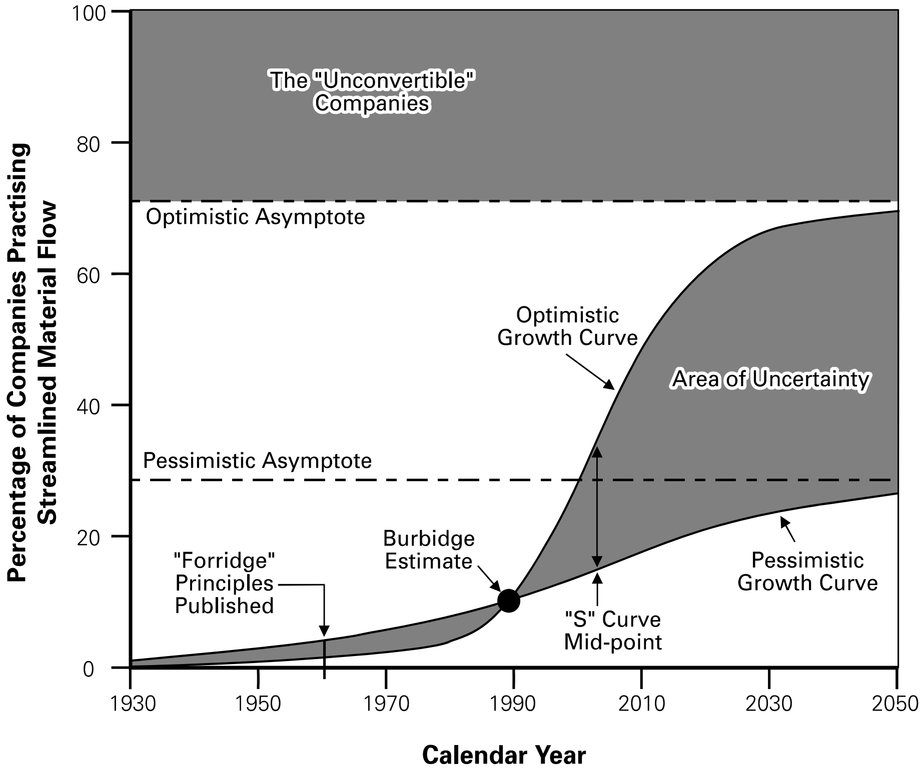

Figure 1. Diffusion Dynamics Curves Describing The Possible Growth Of Steamlined Material Flow Systems (Towill, 1997b)

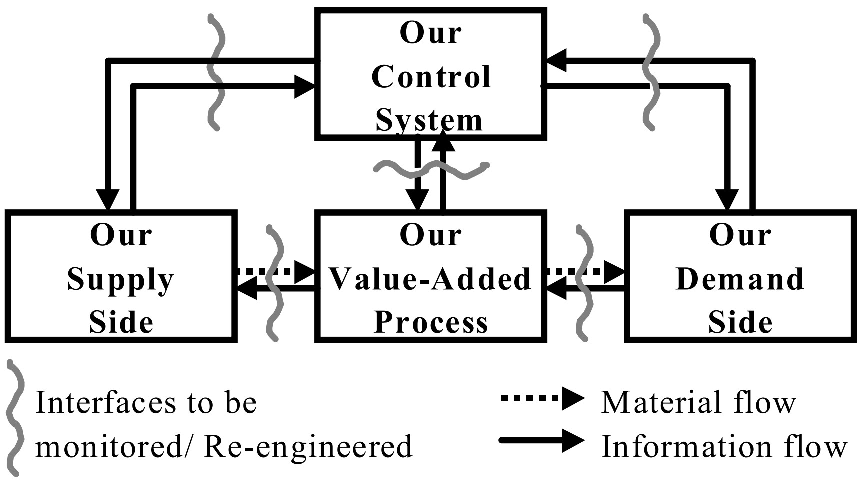

Figure 2. Uncertainty Circle Based Generic Model Used In Supply Chain 2001^{+} Pdp Health Check (Mason-Jones and Towill, 1998)

A number of brainstorming sessions are then held amongst the team so as to triangulate data from all sources, identify gaps in knowledge requiring further investigation, and also to resolve any inconsistencies. Rigorous analysis of the information allows keys problem areas and issues to be highlighted. The QS output is thus a clear assessment of the current status of the company and its supply chain, together with the maturity of its practices and processes and their ability to meet current and future customer needs. Access to best practice databases at this stage can reveal additional opportunities for change. These can then be quantified using simulation tools and flagged for debate and action by company executives. As used in this paper the QS results may also provide benchmarks of supply chain performance and thereby pinpoint best practice.

6. Supply Chain 2001$^+$ - Where Are We Now?

The codifying of the four uncertainty sources was undertaken by members of the QS Team on the basis of the totality of the information at their disposal. In that sense the QS "scores" are an aggregate assessment of supply chain performance. Table IV shows the sample Questionnaire then completed with respect of each value stream. To ensure comparability these uncertainty Questionnaires were activated only when all 20 value stream Quick Scans had been completed and analysed. Where necessary the Likert Scores were verified by cross-reference to detailed QS Reports and re-visiting various data banks set up as part of the Supply Chain 2001$^+$ Project. The choice of a four point Likert Scale was aimed at reducing any tendency to regress towards the mean, and instead to focus on strengths and weaknesses of individual value chains. In some cases it was found that further aggregation to a two point (H-L) Scale gave even better insight into supply chain health status and this is indeed the case for the radar plots to be considered here.

The methodology has to date been applied in depth to 20 value streams covering 12 trans-European sites. The product groups include forgings, sensors, brakes, actuators, and engine systems. Hence the products have ranged from sophisticated components to complete systems. Both second and third tier automotive suppliers have been analysed as part of the Supply Chain 2001+ Project. Our on-site studies have ranged across the spectrum of material flow systems from shop floor controls to aftermarket distribution, thus giving a good understanding of value stream behaviour throughout the automotive sector.

Figure 3 illustrates sixteen possible uncertainty states into which a value stream can be classified using High/Low classification along each dimension. The number of value streams in each state so far identified via the Quick Scans is shown in the top left-hand corner of each cell. Thus the 20 value streams studied to date have yielded 11 of the 16 theoretical possibilities. Most importantly, to date only 2 value streams have achieved "best practice" in the sense of reducing all four sources of uncertainty to an acceptable value. This figure of 10% is comparable with the estimates of 10% (based on material flow considerations) and 7% (based on the retail sector) quoted in Appendix I. Thus our initial contention that the diffusion dynamics of best practice across value streams is an extremely slow process taking many years is strongly supported by this automotive sector sample. This viewpoint is also supported by preliminary Quick Scan results from other market sectors, (Childerhouse, 2000). Even within an individual value stream the benefits enabled by a re-engineering programme can take several years to be achieved in full (Towill and McCullen 1999). Hence patience and perseverance are necessary virtues in successful change management.

Questions Asked of Each Value Stream	Rating by QS Team			
	Strongly agree	**Weakly agree**	**Weakly disagree**	**Strongly disagree**
1. The Value Added Process(es) Generate Low System Uncertainty	1	2	3	4
2. The Supplier Side Generates Low System Uncertainty	1	2	3	4
3. The Demand Side Generates Low System Uncertainty	1	2	3	4
4. The System Controls do not Generate Uncertainty	1	2	3	4

Table IV. Supply Chain 2001+ Questionnaire to Determine Impact of Process, Supplier, Demand, and Control Uncertainty Sources

7. What Now? Identifying and Closing the Gap

The pie chart classification of uncertainty circle results based on the Euclidean Norm of the 4 uncertainty scores (Towill, Childerhouse, Disney, 1999b) is shown in Figure 4. In some senses the results of representing uncertainty by a single performance metric offers something to everyone. Clearly in terms of approaching seamless operation, there are two exemplars which exhibit good material control in all respects. Detailed analysis shows that there are six value streams which have one or more major strengths. In fact four of these could they could be regarded as “best-practice” candidates for benchmarking visitations in a specific area of activity. The remainder of the sample are still in various stages of responding to wake-up calls for improved material flow control. Indeed some of those in the baseline segment are still clearly engaged in making their value-added processes “lean”.

However, reference back to Figure 3 does more than identify good practice. It also highlights the state of play for each value stream within our sample. Thus it is clear that 9 of the value streams are already operating in a state of good internal control (i.e. both P and C low). As individual “players” they may well rate highly but in 7 cases their value stream contribution is degraded either by problems on the demand side, or demand plus supply sides. It is also no coincidence that the two best-practice value streams we have identified involve Japanese OEM's with their much more predictable demand patterns (Harrison 1997). However, and encouraging feature is that much transferable and selective best practice was also observed in other value streams.

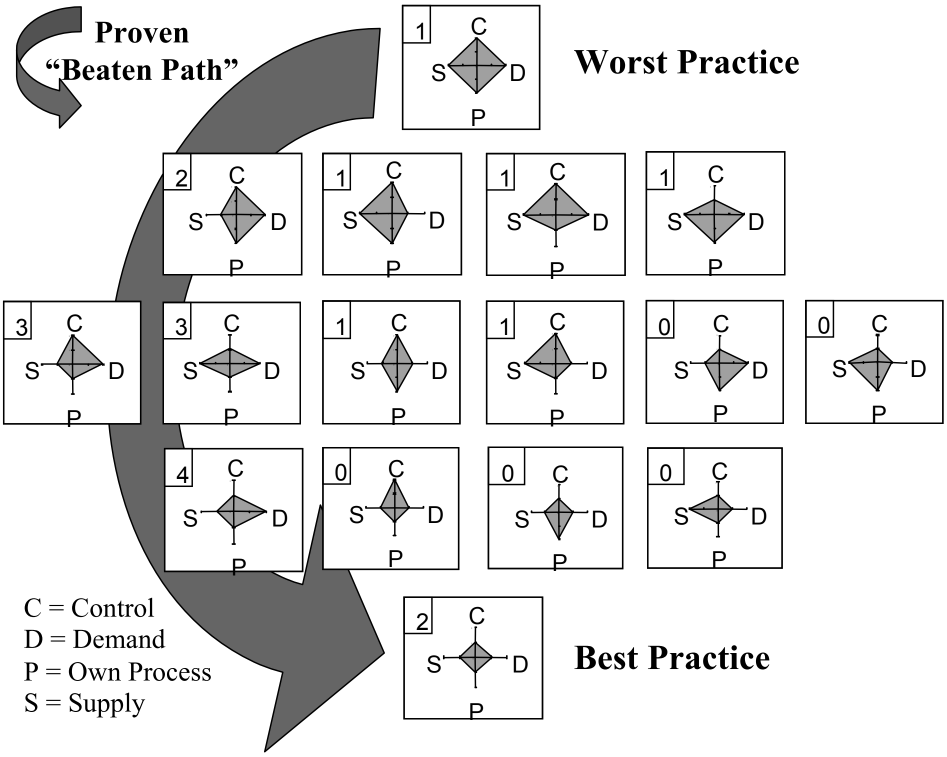

Figure 3. Binary Analysis Of Uncertainty Circle Radar Plots For Twenty European Automotive Value Streams (Towill, Childerhouse and Disney, 1997a)

Effective improvement does depend on our ability to identify windows of opportunity. What bad practices have the QS team diagnosed which hold back individual value streams from approaching seamless operation? Table V is a summary of practical trigger points highlighted for immediate remedial action. The observed weaknesses have been classified into the four Uncertainty Circle quadrants of Process Side: Supply Side: Demand Side: and Control Side. They have also been categorised into issues associated with data problems (masking; shortfalls; and errors); generation of excess delays: and generation of excess variance.

Table V provides a comprehensive list of actions arising from individual QS Reports to be taken by the Task Forces responsible for re-engineering the value stream. Whilst in 2000 we may still expect the "product champion" to encounter the adversarial relationships listed as impeding progress towards streamline flow, the absence of information transparency and satisfactory measurement systems is surprising and a cause for concern. This further emphasises the view that when re-engineering business processes it is essential to put in place good monitoring systems, otherwise there may be temporary improvements followed by regression. (Rummler and Brache 1995). Finally, the arrow on the left hand side of Figure 3 confirms that there is a well worn and effective path for value stream improvement. The message is clearly ***Master your added-value process, transfer your best practice to your suppliers, and then work with your customers to finalise seamless operations, all the while updating the controls in the light of new opportunities.***

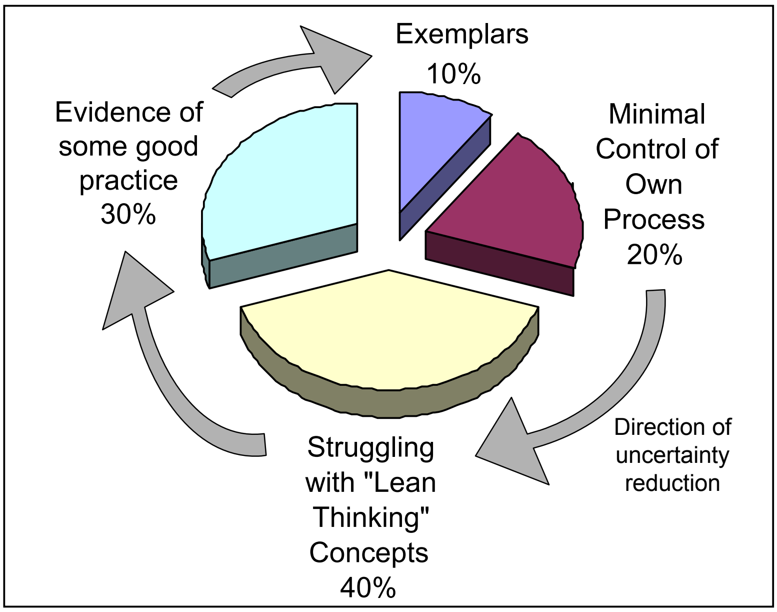

Figure 4. Pie Chart Distribution Of Value Streams Health Status On A Composite Uncertainty Metric

8. Conclusions

The literature is rife with advice on how to re-engineer supply chains back to the standard arguably first achieved many decades (if not centuries) ago. There is also the feeling generated by the press that everything Western performs poorly, and everything Japanese performs well. As shown in this paper, the truth is somewhere between these two extremes, which is why we must diagnose "our" value stream. Measurement must precede analysis which in turn precedes redesign What is undoubtedly true is that value streams needs to be engineered, with as much attention paid to how we do things as is traditionally paid to what we do (Towill 1997c). Poorly performing value streams inevitably suffer from poor business systems engineering (simply defined as the systematic engineering of the business) and this conclusion applies irrespective of country or market sector.

Uncertainty Source	Some Observed Weaknesses	Supply Chain Disruption Potential				
		Data Masking	Data Shortfall	Data Errors	Excess Delays	Excess Variances
Process Side	• No measures of process performance		♦			
	• Reactive rather than proactive maintenance					♦
	• Random shop floor layout				♦	♦
	• Interference between value streams				♦	♦
Supply Side	• Short notification of changes to supplier requirements			♦		♦
	• Excessive supplier delivery lead time				♦	
	• Adversarial supplier relationships	♦		♦		
	• No vendor MOPS		♦			
Demand Side	• No customer stock visibility		♦			
	• Adversarial customer relationship	♦				
	• Large infrequent deliveries to customer				♦	
	• Continuous product modifications causing high levels of obsolescence					♦
Control Side	• Poor stock auditing		♦			
	• No synchronisation and poor visibility during sub-control	♦		♦		♦
	• Incorrect supplier lead times in MRP logic			♦		
	• Infrequent MRP runs			♦	♦	

Table V. Weaknesses Observed During 20 Automotive Value Stream Quick Scan Analysis –Their Supply Chain Disruption Potential

By developing a methodology for diagnosing the health of value streams based on the Uncertainty Circle, we have been able to rank a sample of European automotive supply chains in a meaningful way. The scores and progress observed for each value chain have been compared against the Seamless Supply Chain and the performance gap established. This enables a judgement to be made not only on how much improvement is required, but also provides comprehensive guidance on the direction to move to obtain greatest benefit. There is little point in concentrating on yet further improvements to our internal processes when the highest leverage can be exerted at the value stream interfaces. Hence the provision by the Quick Scan Team of trigger points for action to improve the performance of a particular value stream.

The results available to date are very encouraging. Although only 10% of our sample may be regarded as “exemplars” operating in all respects in a Seamless Supply Chain manner, 20% of our value streams display much good practice. There is thus a rich source of well-engineered value streams available for benchmarking visitations. The remaining 70% of the sample are in various stages of transition requiring trigger point actions identified via the Quick Scan. Some, clearly, are still in a situation where the application of “lean thinking” principles would yield immediate benefits, other value chains have passed this stage and need to give much more attention to interface design and management.

Acknowledgements

We wish to thank the EPSRC, IMI and our Research Partners for supporting the Supply Chain 2001$^+$ Programme with its extensive multi-site involvement. Our colleagues Drs. M.M. Naim and Jayne Lewis, plus Gary Evans, Robert Dumazell, Nick Clifton and Richard Gillingham who have all participated in various individual Quick Scans.

References

Burbidge, J.L. *“Production Flow Analysis for Planning Group Technology”,* Clarendon Press, Oxford, 1989.

Burbidge, J.L., “Back to Production Management”, *Manufacturing Engineer*, April, pp 66-71, 1995.

Burbidge, J.L., and Halsall, J., “Group Technology and Growth at Shalibane”, *Jnl. Prod. Plan. Cont*., Vol 5, No 2, pp213-218, 1994.

Childerhouse, P., *Ph.D. Thesis, Cardiff University, LSDG*, 2000.

Christopher, M., “*Logistics and Supply Chain Management”*, London, FT Pitman Publishing 1992.

Drucker, P., “The Information ThatExecutives Truly Need”, *Harvard Business Review*, Jan-Feb, 1995 pp 55-63.

Fisher, M.L., “The Right Supply Chain for Your Products”, *Harvard Business Review*, March-April, 1997, pp 105-116.

Gattorna, J.L., and Walters, D.W., "*Managing the Supply Chain"*, Macmillan Business, UK. 1996.

Kare-Silver**,** M. de, *"E-Shock 2000; the Electronic Shopping Revolution –Strategies for Retailers and Manufacturers"*, MacMillan Books, London, 2000.Kare-Silver 2000.

Lewis, J., Naim, M., Wardle, S., and Williams, E., "Quick Scan Your Way to Supply Chain Improvement", *IOM Control*, Vol. 24, No. 5, pp 14-16, 1998.

Mason-Jones, R., and Towill, D.R., "Shrinking the Supply Chain Uncertainty Circle",*IOM Control*, Vol. 24, No. 7, pp 17-22, 1998.

Oliver, N, and Delbridge, R., "Benchmarking Manufacturing Performance and Practise in Automotive Supply Networks". *Proc. EUROMA Conf. On Managing Operations Networks*, Venice, pp 3-10,1999.

R.B. Handfield, and E.L. Nichols, Jr., *"Introduction to Supply Chain Management",* Prentice Hall, New Jersey, 1999.

Rummler, G.E., and Brache, A.P., "*Improving performance: how to manage the white space on the organisation chart"* (Jossey Bass, San Francisco) 1995.

Schonberger, R.J., *Japanese Manufacturing Techniques : Nine Hidden Lessons in Simplicity"* The Free Press, NY, 1982.

Shewchuk, P., "Agile Manufacturing: One Size Does Not Fit All", Proc. Int. Conf. Manuf. Value Chains, Troon, (1998), pp143-150.

Sullivan, J., and Bicheno, J., "Case Study: Application of Value Stream Management to MUDA Production in a First Tier Automotive Component Manufacturer", *Proc. EUROMA Conference on Managing Operations Networks, Venice*, pp 311-319, 1999.

Towill, D.R. and McCullen, P., "The Impact of an Agile Manufacturing Programme on Supply Chain Dynamics". Int. J. Log. Man. 10, (1999), 1, pp 83-96.

Towill, D.R., "Forecasting Learning Curves". Int. J. Forecasting, 6, pp 25-38, 1990.

Towill, D.R., "FORRIDGE – Principles of Good Practice in Material Flow", *Int. Jnl. Prod. Plan. and Cont.*, Vol. 8 No. 7, 1997b, pp. 622-632, 1997a.

Towill, D.R., *"Simplicity Wins* – Twelve Rules for Designing Effective Supply Chain", *IOM Control Journal*, Vol. 25 No. 2, 1999, pp 9-13.

Towill, D.R., "Successful Business Systems Engineering", *IEE Management Journal*, Vol. 7, Pt I, Feb., pp 55-64, Pt II, No. 2 April, pp 69-96, 1997.

Towill, D.R., "The Seamless Supply Chain", *Int. Jnl. Tech. Man*., Vol. 13, No. 1, 1997a, pp 37-56.

Towill, D.R., Disney, S., and Childerhouse, P., "Diffusion Dynamics of Supply Chain Management", *Proc. EUROMA Conf on Managing Operations |Networks, Venice*, pp 321-328, 1999.

Towill, D.R.., Childerhouse, P., and Disney, S., "The Seamless Supply Chain – Fact or Fantasy". Paper No. 482 *Presented at 15th ICPR, Limerick*, Aug 1999.

Wikner, J., Towill, D.R., and Naim, M.M., "Smoothing Supply Chain Dynamics", Int. Jl. Prod. Econ., 22, pp 231-248, 1991.

Womack, J.P., Jones, D.T., and Roos, D., "*The Machine that Changed the World"*, Mandarin Books, London, 1990.

APPENDIX 1. Answers to the Seven Interesting Questions on the History of Supply Chain Management

Q1 How long did it take the Venice ***arsenalotti*** to build a warship in the year 1574?
A1 1 day (reportedly the complete cycle time – from start to finish)

Q2 When and where was Value Stream Management invented?
A2 In 1915 by General Motors (USA) as part of a *Keirutsu* initiative (According to Peter Drucker, 1995)

Q3 When did the Retail Sector first exploit Value Stream Management?
A3 In the 1920's by Sears in the USA and in the early 1930's by Marks and Spencer in the UK (again according to Peter Drucker, 1995)

Q4 What manufacturing principle was exploited in UK delivery of Spitfire fighter planes during World War II?
A4 Lean Production (According to Jack Burbidge, 1995, who was reputedly there)

Q5 When and where were the Principles of Material Flow Control first published?
A5 In 1961 in the UK (by Jack Burbidge)

Q6 When were the nine simplification rules inherent in Japanese manufacture first published in the Western Literature?
A6 In 1982 by Richard Schonberger, 1982

Q7 In the year 1995, what percentage of supply chains were thought to be effective?
A7 About 7% in the Retail Sector; about 10% in the Mechanical Engineering Sector (reported by Towill, 1997b)