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Integrating the Automotive Supply Chain: Where are we now?

D.R. Towill*, P. Childerhouse*[1], and S.M. Disney*

* Affiliation: Logistics Systems Dynamics Group
Cardiff Business School
Cardiff University

[1] Corresponding Author: Paul Childerhouse, LSDG, CARBS, Cardiff University, Aberconway Building, Colum Drive, Cardiff, CF10 3EU, Wales UK.
Telephone: +44(0) 29 20876915,
Fax: +44(0) 29 20874301,
E-mail: childerhouse@cardiff.ac.uk

Abstract
Real world value streams differ not only in their current standard of performance, but also in the most effective actions required to move that particular value stream towards world class supply. A generic approach for the identification of the appropriate re-engineering programmes based on the Uncertainty Circle Principle is presented. Twenty European automotive value streams have been analysed via a "Quick Scan" audit procedure. The output is a clear portrayal of the present "health status" of those value streams. 10% of which are performing at the present day level of "best practice", with a further 20% within sight of this goal. Specific re-engineering requirements are identified for the remaining 70% dependent on present maturity levels.

Key Words
Supply Chain Management: Uncertainty Circle: Framework for Change: Best Practice: Supply Chain Diagnostics

Introduction
In 1574 the Venice *arsenalotti* was capable of delivering a warship every 24 hours. Nearly four centuries later, the Second World War was also noteworthy for the very effective supply chains set up to produce fighter aircraft. In the light of this impressive history of supply chain management, it is disturbing to hear that "good practice" is still far from the norm (Towill, 1997a). For example in the retail sector, used by many companies as a performance benchmark, it is estimated that only about 7% of supply chains are operating effectively (Andraski, 1994). This is even more worrying when it is realised that both good and bad practice often sit alongside each other in the same retail business. Such an unsatisfactory situation exists despite present-day enablers such as EDI, flexible manufacturing, automated warehousing, and rapid logistics (Fisher, 1997).

As shown from some critical dates listed in Figure 1, there is considerable overlap between lean thinking and good material flow, as clearly acknowledged by Womack and Jones (1996). The lean thinking route originated in the quality engineering approach pioneered in the USA by Edwards Deming (1982). Early exploiters included Toyota in Japan, Ohno (1988), and the Lucas Group in the UK, Parnaby (1988). Publication of “The Machine That Changed the World (TMTCTW)” by Womack, Jones and Roos (1990), provided compelling evidence that the lean approach led to considerable performance improvements as internationally benchmarked in the automotive industry.

In the UK the major advocate of smooth material flow control was Jack Burbidge (1995). He had been involved in the lean production of Spitfires during World War II, and had published the basic principles of his approach as far back as 1962 (Burbidge, 1962). In subsequent years he applied the method to a wide range of companies. Typical of the results he achieved are those for an automotive supplier including lead time reductions of 7:1, quality levels up by 2.5:1, and ROI up by 30% (1994).

1574	Venice *arsenalotti* regularly deliver one war galley per day, and a “demonstrator” for Henry III of France in half a day.
1916	Value stream management (and *Keirutsu*) invented in USA by William Durant of GM.
1925	Value stream management concepts exploited in the retail sector by Sears Roebuck.
1940	UK deliver Spitfire aircraft via clearly identifiable “lean” supply chains.
1946	UK heaves a sigh of relief and reverts to “comfort levels” of stock throughout the chain.
1955	Value stream management hits the GM rocks of unionisation.
1961	Rules for smooth material flow control published by Jack Burbidge.
1970	Toyota exploit smooth material flow control principles via the ‘Understand Document Simplify and Optimise’ concept of Edwards Deming.
1980	Some Western firms follow suit, impressive results are achieved, but in many cases regression follows progression.
1990	The Machine That Changed The World (Womack et al, 1990) unambiguously benchmarks performance improvement obtained by adopting smooth material flow control principles, hence “World class” performance becomes much more transparent.
1995	It is variously estimated that still only between 7-10% of supply chains properly exploit material flow control with stockpiling providing no guarantee of availability.

Figure 1. Important Dates in the History of Smooth Material Flow Control (Childerhouse et al, 2000)

During his career as an industrial manager and consultant, Burbidge became increasingly frustrated by the “waste” he continually observed in post-war industrial practice. This contrasted with the “lean” World War II approach, where capacity and materials had to be harboured carefully, and where reduced total cycle time was of extreme importance. In 1991 Burbidge estimated that only 10% of western companies were managing their material flow effectively. So where are we know? In this paper we present the results of an in-depth analysis of 20 European automotive value streams. The purpose is to establish the extent to which they approach the "Seamless" Supply Chain (Towill, 1997b) which is the idealised material flow system. As well as identifying "exemplars" demonstrating best practice, the paper also evaluates a framework for methodological change.

Scope of Present Paper

This article is the full report of research initially presented in 2000 (Childerhouse et al, 2000). It is specifically concerned with the Product Delivery Process (PDP) for identifiable value streams i.e. supply chains within complex networks and not the Product Introduction Process (PIP). A particular on-site diagnostic methodology known as a "Quick Scan" was developed for application to business sites and value streams. Here we demonstrate how the method has been exploited in evaluating current European automotive supply chains. One output from the research is the identification of best practice amongst both suppliers and customers. This is displayed via the "Uncertainty Circle" concept which highlights the areas which must be tackled in order to significantly improve supply chain performance (Mason-Jones and Towill, 1998). Although attention herein is concentrated on "value streams" of clusters of similar products, the network aspect is specifically addressed in the Quick Scans by observing and codifying the degree of "interference" between competing value streams.

The original contribution of this article in summary is the analysis and validation of the following three hypothesis;

H1: The Quick Scan is an effective methodology for understanding and documenting supply chains in a consistent and transparent manner.

H2: The Uncertainty Circle concept is an effective mechanism to evaluate a value stream's proximity to the Seamless objective (1997).

H3: The resultant uncertainty scores of the value streams when placed in descending order correlate with the four stage supply chain integration model of Stevens (1989) and therefore provide a framework for change to be followed in order to move towards the seamless objective (Towill, 1997).

The automotive industry supply chain has already been well described elsewhere (Womack et al., 1990) and need not be repeated here. The dominant player is clearly the Original Equipment Manufacturer (OEM) i.e. the car assembler. Despite much publicity since TMTCTW was published relatively little has actually happened to improve automotive supply chain performance. Thus a decade post TMTCTW and post Stalk and Hout (1990) guidelines, it is still found necessary to remind manufacturers to eliminate non-value added time from their process (Sullivan and Bicheno, 1999).

It is our view that making sweeping generalisations do not help individual "players" improve their performance. Hence the creation of the Supply Chain 2001+ health check which assesses their specific strengths and weaknesses, 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 group (Gattorna and Walters, 1996).

The Supply Chain 2001+ Project

This project was conceived by the EPSRC IMI Land Transport Programme in order to provide the UK automotive sector "players" with Decision Support Systems (DSS) appropriate to their needs. The target here is the likely configuration and operation of supply chains as predicted for the early years of the next millennium. Individual re-engineering improvements so far pinpointed and in some cases already implemented have yielded substantial savings including; reduction in transportation and stock holding costs; reduction in demand amplification and supplier capacity variance; batch size reduction and capacity improvements; and labour utilisation improvements.

The 20 Automotive Sector Value Streams studied herein cover a wide range of first and second tier suppliers. The value streams are Trans-European and include suppliers of mechanical systems, electrical systems, and commodity products, as shown in Table 1. Commercial considerations prevent the identification of individual value streams. However, the coverage of value streams in Supply Chain 2001+ is broadly in line with the sample considered by Coleman, Bhattacharya, Kelly and Brace (1995) as possible contenders to become first tier systems integrators.

If Supply Chain 2001+ is to achieve its goal and enable and spread best practice it is necessary to find ways in which present performance may be evaluated and compared with realistic target values. Furthermore the techniques used must be capable of travelling from business to business and from value stream to value stream i.e. make a distinctive contribution to "management theory" (Micklethwait and Woolridge, 1996). Here we bring together three specialist techniques developed under the auspices of the Supply Chain 2001+ project. The "Quick Scan", "Uncertainty Circle", and resultant "Framework for Change", will now be described in turn to test the three previously stated hypotheses.

"Quick Scan" Supply Chain Diagnostics

The "Quick Scan" (QS) Diagnostic Procedure has been developed by the Cardiff LSDG team in collaboration with their research partners. It enables a health check to be made on a supply chain, and to identify and rank areas where improvements would yield most value (Lewis et al., 1998). The aim of the QS is to understand and document the supply chain and its associated material, information, cash, and

Company ID/ Location	Product Description	Value Stream ID	Major Value Adding Processes	Date of QS
A/ England	Diesel engine Component	1	Machining and assembly	11.97
A/ England	Petrol engine component	2	Automated assembly	11.97
B/ England	Automotive sensor	3	Automated assembly	01.98
B/ England	Automotive engine system component	4	Machining and assembly	01.98
B/ England	Automotive engine system component	5	Machining and assembly	01.98
C/ England	Diesel engine	6	Final assembly	04.98
D/ England	Diesel engine component	7	Machining	04.98
E/ England	Automotive component	8	Heat treatment	08.98
E/ England	Automotive component	9	Heat treatment	08.98
F/ Scotland	Automotive component	10	Machining	08.98
F/ Scotland	Automotive component	11	Machining	08.98
G/ England	Automotive engine component	12	Machining and assembly	09.98
G/ England	Automotive engine component	13	Machining and assembly	09.98
H/ Germany	Petrol engine component	14	Forging	08.98
H/ Germany	Diesel engine component	15	Forging	08.98
I/ England	Petrol engine component	16	Machining and assembly	08.98
I/ England	Diesel engine component	17	Machining and assembly	08.98
J/ Germany	Automotive braking component	18	Machining	01.99
K/ Wales	Automotive braking component	19	Distribution warehousing	02.99
L/ Wales	Automotive braking component	20	Machining and assembly	02.99

Table 1. Overview of companies and specific value streams Quick Scanned (Source, authors)

resource flows (Childerhouse et al, 1999). It identifies quick hit (but not quick fix liable to subsequent failure) improvement opportunities plus longer-term action plans for "players" in the supply chain. Typical "quick hits" aim to eliminate Non-Value Added activities both within processes and across process interfaces as typified in lean thinking. Longer-term action plans include reduction in the time taken to perform Value Added activities. The industry and research outputs from the "Quick Scans" are summarised in Figure 2.

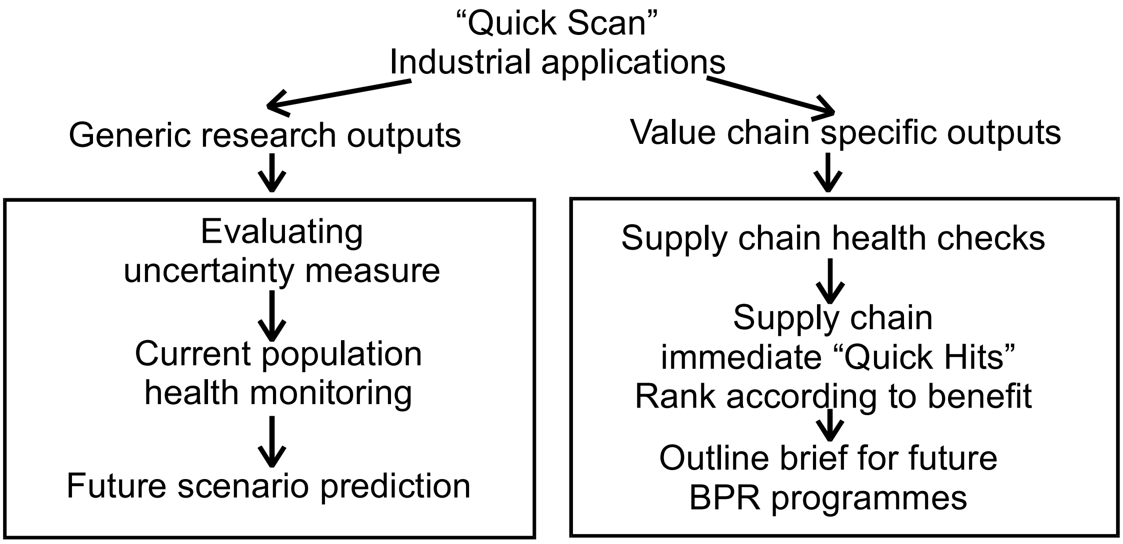

Figure 2. Industry and research "Quick Scan" outputs (Childerhouse et al, 2000)

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 research partners. The latter are responsible for supply chain competency development across groups of companies. The QS utilises the four well-honed techniques of questionnaire analysis, process mapping, semi-structured interviews, 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.

Figure 3 illustrates the major sources of information collected during the intensive on-site stage of the QS process. The primary information collected from people contact during QSs is via interviews. On average twenty such interviews are conducted covering a cross-section of functions and management levels. In relation to written documentation, account and procedural information is always collected. The investigative methods are focused upon process flow analysis and questionnaire. The former is of primary importance and on average four man-days are allocated in order to gain an in-depth understanding of material and information flows. The questionnaires are in two formats; a singular comprehensive quantitative questionnaire covering such aspects as lead times, levels in BOMs and number of employees; and eleven qualitative questionnaires designed to evaluate the subjective issues often overlooked during such diagnostics. The final source of information illustrated in Figure 3 is the numerical techniques. In this case time series data is always collected. Examples of such information include; scrap, production and scheduled delivery adherence rates.

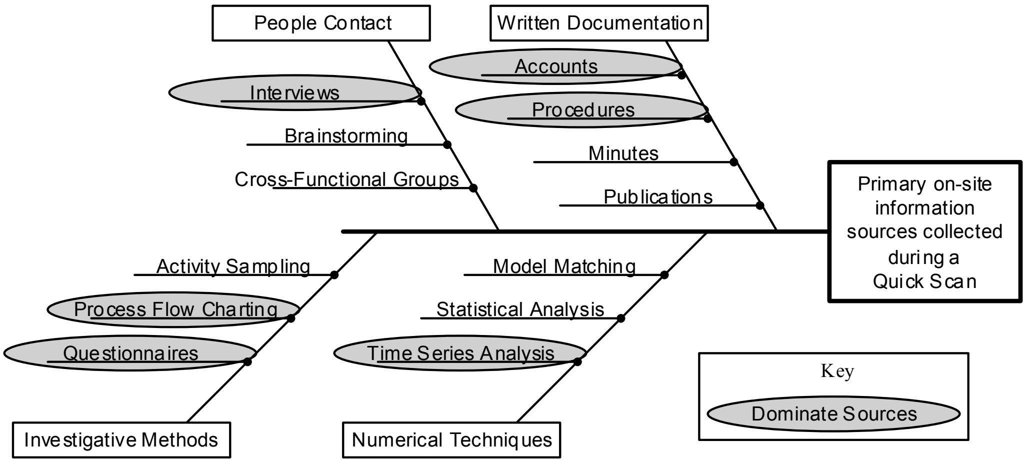

Figure 3. Ishikawa Diagram of Information Sources Used in Quick Scans (Source, authors)

During the off-site stage of the QS a number of brainstorming sessions are then held 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 key problem areas and issues to be highlighted. The 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 will also provide benchmarks of supply chain performance and thereby pinpoint best practice.

The Quick Scan as a Source of Research Data

The QS audit has been successful every time it has been applied to date. Those organisations being Quick Scanned have received significant benefits in the short, medium and long term (Childerhouse et al, 1999). Besides these outcomes as illustrated in Figure 2, the QS is a valuable tool for collecting rich and highly valid research data. Each individual QS on average takes 25 person days to complete, of which 10 days are spent on site, as illustrated in Figure 4. This time spent within the organisation under audit is very intensive as the six dominant sources of data illustrated in Figure 3 are collected. This is achieved via presentations (1 person day), investigative methods (3 person days), collecting and evaluating written documentation (2 person days), numerical techniques (2 person days) and people contact (2 person days).

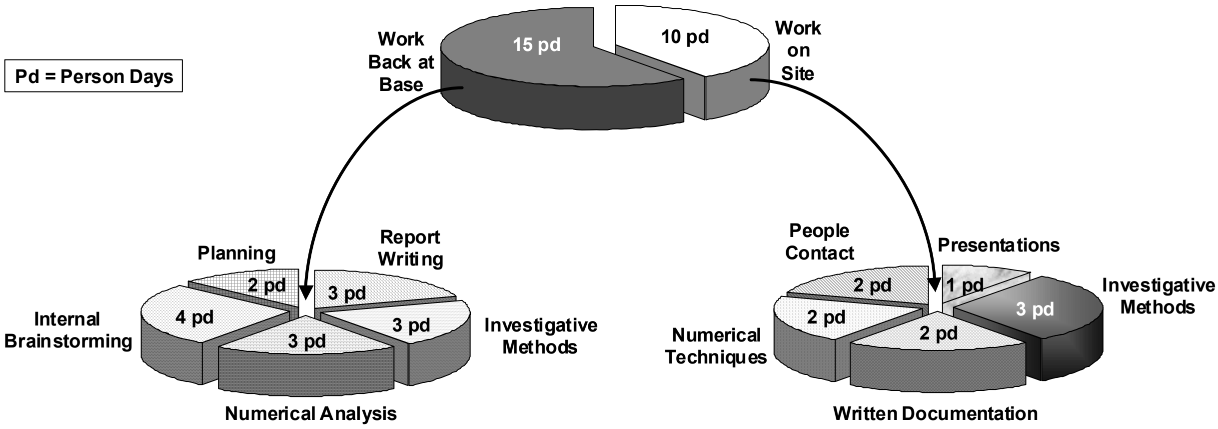

Figure 4. Distribution of Team Effort During a Typical Quick Scan Undertaken by Experienced Auditors (Source, authors)

The depth of knowledge obtained from each individual QS mirrors the large investment in time by the researchers conducting the analysis. The understanding is not as great as the comprehensive knowledge obtained via case study analysis, for example Burbidge and Halsall (1994). However, a far greater in-depth understanding is gained via a QS than telephone or postal surveys, for example Schmenner (1998). Figure 5 illustrates this point in relation to depth of knowledge and number of companies analysed. Hence in establishing 'Management Theory' QS provides an additional information source to supplement those listed in Towill (2001).

Given the time invested, benefits to the organisations and structured methodology followed it is the authors contention that H1 is verified as follows;

The Quick Scan is an effective methodology for understanding and documenting supply chains in a consistent and transparent manner.

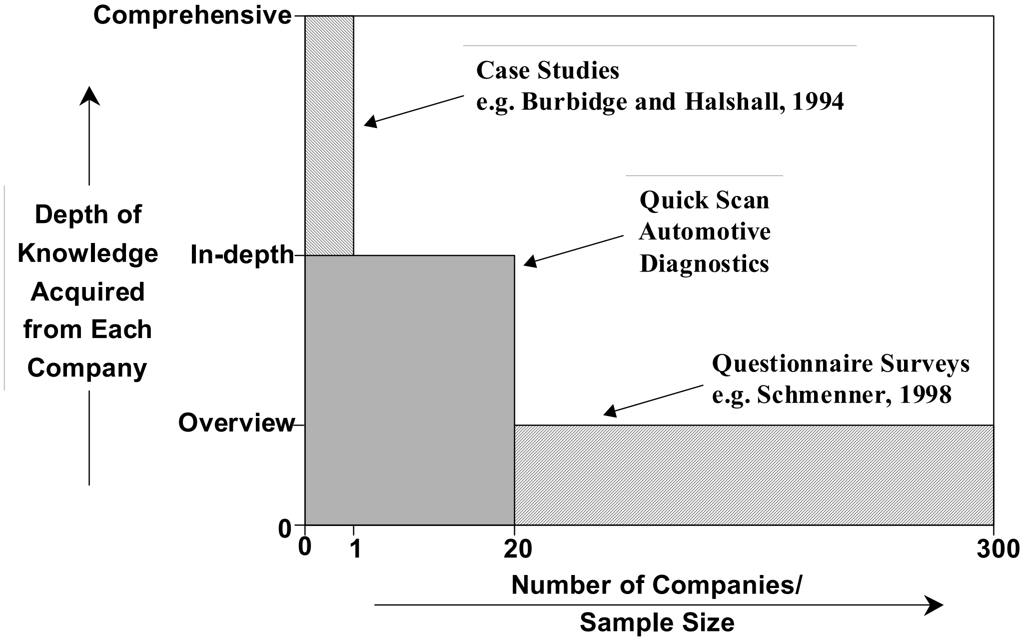

Figure 5. Scope and Depth of Understanding Gained via Quick Scan Analysis (Source, authors)

The Supply Chain Uncertainty Circle

To protect market share and ensure survival supply chains have to meet future customer demand. Forecasting is a predictive process which inevitably carries an element of uncertainty. However accuracy can be improved by re-engineering the supply chain especially via lead-time reduction (Towill, 1996). Unfortunately, much uncertainty is system induced as opposed to being introduced by the marketplace and is further magnified by the 'Bullwhip Effect' (Lee et al., 1996). This realisation of the importance of system effects has led to complimentary work by Wilding (1998) and van der Vorst et al. (1999). Their outputs support our contention that the best way to cope with uncertainty is to work hard to reduce it at source.

Numerous authors have identified the need to manage, minimise and remove uncertainties from their business in order to increase control and co-ordination and improve the effectiveness of their decision making processes. This also holds true in a supply chain context as Christopher (1992) explains '*One of the main reasons why any company carries safety stock is because of uncertainty. It may be uncertainty about future demand or uncertainty about a supplier's ability to meet a delivery promise, or about the quality of materials or components*.' This point is further emphasised by Bowersox and Closs (1996) when they state *'..., a basic objective of overall logistical performance is to minimise variance'*. Wilding (1998) has utilised these principles in the development of a supply chain complexity triangle specifically for the identification of uncertainty generation in the supply chain. Both Davis (1993) and Mason-Jones and Towill (1998) have segmented supply chain uncertainties into four areas, so that root causes and methods for minimisation can be developed. The latter reference identifies the four areas of supply, demand, control and value adding process as illustrated in Figure 6. This is the procedure adopted in this paper.

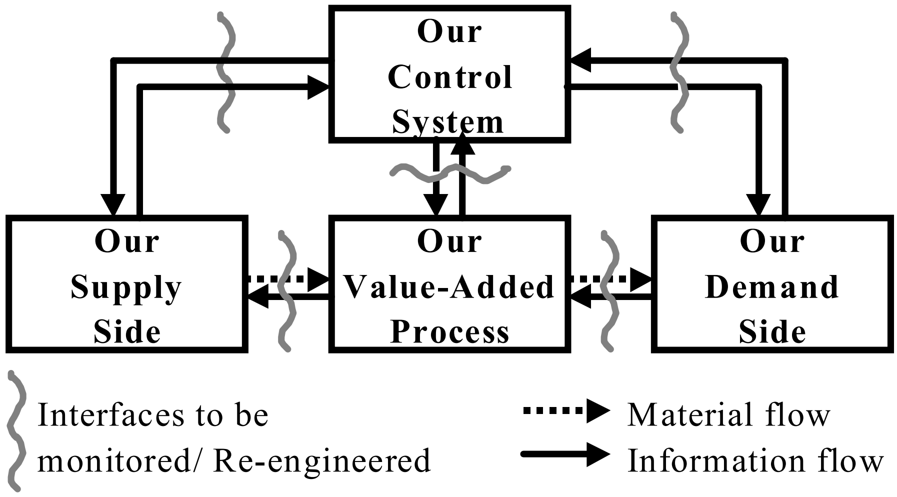

Figure 6. Block diagram of the uncertainty problem (Mason-Jones and Towill, 1998)

The ultimate goal in our approach is the Seamless Supply Chain (SSC), (Towill, 1997b). This aims to obtain a greater market share to the benefit of all the 'players' within the chain by encouraging them to think and act as one. However, in striving to achieve this goal it becomes apparent that there are other sources of uncertainty which must be reduced, if not entirely eliminated. What is needed is a systematic method of identifying and codifying the uncertainty experienced by our business. The Uncertainty Circle provides the necessary focus.

Regardless of our position within the supply chain, the PDP uncertainty problem may be simplified and put into the generic format of Figure 6 (Mason-Jones and Towill, 1998) and which may be recognised as having its origins in the principles of Systems Engineering. 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 6 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) via the application of this generic model and thus based on these theoretical arguments it is plausible to accept H2:

The uncertainty circle is an effective mechanism to evaluate a value stream's proximity to the Seamless objective.

Interpreting Uncertainty During the "Quick Scan" Investigations

As interpreted by the QS Team, the four uncertainty definitions are as follows:

- **Process Uncertainty.** This affects our internal ability to meet a production target. It is established by understanding yield ratios and lead-time estimates of operations for each work process. Also, if the particular value stream is competing against others for resources, then the interaction between these value streams must be studied and codified.
- **Supply Uncertainty.** This results from poorly performing suppliers not meeting our requirements thereby handicapping our Value Added processes. This can be evaluated by looking at supplier delivery performance, time series of orders placed or call-offs and deliveries from customers, actual lead-times, supplier quality reports and raw material stock time series.
- **Demand Uncertainty.** This is associated with specific customers in relation to schedule variability and transparency of information flow. It can be visualised as the difference between the end marketplace demand and orders placed on us by our customer. It is also indicated by how well we are able to meet our customer requirements. This is identified by developing a time series of customer orders, call-offs, deliveries and forecasts.
- **Control Uncertainty.** This is concerned with how internal decision making affects our ability to transform customer orders into production targets and supplier raw material requests. It can be investigated via the time series of customer requirements and supplier requests to deliver, time series of production targets and a thorough understanding of the algorithms and control systems that are used to transfer the customer orders into production targets and supplier raw material requests.

The Primary Data used for assessing uncertainty during QS investigations is listed in Table 2. There was considerable variation between Value Streams studied in terms of the quality of data. Quantity was rarely the problem, as previously noted by Feltner and Weiner (1985). The problem is that despite publicity for the Balanced Scorecard (Kaplan and Norton, 1996), there is still a fundamental difference in data used for accounting purposes rather than that needed for modelling and performance audits. Hence the emphasis in QS on process mapping and activity sampling in order to compensate for rich data shortfall.

The codifying of the four uncertainty sources was undertaken by members of the QS Team on the basis of the total information at their disposal. Table 3 shows the simple Questionnaire then completed with respect to each value stream. To ensure comparability the Questionnaires were activated only when all 20 value streams had been 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.

Uncertainty Source	Typical Primary Data Used During "Quick Scan" Investigations
Supply Side	MOPs placed on suppliers especially schedule adherence, invoices, call-offs, BOM, forecasts, receipts, supplier quality reports, MRP, lead-times, stock reports.
Demand Side	Delivery Frequency, echelons to end consumer, marketplace variability, stage of product life cycle, customer ordering procedures, forecast accuracy
Process Side	Scrap reports, cycle times and variability of cycle times, production targets and output, downtime reports, stock consolidations, costed BOM, capacity planning, asset register.
Controls Side	Time series of customer orders, supplier orders, demand forecasts, kanban logic, batching rules, MRP logic, call-offs, purchase orders, BOM number of variants, delivery frequency, number of completing value streams.

Table 2. Primary data used during uncertainty circle investigation in supply chain 2001+ (Childerhouse et al, 2000)

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

Table 3. Supply chain 2001+ questionnaire to determine impact of process, supplier, demand, and control uncertainty sources (Towill et al, 2000)

A Reference Framework for Movement Towards the Seamless Supply Chain

The Seamless Supply Chain (Towill, 1997b) is the state of total integration in which all "players" think and act as one. It is shown in block diagram form in Figure 7. The SSC will clearly have low uncertainty scores for Process, Supplier, Demand, and Control Sources. Hence in Table 3 good performance has been targeted with low scores since the "perfect" SSC will have zero uncertainty.

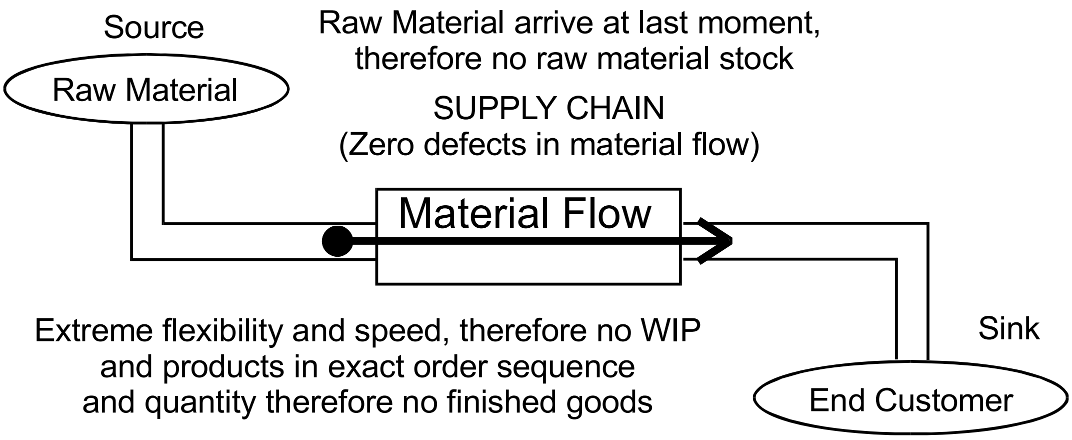

Figure 7. The seamless supply chain (Towill, 1997b)

A Reference Framework for moving from a situation of poor supply chain performance towards the ultimate SSC goal has been proposed by Stevens (1989). It has become widely accepted as providing a logical sequence for a structured approach to defining and managing Change Programmes. In fact, the framework is recognised by many authors as one of defining theories in the field of supply chain management and has received multiple citations including, van der Vorst (2000), Christopher (1992) and Barratt (1999). The aim here is to use the Reference Framework to provide benchmarks against which the 20 Supply Chain Value Streams may be judged.

Stage of Supply Chain Integration	Summary of Associated Supply Chain Characteristics	Corresponding Estimated Uncertainty Circle "Scores"			
		Process	Supply	Control	Demand
1. BASELINE	Reactive Short Term Planning: Fire Fighting: Large Pools of Inventory: Vulnerability to Market Changes	4	4	4	4
2. FUNCTIONAL INTEGRATION	Emphasis still on cost, not performance. Focus on Goods Inward. Reactive towards Customer. Some internal trade-offs.	2	4	3	4
3. INTERNAL INTEGRATION	All Work Processes Integrated. Customer back to Supplier Planning, EDI widely used. Still reacting to customer.	1	2	2	4
4. EXTERNAL INTEGRATION	Integration of all Suppliers. Focus on Customer. Synchronised Material Flows, SC forms extended enterprise.	1	1	1	1

Table 4. Scoring the Stevens reference framework for moving towards the seamless supply chain (Childerhouse et al, 2000)

The Reference Framework has four levels as follows: Baseline: Functional Integration: Internal Integration: and External Integration. Table 4 briefly summarises the associated supply chain characteristics corresponding to each stage. Our estimated "Uncertainty Circle" scores are also shown at each stage. They are based on our practical experience of using the Framework in an industrial context.

At level four, full supply chain integration is achieved by extending the scope of management outside the company to embrace the suppliers and customers. It embodies a change of focus away from being product oriented to being customer oriented. Thus there is penetration deep into the customer organisation to understand the products, culture, market and organisation. Integration back down the supply chain to include all suppliers is also undertaken. Thus the stated aims of full integration are seen to be entirely consistent with, and leading to, the establishment of the Seamless Supply Chain shown in Figure 7.

Analysis of Uncertainty in the Twenty Value Streams

It has been found extremely convenient to display the Supply Chain Uncertainty Circle results as a set of radar plots with control; supply; demand; and process metrics forming orthogonal axes. The results are shown in figure 8. The "scores" estimated at various stages of the Reference Framework are also shown as benchmarks and occupy the four corners of the Figure. Linking the four benchmarks are the radar plots for the individual value streams positioned in order of descending uncertainty scores. Note that the area enclosed by the radar plots is an indication of the total uncertainty experienced in an individual value stream. Also, the shape clearly indicates the area(s) where uncertainty reduction is an essential next step.

The objective is to move to the next level of integration (corner radar plots), therefore re-engineering requirements are identified to reduce specific areas of uncertainties to desired levels. Once achieved the next level of integration becomes the goal with resultant re-engineering requirements tailored to reduce uncertainties to these new desired levels, the process continues until external integration (Best Practice) is reached.

The Reference Framework identifies re-engineering requirements in relation to process uncertainty as the first step in supply chain integration because a companies own processes are the most visible and accessible area to influence. This is followed by reducing supplier induced uncertainty as this is the next area of most influence. Demand uncertainty is reduced in the final stages as a change of focus with the integration of customers is required. Control uncertainty is assumed to be ramp-wise over the whole change programme as better quality information leads to the use of better and more robust algorithms. A preliminary study suggests that fifteen of the twenty value streams fit the Reference Framework progression model in terms of the sequence of steps taken to reduce uncertainty.

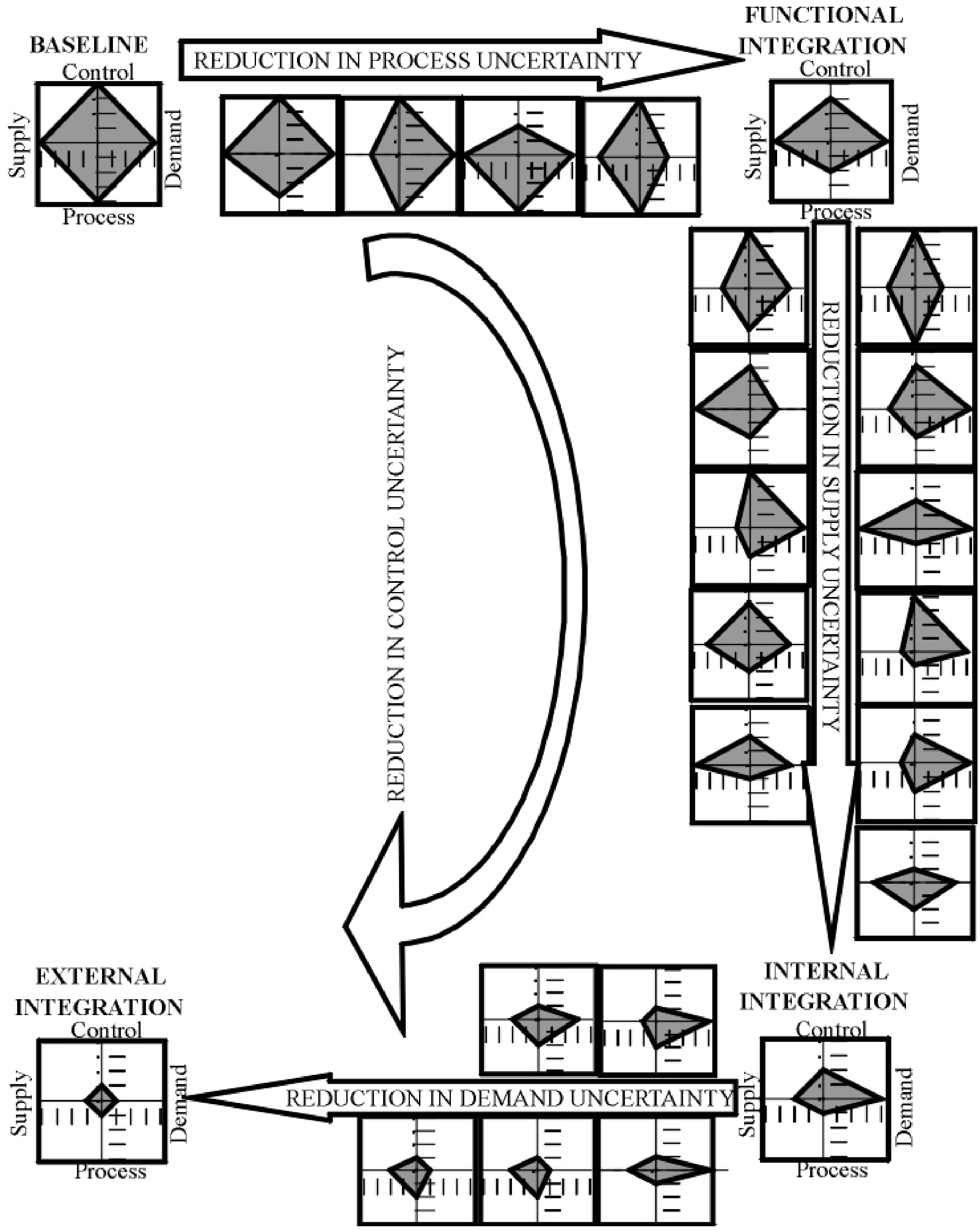

Figure 8. Radar displays of uncertainty perceived in the twenty automotive sector value streams (Childerhouse et al, 2000)

A detailed investigation is currently being undertaken to establish whether there are important features and hence lessons to be learned from the status of the five "others" (Childerhouse, 2001). The strong correlation between the integration model of Stevens (1989) and the uncertainty evaluations of our automotive sample therefore validates H3:

The resultant uncertainty scores of the value streams when placed in descending order correlate with the four stage supply chain integration model of Stevens (1989) and therefore provide a framework for change to follow in order to move towards the seamless supply chain objective (Towill, 1997).

The Seamless Supply Chain as a Mechanism for Identifying Re-engineering Requirements

Using the SSC scores of [1:1:1:1] as target values we have calculated the Euclidean Norm for each value steam. This procedure provides a single metric which allows us to rank the twenty value steams as shown in Figure 9. Here the scores obtained from the four stages defined by the Reference Framework are used as benchmarks with the horizontal axes being adjusted for convenience to generate a linear scale. The individual value stream scores have then been superimposed so that there is a logical progression from the traditional to the Seamless Supply Chain.

Our experience suggests that the twenty value streams may be broadly classified into three clusters. About 70% of our sample are still in various states of transition. It could be argued that this statistic explains the popularity of "lean thinking" i.e. many value streams need to be re-engineered to significantly reduce waste. 10% of our sample are clearly "exemplars" with little uncertainty from any source. Perhaps of even greater importance is the presence of 20% of the sample, who, whilst not "seamless" nevertheless exhibit much good practice in reducing uncertainty and hence provide good sites for benchmarking visitations. Thus by avoiding a black-and-white classification of good/bad the Uncertainty Circle approach has provided many more opportunities for identifying and transferring best practice both within and across market sectors.

Value streams 20,16 and 8 are struggling with lean principles, their re-engineering requirements are therefore focused around removal of non value adding time in their own processes so they can move initially towards functional integration. Examples of which are set-up time reduction and implementation of cellular shop floor layouts. Eleven of the value streams studied have achieved functional integration and are at present aiming at internal integration. Their resultant re-engineering requirements are therefore predominantly supplier focused, for example supplier lead time reduction, vendor managed inventory, consignment stocking and partnership souring. The remainder of the sample have reached internal integration and are now in a position to move towards external integration.

In such cases the re-engineering requirements are aimed at reducing demand uncertainties, for example utilisation of EPOS data, increased customer schedules and stock holding visibility and application of postponement strategies.

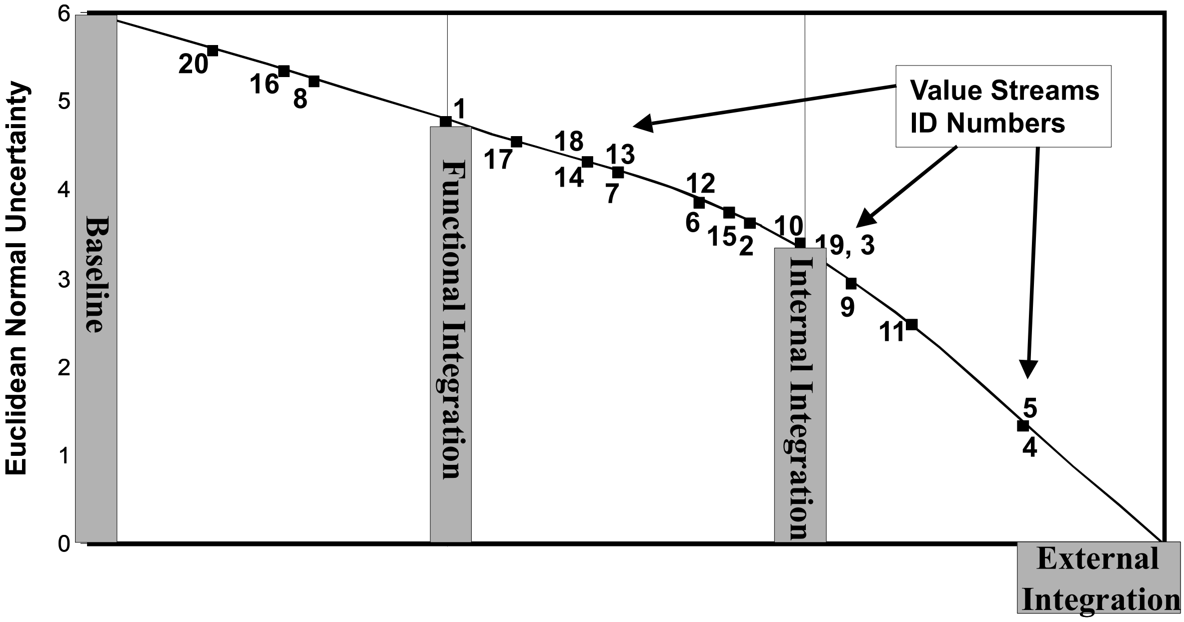

Figure 9. The Seamless Supply Chain (Childerhouse et al, 2000)

Conclusions

The relatively slow diffusion dynamics of supply chain management in the real world was first discussed by Towill (1997a). Our study of 20 value streams presented in this article significantly add to this debate. Although the sample is neither random nor representative of the automotive system suppliers and their associated supply chains, some interesting conclusions can be made. For example only 10% of our sample are approaching the Seamless goal (Towill, 1997b). This is in line with Burbidge's estimate of 10% in 1991 and Andraski's retail sector evaluation in 1994 of 7%, but of course this is years later, hence confirming the slow propagation of supply chain best practice.

The literature is rife with advice on how to re-engineer supply chains back to the standard arguably first achieved many decades ago. There is also the feeling generated that everything Western performs poorly, and everything Japanese performs well. The truth is somewhere between these two extremes. What is undoubtedly true is that value streams need 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 (the systematic engineering of the business) and this conclusion applies irrespective of country or market sector.

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 automotive supply chains in a meaningful way. The scores for each value chain may be compared against a Reference Framework. This enables a judgement to be made not only on how much improvement is required, but also there is guidance on the direction for greatest benefit. This framework identifies specific re-engineering requirements dependent upon present status and the desired next stage of supply chain integration i.e. 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.

The results available to date are very encouraging. Although only 10% of our sample may be regarded as "exemplars" operating 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. Some, clearly, are still in a situation where the application of "lean thinking" principles would yield immediate benefits, others have passed this stage and need to give much more attention to interface design, elimination, and management.

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