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A Comparative Study of Manufacturing and Service Sector Supply Chain Integration via the Uncertainty Circle Model

Abstract

Purpose – The purpose of this research is to contrast manufacturing and service sector supply chains in order to develop an audit methodology capable of providing objective, cross-sector comparisons of supply chain integration performance.

Design/Methodology/approach – A robust, site-based multi-method supply chain diagnostic for detecting manufacturing supply chain system uncertainty (QSAM) was modified for the service sector so as to yield the (normalised) supply chain integration performances of 109 separate organisations.

Findings – Service supply chains do not always exhibit the unique attributes that effectively bar manufacturing supply chain best practice from being adopted (and vice versa). The research confirms the value of utilising an uncertainty circle model lens, which makes objective cross-sector comparisons of supply chain performance possible.

Originality/value – Combining the uncertainty circle model with the QSAM approach yields performance vectors that can be used to align estimates of value stream 'health' irrespective of the organisational setting. This can assist identification and transfer of appropriate best practice even between firms located in dissimilar industry sectors and settings.

Key words: service, manufacturing, uncertainty circle, supply chain integration

Paper Type Research paper

Introduction

Some researchers describe service supply chains as being distinct from manufacturing supply chains (Sampson and Spring, 2012) due to both structural and management approaches that arise from the role of the customer in the supply chain. The underlying difference between manufacturing, with its product-centric focus, and services with its customer-derived activity focus, is the degree of customer involvement in the value creation process (Maull *et al*, 2012). The duality of customers being providers of inputs, as well as consumers of outputs, differentiates

service supply chains from manufacturing and is an aspect viewed as being most critical and challenging to traditional supply chain thinking (Sampson, 2000). Consequently, some manufacturing-based supply chain models that are applied to services have required adaptation to reflect the indispensable contribution of the customer in supply chain service provision. Ellram *et al* (2007), in investigating the application of manufacturing supply chain models to services, highlight several contradictory aspects of the models and concluded their research with a call for studies that recognize how service supply chains are challenging to quantify and measure.

Researching uncertainty in service supply chains is a step toward answering this call, since a basic requirement of supply chains is to ensure stable operation against a background of changing constraints and uncertainty (Parnaby and Towill, 2009). For at least two decades, researchers have investigated the sources of uncertainty and the management approaches used by organisations as they endeavour to manage the ambiguity that exists internally and externally to their supply chains (Davis, 1993). Here, the primary focus has been on manufacturing supply chains and their uncertainty, through the use of such frameworks as the uncertainty circle model and on management approaches for reducing or coping with uncertainty via lean and agility approaches (Simangunsong *et al*, 2012).

This paper moves the discussion forward by investigating uncertainty in service supply chains through the application of the uncertainty circle model. It begins by presenting literature that contrasts manufacturing and service supply chains. The uncertainty circle model is then explained and a review of uncertainties across the two sectors given. Next, the QSAM methodology is explained and a cross-case analysis provided. Finally the discussion, contribution to knowledge and conclusions are presented.

A comparison of manufacturing and service supply chains

The possibility of adapting and transferring supply chain management (SCM) best practice from manufacturing to the service sector has only recently begun to interest academics, due to the increasing importance of services in mature economies (Goldhar and Berg, 2010; Sengupta *et al*, 2006). For example, in the United States the service organisation contribution to GDP recently exceeded 75% (Samuel *et al*, 2010). Researchers claim that five unique attributes of services ‘have implications’ for those who seek to transfer manufacturing-based SCM best practice frameworks into the service sector: *intangibility*, *perishability*, *heterogeneity*, *inseparability*, and *customer participation* (Akkermans and Vos, 2003; Sampson, 2000; Vargo and Lusch, 2004).

While the service attribute most commonly cited by academics is *intangibility* (Sampson and Froehle, 2006), its legitimacy and uniqueness as a concept for services has been challenged (Vargo and Lusch, 2004). The Oxford Dictionary (2012) defines intangibility as ‘not having a physical presence or not being able to be touched’, yet many service processes can be viewed as tangible in terms of their outputs. For example, repair of a crashed car is a service provided to owners that results in rectification of the vehicle plus the tangible return of the car to its pre-crash status

(Aitken and Murray, 2011). Similarly, original production of the vehicle in a car plant would be classed as a tangible manufacturing output; however delivering the car to the customer requires that intangible transport services be used (Bozarth and Handfield, 2006). Thus, tangibility and intangibility coexist in manufacturing and service supply chain settings.

Manufacturing supply chains utilise inventory to buffer against lead-time variability and demand uncertainty (Spearman and Hopp, 1998). However, services are deemed to be *perishable* due to their time-sensitive nature since in general they are only required when customers engage the process, and service capacity cannot easily be stored—leading to the possibility of a queue forming and deteriorating service provision (Noon and Murray, 2003). Three of the most common causes of queues are *variations in arrival demand*, *service process time variability*, and *capacity constraints*. Irregular arrival demand can disrupt evenness of flow through the service process and leads to delays or queues (Schmenner, 2004). Service organisations attempt to manage queues (an inventory of clients) by delaying the demand arrival time—for example by maintaining service lead-times and utilising an appointment system. However this approach is not universally acceptable since, for example, delays in time-sensitive medical services might have major or fatal consequences. Service process time variability can mean delays that lead to (re)prioritisation of the offered services. Capacity constraints can also cause queues since at higher levels of capacity utilisation the likelihood of service failure increases (Walley *et al*, 2006). Thus queues in services equate to inventory in manufacturing supply chains, and both are used to buffer against demand uncertainty.

The third characteristic quoted as being unique to service supply chains is the *heterogeneous* nature of services. Outputs from service operations are frequently viewed as being customer-unique; implying that service processes are incapable of being improved by adopting manufacturing best practice. However, manufacturing modularity practices also provide heterogeneity of outputs driven by heterogeneity of inputs (Sampson and Froehle, 2006). Both service and manufacturing supply chains offer customers the ability to specify their own unique output from a pre-determined menu of input options; examples include the sandwich service company *Subway* and the computer manufacturer *Dell*. In short, both service and manufacturing supply chains offer heterogeneous options to customers.

Inseparability highlights the fact that unique to service supply chains, some offerings are provided and consumed simultaneously. However, this aspect also has parallels in manufacturing since the advent of just in time (JIT) practices; as soon as a part arrives the production process consumes it (Karmarkar, 1996). Not every service supply chain is deemed to be inseparable in nature since delays often occur between the times of customer input and service output (Shugan and Xie, 2000), and imperfect synchronisation of the added value service with the front office can extend the throughput time of the service encounter (Schmenner, 2004). Similarly, Sampson (2000) suggests that service supply chains can be depicted as linear, which illustrates the sequential nature of some service supply chains. **Figure 1** shows the service supply chain repair cycle for a crashed car repair, where the time delay between the car being reported to the insurer (customer engagement) and the car being fixed and returned to the customer (service consumption) is 28 days; which represents a significant departure from the concept of service inseparability.

The final characteristic often quoted as being a unique aspect of service supply chains relates to the requirement for *customer participation*. Service supply chains experience customer participation in three forms: actual physical presence (e.g., a medical appointment), product input (e.g., a vehicle compliance check), and information input (e.g., a passport application). These same three forms of customer participation are also reflected to some extent in manufacturing supply chains as multiple material and information inputs. The underlining message from services research that service provision can only begin once the customer engages with the service supply chain is also matched by developments in manufacturing, as lean supply chains are designed to only commence production at the ‘pull’ or engagement of the customer (Womack and Jones, 1996: p. 67).

Figure 1 Service Supply Chain Repair Cycle

Table 1 summarises the similarities in structure and meaning of terminology at each of the supply chain stages; highlighting the commonality in principles across service and manufacturing supply chains. In short, while service and manufacturing supply chains may appear on the surface to be significantly different, the authors contend that only their respective terminology truly sets them apart (Sampson and Froehle, 2006). Although the introduction of best practice manufacturing models into a service environment may appear to be very challenging there are enough similarities to support their relevance (Di Mascio, 2008, Goldhar and Berg, 2010; Schmenner and Swink, 1998).

Table 1 Manufacturing and service supply chain stages

Supply chain characteristic	Manufacturing	Service
Supply chain input	Suppliers materials and forecast information	Customers participation in the form of their physical presence, product and/or information
Value-added process	Physical production and intangible services	Tangible and intangible services
Demand uncertainty management	Inventory	Queues

Supply chain output

Pre-defined product specification that can be made unique to consumers through modularity structures

Heterogeneous service

Some manufacturing-based supply chain models applied to services, and which thereby fulfil the test for establishing new management theory identified by Micklethwait and Wooldridge (1996), include: the Hewlett-Packard Model, the Global Supply Chain Forum Framework and the SCOR Model (Ellram *et al*, 2004; Giannakis, 2011; Sengupta, *et al*, 2006). Each model required adaptation to reflect the indispensable contribution of the customer in supply chain service provision, particularly since the customer assumes the dual role of demand creator and principal supplier to the supply chain. This aspect is viewed as being most critical and challenging to traditional supply chain thinking (Sampson, 2000). For example in service supply chains the lead-time is determined from the time the customer engages with the process, whereas in manufacturing the lead-time is determined by the delivery time from stock (Samuel *et al*, 2010). The next section discusses the uncertainty circle model (UCM), which has been modified to take account of the duality characteristic to enable transfer of best practice from manufacturing to services.

The uncertainty circle model (UCM)

Development of an objective and (above all) transferable measure of supply chain performance is complicated both by the sheer variety of supply chains and the complicated and complex multi-functional, multi-organisational measures required. Consequently, many researchers simply utilise subjective Likert scale measures (e.g., Rosenzweig *et al.*, 2003) to capture respondents' perceptions about their own supply chain performance; an approach to benchmarking that heavily relies on the practitioner's personal view of proficiency and his/her perception of the strengths and weaknesses of their own organisation. Other researchers use a subjective norm approach based on standard metrics, as is well-demonstrated by the SCOR model to assess the relative performance of five key business process areas (Supply Chain Council, 1999). However, given the seemingly endless variety of supply chains this approach to benchmarking is clearly fraught with difficulty and can result in errors when comparing 'apples with oranges'.

Manufacturing and service supply chains are established on the premise that organisations need to manage and control their assets and process uncertainties to deliver value to customers in a cost-effective manner (Ellram *et al*, 2004, Towill, 2006). These shared aims have led researchers to apply operations management and systems engineering lenses originally developed for manufacturing to service supply chains (Goldhar and Berg, 2010; Parnaby and Towill, 2009). Numerous authors have also identified the need to manage, minimise, or remove uncertainties from their business in order to increase control and co-ordination and otherwise improve the effectiveness of their decision-making processes. As stated by Sabri & Beamon (2000), 'Uncertainty is one of the most challenging but important problems in supply chain management' and Christopher (2011) helps explain why, '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 emphasised by Bowersox *et al.* (2002) when they state, '... a basic objective of overall logistical performance is to minimise variance'. Increasing variance reduces the performance of the process to deliver value (Schmenner, 2004).

Wilding (1998) utilised these principles in the development of a supply chain complexity triangle, specifically for the identification of uncertainty generators in the supply chain. The authors' view is that the systems goal should be the execution of "smooth and seamless material (or service) flow" (Towill 1997), with no unnecessary departures from this target, irrespective of cause. The North American equivalent to this goal is the "Swift and Even Flow" paradigm of Schmenner and Swink (1998).

A growing number of researchers are using uncertainty as the means of assessing and framing supply chain concepts (e.g., Lee, 2002; Sanchez-Rodrigues *et al.*, 2010; Sun *et al.*, 2009; van der Vorst & Beulens, 2001; van der Vorst *et al.*, 2001; van Donk & van der Vaart, 2005; Vidal & Goetschalckx, 2000; Wong & Boon-itt, 2008). Much of this work can be traced to the original supply chain uncertainty approach by Davis (1993), which was later clarified by Mason-Jones & Towill (1998). The application of system engineering to a set of elements required to operate in an integrated way has become an insightful approach to understanding supply chains (Parnaby and Towill, 2010).

Figure 2 illustrates how the systems engineering view of the resulting uncertainty circle model involves a focal supply chain perspective, as described in detail by Towill and Childerhouse (2011). Consideration of supply chain uncertainty begins with demand side uncertainty at the customer interface. Conversely, the upstream interface is assessed through supply side uncertainty at the supplier interface. The internal value-adding uncertainties are also considered through consideration of both control uncertainty and process uncertainty.

Figure 2 Block diagram depicting uncertainty circle model (Mason-Jones & Towill, 1998)

Definition of these four areas of uncertainty and the forms of empirical data collected and used as evidence is now described:

Supply uncertainty

- Results from poorly performing suppliers or an inability of the focal company to order raw material efficiently. Can be evaluated by looking at supplier

delivery performance, time series of orders placed, call-offs, deliveries from customers, lead-times, supplier quality reports, and raw material stock time series.

Demand uncertainty

- Associated with a specific customer in relation to schedule variability, it can be visualised as the difference between end-customer demand and orders placed on the focal company by their customer. It is also an indication of how well the focal company meets its customer requirements. Can be evaluated by developing a time series of customer orders, call-offs, deliveries, and forecasts.

Process uncertainty

- Affects the focal company's ability to meet a production target. Can be evaluated via consideration of reject rates, yield ratios and lead-time estimates in the operation of each business process. Also, if the value stream is competing against others for resources, the interference between these value streams must be identified.

Control uncertainty

- Affects the focal company's ability to manage its activities and to transform customer orders into production targets and supplier raw material requests. Can be evaluated via time series of customer requirements and supplier requests to deliver. Additionally, time series of production targets is necessary. A thorough understanding of the decisions or control systems used to transfer the customer orders into production targets and supplier raw material requests is also required.

The next section compares and contrasts the nature of the four areas of uncertainty faced by manufacturing and service supply chains as they strive for stable operations.

Supply chain uncertainties in the service and manufacturing sectors

Supply uncertainty considerations in the manufacturing sector focus on two aspects of supply; namely supplier performance and the ability of the customer to place an order on the supplier (Childerhouse and Towill, 2003; Geary *et al.*, 2002). Of particular import to managing supply uncertainty in manufacturing is the performance of the supplier in terms of delivery performance, lead-time, and quality. By way of contrast, in the service sector the main supplier is often the customer that delivers tangible belongings, information and self into the supply chain (Sampson and Froehle, 2006). Service providers do not generally have the ability to regulate the arrival of inputs from customers (Sampson, 2000), and customers' ability to deliver inputs at an agreed time and with accurate information can be a major challenge to many service supply chains. For example, costs associated with patients failing to show for medical appointments are currently around 15 million pounds sterling per annum in the UK (BBC, 2010). Inability of the focal company to place timely orders on its supplier and to manage its own inventories was highlighted as a source of manufacturing supply uncertainty by Childerhouse and Towill (2003), and such problems are also common in the healthcare service sector when ordering medicines to maintain inventory levels (Böhme *et al.*, 2011).

Demand uncertainty in manufacturing is the difference between end-customer demand and the actual order placed on the focal firm by *its* customer (Geary *et al*, 2002). Certainty related to demand and its related schedule variability can be achieved by the sharing of forecast information among supply chain actors (Datta and Christopher, 2011). Manufacturing product variety is based around SKUs (stock keeping units); the customer specifies what variant they require and the manufacturer incorporates this into their catalogue of offerings. Variability can be minor (e.g., packaging) or quite major, such as requiring additional sub-assemblies. It is often a straightforward task to deduce product variety as this information is typically incorporated within the production planning system.

Service demand uncertainty can, in general, be ascertained through consideration of five sequential categories that mirror the normal service transaction route: arrival of customer demand, request variability on type of service needed, customer capability to interact with the service, effort (required of customer) variability, and subject preference variability of customers (Di Mascio, 2007; Frei, 2006). Each category has the potential to impact how service organisations manage demand and deliver the service required by the customer. Generally, the end-customer and the focal firm customer are one and the same and their role in supplying input and demand for the service can increase supply chain uncertainty (Meijboom *et al*, 2011). Service variety is challenging as customisation is almost always needed to some extent to meet customer requirements. For example, it is rare for two patients to need the same medical treatment; a fact that essentially makes the number of service variants equal to the number of patients.

Alignment of the end-customer with the customer placing the order does not imply that the distortion and amplification effects frequently observed in manufacturing supply chains is not present, as researchers have also found evidence of demand amplification in service supply chains (Anderson and Maurice, 2000). For example, Akkermans and Vos (2003) found that amplification in service supply chains was due to poor demand signalling across business functions. In manufacturing, such amplification is evidenced by excess inventory and in the service sector it appears as customer backlogs, queues and inefficient capacity utilisation. Ellram *et al*. (2004) propose that capacity in service supply chains is an analogous measure for inventory in manufacturing

Process uncertainty, in terms of failure to meet production targets due to quality problems and poor yield ratios, can inhibit the focal firm's ability to improve performance via reduced supply chain costs and on-time product delivery. Similar issues face the service sector since increases in process service time uncertainty are posited to lead to less favourable customer responses and a decline in demand (Kumar and Krishnamurthy, 2008). While improving the yield ratios in manufacturing can reduce process uncertainty and improve delivery performance, in the service sector high utilisation (yield ratios) of resources can lead to long service times and queues when demand exceeds capacity (Aronsson *et al*, 2011; Di Mascio, 2007). Competing value chains are also generators of process uncertainty when they vie for the same resources and production capacity (Towill, 1999). This can be extremely serious when a person's health is involved, since a patient can pass through several different healthcare value streams (specialist care centres) to receive treatment; leading to delays and potential service failure (Aronsson *et al*, 2011).

Control uncertainty impacts decision making and can threaten service delivery (McCaughrin *et al*, 2003). Poor information management regarding product or service demand, forecasts, capacity, and production/service plans can lead to increased uncertainty (Childerhouse and Towill, 2003; Childerhouse *et al*, 2010). Conversely, unimpeded information flows reduce uncertainty in the supply chain (Childerhouse *et al*, 2003). In service supply chains, control uncertainty caused by inadequate information affect the ability to complete tasks (McCaughrin *et al*, 2003). Control in a service environment is also more challenging since the customer can alter the sequence and scheduling of tasks (Goldhar and Berg, 2010; Schmenner, 2004). For example in a crash repair scenario, clarity of information through triage of the car and discussion with the customer (information and tangible inputs) before the car enters the repair process, reduces service time and reject rates. By increasing the flow of accurate and timely information the engineer is able to make decisions regarding parts ordering, scheduling capacity and estimating lead-time.

In summary, four areas of the uncertainty model germane to service and manufacturing supply chains have been contrasted and the many similarities are noted in **Table 2**. The most significant difference appears to be the dual role of the customer as both primary supply source and demand creator in the service supply chain.

Table 2 Comparison of uncertainty in service and manufacturing supply chains

Area of uncertainty	Service supply chain	Manufacturing supply chain
Supply	Supplier (customer) performance; Arrival lead-time Punctuality Service firm performance on ordering materials Inventory control	Supplier delivery performance, Lead-times, Supplier quality Manufacturer order placement Raw material inventories
Value-added process	Back logs Service-time Capacity utilisation Competing value streams	Reject rates Lead-time Yield ratios Competing value streams
Control	Information management Decision and control systems	Information management Decision and control systems
Demand	Amplification of demand Customer orders Backlogs/Queues Capacity utilisation	Schedule variability Customer orders Deliveries Forecasts

Research Methodology

In order to gain further valuable insights into the status of actual manufacturing and service supply chains the authors employed the site-based Quick Scan Audit Methodology (QSAM) to collect empirical uncertainty data (Naim *et al.*, 2002). QSAM is anchored in the uncertainty circle model and involves a rigorous, multi-method diagnostic approach designed to perform a health-check of a supply chain (Childerhouse and Towill, 2011a). It was originally developed to enable researchers to obtain accurate comparative performance and operational assessments (Childerhouse and Towill, 2011b) while also minimising interruptions to the host organisation. Typically, it takes four researchers one week to fully audit the supply chain of a medium-sized organisation, with around half of this time being spent onsite walking the process(es), interviewing, reviewing documentation...etc., as required. It is important to note that QSAM is a team-based approach involving ‘players’ from the host organisation, so that everyone is able to contribute considerably to audit quality.

The QSAM framework was specifically developed to allow researchers with a range of expertise to work together to reach a consensus view of real-world supply chains. To this end, a battery of tools and checklists ensure comparability and standardisation. For instance, process mapping follows a standardised best practice approach. Similarly, a database of good/bad/indifferent practice is augmented each time a Quick Scan is conducted, which is able to be employed when identifying potential improvement opportunities. A set of standard interview protocols and semi-structured questions for each managerial role within the supply chain is utilised; and a range of quantitative and attitudinal questionnaires offer cross-comparisons and triangulation of subjective data sources.

Some of the key QSAM elements that enable a successful supply chain assessment are:

- The buy-in obtained during a preliminary presentation to the host organisation is based around the targeted win-win situation of the identification of improvement opportunities that helps secure open access to research data and full practitioner participation
- A team of four academic researchers provides investigator triangulation
- The considerable skills and knowledge of the team over and above supply chain knowledge ensures the multi-disciplinary nature of the subject matter is addressed
- Five independent although cognate data collection approaches ensure methodology triangulation
- Direct involvement of practitioners during data collection and analysis and a verification feedback presentation greatly enhances the reliability of the audit
- Application of a refined, systematic and, hence holistic methodology makes it feasible to conduct a comprehensive assessment of complex phenomena
- An opportunity is provided to integrate the best features of USA management research (horizontal; questionnaire based) with European style (case study based) research.

To-date, 109 site-based value stream audits have been performed over a 14-year period with the Quick Scan approach. **Table 3** outlines the span of the resulting dataset. Although manufacturers and service providers are not equally represented in this (opportunistic) sample, there are sufficient numbers of each type to allow some basic statistical comparisons. The sample is drawn from several national settings and

the value-adding activities of the focal firms cover a broad range of service and manufacturing environments.

Table 3 Sample Coverage

	Manufacturing	Service
Sector	Automotive (22) Food processing (20) Make-to-order engineering (15) Electronics manufacturing (13) Heavy engineering (7) Pulp and paper mill (5) Steel mill (5)	Regional hospital (9) Printing and scanning service (6) Third party logistics provider (3) Heat treatment (2) Regional utility provider (1) Hardware retail (1)
Total:	<u>87</u>	<u>22</u>
Audit timeline	1997 - 2010	1998 - 2009
National Setting	Germany, New Zealand, Thailand, UK	New Zealand, Thailand, UK
Value adding	assembly, machining, forging, packaging, processing	service provision, distribution, health care

Cross-sector case analysis

Comparative statistics regarding the *subjective* evaluation of uncertainty in service and manufacturing supply chains is given in **Table 4**. Evidence (expressed as a mean percentage) of each of the four uncertainty areas is displayed; a lower value is indicative of superior supply chain performance. The largest (statistically significant) difference between the sectors is in the *Process uncertainty* area, where service providers on average experience more uncertainty than manufacturers. Although the service supply chains on average were found to exhibit higher overall levels of uncertainty, these differences are not statistically significant.

Table 4 Uncertainty Circle Model Applied to Manufacturing and Service Sectors

	Manufacturing (87)	Service (22)	Δ	T Test sig.
Process uncertainty	55	66	+11	0.06*
Control uncertainty	74	79	+5	0.38

Supply uncertainty	64	63	-1	0.94
Demand uncertainty	73	77	+4	0.55
Total (Euclidean Norm)	62	68		0.12

Cumulative uncertainty in all four areas is calculated using the Euclidean Norm. As a chain is only as strong as its weakest link a high uncertainty score in one area outweighs moderate levels in all four. **Figure 3** illustrates the overall level of integration of the service and manufacturing samples. Although a broader spread of integration maturity is evident in the manufacturing sector sample, it is clear both sectors are struggling to integrate their supply chains towards the seamless goal.

Figure 3 Supply Chain Integration Maturity Frequency Distribution

In addition to the subjective evaluation of uncertainty, objective data concerns specific supply chain uncertainty characteristics. Although some 70 variables arising from the QSAM audits were analysed, testing revealed that only those in **Table 5** exhibited statistical significance.

Table 5 Statistical Analysis of Manufacturing and Service Differing Attributes

Attribute	Scalar	Manufacturing	Service	T Test sig.
Seamless transparent information flows	Observed %	51	37	0.08
Unexpected or counter-intuitive system behaviour	Observed %	54	18	0.02
Competing value streams	Observed %	56	27	0.07
Excessive layers of management	Observed %	30	50	0.10

Customer base	No. alternative customers	411	37,512	0.01
Customer delivery frequency	Deliveries/ annum	430	71,428,573	0.02
Supplier delivery frequency	Deliveries/ annum	202	507	0.04
Life cycle	Duration- annum	17	32	0.04
Profit margin	% of sales price	17.6	3.8	0.10

Analysis reveals that:

- Manufacturing supply chains, on average, enjoy significantly more transparent and seamless information flows compared to service supply chains
- Conversely, service providers experience fewer unexpected or counter-intuitive system behaviours
- Services outperform manufacturing regarding competing value streams: more often than not there seems to be dedicated service provision on a one-to-one basis, as opposed to batch production of shared capacity
- Service providers on average have more layers of management compared to manufacturers; however, the large proportion of public health sector providers within the sample may have significantly affected this finding
- Service providers on average have significantly more customers and, as expected, deliver their service far more frequently compared to manufacturers (In our sample the ‘customer’ is defined as the next stage in the supply chain to where the manufacturer or service provider delivers their product or service).
- The need for service providers to be more responsive to customers seems to have affected the expectations placed on their suppliers, since on average the incoming delivery frequency to the service providers is significantly higher than in manufacturing
- The product life cycle for service providers is on average around double that for manufacturers
- Profit margins indicate that, compared to service providers, manufacturers are generally in a better position to appropriate value.

Discussion

This paper has described the application of a robust, site-based audit methodology that enables direct, objective comparison of supply chain performance even when the host firms are located in dissimilar sectors (manufacturing and services in this study). In spite of the commonly held view that services possess unique attributes that have significant implications for anyone seeking to transfer manufacturing supply chain best practice, review of the literature reveals compelling evidence that this is not always the case. Subsequent consideration via application of the uncertainty circle model (UCM) in both sectors confirmed that there are more similarities than dissimilarities, at least from a supply chain perspective. Hence, although

manufacturing and services may appear on the surface to be significantly different, the authors contend that only their respective terminology truly sets them apart.

Comparative results of the various sources of uncertainty in both sectors provide some interesting initial insights into the two environments. While service supply chains on average appear to suffer from the effects of having higher levels of uncertainty, this result is not statistically significant and requires further data acquisition to support the observation. The largest difference between the sectors was detected in the *Process Uncertainty* category, where the service providers on average experience more uncertainty than the manufacturers, and this finding is statistically significant. This comes as no surprise given the complexity and agility needed to provide services that directly involve customers, as opposed to a repeatable and more controllable shop floor environment. This equates to the differences expected between the Schmenner (2004) genres classified as ‘Service Shop’ and ‘Mass Service’.

Analysis of (statistically significant) objective measures of uncertainty provided some evidence of the structural differences of service and manufacturing supply chains. Service supply chains on average have more customers compared to manufacturers, and a far higher customer delivery frequency expectation is placed on service providers. The large difference in customer numbers recorded in our sample reflects the focused structure of manufacturing supply chains that deliver to OEMs or a few large customers, as opposed to service companies that directly interact with such ‘end user’ customers as hospital patients. However it is noted that the position of the business within the end to end supply chain may also have a bearing on the number of customers involved and on interactions leading to heterogeneous service offerings that are customer-unique. [This positional dimension will be investigated in future research

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Although the QSAM approach was originally developed for the purpose of conducting rigorous and objective site-based value stream ‘healthcare’ checks in the European automotive sector, the technique was recently transferred into the public healthcare services arena (Böhme *et al.*, 2012) and valid comparisons of medical supply value stream processes obtained. The researchers experienced no additional difficulty in applying the uncertainty lens to this service sector rather than to manufacturing.

In summary, the relatively small number of service sector samples compared to manufacturing, requires that more testing is required before the present findings can be confidently extrapolated. However, the uncertainty circle model has the potential to become a powerful tool to compare supply chain sophistication/maturity across markedly different settings (Parnaby and Towill, 2008). Combining the uncertainty circle model with the QSAM approach provides a robust framework and standardised data collection and analysis tools that will assist the diffusion of proven good practices across different industry and business sectors; by assisting the transfer of learned solutions between service and manufacturing sectors (Parnaby and Towill, 2012).

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Contribution to Knowledge and Future research

This study has three major outputs as follows:

- Substantial and substantive evidence is provided both from the literature and from application of the UCM that services do not always exhibit unique attributes that effectively bar manufacturing-based supply chain best practice from being adopted within the service sector (and vice versa). This finding is contrary to the commonly held view.
- Site-based evidence shows that a robust, multi-method audit methodology that is focused on detecting supply chain system uncertainty can provide objective comparisons of (normalised) supply chain integration performance even when the firms being compared are located in *dissimilar business sectors and settings*.
- The potential of the uncertainty circle to be a powerful tool to assist in the identification and transfer of appropriate best practices between the service and manufacturing sectors is highlighted.

Research to increase the sample size of the service supply chains and bolster the statistical analyses is planned, as are longitudinal case studies to provide further insights into the homogenous nature of the two contexts and the usefulness of the uncertainty circle model as a generic approach for aiding transferable best practice between sectors. Investigations are currently underway into the crash repair sector and the health sector. In short, our continuing research aims to identify manufacturing and service supply chain best practices that can adapt and translate into further supply chain settings, hence fulfilling the test for establishing new management theory as proposed by Micklethwait and Wooldridge (1996).

Conclusions

In the 1990s academics were challenged to develop a methodology for establishing the health of value streams in the European automotive sector as a precursor to identifying likely future design and operational trends. The uncertainty circle model (UCM) was conceived as the basis for providing realistic and repeatable performance vectors, and one capable of aligning estimates of value stream health status even when comparing supply chains with differing objectives, configurations, and performance goals (Childerhouse and Towill, 2011b). The ability of UCM to provide a platform for statistical analysis of value stream samples enabled site-based audit results to form the basis of informed comparisons of supply chains. Hence, statistically identified best practice and associated *raison d'être* could be readily exploited to advantage (Childerhouse and Towill, 2004). The UCM also enabled a strategic link to be established between North American management research methodologies based on horizontal questionnaire analysis, and European research based on exploiting vertical case studies (Towill, 2006).

In this paper the UCM has been refined to enable inter market sector comparisons, thus providing the evidence needed to test prevailing viewpoints that characterise the manufacturing and service sectors. It is recognized that further development and evaluation are needed to overcome the potential biases of a small sample size and to address positional aspects of the supply chain. However the intention of the research was to highlight both the operational similarities and the differences across the two sectors. Application of the UCM yielded uncertainty vector comparisons which are amenable to tests for statistical significance via standard techniques. It was also shown how value stream attributes that differ between the two sectors can be similarly

Commented [J3]: This addresses both positional and sample issues "make caveats clearer in final remarks"

derived; for example, the finding that manufacturers on average enjoy significantly more transparent and seamless information flows compared to services supply chains. Indeed opaqueness in the services sector is sometimes deliberate, since for example there are numerous reports of UK National Health Services that recount substantial unofficial queues of patients (sometimes six months long) needing hospital treatment who are waiting to join the published Official List (which is maybe four months long) and on which the hospital's income may depend.

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