International Journal of Manufacturing Research
Special Issue on SYSTEMS FOR EXTENDED ENTERPRISES

SUPPLY NETWORK INTEGRATION IN MULTI-ORGANISATIONAL NETWORK SYSTEMS

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Abstract

This paper explores supply network integration in complex product service systems involving close collaboration between primes. Four case study networks are studied (aerospace, naval, power and telecoms), each involving equipment manufacture and service provision. Factors that support network integration, identified from the literature and refined in the in-depth pilot case, were used to explore which processes support integration of the extended enterprise. The research methodology involved the use of supply chain capability and process hierarchy concepts, to assess supply network integration between key partners.

Results suggests that a select set of processes support integration of the extended enterprise, and that the absence of a shared view on these critical enabling processes results from contextual complexity of the network rather than competing commercial interests. An approach that aligns objectives of the various entities is piloted to develop a common enterprise perspective, captured within a 'hierarchy' of strategic, operational and routine activities.

Keywords: Supply Network Integration, Extended Enterprise, Multi-Organisational Networks

Biographical Notes

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1.0 Introduction

The concept of service supply chains is relatively new and addresses the traditional challenges of Supply Chain Management (SCM), the effective management of materials and information within the network of interdependent organisations in the supply chain, with those operational processes that support the provision of an integrated 'service solution'. These typically include after-sales service processes (often the stage in the value chain where value is captured) but also include other activities and processes in the value chain that support service delivery (often where value is created).

Despite extensive SCM literature over the last two decades and the increasing importance of services to many OEM manufactures (and non-manufacturers), the area of service supply chains (SSCs) is largely unexplored

in academia as commented by several authors (Baltacioglu et al, 2007, Niranjan, 2007). This is particularly surprising since the SSC concept is increasingly prevalent in industry (although sometimes alternative terminology such as service chains, after-sales services etc are used). This gap in the academic arena is now being progressively addressed, directly using the SSC terminology/concepts (e.g. Baltacioglu et al, 2007, Niranjan, 2007, Sampson, 2000, Anderson et al, 2005, Ellram et al, 2004) and more broadly within the service domain (e.g. Cohen et al, 2006, Olivia and Kallenberg, 2003). One of the key challenges in ensuring effective and efficient service operations in complex and dispersed (multi-node) supply network environments is the integration of demand and supply processes, typically covered by contractual service agreements. Transparency on collective and individual service delivery within an environment where there are multiple interdependencies on effective service provision, often involving bi-directional service supply chains operating in parallel, present particularly complex process integration, accountability and delivery management challenges.

Another key challenge is the migration path to service supply networks. These involve the development of new 'concepts of operation' or the selection of service operating models and their operating protocols, and in many cases, the progressive transfer of operational processes between customer and supply organisations. The development of these operational frameworks needs to be supported by organisational routines (process capabilities), some of which may be model-specific. Performance metrics that take into account key inputs, supply chain process development, and output performance become a key component of the operational framework. These metrics need to be considered in a broader context, where the more elusive 'end-to-end' supply network performance and partnering perspectives are assessed, as well as contractual metrics that support service contract delivery.

Although integration in supply networks is a well established concept in the literature, researchers have made little progress on defining the processes that might support network integration (as discussed in Lambert et al, 2000) and how it applies in multi-organisational network systems. This paper compares four in-depth case studies involving complex product equipment manufacturers and the challenges they face operating within multi-entity service supply chains, where service and support activities represent their dominant revenue generator. The key focus of the study was to develop a methodology to explore whether a common set of service supply chain process-objectives across the extended supply network could be developed to support more effective product service delivery.

2.0 Key concepts in Service Supply Chains (SSCs)

Within the limited literature in the field of SSCs several concepts have been identified that provide a useful foundation to support research in the area. Initial research in complex SSCs suggests that the concepts may be usefully grouped into Strategic, Operational and Technology aspects. The first two of these dimensions are briefly reviewed below in terms of their relevance to this study.

2.1 Strategic considerations in SSCs

The literature on service supply chains identifies several concepts that may be classified as strategic level considerations and include;

- SSCs as a new source of value capture (Baltacioglu et al, 2007, Chamberlain and Nunes, 2004) with service providers moving up the value chain (Neely, 2007)

- Perishability of services, with the inability to store 'inventory' as in conventional SCs, with inventory equivalence being considered as installed 'service capacity' (Baltacioglu et al, 2007 , Niranjan, 2007, Anderson et al, 2005)
- The 'variable capacity' nature of services (Niranjan, 2007)
- Incentivisation of SSC partners that support value adding behaviours with suitable pain/gain share mechanisms
- The elevation of information and knowledge based 'flows' in SSCs in addition to the effective management of material flow (Anderson et al, 2005, Cohen et al, 2006)
- Bidirectional SSCs involving dual customer-supplier roles for the principal partners with roles reversed for specific elements (e.g. enabling infrastructure delivery provided by 'customers'), with service delivery and quality highly interdependent (largely involving single tier dependencies), providing complex capability, performance and contract management issues (Sampson, 2000, 2007, Srai, 2007)
- The contractual nature of service delivery in complex equipment maintenance contracts, involving 'enduring' contracts of significant value and scale, rather than the one-off transactional nature of traditional supply chains (Srai, 2007).

2.2 Operational considerations in SSCs

From an operational perspective, the literature presents some unique aspects of service supply chains, namely

- Involving dispersed operations for aftermarket support, with service providers co-located at customer sites (Srai, 2007, Farris et al, 2005)
- Complexity of SSC operational processes and capabilities, with performance management challenges (Pavlov and Bourne, 2007), and attempts to provide operational level decision trees and metrics (Chiba, 2007), SC performance hierarchies (Hofman, 2004, capability models and capability hierarchies (Cohen et al, 2006, Srai, 2007)
- Multi-entity contracting, partnering and sub-contracting (Sampson, 2000, Farris et al, 2005)
- The very specific demand characteristics in complex equipment and service contract environments (large contracts) and the management of ongoing demand on-contract (Baltacioglu et al, 2007 , Anderson et al, 2005)
- The influence of on-site service (real-time operational and near-future) demand signals leading to capacity and capability development supporting both primary volume demands and new service development opportunities.

3.0 Key Research Challenges

The research extends previous work undertaken in the area on supply chain capability model development, capability development paths, capability and performance metric architectures and hierarchies, taking both a strategic supply chain and operational perspectives. Literature on aftermarket support (Cohen et al, 2006), supply chain performance metrics (Hofman, 2007), capability hierarchies (Srai, 2007), provide potential approaches to these elements of the research. The extendibility of SCM concepts to SSCs is addressed by understanding the equivalence of concepts such as inventory, demand, capacity etc.

A sub-theme within this research is on 'end-to-end' supply chain integration (Samson, 2000, Srai, 2007) by capturing those supply network capabilities that facilitate customer-supplier alignment, and the combinations of operational-routines that support particular service supply chain models. The hierarchy of service supply chain capabilities is seen as key to providing linkages between discrete strategic and operational processes, including complex support activities, providing a platform for process alignment, metrics development and 'end-to-end' integration. Typology/classification considerations in this research are restricted to the service supply chain domain identifying service supply chain based segmentation and differentiation concepts extending from other authors in the area (e.g. Deshpande et al, 2003). The focus in this area is on future supply model configuration options (Srai and Gregory, 2008).

The development of suitable SSC configuration parameters and supply chain mapping techniques are also considered to understand how configuration influences service delivery, and which configurations support particular service models. Due to the integral nature of product development in many service solutions, the configuration of the value chain (or 'footprint') and its impact on service delivery modes and capabilities is considered; the research methods involve application at a top-line level value stream mapping and supply network configuration mapping techniques (Srai and Gregory, 2008). The 'service product' dimension within this research is on complex equipment (supply/upgrade/maintenance) centric services where the SSC concepts of relationship management (Baltacioglu et al, 2007), bidirectional SC's (Sampson, 2000, 2007) and complex capability hierarchies manifest (Srai, 2007). These environments also provide opportunities to understand the complexities of mass-partnering (Sampson, 2000) and the emerging role of (service and support) systems integrator within a SSC context. The evolution journey from product manufacturer (or SCM) to systems process integrator and expert partner management (or SSCM) is facilitated by these complex dispersed service networks (Baltacioglu et al, 2007, Niranjan, 2007, Cohen et al, 2006, Oliva and Kallenburg, 2003, Neely 2007).

A potential output from this research is in informing the future development of SSC process models and frameworks, beyond concepts currently reported (Baltacioglu et al, 2007 , Niranjan, 2007, Farris et al, 2005), providing a 'process-based' foundation for service operations management. The research aims to enrich traditional operating frameworks by introducing the concepts of 'service and support' operations, integrated with equipment 'design and build' processes.

4.0 Methodology

The principal aim was to establish the relative alignment of service supply chain process objectives across key operational nodes in the multi-organisational service network, using process-capability model assessments. Further, to evaluate reasons for any differences in their strategic and operational classification, and possible causes for differing perspectives. The multiple case study method was selected as most appropriate to address the research agenda, as the operations for equipment based product service solutions are complex.

Four case study multi-organisational service networks were selected, based on the criteria set for the study of analysing complex equipment service provision. The cases included large service contracts, each representing complex 'product service systems' in aerospace (aircraft maintenance and support), naval (naval-base service operations), power (power supply systems) and telecoms (equipment) sectors. Cross-case comparisons were necessary for deriving generalizable observations.

The research methodology involved the application of a number of capability assessment and configuration mapping techniques previously developed by the authors (Srai, 2007, , Srai and Gregory, 2008, Srai, 2008),

but tailored to the complex dispersed bidirectional SSC context described above. Supply chain capability assessment 'process models' (Srai, 2008) were used to assess from an extended supply network perspective, supply network integration drivers between key nodes in the supply chain; between 'end-customers', 'on-site service' teams, 'original equipment manufacturing hubs' and key 'tier 1 suppliers'. Key elements of the methodology involved the following activities;

1. An outline configuration mapping activity, capturing the principal entities involved in service delivery, was undertaken to improve understanding of the dynamics of 'end-to-end' integration task across the multi-organisational service network using established methodologies from the SC literature (Srai and Gregory, 2008).
2. Capturing the key material and information flows as part of an 'end-to-end' (bidirectional) supply chain mapping activity using supply network configuration mapping tools (Srai and Gregory, 2008)
3. The application of SC capability models (those with sufficient operational granularity) in a service & support environment; specific methods varied depending on either in-company capability models and generic models available in the literature (Srai, 2008)
4. The exploration of capability hierarchy concepts using the framework depicted in Fig.1, adapting previous concepts on SSC Capability Hierarchies (Srai, 2007), and work on performance measurement hierarchies (Hofman, 2004).

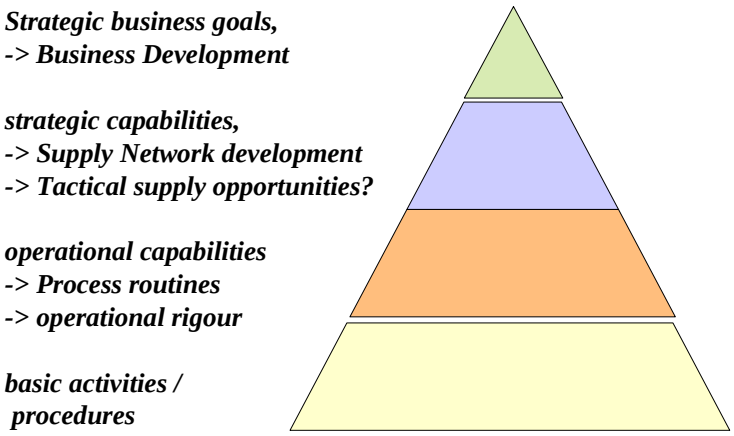

Fig. 1. Developing Capability Hierarchies to Support Strategic and Operational Alignment (Srai, 2007).

Case Descriptions:

Case 1: Aerospace

The case involves a main service provider within a complex multi-prime PSS involving the delivery of equipment and service in the defence sector. The complex multi-partner arrangement is based on long-term service contracts between the customer and several service providers. The latter themselves are dependent on a complex multi-organisational network of suppliers, other primes and infrastructure support from the 'customer'. The customer has retained some capability for routine maintenance with contracts being bespoke.

Case 2 Naval

The naval sector case involves complex multi-partner arrangements in the maintenance of fleet operations by the original equipment manufacturers. Unlike case 1 the customer has significant capability to undertake significant maintenance activities requiring careful coordination of requirements constrained by fleet availability. Service schedules are often dictated in some detail by the customer, with supplier inputs key to advising what is possible within tight timescales.

Case 3 Power

A complex downstream service network is managed supplying standardised PSS to a broad international customer base. Product manufacture involves assembly of complex but standard equipment items supplied within a 'containorized' (larger items) or 'modularised' (smaller duty) generator sets that are made to firm order and shipped at relatively short notice from their single site global facility. The multi-organisational network involves key suppliers, a single global manufacturing facility supplying to the service arm of the same organisation.

Case 4 Telecoms

Case 4 involves a complex upstream supply network serving an international telecoms systems provider. The OEM is a flagship national organisation which competes favourably with more established international rivals in terms of achieving faster response in equipment supply and speed to market. Service operations are dispersed in the client markets and involve local equipment and technical support. The upstream supply network uses multiple suppliers who share risks and rewards as part of an agile equipment supply capability.

Supply Chain Capability Review:

The service supply chain process capabilities, for each of the cases (see Table 1), were evaluated using the capability hierarchy shown in Figure 1. In the first two cases, this was extended to multiple 'nodes' in the multi-organisational service network, with results from multiple nodes compared to assess the principal reasons for any capability hierarchy classification differences. In the in-depth pilot case study (Case 1) an approach to the development of a shared perspective was tested; this involved the (multi-nodal) group review of the process-capabilities where there was a 'mismatch' either in the perceived importance of a process, or its strategic and operational classification. Reasons for the mismatch were then discussed.

Table 1 sets out the case service networks studied, summarises the process-capability tools used to undertake the analysis, and the scope of the capability hierarchy assessment. In all the case studies, the capability assessment tools included the generic model (Srai, 2008), and in case 1 and 2 company specific models were used to provide additional operational detail and familiarity with the questions on specific supply chain operational routines, their strategic or operational importance, position in the process hierarchy and the nature of the PSS.

Table 1.
Case Studies

Case		Description	capability models used	informant scope
Case 1	Aerospace	complex multi-partner	in-company, generic ref *	extended service chain
Case 2	Naval	complex multi-partner	in-company, generic ref *	extended service chain
Case 3	Power	complex downstream	generic ref *	service provider
Case 4	Telecoms	complex upstream	generic ref *	service provider

(*Reference model – Srai, 2008)

In each of these case studies, the SSC data collection and capability hierarchy classification involved interactions with the supply chain leadership teams of the major OEMs. Case 1 and Case 2 also involved in-depth interviews with multiple supplier and customer organisations as part of a review of processes, and supporting tools. In addition to existing service solution projects, a review of exemplar pioneer projects was undertaken in the pilot case (Case 1) to capture key transition themes, capturing evolution path history. The results of the relative 'alignment' between supply-chain process capabilities are shown in Table 2.

5.0 Results

5.1 Cross - Case Comparison and Review

The four networks studied demonstrated that the provision of a product service solution where complex equipment is involved places a heavy reliance on a network of multiple partners, with the need to constantly upgrade equipment, in many cases in-situ at the customers' premises. Furthermore, maintenance activities require close partnership between customer, prime service provider(s) (the holder(s) of the design authority) often involving complex bi-directional supply chain arrangements. In addition to network structure and complexity (as identified in supply network configuration mapping activity and observations on the nature of the partnership), the supply chain capability process models were used to assess capability hierarchy and whether there was clarity of objectives between key partners in the multi-organisational service network. The results are summarised in Table 2.

Table 2.
Case Studies Summary Results

Case	**Network Complexity**	**Nature of Partnership**	**Capability Hierarchy Match/Mismatch**
Case 1 Aerospace	High multiple-prime(s)	Co-located and Enduring	shared objectives but hierarchy mismatch
Case 2 Naval	High Multiple-primes(s)	Co-located and Enduring	shared objectives but hierarchy mismatch
Case 3 Power	Downstream complexity /single prime	Transactional, Short-term contracts	downstream match (limited KPI based data)
Case 4 Telecoms	Upstream complexity /single prime	Transactional, Fixed-term service contracts	upstream match (limited KPI based data)

Initial findings suggest that the individual entities regard end-to-end integration as a desirable and mutual goal, but (as shown in Table 2) view the criticality of particular enabling process-capabilities quite differently, with important differences also on their perspectives of what constitutes strategic and operational processes. This finding suggests that misalignment through the service supply chain is fundamentally a design issue (as well a difficult operational task), particularly in complex multi-organisational service networks where complexity is not confined to upstream or downstream partners that might be controlled by standard product service solutions, but where service is more contingent on ongoing interactions of an enduring nature, that do not as yet have standardised solutions.

The misalignment in objectives were further explored in the first two cases where mismatches were apparent (and more likely due to the complex nature of the PSS). In these case studies, (Case 1 and Case 2) capability hierarchy results were compared to evaluate differences and the results shared between the respondents. In these discussions, the mismatches appeared to be driven by different operational perspectives, and lack of

understanding of the extended service supply chain, rather than what might result from competing commercial interests.

5.2 Pilot Case Review

5.2.1 Identifying integration factors that support end-to-end integration

The review of the literature identified a number of integration enablers which were tested across the key nodes of the product-service chain [20]. Strategic and operational processes that support end-to-end integration were selected in terms of their contribution to these integration enablers. Within the detailed pilot case study, the methodology involved key network members in the product-service chain to evaluate which processes contributed to these 'integration enablers'.

Detailed case study data and findings have been reported separately (Iakovaki, Srai and Harrington 2009), but confirm the contextual complexity of this extended enterprise service systems. The integration enablers were themselves classified to identify an 'integration hierarchy' (using concepts similar to the process hierarchy classification used earlier).

Five integration enablers emerged from this analysis, together with their supporting factors, that support the integration of multi-organisational network systems;

- Common goals
- Shared risk and rewards
- Network Synchronisation
- Collaborative resources:
- Knowledge sharing

Figure 2 below identifies the integration enablers and their supporting processes;

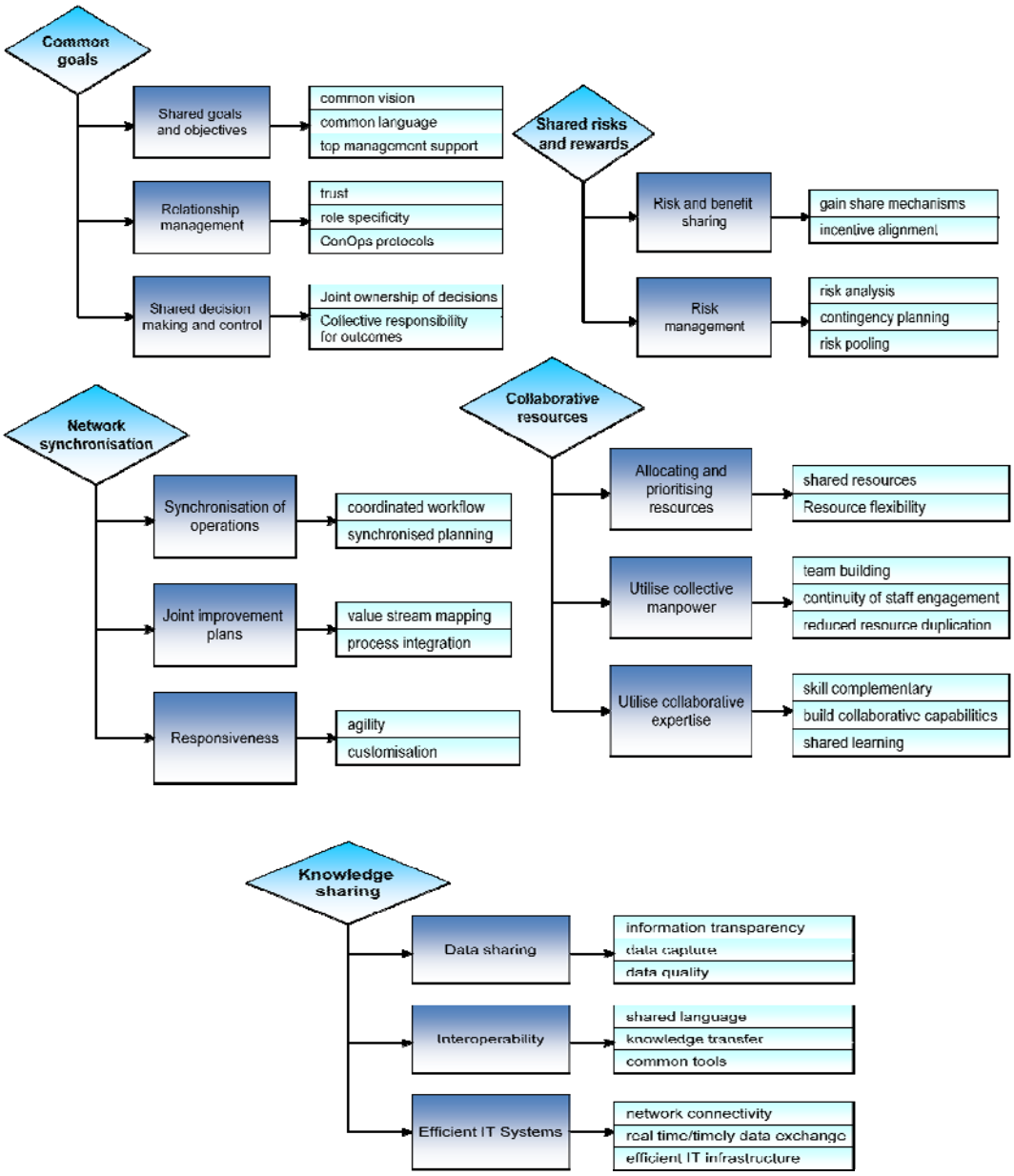

Fig 2. Five Enablers of Network Integration (adapted from Iakaovaki, Srai and Harrington, 2009)

5.2.2 Mis-match in Capability hierarchy

For the pilot study case, Case 1, described in the schematic Figure 3, an in-depth review of the mismatch between hierarchy classifications was conducted to establish the nature of the determinations by the different organizational entities, within the service supply chain. The analysis involved the capturing of the supporting rationale for capability hierarchy classification.

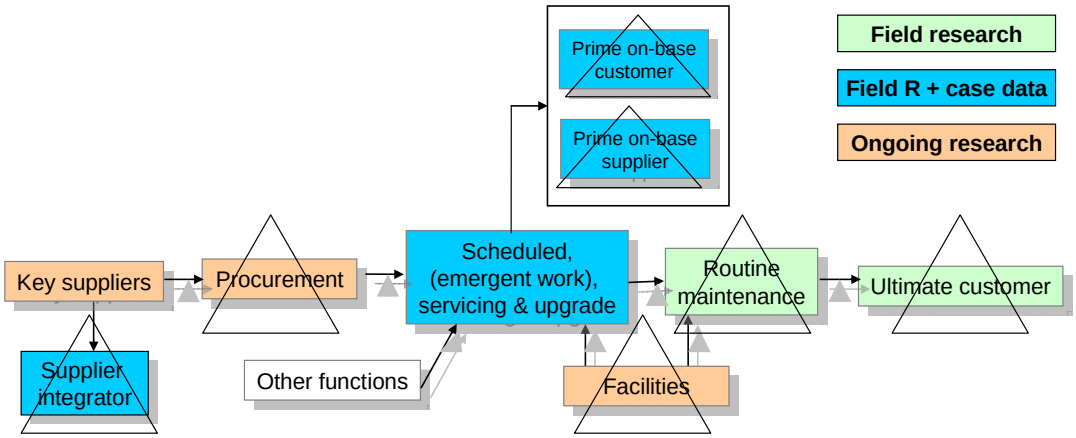

Fig 3 Evaluating Process Capability and multiple nodes in the Extended Enterprise
(adapted from Iakaovaki, Srai and Harrington, 2009)

Initial results of this analysis, suggest that the differences result from an absence of a shared view on critical enabling processes and that this largely results from contextual complexity (supply network and product service) rather than competing commercial interests. To further verify this observation, the 'group' sharing of the classification of partner-organisations was then conducted. The different classifications of supply chain process-capabilities appeared to be driven from differing operational perspectives, and suggested that a common perspective can be arrived at, with the supporting rationale discussed collectively, and thus contributing to common set of process objectives.

Figure 4 summarises the supply chain processes that were identified as critical to the group and were modified to accommodate a shared enterprise perspective. The agreement of a common set of supply chain processes and their strategic and operational relevance, represented a key outcome of the research, providing a generalisable approach to integrating systems of extended enterprises.

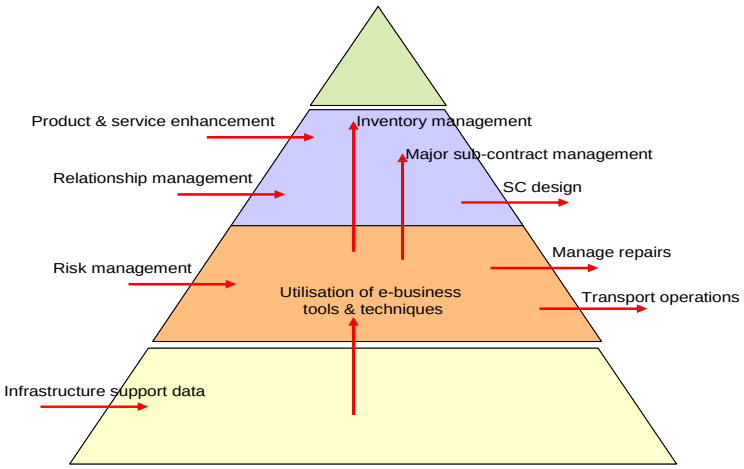

Fig 4 Developing an Enterprise Perspective on Processes key to Network Integration
(adapted from Iakaovaki, Srai and Harrington, 2009)

6.0 Conclusions

The main conclusions from this study include;

- There is an absence of a shared view on critical enabling processes in complex multi-partnered service supply chain cases studied, particularly evident in the cases where multiple primes are active and where no standard PSS exist.
- Integration enabling factors developed in this case study and reported separately (Iakovaki, Srai and Harrington, 2009), can be used to identify a select set of processes key to the integration of the extended enterprise.
- A significant contribution to the different strategic-operational classification of capability-hierarchy by network members results from contextual complexity (supply network and product service) rather than competing commercial interests
- An approach to make transparent the misalignment in process objectives and priorities of the various supply network entities suggest 'common perspectives' can be arrived at by sharing operational information about criticality of key processes and their strategic and operational relevance
- A common set of service supply chain capability hierarchies may lead to the development of better understood process enablers and their strategic and operational relevance.

The pilot explores possible processes for achieving a common multi-entity set of supply chain process-capabilities, captured within a 'hierarchy' of strategic, operational and routine activities. An approach to formulating a shared (multi-organisational) supply chain process-capability hierarchy is presented, extending the work of this study to understand more fully the contextual factors that may contribute to mismatches in process objectives, and exploring their practical and commercial implications.

References

Anderson E.G., Morrice D.J., Lundeen G., "The 'physics' of capacity and backlog management in service and custom manufacturing supply chains", *System Dynamics Review*, Vol. 21, No. 3, 217-247, (2005).

Baltacioglu T., Ada E., Kaplan M., Yurt O., Kaplan C., "A new framework for service supply chains", *The Service Industries journal*, Vol. 27, No. 2, 105-124 (2007).

Chamberlain J., Nunes J., "Service-parts management: A real-life success story", *Supply Chain Management Review*. 38-44 September (2004),

Chibba A., "Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers", *14th International Annual EurOMA Conference*, (2007)

Cohen M.A., Agrawal N., Agrawal V., "Winning in the aftermarket", *Harvard Business Review*, 129-138, May (2006).

Deshpande V., Cohen M., Donohue K., "An empirical study of service differentiation for weapon system service parts", Operations Research, Vol. 51, No. 4, (2003).

Ellram L., Tate W., Billington C., "Understanding and managing the services supply chain", *Journal of Supply Chain Management*, Vol. 40, Issue 4, (2004).

Farris T.M., Wittmann M.C., Hasty R., "Aftermarket support and the supply chain: Exemplars and implications from the aerospace industry", *International Journal of Physical Distribution and Logistics Management*, Vol. 35 (1) 6-19, (2005).

Hofman D., "The Hierarchy of Supply Chain Metrics", *Supply Chain Management Review*, 28-37 (2004).

Srai J.S., "Global Solutions; Supply Chains - Emerging Models. Manufacturing Engineer", *The Institution of Engineering and Technology*, Vol. 86 (5) 32 – 35, Oct-Nov (2007).

Iakaovaki A., Srai J.S., and Harrington T., "Service Supply Chain Integration in Multi-Organisation Networks - Applying integration enablers and aligning process capabilities", *The 14th Annual Cambridge International Manufacturing*

Symposium - Configuring manufacturing value chains - responding to an uncertain world, Cambridge, September (2009).

Niranjan T.T., "Equivalence of 'goods' and 'services' supply chain concepts", *14th International Annual EurOMA Conference,* (2007).

Sampson S., "Customer-supplier duality and bidirectional supply chains in service organizations", *International Journal of Service Industry Management,* Vol.11, No. 4, 348-364, (2000).

Neely A., "The Servitization of Manufacturing: An analysis of global trends", *14th International Annual EurOMA Conference,* (2007).

Oliva R., Kallenberg, R., "Managing the transition from product to services", *International Journal of Service Industry Management,* Vol. 14, No.2. (2003).

Pavlov A., Bourne M. "Responding to contemporary challenges in performance management: Measuring organisational routines", *14th International Annual EurOMA Conference,* (2007).

Sampson S., "Why do we need an Operations paradigm for services?", POMS College of Service Operations and EurOMA Conference, London Business School, (2007).

Srai J., "Developing a more integrated supply network through process and capability alignment – An initial review of an output-based service supply contract", *SEIC Conference,* Loughborough, (2007)

Srai J.S., Gregory M.J., "A Supply Network Configuration Perspective on International Supply Chain Development." *International Journal of Operations Management,* Vol. 28 (5) 386-411, May (2008).

Srai J.S. "Process Organisation, Capabilities and Supply Networks - Enterprise organization and operation", Chapter 15, 1279-1289 In: *Springer Handbook of Mechanical Engineering,* Editors: Karl-Heinrich Grote, Erik K. Antonsson, Springer, Heidelberg, (2008).