Managing Information Flows for Product-Service Systems Delivery

C. Durugbo, A. Tiwari, J.R. Alcock
School of Applied Sciences, Cranfield University, Cranfield, United Kingdom
{c.durugbo, a.tiwari, j.r.alcock} @cranfield.ac.uk

Abstract

The delivery phase is an integral part of the product-service system (PSS) approach that requires interactions involving the external and internal flow of information. Managing information flows for a company that adopts the PSS approach is therefore important to understanding interactions between manufacturers and customers during the delivery of a PSS.

The purpose of this paper is to use literature to identify the main approaches for managing information flow during PSS delivery. This paper plans to contribute to knowledge by: analysing the main approaches for managing information flow during the delivery phase and, making recommendations for future research.

Keywords

Product-service systems, information flow modelling, communication, organisation, collaboration

1 INTRODUCTION

According to a widely accepted definition by Baines *et al*. [1], a product-service system (PSS) is 'an integrated product and service offering that delivers value in use'. For the supplier, value is realised in the PSS approach which supports minimising inputs and maximising outputs during delivery. For the customer, value is realised in PSS propositions that centre on closely linking services to delivered products in configurations based on function provided by products, availability of product or the result required from the product (or service).

Interactions are required during the delivery phase by suppliers to manage internal and external flows, including the flow of information [2]. Internal information flows centre on interactions within company departments, projects, divisions and so on. External information flows centre on interactions between the supplier and the customer for managing the delivery of products and services. External information flows also involve interactions within trans-organisational partnerships and alliances that could be formed to manage aspects of the delivery phase [3]. Consequently, information flows for a company that adopts the PSS approach is important to understanding interactions between manufacturers and customers during the delivery of a PSS.

This understanding of information flow can assist PSS adopters to improve delivery performance.
This paper reviews the current state of research of information flows for PSS delivery. The aim of the paper is to identify the main approaches for managing information flow of during PSS delivery. This paper plans to contribute to knowledge by: analysing the main approaches for managing information flow during the delivery phase and, making recommendations for future research.

The paper begins with an overview on information flow in terms of its dimensions and main attributes. Next, the review methodology is presented followed by a review of PSS delivery in literature. The main approaches for managing the flow of information flow during PSS delivery will then be analysed and used to make recommendations in terms of future research needs and challenges for product-services systems.

2 INFORMATION FLOW OVERVIEW

2.1 Information flow dimensions

The flow of information is determined by three main dimensions: information access, information exchange and documentation [4] as shown in Figure 1.

Information access (or accessibility of information) relates to the presence of data and the ease with which information can be retrieved. It also describes how information is readily available for use in activities. The accessibility of information is dependent on the reliability of the source, convenience of the channel and ease of use of the contents [5]. In terms of information and communication technologies, accessibility of information is also required for remote systems, databases, files transfers and advanced work station facilities [6] and varies in terms of urban vs. rural contexts [7].

Information exchange is concerned with data flow, team interactions and the generation of knowledge [4]. It is required for the dissemination of information through avenues such as gatherings and forums [8] and is closely related to information sharing [9]. Team briefing, management meetings and the cascading of information are also useful means for communicating and disseminating information in organisations such as the social services and health care as noted by Blackburn [10]. Wamba and Boeck [11] identified information sharing as a dimension of information flow that is required for the communication of critical and proprietary information. Furthermore, information sharing between two entities could be generic (inventory control policies) or specific (weekly manufacturing schedule) [12].

Documentation refers to facilities to record and to store data [4] and also offers a useful avenue for the dissemination of information by means of newspaper articles, surveys and so on [8]. Stapel *et al*. [13] identified document flow as means of information flow achieved exclusively by the use of documents. In this form of information flow, documents (letters, memos etc) are considered inputs / outputs of activities. Documentation also involves developing models for describing the technical and non-technical elements of a system [14]. According to the Internet Engineering Task Force (IETF) [15], an information model is a protocol neutral tool used by designers and operators to give conceptual and

abstract representations used for the creation of data concrete/detailed data models for use by implementers. Considerations and modelling for information flow is one aspect of an information model. Other aspects that could be captured by an information model include information structure and integrity.

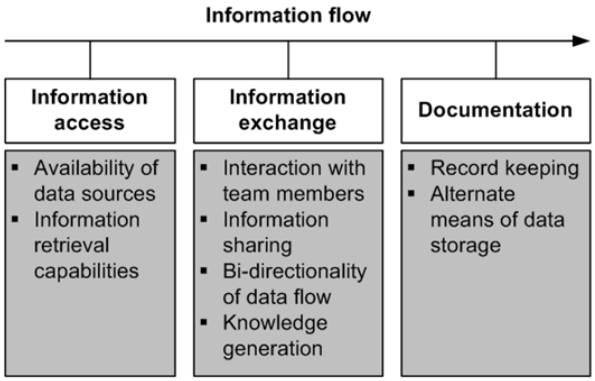

Figure 1: Dimensions of Information Flow [4]

2.2 Information flow attributes

According to Smith, Stoker and Maloney [16] the main attribute of information flow is quality**.** *Information flow quality* describes the free flow of information within an organisation or business [16]. Tarhule [17] noted that the quality of information flow in organisations is aided by the prioritisation of feedback paths and the channelling of efforts for making information available to stakeholders and team members. Manecke and Schoensleben [18] argued that the quality of information in an organisation directly translates to the efficiency of an organisation's business processes. Their argument is based on linking effective communication and information flow with the ability of an organisation to coordinate activities and processes. Citing the 'garbage in garbage out' (GIGO) concept in computer technology, Kehoe, Little and Lyon [19] suggested that information without quality is useless. This means that qualitative characteristics defined during the input of information must be met to ensure outputs are useful.

Information flow format is another aspect of information flow that describes the standardisation of communication to support interaction between processes [20]. Berente, Vandenbosch and Aubert [5] also identified *timeliness*, *transparency* and *granularity* as attributes associated with information flow. Transparency relates to how understandable information is for users whereas granularity refers to the level of detail of information. Timeliness describes the availability of information when it is needed.

3 REVIEW METHOD

A search for literature (journal articles and conference papers) on SCOPUS an online digital library using keywords 'information flow', 'delivery' and 'product-service systems' produced no results. 'Information flow' and 'product-service systems' produced 1 article that dealt with lifecycle management and only used the term 'information flow' in the abstract.

A search for literature based on keywords 'product-service systems' and 'delivery' produced 7 articles (3 relevant). Focusing on these articles this paper plans to examine the approaches for managing information flow that the article authors have highlighted and to use them to make recommendations for improving delivery performance of a PSS.

The main contribution to knowledge will be an analysis of the main approaches for managing the flow of information during PSS delivery.

4 PRODUCT-SERVICE SYSTEM DELIVERY

The delivery of 'value bundles' (made up of services and physical goods) by a PSS is closely linked to the emphasis placed on business, operations management, service sciences management and engineering (SSME), information systems (IS) and engineering [21]. From the business perspective, the delivery of a PSS is driven by marketing needs so as to define value propositions and business models for meeting customer needs. Operations management emphasises cooperation to maximise efficiency in operations and to better analyse customer needs. SSME emphasises service design and delivery especially involving the co-creation of value between supplier and customer. IS emphasises the need to model, analyse, propose and aid information flow. Within the context of PSS delivery, the discipline of IS emphasises the need for managing business processes that deliver value bundles for customers. Within engineering, the focus is on a clear split between the engineering of products and services.

Focusing on IS research, Becker *et al*. [21] argued for conceptual models aimed at PSS delivery for supporting value networks (value-nets). This is because in industry, companies have continued to move from sequential processes for creating value during production (value-chains) to a collaborative process that emphasises partnerships with customers, and among suppliers (value-nets) [22]. Becker *et al*. identified a conceptual model as 'a (re-)construction of a reality' and discussed the benefits of conceptually modeling PSS delivery. These benefits include: support for integration of processes and ICT, interdisciplinary communication among team members and complexity management during design.

In a study of battery-powered drill suppliers, Mont [23] investigated how a PSS can be delivered as a business model that emphasises services and value creation. The study involved an online survey of 618 households combined with interviews conducted with 10 producers, 20 retailers, 20 customers of rental services, 10 community-based sharing systems, 5 caretakers and 2 housing companies. Based on interactions with participants Mont analysed a PSS as a 'value system' made up of actors and scenarios required for the delivery of a PSS. The main actors include producers, rental companies, retailers, households, real estate companies, local organisations and caretakers that maintain community buildings. For the battery-powered drill business, possible scenarios for a PSS proposed include: (1) manufacturer retains drill ownership scenario, (2) sharing a drill between 2 or 3 neighbours, (3) a system for sharing drill(s) within a community of about 25, 50 and 100 households and (4) drill renting services. In an economic and environmental analysis of the delivery scenarios, Mont demonstrated that sharing a product within a community significantly reduces life-cycle environmental impacts, but requires a wide range of considerations for factors such as solution cost, product availability, travelling distance and customer comfort.

'Technology insertion' is a concept used in the defence industry to describe 'the utilization of a new or improved technology in an existing product' [24]. It involves researching new technologies (new service development) for supporting exiting products. Technology insertion is in principle a special case of product-related services – an orientation for the delivery of a PSS [25]. In this orientation, products are supplied or sold to customers, and the supplier also opens service channels for

additional services such as upgrades, maintenance and repairs. In terms of technology insertion (PSS delivery for defence), Kerr [24] identified and discussed two main delivery considerations focused on end-users (air force, army and naval personnel), defence departments and industrial providers. Firstly, the need for planning how technology can be inserted at platform-, systems-, equipment and component-levels of a product hierarchy. This planning requires addition considerations for service needs, customer requirements and market/end-user needs. The second consideration involves the adoption of open system architectures and the use of commercial-of-the-shelf (COTS) technologies for technology insertion. Whereas the use of COTS is recommended for reduced costs (as a result of avoiding new specifications), open system architectures offers benefits of accessibility, evolvability, interoperability, maintainability, modularity, portability and scalability [24].

5 MANAGING THE FLOW OF INFORMATION DURING PRODUCT-SERVICE SYSTEMS DELIVERY

5.1 Managing communication for community and interdisciplinary access/exchange of information and for life cycle management

To support accessibility of information during delivery, PSS adopters can identify and implement suitable networks for aiding community communication. Two forms of networks are associated with the flow of information: soft networks that involve gathering knowledge by social interactions; and hard networks that make use of the internet to exploit ubiquitous technologies such as computing, telecommunications and information media [26]. Both networks can be combined for flexibility in communication and interactions with internal and external actors during PSS delivery.

Similarly, to aid information exchanges, PSS delivery can be based on suitable means for communication that take into account factors that affect PSS actors and scenarios such as travelling distance, available resources, customer preference and available resources. Examples of means for communication include electronic mail, facsimile, reports and letters. However, communication by social interactions such as face-to-face contact, word of mouth and meetings remain the richest form of communication. This is because social interactions are natural and informal forms of information exchange for businesses [27].

In a PSS, the ability to manage the flow of information during the life of a provision enables a business to continuously review and improve its operations. This is because information gathering is an internal function that supports PSS delivery and is a life cycle long process [28]. The process of managing information flow may also be standardised for compatibility and continuity in business operations.

5.2 Information systems for defining configurations during delivery

Information systems for managing interactions are important avenues for configuring a PSS. This is because a PSS could be based on centralised or decentralised configurations depending on the type of PSS partnership (or collaboration). PSS configurations may be decentralised to facilitate interactions between customers and manufacturers [29]. PSS configurations may also be centralised for monitoring resources and capabilities of manufacturers. In centralised configurations, main decisions are typically made by upper or senior management as a means of ensuring uniformity in applying policies and procedures.

In terms of improving PSS performance, feed-back and feed-forward paths of information flow for a PSS are also useful avenues for promoting innovation and competitiveness in a PSS. This is because feedback paths based on product market and customer requirements could capture key life-cycle information that could assist service designers in proposing new and cost-effective means for the delivery of a PSS. Similarly, feed-forward paths from the design process centres on the realisation of conceptual models for realising a PSS. Consequently, life-cycle information could drive innovation in a PSS based on the conceptual thinking process during the design phase. The competitiveness of a PSS could also be driven by life-cycle information during the delivery phase for maintaining profitable operations and affordable customer solutions [2].

5.3 Information flow models for conceptual design

Information flow during PSS delivery can be modelled by diagrammatic tools such as data flow diagrams, Integrated DEFinition (IDEFØ) technique, Graphes à Résultats et Activités Interreliés (GRAI) grids and nets, Petri nets, Input-Process-Output (IPO) diagrams and Design Structure Matrices [30]. Data Flow Diagrams analyse information flow within and between organisations or systems. IDEFØ illustrates information flow along with constraints and mechanism which affect system functions. GRAI grids and nets support information flow in decision communication, feedback and review. Petri nets represent automated and event-driven information flow in systems. IPO diagrams describe and document the organisation and logic of information flow. Design Structure Matrix depicts dependency, independency, interdependency and conditionality of information flow for systems and organisations. Morelli [31] recommended that for the conceptual design of a PSS, information flow models such as the IDEFØ technique must be complemented with additional representations for envisioning the scenarios and the use cases in a PSS.

Consequently, modelling information flows for the delivery of a PSS can serve as an enabler for realising PSS objectives and goals. This is because models present depictions of system components or subject area in order to understand, analyse or improve a system [26].

Some important features of a model that are required to define the quality, timeliness, transparency and granularity of information flow during PSS delivery include: interfaces and interconnections of business processes, business inputs and outputs, business functions and processes, and independency, collaboration and distribution within an organisation. When understood, these features can be improved or redesigned for enhanced organisational productivity [30].

A model of information offers a partial view of a PSS. Other models of PSS characteristics required to create a 'complete view' of a PSS include process and cash flow. Formal product/process models support standardisation of operations and must be used in cases where they are mandatory.

In other cases, trade-offs between creativity and conformity during the modelling of information flow in businesses [27]. Creativity in modelling information flow may be individual-focused i.e. designers and engineers are allowed to make use of intuitive and individual approaches for managing information flow. Conformity in modelling information flow on the other hand could be based on the use of a common modelling technique to support collaboration among different working groups.

6 FUTURE RESEARCH FOR INFORMATION FLOW

Figure 2 summarises the main approaches for managing information flow during PSS delivery. It also shows the motivators for PSS delivery (competiveness and innovation, life cycle impact, and value creation) and the benefits of PSS delivery. Focusing on the particular needs of PSS delivery a supplier could manage the flow of information based on:

- A comprehensive approach to capture key customer requirements and PSS needs. This could involve collaboration of technical personnel specific to a domain as well as marketing and distribution staff.
- An exploratory approach that allows flexibility in information access, information exchange and documentation.
- A methodical approach with well defined information access and communication. The flow of information in this case is based on established or pre-defined links and networks.
- A dynamic approach for which information flow modelling could be applied to cope with changes in stakeholder behaviour and non-deterministic characteristics of component lifetime distribution.

For a PSS, these approaches for managing the flow of information could also be considered in terms of their contribution to competiveness and innovation, life cycle impact, and value creation in a PSS. Further considerations could also be made for how replacing one strategy with another may impact a PSS and rationales for strategy selection.

6.1 Capturing Information Flow

Capturing information flow is an activity that offers opportunities to understand a PSS and the information needed during PSS delivery. This is because the design and delivery of a PSS requires the exchange of information so as to understand customer needs and the means to deliver them. Information flow research could focus on capturing information across industry sectors and developing ontology and frameworks for information flow that meet specific customer and manufacturer needs during PSS delivery.

Research in this area could also consider the role of factors such as timeliness, transparency and granularity of information flow for PSS delivery. This is because capturing information flow can require a deal of analysis since a unit of information may present useful information; but when information cumulates to form fragments, this piece, as part of a set, may offer a different meaning. For instance a reported faulty product may suggest a problem in a manufacturing process but a Pareto analysis may reveal a specific faulty tool in a fabrication process. The item of information can serve as an indicator for scope, frequency, source, timing and even accuracy whereas the cumulative or 'grouped' information, much like a system, can identify significance and wholeness for consideration.

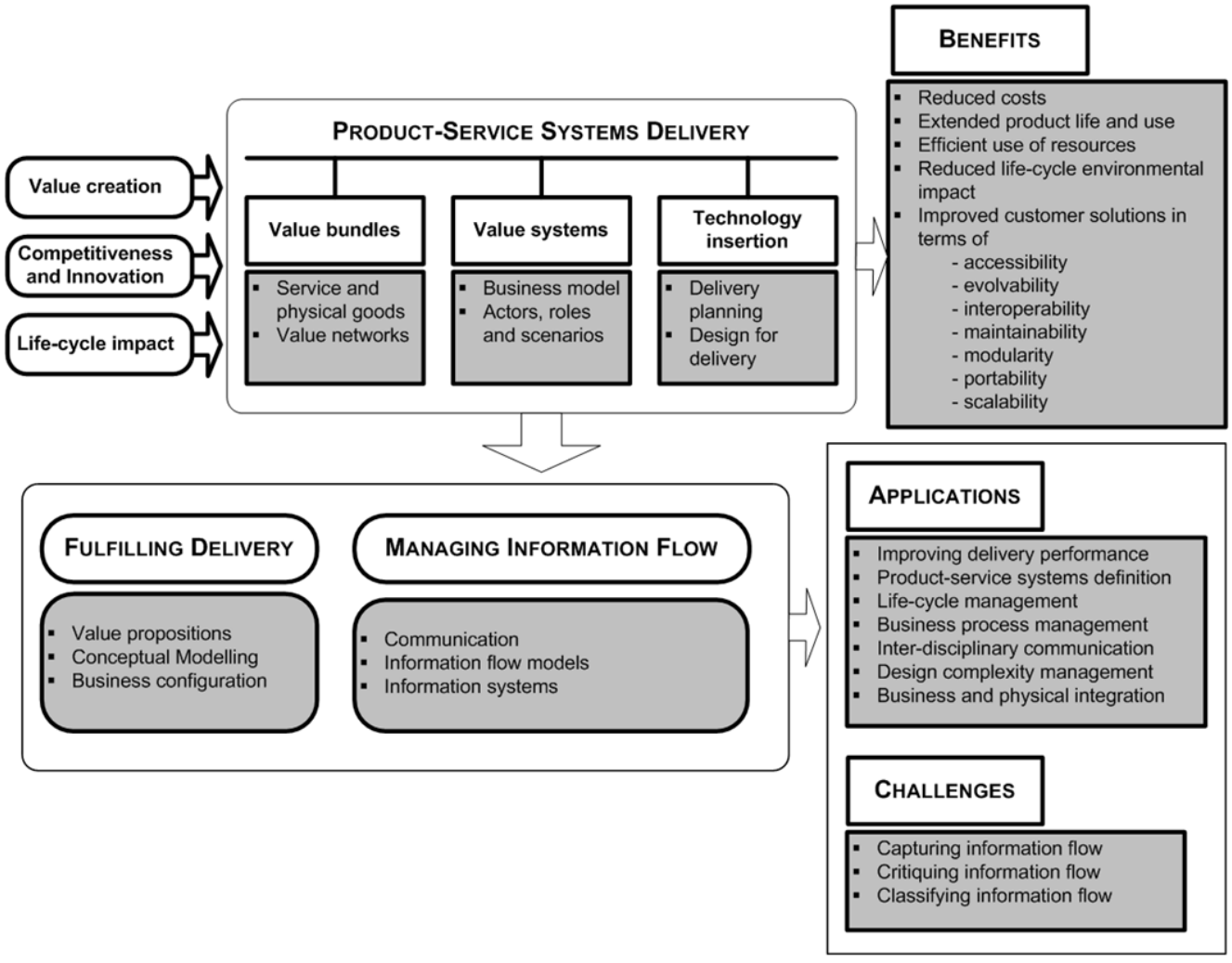

Figure 2: Managing information flows for product-service systems delivery

6.2 Classifying Information Flows

The focus of these research activities may centre on segmenting information flows during PSS delivery or exploiting related flows of information. Further considerations could also be made for the nature of information flow in terms of alternate classifications and orientations of information flows during PSS delivery. Classifications may be based on content (technical, social and economical), access (high-level versus low-level), channels (formal versus informal), direction (upstream versus downstream) and so on.

6.3 Critiquing Information Flow

For this area of research the focus could be to examine the necessity and requirements of information flow in a PSS. This examination may offer clues as to the presence of irrelevant, misinterpreted and redundant information in a PSS. Research in this area could also focus on understanding the interactions in a PSS so that information systems could be designed around communications and interactions.

Studies could also be conducted to examine how reconfiguring a PSS could improve delivery performance. Possible areas for studies include the impact of: standardising the flow of information, outsourcing information flow management or assigning an organisation (or personnel) to manage information flow. Further research could also consider the optimum level and timing of information audits to update and improve the flow of information. Information audits are measures designed to periodically evaluate the flow and processing of information by organisation [6]. This ensures redundant or repeated flows are minimised and inefficient flows are improved.

7 SUMMARY

This paper has attempted to identify approaches for managing information flow during the delivery of a product service system (PSS) with a view to improving PSS delivery performance. A literature review was carried out to examine the approaches for managing information flow during PSS delivery.

The main approaches for managing information flow during PSS delivery were then analysed in terms of: managing communication for community and interdisciplinary access/exchange of information and for life cycle management, information systems for defining configurations during delivery, and information flow models for conceptual design.

Future research challenges for managing information flow during PSS delivery were also highlighted with regards to investigating approaches for capturing, classifying and critiquing information flows.

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