Identifying and categorising knowledge reuse activities in electronic repositories.

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IDENTIFYING AND CATEGORISING KNOWLEDGE REUSE ACTIVITIES IN ELECTRONIC REPOSITORIES

Abstract

Purpose: Knowledge reuse using electronic repositories, while increasingly important, requires more thorough analysis. Service modularity has been recently applied in services research but has not been integrated into knowledge reuse studies. The purpose of this paper is to draw on both service modularity and knowledge reuse to develop and validate a framework that categorizes forms of packaged knowledge in an electronic repository.

Methodology: Drawing on knowledge reuse and service modularity research a model is proposed. The model is empirically tested using a case study research design.

Findings: This research highlights the value of including both context and process as key dimensions when packaging service knowledge for reuse. The study identifies knowledge types present in modular solutions and how they were configured and reconfigured in the knowledge repository. The research identified five ways modularized services were leveraged. In addition to the traditional scale and stretch approaches, already present, but conflated, in the service literature, three other configurations were identified; shrink, separate and segment.

Limitations: The findings are based on a single empirical case study which may limit the generalizability of the findings. There is a need for additional research to further validate the model in additional contexts.

Practical Implications: This study provides managers with empirical examples of how a modular repository was used in practice and outlines five ways of recombining contextual and processual elements to enable service codification and reuse. It has implications for how knowledge is decomposed and recombined in repositories, suggesting an explicit separation of context and process knowledge while developing modular elements within both.

Originality: This is the first study that explicitly uses context and process as dimensions and draws on service modularity to understand types of knowledge reuse in electronic repositories. In doing so it adds value by developing and validating a model that identifies five types of reuse.

Keywords: Knowledge Reuse, Electronic Repositories, Modularity, Service Firm, Case Study.

IDENTIFYING AND CATEGORISING KNOWLEDGE REUSE ACTIVITIES IN SERVICE FIRMS: SCALING, STRETCHING, SHRINKING SEPARATING AND SEGMENTING

Introduction

Knowledge reuse is a central aspect of knowledge management (Hsiao et al., 2006, Markus, 2001, Alavi and Leidner, 2001, Majchrzak et al., 2004, Watson and Hewett, 2006, Akgun et al., 2005). The ability to increase knowledge reuse brings with it benefits (Kogut and Zander, 1992) such as improving work processes (Majchrzak et al., 2013) increasing organizational effectiveness (Markus, 2001) as well as allowing organisational growth using electronic repositories (Hansen et al., 1999). There is existing research on electronic repositories and knowledge reuse (Hsiao et al., 2006, Kankanhalli et al., 2011, Chhim et al., 2017, Filieri and Willison, 2016) with this area recently identified as being of increasing importance (Tams et al., 2020). Nonetheless, it has been argued that there is a need for a more thorough analysis of knowledge reuse using electronic repositories (Chhim et al., 2017) such as how repositories are designed to enable versioning and modification of the codified knowledge (Silventoinen et al., 2014).

The importance of services is increasing (Pekkarinen and Ulkuniemi, 2008, Brax et al., 2017, Gremyr et al., 2019). How service firms leverage knowledge to meet client demands (Coff et al., 2006) is a key, but problematic capability (DenHertog et al., 2010), a solution to which in the services field, is the development of service modularity (Storbacka, 2011). This is a relatively recent (Avlonitis and Hsuan, 2017a), still expanding (Brax et al., 2017), though currently underexplored (Nätti et al., 2017, deMattos et al., 2019) research area, at an early stage of development, both conceptually and practically (Iman, 2016, Brax et al., 2017). Some areas suggested for future research include providing empirical examples of service modularity (deBlok et al., 2010) with Brax et al. (2017) highlighting the need for research to understand technologies as they relate to service modularisation.

While the codification of both context (Bennett and Bennett, 2008, Zollo and Winter, 2002, Walsh, 2014) and process (Aurich et al., 2006, Baxter et al., 2009) are important elements of

knowledge reuse prior research has not used them together to categorise the different ways in which knowledge is packaged for reuse. In addition, while service modularity is seen as a way of codifying knowledge, through the decomposition and recombination of components, this is not present in the knowledge reuse literature (Pekkarinen and Ulkuniemi, 2008, Carlborg and Kindstrom, 2014, Cheng and Shiu, 2016, Laan et al., 2016, Pohjosenpera et al., 2019). The objective of this study is to develop and validate a framework to categorise forms of packaging knowledge in electronic repositories. To do so it will, in the next section, draw on literature on knowledge reuse and service modularity. The integration of this material enables a theoretical model to then be developed and, using a case study, empirically validated. This paper then examines and discusses a number of forms of packaged knowledge.

Literature

Knowledge Reuse

Knowledge reuse is a key concern of knowledge management (Hsiao et al., 2006, Markus, 2001, Alavi and Leidner, 2001, Majchrzak et al., 2004, Watson and Hewett, 2006) with Akgun et al. (2005) positing that reuse is a major justification for KM. It involves the application (Chhim et al., 2017) or reapplication of existing knowledge (Kaner and Karni, 2004) to routine activities or recurring problems (Filieri and Willison, 2016). The more frequently knowledge is reused, the higher the accruing benefits accrue (Kogut and Zander, 1992, Markus, 2001). In addition, firms can grow their business by achieving scale in knowledge reuse through using electronic repositories (Hansen et al., 1999).

In her early seminal literature review of knowledge reuse Markus (2001) distinguishes between knowledge processes focusing on knowledge creation for innovation and what she terms knowledge reuse which involves solving common technical problems and sharing best practices. Later studies use this distinction, albeit with sometimes different terminology; Tan et al. (2007) refers to applying and adapting knowledge while other studies refer to the alternatives as reuse for innovation and reuse for replication (Kyriakou et al., 2017, Majchrzak et al., 2004). While Hsiao et al. (2006) found knowledge reuse problems related to both

innovation and replication most research focuses on one of these reuse processes. Some studies examine reuse in the context of new product development (Bryson et al., 2009, Filieri and Willison, 2016), redesign Ahmad et al. (2013), and innovation, reinventing knowledge as it is reused (Majchrzak et al., 2004). Reuse for innovation results in novelty through integrating old and new knowledge (Kyriakou et al., 2017) and the adaption and integration of knowledge (Tan et al., 2007). It is argued (Majchrzak et al., 2004, Tan et al., 2007) that knowledge reuse for replication draws on the work of Szulanski (2000). This involves applying knowledge (Tan et al., 2007) to solve a particular problem, with no resultant novelty (Kyriakou et al., 2017). Replication is easier where there are clear cause and effect relationships (Majchrzak et al., 2004) and stable knowledge bases, allowing firms to benefit from existing knowledge (Hsiao et al., 2006). Some studies do not refer to reuse for replication but nonetheless their knowledge reuse efforts focus on exploiting existing knowledge (Liu et al., 2013a, Quintana-Amate et al., 2015, Posenato et al., 2019).

Some research examines the role of electronic repositories for knowledge reuse (Hsiao et al., 2006, Kankanhalli et al., 2011, Chhim et al., 2017, Filieri and Willison, 2016). Electronic repositories can facilitate (Kankanhalli et al., 2011) and stimulate (Glomseth and Gottchalk, 2007) knowledge reuse. They enable the systematic capture, transfer and reuse of knowledge, improving its maintenance and use (Rocca and Cooper, 2007) and facilitate flexibility around the management and reuse of knowledge (Rocca, 2012). Once stored in an explicit format (Markus, 2001) repository knowledge can be reused as needed (Akgun et al., 2005). Repositories, while only one aspect of KM in a firm, are becoming increasingly important (Watson and Hewett, 2006, Tams et al., 2020). Research on repositories is important given one of the biggest reasons for disappointment with organisational KM is the lack of knowledge reuse (Dixon, 2000, Minbaeva et al., 2003) with research identifying low KM systems reuse as problematic (Rozwell, 2009).

Knowledge must be codified and packaged for reuse, typically in repositories, as part of employees' work processes (Markus, 2001, Kankanhalli et al., 2011). Knowledge can be captured for reuse in four ways: (1) as a passive by-product of work (2) through structured techniques such as brainstorming (3) through the creation of (pre)structured records such as for 'technical support interventions' and (4) through a systematic filtering, indexing and

packaging and sanitizing knowledge 'after the fact' (Markus, 2001). To be effectively reused knowledge must be codified and stored correctly (Filieri and Willison, 2016). Packaging knowledge involves developing 'knowledge objects' through codification by adding or deleting, as well as filtering and pruning, context (Markus, 2001).

Knowledge can be packaged, in part, using classification schemes to structure and format knowledge (Markus, 2001) through activities such as culling, cleaning structuring, formatting processes using taxonomies (Kankanhalli et al., 2011). A key aspect of knowledge codification for reuse is the capture and codify processes. Knowledge reuse involves the reapplication of knowledge (Tan et al., 2007) including the reapplication of practices (Szulanski, 2000). This can. For example, involve developing a library of codified processes (Aurich et al., 2006). In representing process knowledge Baxter et al. (2009) focuses on prescribing practices as a sequence of tasks to define how products were created and linked to a database of components used in the reuse process. Process knowledge can be codified using 'know-how' as this knowledge type is procedural in nature (Cross and Sproull, 2004, Borgatti and Cross, 2003, Schultz and Leidner, 2002) and can give details of the solution to a given problem (Liu et al., 2013b). It may be improved by 'learning, understanding and applying knowledge' Soo et al. (2002) as employees attempt different solutions to a problem (Lee and Steen, 2010). Know-how is also codifiable, being embodied in processes, activities (Tiwana and Ramesh, 2001) or methods (Eppler, 2008).

In addition to codifying processes it is also useful to codify the context in which those processes are reused. Knowledge relates not only to content to the contexts in which it is useful (Bennett and Bennett, 2008). However, knowledge can be 'sticky and contextualized' making transfer more difficult (Szulanski, 1996) with knowledge ambiguity also acting as a barrier to reuse (Szulanski, 2000, Lippman and Rumelt, 1982, Szulanski et al., 2004). Reuse requires understanding how and why things work potentially making reuse ineffective in different contexts and situations (Brown and Duguid, 2001). Unambiguous knowledge aids repository reuse (Filieri and Willison, 2016). Context codification and the provision of rationales are particularly beneficial when there are time constraints (Zollo and Winter, 2002). By including such rationales employees could specify contexts more precisely, reducing the risk of inappropriate reuse (Walsh, 2014) with successful employees considering the wider

implications of their codified work to related contexts (Walsh, 2015). This is why Bennett and Bennett (2008) distinguish between the content element which represents theories and principles that result in effective action and the proceeding part of knowledge which represents the process of applying that content knowledge. Two types of knowledge can be used to define context, know-what and know-why. Know-what is easily codifiable (Johnson et al., 2002) being declarative (Cross and Sproull, 2004, Borgatti and Cross, 2003, Schultz and Leidner, 2002), encompassing facts (Cheung, 2006, Woitsch and Karagiannis, 2002), concepts (Eppler, 2008) as well as categories, definitions and assumptions (Tiwana and Ramesh, 2001). Defined thus, know-what can be used to define contexts. The inclusion of rationales draws on know-why. This knowledge type involves logical reasoning (Capurro, 2004) related to scientific knowledge (Schultz and Leidner, 2002). It has been described as rule based (Woitsch and Karagiannis, 2002) and declarative (Chandrasekar, 2012) making it suitable for codification. Its value is that it provides an understanding of the principles of cause and effect (Cheung, 2006, Ahlstrom and Nair, 2000) including rationales for actions (Wang and Ramiller, 2009). While its absence does not prevent employees carrying out organisational activities its possession offers deep insights which enable new knowledge to be generated (Ahlstrom and Nair, 2000, Mukherjee et al., 1998).

Based on the type of user and the purpose of reuse (Markus, 2001) outlines 4 reuse situations: shared work producers; shared work practitioners; expert-seeking novices and secondary knowledge miners. Shared work producers, such as software support workers, are homogenous work groups who produce knowledge for themselves which they later reuse (Markus, 2001). They need contextualized knowledge so peers can quickly comprehend the situation and may find it difficult to user records where contextual information has been 'stripped away': however, sharing a common understanding, once they have identified knowledge they have 'little difficulty' in using it, often using sophisticated knowledge management systems (Markus, 2001).

For effective knowledge reuse electronic repositories should be capable of storing knowledge in its original form and context (Bryson et al., 2009). Some, such as Tan et al. (2007), take the position that once captured in a knowledge file, knowledge can be disseminated and reused unproblematically. However, many codified documents are not reused (Chai and Nebus,

2012). Walsh (2015) found that, to get the most value from a repository, there was a trade-off between codifying knowledge narrowly, requiring subsequent dissemination through costly restructuring solutions and broadly written solutions open to the costs of inappropriate re-use. Even where there is a strong case for knowledge reuse in mature industries software support can be lacking (Baxter et al., 2009). Reuse failures include knowledge being captured out of context and a lack of software tools to enable the reuse of captured knowledge (Demian and Fruchter, 2006). While Chhim et al. (2017) argue that previous research on electronic knowledge repositories has focused on knowledge contribution (Kankanhalli et al., 2005b, Wasko and Faraj, 2005, Watson and Hewett, 2006) repository usage (Lin and Huang, 2008, Wu and Wang, 2006) or knowledge seeking (Kankanhalli et al., 2005a, Bock et al., 2010) they argue that knowledge reuse has not been thoroughly examined. A challenge of using information repositories for knowledge reuse is designing repositories to enable a 'dynamic reuse system' that allows the modification and versioning of knowledge, enabling it to improve and evolve over time (Silventoinen et al., 2014).

Service Modularity

Modularity can create value for firms (Pohjosenpera et al., 2019). It reduces process complexity by grouping activities into modules (Zhang et al., 2019, Frandsen, 2017). Modularity initially focused on physical products which were decomposed into independently designed (Baldwin and Clarke, 1997) components (Gershenson et al., 2003) that could be recombined (Schilling, 2000) or re-sequenced (Pohjosenpera et al., 2019). These components provide functional elements (Ulrich and Eppinger, 1995) that, when bundled together, can be reused (Scheidt and Zong, 1994). Modularity improves coordination as modules can be combined to meet customised needs (Zhang et al., 2019). Interconnectedness enables customisation by recombining existing modules (Gremyr et al., 2019). The aim is to package individual component capabilities so that modules are as reusable as possible (Hyotylainen and Moller, 2007). Modularity can facilitate knowledge codification, even where the knowledge was tacit or expert-embedded (Natti et al., 2017). Converting tacit to explicit modular knowledge can be supported by IT tools (Heikka et al., 2018). Developing modular services is easier where the underlying knowledge base was more explicit, such as in engineering firms (Natti et al., 2017).

While developed for physical products some research applies modularity to services and is central to scaling and stretching services. Service modularity helps firms deal with complexity (Silander et al., 2017) improving firm performance (Cheng and Shiu, 2016). It was initially argued that, where input is homogenous, but customers have a variety of needs, modularity allows scale flexibility, but may not increase the scope of service configurations (Schilling, 2000). However, more recently, modularity has been suggested as a tool to achieve the flexibility of tailored offerings with the efficiency of standardisation (Rahikka et al., 2011, Zhang et al., 2019). For services "*modularity provides the basis for customization, yields economies of scale and scope and can help structure products*" (Voss and Hsuan, 2009:543). Some see it as a way of achieving mass customisation (Duray et al., 2000, Pine, 1993, Bask et al., 2011, Carlborg and Kindstrom, 2014). As with product modularity, standardisation and interconnectedness are key to service modularity (Gremyr et al., 2019, Pohjosenpera et al., 2019).

Designing reconfigurable components is central to implementing modularity. Components are the smallest process steps (Pekkarinen and Ulkuniemi, 2008) into which it is meaningful to divide a service (deBlok et al., 2014). A service can be composed of one or more service modules (Pekkarinen and Ulkuniemi, 2008) assembled by selecting from (Carlborg and Kindstrom, 2014) and/or combining (deBlok et al., 2014) from those available modules. Firms engaged in service modularity need to be able to separate and combine components (Cheng and Shiu, 2016). Decomposition can take place at the process level (Laan et al., 2016) with process modularity enabling faster and more flexible problem solving, enabling customized solution development (Natti et al., 2017). This involves processes being modularized through being standardized and categorized into sub-processes (Pohjosenpera et al., 2019). Broekhuis et al. (2017) argue that, in examining decomposition, there needs to be a balance between decomposition that is too broad and generic and detailed 'tree-like' decomposition at multiple levels that is very detailed. Decomposition should minimize dependencies and codify interdependencies among a module's functional parts (Eissens-vanderLaan et al., 2016).

To get the full benefit of modularisation consideration should not only be given to breaking down processes but also to how processes are subsequently combined to make a complete

service process (Carlborg and Kindstrom, 2014). Decomposition should minimise dependencies and codify interdependencies among a module's functional parts (Eissens-vanderLaan et al., 2016). Modular packages provide the ability for components to be used individually to perform specific functions (Ulrich and Eppinger, 1995), but also be mixed and matched as they are combined to suit individual needs (Frandsen, 2017) and enable reuse (Scheidt and Zong, 1994). Technologies need take into account that decomposition should occur in ways that lend themselves to subsequent recombination and resequencing (Pohjosenpera et al., 2019). Therefore, both decomposition and recombination are required in the design of modular services (Giannakis et al., 2018).

While the decomposition and recombination of components has been referred to in the service literature there is a lack of detailed empirical examples, particularly indicating the potential forms they can take and how those forms are codified using information systems. Recently, Pohjosenperä et al. (2019) found information systems for service modularity in hospitals to be problematic while Gremyr et al. (2019) posited more support was needed to 'define and delimit' the outputs of service modules and found a lack of the interconnectedness which is required to enable modules to be recombined.

Model Development

Reuse seeks to explicitly codify customised, knowledge-intensive solutions to clients (Nordin et al., 2011, Sheehan, 2005, Nurmi, 1998) thus leveraging services (denHertog, 2000, Coff et al., 2006, Bettiol et al., 2012). Given services involve events and activities that are procedural in nature (Lee and Steen, 2010, Murray and Peyrefitte, 2007) knowledge processes need to be codified (Baxter et al., 2009, Aurich et al., 2006) then know-how is the appropriate knowledge type to codify such content. Activities or processes are a common denominator of most service definitions (Vargo and Lusch, 2008). Codification of these processes may result in the reuse impediment of causal ambiguity (Szulanski, 2003). This can be ameliorated by using rationales outlining logical reasoning and include an understanding of the underlying reasons and principles for the activities (Capurro, 2004, Cheung, 2006), which are a form of know-why. The other dimension, context, is present in the knowledge reuse literature (Markus, 2001, Walsh, 2014, Bennett and Bennett, 2008) but absent from service research. As this involves declarative, factual statements to create usable categories then know-what

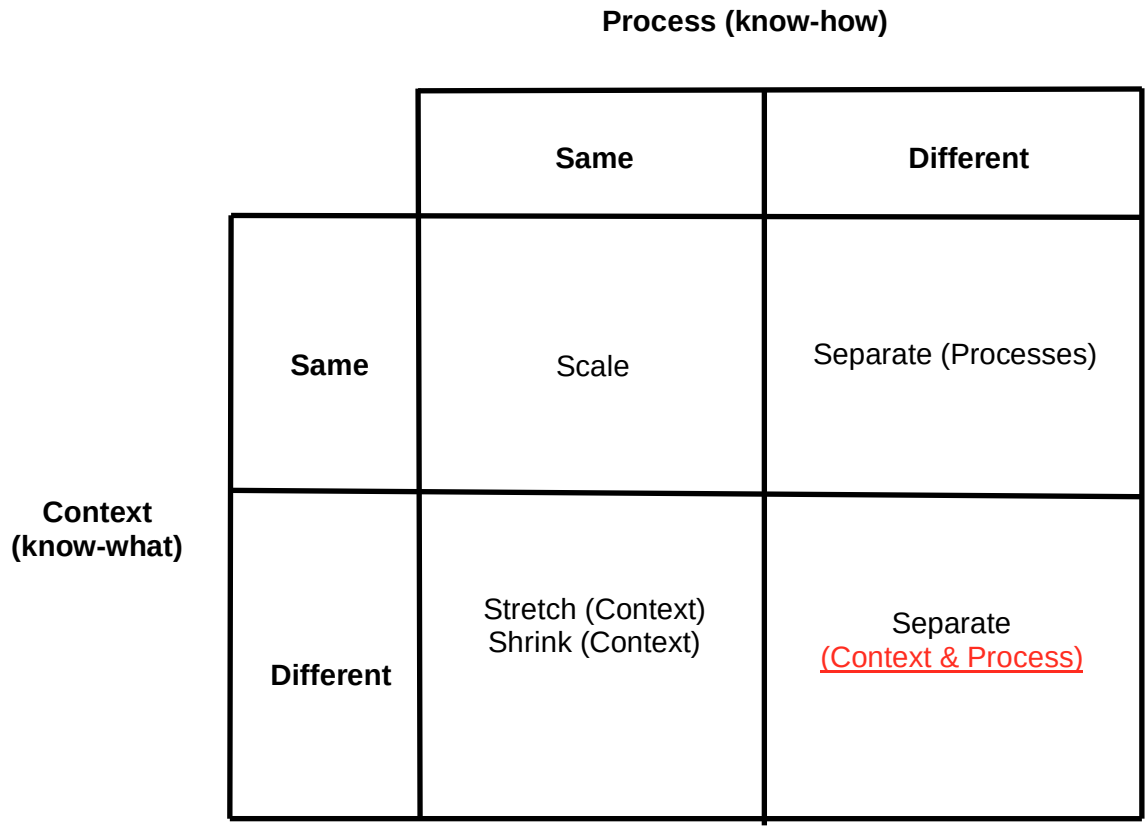
(Johnson et al., 2002, Schultz and Leidner, 2002) is the most appropriate knowledge type to codify context.

When designing services for reuse what constitutes an appropriate measure of similarity between an original and new variation is a matter of debate (Tuunanen and Cassab, 2011). The reuse framework outlined in figure 1 examines the intersection of context (know-what) and process (know-how). Opportunities are categorised based on whether they involve the original, or variant, contexts and processes. This enables the framework to distinguish between a number of forms of reuse. Scale is defined as reuse that does not require any variation in either process or context. It is most valuable when a high degree of service replication is present (Bettiol et al., 2012). Stretch, of context, is defined as situations where the same process is reused while the context (know-what) is varied by making it applicable to a wider range of settings.

While stretch seeks to take advantage of the economics of reuse (Hansen et al., 1999) it is also important to minimise the identified risk of inappropriate reuse (Zollo and Winter, 2002, Walsh, 2014, Walsh, 2015) so that a firm should, as new instances of a situation arise, consider whether the existing context should shrink to more narrowly define the appropriate problem context. We therefore define shrink as instances where the process is unchanged but applicable contexts are narrowed.

The model defines two types of what are termed 'separation'. Both involve modification of service processes. First, separation of processes involves context remaining static while multiple separate processes are developed. This may occur when it is not possible to redefine contexts, more narrowly, as new processes are developed to similar but distinct problems. Therefore, multiple processes are included, with employees identifying the appropriate process from multiple alternatives. Second, it is possible that what was bunded as a single solution to a problem could later be found to contain the solutions to multiple, interrelated problems, which could subsequently occur independently. This would require the separation of both context and processes into separate solutions.

Figure 1: Proposed Framework of Knowledge Repository Categories.



Research Methodology

A single case study was chosen to validate the service knowledge reuse framework. Case studies have been used to explore how knowledge was embodied and disseminated (Hazlett et al., 2008), in the development of a knowledge classification system (Walters et al., 2007). It has been argued that the use of multiple cases, for Eisenhardt (1989) between 4 and 10, is important to increase external validity (Barratt et al., 2011). In contrast, the value of a single case study is that it offers rich contextual insights into the dynamics of phenomena (Dyer and Wilkins, 1991) with fewer cases increasing the depth of observation available (Voss et al., 2002, Prajogo, 2008). Yin (1994) argues that single cases are appropriate where the case is revelatory, critical to theory testing. Cases are also viable when few previous studies exist (Benbasat et al., 1987) with single cases being used to explore research issues at an early stage of formation (He et al., 2009, Prajogo, 2008) for under-explored phenomena (Natti and Palo, 2012).

Case studies can help build (Barratt et al., 2011, Piekkari et al., 2009) test theory (Iacono et al., 2011) and validate models (Dagger et al., 2006). There are various types of case studies

such as intrinsic, instrumental and collective (Jones and Hocking, 2015, Compton-Lilly, 2013). The type of case study in this paper is the instrumental type which examines the specifics of the case so as the generate insights that can be applied to other settings (Jones and Hocking, 2015, Compton-Lilly, 2013). Case selection is based on its ability to its ability to connect local practices and actors to the more general theoretical concepts (Compton-Lilly, 2013). Consequently, for validation "*case is of secondary interest, it plays a supportive role, and it facilitates our understanding of something else*" (Stake, 2000:437). Single cases can identify elements of the framework more specifically (Krull et al., 2012), gain more insights into the framework (Qui and Lui, 2014) and provide examples of how a framework could be applied (Pan and Scarbrough, 1999). This study used a deductive approach, starting with initial concepts that were used when examining data. This paper is similar to papers developed by Jiebing et al. (2013) who also used a single case study to validate a KM related framework, Themistocleous et al. (2004) who evaluated IT integration using a single study and Verner and Abdullah (2012) also used a single case study to examine IT development.

Case Selection

Call centres are a useful sector on which to focus for two reasons. First, information systems are heavily used to codify solutions to clients' problems. Second, depending on the task they require employees from unskilled people to impart standard information to highly qualified personnel that deal with unique and complex problems (Dormann and Zijlstra, 2003) so that work differs in terms of the complexity and variability of the product, the depth of knowledge required of staff and the extent that this knowledge is contextually bounded (Callaghan and Thompson, 2002). While Information technology can promote knowledge reuse (Gold et al., 2001, Markus, 2001) repositories have more chance of success where there is a specific and testable end goal and where the individuals reusing the knowledge occupy similar roles (Gray and Durcikova, 2005).

Call centers use multi-tier service systems (Hasija et al., 2005, Levin, 2009, Maher and Bennett, 2019) with unsolved problems escalating up tiers (Hasija et al., 2005). Tier 0 involves customer self-service, tier 1 escalates enquiries to the call center help-desk while tier 2 is staffed by domain experts (Levin, 2009) with some firms having an even more expert tier 3

(Maher and Bennett, 2019). Tier 1 employees are the least experienced in the firm with experts present at the higher tiers (Maher and Bennett, 2019).

The case company 'Chi-Corp' (a pseudonym) is a multinational corporation supplying hardware and software products for medium to Fortune 100 corporations. It was chosen for several reasons. The firm used an electronic repository to codify knowledge with sections outlining both context and process. The study focuses on Tier 1. While expertise is traditionally the preserve of higher tiers Chi-Corp was different. It dealt with only business customers and the work was knowledge-intensive involving the integration and synthesis of technical knowledge, even at tier 1. Also, as higher tiers focused on escalated cases there was less likelihood of identifying knowledge replication while tier 1 was involved in knowledge reuse for replication for more standard cases while also solving some more difficult cases that required innovation through reuse of existing knowledge.

Research Methods.

The research methods used included; predominantly content analysis to determine the structure and content of solutions in the electronic repository with some support from 23 semi-structured interviews across experience levels and between hardware and software departments, to draw out and develop an understanding of how solutions for reuse were developed. Interviewees included 3 managers, 3 shift leads, 12 experienced product support engineers and 5 novice product support engineers. In addition, participant observation of work being performed as well as observation of training sessions on how to write, structure and search the repository was possible. The following sections examine whether each of the forms of modularity derived from the model was present while being open to identifying additional forms present in the repository. We also examine what knowledge types are present and the ways in which modular solutions are used in practice to achieve knowledge reuse. This study seeks develops analytics generalizations (Yin, 2016) that seek to illustrate how the particular study's findings can inform concepts and theories.

Service Solution Codification

Repository solutions were structured by Chi-Corp into six distinct sections outlined in table 1. The problem context was defined using know-what in the Goals, Environment, Symptoms,

Changes and sections. Know-how, outlined in the Fix section, detailed the series of actions to be followed. The Root Cause section provided a description linking changes to effects and was an example of know-what and could also include a rationale (know-why) if employees believed this aided understanding. Know-why, was also present and used by employees to provide rationales for actions to be taken as detailed in the fix section which defined the process element of the solution. The repository structure illustrates solutions as being composed of different knowledge types with context, defined primarily in terms of know-what and processual elements which involve know-how and, when potentially ambiguous, know-why. As expected, know-what was used to define context, though in Chi-Corp this definition was spread over five discrete parts of a solution.

Table 1: Sections of a Chi-Corp Solution

Solution Section	**Description**	**Knowledge Type**
Goals	The actions performed and documented in the fix	Know-What
Environment	Clients' configuration using terms in a taxonomy of hardware and software environments.	Know-What
Symptoms	Describe problem characteristics and are objective statements detailing occurrences	Know-What
Changes	Changes instituted or attempted by the client	Know-What
Root Cause	Links symptoms (effects) to actions (changes)	Know-What Know-Why
Fix	Outlines the procedure to follow and involves explicitly documenting the sequence of actions taken	Know-How Know-Why

A specific 'fix' section details know-how as processes to be followed and includes sequences of actions to be taken. These could be lengthy and, for complex situations, involve a series of tasks, each comprising sequences of actions.

An examination of solutions in the repository, in conjunction with interviews at all levels in the department, were used to validate the framework. Solution structures were identified and compared with types theorised in the framework (figure 1), as well as seeking to identify if there were additional forms in the repository, not present in the framework. Solutions were found to include forms dealing with both reuse for replication and reuse for innovation.

*REUSE FOR REPLICATION*Three solution categories, scale, context stretching and context shrinking, outlined below, are examples of reuse for replication. Scale and context stretching focus on reusing the same process to the largest extent possible while context shrinking is a mechanism to ensure that replication does not expand to the degree that it would be used inappropriately. "If we take the wrong actions, we can take a client's information systems off-line so they cannot operate." Interview notes (Knowledge Manager).

Scale

The value of reusing codified solutions is dependent on the degree to which the underlying problems reoccur (Sundbo, 1997, Bettiol et al., 2012). For the case company, this happened when the same problem arose among different customers possessing the same hardware and software configuration enabling the same solution to be leveraged through reuse without modification to either context or process. As one interviewee put it "*if you're putting in a specific errorcode it will take you there. It should say if you put in say 04box2.00 or whatever it will actually bring you up the exact solution you should be following right*". To increase the efficiency with which solutions were codified the repository automatically transferred details of the context in which the problem occurred, contained in the environment, symptoms and changes sections, to a new solution template. Employees then included the actions they had taken to resolve the issue. Achieving scale through solution reuse was the main type of solution category present. "*To me 20% to 30% of the time you'll hit the first time. Another 40% of the time it's actually in there and actually a good one in there."* (Experienced product service engineer).

This process was supported through an organisational taxonomy of possible hardware and software environments which were used to populate the 'Environment' section. Employees then documented the fix procedure and, using an organisational taxonomy, defined the goal statement. Where employees feared inappropriate reuse due to ambiguity, rationales, in the form of know-why, were included. This is an example of reuse for replication that exploits existing knowledge without any decomposition or recombination by employees.

Shrink Context

Defining context accurately was important. "*I mean we could sell a product to ten different customers but every one of them would use it differently, because our products will allow that, so you may resolve an issue today that's unique to the customer and write out a solution on it but it may not be suitable again for the other nine customers because but they've the same issue but it manifests itself differently and your solution may not apply*" (Software Manager). Similarly as outlined by a hardware engineer "*so this* [solution] *could be tailored for 65, 68 and it mightn't be for 70 you know. usually it will actually be quite different because I mean the box physically changes as well*".

For new problems, the system automatically pre-populated the context sections of a solution template. As new instances of a problem arose a solution's context might be found to be too broadly defined, with elements automatically included, but not needed. This was remedied by employees manually removing or redefining the know-what in the context sections. In addition to removing unnecessary elements it was possible to explicitly define a context as 'not applicable' (table 5). This allowed the context to shrink over time, more accurately defining the problem context. This form involves reducing the range of contexts over which process replication can take place. It is a way of avoiding negative consequences of inappropriate replication reuse.

Table 5: Narrowing Down Contexts

Environment: Product: PI-CORP Hardware CX4 Series

This statement does not apply: Product: PI-CORP Hardware FC Series PI-CORP Firmware: FLARE Release 19 and later **This statement does not apply:** PI-CORP Firmware: FLARE pre-Release 19

Stretch Context

The context in which a solution was reused could be stretched by adding additional elements to the Environment, Symptoms and Changes sections of the solution (table 2). Stretching of context took place when an existing process was verified as working in a different context so that the process remained the same, but the context was widened. Employees then added the new context to the environment section.

Table 2: Examples of Stretching the Environment Section

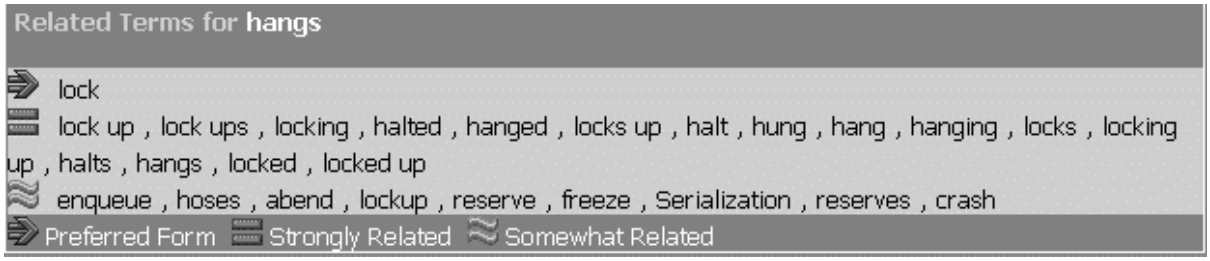
Environment: Product: PI CORP Hardware PX4 Series Environment: Product: PI CORP Hardware PX3 Series Environment: PI CORP Firmware: FLARE Release 19 and later

The degree to which this might occur was partially dependent on the level of granularity of the taxonomies and ontologies used (table 3). The case company used the idea of 'concepts' to link related terms.

> "*A concept is a term or groups of associated terms that convey one idea such as hang, hung, and crash."* Internal Training Document

This form was another example of reuse for replication. Solutions' contexts were modified to increase the opportunity for replication, exploiting existing process knowledge.

Table 3: Ontologies and the use of 'related terms'.



REUSE FOR INNOVATION.

As reuse involves adapting and integrating new and old knowledge (Kyriakou et al., 2017, Majchrzak et al., 2004, Tan et al., 2007) stretching process, separating processes and separating context and process as well as segmentation support reuse for innovation. The former is an example of adapting existing knowledge to new circumstances as they arise by integrating new knowledge. The forms that involve separation support reuse for innovative purposes by adapting knowledge by decomposition, both of process alone and of context and process together. In doing so they provided more modular functional components. The latter category, segmentation is an example of recombining these components to create new knowledge.

Stretch Process

Keeping the process, i.e. the fix section, static was referred to in the case company as a 'one cause-one fix rule'. However, during both interviews and the solution content analysis stage of the research it was found that this formal 'one cause-one fix' was not always followed. *"You can get the same errorcode and it can point to, it can be caused by a lot of different reasons."* Product Support Engineer. An examination of the repository identified instances of process stretching where a single solution provided alternative processes (tables 4). It was facilitated where employees added know-why and know-what in both the 'Root Cause' and 'Fix' sections so that the rationales for and consequences of alternatives were outlined. *"So documenting everything in Primus is great for helping other people know why you're doing such a thing, going down such a road… it may not always be necessary but it is to a certain extent yes it is important to explain why you're doing such a thing."* Experienced Hardware Engineer. While company rules and modularity theory would indicate a need for separation this form was an example of reuse for innovation where processes were adapted by combining new processes with existing solutions into a single component. Rather than

unbundling (alternatives), rationales were used instead as a way of avoiding decomposition of processes into separate solutions. This involved combining alternative processes together within a single 'component'.

Table 4: Stretching Processes

Root-Cause: This will happen when taking a disk from a Windows host ... Fix: There are a number of solutions for this: (1) Should you wish to erase the VTOC from [SYSTEM] you can do this with the solution below... (2) Should you wish to...

Separate Process

The repository allowed both context and process to be altered to manage alternatives. The firm had a 'one cause-one solution' requirement.

> "*There should be only one cause and one fix per* [solution]. *It is possible to have an interim Fix, a Workaround/Circumvention, and a Permanent Fix in a single article. However, this is typically an either/or situation rather than two fixes to one cause."* Internal Standards Document

This would result in employees decomposing processes unbundling them, into separate components. *"There'd be a new solution saying if you've got this this and that then you follow this for the solution* [process] *if you don't then follow something else"* Service Engineer.

Separate Context & Process

The one cause-one fix requirement was achieved by decomposing hitherto entangled solutions. This involved separating alternative processes with initially identical contexts into separate solutions each with its own context and process. However, the inclusion of rationales aided choosing between alternative solutions.

> "*Use a hyperlink to direct users to an alternative article to avoid having them perform another search. For example, there may be an article that solves a problem 80 percent*

of the time. If there is an alternate article that addresses the problem for 20 percent of the readers, use a hyperlink to link the two articles together. Make it clear in the original article that users should go to the hyperlinked article only if the original article does not solve the problem." Internal Standards Document

Segment

When examining repository solutions an additional category, not present in the framework, was identified. When a process-stretched solution became lengthy, it was possible for employees to segment the process into a series of sub-processes. They retained the original solution or 'meta-solution', and developed sub-processes to create new (table 6) 'sub-set' solutions. They incorporated their know-why to point users from the meta- to the sub-solutions. Sub-set solutions were also found to reference their 'meta solution' such as in table 7 where a particular error message is present the reader is directed to another solution. As an experienced support engineer stated outlined *"What you generally would do is link from that solution that I found in* [the Repository] *and then I found a different fix I would either create a new solution and link it from the original one so people would know how to follow it through or if I found one that was very similar then it would maintain it within the same solution."*

Table 6: Run a subset solution

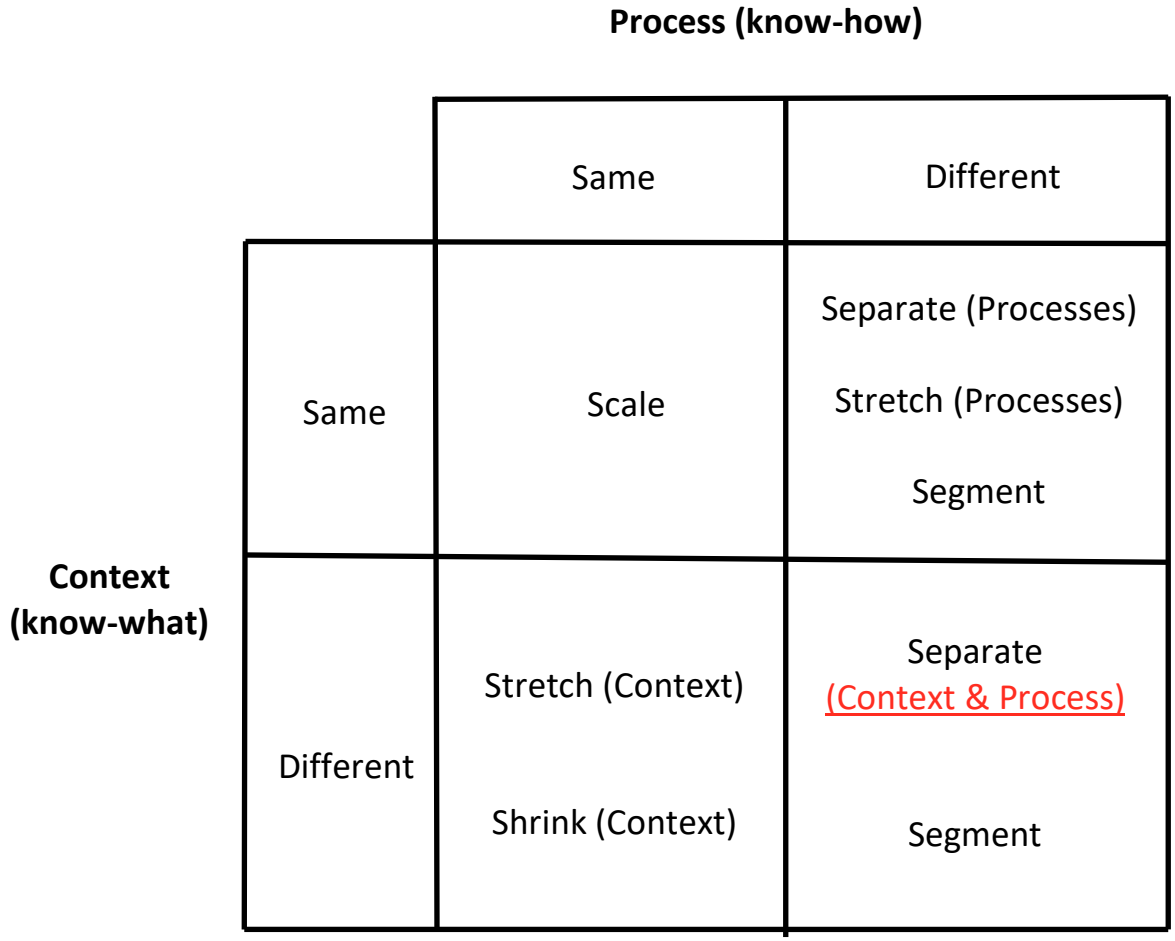
Fix: If the error message reads :JServer reports nas_cmd errors DO NOT RUN THIS PROCEDURE! Reference [INTERNAL REFERENCE CODE] instead...

Table 7: Subset solution reference to parent

Root Cause: This solution is a subset of solution [INTERNAL REFERENCE CODE]

As different processes could refer to the same or similar contexts, depending on how narrowly or widely problems were defined respectively, segmentation is placed in both right-hand quadrants of the revised framework (figure 2).

Figure 2: Framework of Knowledge Repository Categories.



Discussion and Implications

The objective of this study was to develop and validate a framework to categorise forms of packaging knowledge in electronic repositories. Although modularity research is at an early stage of development (Avlonitis and Hsuan, 2017b, Brax et al., 2017) requiring further research (Frandsen, 2017) it is increasingly used by service firms (Storbacka, 2011) as a way to leverage knowledge to stretch and scale activities (DenHertog et al., 2010, Coff et al., 2006). From a knowledge management perspective this was conceptualized as a case of knowledge reuse for replication (Szulanski, 2000). By drawing on the knowledge reuse literature distinction between reuse for replication and reuse for innovation (Kyriakou et al., 2017,

Majchrzak et al., 2004) the model developed in this study, by categorizing forms of packaged knowledge, extends these notions to service modularity. It does so by drawing on knowledge management research to propose a two-dimensional framework that separates service process and context codification leading to the elaboration of five forms in which repositories package knowledge for reuse.

This research illustrates the value of considering process and context simultaneously when considering knowledge reuse. Processes are central to both modularity (Carlborg and Kindstrom, 2014, Pekkarinen and Ulkuniemi, 2008) and knowledge reuse (Baxter et al., 2009, Szulanski, 2000, Aurich et al., 2006). Context, however, is viewed differently in the two literatures. Prior studies focus on services from process perspective (Carlborg and Kindstrom, 2014, Pekkarinen and Ulkuniemi, 2008, Bask et al., 2010). Service research considers context either in relation to standardization (Vargo and Lusch, 2008) where it was static, or to customization (Sveiby and Risling, 1986), where it was unique and so does not need subsequent modification. As service research seeks to leverage knowledge by moving toward modularity (Natti et al., 2017) the role of context requires a more explicit treatment. Existing frameworks categorised service processes as being dynamic or rigid (Carlborg and Kindstrom, 2014). We extend such work by including and relating the role of context to process to better understand knowledge reuse. The KM literature is central to achieving this by addressing the importance of context (Brown and Duguid, 2001) in reuse generally and in electronic repositories (Walsh, 2014, Filieri and Willison, 2016) in particular. Nonetheless, even the knowledge reuse literature considers context and process separately. We are not aware of any study that seeks to use context and process as dimensions to categorize different types of knowledge reuse activities and so this study extends research on knowledge reuse.

In addition, Brax et al. (2017) calls for a better understanding of the role of technologies used for modularization. This paper answers this call by examining the use of electronic repositories for reuse, drawing on similar research in the KM discipline (Hsiao et al., 2006, Kankanhalli et al., 2011, Chhim et al., 2017, Filieri and Willison, 2016). Predominantly, systems, discussed in the service literature, refer to the modularisation of the 'service system' (Rahikka et al., 2011, Dorbecker and Bohmann, 2013). Though the necessity of information

systems is recognised (Pekkarinen and Ulkuniemi, 2008) and their use examined (Bask et al., 2010, Carlborg and Kindstrom, 2014) there is no consideration of how information systems facilitate modularity and reuse. While Pekkarinen & Ulkuniemi (2008) argue that information systems act as a barrier to increased modularity this study found the information system facilitated increased modularity through providing: taxonomies and ontologies to define contexts, automated context definition, the ability to structure and reference elements of a service that enabled both decomposition and recombination.

Although decomposition and recombination of are central activities for modularity (deBlok et al., 2010, Bask et al., 2011, Pohjosenpera et al., 2019), apart from a few studies such as Bottcher and Klinger (2011), those processes are not examined in the services literature. This research identified typologies providing novel empirical examples of decomposition and recombination. Decomposition was used to shrink contexts so that knowledge was not used inappropriately, separate both contexts and processes to create new solutions that focused on narrower issues creating more functional components, and segment lengthy solutions into meta- and sub-solutions. As these segmented sub-solutions were standalone components, they were a way of managing complexity through being recombined in different sequences using new meta-solutions while allowing the components to provide more narrowly defined functions. Therefore, integration of the modularity concepts of decomposition (Natti et al., 2017, Pohjosenpera et al., 2019, Laan et al., 2016) and recombination (deBlok et al., 2014, Schilling, 2000) were useful in understanding forms of knowledge reuse.

Overall, this study finds that both sets of literature can be enriched from concepts present in the other. Given problems with a lack of knowledge reuse (Dixon, 2000, Minbaeva et al., 2003) particularly relating to electronic repositories (Rozwell, 2009) this study provides examples of different forms of packaging knowledge in repositories. Doing so indicates the benefits derived from explicitly identifying context and process as this facilitates subsequent decomposition and recombination of knowledge to take advantage of modularity.

There are also practical implications to this study. When designing repositories, it is beneficial to have separate context section(s) to ensure that employees do not just codify actions but that they also consider the circumstances in which they knowledge should be reused. It is also useful to include functionality to define the context(s) in which knowledge should not be

used. The framework developed in this study indicates that KM managers need to examine repositories to determine, and quantify, the forms in which knowledge is codified for reuse as well as using the framework to assess if alternative forms are appropriate. Employee training should indicate how existing knowledge can be converted between forms as the underlying knowledgebase is better understood using decomposition and recombination.

Conclusions

This study set out to develop and validate a framework to categorise forms of packaging knowledge in electronic repositories. The forms theorised in the framework were identified, indicating the value of defining categories of reusable knowledge in terms of context and process. The forms identified related to reuse for both replication and innovation in a single repository. Rather than consider reuse for replication as a single act of leveraging existing knowledge the framework developed in this paper shows that this may take place in varying ways. In addition to the scale form knowledge for replication also involves stretching context and stretching process. Also, by shrinking context it was possible to reconfigure solutions to not only more accurately match the environment in which they occurred, making searches easier, but this also acted to reduce the risk of inappropriate reuse, inhibiting replication.

Reuse for innovation has traditionally been seen

Limitations:

The model was validated using a single case study of a call centre. While appropriate given our objective to develop and validate our model it is not claimed that the framework or concepts are generalizable to a wider set of service firms but rather that they provide a direction for future research to validate and refine the model using additional knowledge intensive service firms. In particular, given the deterministic nature of the underlying knowledge present in the call centre, additional research with a focus on more ambiguous or interpretively flexible knowledge would provide additional insights. Also, the study involved knowledge reuse among shared work producers: future work needs to consider situations where the knowledge creator and reuser possess less common knowledge. Nonetheless, this

study provides useful guidance for knowledge managers by providing empirical examples of how knowledge repositories can codify service modularity and a framework within which to distinguish and understand them.

Future Research:

Although separate research streams examine knowledge reuse based on whether it is designed for replication or innovation the findings of this study indicate that a repository can store knowledge for both purposes and future research should consider the degree to which knowledge created for these different purposes is separate or symbiotic in nature. While this research focused on identification of categories future research could fruitfully examine how packaged knowledge is reconfigured as it moved between categories over time. While not the focus of this study there were indications, during interviews, that employees had different motivations for if and how they codified solutions. Future studies could use techniques such as structural equation modelling (SEM) to consider the role of motivation on the types of solutions generated by employees. This work also raises questions about whether studies on reuse for innovation, that traditionally focus on phenomena such as new product development, should also consider lower-level day-to-day activities that can enable new knowledge to be created at a more micro-level through decomposition and recombination. Additionally, for service firms that have traditionally focused on reuse for replication through scaling and stretching, there is a need for future research to not only disentangle these conflated concepts but also to consider other categories of reuse for innovation.

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