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A Systematic Mapping Study on Off-The-Shelf-based Software Acquisition

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Abstract

Acquiring software from external suppliers and developing less software in-house can help software-developing organizations improve operational efficiency by reducing costs, time and reusing current technologies. Software projects increasingly use Off-The-Shelf (OTS) products. From the acquirer perspective, there is a need to understand in more detail OTS-based software acquisition processes, because they are different to and less well-understood than those for the acquisition of custom software. In this paper we have undertaken a systematic mapping study on OTS-based software acquisition. The study compares and contrasts OTS-based software acquisition and non-OTS-based software acquisition, and identifies factors influencing decision making in OTS-based software acquisition. We find that the main difference is that there is a relationship between determining the software requirements and OTS selection in OTS-based software acquisition. For commercial OTS software, the major factors are functionality and quality of the software, but for open-source OTS software, cost was the most important factor.

Keywords

Software acquisition, OTS-based software acquisition, process, decision making

INTRODUCTION

Software development projects increasingly use Off-The-Shelf (OTS) products, integrating them into the systems under development. Software-developing organizations can avoid building every part of their product software "from scratch" by reusing technologies available from third parties (Braun 1999). OTS products have been defined as "a commercially available or open source piece of software that other software projects can reuse and integrate into their own products" (Torchiano and Morisio 2004). We follow this definition and class open source software (OSS) as OTS. Acquiring "OTS-based software", i.e. software that itself uses OTS software platforms or components, can be less expensive than acquiring fully custom-developed software. However, there is a need to better understand the OTS-based software acquisition processes, and to understand how such acquisition decisions are made. Most existing studies and guidance on software acquisition do not explicitly deal with the acquisition of OTS-based software. For example, the IEEE Std 1062-1998 Edition: Recommended Practice for Software Acquisition (IEEE 1998) can be applied to software acquisition process regardless of the size and complexity of the software (IEEE 1998). However, this recommended practice is more applicable for fully developed software and must be tailored to other types of software acquisition (IEEE 1998). This has motivated us to investigate both the detailed processes of OTS-based software acquisition, and also how make vs. buy decisions are made in OTS-based software acquisition.

In the context of empirically-based software engineering, our study has used a systematic mapping study or scoping study to map evidence about this topic (Budgen et al. 2008; Kitchenham and Charters 2007). A systematic mapping study is "a broad review of primary studies in a specific topic area that aims to identify what evidence is available on the topic" (Kitchenham and Charters 2007). The main goal of a systematic mapping study is to provide an overview of a research area and to identify the nature and quantity of evidence in a research area (Kitchenham and Charters 2007). This paper presents the process and results of a mapping study to identify, compare and classify a set of primary studies of software acquisition and OTS-based software acquisition.

We use definitions about software acquisition from (IEEE 1998). An acquirer is defined to be "A person or organization that acquires or procures a system or software product (which may be part of a system) from a supplier" and supplier is defined to be "A person or organization that enters into a contract with the acquirer for

the supply of a software product (which may be part of a system) under the terms of the contract" (IEEE 1998). In this paper we use the term "developer" to refer to a "supplier", because the suppliers we consider develop software that itself uses OTS software components or platforms.

The remainder of this paper is organized as follows. Next section discusses related work on software acquisition and OTS-based software acquisition. Following section describes our mapping study protocol including the results. In next section, we discuss the results and analyze the results based on the research questions. Last section concludes the paper.

THEORETICAL BACKGROUND

One of the challenges in software acquisition when acquiring OTS-based systems is the simultaneous definition of system requirements and OTS selection criteria (Brownsword et al. 2000; Morisio et al. 2002). Available OTS products may not be consistent with all defined system requirements for the OTS-based system. Therefore the system requirements, aspects of the system architecture, and OTS selection criteria must all be simultaneously developed. However, there are currently no comprehensive OTS-based software acquisition standards or process models that address this challenge.

In Table 1, we summarize several software acquisition and OTS-based software acquisition process found in the literature. There are four software acquisition processes: IEEE Std 1062-1998 Edition: Recommended Practice for Software Acquisition (IEEE 1998), ISO/IEC/IEEE 12207:2008 Standard for Systems and Software Engineering - Software Life Cycle Processes (ISO/IEC-IEEE 2008), GARP (Generic Acquisition Reference Process) (Gantner and Häberlein 2002; Getto et al. 2000), MPS.BR Model-based software acquisition (Chaves Weber et al. 2007; Montoni et al. 2009). Three OTS-based software acquisition processes are found in the literature: Commercial Off-The-Shelf (COTS) Acquisition Process (CAP) (Ochs et al. 2000), COTS Software Acquisition Meta-Model (SAMM) (Mosko et al. 2000), COTS Software Component Acquisition process framework (CSCA) (Ulkuniemi and Seppanen 2002). Table 1 shows that the only OTS-specific process previously identified is for OTS selection from the perspective of the developers of OTS-based software. This has motivated us to further study OTS-based software acquisition process, using the systematic mapping study reported in the next section.

Table 1. Software Acquisition and OTS-based Software Acquisition Found in the Literature

Model/framework	Software acquisition processes	Generic software acquisition	OTS-based software acquisition	OTS specific processes
IEEE 1062 Recommended Practice for Software Acquisition (IEEE 1998)	Planning organizational strategy, implementing organization's process, determining the software requirements, identifying potential suppliers, preparing contract requirements, evaluating proposals and selecting the supplier, managing supplier performance, accepting the software and using the software	√	-	-
ISO/IEC/IEEE 12207 (ISO/IEC-IEEE 2008)	Acquisition preparation, acquisition advertisement, supplier selection, contract agreement, agreement monitoring, acquirer acceptance, closure	√	Must be adjusted	-
GARP (Gantner and Häberlein 2002; Getto et al. 2000)	Refer to IEEE 1062 (IEEE 1998)	√	-	-
MPS.BR Software Acquisition	refers to IEEE 1062 (IEEE 1998) and ISO/IEC/IEEE	√	-	-

(Chaves Weber et al. 2007; Montoni et al. 2009)	12207 (ISO/IEC-IEEE 2008)			
CAP (Ochs et al. 2000)	Initialization Component, Execution Component and Reuse Component	-	√	COTS selection and evaluation as the basis for a make-or-buy decision
SAMM (Mosko et al. 2000)	Choice phase and implementation phase	-	√	Purchase/iterate approach to select COTS products
CSCA (Ulkuniemi and Seppanen 2002)	Planning, analyzing and evaluating, negotiating, managing and reusing	-	√	Use make vs. buy decision implicitly to select COTS products

METHOD

Our mapping study protocol was created using guidance by Petersen et al (Petersen et al. 2008), adapted by combining last two steps of the protocol.

Research Questions

The research questions in a mapping study are part of the mapping study protocol. Our research questions try to better understand how OTS-based software acquisition processes compare to generic software acquisition processes:

RQ 1. "What are the similarities and differences between (generic) software acquisition and OTS-based software acquisition from the process perspective?"

RQ 2. "What factors influence decision making in OTS-based software acquisition?"

Conduct Search for Primary Studies

A mapping study is based on a systematic literature review using search strings. The search strings can be structured according to population, intervention and outcome (Kitchenham and Charters 2007):

1. Population: published articles including empirical studies, industry and government experiences in the software acquisition domain
2. Intervention: processes, practices and techniques in software acquisition
3. Outcomes: quantity and type of software acquisition and OTS-based software acquisition processes, practices and techniques.

The search string defined in this mapping study is based on keywords from the research questions. The keywords "software procurement" and "software purchase" are also used as synonyms for "software acquisition". To extend the search, we also used "COTS", for commercial-off-the-shelf and "OTS" for off-the-shelf combined with one of the following strings: "acquisition", "procurement" and "purchase". All of the strings are combined using Boolean ORs and AND to construct the search string used in this mapping study. The search string is: **"software acquisition" OR "software procurement" OR "software purchase" OR ((cots OR ots) AND (acquisition OR procurement OR purchase)).** The search results using the search string are shown in Table 2 describing publication resources, years of publication, advanced search methods for each of the publication and results. We used Zotero ("Zotero" 2011), a bibliography management tool, to manage literature search results.

Table 2. Search Results Using the Search String

Resource	Year	Advanced search	Query Result
ACM Portal	1985-2010	Title, abstract, keywords	16
IEEE Xplore	1998-2010	Title, abstract, indexing terms	172
Springerlink	1998-2010	Title, abstract	42
Elsevier	1984-2010	Title, abstract, keywords	36

Wiley InterScience	1990-2010	All Fields, all subjects and Journals	51
Citeseerx	1998-2008	Title, abstract, keywords	86
Manual using Google Scholar	1997-2009	- (manual searches)	9

Screening of Publications for Inclusion and Exclusion (Relevant Publications)

Explicit inclusion and exclusion criteria were used to filter the search results to those publications relevant to the research questions.

1. Inclusion: books, papers, technical reports, reference models and standards that relate to software acquisition process. For several publications reporting the same study, the one published in a peer reviewed publication was used, or else the most recent one. Where one paper reported several studies, each relevant study was treated separately.
2. Exclusion: hardware acquisition, acquisition risks only, papers not related to the software acquisition process.

Table 3 provides the refined results of the relevant papers after inclusion and exclusion criteria were applied. The results are classified as relating to (generic) software acquisition and OTS-based software acquisition.

Table 3. Refined Results after Publication Screening

Resource	Software acquisition	OTS-based software acquisition	Total
ACM	1	3	4
IEEE	13	19	32
Springer	8	16	24
Elsevier	5	5	10
Wiley InterScience	4	6	10
Citeseerx	1	5	6
Manual using Google Scholar	7	2	9
Total	39	56	95

Data Extraction and Mapping of Study (Systematic Map)

The data extraction process in a mapping study uses a classification scheme (Kitchenham and Charters 2007). In this paper we used keywording of abstracts (Petersen et al. 2008) as a technique to extract data. The keywording was conducted by reading abstracts and identifying keywords reflecting topics under investigation. In the case of insufficient information provided by the abstracts and keywords, we also read the introduction and conclusion of the paper.

In order to identify direct evidence from primary studies, we defined in the study protocol a classification of software acquisition processes based on IEEE 1062 Recommended Practice for Software Acquisition (see Table 1, first row) (IEEE 1998). These processes are: Planning organizational strategy, implementing organization's process, determining the software requirements, identifying potential suppliers, preparing contract requirements, evaluating proposals and selecting the supplier, managing supplier performance, accepting the software and using the software. This topic classification was used to map data extracted from the publications.

During the keywording process, new sub-categories were identified and added into the topic classification based on screening results that could not be classified into the topic classification sub-categories but suited the population, intervention and inclusion criteria. Because the purpose of this mapping study was to identify process similarities and differences between software acquisition and OTS-based software acquisition, the mapping study separated publications into two different classes: (generic) software acquisition and OTS-based software acquisition. After finishing the keywording process, new topics were added as sub-categories, as shown in Table 4. For the (generic) software acquisition classification, six new topics were added: decision making: make vs. buy, modeling and simulation, software acquisition improvement, process life cycle, architectural decision and relationship between developer and acquirer. Seven new topics were added to the OTS-based software

acquisition classification: decision making: make vs. buy OTS products vs. use OSS, process life cycle, architectural decision, OTS selection, relationship between OTS adoption and acquirer's organization, relationship between OTS vendor and developer and relationship between developer and acquirer. A process life cycle topic was also added to both of the software acquisition classifications.

Table 4. Number of Mapped Publications of Software Acquisition Classification

Process	Number of publications in each (generic) software acquisition topic	Number of publications in each OTS-based software acquisition topic
Planning organizational strategy	1	1
Implementing organization's process	-	1
Determining the software requirements	-	14
Identifying potential suppliers	1	1
Preparing contract requirements	-	1
Evaluating proposals and selecting the supplier	5	2
Decision making: make vs. buy (also vs. buy OTS products vs. use OSS for OTS-based software acquisition classification) (*)(+)	6	7
Process life cycle (*)(+)	14	8
Architectural decision (*)(+)	1	6
Modeling and simulation (*)	5	-
OTS selection (+)	-	31
Relationship between developer and acquirer (*)(+)	3	1
Software acquisition improvement (*)	7	-
Relationship between OTS adoption and acquirer's organization (+)	-	1
Relationship between OTS vendor and developer (+)	-	1
Total	43	75

Legend: (*): new topics added to software acquisition classification, (+): new topics added to OTS-based software acquisition classification

Three initially-proposed software acquisition topic sub-categories (IEEE 1998) were deleted because there were no matching results from the primary studies. The deleted topics were: managing supplier performance, accepting the software and using the software.

After finishing the keywording and classifying the primary studies based on software acquisition and OTS-based software acquisition topics, the frequencies of primary studies was determined, as shown in Table 4. Our discussion as follows is based on this table and on a thorough reading of the identified publications.

DISCUSSION

This section provides a discussion to answer the research questions.

RQ 1 "What are the similarities and differences between (generic) software acquisition and OTS-based software acquisition from the process perspective?"

OTS-based software acquisition is the acquisition of software that itself uses OTS software platforms or components. We identified OTS-based software acquisition processes from the literature, and compared these with a process standard for software acquisition (IEEE 1998). The differences between these processes concern the acquisition of OTS products (Mosko et al. 2000; Ochs et al. 2000; Ulkuniemi and Seppanen 2002) and also relate to the influence of the use of OTS products on software development approaches (Brownsword et al. 2000; Li et al. 2006; Morisio et al. 2002). Traditionally, software development starts with system requirements

definition, then defines the system architecture, and continues with implementation. In OTS-based systems development, there is simultaneous definition and tradeoff among the OTS marketplace, system requirements, and system architecture and design (Brownsword et al. 2000; Li et al. 2006; Morisio et al. 2002).

Even though not all the standard software acquisition processes (first row, Table 1) exist among the software acquisition processes identified from the literature (Table 4), both cover the life cycle (IEEE 1998). The standard identifies processes for managing supplier performance, accepting the software and using the software (IEEE 1998), which were not found in the primary studies. However, the primary studies include implementing the organization's process, determining the software requirements and preparing contract requirements topics, which are not found in the software acquisition standard. Elgazzar et al. (Elgazzar et al. 2005) discuss the planning and contracting phase of OTS-based software acquisition stressing the impact of OTS on requirements and contract structure.

There are some commonalities between (generic) software acquisition and OTS-based software acquisition. One common process involves decision making to make or buy software, but a particular condition of OTS-based software acquisition is the consideration of use of third party Commercial Off-the-Shelf (COTS) products (Seibel et al. 2006), Enterprise Resource Planning (ERP) systems (Keil and Tiwana 2006), and open source software (OSS) (Holck et al. 2005b; Morgan and Finnegan 2010). Another commonality concerns making architectural decision during software acquisition (Briand et al. 1998). These should be suited to organization's needs (Briand et al. 1998), corporate governance (Holck et al. 2005a), and system architecture (Albert and Brownsword 2002). Another common concern is the nature of the working relationship between developers and acquirers, through cooperation, integration and establishing familiarity (Aigner et al. 2004; Haglind et al. 1998; Heiskanen et al. 2000; Holck et al. 2005a).

Two processes were found for generic software acquisition during the literature search that is not referenced in the software acquisition standard: modeling and simulation, and software acquisition improvement. However, there was no explicit mention of these processes within the OTS-based software acquisition literature. These can be viewed as gaps in the literature.

The main difference from generic software acquisition introduced by OTS-based software acquisition is the relation between OTS selection and determining the software requirements. As shown in Table 4, 31 of the total 75 publications on OTS-based software acquisition concern OTS selection. This indicates that in OTS-based software acquisition classification, OTS selection is a key process. As can be inferred from Table 4, OTS selection not only influences user requirements, but also architectural decisions (Albert and Brownsword 2002). In regard to software requirements, OTS selection is intertwined with software requirement definition (Albert and Brownsword 2002) to avoid risk in OTS selection (Shaffer and McPherson 2002). Along with determining software requirements and performing OTS selection, architectural decisions are also defined and adjusted iteratively to build an OTS-based system solution (Albert and Brownsword 2002). In OTS-based software acquisition, these three processes are intertwined because OTS product selection cannot be conducted after architectural design. This is because an architecture designed without awareness of available OTS components is unlikely to find appropriate OTS products to meet its needs (Albert and Brownsword 2002).

There are relationship and organizational issues that must be addressed in OTS-based software acquisition. Two specific issues in OTS-based software acquisition that do not occur in generic software acquisition concern the relationship between the (third-party) OTS vendor and the acquirer organization, and the relationship between the OTS vendor and developer. In regard to organizational issue, OTS-based software acquisition must consider several characteristics of the organization and its personnel (Ball et al. 1987). Finally, a long-lasting and deep partnership relationship between the OTS vendor and the developer can provide benefits in the commercial negotiations with the acquirer (Helokunnas and Nyby 2006).

In sum, OTS product selection is a significant process in OTS-based software acquisition that distinguishes it from generic software acquisition process (IEEE 1998). Existing software acquisition standards and processes (IEEE 1998) must be adjusted to accommodate the impact of third-party OTS components in software acquisition.

RQ 2 "What factors influence decision making in OTS-based software acquisition?"

We analyzed the 7 papers covering the issue of the "make vs. buy decision" related to OTS-based software acquisition classification found in this study (summarized in Table 5). We mapped these papers into a generic make vs. buy decision framework (Cánez et al. 2000), as shown in Table 6. The framework incorporates multiple attributes. There are two components of the framework are used here: triggers and areas of consideration. The triggers are "the reason(s) for undertaking the make-or-buy review and can be easily identified by asking why is the decision being made" (Cánez et al. 2000). Areas of consideration are clusters of relevant factors for make vs. buy decision making (Cánez et al. 2000). In this section, we detail mapping of these papers into the two components of the framework.

Table 5. Seven Factors Influencing OTS-based Software Acquisition Make vs. Buy Decision Found in this Study

Publication ID	Publication	Factors
D1	(Morgan and Finnegan 2010)	Technological, organizational, environmental and individual
D2	(Salter and Buede 2001)	Business processes, IT strategic planning
D3	(Keil and Tiwana 2006)	Enterprise Resource Planning evaluation criteria (functionality, reliability, cost, ease of use and ease of customization)
D4	(Seibel et al. 2006)	COTS upgrade decision based on: Meets Business Goals, Application's Impact on Productivity and License Cost
D5	(Holck et al. 2005b)	Information technology (IT) architecture and economic
D6	(Feblowitz and Greenspan 1998)	Enterprise-level impacts on sofware acquisition decision
D7	(Schneidewind 1999)	Cost

Table 6. Mapping of the Identified Literature (summarized in Table 5) into Multi-Attribute Decision Making Framework (Cánez et al. 2000)

Multi-Attribute Decision Making Framework	Publication ID (from column 1 Table 5)						
	D1	D2	D3	D4	D5	D6	D7
1. Trigger							
1.1. Cost reduction			x	x	x		x
1.2 Increase system quality			x	x			
1.3 Enterprise-level impacts						x	
2. Cluster areas of consideration							
2.1 Technology and Manufacturing Process			x		x		
2.2 Support System	x	x					

As can be seen from Table 6, economic/cost, as expected, is a common trigger in the framework. Cost reduction is the most important factor in open source usage in small organizations (Holck et al. 2005b). However, consistent with COTS application value studies (Keil and Tiwana 2005, 2006), cost is the third most important attribute after functionality and reliability when selecting COTS products. In COTS upgrade decisions (Seibel et al. 2006), "Meets Business Goals" and "Application's Impact on Productivity" take precedence over cost. Cost is not only the upfront cost but also ongoing costs including for COTS upgrades (Keil and Tiwana 2006; Seibel et al. 2006). Two of the COTS upgrade factors (Seibel et al. 2006), "Meets Business Goals" and "Application's Impact on Productivity" can be mapped into increase system quality as they are the answer of why is the decision being made (Cánez et al. 2000).

In the Enterprise Resource Planning (ERP) domain, Table 6 shows how the factors reported in publication ID D3 (Keil and Tiwana 2006) are mapped into the triggers and considerations of the decision framework (Cánez et al. 2000). The functionality and ease of use criteria (Keil and Tiwana 2006) are triggers of making decision in the framework (Cánez et al. 2000) by deciding useful features to be implemented and make them easy to use to increase system quality. In addition, the reliability criterion (Keil and Tiwana 2006) also concerns to increase system quality. Furthermore, ease of customization (Keil and Tiwana 2006) can be mapped to Technology and Manufacturing Processes (Cánez et al. 2000), one of the factors of the framework concerned with adapting the system to change.

Three other publications can be mapped into the framework (publication ID D5, D1 and D2). Firstly, benefit of OSS (also regarded as OTS) adoption into IT architecture (Holck et al. 2005b) is an example of a technology-

related factor in software acquisition decision making. Secondly, OTS-based software acquisition can support organizational processes by using information technology management to align external system development with internal business processes (Morgan and Finnegan 2010) (Salter and Buede 2001).

Feblowitz and Greenspan present a method for determining Enterprise-level impacts on software acquisition decisions (Feblowitz and Greenspan 1998). The authors' work enriches the triggers of the existing make vs. buy decision framework (Cánez et al. 2000) by adding OTS-based scenario-based analysis. The proposed scenario-based analysis of COTS acquisition impacts (Feblowitz and Greenspan 1998) can add reasons for make vs. buy decisions by asking "why" questions to justify the trigger of the decision to acquire OTS-based software.

In sum, in OTS-based software acquisition, the make vs. buy decision is a multi-attribute decision making process, where the acquisition decision is not only based on cost but also the other factors as mentioned above.

CONCLUSION

OTS-based software acquisition is the acquisition of software that itself uses OTS components or products. We have presented the findings of a systematic mapping study on OTS-based software acquisition. We have suggested that for OTS-based software acquisition, changes should be made to existing software acquisition process standards (IEEE 1998), and also to how make vs. buy decisions are made.

Both generic and OTS-based software acquisition have the same overall process lifecycle. The main difference in OTS-based software acquisition is that there is a relationship between determining the software requirements and OTS selection. Almost half of publications covering OTS-based software acquisition concern OTS selection. OTS selection is also related to architectural design (Haglind et al. 1998). Together, architecture and OTS selection criteria are defined and adjusted iteratively to build an OTS-based system solution (Haglind et al. 1998). Two additional impacts in OTS-based software acquisition concern the relationship between the OTS vendor and the acquirer's organization, and the relationship between the OTS vendor and developer.

The make vs. buy decision in OTS-based software acquisition is based on multi-attribute decision making. The primary factors are functionality and quality in selecting COTS products – cost is secondary (Keil and Tiwana 2005, 2006; Seibel et al. 2006). However, when deciding to use open source components in small organizations, cost reduction is typically the most important factor (Holck et al. 2005b). Other factors that are considered when deciding on make vs. buy of OTS product are increase responsiveness, enterprise-level impact, technology-related factors, and the support system.

This paper provides a basis for future work, including the proposal of detailed OTS-based software acquisition processes identified in this study. Additional future study may empirically investigate the details of the relationships among acquirers, developers and OTS vendors.

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