A Systematic Mapping Study on the Current Status of Total Cost of Ownership for Information Systems

Görkem GİRAY[1], Eray TÜZÜN[2]

[1]Independent Researcher, İzmir, Turkey
[2]Department of Computer Engineering, Bilkent University, Ankara, Turkey
gorkemgiray@gmail.com, eraytuzun@cs.bilkent.edu.tr
(Geliş/Received: 10.07.2017; Kabul/Accepted: 23.02.2018)
DOI: 10.17671/gazibtd.327544

***Abstract*—**More and more organizations are being run dependent on information systems. This makes information systems a pivotal component of our lives. Because of globalization and harsh competition, strategic cost management has become essential to keep or gain competitive advantage. These two trends make the investigation of Total Cost of Ownership (TCO) for information systems crucial. To this end, a systematic mapping study (SMS) is presented to identify the use of TCO in information systems context. A summary of the findings after analyzing and synthesizing 75 relevant publications are as follows: (1) an increased interest in TCO for information systems is observed over the years; (2) 76% of the selected publications lack validation and evaluation; (3) the main motivation behind the 72% of the publications is reduction of TCO; (4) essential means of reducing TCO are cloud computing, SaaS model, and multi-tenancy; (5) TCO calculations are also generally made to compare cloud-based infrastructures with in-house infrastructures and SaaS model with on-premise software; (6) TCO is an important criterion in making investment decisions for information systems such as ERP, CRM.

***Keywords*—**Total cost of ownership, cost management, information systems, software-intensive systems, business applications, systematic mapping study

Bilgi Sistemlerinin Toplam Sahip Olma Maliyetinin Mevcut Durumu Üzerine Bir Sistematik Haritalama Çalışması

***Özet*—**Giderek daha fazla sayıda organizasyonun faaliyetleri bilgi sistemlerine bağımlı duruma gelmektedir. Bu da bilgi sistemlerini hayatımızın önemli bir bileşeni durumuna getirmektedir. Küreselleşme ve sert rekabet koşulları nedeniyle, rekabet avantajı elde etmek ya da bunu korumak için stratejik maliyet yönetimi vazgeçilmez bir konuma gelmiştir. Bu iki eğilim, bilgi sistemlerinin toplam sahip olma maliyetinin (TSOM) hesaplanmasını önemli kılmaktadır. Bu amaçla, bilgi sistemleri bağlamında TSOM kullanımını irdelemek için bir sistematik haritalama çalışması sunulmuştur. Konuyla ilgili 75 yayın analiz edildikten ve sentezlendikten sonra elde edilen bulguların bir özeti şu şekildedir: (1) bilgi sistemleri için TSOM'a yıllar boyunca artan bir ilgi gözlemlenmektedir; (2) seçilen yayınların %76'sı geçerlilik ve değerlendirme eksikliği taşımaktadır; (3) yayınların %72'sinin arkasındaki en büyük motivasyon, TSOM'un azaltılmasıdır; (4) TSOM'u azaltmanın vazgeçilmez araçları bulut bilişim, servis olarak yazılım modeli ve çoklu kiracılıktır; (5) TSOM hesaplamaları genellikle bulut tabanlı altyapıları kurum içindeki altyapılarla ve servis olarak yazılım modeli ile kurum içi yazılımları karşılaştırmak için yapılmaktadır; (6) TSOM, bilgi sistemleri için (kurumsal kaynak planlama, müşteri ilişkileri yönetimi sistemleri gibi) yatırım kararlarında önemli bir kriterdir.

***Anahtar Kelimeler*—**Toplam sahip olma maliyeti, maliyet yönetimi, bilgi sistemi, yazılım yoğun sistem, iş uygulamaları, sistematik haritalama çalışması

1. INTRODUCTION

More and more industries and businesses are being run on software, making information systems a pivotal component of our lives. Along with the globalization and harsh competition in the information era, strategic cost management has become an important medium in gaining or keeping a competitive advantage. It presents some opportunities for decision-making improvements in most organizations [1] and takes a broad view of an organization's costs to enhance competitive advantage [2].

Information and Communication Technologies (ICT) related costs have an important share in most of the organizations' budgets. Most organizations are doing and enhancing their business using ICT. In this regard, information systems have become essential components of most organizations. According to [3], "an information system is a software system to capture, transmit, store, retrieve, manipulate, or display information, thereby supporting people, organizations, or other software systems". They are bringing efficiencies, providing important services along with their costs. When assessing the costs and benefits of an information system, it is important to consider all the costs associated with its life cycle, i.e. TCO for that information system.

With the penetration of information systems into organizations, they have become an important item in strategic cost management. Therefore, it is important to conduct TCO analysis for information systems to support an organization-wide strategic cost management. In this systematic mapping study (SMS), we focused on the research done on TCO for information systems. We present the current situation and provide some research directions for future studies.

The remainder of the paper is structured as follows: Section 2 presents the background and the related work. Section 3 explains the research method used in this SMS. Section 4 presents the results along with our comments. Section 5 concludes the paper as well as presenting the future work.

2. BACKGROUND AND RELATED WORK

To the best of our knowledge, there is no SMS on TCO for information systems. There are some studies in grey literature such as [4]. In this SMS, we exclude grey literature and focus on studies made in academia.

TCO is a concept aiming at understanding the relevant costs of purchasing a particular good or service from a particular supplier [1]. TCO concept expands the notion of purchasing cost by combining the life cycle cost effects with the acquisition price [5]. Wouters et al. define TCO as an application of Activity-based Costing that quantifies the costs that are involved in acquiring and using purchased goods and services [6]. Garfamy states that TCO focuses on the true costs associated with the entire purchasing cycle, thus it considers all costs related to the acquisition, usage, maintenance and follow-up of purchased goods or service as well as purchasing price [7].

Considering all definitions, TCO for an information system encompasses all the costs associated with its life cycle. Hereby, the life cycle of an information system refers to the entire time from the idea of developing the system to the end of its life. An information system includes more than one component, namely hardware, software, network related subsystems and humans. These components can be realized by purchasing a good or service. For instance, a server (a good) or a hosting service (a service) can be purchased within the scope of an information system. Moreover, a software component can be purchased (as on-premise or SaaS) or can be developed in-house.

A typical information system should be maintained due to changes in business requirements, legal responsibilities, hardware, communication standards, etc. Therefore, many activities are done during the life cycle of an information system, such as governance, development, and operations. Galberaith and Kyte define TCO for an information system as the full lifetime costs of that system having five key components [8]: cost to implement, cost to operate, costs to support and maintain, costs to enhance and extend, and cost to decommission.

A TCO analysis can be used for many reasons [1], such as

- selecting a supplier and/or system,
- deciding on whether to develop or procure a system or some part of it,
- supporting evaluation of bids and requests for proposals,
- driving improvement, such as performance improvement, process improvement, reducing costs.

These reasons are also applicable to TCO analysis for information systems and drive strategic cost management activities within an organization. To this end, we systematically reviewed the literature on TCO for information systems using a well-defined research method.

3. RESEARCH METHOD

In this study, we used SMS as the research method. SMS is a kind of secondary study, which provides a broad review of primary studies in a specific topic area that aims to identify what evidence is available on the topic [9]. Secondary studies review all the primary studies related to a specific research question (RQ) with the aim of integrating/synthesizing evidence related to a specific RQ [9]. SMS provides evidence by categorizing the results of the primary studies [10]. Moreover, visual aids (such as graphs) are generally used for presenting high-level findings.

This SMS was performed by following the guidelines and process proposed by [10], [11]. The main steps of the process are as follows:

- Identifying the RQs
- Identifying the search string and searching for publications
- Applying exclusion criteria for obtaining relevant publications
- Identifying and refining attributes to build a classification scheme
- Performing systematic mapping by extracting data

Figure 1 illustrates the steps of the process and the artifacts using Business Process Model and Notation (BPMN). The process is iterative; feedbacks are provided to previous steps to produce results of high quality. Identifying and refining attributes provide insight in fine-tuning the existing RQs and finding out new RQs.

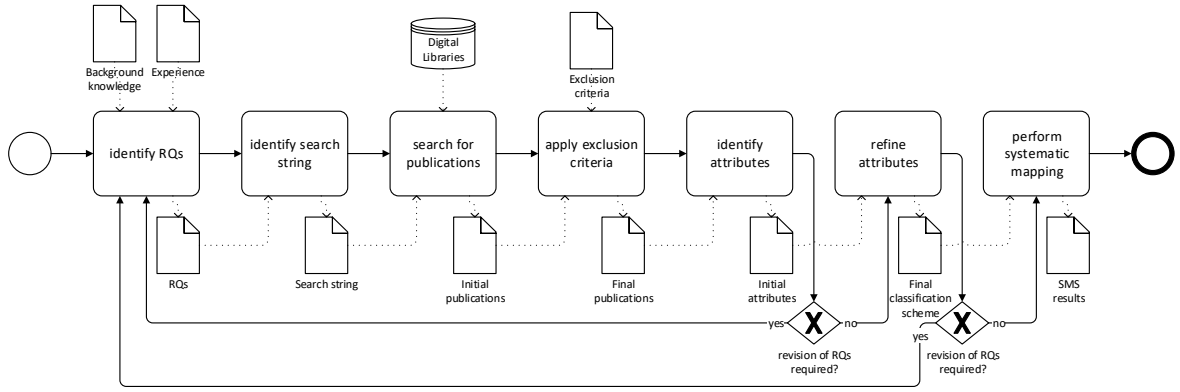


Figure 1. The process used in this SMS

3.1. Research Questions

The objective of this SMS is to structure the research on TCO for information systems. Based on our academic and industrial experience on information systems, we defined the following RQs:

- RQ1: What is the annual number of publications and which trends can be observed in terms of the number of publications over time?
- RQ2: What is the distribution of studies between academia and industry according to the authorship?
- RQ3: What type of research has been conducted related to TCO for information systems?
- RQ4: What is the main motivation, which is related to TCO for information systems, of the research?
    - RQ4.1: What are the main objectives of calculating TCO for information systems?
    - RQ4.2: What are the means for reducing TCO for information systems?
    - RQ4.3: What are the decisions made based on TCO for information systems?

We refined these RQs while identifying the initial attributes and final classification scheme since we obtained more information while reviewing the publications. This feedback loop has increased the quality and enhanced the scope of this SMS. For instance, RQ4.1, RQ4.2, and RQ4.3 have been identified after building the final classification scheme.

3.2. Search in Digital Libraries

Before conducting a search on the academic digital libraries, we identified the search terms. We used "total cost of ownership" as one of the mandatory search terms. To search the publications related to information systems, we used "information system", "software", "application", and "program" as search terms. These terms are combined using OR operator. The resulting search string is as follows:

(("total cost of ownership") AND (("information system") OR (software) OR (application) OR (program)))

We searched the following five major digital libraries to obtain relevant publications: (1) ACM, (2) IEEE Xplore, (3) ScienceDirect, (4) Web of Science, and (5) Wiley.

The resulting search string is adapted to each digital library to conduct the search operation. The details on the search methods used for each digital library are illustrated in Appendix A for replication purposes. There was no start date and the end date was 31 December 2016. We did not include the studies published in 2017 to analyze the trend over the years. Table 1 illustrates the number of results per digital library.

Table 1. Number of results per database

Database	Number of Results
ACM	79
IEEE Xplore	166
ScienceDirect	33
Web of Science	269
Wiley	42
TOTAL	**589**

3.3. Publication Selection

We excluded some publications by applying exclusion criteria. In line with the SMS guidelines [9], we applied the following exclusion criteria (EC) on the publications obtained after the search:

- EC1: Publication is repeated in an already mined source
- EC2: Publication is presenting a summary of a keynote, a workshop introduction, only an abstract
- EC3: Publication's main topic is not related to information systems
- EC4: Books

The first author selected the publications by reading the titles, abstracts, and keywords and applying the exclusion criteria. In some cases, full texts have been reviewed for applying the exclusion criteria. The number of included and excluded publications is illustrated in Table 2. In the search interfaces of some digital libraries, books are excluded while searching wherever applicable. The list of resulting 75 primary studies are presented in Appendix B.

Table 2. Number of included and excluded publications

Inclusion/Exclusion	Number of publications
included	75
excluded due to EC1	107
excluded due to EC2	16
excluded due to EC3	391
excluded due to EC4	0
TOTAL	**589**

3.4. Classification Scheme

A classification scheme is required to categorize the final set of publications to be able to answer RQs. We formed this classification scheme iteratively by reviewing the final set of publications.

Table 3 illustrates the final classification scheme that we developed after applying the process visualized in Figure 1. In the table, the first column is the list of RQs, the second column is the corresponding attribute. The third column is the set of all possible attribute values for the attribute, if applicable. Finally, the fourth column indicates for an attribute whether multiple selections can be applied.

Table 3. Classification scheme used in this SMS

RQ	Attribute	Attribute Values	Single/Multiple Selection
RQ1	Publication Year	An integer value	S
RQ2	Academia/Industry	• Academia • Industry • Both	S
RQ3	Research Type	• Validation • Evaluation • Solution proposal • Opinion	S
RQ4	Main Motivation	• Reduction of TCO • Decision making based on TCO • Calculation of TCO	S
RQ4.1	Main Objective of TCO Calculation	• compare cloud-based infrastructure with in-house infrastructure • compare SaaS model with on-premise software • assess the feasibility of using OSS (Open Source Software) • estimate and assess costs • propose method/tool to calculate TCO	S
RQ4.2	TCO Reduction Mean	• Cloud computing, SaaS, Multi-tenancy • Virtualization, Use of special hardware • Autonomic computing • OSS • Process improvement	S
RQ4.3	Decision made based on TCO	A string value	N/A

The research questions RQ1 and RQ2 are answered by analyzing the publication year and the affiliations of the authors. The publications with affiliations from universities are marked as “academia”; whereas the publications with affiliations from companies are marked as “industry. If a publication has an affiliation with both universities and companies, we have marked as “both”.

The research type attribute is addressing RQ3. We adapted the attribute types from [12] as listed below:

1. *Validation:* The idea/solution/proposal has not been implemented in practice; it was validated in an experimental setting such as a lab experiment.
2. *Evaluation:* The idea/solution/proposal is implemented in practice and the results of the implementation have been evaluated.
3. *Solution Proposal:* The idea/solution/proposal is presented; neither a validation nor an evaluation has been made.
4. *Opinion:* These publications present personal opinions without relying on related work and research methodologies.

To identify the motivations behind dealing with TCO (RQ4), we derived a classification. We inspired from [1] while building this classification.

1. *Reduction of TCO:* Understanding the drivers and calculation of TCO usually drives an improvement, whose ultimate goal is TCO reduction. Therefore, considerable efforts are allocated to propose methods, techniques, and tools to reduce TCO.
2. *Decision making based on TCO:* TCO reflects the total cost of an information system associated with its life cycle. Therefore, TCO is an important criterion for making decisions on implementing a new information system as well as maintaining, keeping, and replacing an existing one.
3. *Calculation of TCO:* Calculation of TCO for an information system is not straightforward. There are

many components in a typical information system, such as hardware, software, network components, staff, etc. Moreover, such a system is a living entity, which needs continuous maintenance and operational effort with associated costs. Therefore, methods and tools are proposed to calculate TCO for an information system.

The motivations above are not mutually exclusive; are interconnected. For instance, you need to calculate TCO before using it as a decision criterion; you need to understand the drivers of TCO before reducing TCO. Therefore, a study might include more than one motivation. In this SMS, we identified the mainly emphasized motivation of a study.

After we identified some attributes to build our classification scheme, we started to review the selected publications to explore further RQs. We formulated RQ4.1, RQ4.2, and RQ4.3 based on the insight we obtained after a more detailed review. We observed some patterns for the answers of RQ4.1 and RQ4.2 and built a list of attribute values. We did not observe such a pattern for the RQ4.3.

The classification for RQ4.2 includes some concepts, which are widely used. We give a brief description of these concepts below:

1. *Cloud computing, SaaS, Multi-tenancy:* Cloud computing enables ubiquitous, convenient, on-demand access to a shared pool of configurable resources (e.g., networks, servers, storage, applications, and services) [13]. It provides five essential characteristics, namely on-demand self-service, broad network access, rapid flexibility on scalability, measured service, and resource pooling [13]. Computing resources are pooled to serve multiple consumers using a multi-tenant model [13]. Multi-tenancy is an approach to share a computing resource between multiple tenants by providing every tenant a dedicated share of the resource, which is isolated from other shares regarding performance and data privacy [14].

   Software as a Service (SaaS) is defined as the capability provided to the consumer to use the provider's applications running on a cloud infrastructure [13]. SaaS is a service model of cloud computing along with Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). A cloud infrastructure is a collection of hardware and software that enables the five essential characteristics of cloud computing [13]. Cloud computing provides the scalable and dependable hardware and storage for SaaS and usually, the Internet provides the communication for SaaS [15].
2. *Virtualization, Use of special hardware:* Virtualization is one of the enabling technologies of cloud computing. Virtualization provides a temporarily simulated or extended version of computing resources such as processors, operating systems, storages, and network [16]. It enables resource sharing ending up with server consolidation, centralization of resource management [16]. Another option could be using a special hardware to reduce costs (such as using handheld computers for data collection).
3. *Autonomic computing:* Autonomic computing aims to realize computer and software systems that can manage themselves with little or no human intervention [16]. As today's information systems are getting much more complex, human interventions cause more failures and cost more. Cloud computing considers autonomic computing to reduce the complexity of managing large and distributed cloud data centers, increase resource availability, enhance flexibility, and ensure optimal utilization [16].
4. *OSS:* OSS is a kind of software whose source code is available with a license providing the rights to study, change, and distribute the software to anyone for any purpose [17]. Use of OSS often could be used as a vehicle to decrease costs.
5. *Process improvement:* Process improvement encompasses identifying, analyzing, and improving existing processes in some dimensions such as efficiency, effectiveness, and flexibility.

3.5. Data Extraction

We extracted the relevant data presented in the selected publications to answer our RQs. The title, abstract, and author keywords are reviewed. We downloaded the full texts of the selected publications and reviewed these, especially discussion and conclusion sections to extract more data with high quality. Data extraction has been performed by the first author and reviewed by the second author. The data are recorded and maintained using Microsoft Excel.

3.6. Potential Threats to Validity

Reliability is achieved if a study yields the same results when replicated by other researchers [18]. To make this study replicable, the process is defined clearly. The search phase is completely replicable. The exclusion criteria for selecting primary studies are defined. The publications were selected only by the first author, which might have introduced some bias in the process. To reduce this threat, the second author has reviewed the selected publications and made some revisions. Moreover, the selection process was carried out iteratively to reduce misinterpretations to a minimum level. In some cases, title, abstract, and keywords were not sufficient for applying the exclusion criteria. In such cases, the full texts of some publications are examined. This also increased the reliability of this SMS.

Building a classification scheme is not completely replicable. It possesses a perspective, which specifies what to consider and what to discard. We tried to build a classification scheme, which enables to answer our RQs, and in line with the body of knowledge and experience accumulated in academia and industry.

4. RESULTS OF SMS

In this section, we present the results of our SMS by answering the RQs.

RQ1: What is the annual number of publications and which trends can be observed in terms of the number of publications over time?

Figure 2 illustrates the number of publications over the years. The earliest publication appeared in 1999. We can observe an increasing trend in the number of publications over the years.

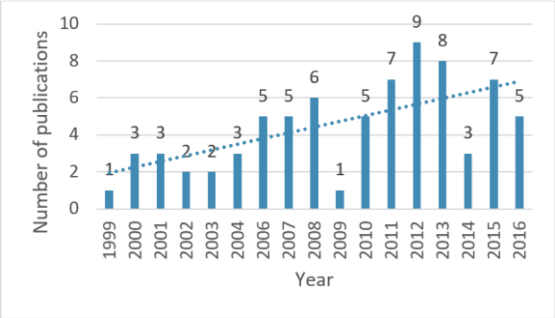


Figure 2. Annual number of publications

RQ2: What is the distribution of studies between academia and industry according to the authorship?

As illustrated in Figure 3, 50% of the publications (37 publications) have been published by academics only, whereas 37% of the publications (28 publications) published by industrial practitioners only. The remaining 13% (10 publications) have been published with collaboration between academic and industrial practitioners.

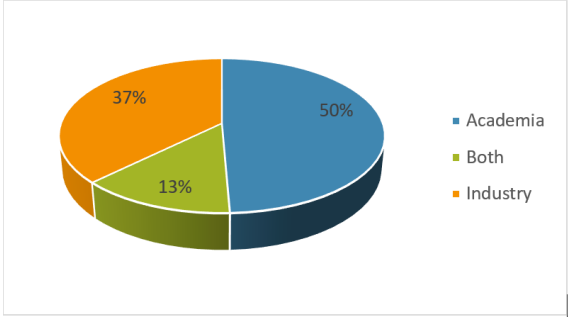


Figure 3. Affiliation distribution

RQ3: What type of research has been conducted related to TCO for information systems?

Figure 4 illustrates how the research type is distributed. Most of the publications are just presenting opinions (55 publications) without any systematic validation and evaluation. Figure 5 shows that there is slightly increased interest in the evaluation (12 publications in total) and validation type research publications (6 publications in total) in recent years. There are very few publications proposing a solution (2 publications without a validation or an evaluation).

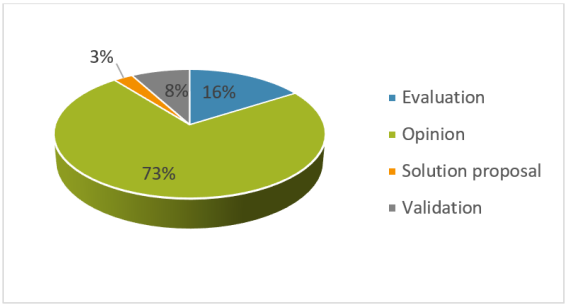


Figure 4. Research type distribution

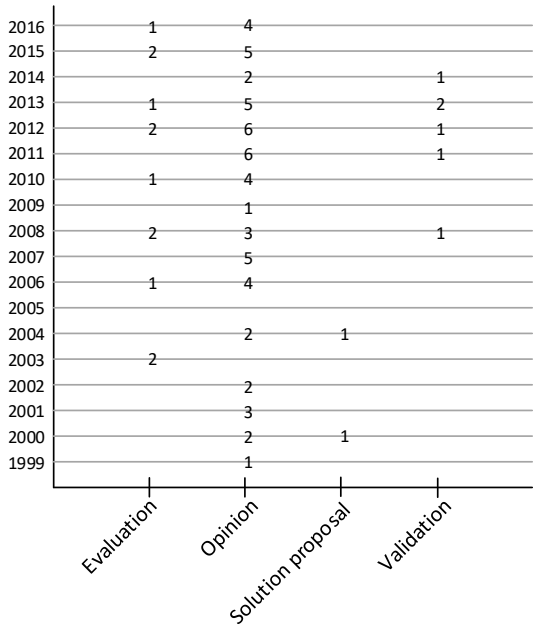
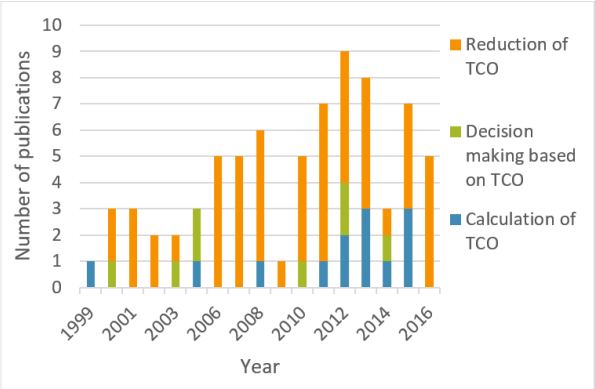


Figure 5. Annual trend of research type

RQ4: What is the main motivation, which is related to TCO for information systems, of the research?

Figure 6 illustrates the mapping of publications in terms of their main motivation. Their cumulative and annual numbers are shown as well. As can be seen, reduction of TCO is the dominating main motivation with 72%. Calculation of TCO and decision making based on TCO are the following motivations with 17% and 11% respectively.



Main Motivation facet	Number of Publications	References
Calculation of TCO	13 (17%)	[PS01] – [PS13]
Reduction of TCO	54 (72%)	[PS14] – [PS67]
Decision making based on TCO	8 (11%)	[PS68] – [PS75]

Figure 6. Mapping of publications by motivation facet

RQ4.1: What are the main objectives of calculating TCO for information systems?

We identified some common objectives of calculating TCO as illustrated in (Table 4).

Table 4. Objectives for calculation of TCO

Objective	References
compare cloud-based infrastructure with in-house infrastructure	[PS01], [PS02], [PS04], [PS07], [PS11]
compare SaaS model with on-premise software	[PS05], [PS06], [PS12]
assess the feasibility of using OSS	[PS08]
estimate and assess costs	[PS03], [PS10], [PS13]
propose method/tool to calculate TCO	[PS09]

[PS01] compares the cost of hosting an information system on a cloud-based (Amazon Web Services) with in-house infrastructure. The TCO for the system decreases 35% when cloud-based infrastructure is selected for the first three years. Moreover, the capital expenses (CapEX) for the cloud-based infrastructure is zero.

[PS02] reports that even small-scale private cloud-based infrastructures can bring economic benefits by reducing TCO. Usage patterns are another important parameter on how many economic benefits can be obtained from cloud-based infrastructures. Economic benefits are more when usage patterns are fluctuating rather than constant [PS04].

[PS07] compares cloud-based and in-house business intelligence solutions and favors cloud-based solution. [PS11] presents an approach for analyzing cloud-based systems.

[PS05] calculates TCO for a Customer Relationship Management (CRM) software both for SaaS and on-premise model. [PS06] and [PS12] present TCO analysis for selecting SaaS or on-premise model for business applications.

[PS08] calculates the TCO for information systems with OSS and investigate the feasibility of using OSS in public and private companies. It points out some hidden costs in OSS adoption [PS08]. [PS03], [PS10], and [PS13] calculate TCO for estimating and assessing costs. [PS09] proposes a tool for calculating TCO along with a cost allocation feature. This tool uses Activity-based Costing method to allocate costs to the appropriate cost centers.

RQ4.2: What are the means for reducing TCO for information systems?

We identified some common groups of medium (method, technology, approach) along with their focus on one or more cost categories driving TCO (Table 5).

Cloud computing removes the CapEx on building an infrastructure (such as a data center) [16]. CapEx is transformed to operating expenses (OpEx) to a large extent based on the usage and spread over time. This lowers the investment cost for many projects. Moreover, resource sharing can provide an increase in utilization and hence significantly reduce operational costs, including human costs; maintenance costs [16]. SaaS model can reduce software license and development costs as well. In addition, maintenance costs for SaaS can be much lower than on-premise software.

Cloud computing provides a powerful infrastructure for many information systems in education [PS20], [PS57], e-commerce [PS30], analytics [PS25], and scientific computing [PS35]. [PS29] proposes to host a SCADA (Supervisory control and data acquisition) system on the cloud. [PS23] and [PS54] propose to host multiple tenants in the same database to reduce TCO. [PS58] extends the idea of multi-tenant database to multi-tenant business applications by having many consumers using the same instance of a business application. SaaS model is used in [PS14] for museum collection management system, in [PS32] for hospital management system, in [PS36] for astronomical data analysis and visualization, in [PS52] for software streaming. An earlier example from the year 2001 is proposing web-based LDAP (Lightweight Directory Access Protocol) management system to reduce TCO [PS51]. Finally, SaaS model is also proposed for ERP (Enterprise Resource Planning) systems [PS37], [PS43].

Table 5. Groups of medium for reduction of TCO

Medium (method, technology, approach)	Cost Category: Infra-structure	Development	Maintenance	Software License	Human	References
Cloud computing, SaaS, Multi-tenancy	√	√	√	√	√	[PS14], [PS17] – [PS21], [PS23] –[PS27], [PS29] – [PS33], [PS35] –[PS37], [PS39], [PS41] –[PS45], [PS49], [PS51], [PS52], [PS54], [PS57] – [PS59], [PS62], [PS64], [PS65]
Virtualization, Use of special hardware	√					[PS16], [PS28], [PS50]
Autonomic computing			√		√	[PS55], [PS56]
OSS		√		√		[PS34], [PS38], [PS40], [PS46], [PS67]
Process improvement		√	√		√	[PS15], [PS22], [PS47], [PS48], [PS53], [PS60], [PS61], [PS63], [PS66]

[PS14] reports that using SaaS model can provide a saving of at least 60% of investment costs and about 50% of annual operating costs. [PS52] observed some savings in TCO in a lab environment.

[PS28] is about virtualizing an infrastructure for hosting DNS, e-mail server software, e-learning software etc. [PS16] used electronic kiosks as hardware to reduce TCO. [PS50] consolidated some hardware for better utilization and reported some savings in TCO.

Within the scope of autonomic computing, [PS55] proposes to create self-directed, self-governing, and self-adapting systems to deliver safer, more reliable and cost-effective systems. [PS56] explains a self-organizing infrastructure for information systems to reduce hardware and human costs, thus lower TCO.

[PS34] discusses the use of OSS in developing countries, specifically in Tanzania. It points out high software license costs hindering the use of technology in Tanzania and concludes that OSS can reduce TCO and increase technology penetration. [PS38] proposes using OSS for electronic publishing in libraries and [PS40] in higher education. [PS46] and [PS67] propose an enterprise-wide use of OSS to reduce software-related costs; [PS67] includes a case study for an organization. Even though OSS offers a significant decrease in software license and development costs, [PS08] points out some problems on OSS adoption, such as the lack of maturity level of OSS, license confusions and lack of knowledge about the implications of various open source licenses.

[PS15] proposes to use a proper programming language for financial computing to reduce TCO. [PS22] focuses on developer productivity and tries to reduce TCO by increasing developer performance. [PS47] uses Model-driven development (MDD) to shorten the development of complex e-business solutions, which is expected to result in lower TCO. [PS66] proposes to use agile and DevOps practices to reduce development and maintenance costs but does not provide any validation. [PS63] presents a single OLTP/OLAP platform to reduce development complexity ending up with an expected reduction in TCO. [PS48] and [PS53] focus on maintenance costs of information systems. [PS60] and [PS61] focus on system development process and aim to reduce the development and maintenance of an information system.

RQ4.3: What are the decisions made based on TCO for information systems?

[PS70] points out that maintenance costs are generally neglected when selecting ERP software. It reports that customizations and add-on procurements done during maintenance phase have a significant impact on TCO, hence proposes to consider TCO during ERP selection. [PS68] uses TCO as one of the criteria for ERP selection along with functionality offered to include lifetime costs. [PS71] identifies TCO as one decision criterion for Customer Relationship Management (CRM) software selection.

[PS69] proposes a framework for SaaS model adoption having TCO as one of the main criteria. [PS72] suggests assessing TCO as one decision criterion in deciding on the

hosting of data warehouse in-house or on an application service provider. [PS75] considers TCO to decide the hosting of an e-commerce platform. [PS73] uses TCO as a criterion to use OSS for an e-commerce system.

[PS74] focuses on software process and discusses the selection of Java or .NET framework based programming platform. It proposes to assess TCO for an information system based on Java and .NET framework to decide on the programming platform.

5. CONCLUSIONS AND FUTURE WORK

To the best of our knowledge, this study is the first SMS on TCO for information systems. In this paper, we report the results of our SMS documenting and analyzing the current state of TCO concept for information systems. We selected 75 primary studies, which discuss TCO concept for information systems. We classified the selected studies in terms of their research type and main motivation for dealing with TCO concept. Moreover, we defined and answered more detailed RQs addressing means of TCO reduction, main objectives of TCO calculation, and decisions made based on TCO.

Among the studies we have analyzed, neither academia nor industry is dominating the studies in TCO for information systems. Most of the studies are just stating opinions without supporting validation or evaluation. We also observe that there is very little collaboration between academia and industry. For validating and evaluating TCO related studies, academia needs data from industry. Therefore, we believe more collaboration between academia and industry is needed.

Most studies target reducing TCO. To achieve this objective, proper calculation of TCO for information systems is needed. Therefore, we believe building TCO calculation methods and frameworks might be helpful. These methods and frameworks should be extendable to handle many usage scenarios, easy to learn and use to be used in industry, include necessary level of detail (not too much to become a burden and too few to prevent proper calculation). Cloud computing, SaaS model, and multi-tenancy are essential means for TCO reduction. Cloud-based systems reduce investment costs dramatically for many businesses, by cutting the costs of a new infrastructure (especially in terms of CapEx) as well as employing and training employees. Moreover, the costs of cloud-based systems are decreasing. The dominating objective for TCO calculation is to compare cloud-based infrastructures with in-house infrastructure and SaaS model with on-premise software. Along with developments in ICT, cloud-based systems and SaaS model are generally selected after a TCO analysis.

TCO is one side of the coin. The other side associated with the ownership is benefit. Cost/benefit analysis, which is an important part of project feasibility studies, clearly addresses this inevitable association. Therefore, TCO analysis should be coupled with benefit realization to assess the success of investing in information systems.

Overall, we observe an increasing interest in TCO for information systems. This trend is compatible with the increasing pressure in cutting costs to become or remain competitive and the essential role of information systems in organizations along with their increasing share in budgets. Since TCO concept has very much practical implication in organizations, some grey literature is present on this topic. Therefore, a Multivocal Literature Review (MLR), which includes grey literature in addition to academic literature (such as [19]), can be conducted as well on this topic.

REFERENCES

[1] L.M. Ellram, S.P. Siferd, "Total Cost of Ownership: A Key Concept in Strategic Cost Management Decisions", *Journal of Business Logistics*, 19(1), 55-84, 1998.

[2] J.K. Shank, V. Govindarajan, "Strategic Cost Management: The Value Chain Perspective", *Journal of Management Accounting Research*, 4, 179-199, 1992.

[3] W. van der Aalst, C. Stahl, **Modeling Business Processes: A Petri Net-Oriented Approach**, The MIT Press, 2011.

[4] P. Scrimshaw, "Total cost of ownership: A review of the literature", *ICT in Schools Research and Evaluation Series*, 6, 2002.

[5] K. Hurkens, W. van der Valk, F. Wynstra, "Total Cost of Ownership in the Services Sector: A Case Study", *Journal of Supply Chain Management*, 42, 27–37, 2006.

[6] M. Wouters, J.C. Anderson, F. Wynstra, "The adoption of total cost of ownership for sourcing decisions: A structural equations analysis", *Accounting, Organizations and Society*, 30, 167-191, 2005.

[7] R.M. Garfamy, "A data envelopment analysis approach based on total cost of ownership for supplier selection", *Journal of Enterprise Information Management*, 19, 662-678, 2006.

[8] S. Galberaith, A. Kyte, **Application Total Cost of Ownership Principles SMBs Should Follow**, Gartner, 2014.

[9] B. Kitchenham, S. Charters, **Guidelines for Performing Systematic Literature Reviews in Software Engineering**, EBSE 2007-001, 2007.

[10] K. Petersen, R. Feldt, S. Mujtaba, M. Mattsson, "Systematic mapping studies in software engineering", **12th International Conference on Evaluation and Assessment in Software Engineering (EASE 2008)**, Italy, 26-27 June 2008.

[11] K. Petersen, S. Vakkalanka, L. Kuzniarz, "Guidelines for conducting systematic mapping studies in software engineering: An update", *Information and Software Technology*, 64, 1–18, 2015.

[12] R. Wieringa, N. Maiden, N. Mead, C. Rolland, "Requirements engineering paper classification and evaluation criteria: A proposal and a discussion", *Requirements Engineering*, 11(1), 102–107, 2006.

[13] P. Mell, T. Grance, **The NIST Definition of Cloud Computing**, NIST-Special Publication 800–45, Gaithersburg, 2011.

[14] R. Krebs, C. Momm, S. Kounev, "Architectural Concerns in Multi-Tenant SaaS Applications", **2nd International Conference on Cloud Computing and Services Science (CLOSER 2012)**, Porto, Portugal, 18-21 April 2012.

[15]

A. Fox, D. Patterson, **Engineering Software as a Service: An Agile Approach Using Cloud Computing**, Strawberry Canyon LLC, 2013.

[16] M. Hamdaqa, L. Tahvildari, "Cloud computing uncovered: a research landscape", *Advances in Computers*, 86, 41-85, 2012.

[17] S. Laurent, M. Andrew, **Understanding Open Source and Free Software Licensing**, O'Reilly Media, 2008.

[18] S.M. Easterbrook, J. Singer, M.A. Storey, D. Damian, "Selecting Empirical Methods for Software Engineering Research", **Guide to Advanced Empirical Software Engineering**, Editors: F. Shull, J. Singer, D.I.K. Sjøberg, Springer London, 285–311, 2008.

[19] V. Garousi, M. Felderer, M.V. Mäntylä, "The Need for Multivocal Literature Reviews in Software Engineering: Complementing Systematic Literature Reviews with Grey Literature", **20th International Conference on Evaluation and Assessment in Software Engineering**, Limerick, Ireland, 1-3 June 2016.

Appendix A. Searching methods in the Digital Libraries

Digital Library and its URL	Search String	Search Method
ACM dl.acm.org	acmdlTitle:(+"total cost of ownership" software "information system" application program) OR recordAbstract:(+"total cost of ownership" software "information system" application program "total cost of ownership") OR keywords.author.keyword:(+"total cost of ownership" software "information system" application program)	"Advanced Search" has been used.
IEEE Xplore ieeexplore.ieee.org	("Abstract":software OR "Abstract":"information system" OR "Abstract":application OR "Abstract":program) AND "Abstract":"total cost of ownership" ("Document Title":software OR "Document Title":"information system" OR "Document Title":application OR "Document Title":program) AND "Document Title":"total cost of ownership" ("Author Keywords":software OR "Author Keywords":"information system" OR "Author Keywords":application OR "Author Keywords":program) AND "Author Keywords":"total cost of ownership"	"Command Search" under "Advanced Search Options" has been used. We queried the database 3 times using the 3 search strings. We combined the results manually on Excel.
ScienceDirect www.sciencedirect.com	title-abs-key((software OR "information system" OR application OR program) AND "total cost of ownership")	"Expert Search" has been used.
Web of Science apps.webofknowledge.com	(TS="total cost of ownership" AND (TS=software OR TS="information system" OR TS=application OR TS=program)) AND LANGUAGE: (English)	"Advanced Search" has been used.
Wiley onlinelibrary.wiley.com	(software OR "information system" OR application OR program) AND "total cost of ownership"	"Advanced Search" has been used. The search string was used for searching "Abstract", "Article Titles", and "Keywords". Each search result has been combined using OR operator.

Appendix B. Primary studies by ID

ID	Study
PS01	K. Konstantinos, M. Persefoni, F. Evangelia, M. Christos, N. Mara, "Cloud computing and economic growth", **19th Panhellenic Conference on Informatics (PCI 2015)**, New York, NY, USA, 2015.
PS02	I. Konstantinou, E. Floros, N. Koziris, "Public vs private cloud usage costs: the StratusLab case", **2nd International Workshop on Cloud Computing Platforms (CloudCP 2012)**, Bern, Switzerland, 2012.
PS03	M. Heikkurinen, S. Cohen, F. Karagiannis, K. Iqbal, S. Andreozzi, M. Michelotto, "Answering the Cost Assessment Scaling Challenge: Modelling the Annual Cost of European Computing Services for Research", *J. Grid Comput*, 13(1), 71-94, 2015.
PS04	G. Me, "Migration to Governmental Cloud Digital Forensics Community: Economics and Methodology", **11th International Conference (GECON 2014)**, Cardiff, UK, 2014.
PS05	J. Jandos, "Total Cost of Ownership Model for Software as a Service", **20th IBIMA Conference**, Kuala Lumpur, Malaysia, 2013.
PS06	E. Turňová, A. Tušanová, J. Paralič, "Learning support tool for SMEs to measure their cloud investments", **11th International Conference on Emerging eLearning Technologies and Applications (ICETA)**, Stara Lesna, 2013.

ID	Study
PS07	M. Muntean, C. Muntean, "Evaluating A Business Intelligence Solution: Feasibility Analysis Based On Monte Carlo Method", **ECECSR 2013**, 2013.
PS08	M. Shaikh, T. Cornford, "Framing the Conundrum of Total Cost of Ownership of Open Source Software", **7th IFIP WG 2.13 International Conference (OSS 2011)**, Salvador, Brazil, 2011.
PS09	S. Agarwala, R. Routray, S. Uttamchandani, "ChargeView: An integrated tool for implementing chargeback in IT systems", **2008 IEEE Network Operations and Management Symposium (NOMS 2008)**, Salvador, Bahia, 2008.
PS10	T.A. Geiser, D. Schaar, "Tackling cost challenges of net centric warfare", **IEEE 2004 Aerospace Conference**, IEEE, 2004.
PS11	E. Filiopoulou, P. Mitropoulou, A. Tsadimas, C. Michalakelis, M. Nikolaidou, D. Anagnostopoulos, "Integrating cost analysis in the cloud: A SoS approach", **11th International Conference on Innovations in Information Technology (IIT)**, Dubai, UAE, 2015.
PS12	S. Bibi, D. Katsaros, P. Bozanis, "Business Application Acquisition: On-Premise or SaaS-Based Solutions?", *IEEE Software*, 29(3), 86-93, 2012.
PS13	K.N. Myers, D. Verma, "System Design to Affordability in a Collaborative Systems Engineering Environment", **INCOSE International Symposium**, 1999.
PS14	S. Wu, P. Chua, "Museum collection management on-demand", **2nd international conference on Theory and practice of electronic governance (ICEGOV 2008)**, Cairo, Egypt, 2007.
PS15	O. Mencer, E. Vynckier, J. Spooner, S. Girdlestone, O. Charlesworth, "Finding the right level of abstraction for minimizing operational expenditure", **4th workshop on High performance computational finance (WHPCF 2011)**, New York, NY, USA, 2011.
PS16	J. Raymond, "Electronic kiosk project: distributed access to e-mail and web browsing", **28th annual ACM SIGUCCS conference on User services: Building the future (SIGUCCS 2000)**, New York, NY, USA, 2000.
PS17	D. Zilio, S. Lightstone, K. Lyons, G. Lohman, "Self-managing technology in IBM DB2 universal database", **10th international conference on Information and knowledge management (CIKM 2001)**, New York, NY, USA, 2001.
PS18	S.S. Lightstone, G. Lohman, D. Zilio, "Toward autonomic computing with DB2 universal database", *SIGMOD Rec.*, 31(3), 55-61, 2002.
PS19	G.M. Lohman, S.S. Lightstone, "SMART: making DB2 (more) autonomic", **28th international conference on Very Large Data Bases (VLDB 2002)**, 2002.
PS20	J. Dietrich, J. Tandler, L. Sui, M. Meyer, "The PrimeGame Revolutions: A cloud-based collaborative environment for teaching introductory programming", **24th Australasian Software Engineering Conference (ASWEC 2015)**, New York, NY, USA, 2015.
PS21	M. Holze, N. Ritter, "Towards workload shift detection and prediction for autonomic databases", **1st Ph.D. workshop in CIKM (PIKM 2007)**, New York, NY, USA, 2007.
PS22	S.S. Benfield, J. Hendrickson, D. Galanti, "Making a strong business case for multiagent technology", **5th international joint conference on Autonomous agents and multiagent systems (AAMAS 2006)**, New York, NY, USA, 2006.
PS23	S. Aulbach, T. Grust, D. Jacobs, A. Kemper, J. Rittinger, "Multi-tenant databases for software as a service: schema-mapping techniques", **ACM SIGMOD international conference on Management of data (SIGMOD 2008)**, New York, NY, USA, 2008.
PS24	M. Kormilitsin, R. Chirkova, Y. Fathi, M. Stallmann, "View and index selection for query-performance improvement: quality-centered algorithms and heuristics", **17th ACM conference on Information and knowledge management (CIKM 2008)**, New York, NY, USA, 2008.
PS25	P. Wong, Z. He, E. Lo, "Parallel analytics as a service", **ACM SIGMOD International Conference on Management of Data (SIGMOD 2013)**, New York, NY, USA, 2013.
PS26	L. Braun, T. Etter, G. Gasparis, M. Kaufmann, D. Kossmann, D. Widmer, A. Avitzur, A. Iliopoulos, E. Levy, N. Liang, "Analytics in Motion: High Performance Event-Processing AND Real-Time Analytics in the Same Database", **ACM SIGMOD International Conference on Management of Data (SIGMOD 2015)**, New York, NY, USA, 2015.
PS27	L. Qiao, B. Soetarman, G. Fuh, A. Pannu, B. Cui, T. Beavin, W. Kyu, "A framework for enforcing application policies in database systems", **ACM SIGMOD international conference on Management of data (SIGMOD 2007)**, New York, NY, USA, 2007.
PS28	H. Masuda, K. Murata, Y. Shibuya, K. Wakasugi, Y. Kuroe, "KIT's campus computer system by virtual machine technology and integrated identity service", **38th annual ACM SIGUCCS fall conference: navigation and discovery (SIGUCCS 2010)**, New York, NY, USA, 2010.
PS29	S. Goose, J. Kirsch, D. Wei, "SKYDA: cloud-based, secure SCADA-as-a-service" *Int. Trans. Electr. Energ. Syst.*, 25, 3004–3016, 2015.

ID	Study
PS30	A. Szajna, R. Stryjski, T. Szajna, "Cloud Computing - Logistic Use Case for E-Commerce", **26th International-Business-Information-Management-Association Conference**, Madrid, Spain, 2015.
PS31	S.K. Santy, "Sourcing Lifecycle for Software as a Service (SAAS)", **International Conference on Advances Science and Contemporary Engineering (ICASCE 2013)**, Jakarta, Indonesia, 2013.
PS32	Q. Yao, Y. Wang, J.S. Li, "Hospital information system integration based on cloud computing", **1st International Workshop on Cloud Computing and Information Security (CCIS)**, Shanghai, China, 2013.
PS33	N.V.S. Kolluru, N. Mantha, "Cloud Integration - Strategy to Connect Applications to Cloud", **10th Annual Conference of the IEEE-India-Council (INDICON)**, IIT Bombay, Mumbai, India, 2013.
PS34	G.S. Oreku, F.J. Mtenzi, "Adoption and Diffusion of Open Source Software in Tanzania: A Way Forward", **IST-Africa Conference and Exhibition (IST-AFRICA)**, Nairobi, Kenya, 2013.
PS35	M. Villamizar, H. Castro, D. Mendez, "e-Clouds: A SaaS Marketplace for Scientific Computing", **5th IEEE/ACM International Conference on Utility and Cloud Computing (UCC)**, Chicago, IL, 2012.
PS36	A.H. Hassan, C.J. Fluke, D.G. Barnes, "Unleashing the Power of Distributed CPU/GPU Architectures: Massive Astronomical Data Analysis and Visualization Case Study", **21st Annual Conference on Astronomical Data Analysis Software and Systems**, Paris, France, 2011.
PS37	M. Lechesa, L. Seymour, J. Schuler, "ERP Software as Service (SaaS): Factors Affecting Adoption in South Africa", **5th International Conference on Research and Practical Issues of Enterprise Information systems (CONFENIS 2011)**, Aalborg, Denmark, 2011.
PS38	R.G. Samuels, H. Griffy, "Evaluating Open Source Software for Use in Library Initiatives: A Case Study Involving Electronic Publishing", *Libraries and the Academy*, 12(1), 41-62, 2012.
PS39	R. Barber, P. Bendel, M. Czech, O. Draese, F. Ho, N. Hrle, S. Idreos, M. Kim, O. Koeth, J. Lee, T.T. Li, G. Lohman, K. Morfonios, R. Mueller, K. Murthy, I. Pandis, L. Qiao, V. Raman, S. Szabo, R. Sidle, K. Stolze, "Blink: Not Your Father's Database!" **5th International Workshop (BIRTE 2011)**, Seattle, WA, USA, 2011.
PS40	S.W. van Rooij, "Higher education sub-cultures and open source adoption", *Computers & Education*, 57(1), 1171-1183, 2011.
PS41	V. Sarathy, P. Narayan, R. Mikkilineni, "Next Generation Cloud Computing Architecture: Enabling Real-Time Dynamism for Shared Distributed Physical Infrastructure", **19th IEEE International Workshop on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE)**, Larissa, 2010.
PS42	M. Sato, "Creating Next Generation Cloud Computing Operation Support Services by Social OSS: Contribution with Telecom NGN Experience", **19th IEEE International Workshop on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE)**, Larissa, 2010.
PS43	V. Borovskiy, A. Zeier, "Enabling enterprise composite applications on top of ERP systems", **Services Computing Conference APSCC 2009**, Singapore, 2009.
PS44	S. Tata, L. Qiao, G.M. Lohman, "On common tools for databases - The case for a client-based index advisor" **IEEE 24th International Conference on Data Engineering Workshop**, Cancun, 2008.
PS45	K. Zhang, X. Zhang, W. Sun, H. Liang, Y. Huang, L. Zeng, X. Liu, "A Policy-Driven Approach for Software-as-Services Customization", **9th IEEE International Conference on E-Commerce Technology and The 4th IEEE International Conference on Enterprise Computing, E-Commerce and E-Services (CEC-EEE 2007)**, Tokyo, 2007.
PS46	J. Krivoruchko, "The Use of Open Source Software in Enterprise Distributed Computing Environments - A decision-making framework for OSS selection and planning", **Open Source Development, Adoption and Innovation**, Editors: J. Feller, B. Fitzgerald, W. Scacchi, A. Sillitti, Springer US, 277-282, 2007.
PS47	R. Acerbis, A. Bongio, M. Brambilla, M. Tisi, S. Ceri, E. Tosetti, "Developing eBusiness Solutions with a Model Driven Approach: The Case of Acer EMEA", **7th International Conference on Web Engineering (ICWE 2007)**, Como, Italy, 2007.
PS48	S. Jansen, W. Rijsemus, "Reducing customers' total cost of ownership within a software supply network", **22nd IEEE International Conference on Software Maintenance (ICSM 2006)**, Philadelphia, PA, 2006.
PS49	S. Raut, D.B. Phatak, A.R. Yardi, "Affordable enterprise application integration strategy involving legacy systems", **7th International-Business-Information-Management-Association Conference (IBIMA)**, Brescia, Italy, 2006.
PS50	M.H. Aziz, O.C. Nie, J.C.M. Yam, L.C. Wei, S. Jamalludin, A. Shahril, "TCO reduction", **9th Asia-Pacific Conference on Communications held in conjunction with the 6th Malaysia International Conference on Communications (MICC 2003)**, Penang, Malaysia, 2003.
PS51	C.S. Yang, C.Y. Liu, J.H. Chen, C.Y. Sung, "Design and implementation of secure web-based LDAP management system", **15th International Conference on Information Networking (ICON-15)**, Beppu, Japan, 2001.

ID	Study
PS52	G. Rueda, C. Spence, "Intel case study: Software on demand", **Portland International Conference on Management of Engineering & Technology (PICMET 2008)**, Cape Town, 2008.
PS53	A. Bagnato, T.E.J. Vos, J.O. Murillo, A. Esparcia-Alcázar, B. Marín, S.I. Folgado, A.C. Alberola, "Testing and remote maintenance of real future internet scenarios: Towards FITTEST and FastFix advanced software engineering", **Federated Conference on Computer Science and Information Systems (FedCSIS 2011)**, Szczecin, 2011.
PS54	B. Gao, W.H. An, X. Sun, Z.H. Wang, L. Fan, C.J. Guo, W. Sun, "A Non-intrusive Multi-tenant Database Software for Large Scale SaaS Application", **8th International Conference on e-Business Engineering (ICEBE 2001)**, Beijing, 2011.
PS55	M.G. Hinchey, R. Sterritt, "Self-managing software", *Computer*, 39(2), 107-109, 2006.
PS56	S. Seltzsam, D. Gmach, S. Krompass, A. Kemper, "AutoGlobe: An Automatic Administration Concept for Service-Oriented Database Applications", **22nd International Conference on Data Engineering (ICDE 2006)**, 2006.
PS57	I.J. Rudas, "Cloud computing in education", **10th International Conference on Emerging eLearning Technologies & Applications (ICETA 2012)**, Stara Lesna, 2012.
PS58	C. Momm, W. Theilmann, "A Combined Workload Planning Approach for Multi-tenant Business Applications", **35th Annual Computer Software and Applications Conference Workshops (COMPSACW 2011)**, Munich, 2011.
PS59	M. Heller, M. Allgaier, "Model-based service integration for extensible enterprise systems with adaptation patterns", **International Conference on e-Business (ICE-B 2010)**, Athens, 2010.
PS60	D. Verma, G. Plunkett, "Systems Engineering and Supportability Analysis: Technology Refreshment for COTS-Intensive Systems", **INCOSE International Symposium 2000**, Minneapolis, 2000.
PS61	D. Verma, T. Strandberg, "Systems and Supportability Engineering and Integration: Best Practices for COTS-Intensive Development", **INCOSE International Symposium 2001**, Melbourne, 2001.
PS62	W. Tang, J. Lee, B. Song, M. Islam, S. Na, E. Huh, "Multi-Platform Mobile Thin Client Architecture in Cloud Environment", **2nd International Conference on Challenges in Environmental Science and Computer Engineering (CESCE 2011)**, 2011.
PS63	J. Ramnarayan, B. Mozafari, S. Wale, S. Menon, N. Kumar, H. Bhanawat, S. Chakraborty, Y. Mahajan, R. Mishra, K. Bachhav, "SnappyData: A Hybrid Transactional Analytical Store Built On Spark", **International Conference on Management of Data (SIGMOD '16)**, New York, NY, USA, 2016.
PS64	V.K. Saxena, S. Pushkar, "Cloud computing challenges and implementations", **2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)**, Chennai, 2016.
PS65	R. Math, A. Goje, "Impact of IoT (Internet of Things) on Growth of Cloud Applications in Service Sector with Specific Reference to Western Maharashtra", **2016 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM)**, Bangalore, 2016.
PS66	W. J.W. Geurts, "Faster is Better and Cheaper", **INCOSE International Symposium**, 2016.
PS67	H. Yang, "Total Cost of Ownership for Application Replatform by Open-source SW", *Procedia Computer Science*, 91, 677-682, 2016.
PS68	D.L. Olson, B. Johansson, R.A. de Carvalho, "A Combined Method for Evaluating Criteria When Selecting ERP Systems", **5th IFIP WG 8.9 Working Conference (CONFENIS 2011)**, Aalborg, Denmark, 2011.
PS69	A. Tušanová, J. Paralič, "A Methodology for Decision Support for Implementation of Cloud Computing IT Services", *Quality Innovation Prosperity*, 18(1), 33-46, 2014.
PS70	M. Fryling, "Estimating the impact of enterprise resource planning project management decisions on post-implementation maintenance costs: a case study using simulation modelling", *Enterp. Inf. Syst.*, 4(4), 391-421, 2010.
PS71	L. Hou, X. Tang, "Analysis of Costs, Benefits and ROI of CRM Implementation", **4th International Conference on Electronic Business (ICEB2004)**, Beijing, China, 2004.
PS72	O. Ratib, B. Liu, M. McCoy, D. Enzmann, "Application Service Provider (ASP) financial models for off-site PACS archiving", **Medical Imaging 2003 Conference**, San Diego, CA, 2003.
PS73	M. Konstroffer, T. Weis, S. Braun, "OpenSource in electronic commerce - A comparative analysis", **1st International Conference on Electronic Commerce and Web Technologies**, London, England, 2000.
PS74	N. Chen, K.K. Ma, "Java's futures: challenge and opportunity", *IT Professional*, 6(4), 19-26, 2004.
PS75	B.O. Odusote, M.O. Adigun, "Technologically enabling resource-constrained enterprises in developing nations through the implementation of E-Commerce on-demand service portals for a grid utility computing platform", **2014 IEEE 6th International Conference on Adaptive Science & Technology (ICAST)**, Ota, 2014.