Greening the Service Selection in Cloud Computing: the Case of Federated ERP solutions

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Abstract

The increasing industrial acceptance of cloud-based IT services has led to a paradigm shift in the development and operation of complex business applications. IT managers are incorporating cloud-based IT services as replacements and/or as enhancements for existing on-site solutions. This strategy leads to the concept of a federated business application, which consists of a variety of on-site and cloud-based subparts, dynamically orchestrated to a single solution. In this setting, the selection of appropriate IT services is critical. Following the discussions of environmental thinking in IT aspects like Green IT and Green IS, the issue of appropriate IT service depends on not only functionality and costs, but additionally also on the environmental impact of the service selection. To address this issue, this paper presents a service selection model for cloud-based services with a focus on the environmental aspects of the selection process. This is done by modeling a multi-criteria decision model based on the rational choice theory. The proposed model provides a selection process which leads to maximal service functionality coverage with minimal environmental impact for a given service provider setting. The application of the model is illustrated in a typical industry case.

1. Introduction

The market for cloud-based IT services is increasing steadily [32]. This gives companies the opportunity to select suitable services to restructure and improve their IT infrastructures. The selection of an appropriate service is challenging [6]. First, it is not easy for companies to formulate their requirements for a particular complex IT solution [10]. From the service provider perspective, a similar problem lies in the service description. In combining an unspecified service request and a uncertain service description, it is highly unlikely to find an optimal solution at first. Moreover, service identification is a critical issue. Several other aspects involve the service pricing, the formulation of appropriate service level agreements and security issues [24]. In the end, the so-called provider lock-in gains more importance since a cloud market lives from its dynamic structure. Provider lock-in means in general that the replacement of similar services from one service provider to another faces relevant obstacles.

For isolated services, various solutions exist in research and industrial practise. But with respect to the composition of different isolated services to a service bundle, the complexity rises and the challenges increase. In addition to the previous mentioned issues, the coordination between the particular services brings up new questions. Moreover, possible scaling effects may be achieved from bundling services. Lastly, the lock-in problem gains more importance since the change of a provider may affect other elements of the service bundle. Besides all these technical and economic issues, ecological issues are becoming the focus of discussions in cloud-based services [3]. There are several works on the linkage between cloud computing and the positive impact of environmental issues like carbon emission and energy reduction [8]. Despite the fact that these discussions are at a very early stage, the general scholarly consensus is that the consideration of environmental issues in information systems is a highly relevant issue for the future. Therefore, all research that sheds light on this linkage generates a value on the future scientific grounding. The present work takes care of this linkage by investigating the cloud-based service selection under an environmental perspective. The key question is how service selection for companies can be done by minimizing the environmental impact of the decision. To investigate this, a case of a federated ERP system

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that should be restructured by cloud-based IT services is considered. The research question is: How can the selection of cloud-based services for a federated ERP system be modeled to obtain maximum eco-efficiency in the whole system?

The article is structured as follows: in Section 2, the foundations of cloud computing, federated ERP, Green IS, and the research approach is displayed. In Section 3, the service selection process is discussed in detail, and the service selection model is developed. This model is a multi-criteria decision model with an emphasis on environmental aspects. In Section 4, this model is applied to a case of federated ERP to demonstrate the application of the model. Implications of the model and limitations are discussed in Section 5. The paper closes with a summary and future research in Section 6.

2. Research Background

2.1 Cloud Computing

Cloud computing is a topic that is given increasing attention from IT managers in companies. The term "Cloud Computing" goes back to a collaboration announcement between Google and IBM [36]. Before this time, various other technologies were discussed in the market which may be considered as predecessors of the term Cloud Computing like "Grid Computing" [14], "Computer in the Cloud" [35] or "Dreaming in the Cloud" [43]. A current definition of "Cloud Computing" is given by NIST: "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."[33]. Breaking this rather complex definition down we can describe Cloud Computing as the delivering of infrastructure, platform, and software in a service model based on a pay-per-use model provided to the customer [10]. The market for Cloud Computing is segmented into three service models: Infrastructure as a Service (IaaS), Platform as a Service (Paas), and Software as a Service (SaaS) [33]. Following a recent study by Sterling Commerce, a software provider from Duesseldorf, Germany, 87 percent of senior IT managers in Germany plan the move to cloud-based information systems in the B2B sector [23]. Main driver for this development according to the survey is cost pressure: most companies promise a cost reduction through the use of cloud-based IT-structures due to a usage-based billing for services. Other aspects are also the better use of their own IT staff, a reduction of manual processes, and an improved transparency of processes. Emphasis on the consideration of cloud-based systems lies in the areas of security and trust [47].

2.2 GreenIS and Green Cloud Computing

The research field Green IS includes measures and solutions to understand the issues of the efficient use of energy and the development of innovative and environmentally friendly strategies and information systems. These information systems can contribute significantly to energy and resource efficiency in companies [38]. A key aspect is the realization of potential savings through the efficient design of business processes using Green IS [7].

In differentiating the development of Green IT to Green IS, the technical analysis refers to the design and implementation of IT systems that help support sustainable business processes. Thus, Green IS addresses broader and deeper problems than Green IT and thereby derives from a greater potential to achieve energy reduction. Therefore, Green IT can be considered as a branch of Green IS [46].

The realization of Green IS measures is typically associated with capital expenditures for companies. However, Green IS and the sustainable development of organizations should not be seen as a cost factor, but as an opportunity to improve company productivity, reduce costs, and increase profitability [46].

There are initial attempts to investigate the issues of Green IS in the context of Cloud Computing. The majority of this research is concentrated on the issue of energy consumption by the cloud service providers (see for example [37, 8, 48, 4, 13]). An extension of this viewpoint is done by Baliga et al. when they investigated energy consumption not only in data centers, but also switching and data transportation [3]. Still, however, this work considers only the technology part of cloud service provisioning. Environmental factors beyond this scope are not considered here.

2.3 Federated ERP Solutions

Enterprise Resource Planning (ERP) systems are information systems to support all business processes within one company [20]. In the classical view, ERP systems incorporate different types of business applications into one holistic system. These systems comprise several functions and requirements which are needed in the company. Depending on the specific requirements of a company, the installation and configuration setting is determined by the customer itself or by a service provider for the ERP system. In contrast to this monolithic view, a federated ERP system is an ERP system which consists of system components that are distributed within a computer network [5]. These system components are provided by network nodes, which are represented by different service providers. The overall functionality of the ERP system is the aggregation of the individual functionality of the single nodes. The components, which are combined to the entire ERP solution, may be developed and provided by different service providers [1]. From a consumer perspective, the collection of components is perceived by the user as single ERP solution. From a cloud perspective, the area of federated ERP solutions is also discussed in the scientific community of inter-cloud research [9].

2.4 Research Approach

The main objective of this research is to create a decision model for cloud-based IT services with a focus on aspects of environmental impact. The research uses a design science approach. Design science is a research method to solve organizational problems by creating and evaluating IT artifacts [21]. These IT artifacts are denoted as constructs, models, methods, and instantiations [31]. Several methodological approaches for the conduction of design science research are proposed in the literature (see for example [31, 39, 27]). For this research, we have adapted the design science research methodology from Kuechler & Vaishnavi. The first process step, problem recognition, has been addressed in the introduction. It could be shown that the inclusion of environmental aspect in the decision making for service selection is relevant, but missing in research and industrial practice. This leads to the main research question: How to develop a decision model with emphasis on the environmental aspects of the IT service selection? In the second process step, we suggest the adaption of a multi-criteria decision model. This suggestion is based on a broad literature study, which identified relevant measures and existing artefacts for assessing these measures. The new model is developed in the third step by integrating environmental aspects as criteria groups into the decision model. This development extends existing decision models and leads to model which is varying in the solution approach based on the type of criteria integration. For the evaluation of the proposed model, we follow the guidelines for design science research according to Hevner et al. [21]. In this research, experimental evaluation based on an artificial business case was selected to demonstrate the usability of the proposed model. The business case was developed with leading industry experts from the area of cloud service providers and business application vendors.

3. Service Selection for Federated, Cloud-based ERP Solutions

3.1 Service Selection Process

Throughout the course of this paper, the focus is on the consideration of the supplier-related tasks, which include essentially methods for the identification, selection, and qualification of potential suppliers [45]. Supplier identification is used to identify service providers on a market who provide the required procurement item, a cloud-based service. Supplier selection covers different activities; firstly, the potential service providers have to be analyzed and rated. Sometimes it is necessary to add additional information to the first results of the search because the potential service providers do not provide enough self-information to get a rating. Secondly, for rating purposes, it would be beneficial to use existing ratings for the service providers to integrate them into a new ranking or to compare the existing ranking with the new ranking. Supplier qualification follows as the third step and leads to the long-term aspects of the supplier-buyer relationship. After the selection of relevant service providers, there is a need to maintain and develop the supplier-buyer relationship for forthcoming issues. In literature, these activities can be found under the term supplier relationship management [28]. Regarding the development of the relationship between a service provider and a customer, the selection process can be regarded as the first step in their collaboration. The importance of this first step is shown by the fact that customers often buy services in a certain order, starting with relatively simple services to more complex and expensive ones [11].

3.2 Selection Criteria

In IT service management, the selection of services and their corresponding service providers is a challenging issue [40]. Mainly, this is because services are generally characterized by intangibility, inseparability of product and consumption, difficulty of standardization, and perishability [22]. It is vital for the service provider to know the specific requirements of the service consumer when they try to make their decisions for a particular service offering [18].

The selection of IT services is based on various criteria. These criteria can be categorized in three different areas: First, functional criteria have to be taken into account [17]. In the functional area, it is necessary to ensure that the functional requirements of the service consumer are met by the cloud service. Second, consumers decide for a service based on non-functional criteria [42]. Criteria in this area are, for example: price, quality, and image of the service provider. Third, emerging ecologic criteria come into play [3, 30, 16]. The discussion of the ecological impact of cloud computing is gaining more momentum. It is assumed that substituting on-site IT services with cloud-based services has a positive impact on ecological issues (see for instance an industry study by Accenture and WSP Environment & Energy [2]). Several criteria have to be considered for an ecological perspective. In the forefront, there are rather obvious factors like carbon emissions, waste, and equipment recycling ratios. Additionally, factors like noise, heat, and carbon footprints of tangible aspects (for example, if consultants have to implement parts of the IT services on location and need to travel to the company) are taken into considering. Research on these and further aspects of the ecological description of cloud services is only in their beginning [15].

3.3 Service Selection as a Decision Problem

Making a decision for an item which is described by various criteria can be a challenging task. It is not only about making the right decision for a single attribute, but rather for the whole combination, which may contain contradictions, making it difficult to find an optimal solution. To address this, operation research provides methods to address this problem. In particular, the described case can be considered as a multi-criteria decision making problem. In daily life, we can see the problem of conflicting criteria. For example, in buying decisions, the criterion of cost often contradicts the criterion of quality. It is unusual that the cheapest offer provides the highest quality. By looking at the IT service industry, we see a conflict between the cost of providing a particular service to the ratio of customer satisfaction. These small examples show that making the right decision in multi-criteria decision environments needs a systematic approach to determine the optimal solution.

Research in the field of multiple criteria decision making started in the early 1960s [26]. There are different types of multi-criteria decision problems, which are typically defined as explicit or implicit. In the first case, each decision alternative is represented by its behavior in each criterion. The challenge is to find the best alternative for a decision maker or sorting the alternatives in relation to a specific goal. In the second case, the alternatives are not explicitly known, and the challenge to find an alternative is by solving a mathematical model. These are called multiple-criteria design problems and are discussed in the area of mathematical programming.

Formulating a multi-criteria decision problem consist of three key elements: First, the criterion space. The criterion space consists typically of a set of criterion functions that represent the relevant criteria of the items to be selected. Second is the decision space, which is the set of possible decisions for the problem. Third, constraints are used to describe the relationship between different criteria with respect to the decision space.

There is a large list of methods which can be used to solve multi-criteria decision models. The most prominent methods are the Weighted Sum Model (WSM), Value Analysis (VA) and Data Envelop Analysis (DEA). It is necessary to take care of applying the appropriate solution method to the characteristics of the model.

The discussion of using multi-criteria selection methods for optimal service selection in Cloud Computing has already started (see for example Rehman et al. [40]). This work provides a general approach to use multi-criteria decision models for the cloud service selection based on very common attributes like cost and performance. The work is extended to an investigation of multi-criteria selection on the IaaS service level for Cloud Computing services [41]. On one hand, environmental aspects are not considered as factors for decision making. On the other hand, the question remains whether these investigations will hold true when considering the SaaS service level, which is necessary for selecting services for business applications.

3.4 Problem Formulation

We denote $x_i \in X$ as the service with index i, selected from the set of services X. The service x_i is provided from a service provider P_j and is able to fulfill the requirements of a certain service to the degree of SC_i. These requirements may not only be functional requirement, but also non-functional requirements (e.g. quality, performance), risk constraints and regulatory issues. Services might be grouped together in service classes. These service classes act as an umbrella for services providing similar functionality and helps the model to narrow the selection of an appropriate service within a service class to ensure no double-selection of services for the same requirements. Each service x_i is related to its specific environmental impact EI_i. The costs of the service are subdivided in two parts: the integration costs IC_i and the compensation costs CC_i. The integration costs are the costs related to the effort of integrating the single services into the basic business application. The compensation costs are those costs which arise because of a lack of functional coverage of the service. A single service $x_i$can be written as tupel:

$$x_i = (P_j, SC_i, EI_i, IC_i, CC_i)$$

The aim of the selection process is to find a set of services which cover the required functionality maximum while concurrently minimizing the environmental impact and costs. As a decision problem, it can be formulated as follows:

$$\max_{SC} \coprod_i x_i$$

with $\coprod X_i$ as the functional orchestration of all selected services. The term "functional orchestration" describes to integration of the selected services with the existing system environment on a system level, data level, and process level. The orchestration covers all tasks to integrate and run the selected services in combination with the existing platform as a single solution. In a simple setting, the services might by orchestrated by just selecting the single services without any integration. In this case, the orchestration is just an adding of services and would lead to a sum in the model formulation. In a complex setting, service might be highly depending on each other. Therefore, orchestration would eventually lead to high individual programming effort, which would lead to a multiply formulation and to a non-linear model. This type of general orchestration concept is necessary to reflect the specific requirements for federated ERP systems. In this type of market, based on the component structure of the ERP system, the orchestration might be different beginning with the mentioned simple setting up to the complex situation of individual programming effort for component and service integration.

Minimizing the environmental impact:

$$\min_{EI} \coprod_i x_i$$

Minimizing costs:

$$\min_{IC+CC} \sum_i x_i$$

with the constraints:

1) $x_i, x_{j,} x_k$ *from different service classes for* $i \neq j \neq k$

2) $SC_i, EI_i, IC_i, CC_i \geq 0$

3) $SC_i \leq 1$

The constraints are interpreted as follows: First, the selected services have to cover all the required service functionalities. Therefore, different services have to be from a different service class to avoid that one service functionality will be provided by two different services which provide the same functionality. Second, all impact and cost measures should be positive. Third, the service coverage of a single service should be in the range of 0 (no coverage) to 1 (full coverage).
The solution of the problem depends on the modeling of the service orchestration. In the simple case of connecting single services together with no or limited interaction, the problem is a linear programming problem and can typically be solved easily by using the Simplex method. For a higher integration ratio between the selected services, the model may develop to a dynamic programming model. It can be assumed that in this case, uncertainty will be an essential part of the service orchestration. Therefore, the problem may develop to a probabilistic dynamic programming model. As soon as we leave the level of dyadic relationships between the suppliers and consider a supply network, the problem will no longer remain linear. The study of these types of problems will lead to new insights in the requirements for service markets in the future. The inclusion of uncertainty and the consideration of supply networks will be part of the future work.

4. Model Evaluation

According to the selected design science approach, several methods can be used to evaluate the proposed model. In this paper, the decision was made to use an experimental evaluation for the proposed model. The decision for an experimental evaluation was based on the fact that the business case of service selection in federated information systems is just at the beginning of practical implementation, and established industry cases are not available yet. Therefore, to evaluate the proposed model and to demonstrate the application of the proposed model in industrial practice, an artificial business case has been developed to serve as an evaluation foundation. This artificial approach may be classified as a simulation, which is an accepted means to evaluate a proposed artifact [21].

This business case has been developed based on intensive round-table discussions with industry experts in the area of data center provisioning and cloud services providers. There was a first discussion with eight industry experts to gain a common understanding of the business case and to collect existing experiences in current industrial practice. In addition, three experts from a leading ERP solution provider were involved in the discussion of the scenario. The round table took one day of discussion in a moderated group setting. All experts agreed on the fact that providing this kind of service is one of the future challenges in information system provisioning and that an enhanced understanding of these selection processes would have a significant impact on future business models for IT service providers. The discussion was voice recorded and analyzed immediately after the session to extract the relevant issues. Based in these first findings, a business case was developed as a foundation for the second round table. Once again, the proposed business case was structured discussed with the same 11 industry experts and refined to its current state. This refinement took again one day of round table discussion in a grouped environment and was voice recorded again. Based on the experiences and knowledge of future user requirements, the following business case has been developed to represent the core of the future challenge. Therefore, this case may be considered representative of the addressed problem from an industry expert's view.

The business case may be described as follows: Assume an existing ERP solution which is implemented on-site by an industry company. This ERP solution should be enhanced in three functional areas: First, for the CRM (Customer Relationship Management) model, an address validation service should be integrated to enhance the quality of the customer addresses. Second, the company wants to eliminate all physical fax machines by introducing a cloud-based fax service. Third, the IT department wants to switch to a backup service level with value-added functionality for the company users. To achieve these enhancements, the company decides to follow a federated ERP system approach rather than implementing the enhancements by themselves. Therefore, services have to be identified and selected, which provide the necessary functionality and can be integrated into the existing solution. For the address validation, an online service has to be selected which is able to receive address data from the ERP system, validate them with a reliable result, and send the validation result back to the ERP system. For the fax solution, an online communication service has to be selected which is able to transform different message formats to a fax format in order to send it to the corresponding recipients. The systems backup should change from an internal solution to a cloud-based backup service to ensure a better service level for the backup functionality. For these three services, a selection has to be made. The case situation can be obtained from Fig. 1:

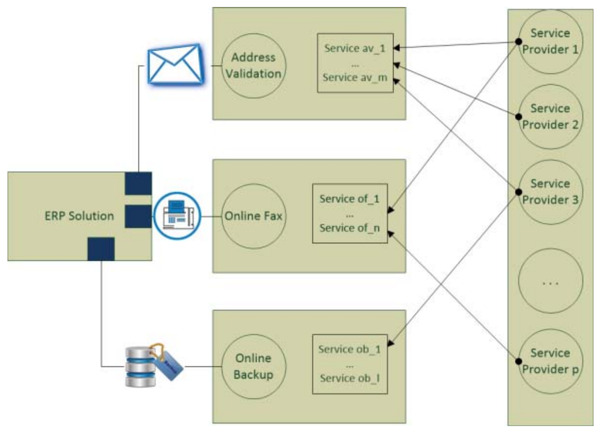

Figure 1. Federated ERP business case

In the IT service market, several service providers exist who are able to provide these services. Some of the IT service providers may be able to provide only one particular service, whereas others may be able to provide multiple services. For structuring purposes, the services from the proposed business case will be categorized by service classes. These service classes consolidate all services from the IT service market into one specific requirement.

This means that the selection problem for the proposed business case is to select three services in three different service classes. To apply the model, a market structure is necessary to be able to conduct the selection process based on the proposed decision model. The market structure to reflect the major market mechanism (service providers for unique services and service providers for multiple services) is defined as follows: for the first service of address validation, three services are available. Two of them come from service provider 1, and the third one comes from provider 2. For the second service, online fax, four services are available. One comes again from service provider 1, one comes from service provider 3, and two come from service provider 4. For the last requirement, the online backup solution, two services are available, one of which from provider 2 and the other from provider 3. For every service, certain assumptions for the characteristic have been made. First, for every parameter (SC, EI, IC, CC), a value range was defined which is aligned with a typical decision situation in practice. For Service Coverage (SC), it was assumed that the identified services are covering the requirements quite well. Therefore, the range was defined from 80% to 100%. For Environmental Impact (EI), the assumption is that the impact will not be higher than 50% of the possible impact. For the Integration Costs (IC) and the Compensation Costs (CC), no limitation was chosen because costs may vary significantly and there is no reason which leads to a limitation on the lower or upper limit. After these restrictions, the parameter value of the specific parameter was selected randomized by using the Random function implemented in Excel. The overview of the complete setting can be obtained from Table 1 to Table 3.

Table 1. Settings for Service Coverage (SC)

	Service	SP1	SP2	Sp3	Sp4
Service Class	**x_AV-1**	100	0	0	0
	x_AV-2	80	0	0	0
	x_AV-3	0	90	0	0
Service Class 2	**x_OF-1**	100	0	0	0
	x_OF-2	0	0	80	0
	x_OF-3	0	0	0	70
	x_OF-4	0	0	0	90
Service Class 3	**x_OB-1**	0	90	0	0
	x_OB-2	0	0	90	0

Services which are not provided by a particular service provider are marked with "0".

Table 2. Settings for Environmental Impact (EI)

	Service	SP1	SP2	Sp3	Sp4
Service Class	**x_AV-1**	30	0	0	0
	x_AV-2	30	0	0	0
	x_AV-3	0	40	0	0
Service Class 2	**x_OF-1**	30	0	0	0
	x_OF-2	0	0	20	0
	x_OF-3	0	0	0	40
	x_OF-4	0	0	0	30
Service Class 3	**x_OB-1**	0	40	0	0
	x_OB-2	0	0	30	0

The settings for the environmental impact are assumed for every single service. It is assumed that the environmental impact may decrease when two or more services are provided by a single service provider due to bundling effects. This assumption is not yet part of the proposed model but will be part of the future work on this topic.

Table 3. Settings for Service Costs (IC+CC)

	Service	SP1	SP2	Sp3	Sp4
Service Class	**x_AV-1**	40	0	0	0
	x_AV-2	140	0	0	0
	x_AV-3	0	100	0	0
Service Class 2	**x_OF-1**	40	0	0	0
	x_OF-2	0	0	140	0
	x_OF-3	0	0	0	120
	x_OF-4	0	0	0	90
Service Class 3	**x_OB-1**	0	30	0	0
	x_OB-2	0	0	60	0

At the model's current development stage, service costs and compensation cost are combined into one cost factor. Again, the bundling of two or more services from one service provider may have a positive impact on the cost factor, especially on the decreasing of integration costs. This assumption is not yet part of the model and has to be investigated in future research.

The proposed decision problem has been solved by using Solver for Excel 2010. The Simplex-LP module was chosen since the problem can be regarded as a linear optimization problem with integer constraints. The solution to the selection decision can be obtained from Table 1: the services-provider combinations which are marked in grey with a "1", have to be selected to solve the formulated decision problem. Therefore, the solution for the proposed setting is to select the services

$$\mathrm{x\_AV} - 1 \text{ and } \mathrm{x\_OF} - 1 \text{ and } \mathrm{x\_OB} - 2$$

with x_AV-1 and x_OF-1 from service provider 1 (SP1) and x_OB-2 from service provider 3 (SP3).

Table 4. Solution for the service selection problem

	Service	SP1	SP2	Sp3	Sp4	SC Sum (constraint)
Service Class 1	x_AV-1	1	0	0	0	1
	x_AV-2	0	0	0	0	
	x_AV-3	0	0	0	0	
Service Class 2	x_OF-1	1	0	0	0	1
	x_OF-2	0	0	0	0	
	x_OF-3	0	0	0	0	
	x_OF-4	0	0	0	0	
Service Class 3	x_OB-1	0	0	0	0	1
	x_OB-2	0	0	1	0	
	Sum (Services)	2	0	1	0	

This service selection has a service coverage rate of 97%, a mean environmental impact of 30, an average implementation cost (integration costs + compensation costs) of 40, and it provides the optimal solution for service selection with environmental focus.

5. Discussion

The experimental evaluation with an artificial business case is on the one hand in alignment with the generic rules for design science research [19], but on the other hand can only be regarded as a first step for a practical implementation of the model. The business case was based on the experiences and requirements knowledge of industry experts, but was kept small to give a clear insight into the functionality and the application of the model. To understand the expected behavior of the proposed model, the business has to be significantly enlarged by considering more services, more service providers, and more parameters for the service description. This can be achieved by extending the simulation data significantly and replacing the predefined market setting used in this paper by a randomized market setting based on a random link between service providers and services. Taking this randomized market setting as a foundation, the simulation can be conducted with large numbers of market participants to reflect a distributed and fragmented market aligned to the practical situation.

The proposed model fits to the situation because there are only dyadic relationships between the company and the service providers. Complexity increases significantly, if there will be a complete supply network for IT service, where multiple tiers of suppliers exist, and one supplier may handle the sourcing request from the company to the supplier one tier lower. This is a typical case in complex cloud computing service markets. Suppliers in the supply network then act as suppliers as well as customers and the service selection face increased challenges. One of these challenges is that the information availability within a supply network over multiple tiers decreases with the rising complexity of the network [29]. Therefore, it is not obvious how to get all information needed to apply the decision model. A second obstacle is the rising complexity of cost calculation, especially of integration costs, within the supply network. This limitation arises because of the decreased availability of information and as well because of the problem of requirements specification of services [12]. Answering these open questions requires a further investigation of the situation. Extending the experimental simulation will first give insights as to how to approach these questions.

The proposed model is on a generic level highly appropriate for a Green IS selection model. Nevertheless, one serious challenge of the proposed model is the quantification of the necessary parameters, especially the environmental impact. In current research, the environmental impact of IT services can only be calculated for simple situations [34, 25]. In a more complex one, the calculation of environmental impact is not easy to achieve [44]. With an increasing understanding of linkage between determining factors and more sophisticated methods for environmental measurement, this situation will become more transparent. This will lead to a better application of the proposed model to increasingly complex situations. The identification and measurement of environmental impact factors for cloud services will be part of future work of this research.

6. Summary and Outlook

The aim of this paper was to develop a decision model for IT service selection that focuses on the environmental impact of the service selection and the resulting service combination. In the emerging IT service industry there is an increasing acceptance of cloud-based services as a substitution and/or enhancement to one-site business applications, as well as an increasing pressure for environmental-friendly IT. Following this, we have developed a multi-criteria decision model which incorporates the environmental impact of an IT service with respect to the corresponding service provider which has a minimal environmental impact for a certain maximum service coverage. The application of the proposed model has been shown on a typical industry business case.

This model can be considered as a first attempt to include environmental thinking into the IT service selection and, moreover, in the IT service industry itself. In the next steps, the model will be extended by the dynamic linkage between the different service providers. From the current perspective, this model works in classic small and midsized situations. The model's behavior in a larger setting is an open question. It can be assumed that scaling effect by distributing a single service functionality to multiple service providers will gain more importance to ensure service quality. As a third aspect, there is the inclusion not only of one-time costs, but also of recurring costs like monthly service fees for example. This would lead to a more long-term coverage of the selection process.

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