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An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing

by

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Completed Research Paper

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Abstract

Companies increasingly extend their outsourcing strategies from single-sourcing to multisourcing combining best-of-breed vendors. This paper includes an analytical model to evaluate a company's multisourcing strategy. The model can be applied for decision support to answer the questions, how many and which outsourcing vendors to integrate in the implementation of an IT project. We identify an optimal vendor portfolio considering monetary benefits and risk diversification as well as transaction costs arising from the integration and coordination of outsourcing vendors. Based upon a simulation, we find that it makes good economic sense to include a risk evaluation into the multisourcing decision process even if it is subject to misestimation. Therewith, companies are able to avoid unnecessary high risk and consequently a possible high damage. Furthermore, we find that it is better to be too cautious in risk assessment than to be too negligent.

Keywords: Multisourcing, multi-vendor outsourcing, portfolio management, analytic model

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Introduction

According to Dibbern et al. (2004) firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes. Increased competition forces companies to deal with the cost cutting which is necessary to stay in business. Therefore, the market for outsourcing services increased significantly over time and is about to outgrow previous prospects (Aspray et al. 2006). IT outsourcing vendors benefit from this development and become more specialized and competitive (Lacity et al. 2009). This provides the opportunity for companies to close more profitable outsourcing deals with vendors that are experts in the respective area. Especially software development projects are affected, in consideration of the fact that today software development skills are global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003). It is of particular importance for companies to identify a profitable software development outsourcing strategy, which encompasses not only strategic, but also economic and social perspectives (Lee et al. 2003). For the time being, in the majority of companies, a viable outsourcing strategy is either unknown or difficult to determine, because project evaluation processes are neither specified nor documented. Therefore, many companies struggle with the execution of an integrative outsourcing strategy and still have difficulties to succeed in the implementation of IT projects. On the contrary, Sauer et al. (2007) illustrate, when project risks are managed by a capable team, follow reasonable plans and tactics, and are of a manageable size, the outcomes are far better. To meet the desired requirement of managing an IT project profitably, multisourcing evolves as a capable strategy (Cohen and Young 2006; Levina and Su 2008; Oshri et al. 2009). The principal reasons for multisourcing from a client's perspective are increased bargaining power and better performance of the vendors (Lee et al. 2009).

Bapna et al. (2010) examine the dependencies of multiple vendors who are competitors and co-workers at the same time. All vendors who participate in the same project have to rely on each other's performance to meet the client's requirements. Little research has addressed this increased complexity. The authors demonstrate that „linear extensions of dyadic client-vendor IT outsourcing relationships are insufficient to capture the nuances of a multisourcing environment." They point out that further research shall address the characteristics of multi-vendor relations. As a first step, we examine a multisourcing strategy from a client's perspective and provide a model that helps the client to render multi-vendor IT outsourcing decisions.

The selection of IT outsourcing vendors is rarely conducted using quantitative methods and it is rarely taking cost, benefits, and risk into account. Especially a comprehensive risk assessment is still very scarce although multisourcing can offer important advantages in this respect. Sourcing IT to a single vendor might lower costs of coordination but the client "puts all eggs into one basket". This is fraught with problems when it comes to a poor performance or even default of the chosen vendor. Furthermore, considering the complex dependencies within every IT project (Kundisch and Meier 2011) an unfortunate allocation of a single vendor to several essential subprojects can bear extreme risk for the project as a whole.

As today's decision makers oftentimes neglect the assessment of risk, it is very difficult to acquire data for an empirical evaluation. Especially the comparison of the respective projects' success and the used methods of risk assessment is demanding. Though, to generate further insights, we developed a formal deductive economic model to provide an understanding of the importance of risk assessment in the multisourcing decision process. A common reason for neglecting risk is the fact that the estimation of risk is often prone to error and requires a considerable amount of time and money. Regarding the vendor selection process, we illustrate that even if risk is assessed with a substantial estimation error, much better project outcomes can be achieved than in a scenario without risk assessment.

From a practitioner's point of view, the model enables companies to improve their multisourcing strategy in an economic sense by considering costs, benefits, and risk of the decision. Our model shall not serve as a substitute for existing selection processes (see e.g. Cao and Wang 2007; Michell and Fitzgerald 1997; Wadhwa and Ravindran 2007) but it might do so as a complementary tool for decision support. As drawing normative conclusions from our model requires empirical evaluation, the data gathered from its application may be used to empirically evaluate its utility in the future.

Considering the aforementioned insights from research in multisourcing, transaction cost, and portfolio theory we pose the following research questions:

1. Given a set of outsourcing vendors what is the optimal multi-vendor IT outsourcing strategy from a client's perspective, i.e. which vendor should conduct which subproject?
2. How does the assessment of risk affect this decision? How substantial is the error when neglecting risk?

To the best of our knowledge there are no scientific papers addressing a quantitative portfolio selection as well as the importance of risk assessment in multi-vendor IT outsourcing.

Subsequent to a brief survey of the essential literature, we describe the basic setting and assumptions of our model. The risk-adjusted net present value of a project constitutes our objective function. We derive first results by the means of an analytical two subproject example. Then, we use a Monte Carlo simulation and identify the best multi-vendor IT outsourcing solutions. After describing the simulation framework, we evaluate and discuss the robustness of our model. To conclude, we derive results and address practical implications, limitations and prospects of our model.

Literature Overview

IT outsourcing is defined as the decision on relocating an IT department's tasks to a third party vendor, who conducts them and charges a certain fee for the service (Apte et al. 1997; Lacity and Hirschheim 1993; Loh and Venkatraman 1992). The reasons for IT outsourcing are manifold, e.g. Di Romualdo and Gurbaxani (1998) identified three strategic intents for IT outsourcing, in particular IS improvement, business impact, and commercial exploitation. But the main motive is the cost advantage outsourcing bears, if implemented appropriately (Dibbern et al. 2004; Lacity and Willcocks 1998). To succeed in the implementation, firms need a strategy to manage the costs, benefits and risks of outsourcing decisions (Nault 1997; Willcocks et al. 1999). An integrated view of outsourcing, containing strategic, economic and social aspects, helps firms to realize the anticipated gains (Lee et al. 2003). In the past fifteen years, instead of closing "outsourcing megadeals" selective outsourcing evolved, where companies decide deliberately on their outsourcing activities (Lacity et al. 1996). Aron et al. (2005) coin the term "rightsourcing", which means that a conscious risk and relationship management with multiple outsourcing vendors enables companies to reap benefits. Therewith, outsourcing clients are able to combine the best-of-breed vendors to implement their IT strategy optimally (Bapna et al. 2010). Furthermore, developments in integration technologies lead to lower costs of technical integration and coordination, which facilitates the collaboration of numerous parties (Moitra and Ganesh 2005).

Besides the benefits, drawbacks have to be taken into account, when deciding on outsourcing (Dewan et al. 2007). Outsourcing can entail disadvantages like unauthorized knowledge transfer, inflexibility though long term contracts, poor relationship management and accompanying poor loyalty and quality (Bryce and Useem 1998). Also the choice of the outsourcing contract is relevant for outsourcing failure or success (Gopal et al. 2003; Susarla et al. 2010). Therefore, risk factors must be included into the evaluation of outsourcing decisions. Since the formerly mostly dyadic relationships of client and vendor evolved to complex relationships of client and multiple vendors, which implies dependencies on mutual performance and willingness of collaboration (Bapna et al. 2010; Cohen and Young 2006; Levina and Su 2008), interdependencies have to be considered when determining an IT project's risk. Many articles focus on the qualitative assessment of risk, for example Aron et al. (2005) and Willcocks et al. (1999), whereas few focus on the quantification and computation of risk, like Aubert et al. (1999). Due to the increased professionalism of outsourcing service providers there is a high potential of saving development time and cost reduction. When multi-vendor outsourcing is implemented appropriately, the specific risks of IT, such as project failure, time over-run, budget over-run and missing targets could be diminished.

In addition to the risky costs and benefits of development, transaction costs occur, if a project is outsourced to a vendor (Aubert et al. 2004; Lammers 2004). Transaction costs can be split into fixed and variable components, whereas fixed transaction costs occur as soon as certain projects or fractions of a project are outsourced, for example costs of negotiation and project initiation (Patel and Subrahmanyam 1982). Variable transaction costs depend on the magnitude of the fraction or project outsourced, e.g. costs of communication and control (Dibbern et al. 2006). For a brief survey of transaction cost economics and "extra cost" evolving from client vendor relationships in the context of outsourcing see Dibbern et al. (2008).

Today, firms are trying to establish a comprehensive IT portfolio management, in order to get the most advantageous rates of risk and return (Oh et al. 2007; Weill and Aral 2005). Therefore, many papers address the issue of how to govern an IT project portfolio. Quantitative approaches on IT portfolio management, e.g. Verhoef (2005), work with economic theory such as the discounted cash flow but mostly omit interdependencies between projects. Some approaches model interdependencies by using portfolio theory (Butler et al. 1999; Santhanam and Kyparisis 1996). Zimmermann et al. (2008) for example adapt portfolio theory to propose a decision model for global IT sourcing decisions. They consider the costs of site and project combinations as risky and build a portfolio optimization model. Approaches which apply portfolio selection methods on multi-vendor IT outsourcing are scarce and mostly focus on programming issues like Chen and Cao (2009).

Similar to most of the aforementioned articles, our model does not consider the risk of outsourcing in its entirety (e.g. qualitative vs. quantitative risk, risk of costs vs. returns). We focus on risk as estimated and computable variations of the net present values of IT (sub-) projects. Using this abstraction we are able to provide an economic model that delivers relevant insights supporting the design of outsourcing decision processes in today's businesses.

Model

Our focus is the analysis of a situation where an outsourcing client wants to optimize the IT outsourcing strategy considering multiple vendors. Therefore, we look at a set of outsourcing vendors V, v denoting an element of V. The project at hand consists of indivisible, consecutively numbered subprojects $s = 1..S$ which are all obligatory for the project's success. Without loss of generality, each subproject is assignable to any of the outsourcing vendors in V. The model is also capable of picturing in-house development; if a subproject is developed internally the client is modeled as one of the service providers.

We define the row vector $\vec{v} \in V^S$ as our decision vector. The column s of $\vec{v}$ contains the selected vendor for subproject s. We define the function $v(s)$ to return the selected vendor for any subproject s. We model a subproject's net present value $\widetilde{NPV}_{s,v}$ as a random variable depending on the respective outsourcing vendor.

By using the expected net present value and its standard deviation, we are able to capture all IT-specific risks albeit on an abstract level. The risk of budget overruns directly influences the amount of the cash outflows and can therefore be modeled by the standard deviation. Time overruns lead to delays in cash inflows. Even if a project fails or misses its targets cash out- and inflows vary accordingly. As over-estimating the required time or budget is also unfavorable, a two-sided risk measure like the standard deviation is applicable. Therefore, all kinds of IT specific risks are taken into account by considering a projects' $\widetilde{NPV}_{s,v}$.

Regarding the decision on vendors for subprojects $\vec{v}$ considering every subprojects' $\widetilde{NPV}_{s,v}$, we make the following assumption 1:

Assumption 1: *The decision maker maximizes the entire project's risk adjusted net present value. The calculation of the risk adjusted net present value follows the general structure $\Phi = \mu - \alpha\sigma^2$. μ denotes the expected net present value; σ^2 denotes its variance as a measure of risk. We define α as the parameter of risk aversion and assume that the decision maker is risk-averse ($\alpha > 0$). The correlation between subprojects is depicted by the Bravais-Pearson correlation coefficients $\rho_{s,v,\dot{s},\dot{v}}$ for the respective subprojects s and $\dot{s}$ as well as vendors v and $\dot{v}$.*

The risk adjusted net present value can be interpreted as the certainty equivalent of $\widetilde{NPV}_{s,v}$ for normally distributed random variables and an exponential utility function and thus as a sum of money. This approach is in line with the Bernoulli principle and an established method of decision theory (Bernoulli 1738; Bernoulli 1954; Markowitz 1959; von Neumann and Morgenstern 1947). The parameter $\alpha > 0$ is a linear transformation of the Arrow-Pratt characterization of absolute risk aversion (Arrow 1971). The higher the value of α, the more risk-averse is the decision maker. A risk-averse decision maker favors the utility of a risk-free net present value over a risky net present value with identical expected value. To determine the value of α, a company can draw on a market's utility function (competitors etc.) and thereof derive α (Kasanen and Trigeorgis 1994). Similar formal approaches and assumptions for risk adjusted economic value analysis have been derived by Longley-Cook (1998) and have been applied in the context of IT portfolios numerous times, for example in Bardhan et al. (2004), Fridgen and Müller (2009), Hanink (1985), Fogelström et al. (2010), and Zimmermann et al. (2008).

As described above, outsourcing one or more subprojects to a certain vendor causes fixed and variable transaction costs. Assuming the variable transaction costs to be part of the respective $\widetilde{NPV}_{s,v}$, we account for the fixed transaction costs by the following simplifying assumption 2:

Assumption 2: *Each outsourcing vendor v conducting at least one subproject causes risk-free transaction costs k_v. The function $K(\vec{v})$ returns the sum of the transaction costs k_v for all distinct components of $\vec{v}$.*

There might be real world situations where certain combinations of vendor and subproject are not practicable. For instance, a small company specialized on user-friendly front-end design is most probably not able to setup a complex database infrastructure. This issue can be covered by our model and the respective optimization algorithms through assuming prohibiting (e.g. infinite) values for the respective $\mu_{s,v}$ and $\sigma_{s,v}$.

Objective Function

A project's risk adjusted $\widetilde{NPV}_{s,v}$ minus transaction costs constitutes the objective function which is to be maximized by choosing an optimal $\vec{v}$.

$$\Phi(\vec{v}) = \sum_{i=1}^{S} \mu_{i,v(i)} - \alpha \sum_{i=1}^{S} \sum_{j=1}^{S} \sigma_{i,v(i)} \sigma_{j,v(j)} \rho_{i,v(i),j,v(j)} - K(\vec{v})$$

With having a decision vector instead of a single decision variable, the model can be solved analytically for small problems only. This is due to the fact that all subproject-vendor combinations have to be analyzed and compared to each other individually. For example, with 4 subprojects and 5 vendors, $5^4 = 625$ different cases arise. Therefore, a full enumeration demands for computerized support. As real-world multi-vendor portfolio selection problems will be of a magnitude that can be handled by computers within seconds, a computer-aided full enumeration usually will be preferred to applying heuristics.

Model Evaluation

As described above, in today's companies a risk assessment, as requested by our model, is difficult to find. Consequently, at this point in time it is virtually impossible to acquire real world data to examine the benefits of risk assessment profoundly. However, as stated in the following, considerable advantages can be realized by applying the model. Therefore, companies might adopt it and a real world evaluation using case or field studies will be possible in the future.

According to Hevner et al.'s (2004) design science approach, an analytical evaluation or gathering data by simulation are legitimate means. For illustration and to derive first results for the mathematically interested reader, in a first step we analyze the setting of an IT project consisting of only two subprojects offered by two vendors analytically. Due to the model's complexity when applied on larger problems, an analytical evaluation is not auspicious. In a second step, for more complex project settings, we present and analyze the results of a Monte Carlo simulation.

Analytical Evaluation: Two Vendors and Two Subprojects

In the following, we examine the setting of an IT project consisting of two subprojects ($S = 2$) offered by two vendors ($V = \{A, B\}$). Consequently, $\vec{v}$ may contain four different tuples:

- $\vec{v} = (A, A)$, i.e. both subprojects are conducted by vendor A
- $\vec{v} = (B, B)$, i.e. both subprojects are conducted by vendor B
- $\vec{v} = (A, B)$, i.e. the first subproject is conducted by vendor A, the second by B
- $\vec{v} = (B, A)$, i.e. the first subproject is conducted by vendor B, the second by A

For an optimization, it is necessary to compare the results of the objective functions $\Phi((A,A))$, $\Phi((B,B))$, $\Phi((A,B))$, $\Phi((B,A))$ and identify the $\vec{v}$ with the maximum $\Phi(\vec{v})$. Therefore, we consider

$$\Phi\big((A,A)\big) = \mu_{1,A} + \mu_{2,A} - \alpha\big(\sigma_{1,A}^2 + \sigma_{2,A}^2 + 2\sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A}\big) - k_A,$$
$$\Phi\big((B,B)\big) = \mu_{1,B} + \mu_{2,B} - \alpha\big(\sigma_{1,B}^2 + \sigma_{2,B}^2 + 2\sigma_{1,B}\sigma_{2,B}\rho_{1,B,2,B}\big) - k_B,$$
$$\Phi\big((A,B)\big) = \mu_{1,A} + \mu_{2,B} - \alpha\big(\sigma_{1,A}^2 + \sigma_{2,B}^2 + 2\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B}\big) - k_A - k_B,$$
$$\Phi((B,A)) = \mu_{1,B} + \mu_{2,A} - \alpha\big(\sigma_{1,B}^2 + \sigma_{2,A}^2 + 2\sigma_{1,B}\sigma_{2,A}\rho_{1,B,2,A}\big) - k_B - k_A.$$

According to our research question, it is of particular interest, under which conditions the client favors the multiple vendors solutions (A,B) or (B,A) over the single vendor solutions (A,A) and (B,B). In our illustration A and B are interchangeable without loss of generality. Hence, we focus on one representative comparison:

$$\Phi\big((A,B)\big) > \Phi\big((A,A)\big)$$
$$\Leftrightarrow \big(\mu_{2,B} - \mu_{2,A}\big) - k_B - \alpha\left(\big(\sigma_{2,B}^2 - \sigma_{2,A}^2\big) + 2\big(\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B} - \sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A}\big)\right) > 0$$

Since in this example the first subproject is conducted by A in either option, the expected net present value of the second subproject might be critical for either a single vendor or multiple vendor strategy. It therefore is an advantage for (A,B) if $\mu_{2,B} > \mu_{2,A}$ and a disadvantage if $\mu_{2,B} < \mu_{2,A}$. Choosing (A,B) instead of (A,A) causes additional transaction costs k_B which is a downside of multisourcing.

Risk has to be examined in more detail: First, we look at the respective values of the variance as our measure of risk. $\sigma_{2,B}^2 < \sigma_{2,A}^2$ (B delivering the second subproject at a lower risk than A) is an advantage for (A,B), analogous $\sigma_{2,B}^2 > \sigma_{2,A}^2$ is a disadvantage. Second, we examine the dependencies between the two subprojects depicted by the respective covariances $\sigma_{1,A}\sigma_{2,B}\rho_{1,A,2,B}$ and $\sigma_{1,A}\sigma_{2,A}\rho_{1,A,2,A}$. Depending on the values of the standard deviations $\sigma_{2,B}$, $\sigma_{2,A}$ and the correlation coefficients $\rho_{1,A,2,B}$, $\rho_{1,A,2,A}$, those can be an advantage or disadvantage for (A,B).

In reality, however, we will find that subprojects conducted by different vendors feature lower dependencies than subprojects conducted by the same vendor. This can be explained by vendor specific risk, e.g. unexpected low performance of a single vendor. Consequently, in a real-world setting we can expect that $\rho_{1,A,2,B} < \rho_{1,A,2,A}$. As long as this effect is not outweighed by a high standard deviation $\sigma_{2,B}$ compared to a lower $\sigma_{2,A}$, multisourcing bears the opportunity of risk diversification.

Altogether, we can state that the decision on multisourcing heavily depends on the respective values of the different variables. Especially risk can be an aspect in favor of or against multisourcing and neglecting risk can lead to a different decision outcome. In the following sections we analyze in more detail what consequences neglecting risk might lead to.

Evaluation based on a Monte Carlo Simulation

The problem at hand is very complex, as it requires a full enumeration for each project setting to derive the respective optimal vendor selection. Consequently, a sensitivity analysis cannot be conducted analytically for large project settings. We chose the Monte Carlo method as it permits the processing of complex problems within reasonable time and derives results based on the law of large numbers. Using a Monte Carlo simulation, we can treat the full enumeration as a black box and implement a sensitivity analysis by running the simulation with original and slightly adapted input parameters. Lacking real world data, we furthermore need to create those project settings assuming realistic distributions for our input parameters. This way, we are able to confirm effects identified during the analytical evaluation for a very small project setting or to identify effects which occur in large project settings only.

We generated 1000 different project settings. Each project consists of 6 subprojects each of which is conducted by one of 7 vendors. The following table 1 shows the respective ranges of the input data for the simulation of a single project setting. In this context, the term "vendor specificity" means that for each subproject a basic expected net present value and standard deviation were created randomly within the given range and then varied for each individual vendor. For reasons of simplicity we speak of μ, σ, ϱ, and k in the following, meaning all expected values, standard deviations, correlations, and transaction costs, respectively, for all subprojects and vendors.

Table 1. Monte Carlo input data		
	Range	Distribution
Expected net present value of each subproject (μ)	10,000 – 100,000	equal
vendor specificity		gaussian (±10 %)
Standard deviation of each subproject (σ)	0 – 20% of subproject's net present value	equal
vendor specificity		gaussian (±10 %)
Transaction costs of each vendor (k)	20,000 (mean)	gaussian (±25 %)
Parameter of risk aversion (α)	$5{\cdot}10^{-5}$ – $15{\cdot}10^{-5}$	equal
Correlations (ϱ) for subprojects outsourced to the same vendor	0.0 – 0.8	gaussian (mean: 0.4)
Correlations (ϱ) for subprojects outsourced to different vendors	0.0 – 0.8	gaussian (mean: 0.2)

For each project setting, we identified the vendor selection $\vec{v}$ that maximizes $\Phi(\vec{v})$, the value of $\Phi(\vec{v})$, and how many different vendors are components of the vendor portfolio described by $\vec{v}$.

To conduct the sensitivity analysis, we furthermore generated comparative scenarios by varying the input parameters listed below individually by -50%, -25%, -5%, -1%, +1%, +5%, +25%, and +50%.

- Parameter of risk aversion (α)
- Expected net present values (μ)
- Standard deviations (σ)
- Correlations (ϱ)
- Transaction costs (k)

Defining $\vec{v}'$ as the decision vector of a comparative scenario and Φ' as value of the comparative objective function, we identified for each project, which vendor selection $\vec{v}'$ maximizes $\Phi'(\vec{v}')$. For comparison we furthermore evaluated, in how many positions the comparative vendor selection $\vec{v}'$ differs from the optimal vendor selection $\vec{v}$ and by what amount the initial objective function differs when inserting the initial and comparative selection respectively: $\Phi(\vec{v}) - \Phi(\vec{v}')$, i.e. we determined the monetary damage the variation of the input parameter causes in reference to the initial objective function.

The damage can be interpreted as follows: With Φ based upon "accurate" values and Φ' based upon an erroneous estimation, the damage measures the difference of the value of the initial objective function Φ with different input vectors: on the one hand the optimal selection $\vec{v}$ and on the other the "wrong" selection $\vec{v}'$. As $\Phi(\vec{v})$ is optimal and as $\Phi(\vec{v}')$ is suboptimal, we can conclude that the damage is always greater than or equal to zero. Interpreting $\Phi(\vec{v})$ and $\Phi(\vec{v}')$ as certainty equivalents (amounts of money), the damage can be interpreted as an amount of money, too.

Model Robustness

Appendix I contains the list of average results derived from 1000 Monte Carlo runs. It shows the respective input parameter that is varied to generate the comparative scenario (column 1) and the respective rates of change (column 2). The third column lists the average number of differences in the portfolio composition, i.e. the different vendor selection of the initial and the comparative scenarios. The fourth column contains the average absolute damage concerning the risk adjusted net present value of the project resulting from the variation. In order to provide a more generally interpretable measure of the consequences of the variation, the fifth column lists the relative damage based upon the average project net present value of 3,153,415.13 which was calculated from all project settings generated by the Monte Carlo simulation. The analysis of the data implies four interesting findings:

1. According to a Wilcoxon signed-rank test, there is a statistically significant difference in the medians of $\Phi(\vec{v})$ and $\Phi(\vec{v}')$ despite one exception (transaction costs varied by +1%, fourth from last row). This means, that for all other parameters even an erroneous estimation of only ±1% leads to a statistical significant damage.
2. Surprisingly, the damage is very small: Even with an estimation error of +50%, for the standard deviation the relative damage stays below 5%. For all other parameters estimation errors between ±50% lead to relative damages below 1.5%.
3. Despite the above mentioned low average and relative damage, the portfolio composition shows remarkable changes. The composition of the vendor portfolio alters up to an average of 2,57 positions (standard deviations varied by -50%, row 17) for a certain variation, due to the misestimation.
4. Overestimating the input parameters of the objective function causes less damage concerning the risk adjusted net present value of the project than underestimating them. Concerning research question 2, this is especially interesting for the parameters modeling risk (α, σ, and ϱ). Obviously, it causes less damage to be too cautious in risk assessment, than to be too negligent.

In summary it can be stated, that assessing risk not only is of utmost importance, but also the model elaborated above is very robust in regard to estimation errors.

On the importance of risk assessment

Neglecting risk, a decision maker decides on a multi-vendor IT outsourcing portfolio only by evaluating whether increased expected net present values due to specialization of certain providers are outweighed by the respective transaction costs. In our model this exact situation can be produced by setting α and/or σ equal to zero (zeroizing the parameter of risk aversion α and all standard deviations σ has the exact same effect as they are multiplicatively linked).

The robustness of the model elaborated above, exposed a limited sensitivity regarding the variation of individual parameters even by ±50%. This finding might lead to the presumption, that neglecting risk (i.e. varying α and/or σ by -100%) would also lead to minor damage concerning the risk adjusted net present value of the project.

To scrutinize this presumption, we evaluated a comparative scenario setting the parameter of risk aversion α equal to zero. Therewith, risk is not taken into account when indentifying the optimal vendor portfolio selection of a project. We get the values as depicted in table 2.

Table 2. Consequences of neglecting risk

	Estimation error	Average # of differences in vendor selections	Average damage	Relative damage
Parameter of risk aversion (α)	-100%	3.844	1323578.528	41.973%

According to table 2, the damage from neglecting risk exceeds the damage from overestimating or underestimating risk tremendously. Considering the comparative scenarios listed in appendix I, underestimating the standard deviations by 50% has the highest impact. It leads to an average of 2.57 subprojects assigned to different vendors and to a relative damage of less than 5%. Neglecting risk leads to an average of nearly 4 subprojects (⅔ of the entire project's components) assigned to different vendors and to a relative damage of more than 40%.

This investigation also suggests the presumption that there is a positive correlation between the number of differences in vendor selection and the resulting damage. While this might seem trivial on first sight, it is not necessarily a predicate of portfolio selection. Completely different portfolios can still feature similar risk-adjusted net present values. We tested our dataset for this correlation and found that the damage when neglecting risk is indeed positively correlated to the number of differences in portfolio selection with a correlation coefficient of 0.397 (significant at the 0.01 level).

As a consequence we can state that risk assessment based upon an erroneous estimation still leads to much better results than neglecting risk completely whereupon the resulting damage is substantial. We would therefore strongly recommend practitioners to integrate the assessment of risk and dependencies into their vendor selection processes. As a first step, our model could be used and adapted for decision support.

Practical Implications, Limitations and Conclusion

Today's businesses usually omit a quantitative risk assessment when deciding on multi-vendor IT outsourcing. Some do extend their focus from a pure cash-flow oriented view to a more generic one and integrate risk and dependencies into their decisions. Nevertheless, these approaches are often pragmatic and methodically weak. The vision of a value adding quantitative IT portfolio management in the context of multi-vendor IT outsourcing requires methodically rigor models that deliver initial reasonable results, although they might not be suitable to be applied in practice without some company-specific adjustments.

Although it bears great potential of economic improvement, still little quantitative research exists in the field of multi-vendor IT outsourcing. Therefore, this paper not only presents an analytical model to allocate vendors to subprojects in an optimal way, accounting for expected net present values, risk, transaction costs, and dependencies between subprojects conducted by either the same or different vendors (research question 1). But also, this contribution illustrates the importance of risk assessment within multi-vendor IT outsourcing decisions using a Monte Carlo simulation. The model is quite robust in terms of estimation errors. It shows that optimizing the allocation of vendors and neglecting risk completely causes significantly higher damage (research question 2). Moreover, the approach shows that overestimating the model's parameters seems to have a smaller impact than underestimating them.

Altogether, we can derive the following implications for management from this paper:

a) When allocating multiple vendors to a project, it makes good economic sense to include a risk evaluation into the decision process.
b) An erroneous estimation of risk and the corresponding interdependencies is might still be better than neglecting risk completely.
c) Make conservative estimations regarding risk: Overestimating standard deviations and correlations causes less damage than underestimating them.

One aspect which is not covered by this paper is the following: The main reason for omitting a profound risk assessment in today's companies is most likely the fact, that risk assessment is a complex task which incurs a decent amount of time and money itself. This raises further research questions which we might address in future contributions, e.g. questions about an economical optimal degree of estimation accuracy in risk assessment. Nevertheless, according to our management implication b) it is economically reasonable to include at least some sort of risk assessment in the evaluation process of multi-vendor outsourcing.

Considering limitations of our findings, one has to mention that the model's inherent interpretation of risk is rather abstract. That means our model is limited to deal with quantifiable and attributable components of risk, only. When applying our model, risk factors that are hard to quantify (e.g. cultural aspects) have to be either neglected or converted into quantitative figures by using appropriate methods. Furthermore, our model pictures dependencies within one project only. The development of an integrated model considering the existing outsourcing vendor and project portfolios as well as the decision on additional vendors and projects might be of great significance to practitioners as well as to researchers.

Although the model pictures reality in a slightly constrained way, it provides a basis for firms to plan and improve their multi-vendor outsourcing strategies. Moreover, it is a theoretically sound economical approach which allows further development and delivers insights in the assessment of risk.

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Appendix I

	Estimation error	Average # of differences in vendor selections	Average damage	Relative damage
Parameter of risk aversion (α)	-50%	1.556	32949.93	1.045%
	-25%	0.676	4454.25	0.141%
	-5%	0.125	164.75	0.005%
	-1%	0.025	7.22	0.000%
	+1%	0.03	6.99	0.000%
	+5%	0.104	115.23	0.004%
	+25%	0.531	2510.68	0.080%
	+50%	0.888	7414.73	0.235%
Expected net present values (μ)	-50%	1.315	18478.94	0.586%
	-25%	0.658	3974.87	0.126%
	-5%	0.133	173.99	0.006%
	-1%	0.029	5.84	0.000%
	+1%	0.024	7.00	0.000%
	+5%	0.122	134.30	0.004%
	+25%	0.532	2623.37	0.083%
	+50%	0.934	9814.07	0.311%
Standard deviations (σ)	-50%	2.57	152203.91	4.827%
	-25%	1.301	21928.34	0.695%
	-5%	0.251	580.96	0.018%
	-1%	0.039	16.14	0.001%
	+1%	0.042	12.10	0.000%
	+5%	0.259	501.51	0.016%
	+25%	0.924	8211.75	0.260%
	+50%	1.498	24762.58	0.785%
Correlations (ϱ)	-50%	1.382	35792.81	1.135%
	-25%	0.665	6136.45	0.195%
	-5%	0.096	130.15	0.004%
	-1%	0.026	7.96	0.000%
	+1%	0.023	3.64	0.000%
	+5%	0.105	151.21	0.005%
	+25%	0.538	3566.84	0.113%
	+50%	0.962	11266.05	0.357%
Transaction costs (k)	-50%	0.437	1934.62	0.061%
	-25%	0.198	418.17	0.013%
	-5%	0.047	21.07	0.001%
	-1%*	0.006	0.65	0.000%
	+1%**	0.001	0.07	0.000%
	+5%	0.029	8.17	0.000%
	+25%	0.175	342.30	0.011%
	+50%	0.307	1079.04	0.034%

* Median of Φ is different with a significance at the 0.05 level (2-tailed).
** Median of Φ is different with a significance of 0.317 (2-tailed).
All other medians of Φ are different with a significance at the 0.01 level (2-tailed).