Analyzing Cost and Risk Interaction Effects in IT Project Portfolios[1]

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Abstract

Financial Services Providers usually conduct multiple concurrent IT projects and have to constantly allocate their resources on the projects in an efficient way. Naturally, they may realize cost synergies among projects – e.g., due to infrastructure sharing – depending on the projects' resource requirements. However, exploiting resource interactions leads not only to cost synergies but also to risk interaction effects. We propose a conceptual model based on the Modern Portfolio Theory to study these costs and risk interaction effects among IT projects. The main contribution of this research is the conceptualization of the effects of resource interactions on the risk of a Financial Services Provider's project portfolio. Thereby, we illustrate that realizing cost synergies may not only lead to risk accumulation effects but, counterintuitively, also to risk reduction effects.

1 Introduction

Financial Services Providers (FSPs) are expected to spend more than USD 270 billion on IT in 2013 globally [Deutsche Bank Research 2013]. In doing so, FSPs invest more in IT than any other industry [Deutsche Bank Research 2013)] and usually have to handle multiple concurrent projects with the objective to maximize the business value of the project portfolio. According to the IT Governance Institute's VAL

[1] This paper is a slightly adapted and extended version of the paper [Heinrich et al. 2014].

IT Framework [IT Governance Institute 2008], "value is defined as the total life-cycle benefits net of related costs, adjusted for risk and for the time value of money". Naturally, FSPs aim to efficiently allocate their resources to the projects to be conducted by minimizing the costs "with an affordable use of resources and an acceptable level of risk" [IT Governance Institute 2008]. Depending on the projects' resource requirements in terms of labor and infrastructure, potential *resource interactions* among projects (e.g., labor or infrastructure sharing) may be identified and exploited. However, resource interactions are often overlooked what may lead to project failures in terms of costs, quality, or time [Buhl 2012]. Consequently, valuable resources may be wasted.

Resource interactions among projects have been analyzed, in particular, for research and development (R&D) projects [e.g., [Aaker et al. 1978]; [De Maio et al. 1994]; [Eilat et al. 2006]; [Fox et al. 1984]; [Gear / Cowie 1980]) as well as IT projects [e.g., [Bardhan et al. 2004]; [Kundisch / Meier 2011b], [Lee / Kim 2001]; [Santhanam / Kyparisis 1996]). According to these literature streams, resource interactions may occur if the total resource requirements for projects in a given project portfolio cannot be represented as the sum of resource requirements of all of the individual projects [Eilat et al. 2006]. As exploiting resource interactions affects both expected costs and risk of the overall project portfolio, interaction effects are defined as the economic impacts of exploited resource interactions on expected costs and risk. [Lee / Kim 2001] emphasize the practical importance of considering interaction effects. They state with respect to an IT project portfolio planning process that the 'cost of difficulty in data gathering for modeling is not so critical than the risk in selecting the wrong project without considering the interdependencies' [Lee / Kim 2001]. Although selecting the right projects out of a set of proposals is not the primary task for an FSP, the cost/risk efficient employment of resources also necessitates taking resource interactions adequately into consideration. In the project management literature it is consistently emphasized that the exploitation of resource interactions among IT projects results in lower portfolio costs due to the realization of cost synergies (e.g., [Gear / Cowie 1980], [Lee / Kim 2001], [Santhanam / Kyparisis 1996]). However, to this date, there is no systematic analysis of the resulting effects on the portfolio risks (referred to as *risk interaction effects* in the following). Thus, we aim to answer the following research question: *Which risk interaction effects (i.e., risk accumulation or risk reduction) are induced by the exploitation of resource interactions?* This research question is especially relevant from a practical viewpoint, as many FSPs concurrently conduct dozens of IT projects. Thereby they already aim to analyze and realize cost synergies but also wonder themselves which risk effects may result from that.

To answer this research question, we develop a conceptual model rooted in the Modern Portfolio Theory (MPT) [Markowitz 1952] to explore the risk interaction effects resulting from the exploitation of resource interactions among IT projects of an FSP. We structure this research according to the framework proposed by [Webster / Watson 2002]. We contribute to the project management literature by the first paper conceptualizing the relationship between exploitable resource interactions and their resulting risk interaction effects among IT projects. Thereby, we illustrate that realizing cost synergies cannot only lead to risk accumulation effects but, counterintuitively, also to risk reduction effects.

2 Background

To provide an overview on the extent to which resource interactions are treated in other literature streams and to create a basis for our conceptual model, we conducted a synthesis of the literature following [Webster / Watson 2002]. In the first step, we identified journals relevant for our research. Since project management is a multifaceted discipline [Kwak / Anbari 2009], we employed both the surveys of [Lowry et al. 2004] covering the IS discipline and [Barmana et al. 2001] covering the production and operations management discipline. We included the top 20 journals of each of the surveys' rankings as possible outlets for our review. Additionally, we included two important Project Management journals identified by [Kwak / Anbari 2009] into our review as well. After removing the duplicates of journals, which appeared in more than one of the surveys, we obtained 38 high quality journals as the basis for our review. Within these journals, we conducted a keyword search. We searched for all possible combinations of the terms 'project', 'portfolio', and 'allocation' in combination with the terms 'interaction' or 'interdependency' (and their corresponding plural forms). We then went backwards by reviewing the citations for the identified articles to determine previously considered relevant articles. Finally we went forward by using the Google Scholar service (http:\\scholar.google.com) to identify articles citing the previously found articles. As a result of this process we obtained 838 articles, from which 766 could be excluded by a title analysis because they did not address our research topic; from the remaining 72 articles, we excluded 57 by an abstract analysis, because they considered resource interactions only marginally and did not explicitly focus on the discussion of project interactions. In table 1, we present an overview of ten articles, which provide the largest contribution to the problem of considering and modeling resource interactions and their effects. In the following, we briefly discuss the most influential articles.

From the 1960s to the early 1980s resource interactions among projects were discussed primarily in the Capital Budgeting and the R&D project portfolio selection literature.[2] In his seminal article, [Weingartner 1966] focused on modeling techniques for general project portfolio selection problems with project interactions, and laid the foundation for the discussion of different types of interactions for a number of subsequent articles. In this context, he considered positive effects of common resource usage among pairs of related projects. Thus, resource interactions and their effects are introduced into the model by subtracting some monetary amount from the sum of the budgets required for the individual project proposals if a pair of interacting projects is simultaneously selected into a portfolio.

Later, [Aaker et al. 1978] classify three basic types of interactions among R&D projects and incorporate them into an expected value model. They distinguish between (1) *overlap in project resource utilization*, (2) *technical interdependencies*, and (3) *effect interdependencies*. An interaction due to an overlap in project resource utilization (in this article, we refer to this type as *resource interaction*) is characterized as the utilization of 'common equipment, personnel efforts, facilities, etc.' by two or more projects. The authors conclude by stating that 'the budget for such sets of projects would thus be less than the sum of their budgets if pursued individually'. The authors speak of technical interdependencies, if the 'success or failure of one project significantly enhances or retards the progress of other projects'. Effect interdependencies occur, if

[2] While the multi-project scheduling literature also addresses the issue of resource interactions, the resource interactions in this stream of research mainly originate from sequencing constraints. Being different in nature, we do not consider scheduling questions in this article.

“projects are such that their value contributions or payments are non-additive”.[3] This basic classification has become state of the art (e.g., [Baker / Freeland 1975]; [Gear / Cowie 1980]; [De Maio et al. 1994]; [Eilat et al. 2006]) and is also used in the IT project portfolio selection literature (e.g., [Bardhan et al. 2004]; [Lee / Kim 2001]; [Santhanam / Kyparisis 1996]).

Interactions can be further distinguished in intertemporal and intratemporal interactions. Intertemporal interactions are especially relevant when deciding about conducting a project now that enables conducting a follow-up project in the future. The economic effects of intertemporal interactions may be captured by real options analysis (e.g. [Bardhan et al. 2004]; [Benaroch / Kauffman 1999]; [Dos Santos 1991]). Intratemporal interactions may be realized among projects that are conducted concurrently within the same project portfolio. According to these different classifications, we will only focus on intratemporal resource interactions in the following. Table 1 summarizes the different definitions and descriptions of resource interactions in the literature.

Table 1: **Existing Definitions of Resource Interactions**

Article	Term used for resource interaction	Definition and description of resource interactions
[Aaker et al. 1978]	Overlap in project resource utilization	Interdependency due to overlap in project resource utilization may characterize those projects which will utilize common equipment, personnel efforts, facilities, etc. The budget for such sets of projects would thus be less than the sum of their budgets if pursued individually.
[Gear / Cowie 1980]	Internal resource interdependencies	Two projects are interdependent if the total [….] resource requirements when both are selected are not given by the sum of the […] resource requirements of each project when undertaken alone. The resource requirements may be interrelated when two projects are in a common technological field or if the technical knowledge gained from one project provides usable information or facilities to another.
[Fox et al. 1984]	Cost/Resource utilization interactions	Cost interaction may occur among projects in a set if the total cost of projects in the set cannot be represented as the sum of the costs of the individual projects. This is often the case when projects “share” resources.

[3] These interactions are also called *benefit interactions* or *impact interactions* in the literature. For an detailed literature review and synthesis of IT project interactions, we refer to [Kundisch / Meier 2011a].

[Nelson 1986]	Overlap interdependencies	Overlap means that projects share facilities and costs, implying that the investment, if both projects are installed, is less than the sum of the investments required if each is independently installed.
[De Maio et al. 1994]	Resource inter-dependencies	Resource interdependencies derive from the sharing of scarce resources between different projects.
[Santhanam / Kyparisis 1996], [Lee / Kim 2001]	Resource interdependencies	Resource interdependencies arise because of sharing of hardware and software resources among various IS projects such that the implementation of two or more related projects will require less resources than if they were implemented separately.
[Bardhan et al. 2004]	Interdependencies	Interaction between capabilities that are shared or leveraged among IT projects in a portfolio.
[Eilat et al. 2006]	Resource interactions	Resource interactions may occur if the total resource requirements of projects in the portfolio cannot be represented as the sum of resources of the individual projects. This is often the case when projects share resources.
[Liesiö et al. 2008]	Project synergies	When the overall costs of a set of projects differs from the sum of the individual projects' overall costs.

In the following, we will adopt the definition of resource interactions of [Eilat et al. 2006]. Hence, resource interactions may occur if the total resource requirements of the IT projects in the portfolio cannot be represented as the sum of the resource requirements of the individual IT projects. If at all, interaction effects are discussed in the existing literature as the quantified consequences of exploited resource interactions in terms of cost synergies (see Table 1). However, the exploitation of resource interactions also affects the risk of a project portfolio which, to the best of our knowledge, has not been considered so far in the literature. Still, [Gear / Cowie 1980] introduced project-external risk factors that may have an impact on the isolated project costs of several projects at the same time. However, the impact of resource interactions on the risk of a project portfolio is not covered in their analysis. The same holds true for [Zimmermann et al. 2011] who introduce a decision model for an IT Service Provider based on the Modern Portfolio Theory [Markowitz 1952] that comprises expected costs, risk, and correlations among projects which are conducted at different sites. A systematic analysis of resource interactions and their effects resulting from different available sites is still missing so far.

Consequently, we differentiate between *cost interaction effects* and *risk interaction effects* that result both from the exploitation of resource interactions. Concerning the cost interaction effect we refer to cost synergies/cost dissynergies, if the expected total portfolio costs are lower/higher than the sum of the expected isolated project costs. Accordingly, concerning the risk interaction effect we refer to risk reduction/risk accumulation if the total portfolio risk is lower/higher than the sum of the isolated project risks.

Apparently, in the literature, resource interactions are – if at all – either attributed to the asset type *labor* or the asset type *infrastructure*. Two subtypes of resource interactions correspond to these assets. *Common utilization of labor* refers to interactions that result from intelligent staffing of specific labor to more than one project in order to realize economies of scale or scope, e.g. learning curve effects. *Common utilization of infrastructure* refers to interactions that result from infrastructure resource sharing.

The considerations in the analysis of interaction effects are summarized in the theoretical framework illustrated in Figure 1. Each project, which is part of an FSPs project portfolio is characterized by isolated project costs, which result from the required labor and infrastructure (production costs) and the transaction effort (transaction costs). Especially if several projects are conducted concurrently at the same site three subtypes of resource interactions can be exploited: *common utilization of labor* and *common utilization of infrastructure*. However, neither the isolated project costs nor the interaction effects can be determined with certainty. Rather, there exist project-internal as well as project-external risk factors which influence both, the realization of the ex post isolated project costs and the realization of the ex post interaction effects after conducting a project. Project-internal risk factors can be influenced by project management and include, for example, misjudgment of the user commitment, misunderstanding of the requirements, misjudgment of the user involvement, misjudgment of the required knowledge/skills, and misjudgment of frozen requirements (e.g., [Kappelman et al. 2006], [Schmidt et al. 2001]). In contrast, project-external risk factors cannot be influenced by project management and include, for example, changes of the wage level, illness of employees, and changing purchase prices for project infrastructure. Note that the results in the literature about resource interactions are suggestive with respect to their effects on costs, i.e., the exploitation of resource interactions results in cost synergies, but are less well elaborated with respect to risks.

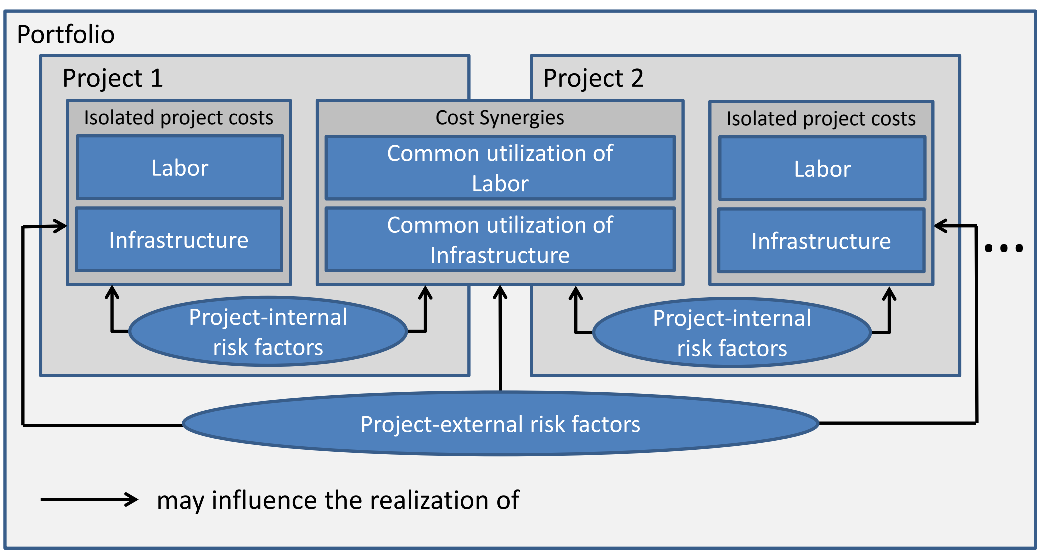

Figure 1: Theoretical framework

To contribute to fill this void, we examine the common case where a FSP has to conduct several IT projects concurrently. These projects may vary in terms of start time, duration, and end time. Still, FSPs (re)allocate their resources periodically (e.g., a period of three or six months) to the projects which are running or starting in the following period. Thus, we examine the point of time where an FSP has to (re)allocate its resources.

Conducting IT projects induces isolated portfolio costs, which include labor costs (e.g., cash outflows to pay a software developer who works exclusively on a single project) and costs for infrastructure (e.g., cash outflows to procure a new server for conducting a single project). In addition, exploiting resource interactions like the common utilization of labor and the common utilization of infrastructure imply cost synergies which may reduce these isolated portfolio costs (see left-hand side of Figure 2). This is the case, for instance, if a project manager concurrently works on two projects resulting in learning effects and thus, ceteris paribus, in cost synergies for both projects (e.g., cash outflows to pay a project manager are getting smaller in total). As neither the isolated portfolio costs of all projects nor the cost synergies are certain, we treat both as random variables with expected values (expected isolated portfolio costs and expected cost synergies) and their variation or dispersion (isolated portfolio risk and risk interaction effect), respectively. In the following we focus on the right-hand side of Figure 2 and deduce propositions P1 and P2.

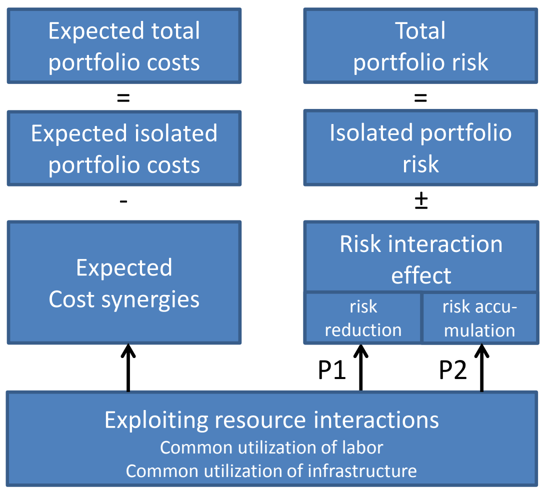

Figure 2: Conceptual model [Quellenangabe]

3 Analyzing risk interaction effects among projects

To determine the risk of a portfolio of assets, the field of Finance has developed a variety of theories [Elton et al. 2007], with the seminal one being the MPT. Each financial asset is modeled as a random variable and evaluated by its individual expected value (return) and variance (risk). Naturally, the return of a portfolio is calculated by the sum of the expected values of the single assets. In contrast, the portfolio risk cannot be determined as the sum of the variances of the individual assets because of possibly existing correlations among the assets. Since the seminal work by [Markowitz 1952], MPT has been extensively applied in different fields of portfolio selection problems, such as customer portfolios (e.g., [Buhl / Heinrich 2008]) and supplier portfolios (e.g., [Braunwarth / Heinrich 2008]). Adopting the MPT to IT project portfolios, the isolated project risk of each project is represented by the variance constituting a possible negative or positive deviation from its expected isolated project costs [Wehrmann et al. 2006]. This variance represents the aggregate of different project-internal as well as project-external risk factors. Methodically, these isolated project risks may be estimated by identifying scenarios which describe both unexpected positive or negative deviations from the expected isolated project costs and their probability of occurrence (see, e.g., [Zimmermann et al. 2012]).

Exploiting resource interactions has the objective to reduce the amount of required resources by sharing resources among different projects. In project management literature it is generally agreed that exploiting resource interactions among two or more projects results in cost synergies. Such cost synergies are not explicitly considered in MPT. As they cannot be realized with certainty, it seems natural to consider cost synergies also as random variables. Thus, the expected total portfolio costs can be calculated as the sum of the expected isolated portfolio costs and the expected values of the cost synergies (see Figure 2). The corresponding risk interaction effect has to be considered in calculating the total portfolio risk. Such a risk interaction effect may result for instance from the fact that exhausting a shared resource (e.g., the capacity of a shared server infrastructure) is much more likely when two or more projects use this very same resource. In general, the risk interaction effect is represented by (1) the variances of the cost synergies, which may result from unexpected project-internal and project-external events. Further, the risk interaction effect results from the fact that an unexpected project-external event may affect (2) the cost synergies themselves and at the same time the isolated project costs and (3) different cost synergies among projects. Table 2 describes and illustrates all three components of the risk interaction effect when exploiting resource interactions.

Table 2: Components of the risk interaction effect

Risk component	Description	Example
(1) Risk that affects one single cost synergy	This risk component is represented by the variance of one single cost synergy.	If a specific server hardware is required by two projects, one server hardware can be saved. Thus, the portfolio risk is reduced by the risk associated with the saved server hardware. The risk associated with the shared server hardware is considered once by this risk component of the cost synergy instead of twice before.
(2) Risk that affects both the cost synergies and the isolated project costs	This risk component is represented by the correlation between the cost synergies and the isolated project costs. This requires an analysis of whether events are likely that affect the cost synergies and the expected isolated project costs in the same vs. different directions.	The fluctuations in price for a piece of server infrastructure affect not only the magnitude of the cost synergies (expected savings for the second piece of infrastructure; see above), but also the isolated project costs (cash outflows for the first piece of infrastructure). Hence, the cost synergies and the isolated project costs are negatively correlated in this case.
(3) Risk that affects different cost synergies	This risk component is represented by the correlation between different cost synergies. This requires an analysis of whether events are likely that affect different pairs of cost synergies in the same vs. different directions.	Along with the expected cost synergy that results from refraining to buy a second server (i.e., common utilization of infrastructure), there is also an expected cost synergy that represents the saved staff responsible for the server administration for this second piece of server infrastructure (i.e., common utilization of labor). Hence, these two cost synergies are positively correlated.

Based on these risk components, the resulting overall risk interaction effect on the portfolio is twofold regarding its direction, i.e., exploiting resource interactions can result both in risk accumulation effects as well as in risk reduction effects. These effects can be substantiated based on the 'phases of the life cycle' of project resources (for a general life cycle of resources and capabilities see, e.g., [Helfat / Peteraf 2003]). Three phases can be identified: Acquisition & Development, Usage & Management, and Suspension & Release (see Figure 3; for a general process to identify resource interactions see, e.g., [Zimmermann et al. 2012]).

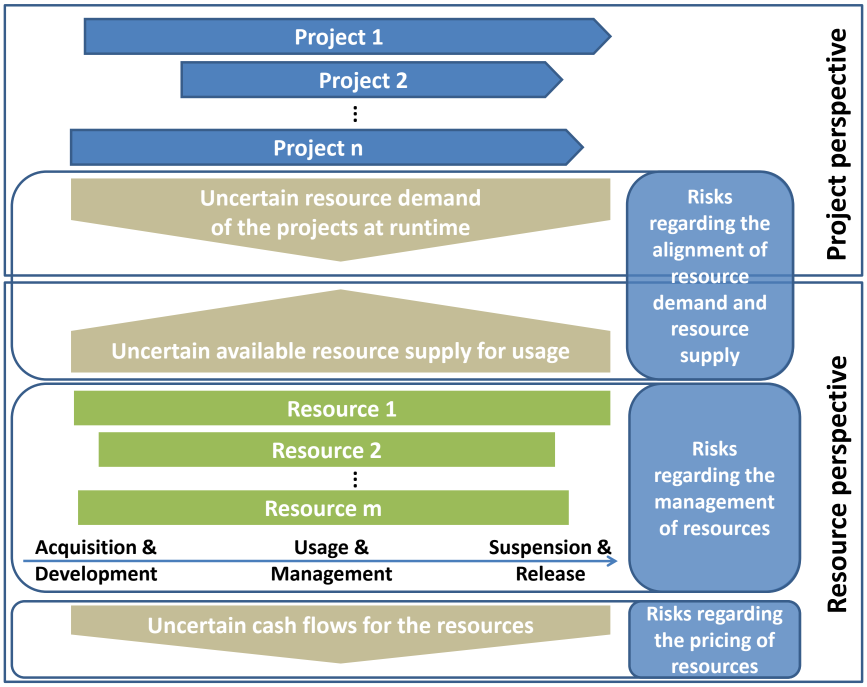

Figure 3: Phases of the life cycle of project resources

Acquisition & Development includes all tasks (e.g., initial training of project staff member or procuring a server infrastructure) and the associated cash flows, and risks that are necessary to make a resource usable for one or several projects. In the Usage & Management phase, a resource is available and can be used by projects. This means that a resource supply is constituted and has to be aligned with the resource demand of the projects (e.g., by means of resource allocation techniques like resource leveling; see, e.g., [Neumann / Zimmermann 2000]). In addition, this phase comprises all tasks, the associated cash flows, and risks to ensure that all project resources are continuously available for usage (e.g., operating and maintenance of server infrastructures). The last phase, Suspension & Release, covers all tasks and the associated cash flows, and risks, which liquidate the provided resource supply (e.g., reintegration of a project staff member into the line organization).

In Figure 3 it is illustrated that different risks may occur during the life cycle of project resources. These risks result from the uncertainty of the pricing of resources (e.g., fluctuations of the purchase price for a server infrastructure), the management and operations of resources (e.g., breakdown of a server infrastructure) and the potential conflicts between resource demand and supply. Based on this and the fact that cost synergies are realized by eliminated or reduced cash outflows due to saved resources, risk accumulation effects as well as risk reduction effects can be substantiated which are both absent from the literature so far.

Of notable interest are risk reduction effects. More precisely, in the case that cost synergies are realized by omitted cash outflows due to resource savings, the risks directly associated with these cash outflows are omitted as well. For instance, if two projects use the same server infrastructure instead of procuring a server infrastructure for each single project, then the expected isolated portfolio costs can be reduced by the resulting expected cost synergy to calculate the expected total portfolio costs (cf. Figure 2). Supposing that the risk regarding the phase Acquisition & Development is only caused by the fluctuations of the purchase price for a server infrastructure, the use of the same server infrastructure for both projects reduces not only the portfolio cash outflows by the expected cost synergy but also, ceteris paribus, the portfolio risk by the risk of associated with the saved server infrastructure (cf. component (1) of the risk interaction effects for the case of omitted cash outflows). In this best possible case, risk reduction effects arise alongside cost synergies.

This effect may not only occur in the phase Acquisition & Development but also in the other phases. For instance, in the phase Usage & Management it is not necessary to manage a saved resource, which also reduces the associated risks (e.g., reduced complexity risks resulting from operating only one server infrastructure instead of two or more). In this case it is possible to realize two cost synergies as the second server infrastructure and the related administration effort can be saved (cf. component (3) in Table 2 for the case of omitted cash outflows). In addition to these *direct* risk reduction effects –realized by eliminated or reduced cash outflows – *indirect* risk reduction effects may occur. This may be the case if one particular resource (e.g., a project staff member) is deployed in two or more functionally related projects resulting in learning effects, motivation, or coordination advantages. This means that the productivity of this resource can be increased by sharing it among projects. This improved productivity is indirectly represented also by an eliminated or reduced cash outflow and the associated risk. For instance, if an employee writes the technical requirement specifications of two functionally related projects the risk of the lack of coordination of these specifications can be reduced. Consequently, the occurrence of risk reduction effects leads to the following proposition:

Proposition 1*: Exploiting resource interactions among IT projects leads to a risk reduction effect if (i) an uncertain cash outflow is directly omitted (i.e., cost synergies) resulting in an elimination of the associated risks or if (ii) the usage of a resource by two or more functionally related projects induces an improved productivity of this resource.*

In contrast, the exploitation of resource interactions may also induce risk accumulation effects. For an illustration of the risk accumulation effects we can also refer to the phases of the life cycle of project resources and, in particular, on the Usage & Management phase. In order to substantiate risk accumulation effects, the lower available resource supply as a consequence of the resource savings that result from the exploitation of resource interactions has to be discussed. Usually, the resource demand of the projects is estimated before making the decision to save a resource. However, since the extent of the resource demand as well as the extent of the available resource supply often unexpectedly change during the project runtime (e.g., due to the illness of a project staff member) both must be considered as uncertain. This means that in the context of resource usage, various events may occur (e.g., loss of a resource, peaks of demand, excessive demands for resources) that lead to bottlenecks and capacity overloads with consequences for multiple affected projects. Such bottlenecks and capacity overloads have a higher probability of occurrence where resources were previously saved, which means the available resource supply is lower on average for each affected project. Therefore the corresponding risk is higher, which is represented by risk accumulation effects (cf. component (2) in Table 2 for the case of capacity overloads). For instance, if more than one single project utilizes the same server infrastructure a breakdown of this infrastructure affects all projects using this infrastructure in a similar way. Consequently, the corresponding risk accumulates regarding the delays, lags of project time, additional recovery costs or efforts, etc. for each affected project.

In addition, risk accumulation effects can also result from tasks related to the management and operations of resources. This is because the management of resources that are used by several projects is often more complex, which in turn leads to a higher risk. Here, a resource has to be usable for different needs of multiple projects at the same time (cf. also component (2) in Table 2 for the case of a more complex management of resources). For example, with regard to the demand of a project to reconfigure the shared server infrastructure it has to be checked whether this reconfiguration negatively affects the usage of the infrastructure by the second project. This may lead to an additional cash flow for the test procedure which represents a risk accumulation effect ex ante. Summing up, we can state the following proposition:

Proposition 2*: Exploiting resource interactions among IT projects results in a risk accumulation effect if (i) the probability increases that the resource supply does not meet the resource demand of multiple projects or if (ii) the management of these resources is more complex resulting from the usage by multiple projects.*

The propositions P1 and P2 as well as the resulting cost and risk interaction effects are illustrated in Figure 4.

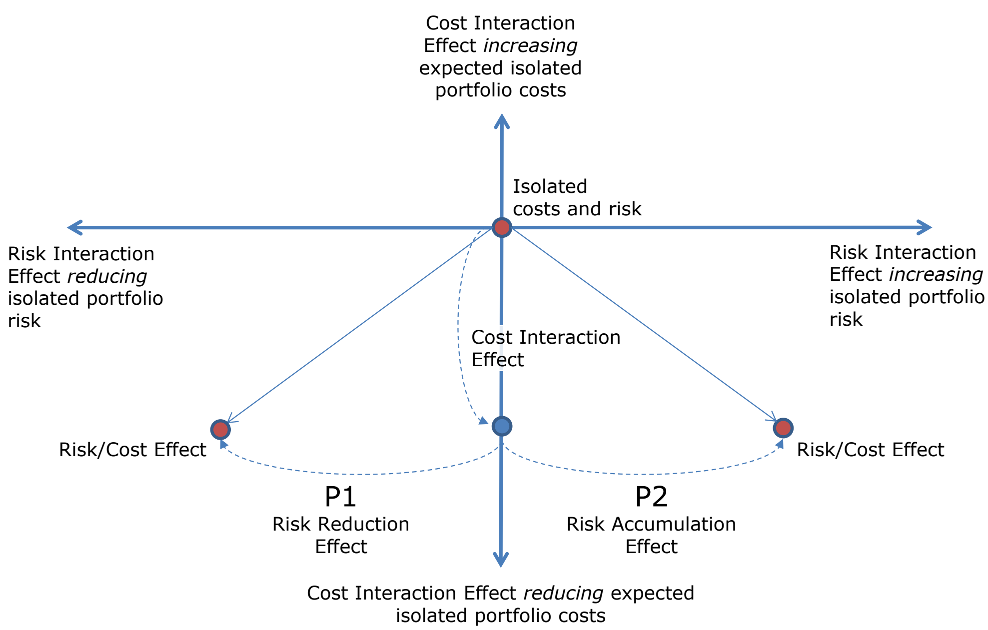

Figure 4. Illustration of the Cost and Risk Interaction Effects

To sum up, in the best possible case, risk reduction effects occur alongside cost synergies that can be realized if uncertain cash flows are directly omitted or if the productivity of a resource can be improved by the usage of this resource by two or more functionally related projects. In contrast, risk accumulation effects result if the probability increases to the point where the resource supply does not meet the resource demand due to exploiting resource interactions, or if the management of resources is more complex resulting from the usage by multiple projects. Considering the entire IT project portfolio of a FSP, the exploitation of resource interactions results in a trade-off between risk accumulation effects and risk reduction effects.

4 Discussion and Conclusion

The major contribution this paper makes to the literature is by providing the first step towards analyzing the effects of resource interactions among IT projects on the risk of a project portfolio. Using a conceptual model based on MPT, this paper examines project costs and their riskiness depending on the exploitation of resource interactions. It turns out that this exploitation of resource interactions has effects on portfolio costs and, in particular, on portfolio risks. While the literature already indicates that the exploitation of resource interactions is expected to realize cost synergies, the determination of the direction of risk interaction effects (risk accumulation or risk reduction) is much more challenging. We deduced propositions that contain conditions under which the exploitation of resource interactions leads to a risk reduction effect (*Proposition 1*) and to a risk accumulation effect (*Proposition 2*), respectively. While this research is intentionally not concerned with the development of a decision model, it contributes to a growing body of theoretically grounded work that helps to examine the economic impacts and the opportunities and challenges that stem from the exploitation of resource interactions for firms, including on an aggregated level. Indeed, research indicates that relevant risk interaction effects can be expected that should not be neglected ([Lee / Kim 2001], [Zimmermann et al. 2012]).

4.1 Managerial implications

A CFO or project portfolio manager interested in optimally utilizing the resources to improve the cost/risk position of the overall IT project portfolio needs to be aware of – amongst others – interaction effects. This implies that the project portfolio planning process has to be enhanced to the extent that resource interactions can be identified based on the project proposals and plans. For instance, hardware infrastructure sharing is only possible if it is ex ante known to the project portfolio planner that the same or at least similar hardware infrastructure is needed in two or more projects. In addition, if resource interactions among projects can be identified, the decision maker still has the option to exploit possible resource interactions – or not – depending on the magnitude of the resulting cost synergies and risk interaction effects of this exploitation. In this context, exploiting resource interactions, and especially their risk interaction effects, have to be analyzed in much more detail in practice [Buhl 2012] as resource interactions are discussed in today's practice – if at all – as an instrument for the realization of cost synergies. This means that project portfolio managers have to examine whether overall a risk accumulation or a risk reduction effect occurs alongside the expected cost synergies. In particular, risk reduction effects are typically not considered in today's practice, although they may be realizable as illustrated above. Developing the skills to systematically identify potential resource interactions and to exploit them in a cost/risk efficient way may contribute to an increasing value of an FSP's project portfolio and a sustainable competitive advantage. In addition, our results are not limited to an application at an FSP. Rather, they are also valid for other IT-intense industries and specialized companies such as IT Services Providers that typically also conduct multiple projects at the same time.

4.2 Limitations and extensions

Our research needs to be followed by future empirical studies developing operationalized models within the suggested theoretical framework. For instance, such studies would enhance the previously presented examples of real world resource interactions among IT projects, which already illustrate the propositions deduced. We suppose that analyzing the potential and realized cost synergies and risk interaction effects from an ex ante and an ex post point of view seems to be most promising. We believe that empirically refutable implications will emerge after our conceptual model has been operationalized in different real world settings, which is clearly an important direction for future studies. Furthermore, this research may affect Global Sourcing decision making as well. The number of exploitable resource interactions may be reduced by allocating projects on different globally distributed sites. Consequently, this may have impacts on the realizable cost synergies and risk interaction effects. To the best of our knowledge these impacts have not been analyzed so far in the Global Sourcing literature.

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