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Sameer Bathallath
Stockholm University

Åsa Smedberg
Stockholm University

Harald Kjellin
Stockholm University

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Managing project interdependencies in IT/IS project portfolios: a review of managerial issues

Sameer Bathallath
Department of Computer and Systems Sciences, Stockholm University
Borgarfjordsgatan 12, Postbox 7003, 164 07 Kista, Sweden
www.shortbio.net/sameer@dsv.su.se

Åsa Smedberg
Department of Computer and Systems Sciences, Stockholm University
Borgarfjordsgatan 12, Postbox 7003, 164 07 Kista, Sweden
www.shortbio.net/asasmed@dsv.su.se

Harald Kjellin
Department of Computer and Systems Sciences, Stockholm University
Borgarfjordsgatan 12, Postbox 7003, 164 07 Kista, Sweden
www.shortbio.net/hk@dsv.su.se

Abstract:
Adequately managing project interdependencies among diverse and simultaneous projects is deemed critical for successful implementation of project portfolios. The challenge is significant because it may entail managing a complex network of project interdependencies that keeps changing over time. The present study investigates the managerial challenges that may undermine effective management of project interdependencies in IT/IS project portfolios. The investigation is based on evidence from reviewing relevant literature and documented studies associated with managing project interdependencies. The main contribution of this study is to discuss three managerial challenges of project interdependencies in project portfolios. We discuss the challenges from three perspectives: types of interdependencies; patterns of interaction in interdependencies; and cost/benefit impact of project interdependencies.

Keywords:
project portfolio management; project interdependencies; project interdependencies management; project management; IT projects; complexity.

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1. Introduction

Although there is much research available about inter-project dependencies, there are still many questions to be solved concerning how to handle these interdependencies. In this context, effective management of project interdependencies is deemed critical for successfully implemented project portfolios [1]–[6] especially under conditions of dynamic environment [7], [8] and increased uncertainties [9]. This implies the need of having a proper organizational arrangement to secure adequate control over the portfolio development cycle, and it also implies the need to maintain continuous coordination among various interdependent activities and tasks in the portfolio. Coordination, in this sense, is defined as "the act of managing interdependencies between activities performed to achieve a goal" [10, p. 361]. Considering this definition and the fact that every project portfolio is a goal driven endeavor [11], it can be realized that goals maintained by interdependent projects are naturally parts of an overall goal specified at the portfolio level. Consequently, any change in the portfolio goal will likely result in other project interdependencies being added, modified, or dropped. For instance, a sudden change in the portfolio goal (due to change in market conditions) may impact the priority and scope of some projects and to some extent may add or exclude some others. In effect, this may end in a situation where effectively managing interdependencies between relevant projects is needed for the portfolio to progress and perform efficiently. Under such circumstances, managing a large network of project interdependencies is more complex, difficult to control, and easy to get wrong [12]–[14]. Guo [15] supports this view by considering interdependency management a significant issue when software systems grow large in scale and complexity. Meantime, less attention to project interdependencies can result in a skewed portfolio direction leading away from the intended objectives of combining the projects [16]. The study aims to highlight the managerial issues concerning the management of project interdependencies between projects comprising an IT/IS project portfolio. The research question for this study is: What are the managerial challenges in managing project interdependencies as project interconnectedness is crucial for any IT/IS project portfolio to succeed?

2. Research method

To address the research question and to identify the possible obstacles that managers may face while managing a portfolio of IT/IS projects with multiple project interdependencies, it is important to first gain deeper knowledge in the following areas.

(1) The emerging need for project portfolio management;
(2) Project interdependencies and their subsequent characterization;
(3) Results from poor management of project interdependencies;
(4) Barriers to effective management of project interdependencies.

To advance our knowledge in the previously mentioned areas and to provide a comprehensive summary of the related literature, we have used Webster et al. [17] guiding principles for conducting the literature review. In the first search round, the Google Scholar search engine was used to identify articles that partially or thoroughly relate to the topic under investigation (i.e. project interdependency management within IT/IS project portfolio context). The search was conducted between the years 2000 and 2015 since there has been a significant improvement in the IT/IS sector during these years. In a similar vein, other contexts including program management and multi-project management, and new product/service development, were also investigated for their close similarity to project portfolio management. As one stream of the studies have used the term "interaction" as equivalent to the term "interdependency" (such as [14], [18], [19]), we considered the use of both terms during the search process. In this regard, we conducted the search using a combination of keywords including "inter-project dependency", "inter-project interdependency", "project interdependency", and "project interaction" together with their corresponding plural forms. Based on the first search round, we extended the search in the databases of International Journal of Project Management, Project Management Journal, and Association for Information Systems AIS Electronic Library, as these journals were a major source for the targeted articles. This has resulted in a total of 187 publications (i.e. research articles, books, and thesis works). After

thoroughly reading through each study's abstraction and conclusion, 81 publications were excluded since only peer-reviewed articles were considered.

The article is structured as follows. In the third section, we present the concept of project portfolio management and its growing acceptance among IT-intensive organizations. In the forth section, we provide a closer view of project interdependencies including their types, patterns of interaction, benefits, and complexity considerations. The fifth section highlights the negative impacts of ineffective management of project interdependencies. In the sixth section, we highlight issues that might impede effective management of project interdependencies. Finally, we provide a comprehensive discussion of the potential role that project interdependencies can play in the performance of project portfolios.

3. An overview of project portfolio management

Nowadays, Information System and Technology (IS&T) projects dominate many industries and particularly those operating in high competitive markets such as new product/service development organizations with high-technology end-products. In such multi-project environments, the number of projects tends to be high, they hold similar characteristics, share common resources, and are greatly dependent [20]–[22]. Projects of this form are often assembled into group(s) or portfolio(s) of projects in which they tend to be closely coordinated and concurrently implemented to secure the ultimate goal by which they were selected and grouped. A project portfolio approach offers a holistic multilevel perspective on how projects can be effectively proposed, prioritized, combined, and later carried out to fulfill the organization's aim and purpose [23]. For instance, implementing a large Enterprise System (ES) (to improve the business competitiveness of an organization) may include multiple interrelated projects ranging from large-scale projects, like IT networking, IT security, and a possible combination of ERP, CRM, HRM, and SCM systems, to relatively small projects such as business intelligence and knowledge management applications. In carrying out such projects, organizations may find it practical to consider a portfolio approach for a better arrangement and synchronization of their projects. From a management perspective, implementing such a system would entail organization-wide involvement coupled with extensive efforts to manage a substantial number of project interactions that keep changing and increasing over time [4], [24]. The changes may, for instance, be due to unexpected external/internal conditions. Prior research on project portfolio management has considered interdependencies between projects a critical aspect in the planning and successful implementation of project portfolios [7], [14], [18], [25]–[27] paying much attention to interdependencies caused by simultaneous utilization of scarce resources [14], [19], [28], [29].

4. Project interdependencies within a project portfolio environment

In general, project interdependencies may exist when one project is partially or wholly being influenced by another project(s) for its development or, literally, when "the success of a project depends upon other project(s)" [2, p. 556]. Interdependencies between projects may occur at different project levels including tasks, objectives, alliance, and even at a project level as whole [25], [30], [31]. For instance, prior to commencing a task in Project A, another task in Project B has to be performed first. This form of serial relationship between the two tasks is recognized as sequential interdependence (Fig. 1, subsection 4.2) where one entity produces an output necessary for the progress of another entity [32]. Other forms of interdependence between projects are presented in subsection 4.2.

The existence of such interrelationships connecting different projects is usually associated with a shared portfolio goal or benefits that can be reached through the interactions between these projects [33], [34]. For example, sharing scarce resources among multiple projects will probably result in an overall cost saving meantime the opportunities of new knowledge being generated would be increased. Such economic and strategic benefits tend to be on top of many discussions that both researchers and practitioners would acknowledge as essential for any project portfolio to succeed. However, increasing the connectivity between projects (where each project has its unique number of constraints and risks), can be a source of further benefits but in the meantime could be a source of management difficulty.

Project portfolios are not only influenced by their immediate environment; instead, they are likely to interact with the external environment as well. According to this view, Gear et al. [34] emphasized that interdependencies between projects can either be influenced by factors external to the organization or by factors internal to the organization. External interdependencies can "arise over time from overall social and economic changes which have effects that cut across many, if not all, subsets of the project set" while internal interdependencies can "arise if the resource requirements and/or the benefits of one project are thought to be significantly affected in magnitude and/or timing by the selection or rejection decisions relating to one or more of other projects in the set" [34, p. 739]. As an example for external interdependencies, a sudden change in market conditions could lead to priority variations in the projects comprising a portfolio. Consequently, some project interdependencies, if not all, will be forced to adapt to these changes. As an example of internal interdependencies, an unexpected delay in one project could affect other dependent projects (in the portfolio) leading to an overall delay in the completion time of a new product or service.

Interdependencies between projects are likely to vary in their types, patterns of interaction, and the cost/benefit returns that they might produce. In the following subsections, a thematic analysis based on close study of the corresponding literature are presented and discussed. First, a brief description of different types of project interdependencies are presented to understand the importance and applications of each type. Different interaction patterns can take place as a result of projects being interdependent; this is another important issue to be highlighted in the second subsection. Cost/Benefit effects (as outcomes of the interaction process) constitute a crucial aspect to consider; this matter is presented in the third subsection.

4.1 Types of interdependencies

This section provides a description of various types of interdependencies that may exist between different kinds of projects across a portfolio of IT/IS projects. Among the interdependency types frequently discussed in the literature are: resource interdependencies; technology interdependencies; technical interdependencies; market interdependencies; and learning-based interdependencies.

Resource Interdependencies: result from sharing common resources across multiple projects or "wait for scarce resources until they are released by another project" [2, p. 556]. It is common that such interdependencies arise in an effort to cut the total portfolio cost [35]. *Example*: an expert who is taking part in different projects can simultaneously work on more than one project. Otherwise, each project is required to wait until that expert is released. *Interaction effects*: sharing the expert cost among the projects would lead to an overall cost reduction while the portfolio is in progress. *Authors*: [2], [19], [22], [28]–[30], [34], [36]–[41].

Technology Interdependencies: this type of interdependencies helps to leverage technical knowledge across multiple projects [22], [30]. Technology interdependencies are more frequent in technology provider companies due to their important role of enhancing technical collaboration and knowledge diffusion across projects. *Example*: a project of developing a new-generation of CPUs is likely to be dependent on another project developing a new operating system release. Both projects should complement one another by sharing the design knowledge of their components to produce a reliable computer. *Interaction effects*: the knowledge diffusion represented by knowledge sharing between the two projects would result in building a reliable computer. *Authors*: [22], [30].

Technical Interdependencies: occurs when the technical success/failure in one project affects the probability of success/failure in another project [28]. In another word, the output generated by one project is a determinant of the success of another project. *Example*: the implementation of a Data Warehouse (DW) system will probably require connecting to other enterprise-wide systems in an effort to capture and store different types of information for future use. Meantime, another project is to implement a Business Intelligence (BI) tool that relies on data being accurately captured and stored by the DW system. In this sense, the DW project is more significant since it can either limit or support the success of the BI project. *Interaction effects*: the interaction can either lead to positive or negative outcomes depending on the behavior of the leading project. *Authors*: [2], [13], [19], [28], [29], [35], [36], [38], [42]–[44].

Market Interdependencies: stem from market-related conditions that may impose additional challenges on project(s). Therefore, the affected project(s) might have to be reconfigured to address these conditions. Reconfiguration can take different forms including new product diffusion into an already existing products' market or a product utilizing a current product's market knowledge [22]. *Example*: the installation of a project capable of providing advanced digital communication solutions is inevitably going to break up a project capable of providing analog communication. *Interaction effects*: linked to this example, and as an effect, the organization will gain a competitive advantage by offering innovative services in the presence of their digital communication platform. *Authors*: [22], [25], [31].

Learning-based Interdependencies: stem from the need to incorporate the capabilities and knowledge gained from another project. *Example*: It can be more beneficial, for a service development team, to utilize the available knowledge (documentations and expertise) of a previous project in order to develop a new service with more attractive features. *Interaction effects*: learning through previously completed projects would lead to knowledge diffusion and innovation. Authors: [2], [13].

In Table 1, a summary of the different types of project interdependencies can be seen, together with the number of references per each.

Table 1. Summary of types of project interdependencies

Category	**Description**	**Number of References**
Resource interdependencies	This type of interdependency occurs when there is a need to share resources or wait for scarce resources until another project releases them	12
Technology interdependencies	The need to leverage common technology across multiple projects	7
Technical interdependencies	Occurs when the technical success in one activity affects the probability of success in another activity	11
Market interdependencies	Stems from a new product diffusion into an already existing product market or a product utilizing a current product's market knowledge	3
Learning-based interdependencies	The need to incorporate the capabilities and knowledge gained through another project	2

4.2 Patterns of interaction in interdependencies

After a brief description of five different types of project interdependencies and their applications, this subsection sheds light on different interaction patterns that can result from projects being interdependent. Although there yet have been no unified structure for project interdependencies, the classifications driven by Thompson (1967) [45] are often cited by most studies on project interdependencies. According to Thompson's view of interdependencies between organizational parts, interdependencies between projects can take three distinct forms including pooled, sequential and reciprocal (Fig. 1) [32], [45]. Pooled interdependence is a seamless association between projects comprising a portfolio, where one project outcome can indirectly impact the performance of the project portfolio as whole, and thus other contributing projects. In other words, a project can be independent of other projects. However, a failure in that project outcomes can threaten the entire project portfolio and hence other projects in the same portfolio as well. For instance, the implementation of a Data Warehouse (DW) system shall enhance the decision-making process in the organization. However, poor quality of data generated by the DW system can negatively impact the decision-making process and might end up in poor project portfolio performance. A sequential interdependence is a serial relationship between two

or more projects where a project requires another project's output as input for its progress. For example, the implementation of a Billing System (BS) (for a telecom company) will probably include testing different call usage patterns generated by a Network Switch (NS). In this case, and in order for the BS project to progress, the NS project has to provide the possible combinations of service usage as input to the BS project. From this follows that project portfolios with sequential relationships become more complicated and difficult to coordinate as the degree of contingency increases [32]. A reciprocal interdependence, on the other hand, is a mutual relationship between two or more projects. This means that the project portfolio becomes more complex due not only to an increased degree of contingency, but also to the more reliance on coordination by mutual adjustment [32]. In other words, Project A' output is required as input for another Project B and conversely, Project B's output is required as input for Project A. For instance, perhaps both BS & NS projects (from the previous example) have to go through mutual adjustments before both projects can be completed. Fig. 1 illustrates Thompson's three forms of interdependencies which are stemmed from organization studies [41]. However, they are cited by many studies on project interdependencies. Most of the previously stated interdependency forms, if not all, are likely to exist in all kinds of IT/IS project portfolio where a reciprocal interdependence is considered complex [32]. A general example, which can be tracked back to the former two examples, is a project portfolio in a telecommunication service provider company. In such project environment, many and different communication elements (i.e. multiple software and hardware components of various vendors) have to undergo a lengthy integration process. Consequently, the projects embracing these elements have to carry out part of their activities through collaboration and mutual adjustment as they come to be interdependent. From this example, it is possible to assume that the three forms of project interdependency have at least occurred once. In other words, any occurrence of reciprocal interdependence would also indicate that both sequential and pooled forms have taken place [32]. Probably, interdependencies between projects can have other forms than those specified by [32], [45].

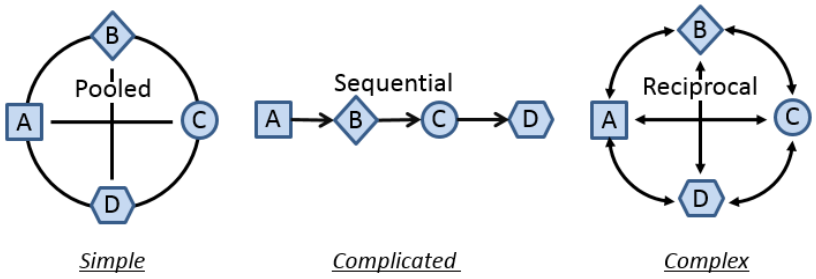

Fig. 1. Thompson's classification of interdependencies (adapted from [32], p. 54)

Although the three interdependency forms are good at depicting the connections between projects still, they remain at a high level of abstraction. A close-related aspect, at this point, is to recognize the interaction (i.e. as a transformation process) accompanying the project interdependency. Such transformational process would involve transforming certain inputs into desired outputs [39]. During that process, different interaction patterns can take place and different interaction effects can be generated (more about interaction effects is discussed in the next subsection).

Kundisch et al. [39] have synthesized a common semantic that could help in understanding different interaction patterns between projects and their effects in the domain of IT/IS project portfolio. They classified interactions between projects into three categories (Fig. 2): 1) Resource-Resource interaction; 2) Output-Output interaction; and 3) Output-Resource interaction.

Resource-Resource interaction: is about sharing resources among projects to optimize organizational performance and gain economic advantages. For instance, a technical expert can simultaneously participate in more than one project. This would result in cost decrease in each project, and thus the total development cost of the project portfolio is also decreased. This pattern of interaction can take place in all interdependency forms (i.e. pooled, sequential, reciprocal).

For instance, in a reciprocal interdependency between the BS and the NS projects (as described before) a typical Resource-Resource interaction would occur if one expert is participating in both projects.

Output-Output interaction: is an emergent relationship between two or more projects' outputs in which the sum of outputs produced by each project can result in different project portfolio performance. For instance, two distinct projects (in addition to their main purposes) are capable of providing a billing functionality. If both projects are requested to deploy this functionality then, the organization can benefit from having a redundancy. This pattern of interaction is likely to be associated with a pooled form of interdependence.

Output-Resource interaction: is a contingent relationship between the outcomes of one or more projects and a resource availability for another project(s). For instance, the installation of a billing system would necessary require a hardware equipment to be available. However the hardware equipment can be a stand-alone project, but it has to be completed before the billing system can be installed (i.e. the hardware equipment needs to be ready by the time the installation of the billing system is started). This pattern of interaction between projects is likely to occur among sequential and reciprocal interdependencies.

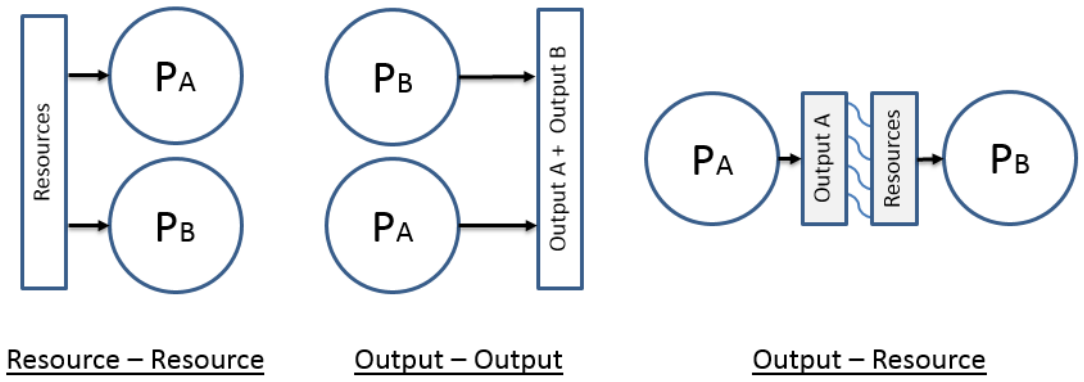

Fig. 2. Patterns of interaction in interdependencies (adapted from [39], p. 483)

Probably there are other patterns of interaction which can be a subject for investigation in future research.

4.3 Cost/Benefit effects of project interdependencies

In the previous subsections, we have overviewed the literature on project interdependencies' types, forms and patterns of interaction. In this part, we bring the attention towards the effects that project interdependencies can bring to project portfolios.

The importance and criticality of project interdependencies have gained much attention in project portfolio management studies due to their contribution to value creation and cost saving. Such wide-ranging benefits can be attributed to the synergistic interactions of particular projects [38], [46]. Several methods and techniques were established to support exploiting such benefits and, therefore, supporting the decision-making for project selection (e.g. multi-objective evolutionary algorithm [29]). A common tradition between these approaches is their advocating of optimal resource utilization and overall cost reduction. For example, developing a portfolio consisting of both IT and IS projects can benefit from sharing hardware and software capabilities among its projects. Hence, the development cost of sharing project resources is lower than the total cost of carrying out the projects individually. On the contrary, a stream of studies has addressed some adverse effects on the project portfolio as a result from improper resource utilization [19], [39]. For instance, the cost of assigning one project team to handle simultaneous projects at a time can be foreseen as

more cost effective than assigning a separate team for each project. However, further expenses might be involved to offset the set-up costs from extra management efforts and extra working hours.

Table 2. Cost/benefit effects of project interdependencies (adapted from [39], p. 483)

Interaction pattern	Competitive	Complementary
Resource – Resource	Cost ↑	Cost ↓
Output – Output	Benefit ↓	Benefit ↑
Output – Resource	Cost ↑	Cost ↓

In a recent study, Kundisch et al. [39] have identified six positions where negative and positive outcomes from project interactions can be anticipated (Table 2). Negative outcomes would result from projects being entangled with competing setup (i.e. the received benefits from projects being interdependently arranged is lower than projects being independent). Along the same line, positive outcomes would result from projects being engaged in a complementing setup (i.e. the received benefits from projects being interdependently arranged is higher than projects being independent). Both competing and complementing outcomes can take place in three different patterns of interaction including Resource-Resource, Output-Output, and Output-Resource.

Resource-Resource interaction:

1) Competitive resource utilization interaction**:** occurs when a joint use of resources among projects results in overall cost increase. Example: in order to reduce the project cost, a technical expert has to participate in different projects. However, this might result in an overall cost increase due to increased working hours. Conversely,

2) Complementary resource utilization interaction**:** occurs when a joint use of resources among projects results in an overall cost decrease. Example: the same expert can work for different projects without additional cost if proper task scheduling arrangement is considered.

Output-Output interaction:

3) Competitive output interaction: the sum of two or more projects' outputs can deteriorate the expected benefits from implementing the projects due to overlap in the projects' outcomes. Example: two distinct projects are capable of providing billing functionality. If both projects have deployed the same billing functionality, then this could result in unnecessary maintenance cost. Conversely,

4) Complementary output interaction: the sum of two or more projects' outputs can enhance the expected benefits of implementing the projects due to appropriate overlap in the provided services. Example: If both projects have deployed the same billing functionality then the organization can benefit from having a backup system in case of an emergency.

Output-Resource interaction:

5) Continuous competitive contingency interaction: the output of one or more projects can deteriorate resources availability for another project(s). Example: the implementation of a standardization project (to improve customers' experience) will probably impose new requirements on other related projects in the portfolio. In response, the influenced projects might need to consume more resources to comply with that demand. Within such a scenario, the adjacent project(s) might suffer from resource shortages. Conversely,

6) Continuous complimentary contingency interactions: the output of one or more projects can enhance resources availability for another project(s). Example: the implementation of a resource management functionality (to

improve resource utilization) might result in increasing the availability of resources. Within such a scenario, the adjacent project(s) will benefit from procuring extra resources.

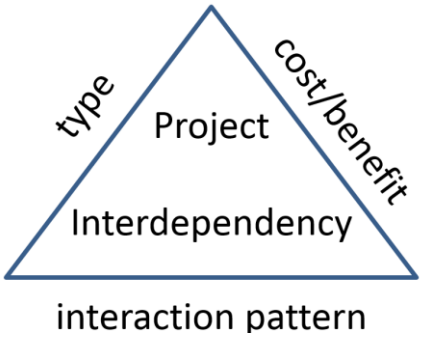

Fig. 3. Constructing perspectives of project interdependencies

In summary, IT/IS project portfolios (e.g. new product/service development portfolios) tends to embrace a hybrid set of fragmented projects that would very much result in raising a substantial number of project interdependencies. In such project environment, managers would have to deal with different project elements and oversee the operations of the interdependent ones. Every single activity between projects has to be well thought for and well coupled with the portfolio's overall goal. Overall, managers have to realize that the challenge of managing project interdependencies resides in the variety of interdependencies a project portfolio might possess. Variety in this sense, and in connection with Ashby (1964) [47] view, is the number of possible states a project interdependency can have. In this respect, we share Teller et al.'s (2012) [48] systematic perspective on project portfolios. The authors have emphasized on three main complexity determinants of a project portfolio. These would include [48]: (1) the number of elements (i.e. the projects and their related parts); (2) the degree of interdependence between the elements; and (3) the magnitude and predictability of changes in the elements and interdependencies. According to this view, the complexity of managing project interdependencies can significantly increase with an increasing number of projects/sub-projects. Similarly, the higher the degree of interdependencies between projects/sub-projects and the rate of change in the business conditions are another source for increasing management complexity. For example, managing a project portfolio of a multinational ICT service provider is more complicated when compared to a project portfolio of a medium-size IT service provider. From this example, the number of projects (elements) would pose a particular challenge in the management of the ICT project portfolio due to the substantial number of projects and relatively large number of interproject activates (interdependencies). Another source of complexity can be attributed to three interlocking perspectives preserved by every project interdependency, namely project interdependency type, the pattern of interaction, and cost/benefit impact (Fig. 3). We regard these perspectives as relevant for all project interdependencies.

5. Effects of poor project interdependencies management

Placing adequate considerations to project interdependencies along the project portfolio development cycle is of particular importance in the project portfolio success. One motivating factor behind the need for these considerations is to avert wrong selection of the portfolio projects [39] which might end in wrong portfolio spending. Also, less attention to project interdependencies may result in a skewed project portfolio direction with respect to the intended objectives of combing the projects [16]. Several studies have pointed out to different kind of problems that can result from ineffective management of project interdependencies. We conclude with four major problem areas as following: 1) resource waste; 2) schedule slippage; 3) budget waste; and 4) inter-project competition. A resource waste would arise from improper

utilization and/ or sharing of scarce resources between interdependent projects [20], [25], [30], [49]–[51]. For instance, an expert has to play a role in several simultaneous projects. Although the expert can be synchronized between the projects, s/he is unable to participate in all projects as no task scheduling is considered. Another impact is the risk of having a schedule slippage where a delay caused by one project may propagate to another interconnected project(s) leading to overall delay in project portfolio completion [50], [52]. As an example, if two projects are technically interrelated then a delay in one project could cause a delay in other project(s). A budget waste will likely occur when interdependent factors among projects are not considered while projects are selected [28]. For example, instead of having two separate projects, both projects can be bundled into single project if the interdependencies between those projects are early considered in the planning phase. Therefore, there is a chance that the financial resources of the company are saved due to considering the interdependent factor between the projects. Inter-project competition is a state when projects start to compete against scare resources to gain more power over other projects and receive more support from top management [50], [53]. This kind of problems will likely to appear in certain organizational structures that do not support an appropriate project-oriented culture. Table 3 shows a summary of negative effects of ineffective management of project interdependencies found in the literature.

Table 3. Impacts from ineffective management of project interdependencies

Risk	Description	Authors
Resource waste	Improper allocation of resources among interdependent projects can lead to resources being misused or misplaced	[20], [25], [30], [49]–[51]
Schedule slippage	A delay caused by one project may propagate to another interconnected project(s) leading to an overall delay at the project portfolio level	[20], [25], [49], [50], [52], [54]
Budget waste	Less consideration of the interdependent factors among projects can lead to poor selection of projects and consequently wasting company's financial resources	[28]
Inter-project competition	Interdependent projects may start a power game to gain more control over company resources	[50], [53]

6. Barriers to effective management of project interdependencies

In connection with what have been raised so far, this part brings into light part of the managerial challenges that may arise when handling a large network of project interdependencies. Several studies have reported evidence of problems affecting overall project portfolio performance. For example, one empirical study has highlighted six problem areas that pose challenges for managing project portfolios. These areas include [55]: (1) inadequate portfolio level activities; (2) inadequate information management; (3) inadequate project level activities; (4) lacking resources, competencies and methods; (5) inadequate management of project-oriented business; and (6) lacking commitment. Only some of the retrieved articles on project portfolio management have paid attention to barriers that may hinder effective management of project interdependencies (e.g. [2], [16], [30]). Among these studies, one empirical study has found that insufficient inter-project learning and absence of specialized methods may create difficulties in managing project interdependencies [2]. The authors have related the problem of insufficient inter-project learning to an inappropriate flow of knowledge between projects. As a result, less chance for lessons learned to be captured and transferred to other projects. This could impact learning from projects' mistakes and would negatively impact dealing with project interdependencies. The absence of a specialized method that deals with multi-level interdependencies is another confirmed problem by the same authors. The challenge is presented as a matter of managing a high accumulation level of project interdependencies (i.e. a state of a project being interdependent with many projects). To deal with this issue, the authors have suggested a network mapping approach that uses visual representation to help in understanding and dealing with

such accumulations of project interdependencies. The same approach can be used, as well, as a tool to enhance project communication and decision-making.

Another empirical study has investigated issues (from six leading high-tech organizations) of importance for effectiveness in managing a group of multiple projects. Overall, the study has indicated that ineffective inter-project processes and incompetent multi-project management pose a challenging aspect of managing project interdependencies [16]. Inter-project process, in this sense, is referred to the necessary steps for carrying out concurrent projects to achieve a certain objective. Such process is important for managers with multiple project management responsibilities to optimize their resource utilization and facilitate multitasking activities. On that account, this would enhance managing project interdependencies. The other raised problem (by the same study) is related to managers' competencies in managing multiple interrelated projects. Managers with multiple-project management task should possess the skills of managing individual projects as well as the ability of managing the interdependencies that emerge between these projects. In this respect, project managers lacking appropriate management skills is highlighted as negatively impacting project interdependencies.

7. Conclusion

In this review study, we have highlighted the potential role and contribution of project interdependencies in the success of project portfolios. We have shown that managing project interdependencies within IT/IS project portfolio environments tend to be a complicated, rather a complex task. Much of this management complexity is due to the total number of projects and their related parts alongside the degree of interdependence between these parts [48]. Another source of complexity can be attributed to the possible number of states (variety) a project interdependency can have. Bearing this in mind, managers would have to consider dealing with various project interdependency types including resource, technology, technical, learning-based, and market interdependencies. Each of these types would have to serve a distinctive purpose with regard to its role in fulfilling the overall portfolio goals. Another issue for consideration is the interdependence form that two or more projects should have and the patterns of interaction accompanying each. Thompson (1967) [45] has distinguished between three forms of interdependence including reciprocal, sequential and pooled. A reciprocal form tends to be complex while the other forms tend to be complicated and simple, respectively. In company with these interdependency forms and in order to produce the intended outcomes from each, different patterns of interaction would take place including Resource-Resource, Output-Output, and Output-Resource interactions [39]. As results of these interactions, managers should realize that different cost/ benefit outcomes can be produced according to their respective targets.

In view of many articles written on the management aspects of project interdependencies, only a few researchers have pointed out the reasons that might negatively impact the management of project interdependencies. Among those reasons is insufficient inter-project learning, the absence of specialized methods, and ineffective inter-project processes. On the other hand, it is crucial to consider the consequences of ill-managed project interdependencies. In this regard, several undesirable effects can occur including the problem of resource waste, schedule slippage, budget waste and inter-project competition. Both areas can be subject to further research.

In conclusion, although much research has paid attention to project selection methods and project interdependency management, there are still many questions to be solved concerning how to handle these interdependencies. In review of the literature, a number of themes stood out which have drawn our attention to three perspectives on the management of project interdependencies. These perspectives are, namely: 1) project interdependency type; 2) the patterns of interaction; and 3) cost/benefit effects. We consider these perspectives as relevant for all project interdependencies. To arrange for a desired project portfolio outcomes, managers should know how to deal with all aspects and measures that relate to these three perspectives which would also help to understand the project portfolio as a whole. Meantime, managers need to realize the complexity aspects of managing project interdependencies particularly in the presence of unexpected events. More research efforts are required to address the managerial issues concerning large project portfolios with many project interdependencies. This article contributes to the understanding of project

interdependencies and their management related challenges. In extension to the issues addressed in this article, we are engaged in an ongoing research addressing how to handle project interdependencies.

Future research in this area should further investigate the complexity of managing project interdependencies when the environmental context of the interdependencies is changing.

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Biographical notes

Sameer Bathallath
Ph.D. candidate in the Department of Computer and System Sciences at Stockholm University. His research interest focuses on project portfolio management in the field of Information System and Technology (IS&T), with specific emphasis on project interdependencies management and understanding impediments of handling project interdependencies of a large IT project portfolio.

www.shortbio.net/sameer@dsv.su.se

Åsa Smedberg
Associate professor in the Department of Computer and Systems Sciences at Stockholm University. Her research interests include systems thinking and development, IT-management, continuous learning and online communities. She is the author of a series of international publications, book editor, member of editorial review boards and committee member of international conferences.

www.shortbio.net/asasmed@dsv.su.se

Harald Kjellin
Full professor in system science at the Department of Computer and Systems Sciences at Stockholm University. He has been responsible for research projects that resulted in systems that were used nationwide in Sweden. His research is focused on management of organizations.

www.shortbio.net/hk@dsv.su.se