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# Circular economy approaches in complex projects

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## Abstract

Projects for delivering complex systems involve significant use of resources, both during their implementation and possible later upgrades. Current sustainability frameworks offer limited insights for promoting sustainable development in project contexts. This chapter draws on the concept of circular economy (CE), focusing on the reduction of resource use in industrial operations, to map out opportunities for increasing sustainability of complex systems. Key aspects of CE approaches are summarized, and two case vignettes are reported, to reveal how such approaches are used in complex system implementation and upgrade projects. The CE practices identified are strongly oriented towards closing resource loops and address technology and design aspects of the project deliverable, whereas CE practices used for complex system upgrade emphasize slowing resource flows and address the routines and processes of the organization operating the project deliverable.

**Keywords:** complex systems, complex project, resource use, circular economy, project business

## Introduction

Current societal challenges including climate change, limited access to clean water, reduction in biodiversity, and increasing consumption of non-renewable natural assets have become the focus of considerable attention. The question of sustainable development, that is, approach to ensuring that the needs of the current generation are met without compromising the ability of future generations to respond to their needs, is particularly central in developing responses to these challenges. A bibliometric study by Olawumi and Chan (2018) reveals a pattern of explosive growth in research on sustainable development research during the past two decades. Project business can offer solutions to these grand challenges, and this paper deals with the circular economy approaches used in complex projects.

Project business has significant sustainability implications as according to a recent empirical study (Schoper et al., 2017), roughly a third of all economic activities in Western economies are organized as projects. The special issue in the International Journal of Project Management

(Huemann & Silviu, 2017) on sustainable development showcased project research addressing sustainability challenges at the levels of strategic management (Aarseth et al., 2018), project managers (Martens & Carvalho, 2017), project organizations (Banihashemi et al., 2017; Kivilä et al., 2017), and broad networks of stakeholders (Keeyes & Huemann, 2017). This emerging stream of research draws attention both to the sustainability of project outcomes, as well as sustainable ways of implementing projects.

The concept of *circular economy* (CE) has recently been attracting increasing interest (Ghisellini et al., 2016). CE emphasizes the need to reduce the use of resources such as energy and natural assets in industrial operations (Bocken et al., 2016; Geissdoerfer et al., 2017), and thereby centers on the efficiency of converting resources into outcomes of value. With its resource focus, CE can be considered to have a clearly delimited scope compared to the all-encompassing concept of sustainable development. CE would, therefore, be somewhat more straightforward to operationalize for the evaluation of the favorable, as well as harmful, impacts of industrial operations. Some scholars have described CE as a means for businesses to implement the widely discussed, yet vague, concept of sustainable development in their production operations (Ghisellini et al., 2016; Murray et al., 2017). CE research has shown that savings in resource usage can often be achieved by means of re-using scarce natural assets, or by increasing the efficiency of production (Rizos et al. 2017).

The delivery of complex systems such as infrastructure and production equipment involves highly significant use of natural assets (e.g., a large power plant may require more than 200 000 cubic meters of concrete), as well as considerable use of energy and other resources during their operations phase (a single steel mill can consume as much electricity as a medium-sized city). Also the projects used for delivering and upgrading the complex systems are complex: they involve challenging technologies and multiple organizations, may have broad implications for the customer and stakeholders, and require significant coordination effort. The concept of CE is likely to have considerable potential for evaluating how complex projects use resources over their lifecycles. The purpose of this chapter is to explore how project-based firms implementing complex projects reduce their resource use via CE approaches. Our goal is to identify, categorize, and compare CE practices in the implementation and upgrade projects for complex

systems. The focus in this chapter is delimited to complex engineering or construction related systems, carried out in the private sector.

We use case vignettes from two firms, here called *MineTech* and *BioTech* (pseudonyms used for sake of anonymity), each with ongoing projects featuring CE-related practices. Their projects *MineSystem* and *BioPlant* deal with complex systems and focus on improving an existing production process. The projects differ from each other in the scope (external delivery project vs. internal investment project), and lifecycle phase (implementation vs. upgrade).

The description of the CE practices identified in this study and their categorization should provide insights for individual project-based firms, regarding how they can transform their operations via CE approaches. The findings promote future efforts to identify projects, project-based organizations and industries that are leaders (or laggards) in terms of their resource use. This understanding is important from both development and policy-making perspectives. Also those who invest in complex systems will benefit from the increased awareness regarding the sustainability of alternative investment options.

## **Circular economy approaches for sustainable resource use**

The concept of circular economy (CE) emerged during the late 1980s (Pearce & Turner, 1989) to challenge the traditional linear take-make-use-dispose industrial model. The premise is that, given the scarcity of resources on our planet, as well as the continuous growth of population and industrial activity, the linear model cannot be sustained over the long run. Thus, the main argument in the CE discourse is that the prevalence of the linear model, where used products become waste, is decreasing, and it will eventually be replaced by a circular model, where the creation of waste is minimized, and any waste that is created is viewed as an asset that is to be used over and over again. That is, the CE can be described as a system that is restorative by its design (Webster, 2016).

In addition to closing resource loops (by re-using waste and renewable resources), the CE discussion highlights the importance of utilizing scarce resources more efficiently (Rizos et al., 2017). Many assets, such as appliances and motor vehicles are typically operational for less than ten per cent of their lifecycles (Pasaoglu et al., 2012).

Earlier academic research has explored many interdependent domains of CE, including, for example, on closed supply chains (Govindan et al., 2015; Wells & Seitz 2005), circular product design (Bakker et al., 2014), enablers of circular economy (Tura et al., 2019), and circular business models (Bocken et al., 2016; Lacy & Rutqvist, 2016). Bocken et al. (2016) categorized CE business models into one or more of the following three generic strategies: *closing resources flows*, *narrowing resource flows*, and *slowing resources flows*. *Closing resource flows* refers to re-using resources that used to be categorized as waste. For example, disposed plastic packages can be reprocessed into new plastic products. During the past two decades, an increasing number of firms that specialize in technological processes required for re-using valuable resources included in different kinds of waste streams including agricultural waste, electronics waste, plastic waste, cardboard waste, and metallic waste. *Narrowing resource flows* refers to leveraging opportunities for producing the same outputs while utilizing less resources. For example, many firms are concentrating on reducing the amount of material that is used for packaging their products or shifting to using biodegradable packaging materials. Finally, *slowing resource flows* refer to lengthening the lifecycles of assets and/or decreasing the time they are idle. For example, many electronics manufacturers sell refurbished versions of their products that contain components extracted from products requiring repair. The question of how individual firms may move transform their operations towards circular economy is of paramount importance.

### **Circular economy approaches in complex projects**

The delivery of complex systems is predominantly organized as projects and includes societally important infrastructure such as transportation networks, production facilities and equipment, and sea vessels amongst others (Hobday, 2000). These complex systems are typically characterized by technological complexity, high cost and resource usage, as well as a long operations phase after the delivery of the system (Davies, 2004). For example, the design and delivery of power plants requires advanced technological systems and, thereby, also complex organizational arrangements, and their operations phase is typically several decades long. Operating the power plants involves a considerable need for maintenance and upgrade operations, and depending on the power source, continuity the acquisition of fuel.

There is a need to differentiate between the resources *included as part of the project deliverable/solution* (e.g., raw materials, components, products, services, and other natural resources, here referred to as core resources, or product-related resources) and resources that are *used for accomplishing the project deliverable* (e.g., human resources, energy, facilities, delivery-related services, equipment or other forms of capital, here referred to as enabling resources, or project resources). The use of different types of resources is planned and managed in different ways (Jugdev & Mathur, 2012): core resources are defined in the product of the project and, thereby, as part of scope management, whereas enabling resources are typically in a separate resource management section of the project plan. Both may require procurement from external suppliers and subcontractors and need to be considered as part of scheduling and risk management.

The product-related resources and enabling capital resources are particularly crucial in the design, implementation and upgrade of complex systems. The business model established for the project implies clear choices regarding which organization's resources are being used in the project delivery and during post-project services (Kujala et al., 2010; 2011). This also means that the resource configuration and consumption occur differently in the different phases of the system lifecycle. However, the actors involved in the project may have different priorities regarding resource use, which may be reflected in front-end value planning and the events of ownership transfer (i.e. handover during commissioning) (Artto et al., 2016; Kirsilä et al., 2007). Thereby, the actors may have quite different incentives regarding the optimization of resource use. The contractor might be keen to optimize the resource use during project implementation, whereas the customer is more concerned with operations-phase resource use. Artto et al. (2016, also Kirsilä et al., 2007) emphasize the need for integration both in technical and organizational terms, to ensure the fluent switch in responsibility. Research has observed that the resource use across the project lifecycle is path-dependent and choices made early in the project will affect the later phases (Artto et al., 2016). Various stakeholders (or third parties) may be involved in creating value and affect customer's or contractor's decision making and resourcing, thereby increasing complexity in the delivery (Ang & Eskerod 2017; Vuorinen & Martinsuo 2019).

As characterized above, CE approaches can be categorized into three distinct types: closing resource loops, narrowing resources flows, and slowing resources flows (Bocken et al., 2016).

Research has not, yet, delved deeply into their use in complex projects, which is the motivation for this chapter. Thus, Table 1 serves as a tentative framework for identifying and characterizing circular economy approaches in complex projects. The below case vignettes explore implementation and upgrade projects that have previously undergone a planning phase.

**Table 1.** Framework for mapping circular economy approaches in complex projects.

Project lifecycle phase	Circular economy approaches		
	Closing resource flows (re-use, recycle)	Narrowing resource flows (reduce)	Slowing resource flows (maintain, optimize)
Planning (design of a system)			
Implementation (process)			
Maintenance and upgrade (during the use of a system)			

### **Circular economy approaches in implementing a complex system**

The purpose of the *MineSystem* project was to replace an external customer’s existing production process, consisting of equipment and control systems, with a more modern, efficient, and environmentally friendly solution. The project-based firm *MineTech* was responsible for delivering and installing a fully functional system on a turnkey-basis and the customer’s site situated in the Middle East. *MineTech* is a leading solution provider firm, specialized in delivering solutions and equipment to mine operators on a global basis. *MineTech*’s customer deliveries are organized as projects. In addition to *MineTech* as the system integrator, the *MineSystem* project included several subcontractors that specialized, for example, in the delivery of containers, pressure vessels, machined components, and reagent dispenser systems.

*MineSystem* delivery was centered upon the idea of modularizing much of the required equipment into standardized sea containers that would be pre-assembled in *MineTech*’s facilities in Europe, transferred to the customer’s site in the Middle East, and installed quickly with minimal need for costly, and difficult to source, skilled local labor. Following the transportation of the container-based system to the customer’s site in Middle East, it was installed to the

customer’s production process by a team consisting of *MineTech*’s site engineer, local subcontractors, as well as customer’s production personnel working at the site.

During project implementation, *MineTech* engaged in several practices that contributed towards CE principles by either closing, narrowing, or slowing resource flows, as summarized in Table 2.

**Table 2.** Circular economy approaches in system implementation project *MineSystem*.

Circular economy approaches	Closing resource flows (re-use, recycle)	Narrowing resource flows (reduce)	Slowing resource flows (maintain, optimize)
<b>Organizational approach</b>	<ul style="list-style-type: none"> <li>Utilizing 2<sup>nd</sup> hand components (used containers) in equipment specific components (containers)</li> </ul>	<ul style="list-style-type: none"> <li>Emphasis on waste management practices in supplier selection</li> </ul>	<ul style="list-style-type: none"> <li>Using highly experienced field-specialists during installation</li> </ul>
<b>Product-oriented approaches</b>	<ul style="list-style-type: none"> <li>Recycling of equipment integrated in design</li> <li>Designing new manufacturing technology (recyclable plastic components) with subcontractor</li> </ul>	<ul style="list-style-type: none"> <li>Material reduction by design (use of innovative design &amp; hi-strength steel)</li> <li>Reduction of installation time by modularization</li> <li>Decreasing installation risks by modularization (leakage of chemicals etc.)</li> <li>Reduction of chemical use (by system design)</li> </ul>	

To **close resource flows**, *MineTech* exclusively utilized secondhand sea containers when fabricating the equipment modules, even though the second hand containers required more effort in terms of painting and finishing to ensure that they meet customer specifications. The recycling of the delivered equipment after their useful lifetime was also considered during the design phase. Efforts were made to ensure that the equipment modules can later be disassembled, and different subcomponents either refurbished or recycled appropriately. In the following, an informant describes the recyclability of the solution:

*“These parts here are maintenance free, and we also have parts that are replaced as necessary. These components here can also be moved [by the customer] from a site to another as necessary. In addition, the parts experiencing wear, such as these composite*

*reactors, rotors and stators, when they are worn down, they are removed [from the equipment]. They are all made out of recyclable materials and will be recycled at the end of their lifecycles.”*

A novel manufacturing process related to manufacturing plastic components (reactor vessels) was developed in collaboration with a subcontractor. This technology substantially improved both the possibilities to cost and material-efficiently repair damaged vessels on site as well as recycle them when they are to be decommissioned.

To **narrow resource flows**, *MineTech* emphasized waste management and recycling practices when selecting suppliers for the project. In addition, following discussions with a subcontractor, the designs for the equipment models were changed to allow the use of hi-strength steels. In this way, the amount of steel required for the delivery could be reduced substantially. In addition, the reduced weight of the equipment modules contributed favorably towards costs as well as lowered the emissions resulting from transporting them over sea. Considerable savings in labor as well as materials could also be achieved by packaging core equipment in standardized modules (which were built inside sea containers). Use of modularization also reduced installation and operations risks as the modules could be pre-tested in Europe where they were manufactured, under optimal conditions. Finally, in collaboration with a subcontractor specialized in optimizing use of chemicals, *MineTech* included technology in the scope of the delivery that allows the customer to significantly reduce the use of chemicals in the production process.

Finally, two practices for **slowing resources flows** were also observed. First, *MineTech* relied on the use of highly experienced field specialists in installing the equipment modules on the customer’s site. While these experienced specialists were highly limited, and more expensive to use as compared to local subcontracted labor, use of these individuals shortened the period of time required for equipment installation. In addition, these individuals were able to detect bottleneck areas in the delivered equipment modules that, if not corrected, could later result to problems and sub-optimal resource use.

## **Circular economy approaches in upgrading a complex system**

The purpose of the *BioPlant* project was to maintain and upgrade *BioTech*’s existing production facility during a pre-scheduled maintenance period. The production facility manufactures various

products for *BioTech*'s global base of industrial customers using renewable forest-based resources as raw materials. For safety reasons, all production operations at the facility needed to be fully suspended for the entire duration of the upgrade, incurring *BioTech* significant costs in terms of lost revenues every day.

The planning of project *BioPlant* was started approximately two years before the beginning of the maintenance period to ensure that work would proceed efficiently. The planning phase included scheduling of various maintenance and upgrade tasks, as well as contacting and negotiating with potential subcontractors. The upgrade project, during which all production operations were halted, lasted for slightly less than two weeks.

While the aim was to pre-plan as many of the necessary maintenance activities as possible, it was known in advance that a certain proportion of project tasks, approximately 10-30 per cent, could only be known when the specific equipment were removed and inspected in person. As replacing all components without inspecting them would be prohibitively costly, managing these kinds of unexpected replace or refurbish tasks gave rise to a need for significant flexibility in the project organization.

During the maintenance and upgrade project *BioPlant*, *BioTech* engaged in a number of practices that contributed towards CE principles by either narrowing or slowing resource flows as summarized in Table 3.

**Table 3.** Circular economy approaches in system maintenance and upgrade project *BioPlant*.

Circular economy approaches	Closing resource flows (re-use, recycle)	Narrowing resource flows (reduce)	Slowing resource flows (maintain, optimize)
<b>Organizational approach</b>	<ul style="list-style-type: none"> <li>• NA</li> </ul>	<ul style="list-style-type: none"> <li>• Preplanning of scaffolding resources (to reduce resource usage)</li> <li>• Emphasizing experience of suppliers to reduce risk of technical failures</li> </ul>	<ul style="list-style-type: none"> <li>• Securing flexible resources to allow agile approach to maintenance process</li> <li>• Flexible inclusion of additional maintenance work as need identified</li> <li>• Reduction of wasted production time</li> </ul>
<b>Product-oriented approach</b>		<ul style="list-style-type: none"> <li>• Refurbishing production equipment to increase process efficiency</li> </ul>	<ul style="list-style-type: none"> <li>• Lengthening the lifespan of production assets</li> </ul>

		<ul style="list-style-type: none"> <li>• Refurbishing production equipment to decrease waste</li> <li>• Refurbishing production equipment to reduce environmental impact (water cleaning equipment)</li> </ul>	
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To **narrow resource flows**, *BioTech*, in collaboration with its subcontractors, made considerable efforts to preplan the use of scaffolding in a manner that would reduce resource usage during the scheduled maintenance period. For example, when planning individual locations for setting up scaffolding, it was considered if several different equipment could be accessed from the same scaffolding. To reduce material usage as well as save costs, *BioTech* followed a strategy of refurbishing components rather than replacing them entirely whenever feasible. To reduce both the quantity as well as the harmful effects of waste produced by the plant, considerable efforts were also made to ensure that equipment affecting waste creation (e.g., water cleaning equipment) would be restored to an optimal condition during the maintenance period. Finally, while price was considered as an important criterion in selecting subcontractors for the project, *BioTech* also placed considerable emphasis on the technical experience of suppliers, as this was considered to reduce the risk of errors in the numerous inspection and installation tasks that needed to be quickly done during the maintenance period.

*BioTech* made several efforts to **slow down resource flows** during the project. Several of the informants emphasized the need to have flexible resources, such as maintenance experts, available at the site that can be moved from task to another at a moment's notice when needed. The role of these flexible resources was to respond to additional maintenance tasks that suddenly needed to be carried out, because inspections of different technical components of the production system had revealed impeding problems. In the following, an informant describes the use of flexible resources

*“To tasks that are unexpected and have not been planned in advance, we always reserve a certain amount of additional personnel. However, I can say from experience, that even though we have these spare resources, there will always be surprises that cannot be fully covered ...”*

Many informants emphasized that the production system should be as good as when it was new when the maintenance period is over. This highlighted the purpose of ensuring that the lifetime of the expensive production assets can be lengthened by carefully conducted maintenance work. In addition, by upgrading certain components of the production system, efficiency of the process (in terms of production output) could be improved as well. An informant discusses this aspect:

*“Yes, certainly, these kinds of maintenance projects are carried out from the starting point, that we want to return the facility to its original condition. Ensure that all functionality it had [when it was opened] is available at the end of the maintenance period. “*

## **Conclusions**

Our main argument put forth in this chapter is that project-based firms apply a wide range of resource-related practices to promote circular economy, and the application of these practices is project-specific. The CE practices observed in project *MineSystem* focused primarily towards closing and narrowing resources flows, whereas practices observed in *BioPlant* were oriented towards narrowing and slowing resource flows. The comparison of implementation and upgrade projects suggests that the use of CE practices is likely to change when the firm moves from implementing the complex systems to operating, maintaining and upgrading them. It appears that the opportunities for advancing CE differ considerably across project types. The system implementation project was predominantly characterized by CE practices that are product-oriented in nature (e.g., by focusing on the design and/or technology aspects of the project deliverable), whereas the system upgrade project used CE practices predominantly organizational (e.g., by personnel flexibility) in their nature.

Our analysis revealed that most of the CE practices that were directed at closing resource loops were product-oriented, that is, they addressed the design, features, and technologies incorporated in the project deliverable. However, most of the CE practices directed at slowing resource resources flows were organizational, that is, they addressed the routines and working methods of the organization either implementing or operating the project deliverable. Practices for narrowing resource flows, consisted of a balanced combination of both product- and organization-oriented practices.

This study contributes to research in three primary ways. The findings, first, contribute to the emerging discourse on the sustainability of investment projects (Aarseth et al., 2018; Huemann & Silvius, 2017) by bringing in the resource-centric view of CE. Specifically, we highlight a number of CE practices and categorize them based on their *type* (closing resource loops, slowing resource flows, and narrowing resource flows) as well as *orientation* (product and organization). Unlike some other studies on CE practices (Banihashemi et al., 2017) that focus on CE practices in developing countries, the present study addressed CE practices in the context of leading economies that, due to higher R&D expenditure, are likely contexts for the introduction of new innovative practices.

Second, the findings offer evidence of implementing CE principles in the special context of complex systems. While earlier research on CE has provided numerous examples from contexts where the outputs of production are rather standardized (Tukker, 2015), the present research illustrates that similar CE practices are applicable also to the context of project business that is characterized by inherent discontinuity, complexity, and uniqueness (Hadjikhani, 1996). The project-based nature of the cases analyzed in the present study also expands current CE literature by highlighting how the application of CE practices changes as a project proceeds from a specific phase of its lifecycle to the next. This observation implies that CE practices that are applicable in a given lifecycle phase, e.g., implementation, are likely not be directly transferable to another lifecycle phase, e.g., upgrade. Thereby, the findings are connected with the lifecycle-oriented project business studies that have emphasized the need to understand the unique nature post-project operations, in addition to the implementation phase (Artto et al., 2016; Brady et al., 2005; Smyth, 2018).

Finally, possibly relating to the high complexity characterizing both project deliverables as well as the organizations established for delivering them, and later operating their deliverables, we found that, in both studied cases, a wide portfolio of different CE approaches was used. Thus, the focal organizations did not limit to one of the CE practice types (closing resource loops, narrowing resource flows, and slowing resources flows), but engaged in practices that contributed to two (case *BioPlant*) or even three (case *MineTech*) types simultaneously. This finding forges a link to use of CE practices in projects and project portfolio management (Clegg et al., 2018; Martinsuo, 2013).

This study was limited by the choice of the two complex projects, representing two different project types (implementation vs. upgrade). In the future, it would be important to investigate the CE approaches of complex projects throughout their lifecycles, to provide an increased understanding on how the CE approach evolves between the project's lifecycle phases. While it may be time consuming and difficult to arrange in terms of research access, such longitudinal research would allow for a better understanding on how the organization implementing the solution, through its CE practices, builds options as well as limitations (in terms of CE) to the project deliverable.

Also the perspective of one focal firm limits the transferability of the findings. It will be important to empirically study CE practices in dyadic and networked contexts involving the project supplier, the customer, and potentially other stakeholders. The need for adopting a network perspective links our study also to the ongoing discourse on service provisioning in project contexts (Artto et al., 2008; Kujala et al., 2013). Project-based firms can develop options for new services, including maintenance and upgrade projects, by using certain CE practices during project implementation, e.g., when designing equipment in a manner that allows parts to be replaceable. This future orientation in CE approaches can benefit either the customer (as its own service organization can service the project product), the supplier (as it is able to sell spare part services during the operations phase), or both.

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