Project Complexity under Carbon Regulation and Trading

An increasing level of regulation on carbon emissions is taking place within the building and infrastructure construction industry. Although the US federal climate and energy policy is still in the early stage, it is becoming clear that both regulatory and market-based methods would be likely implemented to limit greenhouse gas emissions from the construction and operation of facilities. The emerging carbon regulation and market will significantly increase project complexity and profoundly impact project design, planning, construction, and operation. This paper introduces the internal and external complexity caused by carbon regulation. Several dimensions of project complexity under carbon regulation are also discussed, including interaction between carbon emissions and objectives, organization and technological complexity, contracting, and risks.

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Introduction

There are different levels of regulations to control construction project implementation. A successful project should meet all requirements of regulations such as schedule, cost, quality, and safety. In addition to those current regulations, climate change has become a top priority for government, businesses, and the general public. In accordance with this environmental issue, carbon regulation would be added to projects, which means unforeseeable uncertainty and project complexity may increase rapidly (Bennett, 1991; Hamel, 1994; Sommer, 2004). Moreover, previous research has shown that project complexity helps determine planning, coordination, and control requirements (Melles et al., 1990; Austin et al., 2002). Therefore, understanding project complexity and how it might be managed is of significant importance (Baccarini, 1996).

The study of complex systems in a unified framework has become recognized in recent years as a new scientific discipline, the ultimate of interdisciplinary fields (Bar-Yam, 2003). There are several definitions of complexity. Gray (1983) defined a technically difficult task as that with a known method or procedure for doing the work, and one in which implementation of the method and procedure requires all the skills, knowledge, and attention needed from the person concerned with the task to produce the required finished product. Malzio et al. (1988) suggested that a complex process is that which is composed of operations that are innovative and conducted in an uncertain situation or that involve operations that are not clearly defined or lack a complete specification. Baccarini (1996) argued that such conditions often result in variations that demonstrate increased production time and cost. Previous research also indicated different ways to classify the categories of project complexity. Ireland (2007) thought that projects have two primary areas of complexity - the technical aspects of the product, including the degree of difficulty in building the product, and the business scope, which can be called organizational complexity. Other research showed that complexity has two dimensions: system size and the number of interactions among influence variables (Malzio et al., 1988; Schilindwein & Ison, 2005). Unforeseeable uncertainty refers to the inability to recognize influence variables or interactions at the outset. Understanding and addressing complexity in projects is a key to improved planning and project implementation. The effectiveness of the project relies on taking the simplest approach that meets the requirements while avoiding complex situations, both technical and managerial that can impede progress.

In recent years, the U.S. government has started to focus on carbon regulation and trading issues. Many states have begun to execute policies for reducing carbon emissions. Several carbon trading systems already exist in the United States, Europe, and Australia. Carbon regulation and trading have influenced not only the manufacturing and electrical industries but also the construction industry, which must adapt to the new rules (Bird et al., 2007). The new carbon regulation and trading system will significantly increase project complexity and profoundly impact project design, planning, construction, and operation. Additionally, a key element in President Obama's economic agenda is legislating limits on carbon dioxide emissions to combat the supposed threat of global warming. In his budget outlined for the government's next fiscal year, the president has proposed a cap-and-trade policy that claims to reduce carbon emissions by 14% from their 2005 levels by 2020, and by 83% by 2050 (Carey, 2009). Under a cap-and-trade system, the government would assert ownership of the atmosphere over the United States and set a maximum number of permits that it would sell to private companies for the right to discharge carbon dioxide into the air. Over time, the government would decrease the number of permits and increase their price to meet the desired reduction in emission levels. Companies would decide which was cheaper: to buy a permit at the government-set price or incur the expense of introducing technologies to diminish the CO2 emissions (Voss, 2007; Sekar et al., 2007). The following sections will discuss the effects of carbon regulation and trading on projects, and the challenges of project management in different dimensions.

Project System Complexity under Carbon Regulation and Trading

According to the detailed literature review of project complexity (Gidado, 1992, 1996; Baccarini, 1996; Sinha et al., 2001; Laurikkala et al., 2001; Vidal et al., 2008), we decided to utilize the elements that Vidal (2008) summarized. He proposed several factors that could be classified into four groups in two categories. Our research discusses the relationships between these factors and carbon regulation and trading. A brief introduction about these groups and how carbon regulation and trading will influence them follows. The elements of project complexity affected by carbon regulation are listed in Table 1.

The size of the project system

The size of the project system is a project complexity factor and identifying the parameters that characterize the size of the project system gives a first list of drivers of project complexity when one focuses on what project size means. In this group, carbon regulation and trading may affect some factors that include duration of project, largeness of capital investment, number of activities, numbers of decisions to be made, number of information systems, number of objectives, and staff size. The duration of the project may increase due to the carbon regulation being factored into the project. The capital investment may also increase because the project may need to procure equipment to calculate the emissions and may also need to hire employees to operate this new system. Moreover, this new carbon system will raise the number of activities in the project. Project managers may also need to add the carbon issues as factors in making their decisions and determining their project objectives. The information system is another factor that could be affected by carbon emission systems, and other data may need to be added to the current information systems used in projects.

The variety of the project system

The second major group to drive project complexity is the variety of project systems. Diversity relates closely to the number of emergent properties and is a necessary condition for project complexity. Carbon regulation and trading may affect this group directly because it will add more variables to

	Project system size	Project system variety	Interdependencies within the project system	Elements of Context
Technological complexity		- Variety of technological dependencies - Variety of the technologies used during the project	- Interdependence between the components of the product - Resource and raw material interdependencies - Technological processes dependencies	- Demand of creativity - Environment complexity - Institutional configuration - Local laws and regulations - New laws and regulations - Scope for development - Significance on public agenda - Technological degree of innovation
Organizational complexity	- Duration of the Project - Largeness of capital investment - Number of activities - Number of decisions to be made - Number of information systems - Number of objectives - Staff quantity	- Diversity of staff - Variety of financial resources - Variety of organizational skills needed	- Availability of people, materials and any resources due to sharing - Combined transportation - Dependencies with the environment - Dynamic and evolving team structure Interdependence of information systems Interdependence of objectives - Processes interdependence	- Environment complexity - Institutional configuration - Local laws and regulations - Organizational degree of innovation

Table 1. Elements of Project Complexity Affected by Carbon Regulation

each factor in the group. Some projects will need new technology to control and model emissions. Practitioners may also need to consider utilizing new technologies to reduce their emissions to meet policy requirements. After adopting the new technologies, practitioners may spend more time and money operating these technologies. Those actions will increase the variety of technologies used during the project. In order to face these changes, companies may need to hire new employees who have carbon-related backgrounds, or arrange training for current employees to learn about carbon issues. Another way is for companies to establish new programs that focus on carbon issues. Those activities will increase project complexity in diversity of staff and variety of organizational skills needed. Additionally, the variety of financial resources may increase because the carbon trading market allows companies to buy and sell their permissions for carbon emissions legally. Therefore, carbon emission trading may become a new financial resource for projects.

Interdependencies within the project system

Previous research shows that interdependencies are likely to be the greatest drivers of project complexity, and traditional project management tools are not sufficient to encompass the reality of interdependence (Rodrigues and Bowers, 1996; Calinescu, 1998). In construction production processes, numerous kinds of technologies and trades use varying methods and tools. Each requires access, space, and time to carry out its objectives and can often overlap. The number of roles involved in each of the different technologies may vary and are quite often interdependent with one another in a number of ways, depending on the time and location in which they are carried out on site. Some of these include, but are not limited to, the access provided, size of available working space, working surface, and technical requirements. Therefore, carbon regulation and trading may increase the complexity in technological processes' dependencies due to adding new carbon-related technologies to projects. Additionally, the team structure of a project is another factor that may be influenced by carbon issues. Carbon regulation and trading need someone who has a related background to join the project team to control the change, so the team structure may become more complex. Moreover, the varying nature of the interdependencies or interfaces of roles may bring about the occurrence of any one or a number of inherently complex and uncertain factors. In cases where one already exists in the system, the nature of interfacing may increase its effect on production time or cost.

Context dependence

Contextuality is an essential feature of complexity, considering it as a common denominator of any complex system (Chu et al., 2003). Because carbon regulation and trading bring a brand new issue to the construction industry, the demand for creativity is a major item that will be of significant influence. Local laws and regulations about construction and infrastructure may be revised in view of the carbon concept. The scope of development may change the direction from an economic issue to more of an environmental issue. Technological innovation may start to focus on green markets. The importance of complexity to the project management process is widely acknowledged. For example, previous research has shown that project complexity helps determine planning, coordination, and control requirements (Melles et al., 1990). Project complexity also hinders the clear identification of goals and objectives of major projects (Morris and Hough, 1987). Moreover, complexity is an important criterion in the selection of an appropriate project organization form. These researchers also indicated that complexity affects the project objectives of time, cost, and quality, which means that the higher the project complexity, the greater the time and cost (Melles et al., 1990; Morris and Hough, 1987). According to the preceding discussion, carbon regulation and trading may increase the complexity of projects significantly, and practitioners may spend more time and money on their projects due to the influence of carbon regulation. It is, however, of no manifest help to owners or contractors if all they know is that costs and duration may increase. Therefore, this paper utilizes project life cycles to explain how these increasing complexities will influence the construction project process.

Project Process Complexity under Carbon Regulation and Trading

Several research articles have defined the phases of project life cycles (PMI, 2004). Essentially, a project is conceived to meet market demands or needs in a timely fashion. After the scope of the project is clearly defined, detailed engineering design will provide the blueprint for construction, and the definitive cost estimate will serve as the baseline for cost control. In the procurement and construction stage, the delivery of materials and the erection of the project on site must be carefully planned and controlled. After the construction is completed, there is usually a brief period of start-up or shakedown when the new facility is first occupied. Finally, management of the facility is turned over to the owner for full occupancy until the facility lives out its useful life and is designated for demolition or conversion (Hendrickson, 2000).

The elements of project complexity may influence different phases in the construction project life-cycle. We summarized those elements that will be affected by carbon regulation, and put them into the appropriate phase that will influence project life-cycle in Table 2. According to Table 2, we see that over half of the elements of project complexity will affect the initial phase in the project life-cycle. There are eight elements that will affect the intermediate phase; and two elements in the final phase. Finally, there is just one factor variety of financial resources that will influence the operative phase. The trend means that the earlier the project life-cycle, the heavier the carbon regulation effect. In an ideal situation, project costs can be recovered by selling carbon emissions. On the other hand, project planners may have extra expenses from purchasing carbon

Phase of project life-cycle	Elements of project complexity	Influence on performance
1. Initial Phase	Duration of project	Increasing time of project planning in project duration
	Number of activities	
	Number of decisions to be made	
	Variety of financial resources	
	Interdependence between the components of the product	
	Technological processes dependencies	
	Availability of people, materials and of any resources due to sharing	
	Dependencies with the environment	
	Dynamic and evolving team structure	
	Interdependence of objectives	
	Processes interdependence	
	Demand of creativity	
	Scope of development	
	Largeness of capital investment	Increasing project cost
	Number of objectives staff quantity	
	Number of information systems	Both increasing project duration and cost
	Variety of technological dependencies	
	Resource and raw material interdependencies	
	Local laws and regulations	
	New laws and regulations	
	Environmental complexity	
	Technological degree of innovation	
2. Intermediate Phase	Diversity of staff	Increasing communication time in project duration
	Variety of organizational skills needed	
	Variety of technologies used during the project	Both increasing project duration and cost
	Environmental complexity	
	Significance on public agenda	
	Combined transportation	
	Interdependence of information systems	
	Variety of financial resources	May increasing the revenue or cost by selling or buying carbon emission.
3. Final Phase	Environment complexity	Both increasing project duration and cost
	Variety of financial resources	May increasing the revenue or cost by selling or buying carbon emission.
4. Operation Phase	Variety of financial resources	May increasing the revenue or cost by selling or buying carbon emission.

Table 2. Elements of Project Complexity and Project Life Cycle

capacity if they could not meet the requirements of the carbon regulations. Therefore, cash flow can be changed.

Project Management Challenges

Complexity is one such critical project dimension. Project complexity under carbon regulation and trading also makes a difference to the management of projects. Also, it seems that we do not as yet have a proper understanding of carbon regulation and trading and how it will affect projects and project management in the future. In order to manage the increasing risk of changed construction project life cycles, we have proposed two major challenges that the practitioners should focus on. The first is the change in procurement plans by owners and contractors. Carbon regulation may let owners and contractors buy and sell emissions legally during a project life-cycle, which means that carbon trading may become a factor for increasing revenue or costs in projects. Managers should predict and calculate all phases of a project that may need to buy or sell emissions to get a more accurate idea of project costs. Second, the ownership of carbon emissions is another important issue that managers need to consider in the contract. Different project phases and different kinds of contracts should have different ways of defining ownership of carbon emissions. This is also a factor (like float) that may lead a project to litigation. For example, owners may request contractors use some traditional materials or equipment to reduce their cost but let contractors pay the fees for buying carbon emission capacity if the ownership of carbon emissions belongs to the contractor in a design-build contract. Several complex situations may occur if the details of ownership are not spelled out in the construction contracts.

Conclusion and Recommendation

In summary, this paper demonstrates the interaction between project complexity and carbon regulation, and uses project life cycles to explain how the construction process may be influenced by carbon regulation. We have also described the major challenges that practitioners will face in project management. Two major recommendations from the research include the following.

1. Project managers should consider the project complexity when thinking about project planning, especially in the initial phase of planning. In project planning, managers should understand that carbon trading is a financial factor that may either generate revenue for or add costs to a project.

2. Project managers should focus on project risk management. Financial leverage may increase due to adopting carbon regulation, so mangers need to spend more on new technologies to meet carbon emissions standards. Therefore, the larger the financial leverage is, the larger the risk to a project there will be.

This is the beginning of a new research area on which the construction industry should focus. Future research might investigate several areas, including innovative contracting with carbon regulation and trading, the construction process with respect to carbon policy, and construction project finance under carbon regulation and trading.

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