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System Dynamics and Management Science Approaches Toward Increasing Acquisition Process Efficiency

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ABSTRACT

Contracting has a significant impact on the acquisition process efficiency, especially in the context of so-called public private partnership (PPP). Improper contracts may cause significant delay and additional costs in project execution due to opportunistic behavior of private-sector suppliers. We present a system dynamics model combined with a web based management cockpit for project contracting and interactive decision support which can be used to train project purchasers showing that carefully designed contracts help to keep the project on schedule and bring benefits to both, to the governmental entities and the private-sector suppliers.

Keywords: system dynamics modeling, public private partnership (PPP), interactive decision support, web tool for project contracting

1. Introduction

Delays in a public-private partnership project cause a two-fold disadvantages for the contracting authority. Firstly, the planned features often are not available during the period of delay. Secondly, in many cases, due to the delay the features are partly already out of date when they are put into use. However, improvement of the project contracting process may have a significant contribution to reduce project delays, additional costs and improve outcome of the project.

In our research we want to analyze how project contracts that include carefully designed timely penalties may help to keep a project on track and within the planned timeline. The proposed system dynamics model in combination with the web based management cockpit for project contracting and interactive decision support is developed at the Universität der Bundeswehr München (Germany) and shall be used for teaching project contracting in the future.

In this paper we start with a literature review to examine three related research issues: public-private partnership, opportunistic behavior and contracting, as well as project contracting from the view of system dynamics. After that, we describe our concept development using a web based management cockpit with an underlying system dynamics model for project contracting and interactive decision support, along with some preliminary results. Thereby, a better understanding of the problem and the relation between the contracting authority on the one side and the private-sector project supplier on the other side can be achieved.

2. Literature review

Public-private partnership

The evolution of the New Public Management (NPM) idea in the 1980s has shifted the emphasis in the public sector away from stress on process to a stress on output (Hood 1995). One concept within NPM concerns the use of public-private partnerships (PPPs) in order to offer infrastructure and services to the public efficiently. The interest of many nations to take use of PPPs is attributed among others to faster delivery and reduced whole life costs of public infrastructure and services, improved quality, and the generation of additional revenues (European Commission 2003). Especially in a time of financial shortfalls and cuts in public budgets together with increasing infrastructure costs, PPPs become a popular option for many nations (Winch 2012).

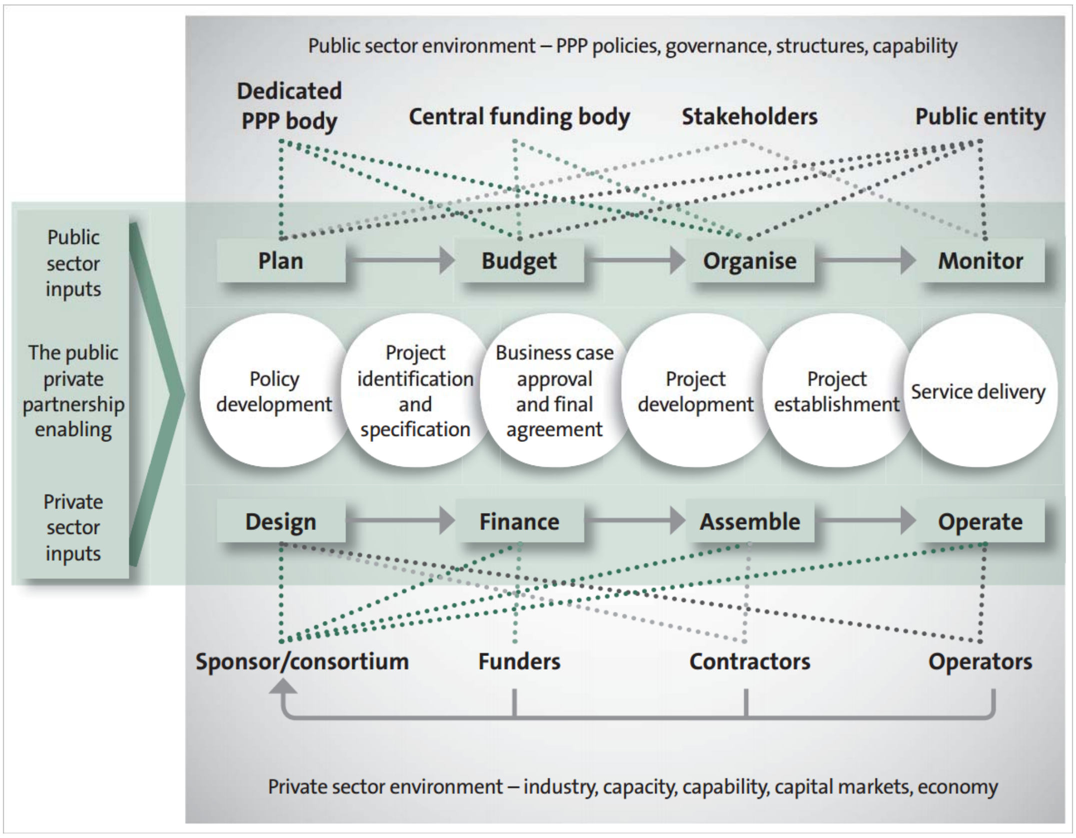

Figure 1: The public private partnership environment (Provost 2011)

Even though there is no universally accepted definition of PPP (Khanom 2009), this kind of partnership lies somewhere between delivery of infrastructure and services by public sector organizations and total privatization of these tasks. The "National Council for Public-Private Partnerships" explains the term PPP as means of utilizing private-sector resources in a way that is a blend of outsourcing and privatization (National Council 2002, p.4). Iossa et al. describe public-private partnership from the infrastructure point of view as a long-term contractual arrangement between the public sector and the private sector in which the private sector is responsible for significant aspects of the building and operation of an infrastructure for the delivery of public services (Iossa 2007, p.3). More generally speaking, a "PPP is a partnership between the public sector and the private sector for the purpose of delivering a project or a service traditionally delivered by the public sector" (European Commission 2003, p.16). PPP may involve design, construction, financing, operation and maintenance of public infrastructure, facilities, or the operation of services to meet public needs. The UK for example has a large body of experience in funding public infrastructure with private capital, the so called Private Finance Initiative (PFI)

(National Audit Office 2011). Figure 1 "provides a general overview of the public and private sector participants and activities that can surround a PPP project or programme. It shows each sector's inputs into the process from policy development to service delivery" (Provost 2011).

Resources, risks, and rewards are shared between public and private entities by - mostly long-term - contracts (National Council 2009). This allows each party to do what it does best. While private entities are responsible for operational aspects, the public sector has to set its focus on planning, contracting and monitoring (European Commission 2003). As a result, sufficient commercial skills are indispensible for public entities to manage PPP projects, which in most cases are complex projects, successfully (National Audit Office 2009). What happens when there is a lack of these skills is illustrated in the following example.

Since the 1980's the mayor of Farum, Denmark has followed an active strategy relying on contracting out and, later, PPPs for delivering various public services. In 2002 the issue about the PPP contract for construction of the soccer stadium and the sports arena, and inadequate money spending led to a local governmental scandal and the mayor's leave. The main reason for the failure of PPP in this case was the fact that the structure of the contractual governance scheme in Farum was too complex for the mayor to oversee the resources (Greve 2002, p.2).

Setting up adequate contracts (a "multidimensional model for PPP contracting" can be found in Zarco-Jasso 2005) by which risks are transferred from the public to the private sector is a critical success factor for PPP projects (Daly 2004). To do this, it is essential for public officials to understand how commercial levers work (George 2009). Without such skills the likelihood of a less than optimal contractual outcome is significantly increased (Campbell 2011).

Opportunistic behavior and contracting

Regarding the regulatory and institutional framework, the quality of contract enforceability and governance are a critical factor affecting PPP agreements (Iossa 2007, p.6). Aspects of the contract design, such as the **risk allocation** or the payment mechanism, significantly affect the PPP outcomes (Iossa 2007, p.7). The sheer complexity of PPP contracts makes opportunistic behavior a key issue for the success of a PPP project. A crucial point is the opportunism which plays an important role for interparty collaboration in every project. On the one hand, opportunism increases transaction costs in repeated exchange mainly because of the crucial fact that covert behavior seeking unilateral gains are difficult to observe and to verify. On the other hand, opportunism can be seen as a significant obstacle to fostering confidence in partner cooperation, and consequently the risk of opportunism may escalates interparty conflicts (Luo 2007, p.857).

Opportunistic behavior can be generally described as taking the opportunity to manage earnings in order to maximize their own utilities at the expense of the contracting parties and stakeholders (Sun 2008, p.407). In details, opportunistic behavior can be explained as the usage of information asymmetry between outsiders and insiders to maximize their utility in dealing with compensation contracts, debt contracts and regulations. Furthermore, investors are thereby misled by the unreliable information reported (Sun 2008, p.410). Consequently, it can be said that opportunism represents a significant obstacle to fostering confidence in partner cooperation, and the risk of opportunism escalates interparty conflicts. In other words, opportunistic parties do their own thing and emphasize their own interests, hence weakening the basic foundation for collaboration (Luo 2007, p.857).

Especially a lack of **quality control** during the project and additional institutional setting allows for opportunistic behavior, increases the likelihood of dealing with inadequate service suppliers, and represents a performance risk for the client (see, e.g., Glückler 2003, p.289). Therefore, one successful way to reduce this opportunistic behavior is personal experience that evolves from interaction between clients and consultants which becomes most important in reducing uncertainty and controlling for opportunistic behavior (Glückler 2003, p.270).

As mentioned at the beginning of Section 1, delays in a public-private partnership project cause a two-fold disadvantage for the contracting authority. In addition, Wood identifies schedule delays as a cost driver of major defense programs (Wood 2012). A central task of a properly concluded contract must thus include a functional **project schedule management**.

Bernheim and Whinston developed a formal model and showed that making the contract more explicit may further encourage opportunistic behavior surrounding actions that cannot be specified within contracts (Bernheim 1998, p.921). Nevertheless, the capacity for contracts to adequately safeguard relationship-specific investments against opportunistic behavior by a contractual partner is limited (Mayer 2004, p.396).

Project contracting and system dynamics

The complexity inherent in many projects exceeds human imagination by far. Although among the most important activities in modern society, **large-scale** and **long-term** projects are one of the least organized activities. Therefore, it is no wonder that these kinds of projects typically experience additional costs, delays and quality problems. Over several years Cooper and Mullen analyzed some major projects in different industries (Cooper 1993). They reported that commercial software projects are more expensive by about 140% than planned and lasted about 190% longer as originally scheduled. For military projects, his analysis reported that there were even 310% additional costs and 460% delay. Another study of transportation infrastructure projects reports a cost overrun in nine out of ten projects (Flyvbjerg 2002). Rail projects, fixed-links projects (bridges and tunnels), and road projects experience an average cost overrun of 28%. According to Flyvbjerg, “the private sector, the public sector, and private/public sector partnerships have a dismal record of delivering on large infrastructure cost and performance promises” (Flyvbjerg 2009, p. 170). Some “famous” examples include the implementation of a tolling system for German motorways (Toll Collect), the construction of the Eurotunnel connecting France and the UK, and the Sydney Opera house. Nowadays, the extreme delay and cost overrun of Berlin’s new airport BER (Niemeier 2013) let classify this large scale infrastructure project as failed.

According to the Project Management Institute, a “project is a temporary endeavor undertaken to create a unique product, service, or result” (PMI 2004, p. 5). With this definition in mind, every project has to keep the balance of “The Iron Triangle” (Atkinson 1999): time, cost, and quality. In PPP projects the objectives of the project, the delivering date, and the price paid are fixed in a contract.

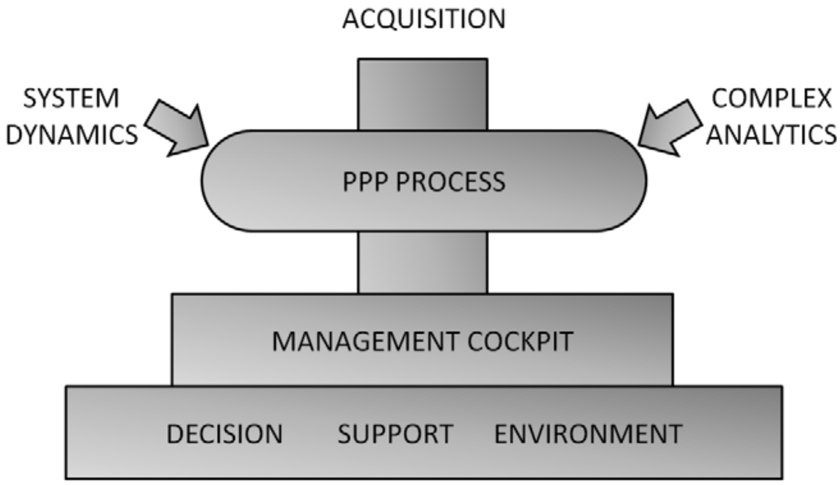

Figure 2: PPP and system dynamics - new form of decision support

The private partner, i.e. the private supplier, is responsible for delivering the project objectives in accordance to the contract. He has to spend and assign resources, among others human resources, to best meet these objectives. To reduce complexity, large scale projects are usually divided into manageable deliverables in form of a so called work breakdown structure (see NASA 2010). The elements in the work breakdown structure are sub-results and define the tasks which have to be fulfilled during the project execution. On the other hand, the public partner, i.e. the contracting authority, has to reward the supplier for the contractual deliverables. The delivered results create a benefit for the public.

A key aspect for successful project delivery, that is on time, on budget, and on value, is to handle project complexity (Baccarini 1996). The evolution of information technology provides methods and tools to support this task by modeling and simulation (Mizzel 2007). One of the computer-aided modeling methods is system dynamics (Figure 2). Properly developed system dynamics models may provide decision support in the project development phase and the support in making decisions concerning the project schedule with a long-term focus on the realization (Lyneis 2001, p.241).

One of the strengths of system dynamics is the representation of the interdependencies within a project and the subsequent tracking of changes in the model. It can be said that system dynamics consists of one of the most developed plans for action, the optimal representation, analysis and detailed explanation of dynamics in complex technical systems as well as in entrepreneurial systems (Sterman 1992, p.6f.). Additional costs and delays can be detected early. System dynamics should be regarded as an additional method for decision support in project management to the existing, traditional project management methods. Especially when handling complex project dynamics, based on causal relationships, feedback loops, time delays and non-linearity, system dynamics can regarded as a potential method (Sterman 1992, p.9).

Summary

System dynamics modeling and simulation is an effective instrument to understand and to improve project contracting process efficiency in many ways. We propose to develop a new approach via system dynamics model for project execution based on (Lyneis 2001) and our previous research projects.

3. Concept development

A web based management cockpit for project contracting

As shown by previous studies, both accuracy of the mental model of the participants for a complex managerial task (Gary 2005) and data presentation (Leopold-Wildburger 2013) may influence the performance of an interactive decision process.

As discussed in Section 2, understanding opportunistic behavior during PPP acquisition and execution is a critical success factor for PPP projects. The right hand side of the causal loop diagram (CLD) depicted in Figure 3 illustrates how `understanding of opportunism` is embedded in a feedback loop. `Understanding of opportunism` influences positively the `quality of` the PPP `contract`. The better the `quality of contract` the fewer `opportunistic behavior` of the private partner is to be expected. In turn, `project outcome` will benefit. Following the link, `project outcome` impacts `project complexity`. The higher the former, the lower the latter is and vice versa. When the project is very complex, the `understanding of opportunism` suffers. On the other hand, a reduced `project complexity` simplifies `understanding of opportunism`. In addition, `project complexity` has a negative relationship to `quality of contract`.

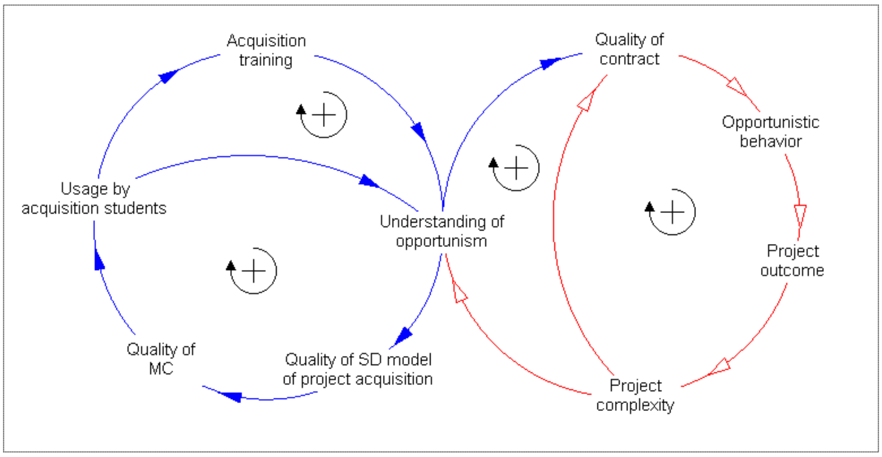

Figure 3: A causal loop diagram of project contracting and management cockpit

Besides reducing project complexity, another solution does exist to increase the `understanding of opportunistic behavior`. This is can be seen on the left hand side of the CLD (Figure 3). A high `understanding of opportunism` results in a high `quality of SD model of project acquisition`. As a consequence, the `quality` of the management cockpit (MC) increases as well. A well designed and implemented management cockpit enhances the usage by acquisition students. This, in turn, impacts positively the understanding of opportunism directly and indirectly via a higher level of acquisition training. Therefore, to control the understanding of opportunism the design and implementation of an adequate management cockpit is key. A properly developed and accessible management cockpit should support both acquisition research and acquisition training.

Based on (Hu 2011) we develop a prototype of a web based management cockpit for interactive project contracting. The system architecture of the whole platform which the prototype is embedded in is shown in Figure 4.

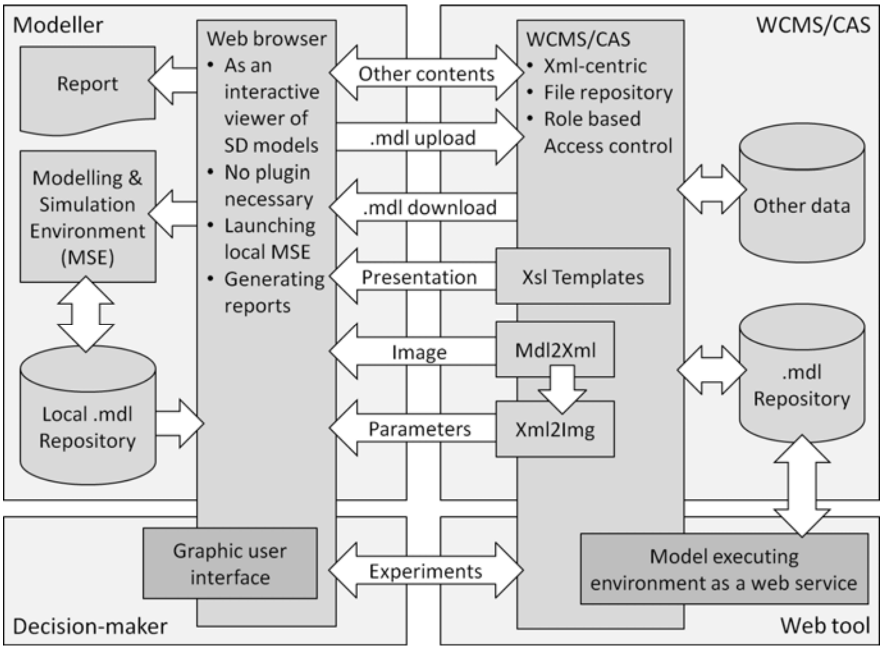

Figure 4: System architecture of the collaborative modeling and experiment platform

Core element of our prototype is a system dynamics model. To be able to integrate the newest research results, the platform is designed in such a way that this model can be easily replaced by a new version or even another system dynamics model. A web based tool not only facilitates deployment but also enhances collaboration. Furthermore, such a tool helps to present data in a more understandable fashion and supports information management. Thereby, users are able to achieve better decisions (Roth 2010).

To implement the web based management cockpit, we extend our specific system dynamics model by an accessible user interface. Students will be invited to use the management cockpit for interactive decision support on project contracting. By analyzing their results and experiences, we will gain new insights into opportunistic behavior during the acquisition and contraction phase of a PPP project.

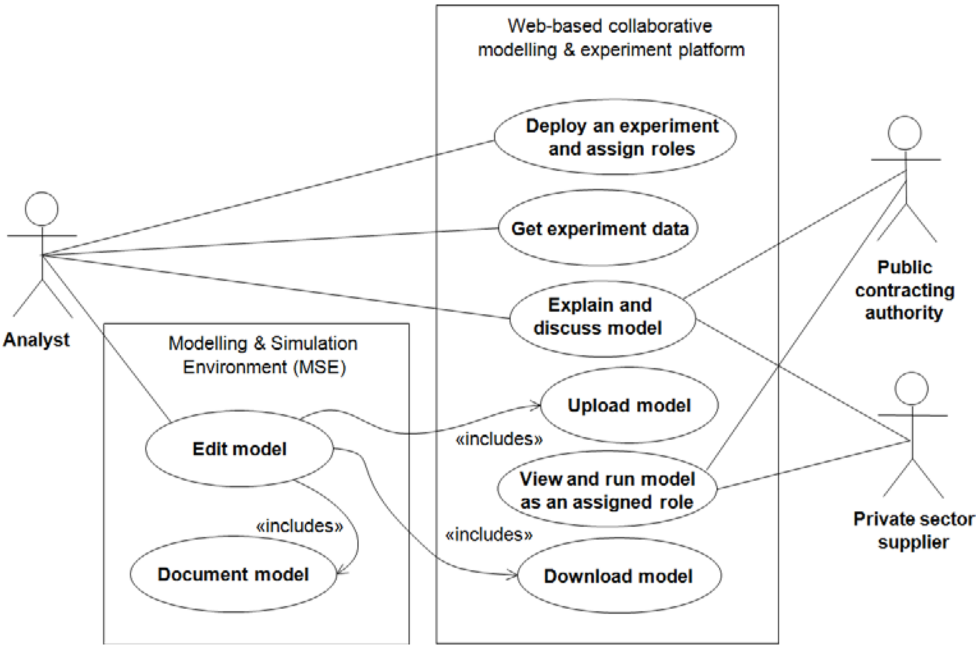

Figure 5: Use case diagram for a web based management cockpit for interactive project contracting

The management cockpit will be tested by students in groups. Each of the participants will act as a project director. For several successive rounds, they will compete against each other under certain PPP contract conditions. Before the start of a test, participants will be provided with a detailed description of the PPP project itself, its contracting details and common rules. In addition, they will receive explicit instructions on how to use the web tool (Figure 5). Decision-makers of both public contracting authority and private sector supplier are involved.

The participants will take turns in acting from the public and from the private side. Main task for the public side will be setting of project contracting indicator values for the specified project. On the other side, as private contractors, the students will be required to pay attention on their profit and on fulfillment of the project. The focus is on necessary resources, i.e. number of employees, for project implementation. Figure 6 shows the web user interface. During a simulated project, the management cockpit informs the participants interactively about project contract and execution details, including:

- `Money` (earned by) `Supplier` - measured in person·month
- Number of tasks to be executed according the project `Plan` - measured in person·month
- `Penalty` - measured in person·month
- Number of tasks which are `Really Done` - measured in person·month
- `Team Size` - measured in person

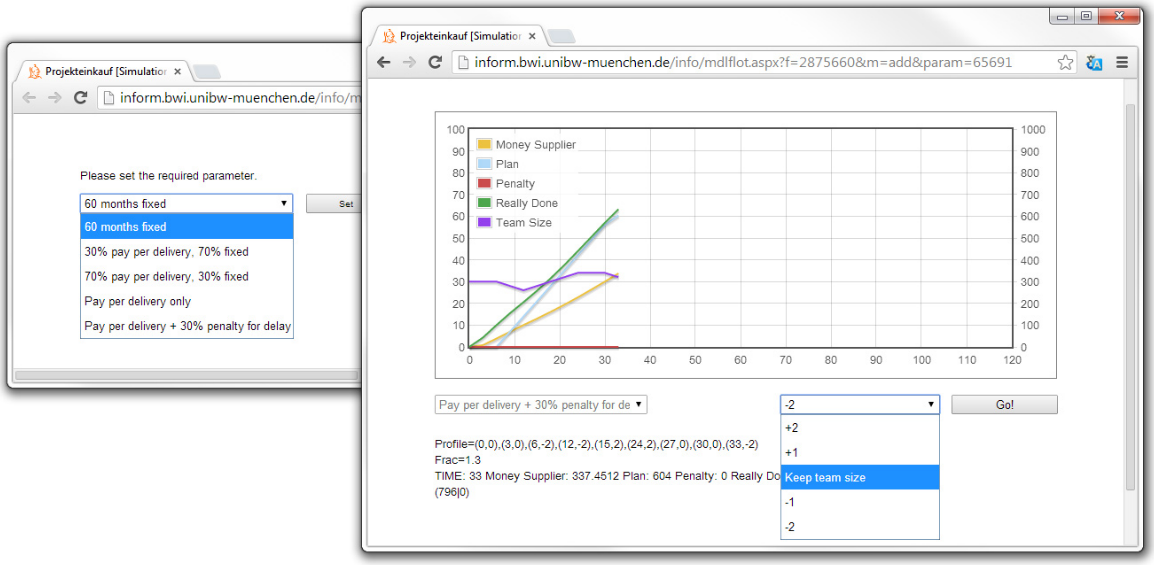

Figure 6: Web user interface. Left: choosing project contracting option by public contracting authority; right: simulating project execution by private sector supplier

Our web based management cockpit for project contracting and interactive decision support offers the possibility to track participants' opportunistic behavior in decision making during the progress of a simulated PPP project in a competitive environment as well as other key indicators for PPP projects. During a simulation run, all relevant data is stored for analysis in a preprocessing step. This allows identifying participants' learning and adaption processes as well as the identification of well working policies.

Preliminary results

As a first step, the students are all asked to play the role of a private sector contractor. Figures 7 and 8 show the results of project execution by two students. Four projects of two different contract terms have to be executed. The term options are given to them successively:

1. pay per delivery + 30% penalty for delay
2. pay per delivery only
3. pay per delivery + 30% penalty for delay
4. pay per delivery only

Notice that in our simulations a delay penalty (if any) may be already payable during the project execution. In the practice this makes necessary detailed project planning and monitoring processes on the side of public contracting authorities.

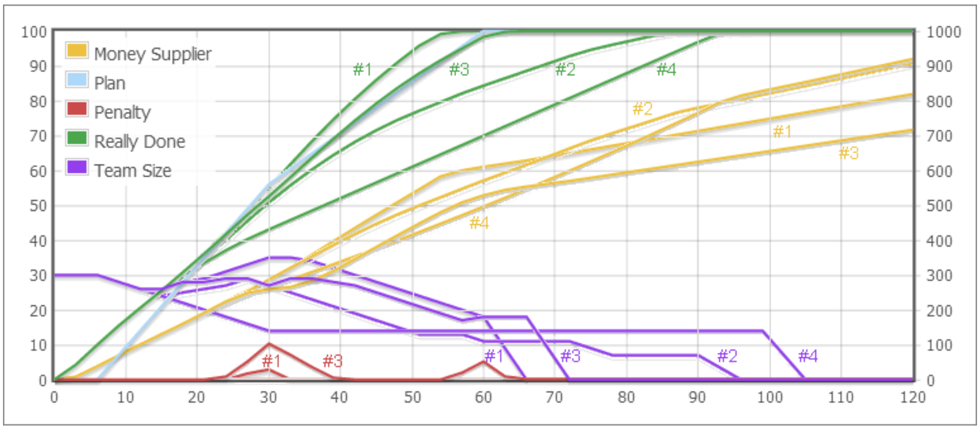

Figure 7: Project execution by Student A

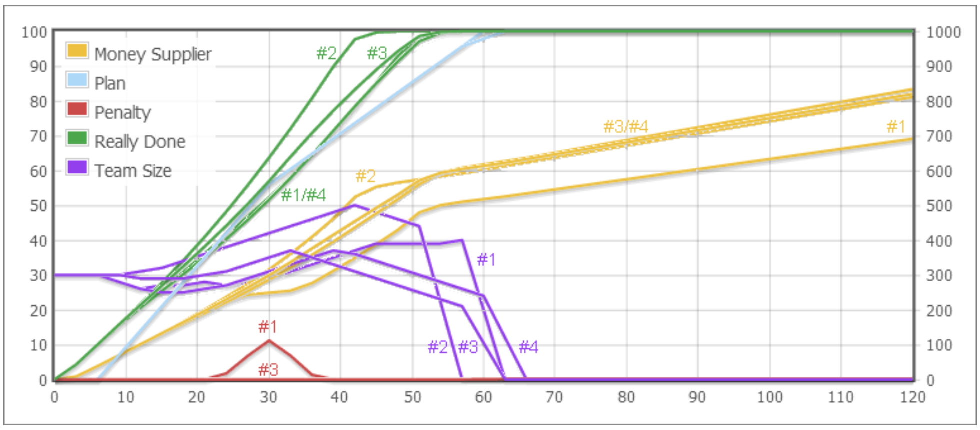

Figure 8: Project execution by Student B

Comparing project execution #2 to #4 by both students, it is obviously that both students have learnt quickly that a smaller team size and thus a longer project duration is beneficial for project suppliers, if there is no danger of delay penalty. In other words, they learnt quickly to behave opportunistically. The difference between the execution #3 and #4, which is significant in the case of Student A and visible in the case of Student B, indicates the potential of a contract term of delay penalty to reduce the negative impact of such an opportunistic behavior.

Behind the scenes: a system dynamics model of project contracting

The system dynamics model which we have developed for our web based management cockpit for project contracting and interactive decision support does not only has a theoretical but also a more practical oriented background. Developing and deploying effective concepts and tools supporting contracting officials during their contracting and strategic planning activities is however an essential and long-term task.

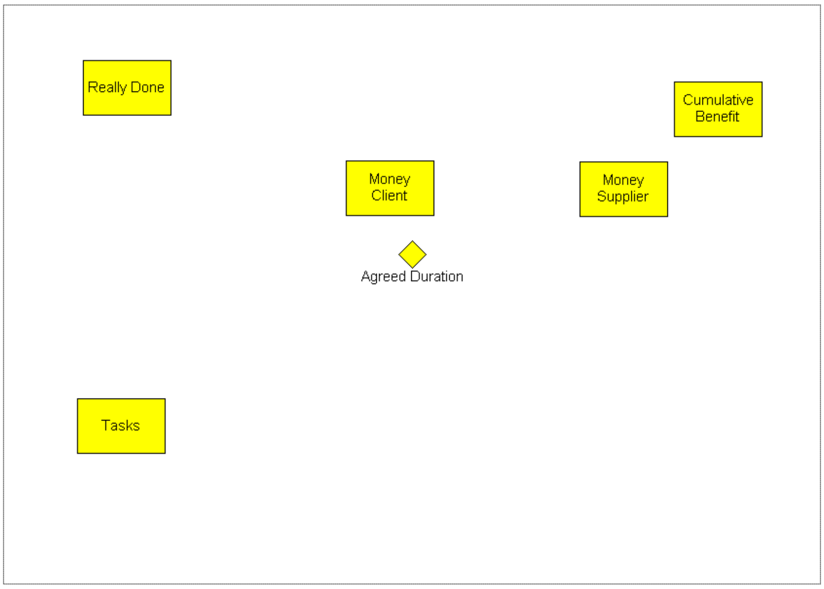

Figure 9: parameter set describing a project

The current existing version of our model is capable of displaying the key indicators which are essential both for the contracting authority as well as for the project supplier. The basic parameter set describing a project includes the `tasks` (measured in person·month) to be executed within certain `agreed duration` (month) and those ones which are `really done` (person·month), as well as the `money` earned by the `supplier` (person·month), the `money` (person·month) spent by the contracting authority or the `client` and the `cumulative benefit` (person·month^2) of the project over the time (Figure 9).

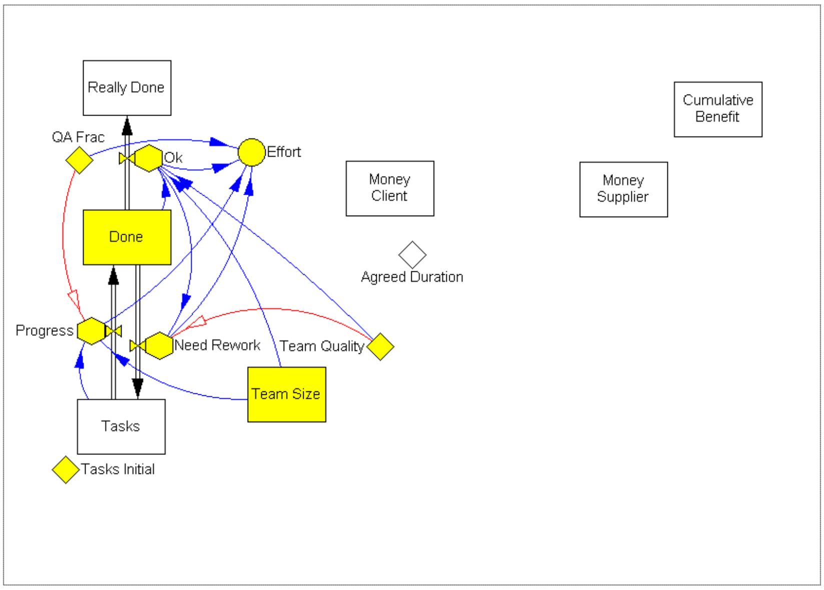

Figure 10: project execution

During project `progress`, planned `tasks` are completed. Therefore, planned `tasks` will change into the status `done`. However, not every executed task produces the intended results but type I or type II errors (Atkinson 1999). In these cases, work is done wrong respectively not as well as it could have been. Hence, these tasks `need rework` and change again into the status planned `tasks`. The fraction of tasks needing rework depends on `Team Quality`. On the other hand, tasks that are completed successfully pass into `really done.`

The model reflects this project executing structure (Figure 10). Similar models can be found for example in (Lyneis 2007, Garcia 2009, Sterman 2000).

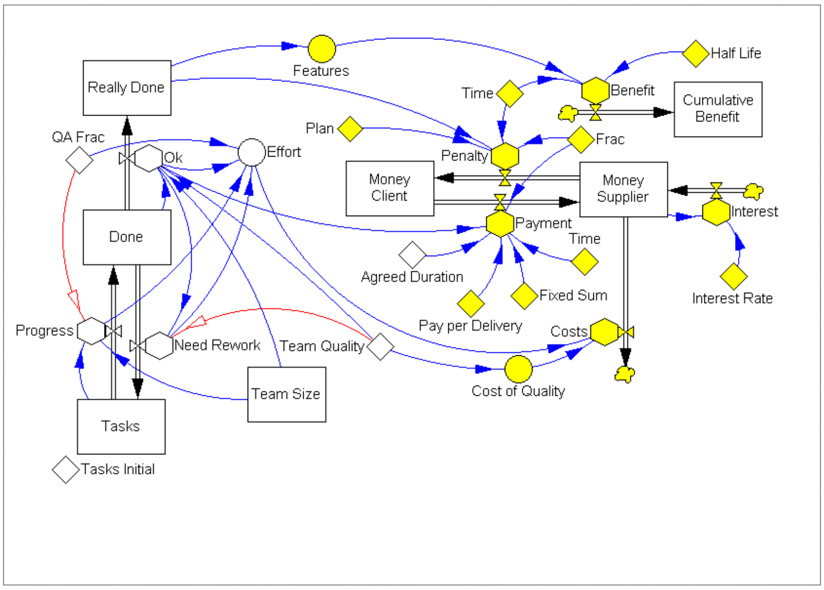

Figure 11: benefits of the project client and the financial aspects

The next modeling step is to reflect the financial flows (`Payment`, `Penalty`, `Interest` and `Costs`) and other dependencies (Figure 11). The contract's term of payment is set by `Frac` which is the fraction of payment on a pay-per-delivery basis. A number bigger than 1 means a penalty applies for each delayed person month according the `Plan`. From the point of view of a public project client the more tasks are finished, the more `Features` can be put into use. Notice that for certain IT and other high-tech projects the `Half Life` during which the time specific benefit is reduced to half the original planned value can be as short as 24 months.

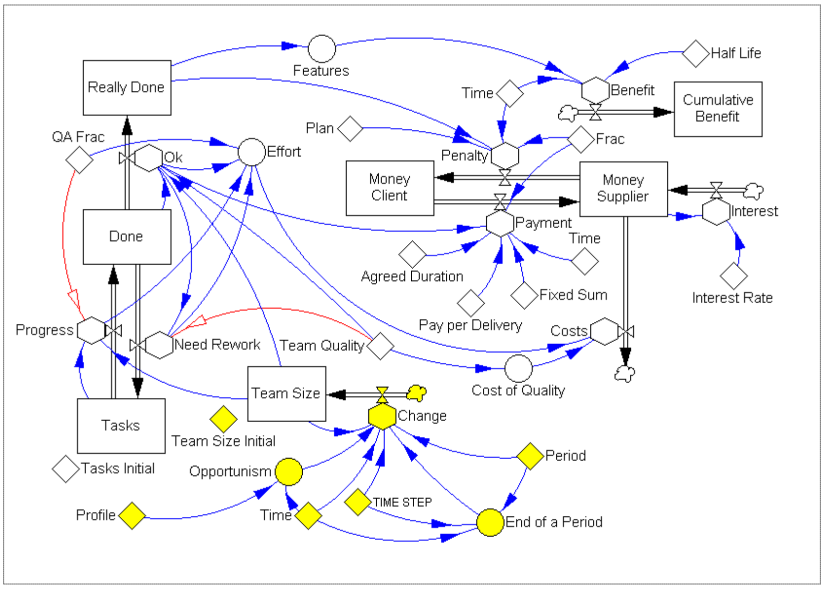

Figure 12: possible opportunistic behavior regarding the team size

Finally, two variants of the model are realized. Using the first one, shown in Figure 12, each participant acts as a possibly opportunistic project supplier. Depending on the value of `Frac` it may be beneficial to reduce `Team Size` at the cost of a significant project delay. `Frac` and `Team Size` are the two parameters which are to be controlled through the user interface shown in Figure 6.

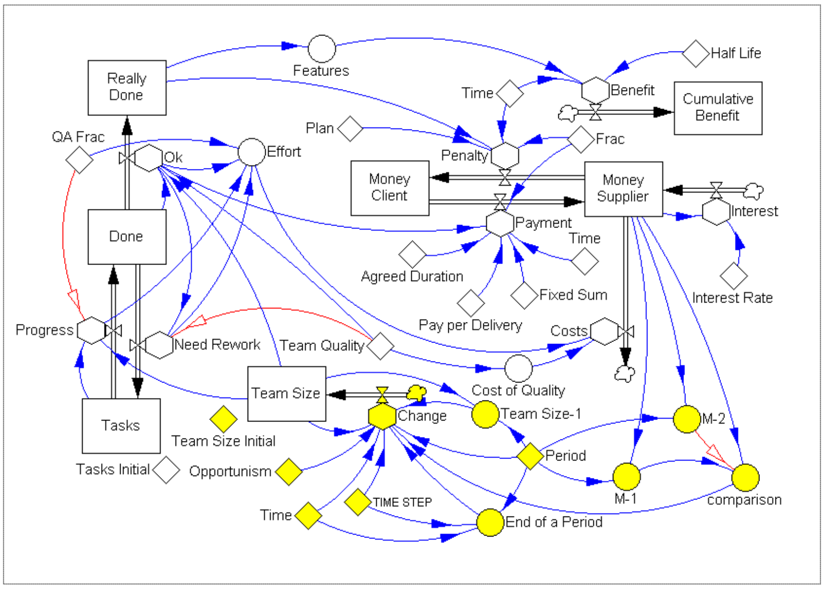

Figure 13: opportunistic computer player

Figure 13 shows another model variant in which the opportunistic behavior is literally programmed. A participant of the interactive decision support based on such a model acts as a public project client designing a contract, or in other words, defining the value of `Frac`.

4. Conclusions

Delays in public-private partnership projects cause significant disadvantages for public contracting authorities. In our research we want to analyze how project contracts that include carefully designed timely penalties may help to keep a project on track and within the planned timeline.

We have developed a prototype of a web based management cockpit for interactive project contracting. Core element of our prototype is a system dynamics model which can be easily replaced by a new version or even anther system dynamics model to reflect the newest research results.

The described web based management cockpit allows students to play the role of both parties involved in PPP project acquisition and contracting: public contracting authority and private sector contractor. During a simulated project, the management cockpit informs the participants interactively about project contract and execution details. Observing students' actions allows understanding different effects of specific decisions and thereby helps to gain important insights into critical interdependencies of PPP project key indicators. On the one hand, these key indicators are the money invested by the public authority, the project's cumulative benefit, and the project duration. All three can be regarded as the key performance indicators for the public partner. He aims to maximize the cumulative project by simultaneously minimizing the money to be invested and project duration. On the other hand, there are the key performance indicators for the private partner: money spent and project duration. Foremost, the private sector contractor aims to maximize profit. He can do this by controlling project duration and resources assigned to the project, i.e. manpower.

As expected, some of the students have learnt quickly to reduce team size to maximize the profit at the expense of a longer project duration. Our preliminary results indicate also the potential of a contract term of delay penalty to reduce the negative impact of such an opportunistic behavior.

This management cockpit is planned to be extended in future research. There already exists the concept that new models with a variety of adapted indicator sets will be used for additional interactive decision support.

Summary

From our point of view, this specific web based management cockpit in combination with the underlying system dynamics model offers a high grade of flexibility and attractiveness for use in the area of project contracting issues with an international focus. Generally speaking, system dynamics can be seen as a powerful decision support tool which can be used in a variety of ways when implemented in a web based management cockpit for decision makers in project contracting.

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