Capability Engineering: Design of a Conceptual Model

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Abstract

The Capability-Based Planning approach offers several advantages for strategic planning, including a systemic view and a coordination among resources and the operational context. Part of the purpose of such approach is to aid decision makers in connecting budgetary decisions with the accomplishment of strategic objectives; however, addressing the complexity a system itself is a difficult and can become an overwhelming task. This is the reason why there is a need for complementary tools that reduce complexity and contribute to the formulation of strategic plans. In this paper the design of a System Dynamics model that serves as a platform for decision making and strategic planning is presented and discussed. The model is expected to simulate the evolution of capabilities and their behaviour under different plausible scenarios.

Key words: System Dynamics, Capability-Based Planning, simulation, capability engineering

I. Introduction

Importance of complementing readiness capability assessment with a capability engineering simulation model that aids decision makers in the development of informed strategic plans and that evidences the connection between capabilities and strategic objectives through a systemic view. An example of the use of simulation models for capability analysis and experimentation is the CAE Capability Engineering model (CAE, 2014).

In this paper, the design of such a model is presented and discussed. Initially, relevant aspects of the Capability-Based Planning approach are summarized, followed by a brief discussion about the purpose and utility of the Capability Engineering Model. Thirdly, the conceptual design of the model is presented. Possible difficulties that may arise along the implementation process as well as a reflection upon some of limitations and scope of the model are discussed.

II. The Capability-Based Planning Approach: A Brief Summary

Capability can be defined as the "ability to do something" (Oxford Dictionaries, 2014). In the military context, for example, a capability can be the ability to transport a determined number of soldiers in a specific time period. A capability, then, is a function of a set of elements founded on doctrinal principles and procedures that aim to generate a desired effect (Sieiro, June 2006).

A capability engineering simulation model: what is the purpose?

As it has been briefly suggested, one of the advantages of the Capability-Based Planning Approach is that it allows decision makers to follow budgetary decisions and connect them with strategic objectives and hence, it facilitates the decision making process in terms of how much and in what to invest. This can be partly achieved with a capability readiness evaluation model, nevertheless, as Coyle mentions, "…military planning has to deal with the evolution of capabilities as time passes and equipment programs take effect" (Coyle, 1989). To do this, measuring readiness does not allow observing capability dynamics (capability evolution) through time under different scenarios. That is, it does not answer "what if?" questions, a central element when planning on a strategic level. Furthermore a capability readiness evaluation model does not capture the delays that are involved in the process of capability acquisitions such as equipment acquisitions, personnel training, among others.

To fill this gap, a Capability Engineering Model that can follow the evolution of capabilities in response to investment and connect them with strategic objectives can be a complementary planning tool for decision makers. Such a model can aid decision makers in understanding how the combination of the capabilities of the different Armed Forces is able to respond to different challenges and hence can enrich the strategic planning process. The model becomes a tool for experimentation and capability redesign.

The model should be articulated with the Capability-Based Planning methodology and should be flexible and adaptive so that it can respond to a changing strategic environment.

III. Conceptual Design of the Capability Engineering Model

In this section the conceptual design of the model is presented and discussed. Initially, there is an initial characterization of the capability concept in a stock and flow model. This characterization is followed by the conceptualization of the Capability Engineering Model; the stock and flow capability concept model is complemented with the feedback processes that arise as a result of Capability-Based Planning and the system's structure itself. Thirdly, the limitations and scope of the model are discussed.

Capability Concept in a Stock and Flow Diagram

Understanding a capability as a combination of components allows planning to consider all the necessary elements to make things happen and not only concentrate on equipment acquisitions or personnel recruitment, for instance. According to Equation 1, one could calculate a determined capability ($Capability_{ij}$) at a specific point in time if one knows the state of the different components that define this capability. To characterize such states one can think about them as stocks that take time to be filled and that also empty in time. For example, it takes time to recruit and train personnel and, in time, some of the personnel will retire or resign. A stock is produced by the interaction among these processes (recruitment, training, retiring etc.) and it is this stock that defines the state of the personnel component of $Capability_{ij}$. Similarly, equipment acquisitions take time from the moment they are solicited until they are acquired and eventually equipment needs to be repaired and maintained until it fulfills its lifecycle; again, a stock of available equipment is produced and it is this stock the one that defines the material and equipment component of $Capability_{ij}$. Infrastructure can also be conceptualized in a similar way, it takes time to build or acquire infrastructures and it also has a life cycle after which demolition or maintenance follows.

In the case of doctrine, a more abstract conceptualization is required. Nevertheless, it can also be understood as a stock, with the difference that it does not accumulate material but instead it accumulates knowledge (procedures and doctrinal principles). Knowledge takes time to be developed but it also becomes obsolete after some time; it requires continuous updates according to new equipment and according to new military concepts. Similarly the Organization component can be characterized as a stock of organizational effectiveness which is the result of how people and resources are organized and operate together. Organizational effectiveness is the product of organizational learning and adaptation and hence it is produced in time by incremental and decrease processes.

Figure 5 illustrates a simplified conceptual stock and flow model that incorporates this capability characterization in a stock and flow diagram. As shown, each component is characterized as a stock and the respective flows. With this conceptualization it is possible to include delays that characterize the time it takes to effectively attain a specific component; some of the possible delays in this type of process are shown in the model of Figure 5.

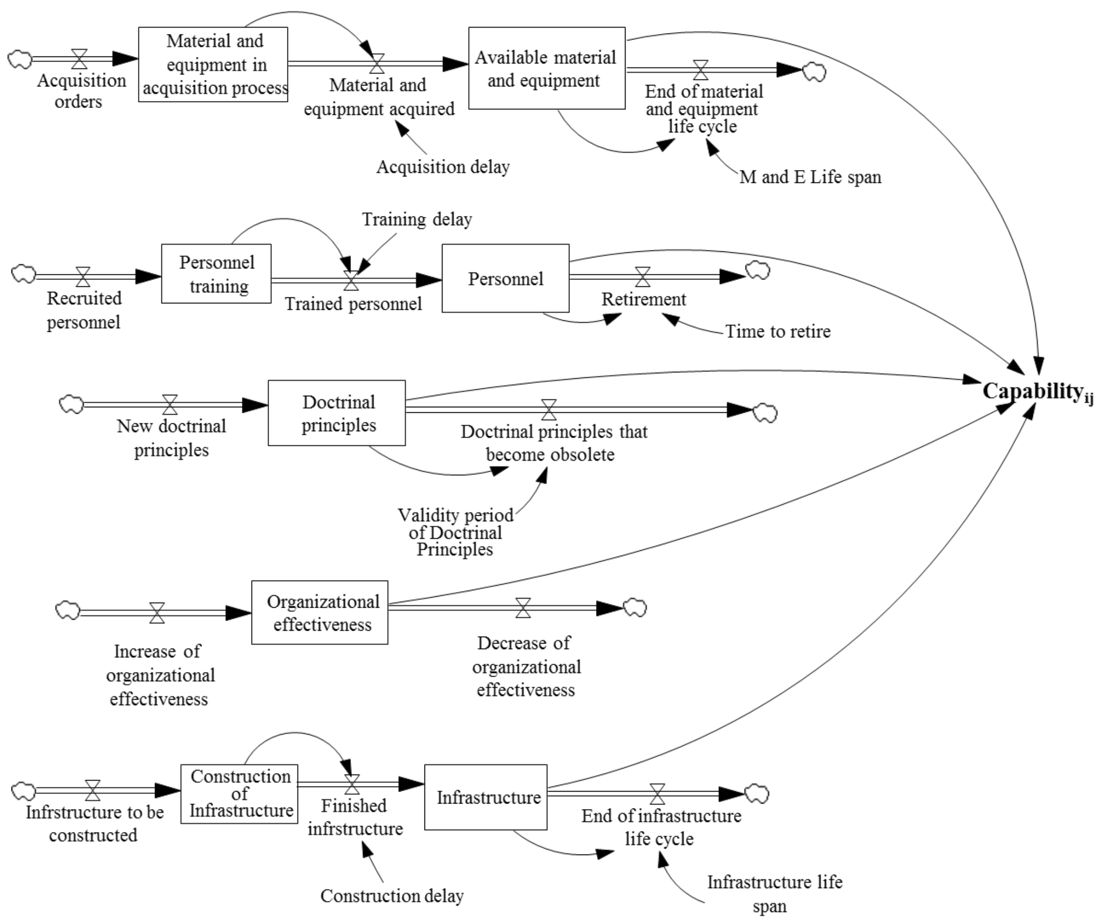

Figure 1 Stock and flow capability characterization

It is important to note, as it has been mentioned in the previous section, capabilities are modular (they can be used to accomplish several operational concepts); in the case of components, these are also modular, which means a specific component that is being used for *Capability*$_{ij}$ could also be used for a distinct *Capability*$_{nn}$. Figure 5 only shows the general conceptualization for one capability. A complete model could differentiate the components into different types of equipment and material, personnel with different competencies, doctrinal principles according to the functionality of the capability etc, with the purpose of linking the specific components that define *Capability*$_{ij}$. The complete model would also include all the capabilities of the system and show which of them use the same type of components. As the CAE defines it, this capability conceptual definition becomes a "system of systems" (CAE, 2014).

The Capability Engineering Model: a General Schema

As mentioned, a system involves a wide range of actors that continuously decide how and in what to invest and how to use capabilities for which Operational Concept(s), among many other decisions. The characterization of this system under the Capability-Based Planning Approach is the basis for the Capability Engineering Model. Figure 6 shows a simplified schema of how this model would look.

It is important to note the schema only shows a part of the model; it includes: one component (material and equipment) and one capability (capability_{ij}). The structure replicates for each additional capability and operational concept. Keep in mind the modularity of capabilities and components that was previously explained. The model uses the stock and flow capability conceptualization shown in Figure 5; again, the complete Capability Engineering Model would include a differentiation of the different types of material and equipment, personnel grouped by their competencies, different doctrinal principles, infrastructure and organizational effectiveness according to their use and functionality.

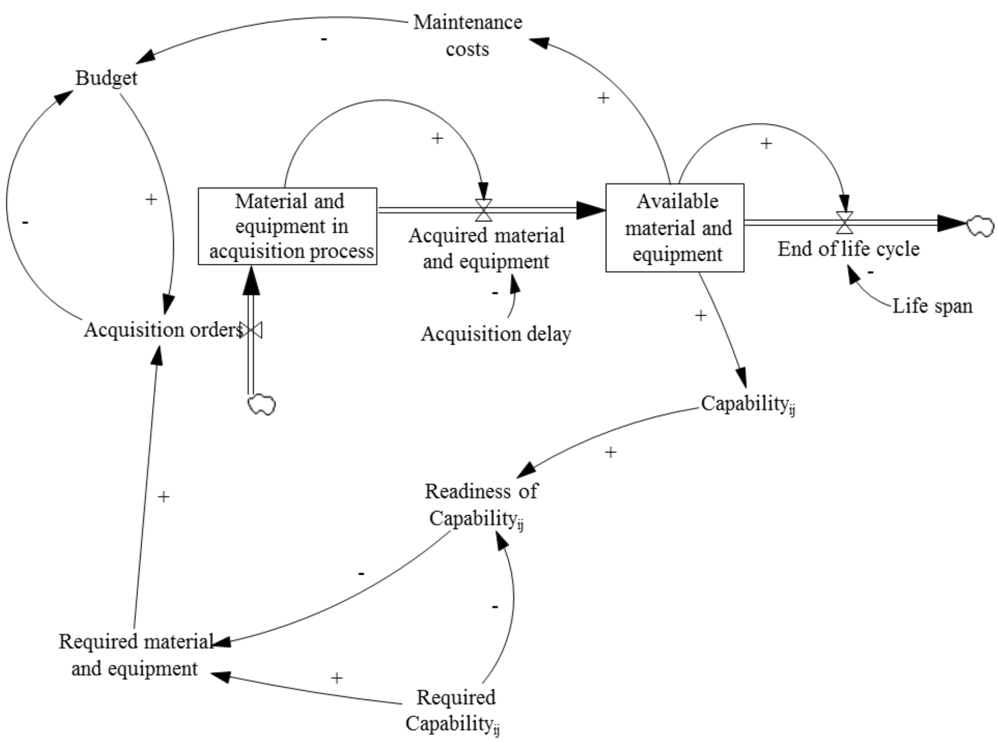

Figure 2 Schema of the Capability Engineering Model

The model in Figure 6 can be explained in the following manner: the Operational Concepts defined in the Capability-Based Planning methodology define the *Required Capability$_{ij}$*. The *Required Capability$_{ij}$* is the ideal level of Capability_{11}, while the actual value for this capability is characterized by variable *Capability$_{ij}$*. These two variables determine the *Readiness of Capability$_{ij}$*. The *Required Material and Equipment* is defined by the gap between *Required Capability$_{ij}$* and *Readiness of Capability$_{ij}$* (in the complete model, this variable would be classified by type of material and/or equipment and would be defined by the capability gaps that need that specific component). *Required material and equipment* then determines the amount of material and/or equipment acquisitions that are necessary, however, these acquisitions (*Acquisition Orders*) are limited by the available *Budget*. In turn, the *Budget* is affected by the *Acquisitions Orders* and *Maintenance Costs* (and any other actions that require expenditure). As it was explained in the previous section, there is a delay in the acquisition of material and equipment (*Material and equipment in acquisition process*); after this delay, acquired material and equipment become available for use (*Available material and equipment*). This material and equipment, however, have a life span that eventually decreases the amount of material and equipment available for use.

This model evidences a control feedback nature of the Capability-Based Planning Approach. In the schema shown in Figure 6, there is a control feedback structure that aims to close the gap between the required capability and the actual capability value by acquiring more material and equipment (see Figure 7). In the complete model, it is expected that this type of structure emerges for each of the capabilities and components included in the system.

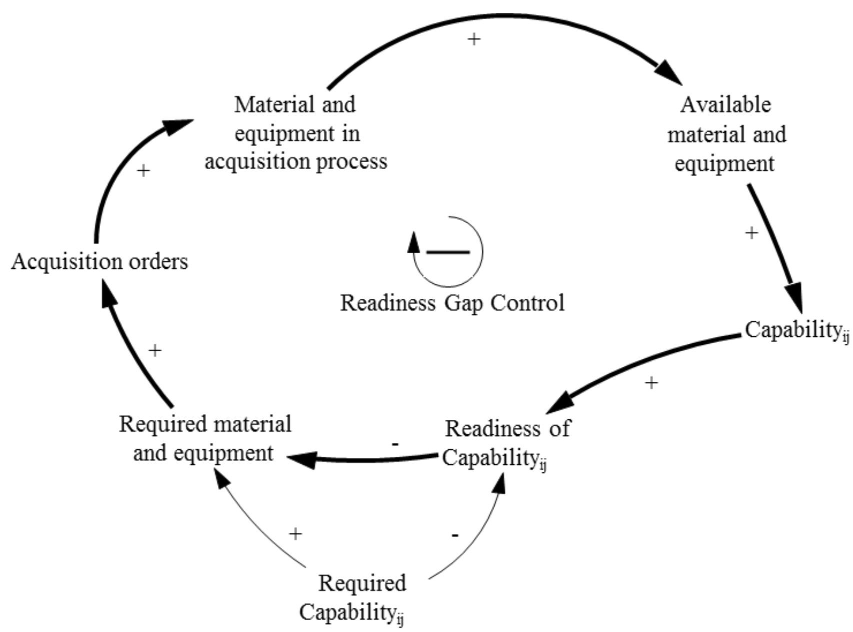

Figure 3 Readiness Gap Control Loop

In addition to the Readiness Gap Control loop, the Capability Engineering Model evidences four other control feedback structures: *Acquisition Delay Control* loop, *Life Span Delay Control*, *Acquisition Budget Control* loop and *Maintenance Budget Control* loop. These feedback structures are important to consider because they limit the effect of the *Readiness Gap Control* loop. On one hand, the delay loops prevent material and equipment from being instantly available (*Acquisition Delay Control* loop) as well as slowly decreases their availability (*Life Span Delay Control*). These loops evidence the gradual nature of acquisition and underline the importance of planning ahead and not only for the short term.

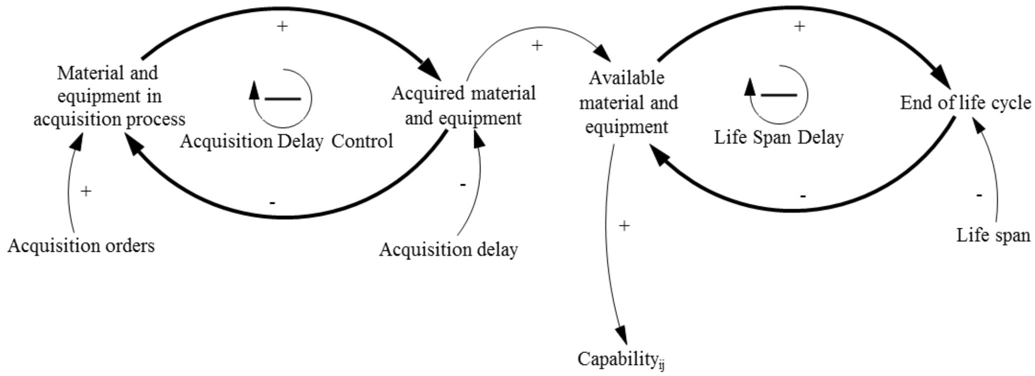

Figure 4 Delay Control Loops

On the other hand, the budget control loops limit acquisition capacity to budget availability. These structures are important because they determine the financial sustainability of the system; even if the system requires material and equipment, these cannot be acquired unless the system has the capacity to sustain it, including the maintenance costs. These structures are only examples of some of the feedback structures present in the system, other similar control feedback structures may be identified once the complete model is built.

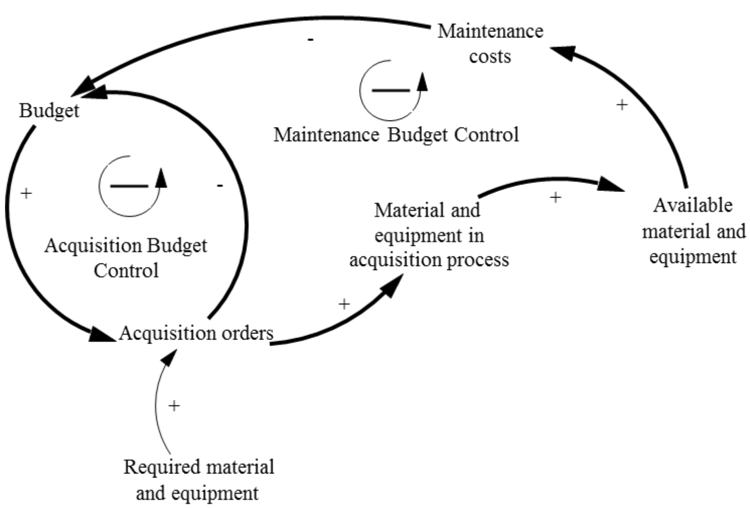

Figure 5 Budget Control Loops

Discussion

In this section, an initial conceptual design of the Capability Engineering Model has been presented. The a system under the Capability-Based Planning Approach by means of a stock and flow structure. The stock and flow structure allows decision makers to recognize the existence of accumulations that are altered by increase and decrease processes. Understanding the system in these terms allows the inclusion of delays involved in the process and evidences the gradual nature of acquisitions, construction, training etc; that is, acquisitions and recruitment for example, do not generate immediate increments in material and equipment, and personnel respectively. Furthermore, the stock and flow structure allows decision makers to understand how inflows and outflows interact to produce stocks. This last point is particularly important because it can lead to changes in decision making given that it is possible to experiment with different decisions and understand how stocks vary given they also have a decrease process.

In addition to the stock and flow structure, the model has allowed the identification of feedback processes. Feedback processes are key features that should be understood as they can determine behavior. For example, the Readiness Gap Control Loop aims to increase capability in response to its readiness; however, the delay control and budget control loops counteract this behavior by limiting acquisitions and delaying their availability or slowly decreasing the available Material and Equipment. In this paper only control feedback structures have been identified, however it is surely possible to find positive feedback structures in the system that can eventually contribute to the strengthening of capabilities and efficiency; these, for example, could be related with organizational effectiveness increase thanks to learning and adaptation to new capabilities. The model facilitates understanding the individual effects of each of these feedback structures as well as understanding the overall effect of the interaction among feedback loops and the stock and low structure.

As Morrison et al assert, “Controlled experimentation is rarely possible in social systems. Learning from our actions is complicated by the difficulty of gathering downstream information (e.g., about public sentiment towards the US), delays between cause and effect (e.g., what and when are the effects of distributing informational pamphlets?) and nonlinear response to our actions (e.g., what are the thresholds for tolerance of aggression?).” (Morrison, Goldsmith, & Siegel, 2008). The stock and flow model presented in this paper addresses this difficulty and allows decision makers to experiment and understand the systems response to distinct decisions.

However, in spite of the advantages that have been underlined, there are a series of limitations that should be considered. These limitations can be classified in two categories: scope and implementation wise.

<u>Scope</u>

The suggested model does not pretend to be a detailed representation of the system nor does it pretend to predict the reaction of the system under different circumstances. The model aims to conceptualize the system in such a way that it serves as a tool for decision making and in this way, it only includes the most pertinent aspects and decisions that serve this purpose. Moreover, the model is aimed to serve as a platform for experimentation so that it contributes to strategic planning and hence it pretends to challenge the mental models of decision makers and help them understand how the system operates and may react under different scenarios.

<u>Implementation</u>

It is still possible to find resistance in the implementation of System Dynamics models for planning procedures. System Dynamics models require a special effort in data gathering and it can become very challenging to quantify some of the variables included in the system (i.e. organizational effectiveness). There are, however, different methodologies that can be used to quantify this type of variables, including sensitivity analysis. Furthermore, it is difficult to quantify the benefits of using these models because their core utility lies in changing the mental models of decision makers and improving their understanding of the system.

In addition, public sector related institutions depend largely on the political environment. This means there can be continuity issues due to changes in the leadership of the institution. The development of the Capability Engineering Model requires long term continuity in order for it to be successful. It also requires that the actors involved in decision making are trained in systemic thinking and recognize its importance, however, this becomes resisted by "senior leaders who are overscheduled and uneducated in systems thinking" (Reed, 2006).

The development of this model requires a high level of compromise from the leadership of the institution, however, this is often difficult as seen in what Col. George E. Reed calls the "Busyness problem": we are so "Immersed in the myriad details of daily existence, it is easy to lose sight of the bigger picture (…) the urgent often displaces the important." (Reed, 2006). This can be evidenced by "leaders who unrealistically demand simplicity and certainty in a complex and uncertain environment" (Reed, 2006).

IV. Outlook

In this paper, an initial conceptualization of an Engineering Capability Model has been presented and discussed. Under this perspective, capabilities are understood as systems of systems that can be examined and redesigned with the use of a simulation platform for experimentation. There is still work to be developed in this direction. First, it is necessary to develop a capability readiness measure in order to evaluate and compare capabilities.

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