A SYSTEM DYNAMIC APPROACH FOR RETURN ON INVESTMENT CALCULATIONS

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Abstract

This paper presents a method and dynamic models for making improvements in a complex organisation. The dynamic models make it possible to simulate and understand the consequences of different improvement alternatives. The challenge has been to understand how relations between technical, organisational and people capability together defines the overall defence power over time. The breakthrough in this methodology work has been to view and model the defence system as a production process. With System Dynamics, the dynamic behaviour over time of the defence system has been better understood and the major constraints have been detected. The paper describe the method and lessons learned from the work.

INTRODUCTION

The Swedish Defence Material Administration makes continuous procurements for the air-based defence system to systematically improve the defence ´power´. The defence system is very complex and consist of technical equipment (sensors, information systems, weapon system etc.) and people with different roles interplaying according to well defined procedures and processes.

The method is aimed at supporting annual budget discussions with responsible for the different subsystems. A limited budget is to be spent only on those subsystems that limit the overall defence power, thus leading to an increase in capacity for the system as a whole. With a well defined method to visualise the consequences of alternative improvement scenarios, the budget discussions will be more effective and focused on the core issues. The method will produce a better understanding and consensus among the participants in the budget process.

The goal with the performed work has been to define methods and dynamic models to support the procurement process and to balance and optimise the defence system. The challenge has been to understand how relations between technical, organisational and people capability together defines the overall defence power over time. Dynamic effects like increased learning and experience and consumption of resources have been analysed and captured to understand the bottlenecks over time for different scenarios.

The paper will describe the approach and the general methodology. Lessons learned from the modelling work and recommendations for others based on our experience will also be reported.

A SYSTEM DYNAMIC APPROACH

The breakthrough in this methodology work has been to view the defence system as a production process, producing results per time unit. With this view, we can identify the major constraint in the production process. The constraint is what limit the overall capacity and is the place to improve capacity. No other improvements will lead to an increase in overall capacity and is thus a short-term waste of money in that sense. System dynamics is the major tool in the methodology to:

- Understand and reveal the dynamic characteristics of the system as a whole by finding the major reinforcing and balancing loops [1] and how they are related to each other.
- Identify the major constraint in the system. With a model in ithink [2] and the possibility to load the system with different scenarios gives a good understanding where potential constraints are located and if the constraint is of technical, organisational or people nature.
- Understand the consequences of alternative improvement scenarios aimed at an overall increase in defence power. These scenarios also provides an understanding of how the major constraint will "move" around in the system due to increase in capacity in the right subsystems.

THE METHOD

A method to support the procurement process has been defined that consist of the following steps:

1. Make a definition of defence power.
2. Define the need of different models
3. Make the dynamics models according to existing modelling methodology
4. Identify and understand the major constraints in the system
5. Remove the major constraint, go step 4.

MAKE A DEFINITION OF DECENCE POWER.

A lot of work has been spent on finding a good definition of what defence power actually is, and to translate this to what the production process produces. It is essential to have a good definition on this. All balancing and optimisation is directed to increase defence power according to the made definition. We found that defence power must be defined as a weigthed relation between different dimensions like capacity, persistence and start-up time.

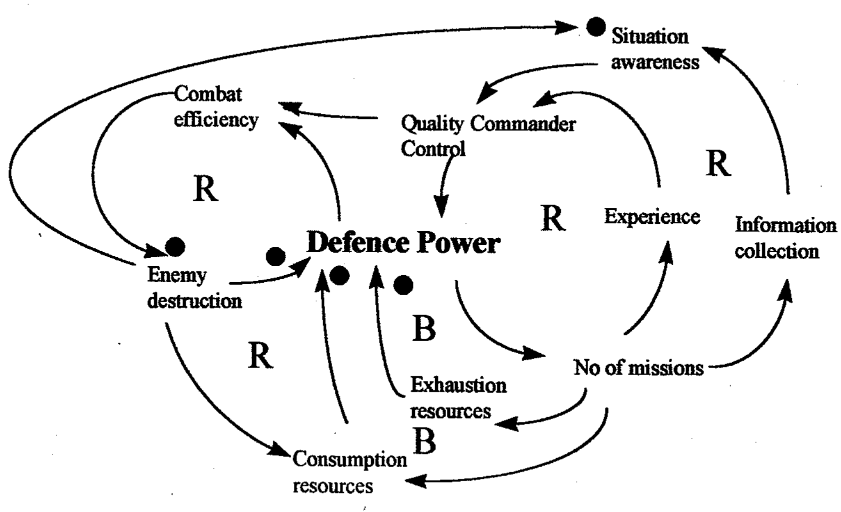
DEFINE THE NEED OF DIFFERENT MODELS

The different dimensions of the defence power definition have lead to different models in ithink focusing on that particular dimension. It is not wise to try to capture all dimensions in the same model. A specific dimension of the defence power requires detailed modelling in certain parts while other can be generalised or omitted totally.

MAKE THE DYNAMICS MODELS ACCORDING TO EXISTING MODELLING METHODOLOGY

The modelling methodolgy is rather straight-forward and contains the following steps:

1. Define the purpose of the model. In this context, it means that we must understand a specific dimension of defence power under specified assumptions.
2. Reveal the reinforcing (R) loops and the balancing (B) loops in the system to capture the overall dynamic behaviour. The figure below is a generalised loop diagram over the system showing components in the system that improve over time (learning, experience, situation awareness etc.) and components that deteriorate over time (consumption and exhaustion of resources and material, enemy leakage etc.).



3. Establish the structure of the model and define where components from the loop diagram should be located. Translate the loop diagram to stocks and flows and identify all main chains in the model.
4. Detail the modelling work and complete the model. Focus is on relations instead of details and to capture patterns of behaviour instead of flow of events.
5. Verify the model and iterate if necessary. It is essential to find the "right" abstraction level that is simple enough to understand but detailed enough to build trust among the future users that the model actually describe their reality.

IDENTIFY AND UNDERSTAND THE MAJOR CONSTRAINTS IN THE SYSTEM

The major constraints in the system have to some extent been understood already during the modelling work due to all discussions and iterations. These discussions in groups are the major source of learning and understanding. By simulating the models and study queues and stocks a more detailed understanding is achieved. Feedback loops and connections in the model can however give false impression of where the constraint actually is. By elaborating in the model with changed capacities for the different parts in the system, the major constraints are identified.

REMOVE THE MAJOR CONSTRAINT, GO STEP 4.

Alternative solution scenarios can now be tested in the model to understand how to increase the defence power. It is recommended to not only look for short-term fixes but to identify long-term investment scenarios for how to step-wise increases the overall capacity in a controlled way. These simulations will probably result in a need of a more detailed modelling activity to explore the constraint to be able to translate the modelling results to action plans. Perhaps already existing simulation models can be used for that purpose.

LESSONS LEARNED

Initially we want to point out that all involved in this work have fully supported the ambition to understand behaviour over time for the system as a whole. Previous simulation models have mostly been focused on understanding a certain part of the system to better be able to optimise that part. Therefore we have had good support for doing this work, even if some people have doubted the possibility to grasp this big and complex system in a few models. In a large organisation like this, a lot of local terminology will evolve over time and many of the problems in capturing the whole system are due to a lack of common language and understanding. We have found that the model represents a "neutral" arena to discuss on leading to a more unified terminology. The process of defining and verifying the model have lead to increased understanding among the different groups and discussions have been much more focused. It is a very efficient process to pinpoint what parts of the system that need to be understood much better in deeper discussions and what parts that all agree on. To make a computer-based model that requires quantified relations between the model components forced all members to really understand and talk the same language to reach consensus. These discussions is the major source of learning during the modelling process.

The modelling method also requires that the modelling team members understand the overall behaviour, relations and patterns for the system as a whole. Initially the team discussions were very much focused on details and events but after a while we started to see and understand the behaviour on a higher level. This process is painful and hard because you leave the comfortable stimuli-response, detailed view and static world to move "up" to a loop view and dynamic world. And when you are there, you don't want to return! A permanent change in attitude happened for the modelling team over time. This lead to sometimes frustrating discussions in the verification meetings with people that hadn't gone through this process - we didn't speak the same language or had the same mental reference model.

Another experience is that a work like this consist of two different phases that are totally different in nature. The first one is to build a model in a group that the group can agree on. The second phase is to "sell" the model and the results from the model work to those that haven't participated in the model work. We did not fully realise the value of being member of the modelling team with all discussions and increased learning and understanding. There were so much new insight and undocumented knowledge within the team that we sometime had problems to handle all the comments from participants in the verification meetings. It is difficult for the "part" experts to give good comments on the model. They can only give comments on their part of the system, and often they found it too simplified. With that feeling in mind, they had sometimes problems to rely on the rest of the model.

Recommendations based on our lessons learned are:

- Allocate enough time to define a clear purpose for the modelling work. If the detailed modelling starts without a purpose of the model, you will end up with a too detailed model of the full reality. With a purpose, a number of mechanisms and concepts can be omitted or abstracted. Begin with very simple models to capture the dynamic behaviour instead of trying to model the "real" world. Use the standard building blocks of supply-chains and understand what is actually produced in the system.

- Involve more people up front to ensure buy-in of the results. You cannot isolate an expert team to make a model and expect that all other will buy all insights and results based on some presentations. The learning and understanding is achieved during the model work and the process that ends up with a final model. This cannot be spread with a number of presentations. Ensure an understanding of system and loop thinking so team members have a common mental reference model.
- Realise that the models themselves are not the most important result of the work. Plan for how the increased learning and understanding is to be maintained and supported after the modelling process. Pay special attention to the permanent change in attitude to those who have participated in the work.

Finally we want to thank all people that have been involved in this work. Without all your comments and discussions, we hadn't been able to get that level of understanding of the system as a whole.

REFERENCES

[1]: *Peter Senge*: 5th discipline.

[2]: *High Performance Systems Inc.*: Ithink manuals, version 4.0.