UPTEC STS10025
Examensarbete 30 hp
December 2009

# Simulation as a means of providing input to the CSMT

Frida Harrysson

UPPSALA UNIVERSITET

**Teknisk- naturvetenskaplig fakultet**
**UTH-enheten**

Besöksadress:
Ångströmlaboratoriet
Lägerhyddsvägen 1
Hus 4, Plan 0

Postadress:
Box 536
751 21 Uppsala

Telefon:
018 – 471 30 03

Telefax:
018 – 471 30 00

Hemsida:
http://www.teknat.uu.se/student

# Abstract

## Simulation as a means of providing input to the CSMT

*Frida Harrysson*

The Collaborative Synchronization Management Tool (CSMT) is an analysis tool that enables morphological and statistical analysis of plans. Input to the CSMT consists of a Cross Impact Matrix (CIM) where the relationships between the different activities of a plan are reflected as its values. This thesis proposes Modeling and Simulation as an alternative method of generating the CIM-values. The usage of this method will hopefully increase traceability and limit subjectivity, and it will also be less time-consuming. Determining the level of detail of the models was shown to be a challenge, as well as finding a suitable case scenario to validate the generation method more thoroughly. The results have provided positive indicators to the usefulness of the generation method of input to the CSMT but the evaluation remains somewhat inconclusive.

Handledare: Farshad Moradi
Ämnesgranskare: Kjartan Halvorsen
Examinator: Elisabet Andresdottir
ISSN: 1650-8319, UPTEC STS10025

# Populärvetenskaplig beskrivning

Analysverktyget Collaborative Synchronization Management Tool (CSMT) används för att genomföra morfologiska och statistiska analyser av militära planer på operativ nivå. Indata till CSMT består av en så kallad cross-impactmatris (CIM) – en matris där förhållanden mellan de olika aktiviteterna i en plan åskådliggörs i form av matrisens värden. På detta sätt kan exempelvis svagheter i en plan identifieras. Detta examensarbete undersöker möjligheten, och värdet av, att använda modellering och simulering som en alternativ genereringsmetod av CIM-värden. Hypotesen är att då en aktivitet genomförs så förändras simuleringstillståndet och därmed även förutsättningarna för övriga aktiviteter i planen som ännu ej genomförts. Simuleringstillståndet består av alla aktörers och miljöobjekts tillstånd. Tillståndet hos aktörer och miljöobjekt beskrivs med hjälp av deras parametervärden.

För att simulera planerna, och på så sätt även utvärdera de framtagna modellerna över aktiviteter och aktörer, utvecklas ett program där en användare kan sätta samman en plan för simulering. En huvudidé är att försöka fånga in påverkan av komplexa och dynamiska beteenden på ett enkelt sätt, vilket bland annat resulterat i skapandet av en relationsdatabas där förhållanden mellan aktörer kartläggs samt att förändringrar hos aktörer designats som mer kontextberoende.

Fördel med den redovisade metoden är att generering av indata till CSMT är väsentligt mindre tidskrävande när modellerna väl är byggda jämfört med manuell hantering. Därtill ökar genereringsmetoden spårbarheten i resultaten och begränsar subjektiviteten gentemot manuell hantering av indata.

## Acknowledgments

I would first and foremost like to thank Dr. Farshad Moradi, my thesis advisor at FOI, for helping me with everything from general connections to more explicit modeling details. He has functioned as a sounding board throughout the whole modeling phase and thesis process. I would also like to thank Eric Sjöberg and Jan Röjerdal for contributing with knowledge and information regarding the Bogaland scenario and its actors. Last but not least I would like to thank Kjartan Halvorsen, my academic advisor at Uppsala University, for his constructive and useful input and comments.

## Table of contents

# List of tables

# List of figures

# 1. Introduction

## 1.1 Field introduction

A world in rapid transition often brings about fascinating developments that were inconceivable just a short period of time ago, resulting in both positive and negative consequences and challenges. Structures that have been founded and constructed in a world that sometimes is significantly different from the world of today can result in a mismatch between modern needs and existing structures – structures more static than the dynamic surrounding in which they exist. This is true also when it comes to military operations and society's needs. The threats of modern day society call for different methods than the ones traditionally used. "Symmetric" warfare is replaced with "asymmetric" warfare and predictable actors in predictable scenarios are now a lot more irregular and unpredictable, both in characteristics as well as in actions. Thus the problems we face are a lot more complex and multifaceted than they have ever been before. Today's needed military efforts might not even have been considered "military" at all in a traditional sense, but can involve international efforts dealing with crisis management such as famine or an epidemic outbreak. New contexts create the room and the need for new methods and approaches, which is something that is becoming more and more visible.

To increase the capability of dealing with these new and complex needs an *Effects-Based Approach to Operations* (EBAO) has of late gained increased interest and support within the military sphere. EBAO is a concept in which alternative methods are used when solving problems. A solution does not necessarily have to be a military operation in the traditional sense but can be for example of a more political, social, or economical kind. One of the key points is maintaining a holistic view of the whole scenario and its included phases, and not put all focus on the individual operation. Ability to cooperate with actors on several different levels also reflects the usefulness of the approach in the management of multi-dimensional problems. Effects that are outside the scope of the immediate operation are also included and hence it is a more comprehensive approximation of effects that is taken into consideration when evaluating different plans in different scenarios. This can be of great importance since many operations now take place on an international level and effects might be carried out in ways that are not intuitive and in places that you would not expect.

The project *Real-time Simulation Supporting Effects-Based Planning* (RSEBP) is conducted at *Totalförsvarets Forskningsinstitut* (FOI) and as the title indicates *Effects-Based Planning* (EBP) is supported by a decision support tool that is under development. Another part of the project is the analysis tool *Collaborative Synchronization Management Tool* (CSMT) through which morphological analysis is enabled – a technique that is developed for dealing with just these complex and multi-layered situations that have already been mentioned. The input data to CSMT consists of a so called *Cross Impact Matrix* (CIM) where impacts between the different objects of a plan are listed. The values of the CIM-entries have been assigned by expert groups through an EBP planning process. In explanation, the values of a CIM represent the effects that the different EBAO-objects in a plan have on each other in the form of a numerical value and also reflects the direction of the impact: if it is negative or positive.

## 1.2 Problem definition

Traceability means that you can "trace" for example a scientific work process step by step, from initiation to end results and vice versa. This enables the evaluation of made decisions and assumptions which is important for the validity of an experiment since traceability make reproducing experiments possible. The expert generation method poses traceability issues since its work process is carried out in a way that does not facilitate reproduction: discussion and also an absence of a more formal structure. It is also known that different people carry different mental models of different phenomena which introduces a potential problem with consistency and validation, and hence it would be desirable that these subjective approximations are replaced with more consistent ones, whose accuracy can be evaluated in a more direct and objective manner. An underlying assumption is that *Modeling and Simulation* (M&S) can facilitate EBP by creating a deeper and more comprehensive understanding of the relationships between activities, and hence modeling and simulation creates a new alternative to the generation of CIM-entries. While the current method can pose those problems, the proposed alternate method does not (or at least not to the same extent) which is one of its most important advantages. The method would also be less time-consuming which also further encourages its use.

In short, the proposed method of CIM generation would involve the modeling of a scenario and then simulating a scenario plan to identify and measure the effects between activities.

## 1.3 Thesis purpose

The purpose of the study is to investigate the possibility of generating input data to the CSMT through simulation models characterized by simplicity. Input data should be generated in the form of a CIM where the CIM consists of values representing effects that in turn reflect the relationships between activities. If findings indicate that this is indeed possible the advantages and disadvantages of the proposed method should be evaluated. Detecting and identifying any potential bottlenecks or pitfalls thus also constitutes an important part of the study since those could also affect the evaluation of the generation method. The objectives stated above can be condensed into the following questions:

- Is it possible to generate a CIM through M&S?
- How simple can the models be made without losing too much result accuracy?
- What is the assessment of the generation method?

## 1.4 Methodology and material

*Choice of theory*
Because of the study's very experimental nature I have not evaluated the posed thesis problems from a particular theoretical standpoint but instead, to increase my understanding of model building and simulation, I have studied literature discussing those processes. The theories have not been put to test but I have instead used the information obtained as guidance throughout the process.

*Information gathering*
The case scenario used in this study is a part of the fictitious Bogaland scenario and since I was interested in obtaining a deeper understanding of Bogaland, and also about military operations in general I met with military and Bogaland scenario experts. Apart from contributing more case specific information they also helped in setting up a case scenario and plan suiting the purpose of the study.

*Work process*
The course of action has been a recursive as well as an iterative process in which results have been evaluated after generation and then I have gone back to some previous process step to

perform suitable adjustments. The process can be divided into five general steps briefly presented below:

1) Literature studying. Literature that deals with modeling and simulation was studied.
2) Model building. Scalability is essential, meaning that models have to be designed in a way that allows expansion so that handling of larger scenarios and similar are made possible without any loss of performance. The steps of model building are described in more detail in section 3.2
3) Programming. The user needs a GUI that is user friendly i.e. a variety of specifications are needed so that no confusion or misunderstandings arise from unclear wording. Of course the program also needs to be designed and built in a way that allows re-usability of models as well as facilitating scalability. The steps of creating a simulation program are described in more detail in section 3.2.4
4) Perform simulation
5) Evaluate and trace results. If results are not satisfactory are there any adjustments that can be tried out? Tracing the results will hopefully provide us with information of where to carry out the adjustments. Are the models too general and do not give us enough information? Are the numerical input data generated satisfactory but the models are too complex? Is there anything I can do to simplify them?

*Source evaluation*
Although this method of input data generation was introduced to get around a problem of subjective estimations it should be noted that not all subjectivity can be removed completely since the modeler will still have his or her own mental model of scenarios and processes. But it can be more controlled and the input data are more consistent than before since models can be evaluated and their results are traceable.

*Assumptions*
Throughout the course of this study I have made several assumptions and simplifications to follow the purpose of the study and to move on with my work. These assumptions (that mostly have to do with the model building) are accounted for and described continuously throughout the text where it is relevant and will not be gathered and presented together in a separate section. I have chosen this method of presentation since the assumptions made probably gain a maximal understanding from the reader when presented in its correct context than on its own.

## 1.5 Thesis delimitation

Since one important aim is to keep the models as simple as possible without losing functionality any stochastic variables or processes have been excluded from the model design. Introducing randomness would open up a whole different kind of thinking, designing and simulating which might be more realistic but also more complex and time-consuming which is not in accordance with the thesis' purpose. The aim for simplicity and low "cost" also means that the results and models do not have to be the most exact ones possible; they just have to be exact enough. The simplicity objective also excluded actor parameters that otherwise would have been important to include, such as *action repertoire* (the different types of actions that an actor is said to be able to perform) and *agenda* (an actor's more short term plan which influences how the actor will act next). These attributes were excluded since actors in this study do not have the ability to respond to activities. Such a behavior will be captured in an alternate fashion instead.

We are not trying to evaluate which order of execution of the activities would be most efficient, but rather trying to determine the relationships between the activities. This in turn leads to the assumption that the outcome of all the activities that are executed can be seen as successful, i.e. they succeed in their mission. The aim of unveiling the relationships of the activities and the aim of simplicity lead to the case scenario being constructed in a rather simple fashion. Decisive Conditions (DC) and Military End State (MES), both further described in section 2.1.2 , were omitted from both the case and hence also the models and simulation. This was done since they were thought to be too complex to fit this thesis' purpose.

I do not intend to evaluate the methods used in the RSEBP-project, for example morphological analysis, since that is outside the scope of this thesis and also outside my knowledge area.

## 1.6 Disposition

In chapter 2 the reader is given both a theoretical background as well as a project background. The process of model design and also structuring the program is then described in chapter 3. Chapter 4 discusses the case scenario the results and findings are presented in chapter 5 and then discussed further in chapter 6. Finally, the conclusions are presented in chapter 7.

# 2. Background and theory

## 2.1 Project background

### 2.1.1 Real-time Simulation Supporting Effects-Based Planning

To support EBP (explained further in the following section) a decision support tool has been developed to enable the decision-makers to test a number of possible plans against different possible event developments. Conclusions regarding what plans best fulfill the desired end state, and at what cost this will be achieved at, are then drawn. Additionally, you also want to evaluate the plan before its execution, not only in terms of the desired end state, but also to uncover and detect any potential weaknesses and to get an understanding for the effects of the plan in a more large scale perspective. Within the scope of the project an operations analytical tool, CSMT, has also been developed – a tool used for analyzing plans using morphological analysis. (Schubert et al., 2008)

The project RSEBP's main focus is the application of EBP within an EBAO, and will investigate how M&S can be used in a decision support tool that supports EBP. The project can be divided into three directions; "the development of a decision support that supports planning and re-planning through simulations", "the simulation of aspects of the EBAO-process to enable planning through war-gaming", and finally "the further development of the analysis tool CSMT". It is in the last of these three directions that this thesis is based. (Schubert et al., 2008)

#### 2.1.1.1 Effects-Based Approach to Operations and Effects-Based Planning

Definition of EBAO according to US Joint Forces Command reads as follows:

> *"Operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims."* (Carlsen et al., 2006)

Before deciding and defining the goals and how to achieve them EBAO emphasizes the importance of analyzing and defining the effects you want to achieve. Thus, traditional military operations involving guns and similar often turn out not to be the means chosen since they often can affect civilian populations in a negative way. Their response can also in turn create new problems that need to be solved. (Schubert et al., 2008) A selection of key points to the way of thinking within an EBAO can be presented in the following fashion:

- Focus on effects instead of actions
- Emphasis on the need to take a holistic approach to the different phases of a conflict
- Emphasis on the importance of creating and communicating and understanding of the situation of conflict in full

(Carlsen et al., 2006)

### 2.1.2 Collaborative Synchronization Management Tool

The usage of the analysis tool CSMT enables morphological and statistical analysis of plans. Values are assigned to a so called Cross Impact Matrix (CIM) where impact relationships between the different EBAO-objects (the constituents of a plan) are illustrated. EBAO-objects are the components that make up a plan and examples are *activities*, *supporting effects* (SE), and *decisive conditions* (DC). The activities are the components that are actually carried out physically (by "our own" actors) while SE and DC are defined on higher levels and should be viewed as measurable (and often desired) consequences or states that results from the activities' executions. Activities can only be affected by other activities but can also affect SE, whereas SE can only affect other SE and also DC. The DC can finally affect other DC and it can also affect the MES (the set of effects that you want to achieve ultimately). Thus, the three EBAO-objects presented can be seen as different levels that need to be achieved before hopefully finally reaching the desired MES. (Schubert et al., 2008) Amongst the EBAO-objects there is, as described previously, a structure of how the objects can impact each other. This structure is visualized in the following figure:

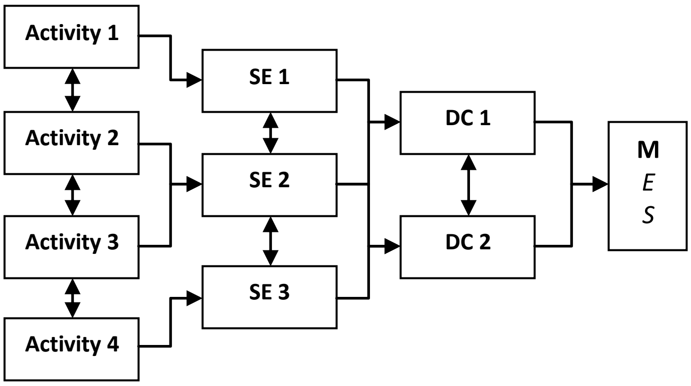



*Figure 1 - Structure of impact connections between EBAO-objects*

Here the arrows of direction show that effects can only occur between objects on the same level or one level "above".

After the CIM is filled with values representing the activities' relationships, the CSMT can be used via its graphical user interface (GUI) to look at several possible numerical analyses that can be carried out such as stability and consistency. The effects eventually propagate to an effect on the MES which can be visualized in different ways. (Schubert et al., 2007)

#### 2.1.2.1 Morphological analysis

Morphological analysis (MA) is a technique used to deal with complex, multi-dimensional, and non-quantifiable problems that are not possible (or very difficult) to solve using traditional causal modeling and simulation. Socio-political dimensions as well as conscious self-reference are some aspects that make factors non-quantifiable and hence the difficulty with using causal modeling and simulation. The difficulty also stems from uncertainties in such a problem basically being non-reducible making the uncertainties very hard, or even impossible, to describe completely. Tracing the process leading up to the drawn conclusions can also constitute a problem that adds to the complexity since the traceability issue poses a scientific problem in terms of challenges reproducing the experiment. MA relies instead on judgmental processes and internal consistency, and the idea is that out of a complex, multi-dimensional whole you can reduce it down to non-quantifiable variables which in turn can be put together into well-defined relationships or configurations representing "solution spaces".

By using MA structures of included objects are created and the internal properties of the problem are investigated. (Ritchey, 1998) In this project MA can be used to identify some events which are then developed into scenarios where condition demands, effects, and activities in different stages of the event can be identified. The process results in a hypothetical model forming the basis for scenario based discussions, discussions around questions like “Are the demand profiles accurate?” “What cooperation is needed?”, “Who are the recipients of prognosis?” Hopefully the discussion of these questions will lead to the participants answering the larger question at hand; “to what degree can this analysis of the course of events be considered accurate?” (Schubert et al., 2008)

#### 2.1.2.2 Cross Impact Matrix

The CIM has up until now been filled with the values resulting from the EBP planning process in which a group of experts have reasoned their way to the values of impact. However, as described in section 1.2, the purpose of this thesis is to instead generate these CIM-entries through simulation. Each row corresponds to an EBAO-object and its impacts on the other EBAO-objects (listed column by column) in the plan. The assigned impacts can be integers between -9 and 9. -9 indicates that the affected EBAO-object is made impossible to execute or achieve, 9 corresponds to a guaranteed occurrence of the affected EBAO-object, and 0 that the two EBAO-objects are independent. (Schubert et al., 2008)

## 2.2 Theoretical background

### 2.2.1 Modeling and simulation

*Models*
According to the Swedish Encyclopedia a *model* is a representation of a phenomenon. Models are also theory-based; the exact form of the theory however is not always stated. (Stokes, 1998) Variables and relations describe the objects that in turn make up the model which represents the part of reality we are interested in. (Stokes, 1998) Humans create models in the aim of systemizing the surrounding world and our place in it. They are also important for the planning of our actions and for the prediction of the outcomes. As the word indicates, a *mental model* is the informal model that represents the way a person perceives and thinks about a phenomenon. Mental models, together with the purpose at hand, form the basis for any more formal model building in the future. (Holm, 2007)

S*tatic models* describe a system that is static at a given instant of time and assumed to be at a state of equilibrium (with no state changes). *Dynamic models* on the other hand can instead describe time-spread phenomena in a system, with the states of the objects changing over the course of time. How the state changes occur determines whether the model is *continuous*, with changes occurring continuously with time, or *discrete* – with state changes occurring at discrete points in time. An example of the former could be the temperature of water coming to a boil, and the latter a traffic light where changes (the light changing color) occur at specific (discrete) points in time. So called *event models* are well suited for situations where you are only interested in events, and hence state changes, that occur at discrete times. (Stokes, 1998), (Anon., 1996), (Holm, 2007)

Depending on how the model generates its response to input it can be labeled as *deterministic* or *stochastic* where the former means that one fixed law determines the output whereas in the latter some fixed probability distribution is determining the generated response. (Stokes, 1998) "*A programmed model is a concretized depiction of a mental model* or even: a programmed model is a model of the mental model." (Holm, 2007) This brings us to the phase of experimenting with the models in the aim of achieving for example a deeper understanding for its inner workings and behavior: the simulation phase.

*Simulation*

To determine and understand behavior and causal connections in a modeled phenomenon during a period of time, simulation can be used as a way of experimenting on the model. (Holm, 2007) During simulations the models are thus examined in an experimental way to find out more about characteristics, behaviors, properties, and causal relations during a certain time period. (Holm, 2007) It is also through the simulation that the accuracy of the models used is put to the test.

*Simulation models* are models where the answer to the posed problem is obtained through conducting experiments using the models and not through some more exact solution algorithm. (Stokes, 1998) A computerized model of simulation can ideally belong to one of three classes; closed (input data are only entered in the beginning), breakable (the simulation may be stopped and parameters reset), or interactive (no automatic decisions are made – active participation from the user is required). (Holm, 2007)

In event-driven simulations only the process events that are defined by the model are studied, not the participating model-processes as such. This is done by converting a process in the model to a description of its start and end events and the time that passes in between these events. During the course of the simulation the model events should be treated one at a time in temporal order. All events are sorted according to their start time in an event list to keep track of what event is next in turn. (Anon., 2008) Event driven simulation is also especially well suited to use when the events occur asymmetrically over time. (Holm, 2007)

*Verification and validation*

If the model behaves in the manner it was intended to behave the model is said to be *verified* which is achieved by correct and accurate instructions and programming, as an example. One mode of verification is "to hold some of the variables constant to determine whether the output changes in anticipated ways as other variables are changed."(Stokes, 1998) You could also use event-logging to try and capture any model and program errors for example. In short you could say that verification is the testing of the simulation program. (System Analysis Group, 1996)

To be confident that the model outputs agree with the reality they are intended to represent a process called *validation* is performed. The accuracy of the model is put to test. Sometimes the model's output can, for example, be compared with the output of an experiment conducted specifically for validation purposes. It should be stressed that a model can never be completely validated; only invalidated. (Stokes, 1998) Validation obviously constitutes an important step in a simulation project, since lack of it could lead to unreliable results. There are different kinds of validation:

- **Computer validation** aims at ensuring that the accuracy level of the input data is known. Poor input data will result in poor output data. If the accuracy of the input data is known the effect of the potential errors on the end result can be evaluated. The model itself can also be used to help determine the level of accuracy that input data needs to have for the output to fulfill some pre-stated demands

- **Hypothesis validation** refers to a control of the accuracy of the model assumptions. The correctness of system delimitations, level of detail, and the different model connections that have been assigned for example are controlled. Simulations can be performed using different models where different possible solutions and assumptions are tested. If this testing indicates significant differences between the experiments, a need for examining what assumptions to move further with is created. Comparing real data and model data is another method that can be used. An important method that can be used for this is sensitivity analysis.
- Since simulation is often used as the only possible alternative for studying the behavior of complex systems there are no analytical solutions available. Therefore it is not possible to analytically determine the effects that errors and uncertainties in input data and model parameters can have. More generally **sensitivity analysis** is:
    - Important for understanding the relationship between different entities within the model
    - The basis for determining to what extent the variability in the data and parameters entered into the model will affect the results.
    - Helps to examine model precision and point out where improved precision in the model description will have the greatest impact

  The sensitivity is proportional to the size of change of an entity, which may be the result of changes of parameters, initial values, or structural changes for example.

- **Result validation** means ensuring that all the other steps of the validation work have been properly conducted, and also determining if the initial goals have been achieved.

(Anon, 1996)

### 2.2.2 Systems analysis and process of procedure

The systems analytical project approach can be split into nine steps presented below:

1) Understanding the problem
2) Formulation of problem definitions
3) Modeling
4) Validation
5) Problem solving
6) Evaluation of results
7) Presentation of results
8) Implementation
9) Gathering of information

(Anon., 1996)

The steps are reasonably self-explanatory but I will further examine the modeling step in the section below.

*Model development*
When attempting to build and formulate a model one of the first steps consists of determining the structure and the parameters – a process called *model identification*. (Stokes, 1998) The

different sub-processes that make up the model are identified during the phase when the model is structured. The processes are only described roughly and the main point is to visualize their behavior more. (Anon., 1996) When building models we must take into consideration what level of abstraction we want the objects to have, and there is continuous balancing between too high a level of detail, which makes the model too complicated (both to create and understand), or a level of detail that is too low, making the model too general, which in turn makes it difficult to draw any useful conclusions from.

The abstraction level depends on what we want to use the model for. (Holm, 2007) The modeling process consists of two steps: first the modeler tries to understand and conceptualize the real system in the form of a mental model, and then he or she converts this model into a communicable *outer formal model* that is also shaped by the study’s purpose.(Anon., 1996) A summarization of how the shape and structure is determined is presented in the following figure:

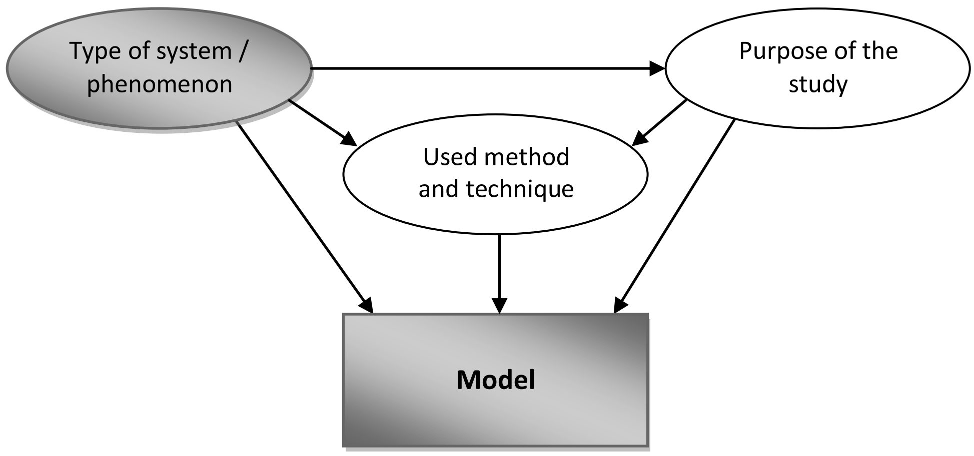



*Figure 2 - The impacts on a models structure and shape (Anon., 1996)*

When developing models it is common to determine the objects forming the basis of the model, objects whose exterior characteristics are known to a satisfactory degree, and presented below is a figure showing the connection between the phenomenon we are studying and the model: (Holm, 2007) (Anon., 1996)

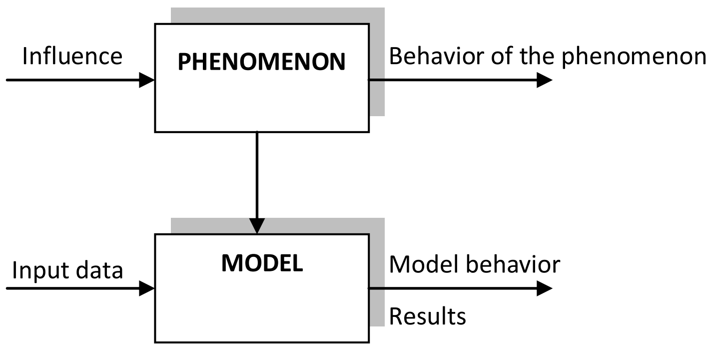



*Figure 3 - Connection between model and phenomenon (Anon., 1996)*

# 3. Model design and implementation

## 3.1 Theoretical foundation

Even though it was already part of the thesis description, modeling and simulation appears even more desirable as the choice of method since the scenario that is being examined and experimented with is fictitious. It also seems like a well-founded choice considering that the alternative method of CSMT input generation means traceability issues as well as introducing some consistency problems. Through using M&S it is easier to carry on a “discussion” around actors and activities for example, and it is also easier to go back and change their structures if needed. The latter problems arise since a lot of subjectivity is included in the estimated CIM-values because of the mental models of the experts. Inconsistency can thus pose problems with verification and emphasizes the need to conduct this study. It should however be kept in mind that mental models and subjectivity still can pose difficulties in this study as well because of the mental models of:

1. The creators of the scenario who all carry individual mental models of the scenario
2. The modeler, me, who has limited knowledge about military matters and hence has created a mental model of the scenario based solely on interpretations of the creators’ scenario
3. The potential users of this program will also carry their own mental models of the scenario and interpret the program according to that model

Point number 3 also illustrates and emphasizes the importance of the program instructions being precise and clear, so that the possible problems introduced by subjectivity in the form of mental models are eliminated as far as possible. Consequently control of potential impacts of mental models and subjectivity is one of the strongest incentives for using the generation method but also the possible implications are something to remain observant of. It should be noted that mental models are not negative in themselves, they make up the basis for all model building, but not being aware of the subjectivity (and its potential consequences) that they can introduce could be the cause of many issues.

The activities of the scenario are time-dependent with their effects occurring at specific points in time (for sequential activities this occurs after the execution has finished and they occur at certain points during the course of the activity for parallel activities) and thus the model of the scenario will be dynamic and discrete. The states of the objects participating in the plan make up the simulation state and the plan develops during a course of time. When the state changes do occur they are modeled to occur instantaneously and do not require any time to develop their full effect. All of this led to the choice of going with an event model since the execution of the different activities of the plan can be seen as events, and event models work especially well with changes that occur at discrete times. Since excluding all randomness constitutes a big part in the study’s purpose, a deterministic model, and also deterministic simulation are natural choices. Any stochastic variables, distributions, or similar would immediately make the program and models a lot more complex which would defeat the simplicity aim of the study.

The simplicity objective also places the simulation model in the closed class. The user is only given the possibility to give input data before starting the simulation (and not during the simulation) and the simulation will run its course once started. The simulation will also be event-driven since the state changes occur with uneven distributions over time due to the different characteristics of the activities, and also because the state changes occur at discrete points in time as previously mentioned.

## 3.2 Design process

The approach to model design has been a version of the systems analytical procedure presented in the previous chapter and in section 1.3. Since the problem definitions were pretty clear from the beginning I did not need to spend time on identifying the problem but instead focus on getting an understanding for the whole problem: everything from the background to the smallest entities. Presented below is a figure representing the creation process of a mental model and its conversion into a formal model that suits the purpose:

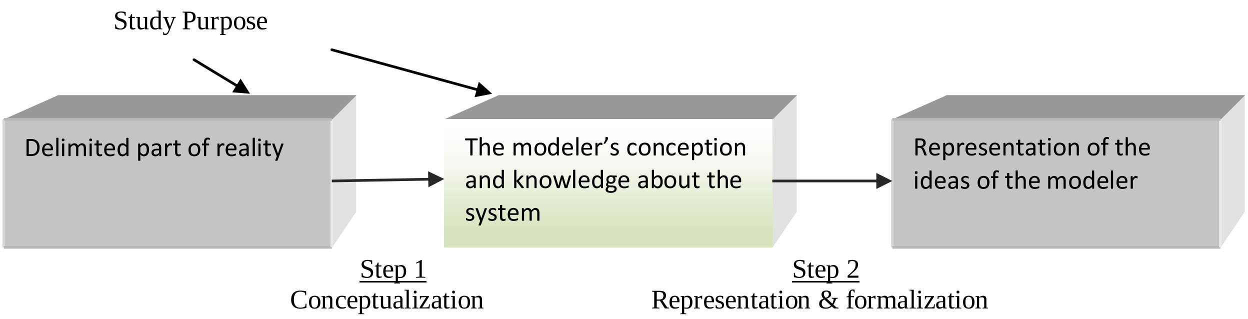



*Figure 4 - The creation process of a mental model (Anon., 1996)*

In step 1 I gathered information about scenarios: plans, activities, actors, et cetera to identify what elements were of importance and to form the knowledge base used in step 2 in which I formed a more concrete representation of all the elements. This was followed by the big challenge of determining what abstraction level was needed to maximize the usefulness of the results while still keeping the complexity level as low as possible. This challenge has been ongoing throughout the whole study and going back to re-evaluate previous choices has often been required.

The process of model building after a first formal model has been defined is described in the following figure:

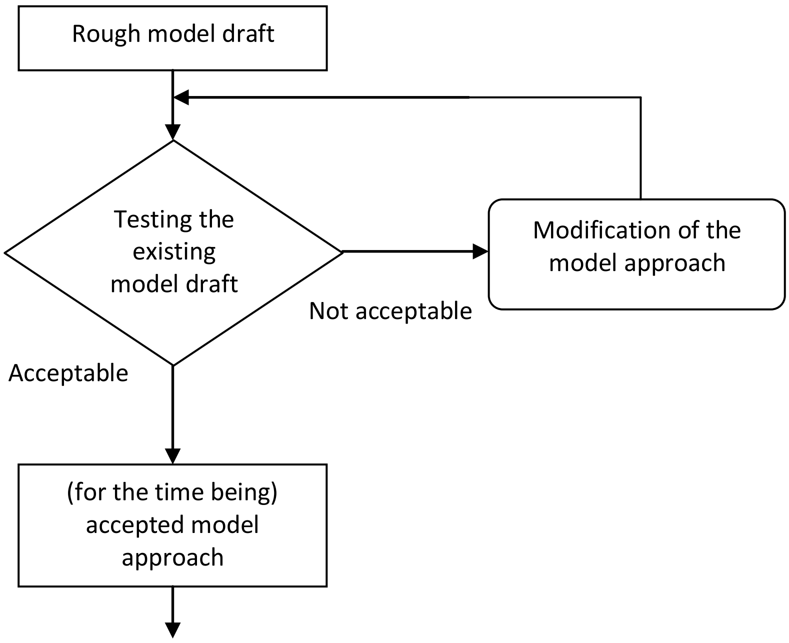



*Figure 5 - Model building. (Anon., 1996)*

The figure also illustrates some of the recursive and iterative aspects, and the process continues until a satisfactory model is reached. To evaluate the existing model verification was performed by holding some variables constant and verifying that the model then behaved in an anticipated fashion.

### 3.2.1 Modeling hypothesis

Concepts used within the EBAO involves *plans*, *activities*, *effects*, and *end state*. The plan, which is made up by a sequence of activities, should result in the desired effects: the end state. The environment in which the plan is set to take place includes different entities, for example *actors* and *environmental objects*, and it is the parameters that describe all these entities' states that together make up the *simulation state*. The simulation state makes up the conditions under which the activities will be executed. The execution of an activity brings on changes in the plan objects and hence also in the simulate state. This consequently alters the conditions for the following activities that are awaiting execution and hence the activities have *impacts* on other activities.

The discussed connections of impact during the course of a plan can be overviewed in the following figure:

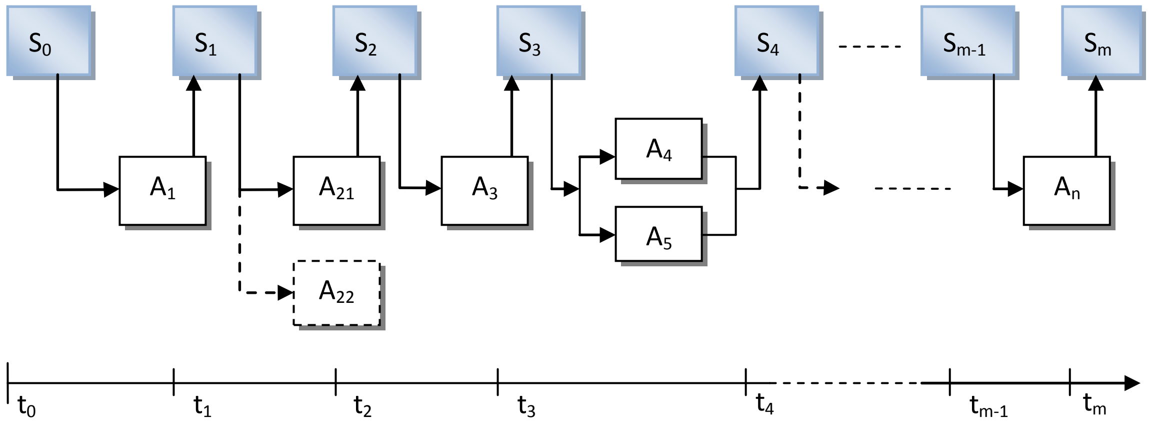



*Figure 6 - Simulation of activities $A_1$ through $A_n$ (Schubert et al., 2008)*

As shown in the figure, the activities (marked A) can have alternatives, see activity $A_{21}$; be parallel, see $A_4$ and $A_5$; or sequential as represented by the remaining activities. As previously stated these activities all have an effect on the objects present in the environment of the plan, leading up to the different simulation states (marked S). We can also see that these activities take place along a time line in a chronological order.

### 3.2.2 The simulation state

As previously described the simulation state consists of the states of all environmental objects and all actors. The simulation state will be updated between each activity, a choice made since it seems more realistic to let an activity start in a simulation state that has been affected by previously executed activities. The alternative would have been to reset the simulation state in between each activity and thus make each activity start from the same simulation state. It should however be noted that in the case of an activity not being allowed to be executed due to lack of resources, the lacking resource' values will be reset to adequate levels enabling the execution of the activity.

#### 3.2.2.1 The models

The environmental objects whose states together with the states of the actors make up the simulation state can be split into different categories, symbolic sites such as churches or other sites of value such as schools and hospitals for example.

Every activity can be described by a certain number of parameters, and one of the challenges is to decide what parameters should be included. We want to capture as much of the "reality" as possible without the activity model getting too complicated. No delays of activities are allowed. It could however be included in a future development of the application if the trade-off between output accuracy and model complexity is deemed to be worth it. The activity brings along with it a set of actors and environmental objects that will be directly affected by the activity. The activity's execution also has starting and ending points; both geographically and time wise.

The actors were parameterized based on a report previously written on the matter (Moradi et al., 2009) and the parameters were then modified to better suit the study. The simplicity aim excluded for example *action repertoire* (the different types of actions that an actor is said to be able to perform) and *agenda* (an actor's more short term plan which influences how the actor will act next) since actors in this study do not have the ability to respond to activities. Thus their agendas are not important either in the scope of this thesis. However, since the behavior of the actors in response to different activities still needs to be captured and included in the program I introduced attributes such as *state of mind* (e.g. content or angry). State of mind could for example serve as an indicator of how an actor will perceive, and react in, a given situation or context. The chosen attributes are briefly described in Appendix 1 and are listed in the following table:

| Arms strength | Logistic ability | Soft power | Intell-igence | Dis-satisfaction | Group dynamic | Clever-ness | Men | Finances | Size |
|---|---|---|---|---|---|---|---|---|---|

*Table 1 - Actor attributes*

Not all attributes are relevant and applicable for all actors, when this occurs a specified default value will be used. The attribute values can take on integer values between 0-3 which roughly corresponds to: *non-existent*, *low*, *medium*, and *high*.

Using the previous report as an initial template also simplified the later recursive and iterative work in assigning values, since it was easier to be consistent when I had a template to fall back on and to start from.

The SE can be fulfilled by the activities and is defined by stating the specific states (of actors and / or environmental objects) that it requires.

#### 3.2.2.2 Strength

I felt there was a need for a more general term to describe the actors' states other than looking at the attributes individually. To describe an actor's ability and capacity to successfully achieve their goals (whatever they might be) I introduced the variable "strength" which is dependent upon some attribute values that are assigned by the user as particularly important for the actor to achieve its goals. A weight describing to what degree the attribute is important to the actor is also assigned, this is done by using the grading scale 0 to 3. The strength can be described by the formula:

$$\frac{1}{n}\sum_{i=1}^{n} w_i * r_i$$

where *w* corresponds to the attribute's weight, *r* to the value of the attribute, and *n* is the number of attributes that are included in the aggregated value.

To visualize a possible assignment of attribute strength weights the following figure is introduced:

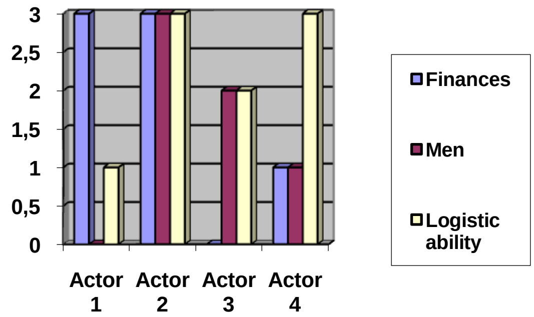



*Figure 7- Example of how strength weights can be assigned*

The attributes included in the figure are just an exemplification and all attributes are possible to include.

While it might be argued that you could manage without this variable I believe that using it fills a purpose since it is intuitive and easy to understand, and it also simplifies the user's work when assigning correlations in the relationship database since you do not have to go through the attributes one by one. The attributes that make up the basis for the strength variable can also be easily changed if found necessary by the user. It should be kept in mind that strength differs from other attributes since it is an aggregated value of other attributes.

#### 3.2.2.3 Relationships between actors

As previously mentioned we still want to capture the effects that a certain state change might have on actors even though they do not have their own action repertoires or agendas. The actors that are listed as involved actors are affected directly by the activity. However, to get a more comprehensive take on an activity's effect I also want to capture the effect on the other actors that are not directly involved in the activity (but still present in the plan). I have chosen to look at the relationships between actors in two different ways:

1) How will an actor A's increase or decrease in strength affect attributes in actor B?
2) How will the change in attribute x in actor A affect attributes in actor B?

This reasoning is visualized in the following figure:

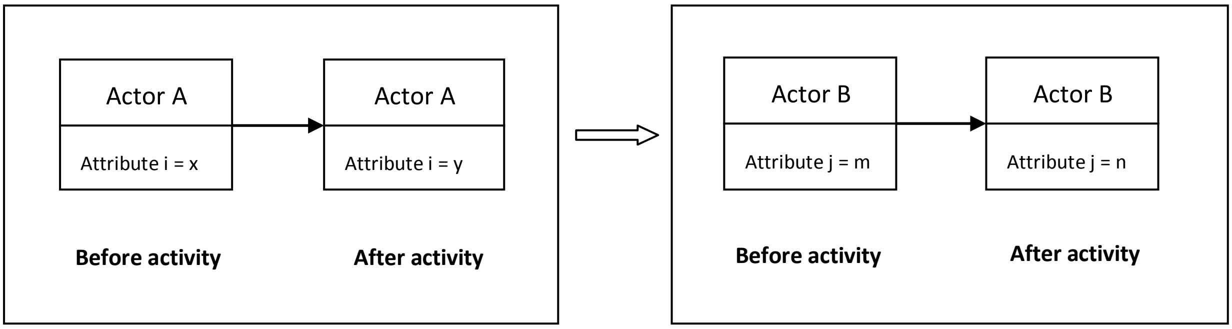



*Figure 8 - Actors' relationships*

It should be noted that while it is possible for impact to go directly from strength to attribute, the opposite is not true. This is due to the fact that *strength* is a kind of aggregated value made up of several different attribute values and if strength would just affect strength without affecting at least one of the values it is made up of we have introduced an inaccuracy into the model. Strength can thus only be affected indirectly.

To better capture the dynamic nature of the relationships the values collected from the relationship database are adapted to the context through for example letting an actor's status (described in the following section) determine the actual resulting effect.

#### 3.2.2.4 Enemies and allies

For every activity the actor is assigned a status representing whether the actor is an enemy (red), an ally (blue), neutral (green), or undecided (yellow). The color is important as it affects the expectations we can have of the different actors which in turn has a great impact on our ability to properly describe the behavior of different actors in different contexts. The current usage of color might not be very realistic since it could be argued that it is oversimplifying actors by saying that an actor could be red in one activity and then in the following it can be blue. It does not seem to capture an actor's actual behavior since it assumes that the actor is able to stand above its feelings and can switch color from one day to another for the sake of its purpose. But for a start we disregard this question and state that the color is "local" to the activity and begins and ends when the activity ends.

#### 3.2.2.5 Initial values

The assigning of initial values in a way that is easy for the user, realistic, and general for all types of data has been shown to be a challenge. At first all initial values were set to 1 to represent the notion that the troops are considered to be at a 100 % level (100 % level for that particular actor, not meaning that all actors are equally strong and/or have the same resources from the start) at the starting point of the simulation and it would also mean that it would be very intuitive to see if the value has increased or decreased as the simulation goes on. This showed to be somewhat inefficient since percentages have to be introduced leading to a more detailed level. Sometimes you want to know more about the initial state other than the fact that it is the initial state.

The idea presented by Farshad Moradi and Johan Schubert in the article *Modelling a Simulation-Based Decision Support System for Effects-Based Planning* (2009) is to assign the value with an integer 0, 1, 2, or 3 was embraced and tested instead. It should however be noted that if actor A has troop size = 3 this does not mean that it is the same actual size that actor B if actor B also has troop size = 3. It just means that they are numerically complete in comparison of their maximum size. This approach is possible since I consider the maximum numerical sizes of “home” troops as static, they cannot “grow”, and also since I have not introduced size as a variable for actors other than home troops. This was done since it would introduce unnecessary complexity since the numerical size of other actors actually can grow (due to for example an increased number of followers), and also since we are interested in unveiling effects and impacts and not describe it in exact numbers. The assigning of initial values is facilitated by the fact that we are interested in casting light over relationships between activities which means that it may not be the value per se that is interesting but the change that the value represents.

### 3.2.3 State changes

#### 3.2.3.1 Actor changes

The execution of an activity can result in state changes in the involved actors. Because of the aim of simplicity, changes can only assume value 0, 1, 2, or 3. At the same time I also want the model to cover as many scenarios as possible. This is why I will use a conditional approach when handling the assigned values of change and in what manner the change will actually be carried out. What this means is that depending on what attribute is changing and what value that attribute is changing from affects the actual change, i.e. an actor’s state of mind is neutral (0) it is easier to make the transition to happier (1) than it is to make the transition from happy (2) to ecstatic (3). You can also describe it as the step size of change is larger around zero but decreases the closer you get to the edges.

#### 3.2.3.2 Post activity

After the execution of an activity the troops and resources used will change status to available, consumed, or reduced capacity. The first two alternatives are represented by troop size and post-availability and the last one through changes obtained from the change in involved actors database. After the activity has been executed the post-availability values are collected and the new value is assigned depending on the actor’s troop size value pre-activity.

$$newValue = postAvailability * \frac{1}{3} * value_{pre-activity}$$

#### 3.2.3.3 Primary effects

It is important to keep in mind that the impacts you assign as results of the various activities are dependent on whether you choose to view the simulation world (and what is going on inside it) from the individual actor’s view, or if you choose a more objective perspective. In this study the former approach is applied which impacts the changes in involved actors always should be assigned with that perspective in mind.

#### 3.2.3.4 Secondary effects

Since all actors that are not own troops are modeled not to have their own repertoires another challenge arises: the capturing of other actors’ responses to changes in the simulation state. To capture this it has been important to map out the relationships between the actors and to try to decide how a change in one actor's attribute can affect attributes in other actors. Possible cascade effects should be caught. There is however a risk of getting caught in the eternity loop of changes that continuously generate other changes et cetera. To avoid this I have made the decision to only consider "first round" secondary effects and then stop the loop. It should however be noted that effects of a secondary effect for a specific actor can be included in the relationship by putting a direct correlation between the change and the attribute.

The secondary effects can only affect actors that are not included in the activity in question, but they, of course, have to be actors included in the plan. This choice is made since it is assumed that all changes that will affect an actor included in a plan are already captured by the primary effects.

### 3.2.4 Impact calculation

How an actor's strength is determined has already been established but how does this affect the impact between activities? After the execution of an activity (called activity A in this section) you go through the list containing all activities of the plan and establish if the activities are parallel or sequential. If parallel the simulation state that is compared to the pre-activity simulation state is a simulation state specific for that pair of activities (see the following section for a more detailed description). If the activities are sequential the simulation state is simply the state post-activity after all the effects of activity A have been carried out. As previously mentioned the relationships we are trying to determine can be described as the effects that the execution of activity A has on the conditions of the other activities in the plan.

Common for all activities is that the strengths of the activity's involved actors are calculated before the execution of activity A and during (for parallel) or after (for sequential) the execution of A. Different actors are of various importance for an activity and this is captured by so called *activity weights.* The weights states how influential the state of the specific actor is to the activity where the actor can be listed as: 3 = very influential, 2 = of medium influence, 1 = of little influence and 0 = of no influence. The direction of an actor's strength change can of course facilitate or complicate the conditions and it reflected by adding facilitating changes and subtracting complicating changes. Other changes than the strengths can of course also be important and are included into the calculation through *attribute weights*. This all adds up to a formula representing the conditions, C, for the activity:

$$C_k = \sum_{i=1}^{m} v_i * s_i + \frac{1}{p}\sum_{j=1}^{p} t_j * a_j$$

The strength of actor i = $s_i$, the weight of actor i = $v_i$, $m$ = number of key actors important to the activity, the value of attribute j = $a_j$, and the weight of attribute j = $t_j$, $p$ = number of individual key attributes important to the activity.

The conditions for each activity in the plan before ($C_1$) and after/under ($C_2$) the execution of A are calculated and compared. The quotient $C_2/C_1$ implies a negative CIM-value if < 1 and a positive CIM-value if >1. If $C_2/C_1$ = 1 it means that the execution of A had no impact on the conditions of the other activity and the CIM-value = 0. The argument is summed up below:

$$CIMvalue = 9 * \{(C_2 / C_1) - 1\}$$

A very similar procedure is followed when calculating the CIM-value between activities and SE, the only difference being that the conditions are not based on the weights presented above but on some pre-set states which, upon achievement, will fulfill the SE.

#### 3.2.4.1 Parallel activities

If two activities have any kind of overlapping execution time they are considered to be parallel. In this program this means that for parallel activities we have a two-way impact relationship to take into consideration as opposed to sequential activities where only the activity that takes place first in time impacts the activity occurring later on during the plan. For every pair of parallel activities there is a “during activity state” that will represent the new conditions for the other activity – a state that will be used in the calculation of CIM-values describes in the previous section.

It is assumed that the effects are distributed in a uniform fashion meaning that if an activity is executed over the course of four days for example, 25 % of the final effect will have taken effect after day one, 50 % after day two, 75 % after day three, and the full effect will have been carried out after the end of day four. However, you must take into consideration over how many days the activity will go on (an activity taking place over a long time has a higher degree of the total effect will have taken place whereas for short activity you cannot assume that you can see any effects until after the activity has already been executed), and also what kind of effects we are talking about; some effects might be carried out in an all-or-nothing kind of manner. You also have to take into consideration in what way the activities overlap, for example, even if the first activity is very short (and you cannot expect the effects to be visible until after the activity is over) its effects can still have an impact on the parallel activity starting later if that activity is executed for a long period of time.

Another idea is that the time the activities overlap affects the impact of the first activity on the other if they share resources (and there is not enough resources to execute the second one) because if they overlap for a long period of time the CIM-value will take on a much more negative value than if they only overlap for a very short period of time.

#### 3.2.4.2 Sequential activities

The situation for sequential activities is much more straightforward: the effects of the activity that has just been executed are assumed to have all been carried out and the troop size is updated according to its post-availability value. The post-activity state is then the state that, together with the pre-activity state, is used to calculate the CIM-values.

### 3.2.5 Structuring the design process

When designing event models and a simulation program which experiments with the models there are a few steps to take into consideration. The structuring of the model is the first one: I identified and roughly described three sub-processes that go on during the execution of an activity, namely:

1) Checking all resources and other values needed for the execution of the activity
2) Collect all changes
3) For each variable state change secondary changes are collected

I chose these sub-processes by starting out from the event of an activity's execution since the execution of activities make up the building blocks of the whole simulation.

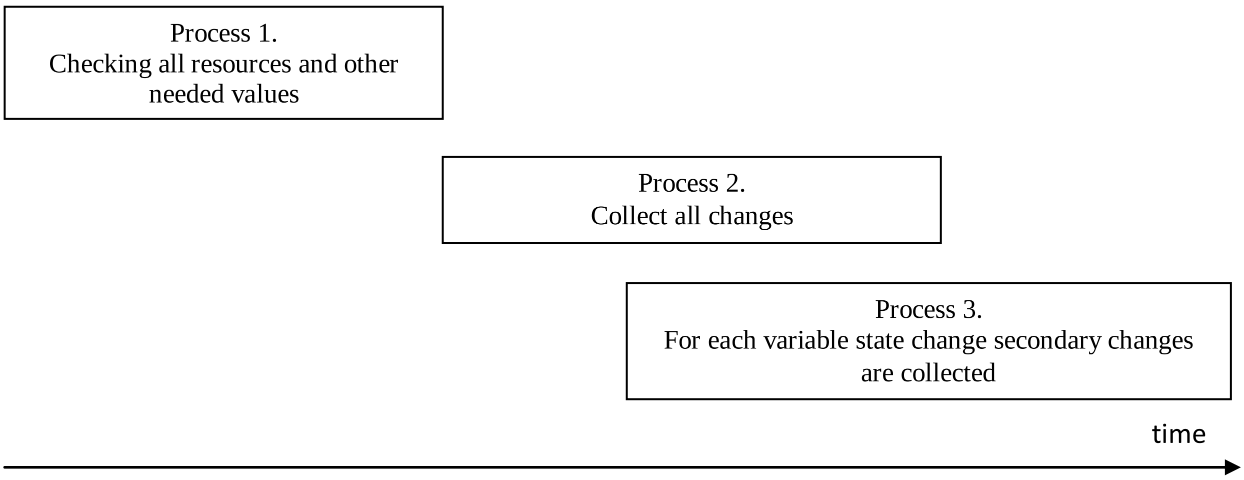



*Figure 9 - General sub-processes of an activity's execution*

The sub-processes then made up a useful more detailed structure on which to base the future developments on.

After the structuring had come this far the programming of the model started and everything from beginning (the GUI where the user creates the plan) to the end (where a CIM is created and exported in the form of a file compatible with CSMT) had to be planned out.

#### 3.2.5.1 Mode of procedure

During the programming phase I chose to use a kind of "top-down"- approach, meaning that I started off by focusing on getting the program to run properly but with empty methods so that no output was generated. After this was achieved I moved on to filling the methods with the commands that needed to be executed. This approach facilitated my study in the sense that bugs and other errors were caught at a much earlier stage and not built into the program. I also verified the program itself by holding some variables constant and making sure that the results changed as expected. By choosing this approach I have also gained an awareness of what input was needed and how the different parts of the program are connected. As previously mentioned it has been an iterative process that has been going on until satisfactory results have been achieved.

Since CSMT is written in Java it was the natural choice for this program as well, and other programming languages were not considered. The integrated development environment (IDE) Netbeans was used in the building process of the application. Netbeans uses the Apache Derby relational database management system which is why I have built my databases in Derby using SQL as the application programming interface (API) and SQL syntax. The computer program I designed and developed to perform the model simulation is largely based on different databases containing the different kinds of information used to create all objects needed, and information regarding all impacts that will affect these objects during the course of the simulation. The databases are presented in the following section in the order that they are used by the program.

##### 3.2.5.1.1 Plan entities

As previously stated an activity consists of starting and ending points, both in time and space. For the execution of an activity a set of "home" troops are also needed – they are included as a list of involved allied actors. Other actors are grouped in a list over involved actors. The actors themselves, regardless of actor type, are described by a specific set of attributes. Not all of the attributes are always applicable for all actors and in if not applicable the attribute will simply be assigned some specific default value. The databases containing all this information are simply called "Activities", and "Actors".

##### 3.2.5.1.2 Necessary resources

The resources that are needed to execute an activity are listed in the database "Needed blue resources". From this database you can collect the levels of resource values that are necessary and also what troop size is required for the execution of the activity. The actors' availabilities post-activity are also listed, i.e. the post-availability states to what extent the troop will be available again after the activity has been executed. Levels of arms strength and men (capacity) are only used as conditions and checks will be performed to see if they are fulfilled or not, but the size of a troop will determine the troops availability (for example to be used in other activities) during the execution of the activity. This design is chosen because of its simplicity but also because there is not enough information available to determine any exact levels of needed resources.

##### 3.2.5.1.3 Change in involved actors

To reflect changes in the actors' states initiated by the executions of the activities, a database called "Change in involved actors" was created to serve this purpose. Through this database information regarding what actors' attributes change because of the activity and also how much they change. The change itself is defined as "how much the attribute will change". I chose this definition as it represents a reasonably realistic view of change. It opens up for a more context-adapted actual change which can increase the realism and accuracy of the results. It can be argued that change should be represented in an even more context-dependent way but the aim of simplicity makes this a good starting point.

##### 3.2.5.1.4 Relationships between actors

Relationships between actors are presented and stored in the database "Actors' relations". This database will provide information regarding the "cascade effects" of the change in different actors' attribute values. To simplify the relationship database it is assumed that if one correlation corresponds to an increase in some value the opposite is also true, i.e. that the correlation also applies for a decrease in the value.

I should emphasize again that while it is possible for the attribute *strength* (further described in section 3.3.2.1) to affect attributes in other actors it is not possible for an attribute to directly cause change in another actor's *strength*. It is constructed this way because the value of *strength* actually is an aggregated value: a function of the values of other actor attributes. Hence there is a need for an exact specification of what attribute has been affected since we otherwise would have introduced an inconsistency in the model.

A development of this database could consist of making it more dynamic, that is, for example having an actor's status as ally, enemy, or neutral function as a condition that determines what relationship is of interest. Such a development would catch the varying constellation of relationships between actors that can be caused by, for example, a "my enemy's enemy is my friend" kind of reasoning.

#### *3.2.5.1.5 Conditions other than resources*

Apart from the conditions listed as "Necessary resources", other conditions can apply as well for an activity's execution. Such conditions could for example include some minimal state value of some environmental object that is required for the execution. Through the use of this database we are also able to capture requirements that do not stem from the capacity of "home" forces.

### 3.2.5.2 Building the program

The next step involved figuring out what should happen when the simulation is run. We have a set of activities that we want to execute in a surrounding world containing actors and environmental objects. A brief overview of the thought process at this stage is presented below:

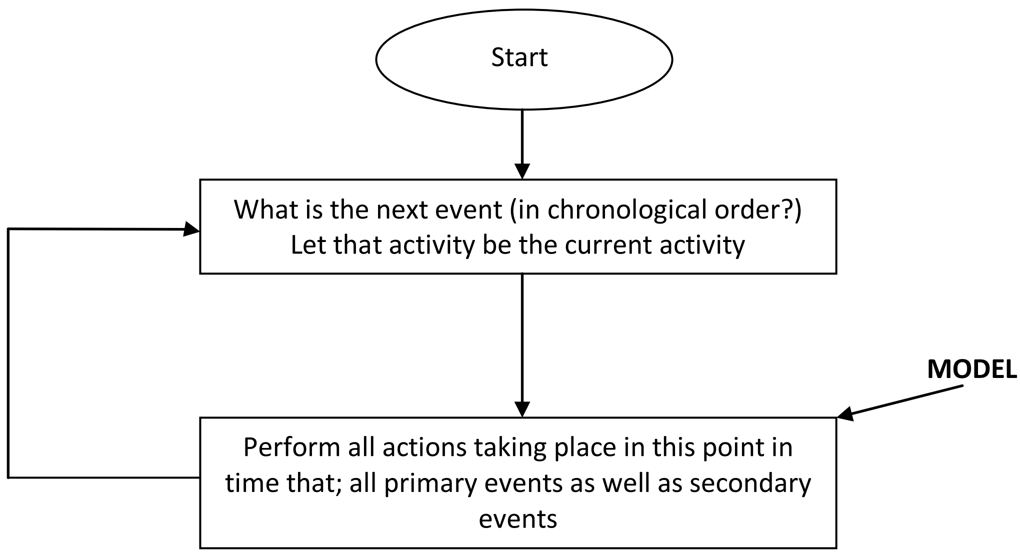



*Figure 10 - Main principle for event driven simulation. (Anon. 1996)*

The focus was then shifted to the contents of the lower box, and I sketched out the course of events during the execution of an activity, seen from the activity's perspective, which resulted in the following figure:

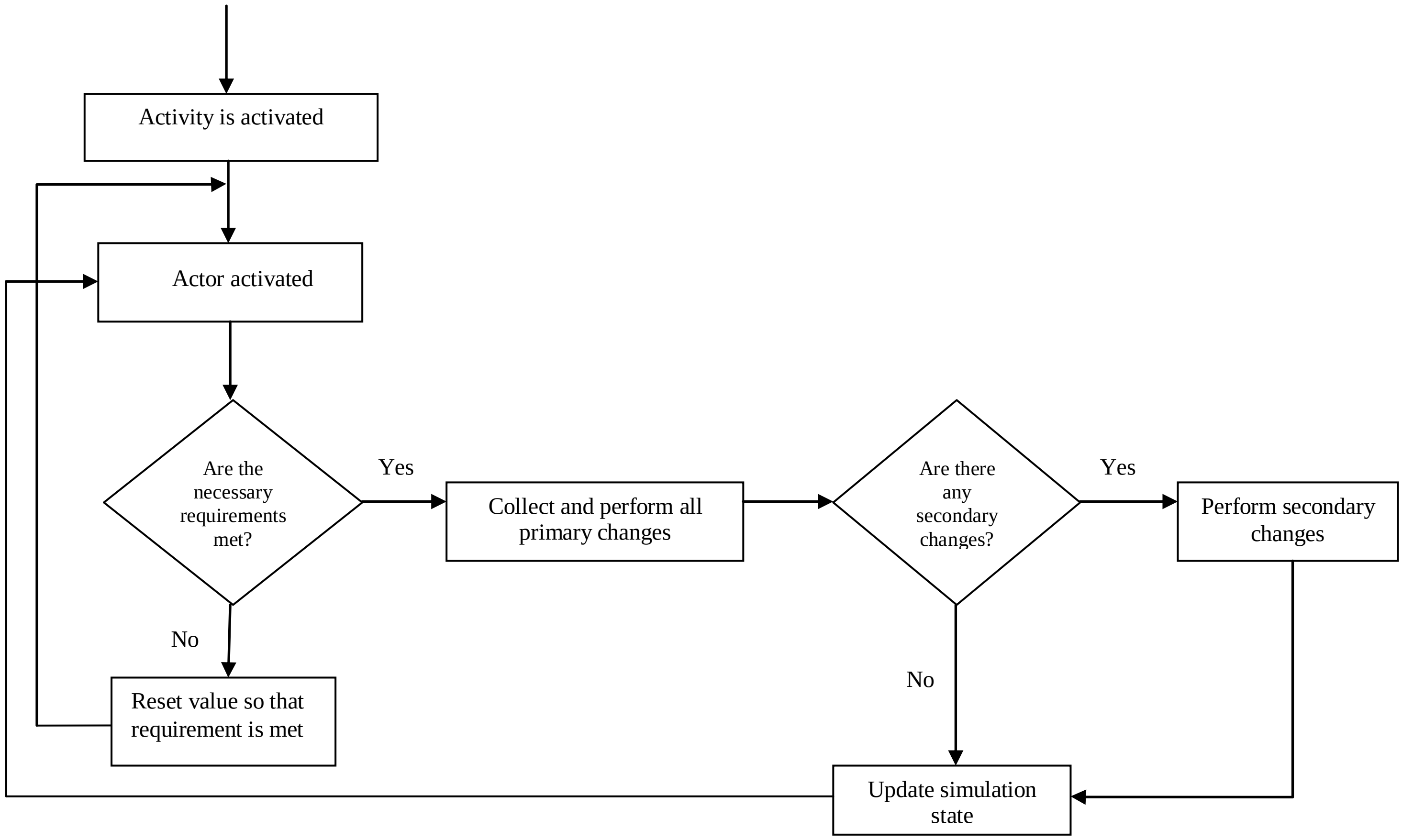



*Figure 11 - The course of events during the execution of an activity*

After an activity has been executed we need to evaluate the state changes it brought on in terms of the other activities in the plan as well as SE. When comparing the remaining activities conditions before and after the execution it is important to first determine if the activities are parallel or sequential. This is important since you will have different simulation states to compare the conditions to. The difference in conditions then form the basis for the impact calculations described in section 3.2.3

The whole program will then be structured according to the following figure:

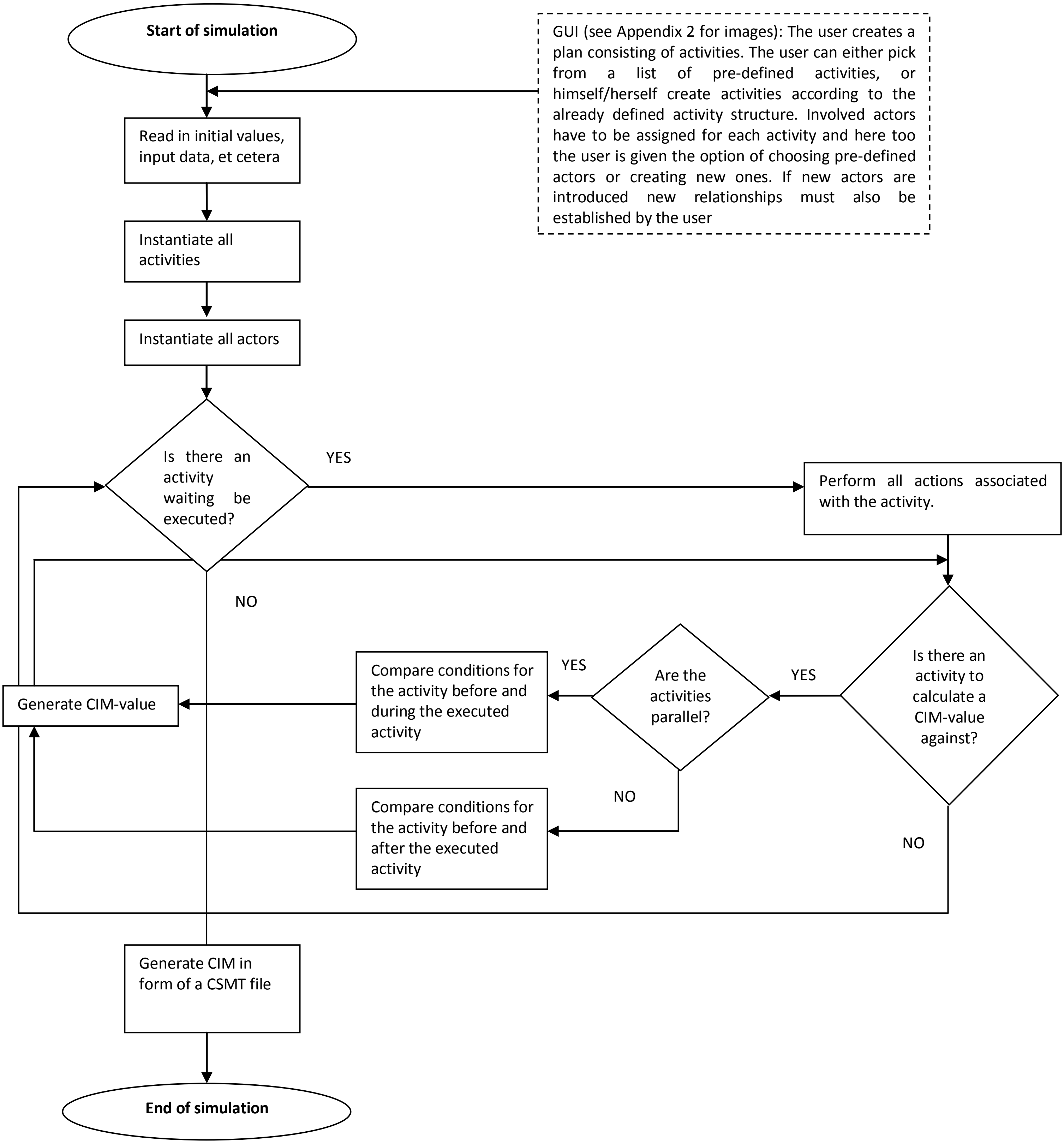



*Figure 12 - The simulation*

Before the execution of an activity is started all required resources and other conditions (for example capacity level) must be checked and cleared. If all requirements are not fulfilled the activity cannot be executed in that simulation state. However, since the activity still has to be executed for effects to be calculated the values that are too low are reset to the smallest acceptable level, a new “pre-activity state” is created and another try of executing the activity is carried out.

When the program is calculating the impacts between the activities a check is done (see figure 10 for a more visual description) to see if the following activity has all its requirements fulfilled. If this is not the case for sequential activities the CIM-value is simply set to -9 (the first activity made the execution of the following activity impossible) but for parallel activities the reasoning is a little more complex: if some requirements are not fulfilled a check is carried out to see what the post-activity availability is or coming changes is the unfulfilled value. If the needed value or values will be obtained after the activity’s execution a comparison is made between how many days it will take before the values are fulfilled, how large a part of the whole execution time of the coming activity this “delay” constitutes, then the strength of the negative CIM-value is based on this quotient, i.e. the smaller the quotient the less negative the CIM-value becomes and vice versa.

# 4. Case scenario

## 4.1 Scenario background

### 4.1.1 Bogaland

The plan that I will be testing takes place in Bogaland, a fictitious republic that is often used as a military scenario since it is adjusted to reflect the sorts of conflicts and the kind of actors that exist in the world today. Bogaland is divided into two parts; Kasuria and Mida. Kasurians and Midans are two different people with different cultural as well as religious backgrounds and they are in conflict with each other. A civil war between Kasuria and Mida has taken place but as of now a peace agreement has been signed and international forces BFOR are present and acting in both parts of the republic. However, the conditions for the local populations in both parts are very poor and the risks of new and old conflicts starting up again are impending. Different war lords, militia, and irregular actors are also trying to undermine and work against BFOR and the peace agreement which adds to the complexity of problems. For example there is a risk of ethnic cleansing threatening to take place in parts of West Kasuria if the situation is not controlled.

### 4.1.2 The plan

The plan which will be modeled and tested by the program consists of nine different activities. For the purpose of this thesis we will not define a MES or DC since that is on too high of a level to fit this study's purpose. However, two SE are defined:

1) Peacefulness in West Kasuria
2) Peacefulness in East Kasuria

These SE consist of different conditions that are stated as ideal to obtaining the SE. The SE is constructed in a way that matches the rest of the program and model structure, and the SE consists of a set of actors' states that are declared as crucial to the SE. In this way the execution of each activity can be determined to either bring the SE closer to or further away from being reached.

To obtain these SE the activities have to be carried out, and each activity will have an impact on the SE. The activities that together make up the plan are presented below:

- Establish area surveillance + Identify key leaders of DSD
- Arrest DSD key leaders
- Recuperation 1
- Penetrate DSD area
- Check-pointing
- Recuperation 2
- Handover Civilian Security to the UN
- Establish and maintain Freedom of Movement (FOM) in West Kasuria
- Establish and maintain FOM in East Kasuria

Each activity is described by the actors that will be participating in the activity (either in a neutral capacity, as allies, or as enemies), the resources (both in terms of numbers and capacity) that are needed to execute the activity, and what days the activity starts and ends. It is also specified what the states the used resources will be in after the activity's end: available, consumed, or at reduced capacity. Activities are said to be sequential or parallel in respect to each other, which is discussed in further detail in section 3.2.3.1

The non-BFOR actors included in the plan (but not in every activity) are described in the table below:

| Name | Type | Short description |
|---|---|---|
| Erik Johansson | Influential single actor | Influence to be reckoned with. Shady income sources |
| Erik Andersson | Influential single actor | Powerful and often shares the same goals as BFOR |
| Westland | Neighboring country | Primary objective is to protect Midans in every situation |
| Death Star Devision | Irregular actor | Enemy actor. Anti - Midan beliefs |
| UN police | International Forces | Ally. Control civilian security when the situation has stabilized |
| Kasuria Special Police | Irregular actor | Enemy actor. Anti - Midan beliefs |
| Mida Delta Christian Tradition | Irregular actor | Enemy actor. Anti - Midan beliefs |
| Local Midans | Local population | |
| Local Kasurians Pro-Peace | Local population | |
| Local Kasurians Nationalists | Local population | |

*Table 2 - Brief description of actors involved in case plan.*

Regular Kasurian forces are not included as an actor in the plan because they are not directly affected by any of the activities described. However, they do operate in West Kasuria and could be interesting to introduce in a future, more realistic scenario since they have the right to act during the 30 days after the peace agreement came into force. If they for some reason decide to reject the peace agreement it could have very negative consequences for BFOR achieving their goals, and obtaining the SE.

In this particular scenario there were unfortunately no environmental objects that could be included but they can most definitely play a significant role in other scenarios.

#### 4.1.2.1 Assumptions

When modeling the scenario it is important to remain consistent with respect to assumptions, since it could have a significant impact on what values would be considered reasonable. As an example, in the first activity it is assumed that BFOR do their work so smoothly that DSD (an actor that BFOR are trying to defeat) are unaware of their activity. This assumption results in some preconceptions regarding how you expect actors to act later on in the plan. If this assumption had not been made, DSD might instead have been assumed to have gained knowledge of BFOR's plans and consequently moved important equipment to Northland (a neighboring country). This would in turn have had implications for future activities since it would not have been possible to eliminate DSD completely and hence there would have remained a risk of DSD coming back even after having been defeated in activity four.

It should also be noted that not all attributes are relevant for all actors, finances for BFOR have been excluded for example since it is assumed that they have enough financial resources to execute the activities.

### 4.1.3 Assigning values

Apart from enabling all attribute changes to be treated in the same fashion, switching to Moradi's idea (see section 3.2.2.1) also made it easier to compare output from the program to values received from the case scenario. When assigning initial values the corresponding meanings to the values are as follows:

0 = insignificant level

1 = low level

2 = medium level

3 = high level

The perspective from which you model the scenario to a high degree impacts what values will be assigned. I have like previously mentioned chosen to use the perspective of the individual actors with the results such as DSD not being impacted by the activity "Establish area surveillance and identify key leaders in DSD". I have modeled it as the activity having no impact on DSD's strength since I look at it from DSD's perspective: they have no knowledge of the activity. If I were to look at it from a more objective and general perspective DSD's strength would decrease after the execution of the activity.

The changes that I do have accounted for are assigned according to the following criteria:

0 = no change

+- 1 = small positive/negative change

+- 2 = medium positive/negative change

+- 3 = significant positive/negative change

The changes mentioned above constitute the primary changes of an activity, and the secondary changes are obtained via the actor relationship database. The secondary effects are only "run through" once to avoid getting stuck in an eternity loop of secondary changes trigging more secondary changes but it should also be noted that effects of a secondary effect of a specific actor's change can be included in the relationship by directly connecting the change and the attribute (which really should have been affected by running the secondary changes one more time). An example where this is applied is when Eric Johansson's financial situation may be affected by BFOR taking control over the area in which he operates. This will lead to a decrease in Johansson's logistic ability and that is really what affects his financial situation, not the taking over control by BFOR in itself even though it looks like that from the relationship database. So even if the worsened financial situation is really more of a "side affect" it is an important effect and needs to be included.

# 5. Results and observations

## 5.1 Findings and results

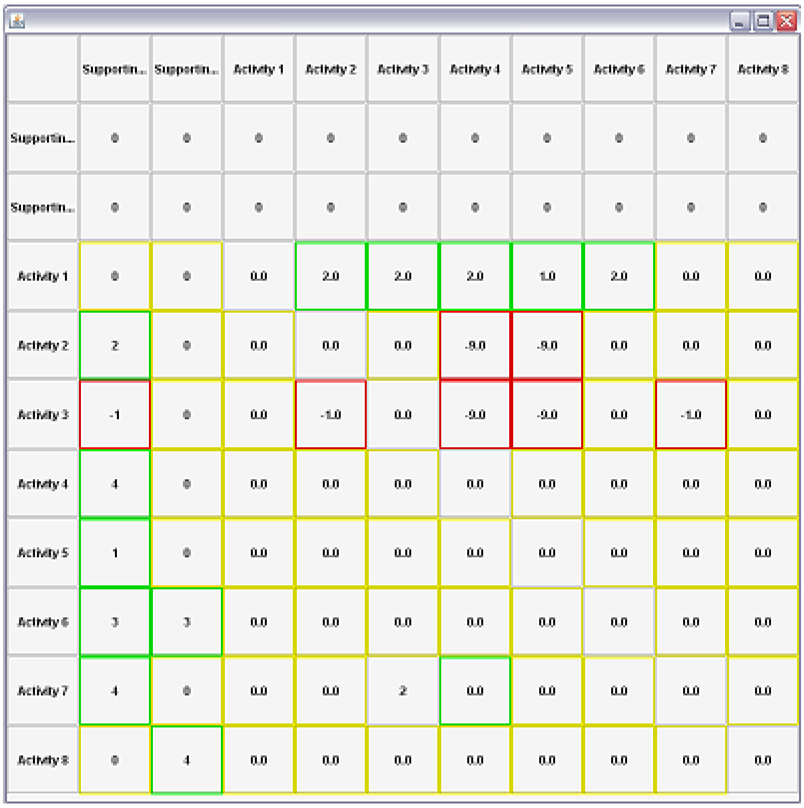
Building the models and the program have been a long ongoing processes throughout the course of this study where both processes also have had an effect on the design of the other. Of course the models have shaped the structure and design of the program but sometimes the actual code writing and program constructing has also showed me how the design of the model could be adjusted to become more accurate.

The scenario was challenging but still very much possible to model and the state of the actors changed within the scope of the expectations as the activities were executed, however the CIM-values were somewhat on the low side. The often low CIM-values could perhaps constitute an indicator that the contextual conditions that determine the actual impact of a change should have been modeled in greater detail. Expanding the number of different values an attribute can assume could also be a possible alternative to try out.

Verification of the models was carried through by holding variables constant and confirming that the output changes as expected. Finding a suitable scenario that was both small enough to be modeled in this study but also detailed enough to produce results that can be compared to those made by experts was found to be harder than expected. Hypothesis validation in the form of comparing the model data to some real data was not an option because of the fictitious scenario. Using CIM-values generated by a military expert for comparison with my results was not an option because the detail level of the case scenario turned out to be too low. Every expert would probably have come up with a different CIM and hence validation would not have been possible. Instead I opted to use the case scenario set-up which had been examined and approved by experts. In this set-up the actors' strengths were set before and after the execution of each activity. Since I had also introduced strength as an aggregated attribute I compared the relative increases / decreases in strength that were brought on by the specific activity with those in my own program. The results were encouraging since the actors' strengths changed in a similar fashion through my simulation and in the case set-up. I should also add that no other value than strength were indicated in the case set-up which strengthens my opinion that the actors are changing in a similar fashion because of suitable models. It should however be noted that the term strength referred to in the case scenario should not be confused with the aggregated term that has been included by me in this study; they are two different descriptions of the same type of concept so while the numbers may not be comparable in absolute terms a comparison between them is still useful since they are aiming to describe the same thing. The sensitivity analysis performed indicated that there were no variables whose impacts seem unreasonable but a more thorough analysis should be carried out if another scenario is modeled.

Although a lot more difficult than anticipated, all possibility of evaluating the accuracy of the CIM-values may not have been eliminated. The small and fairly simple scenario actually opened up the possibility for me to validate the values myself to a certain extent just by using logical thinking to determine if a value seemed plausible or incorrect. The CIM-values were often low in absolute terms as previously mentioned but they do, however, seem to follow the direction of change that is plausible.

An example of how a resulting CIM can look like is shown below:



| | Supportin... | Supportin... | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 | Activity 6 | Activity 7 | Activity 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| Supportin... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Supportin... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Activity 1 | 0 | 0 | 0.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 0.0 | 0.0 |
| Activity 2 | 2 | 0 | 0.0 | 0.0 | 0.0 | -9.0 | -9.0 | 0.0 | 0.0 | 0.0 |
| Activity 3 | -1 | 0 | 0.0 | -1.0 | 0.0 | -9.0 | -9.0 | 0.0 | -1.0 | 0.0 |
| Activity 4 | 4 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Activity 5 | 1 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Activity 6 | 3 | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Activity 7 | 4 | 0 | 0.0 | 0.0 | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Activity 8 | 0 | 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Figure 13 - A visualization of the generated CIM – a simulation of the case plan*

## 5.2 Challenges and difficulties

The sometimes lacking information about the activities and actors has been a challenge for me as a modeler, perhaps due to my inexperience as a modeler, but a challenge nonetheless. No connections have been completely obvious to me and a larger knowledge base regarding different actor types and similar background information would have been facilitating. Assigning of value was thus complicated at times and the fictitiousness of the scenario has also meant that it was sometimes hard to determine if a value was "off" since I had no reality base to compare it to. Plausibility was often hard to assess for different kind of connections and relationships as well.

The relationship database will be increasingly important in a potential future development of this program and further work should then be put into the design and contents of the database. In my scenario it has not played a prominent part because most actors were involved in most activities and there were no environmental objects included in the scenario, and hence the relationship database was not used that much and therefore it is hard to evaluate its use and accuracy.

Another challenge is constituted by the constant balancing between wanting to keep the models as simple as possible but still capturing behavior in as a dynamic way as possible. There is an endless variety of context conditions for different changes, behaviors and so on, that could be tried out.

As the program grew more and more complex it became hard to overview which increases the risk of affecting the program and the results negatively. Maybe it could be solved by using a different way of structuring the program or maybe a different kind of simulation like pseudo-parallel simulation (which can be suitable for more complex modeling) could be tried out.

# 6. Discussion

## 6.1 Thesis purpose and findings

While the model building of the scenario has been done, it has not been done without difficulty. It was shown to be harder than expected to first find a scenario that was small enough to be suitable for our purpose, but also to find the information about actors' behaviors that I felt were needed to build the models. A few possible disadvantages have arisen and need to be addressed. As discussed earlier the validation process has included a few challenges and called for some inventive alternate ways of trying to at least to some extent validate the results. This means that the question about the benefits and advantages of using this method of CIM generation remains somewhat unanswered even though there are some positive indications of its usefulness. The difficulty of validating the output probably stems from a case scenario that was shown insufficient for the study purpose but one should keep in mind that there is a risk that validation might still be an issue also for other case scenarios. To answer that question more scenarios would have to modeled and simulated.

It should however be stressed that the biggest challenges to building and designing the simulation model as well as evaluating the output seem very possible to overcome with a little more military experience from the modeler's side as well as more detailed background knowledge. So the challenge seems to have more to do with the input than the method itself. There are still valid objectives to the usage of this method such as traceability, limiting the impact of subjectivity, and increasing consistency.

Another scenario that facilitates the validation of the generated CIM to a CIM generated by experts could be modeled and tested to verify the indications of the usability of the generation method. It is also advisable to try to create a scenario containing some environmental objects which has not been the case with the scenario used in this study.

## 6.2 Interesting areas for future exploration

There are plenty of interesting alternatives that would be exciting to explore further;

- on attribute level:
    - Would the accuracy be improved if "inclination towards violence" would be introduced as a variable? Could it possibly interact with "religiosity" and how can this affect an actor's behavior?
    - Splitting the finance attribute into the different sources of income that exists could more accurately reflect the connections that exist in reality
    - Including ideological conviction and tenacity of purpose could have a big impact on how actors are expected to react in response to certain events
    - There also exist many different options of other attributes that could be tried out in the future and might have a significant impact on the expected response of an actor, for example. However, this has yet to be tried due to the wish for results as accurate as possible with the simplest model possible.

- as well as on a higher level:

    - To make the modeling a little more realistic, and hopefully fine-tune the results a little bit, time delay could be introduced in the *relationship database* and *change in involved actors* for example. Time delay captures the effects that are not instantaneous but rather introduced and made visible over time.
    - The relationship database could be developed even further and be made more dynamic (different contexts call for different connections), and different correlations for decreases and increases in the value at hand might perhaps also be introduced
    - To investigate the value of introducing the possibility of delaying activities. This could affect what happens when there are insufficient resources for the execution of some activity for example. If a delay is possible the user can decide if the activity should just be re-scheduled to a later time or maybe canceled.
    - Dividing the effects for parallel activities into both discrete as well as time-continuous effects (assuming that the effect allows for time-continuousness)
    - An actor's status as ally, enemy, or neutral could be given a much more prominent role and could make reactions and behavior more context-based.
    - By choosing a different modeling perspective (modeling the impacts of the activities from a general perspective instead of from the individual actor for example) could alter the results and perhaps also their level of accuracy.

If the results are still not thought to be satisfactory enough a stochastic model and simulation could be introduced. Introducing some stochastic elements to the model might not make the complexity unacceptably high, but of course the gain of the generation method has to be re-evaluated.

# 7. Conclusion

Using M&S as a means of providing input data to the CSMT is a viable method of generation but its usefulness remains somewhat inconclusive. There are some positive indicators but there are also some uncertainties that need to be cleared out before something definite can be said. The modeling of actors and especially the modeling of their relationships to one another have appeared to be important to put a lot of focus on. However, it seems like the question marks that are still unanswered can probably be answered without increasing the model complexity too much. This, together with the positive indicators and advantages such as increased traceability and more controlled subjectivity, speaks in favor of continuing the development of this generation method and its possible usability.

# References

Anon., (1996) Simulering. Systems analysis & simulation 6th ed. Uppsala University

Anon., (1996) Systemanalys och operationsanalys. Systems analysis & simulation 6th ed. Uppsala Univeristy

Carlsen, H., Carling, C., Eriksson, E.A., (2006). EBO och effektbaserat tänkande i internationell konflikthantering. FOI-R—1990-SE, Division of Defence Analysis, Swedish Defence Research Agency, Stockholm

Holm, G., (2007) Systemmodellering och Simulering med särskild inriktning mot försvarsmakten. FOI, Stockholm. ISBN: 978-91-7056-124-5

Moradi, F., Schubert J., (2009) Modelling a Simulation-Based Decision Support System for Effects-Based Planning, in Proceedings of the NATO MSG-069 Symposium on "Use of M&S in: Support to Operations, Irregular Warfare, Defence Against Terrorism and Coalition Tactical Force Integration", 15-16 Oct, Brussels, Belgium.

Schubert, J., Wallén, M., Walter, J., Malm, M., (2007) Analys och förfining av planer i effektbaserad planering. FOI-R--2307--SE, Division of Command and Control Systems, Division of Defence Analysis, Swedish Defence Research Agency, Linköping

Schubert, J., Holm, G., Hörling, P., Kamrani, F., Kylesten, B., Moradi, F., Sjöberg, E., Svensson, P., (2008) Realtidssimulering som stöd för effektbaserad planering 2008. FOI-R--2616--SE, Division of Information Systems, Swedish Defence Research Agency, Stockholm, pp. 3 – 41.

Stokes, V. P., (1998) Web dictionary of cybernetics and systems. Systems analysis & simulation 6th ed. Uppsala University

FOI (2009) Ritchey, 1998, www.foi.se/ma/zwicky3.pdf (2009-11-12)

Nationalencyklopedin (2009), www.ne.se (09-11-11)

# Appendix 1

**Arms strength:** Fire power, mobility

**Logistic ability:** Infrastructure, channels of propaganda

**Soft power:** Contact network, reputation

**Intelligence:** Information regarding matters of importance

**Dissatisfaction:** Perceived distance from ideal state

**Group dynamic:** level of unity and cohesion

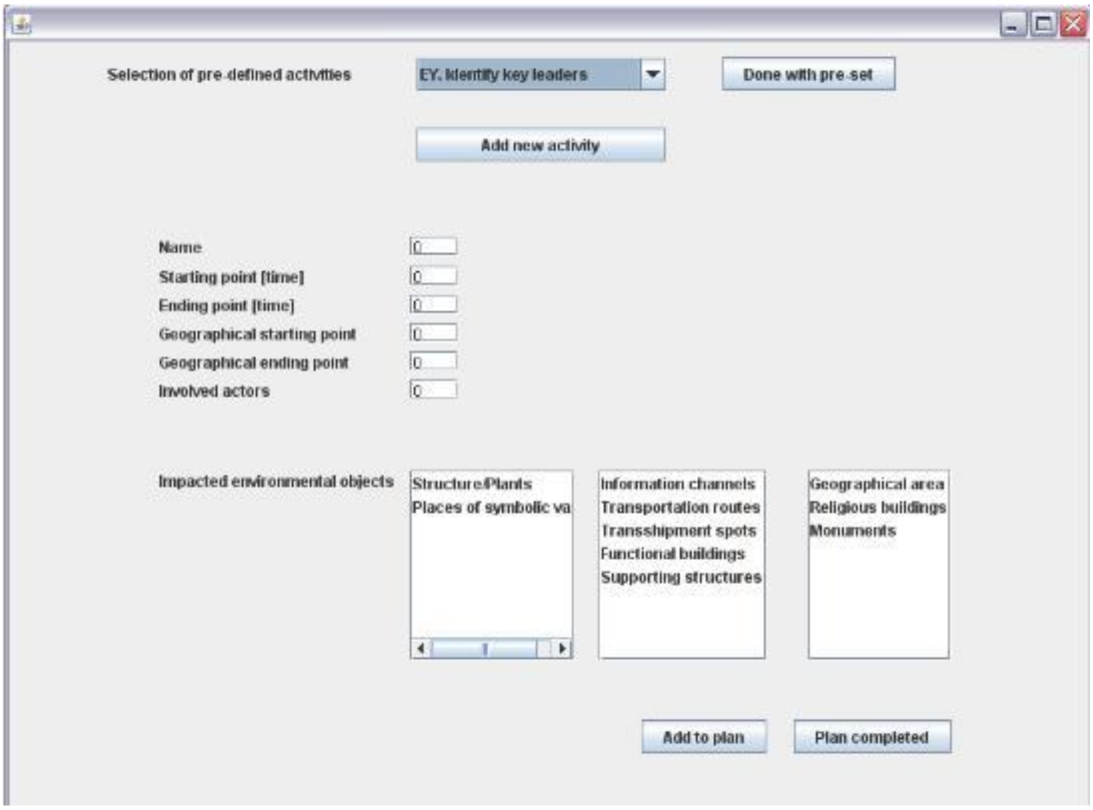
**Cleverness:** degree of cunning and wisdom

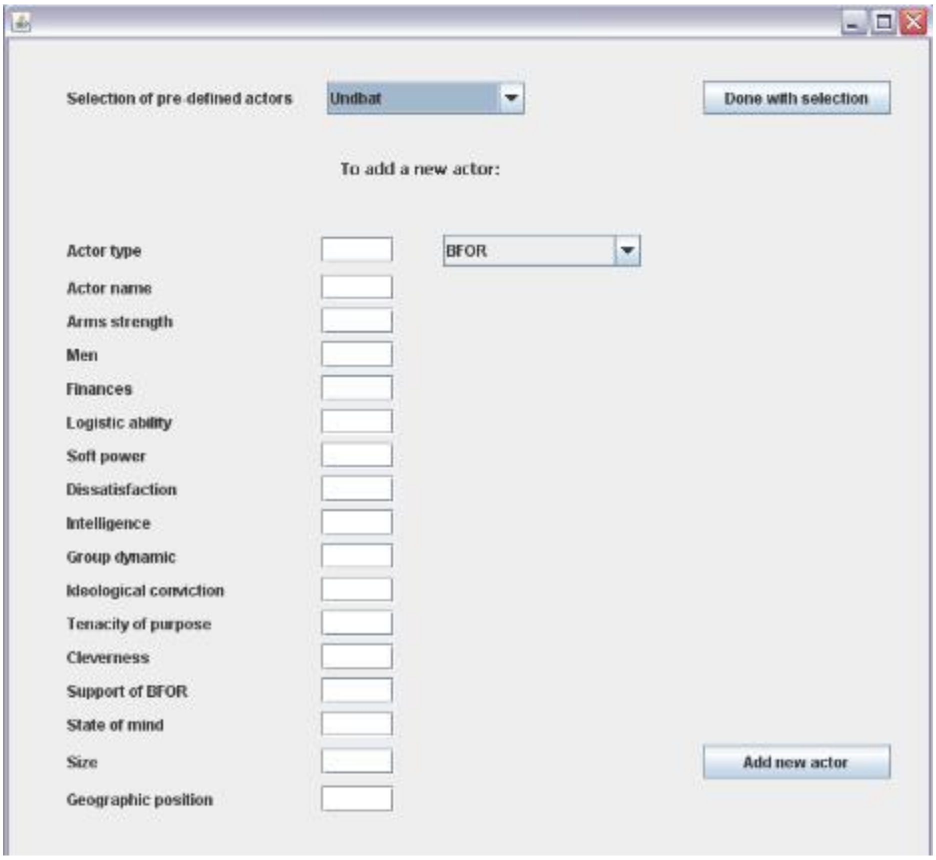
**Men:** number of people fit for military service, number of sympathizers, position

**Finances:** size, stability, spatial dominance

**Size:** the part of a group that is available

# Appendix 2


Selection of pre-defined activities
EY. Identify key leaders
Done with pre-set
Add new activity
Name
Starting point [time]
Ending point [time]
Geographical starting point
Geographical ending point
Involved actors
Impacted environmental objects
Structure/Plants
Places of symbolic va
Information channels
Transportation routes
Transshipment spots
Functional buildings
Supporting structures
Geographical area
Religious buildings
Monuments
Add to plan
Plan completed


Selection of pre-defined actors
Undbat
Done with selection
To add a new actor:
Actor type
BFOR
Actor name
Arms strength
Men
Finances
Logistic ability
Soft power
Dissatisfaction
Intelligence
Group dynamic
Ideological conviction
Tenacity of purpose
Cleverness
Support of BFOR
State of mind
Size
Geographic position
Add new actor