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Strategy-to-task resource management : application of hierarchies in Defense Resource Planning

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THESIS

STRATEGY-TO-TASK RESOURCE MANAGEMENT: APPLICATION OF HIERARCHIES IN DEFENSE RESOURCE PLANNING

by

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Current defense planning methods do not ensure a direct connection between national security objectives and military tasks. The Strategy-to-Task method provides a framework for solving this deficiency by establishing a hierarchy, starting from national objectives, through military objectives and missions to military tasks. Below these tasks, performance standards can be used for estimating the utility of a given task. This hierarchical approach helps decision-makers understand these important linkages. It could also serve as a framework for prioritizing the different tasks and contribute to better resource allocation, by analyzing different alternatives in a multi-attribute space. There are two decision-supporting methods for setting up priorities within this hierarchy of multi-attribute objectives. The first one, Multi-Attribute Utility Function Analysis, is a useful method for cases when performance standards can easily be established. This method could be used under both certainty and uncertainty and can address dependence and independence among the attributes or their utilities. The second method, the Analytic Hierarchy Process, could be used in cases when performance standards are difficult to establish as is typically the case in the higher levels of the hierarchy. The hierarchical approach and the two methods are illustrated through the case of Hungary's participation in NATO peace-operations.

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STRATEGY-TO-TASK RESOURCE MANAGEMENT: APPLICATION OF HIERARCHIES IN DEFENSE RESOURCE PLANNING

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ABSTRACT

Current defense planning methods do not ensure a direct connection between national security objectives and military tasks. The Strategy-to-Task method provides a framework for solving this deficiency by establishing a hierarchy, starting from national objectives, through military objectives and missions to military tasks. Below these tasks, performance standards can be used for estimating the utility of a given task. This hierarchical approach helps decision-makers understand these important linkages. It could also serve as a framework for prioritizing the different tasks and contribute to better resource allocation, by analyzing different alternatives in a multi-attribute space. There are two decision-supporting methods for setting up priorities within this hierarchy of multi-attribute objectives. The first one, Multi-Attribute Utility Function Analysis, is a useful method for cases when performance standards can easily be established. This method could be used under both certainty and uncertainty and can address dependence and independence among the attributes or their utilities. The second method, the Analytic Hierarchy Process, could be used in cases when performance standards are difficult to establish as is typically the case in the higher levels of the hierarchy. The hierarchical approach and the two methods are illustrated through the case of Hungary's participation in NATO peace-operations.

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I. INTRODUCTION

Defense is still a substantial task of governments. There is a significant gap between the resources required by the military for the implementation of its politically determined tasks and the resources provided by elected politicians through the 'power of the purse'. As far as this gap is concerned, defense resource planning plays an important part in defense planning, because it tries to match the required and the available resources and to ensure efficient and effective resource allocation.

Resources are not ends in themselves, but they must be provided because defense forces are to accomplish special tasks. Defense Resource Planning should be a simple, transparent and logical procedure. It should reflect the given national interest, national security objectives, national strategy, and the available human, financial and infrastructure resources. Therefore, it should organize different alternatives in such a way that optimal decisions can be made and those decisions can be proved by decision-makers before political leaders. Strategy-to-Task Resource Management (STRM) provides a framework for systematically addressing resource issues by stating what politicians expect the military to do with the assigned forces and how the military plans to meet those expectations.

By establishing hierarchies, to create a linkage from national objectives down to tasks, decision-makers can keep competing objectives in view and take into account

every aspect of their resource allocation decisions. Setting up priorities gives decision-makers a tool to create better understanding of dependent objectives.

Current application of Multiattribute utility function analysis (MAUFA) and Analytical Hierarchy Process (AHP) for planning, resource allocation and group decision making suggests its potential use for defense resource planning. Decision-making in a complex situation, such as defense resource planning and allocation, is difficult, because attributes on the same level of the hierarchy can depend on each other as well as on the attribute in the next higher level. In this case, the application of the Multiattribute Utility Functions might be more adequate. By applying the best priority setting method, decisions concerning defense resources could ensure more effective and more efficient resource allocation in the era of scarce national resources.

Peace operations became important tasks for the military after World War II. Certain objectives must be met during a peacekeeping mission. These objectives depend on the particular situation but may include implementing the special peacekeeping task, defending convoys providing humanitarian assistance, and defending members of the peacekeeping mission should they be attacked.

Hungary's active participation in peace operations was an important consideration in the evaluation of its armed forces when Hungary was invited to join NATO. Considering the increasing importance of peace operation activities in NATO's future, the thesis will

analyze STRM through these activities and the capability of Hungary to take part in these operations.

A. PURPOSE

There are several purposes of this thesis. One of the purposes is to show what Strategy-to-Task Resource Management is and what the advantages and disadvantages are of using STRM. The second purpose is to demonstrate the possibilities of applying hierarchies in defense resource planning. Another aim of this thesis is to explain the advantages of using Multiattribute Utility Functions and AHP for defense planning. The fourth objective of this study is to show how a hierarchy could be configured for defense planning and how priorities could be set in defense planning with using the AHP and Multiattribute Utility Function approach. An additional purpose of this thesis is to explain how using hierarchy-based Strategy-to-Task defense planning could ensure the civilian control.

B. RESEARCH QUESTIONS

The thesis tries to find answers to the following questions.

1. What is Strategy-to-Task Resource Management method (STRM)? What are the advantages and disadvantages of STRM?

2. What are the possibilities for applying hierarchies in defense resource planning?

3. What are the advantages of using Analytic Hierarchy Process (AHP) and Multiattribute Utility Functions for defense planning?

4. How can a hierarchy be configured for defense planning?

5. How can priorities be set in defense planning with using the AHP and Multiattribute Utility Function approach?

6. How can the civilian control be ensured by using hierarchy-based Strategy-to-Task defense planning?

C. THESIS OUTLINE

The thesis will start with an overview of defense planning. It will study the objectives of defense planning, the different planning approaches and describe the various participants of this process. The first part will conclude with a description of the major steps of defense planning

The second part of this thesis deals with the Strategy-to-Task Resource Management method. After a general description of STRM and the role of hierarchies in defense resource planning, the thesis will analyze the major levels of the STRM method, examining national security objectives, national military objectives, missions, operational tasks, force elements to accomplish tasks, capabilities and defense resources. This part will include the analysis of the case of Hungary's participation in NATO peace operations (peacekeeping and peace enforcement) from the STRM aspect.

The third main part of the thesis deals with the role of priority setting in the Strategy-to-Task Resource Management model. This part mainly will discuss the application of Multiattribute utility function analysis (MAUFA) for defense resource planning and allocation and the process of priority setting with Analytic Hierarchy Process (AHP).

D. EXPECTED BENEFITS OF THIS THESIS

The thesis will provide benefits in defense planning in several ways. First, it will illustrate a useful tool, the hierarchy approach, for political and military decision-makers to understand the connection between the basic national security needs and the tasks of the defense forces. This understanding can help the decision-makers to make decisions that provide a better resource allocation among the government branches and within the defense sector. Second, the thesis will present and study two different analytic approaches to support resource allocation decisions by using the hierarchy. These two approaches help decision-makers in the resource allocation process by ranking alternatives. It makes prioritization easier. Overall, the main benefit of the thesis is to provide a new, clear and comprehensive approach to defense planning.

II. OVERVIEW OF DEFENSE PLANNING

Before studying the Strategy-to-Task Resource Management method, it is important to provide an overview of defense planning. It is essential to understand the objectives, participants and the different steps of defense planning, as well as the different commonly used planning methods.

A. OBJECTIVES OF DEFENSE PLANNING

To understand the objectives of defense planning it is necessary to study the role of planning in organizations and the various planning functions in budgetary decisions.

1. The role of planning

Planning has long been an important activity in both government and private business organizations. It provides a sense of direction to the organization by informing members of the organization about the organization's goals and the general types of policies, which the organization intends to pursue to achieve those objectives.

The plans having the greatest resource-allocation impact are those, which specify the activities an agency intends to pursue over some future period, because activities are directly accompanied by resource consumption. Defense planning is included in this type of planning. These plans differ in their content; however they have some common elements. They include a forecast of the environment in which the agency will be

operating, a statement of the objectives the agency wants to pursue. Furthermore, plans contain a discussion of how the agency intends to go about pursuing those objectives and also address the resources required to achieve the objectives.

2. Planning functions in budgetary decisions

Plans have many important implications for budgetary decisions. The first major function of the plan is to signal the current budgetary decisions that must be made in order to realize future programs. Only by planning what will be used in the future can a decision-maker know what is needed to be done now. The advanced procurement of long lead-time items is a good example for this function.

The second function of the plan is to give an agency some idea of its future requirements for existing assets and for assets that can be acquired. Weapon systems are good example for this function. They may be effective now, but do not satisfy requirements in ten years time.

The third function is the consideration of the utilization of existing resources. If the military has equipment no longer needed because the function it performed is no longer necessary, the utilization of this equipment for future programs has to be decided. Proper planning can help in answering this matter by showing the future requirements of the organization. Decision makers can then decide whether this equipment could be useful for the organization in later time or not.

B. PLANNING APPROACHES

Countries live in different political, economic and cultural environments. These environments strongly influence the general approaches to different social issues. For example, when an economy is weak, and there are very limited resources for defense, all military "needs" will probably not be satisfied. In different situations different planning approaches have to be used in order to ensure the most effective and efficient resource allocation for and within defense. There is no best approach for all situations. Every country should find a combination of the following approaches that fits best for its political, economic and cultural environment.

When studying the different approaches, two points have to be considered critically. One is the allocation of scarce resources and the other is the relationship among ends, means and risks. According to the first argument, there will never be enough resources to satisfy all the nation's needs. Therefore, decision-makers have to establish requirements, set priorities, make decisions and allocate scarce resources to the most critical needs. To get the most from the limited national resources (means), decision-makers must determine their objectives (where they want to go) and the strategy (how they plan to get there). In some cases it becomes necessary to adjust security objectives (ends) to fit within the borders of the nation's economic, political, and military power (means). The mismatch between these two elements creates some danger (risk) to the overall security interests.

1. Bottom-up Approach

In the Bottom-up approach current capabilities and resources play a dominant role in defense planning. This approach tends to focus on current resources and threats.

The major advantage of using this approach is that is based on local reality. Defense planners are obliged to see how existing objectives can be reached by using currently available resources. Therefore, it can help to balance the efforts focusing only on the contribution of future capabilities and resources. Second, by concentrating on existing forces, this can lead to improved strategies that can help to refine force requirements.

The major disadvantage of using only this approach could be that a tendency to lose sight of national security objectives could occur. Another pitfall of this approach is that it could lead to neglect of long-term goals.

2. Top-down Approach

In this defense planning approach objectives play an essential role. These objectives drive the whole defense planning process. The first step is to decide what the decision-makers want to achieve. The next step is to develop a strategy or game plan that specifies how the objectives will be accomplished. After defining the objectives and the strategy, forces are determined. This approach is a good way to minimize the risk associated with military threats to vital national interests.

This approach continues through a hierarchy of several levels of objectives and strategy. At the highest level, where national security decisions are made, broad objectives and grand strategies are developed to further or defend overall national interest such as to guarantee the independence, sovereignty and territorial integrity of the country, to contribute to the implementation of what has been laid down in the North Atlantic Treaty Organization and to the security of its Allies or to facilitate the preservation of international peace and the enhancement of the security and stability in the region.

At a lower level individual objectives and strategies are being developed that support higher level decisions. Continuing the example of preservation of international peace and implementing obligations associated with NATO's strategy to focus on out of area peace operations, such as peacekeeping and peace enforcement; the military objective could be participation in NATO peacekeeping operations. At an even lower level there are theater objectives and strategies.

There are many advantages of using a Top-Down approach in defense planning. First, going through the hierarchy, it helps defense planners to focus on ends. Second, it gives a systematic way to think through defense requirements starting from the macro perspective and going down to micro tasks. Third, this approach manages different timelines. At the highest, national security level, objectives and strategy are rather longer term. The lower the level, the shorter the range of the focus becomes. Fourth, if the strategy is clearly defined, it will help as a valuable criteria for judging, evaluating and choosing among for example different defense force structures. The fifth advantage is that this approach can be summarized in a simple model. When a threat or opportunity

occurs, the main variables planners should concern are objectives, strategy, resources and risk.

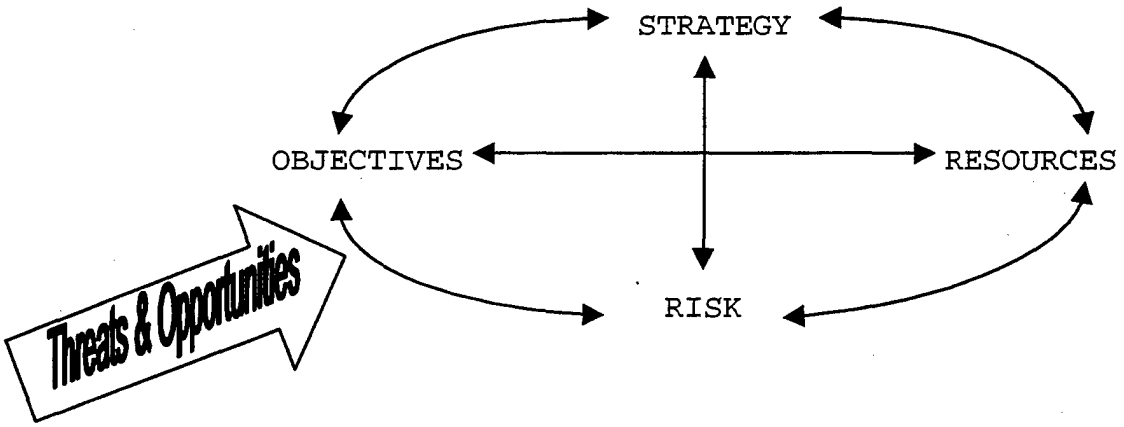


Figure 1. Relationship between Strategy, Objectives, Resources and Risks

When objectives and existing resources are not in balance, defense planners are faced with a mismatch between objectives and resources that will produce a high level of risk. Sometimes in this case, the planners tend to concentrate only on increasing the means. Nonetheless, there are other solutions for this situation like more clearly defined or limited objectives, a different strategy, or the definite acceptance of the risk coming from the mismatch. In the first two cases the information goes back to the top level and leads to changes in objectives and/or strategies. This feedback loop ensures that the balance between strategies and means can be achieved.

While there are much strength associated with the top-down approach, there may be several pitfalls of using this approach for defense planning. First, there is a tendency

of future-oriented concepts' dominance at the expense of current forces and resources. Second, it leads to greater public awareness of strategy. This implies that strategy will be debated openly during the budget process and questions of state security may arise.

3. Fiscal Approach

The fiscal approach to defense planning is budget driven. Overall budget constraints are established at the outset based on a criterion such as a certain percentage of gross national product[1] or the Central Budget[2]. Within this limit other planning approaches are integrated to make the most of what is available.

The first advantage of this approach is that resources for defense are placed in the context with the overall state of the economy and the political emphasis of the public at large toward defense and other goods. The second strength is that additional focus is placed on efficiency and effectiveness[3]. Because the costs of operating current forces will constrain the amount of resources remaining for research and development and modernization, there are incentives to operate efficiently.

The primary weakness of this approach is that it might not be directly related to the threat level. The second pitfall of the Fiscal approach is that when planning starts

[1] Hungary, for instance, agreed on increasing the percentage of defense portion of the gross domestic product within the next years by 0.1 percent-point.
[2] Central Budget represent Federal Budget in this paper
[3] Effectiveness is used in this context as 'efficiency in the large'. According to Hitch and McKean (The Economics of Defense in the Nuclear Age, p. 125) "Efficiency in the large, or at relatively high levels, involves getting the gross allocations right in reference to major objectives."

with a fiscal emphasis, the focus tends to be on the apportionment of overall resources instead of the optimal combined military solution to common problems.

C. PARTICIPANTS OF DEFENSE PLANNING

Defense planning is a dynamic process that involves many participants both from the military and non-military side. These participants have different interest and different power to represent their interest in the defense planning process. The following examples represent the Hungarian perspective.

1. Elected Politicians (Parliament)

As far as democracy is concerned, freely elected political representatives and governments play a significant role in governing a country. Representatives deal with defense issues on the highest level. Based on their understanding of national interest, constraints on national power and both external and internal pressures, they have to identify national objectives. These objectives then show up in foreign and defense policies. Usually parliaments[4] have at least two committees that play a significant role in forming defense issues. They participate, therefore, in defense planning. These committees are the Foreign Affairs Committee and the Defense Committee. Defense Committees work on all defense issues occurring in the Parliament. They have to prepare House resolutions on issues like the principles of national defense, principles of security and defense policy, use of defense forces and long term transformation of defense forces

[4] Parliament represents Congress and National Assembly in the paper.

and their size. These functions are very important in both defense planning and implementing an effective civilian control over the military.

2. The Administration[5] (Ministry of Defense)

Different ministries of the government deal with different issues. The Ministry of Defense is responsible for the day-to-day business of defense issues, including resource allocation problems, budgetary issues and the question of effectiveness and efficiency. Top leaders of the Ministry of Defense are the decision-makers in these issues. The different departments within the MoD deal with special segments of defense, like human resource, infrastructure, and budgeting, bilateral and multilateral international relations. Defense planning is a crucial part of this business; therefore MoD's participation in the process is essential.

3. Military Planners

After foreign and defense policy has been determined, the military becomes involved into the defense planning process. They make assessments about how to balance the current and possible threat by using resources available to the military. They look for a force structure that fits best to national military objectives. Since this part of the planning requires special knowledge about military resources (e.g. human resources, training and practice, weapons, special equipment, operation and maintenance requirements) the core of actual defense planning is carried out by military planners.

[5] Administration represents the governing body of a country (government)

Military planners should focus on allocating resources (human and financial resources and infrastructure) in order to assure achieving certain capabilities required for implementing certain military tasks.

D. THE MAJOR STEPS OF DEFENSE PLANNING

Defense planning is a dynamic process that involves many participants both from the military and non-military side. Defense planning can be described in a five-step process. In the first step purposes are specified. The second step appraises opposition. The third step formulates strategy to satisfy objectives. In step four resources are allocated in order to cover requirements without excessive level of risk. The last step is to review alternatives in case current assets are inadequate to support the selected concept.

1. Specifying purposes

Defense planning must seek ways to protect and promote various interests that form the foundation for national security.

As an example, preserving independence, sovereignty and territorial integrity of the country is basic national interest of the Republic of Hungary. Defense planners should keep these interests in mind, since the whole planning process exists in order to protect these interests.

2. Appraising Opposition

The nature, closeness and intensity of obvious danger determine what should and could be done in what order of priority to protect national interest form all foes. Adequate evaluation starts with enemy capabilities[6].

3. Formulating strategy

Defense planning should include different strategies for different cases. According to Collins's Law "If you don't know what you want to do, you can't plan how to do it."[7] Proper political and military objectives thus have to describe at the beginning what must be done to obtain desired level of security. In a scarce resource environment A conflict exists between domestic goals and the needs for national defense. Priorities therefore are crucial in order to establish an effective and efficient allocation of national resources. Concept formulation starts with policy guidelines, keeping national aims in mind. Thereupon defense planners fit operational concepts into the policy-commitment framework, in ways they believe would best achieve objectives selected to safeguard national interest.

4. Allocating resources

Conceptual planning identifies what should be done to provide crucial security interests. Resource allocation compares the requirements coming from the upper level

[6] In case of Hungary this is rather difficult, because according to the Resolution 94/1998 (XII.29.) of the National Assembly on the Principles of the Security and Defense Policy of the Republic of Hungary paragraph 5 states that "The Republic of Hungary considers no country an enemy and it treats all actors of the international politics who abide by the principles of international law as its partners. Hungary intends to settle disputes in accordance with international law, taking into account the European practice."

[7] John M. Collins. Defense Planning Steps. p.145, 1990.

strategies with available and projected capabilities, in terms of human resource, equipment, infrastructure and funds, to approve or reject its feasibility. Priorities also occur in the process of resource allocation, since decisions are made according to priorities established within strategies. In case expectations and resources fit completely, the defense planning process terminates at this point. If there is misfit between them, steps must be taken.

5. Reconciling end with means

Reconciliation is required when unallowable risks maintain the gap between objectives and resources. Collins suggests six choices to implement reconciliation. These are the following: reduce waste, compress or discard objectives, reshape strategic concepts, revise force requirements, increase resources or bluff. These choices could be used singly or in combination. Collins pinpoints some sensitive points in the process:

> Planners must be cautious, because reducing risks can be a risky business. Reducing waste is properly top priority, but trimming "fat" can cause serious problems, if careless surgeons cut into "muscle." Telescoping objectives and tinkering with strategies is less likely to stir up political storms than requests for more resources. Critical interests, however, remain and must be covered. Overoptimizing forces for any set of concepts stifles flexibility. Bluster sometimes holds foes at bay, but habitual bluff is bound to be a looser.[8]

[8] Collins. Defense Planning Steps, p.147.

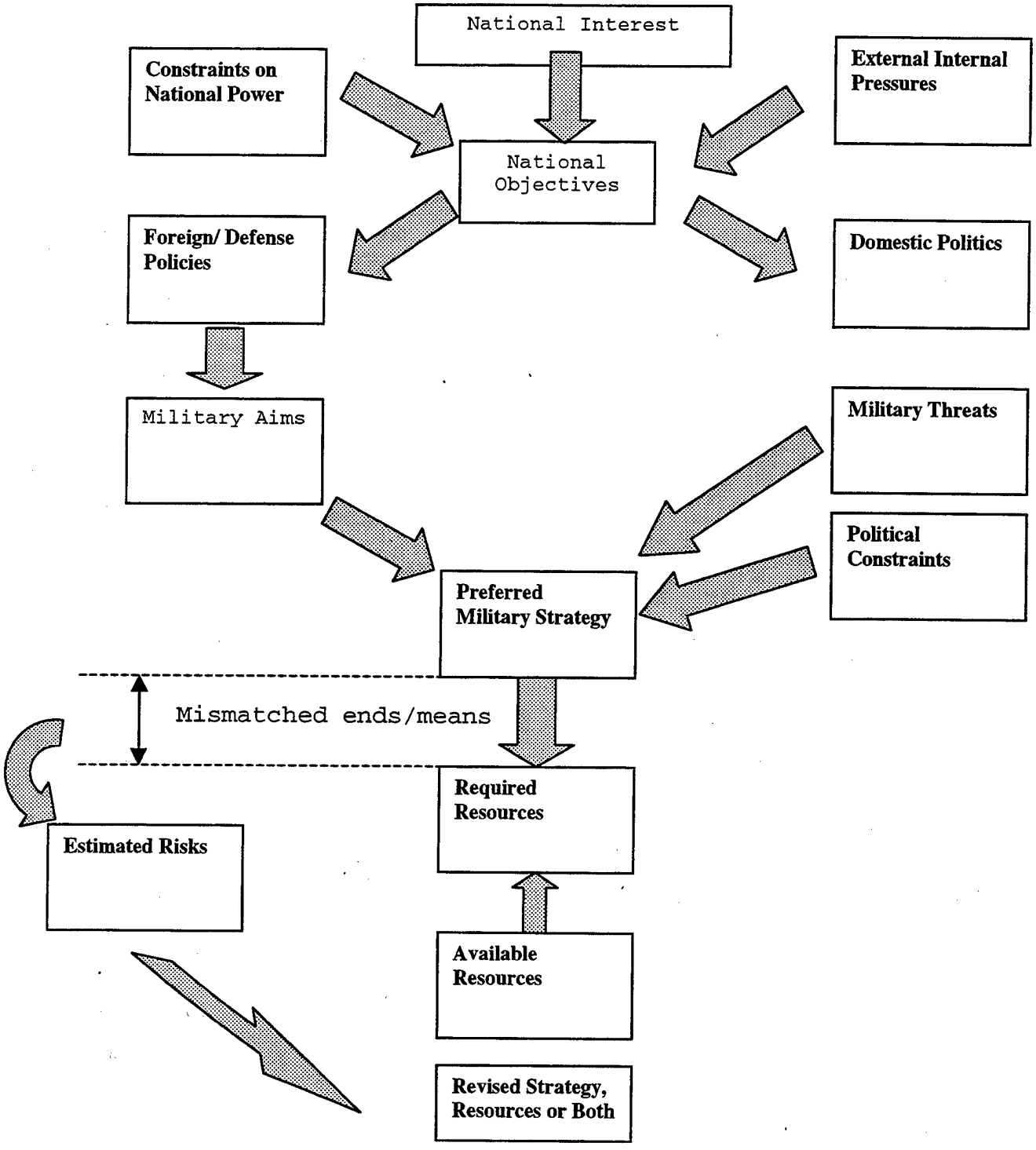


Figure 2. Defense Planning Process[9]

[9] John M. Collins. Defense Planning Steps. p.145.

E. CHAPTER SUMMARY

Defense planning is a complex process. This chapter discussed the objectives and the participants of defense planning and the different planning approaches. The analysis of the different approaches showed that the top-down approach should be dominant factor, when planning is based on objectives. The next chapter will study such an objective-based defense planning approach. However, defense planning is unlikely to be based on only one approach. The appearance of some parts of other approaches is inevitable. The next chapter examines a new defense-planning model that is new in its approach, because it connects national security objectives to military tasks.

III. STRATEGY-TO-TASK RESOURCE MANAGEMENT

A. INTRODUCTION

There is a strong need in planning of military forces and capabilities for a clearer sense of linkage and direction to national interest. The annual reports of the executive branch of a country, to the legislative body, should explicitly show the national interests and objectives. It is important, because the legislative body has to make budgetary decisions, based on the importance of the different programs. On one hand, it makes it easier for the representatives to allocate resources among the different programs and task for the Ministry of Defense. On the other hand as far as a Ministry can show how the programs, or tasks of the ministry are directly related to national interest, the ministry has a bigger chance to get the requested funds than other ministries have.

B. STRM: A NEW FRAMEWORK FOR RESOURCE DECISION-MAKING

The Strategy-to-Task Resource Management model meets the above-described necessity of linking military tasks to fundamental national interests. This concept is based on the argument that a plan for accomplishing certain goals at one level of organization defines objectives to be attained at subordinate levels of accomplishment. Therefore, plans for the Ministry of Defense determine objectives for main main departments within the Ministry of Defense and for the armed forces.

1. General description of STRM

The Strategy-to-Task Resource Management Model describes a process by which one may move consistently from established national security objectives, to national military objectives, to regional campaign objectives, to missions, and finally to military tasks. The model gives a clear audit path from top to bottom, offers a definite stability for national security planning and provides clear meaning to strategies[10] formulated at each level.

2. Hierarchies in defense resource planning

The hierarchy of defense planning objectives starts with national security objectives, obtained from the requirement of protecting the country's basic goals down to exact military tasks. Figure 3 shows the hierarchy of defense planning related objectives.

Strategies are determined each level in reaction to perceptions of the threat and the environment. While strategists at the national security level define national security objectives, planners at the national military level identify national military objectives and regional campaign objectives to support the higher level objectives. Afterwards, regional commanders and planners identify missions in campaign plans and military tasks to be achieved in a theory of employment. Feedback is crucial, because it helps in

[10] Strategies refer to plans of action. According to the Joint Dictionary of Military Terminology, a strategy is a plan for using available resources to achieve specified objectives.

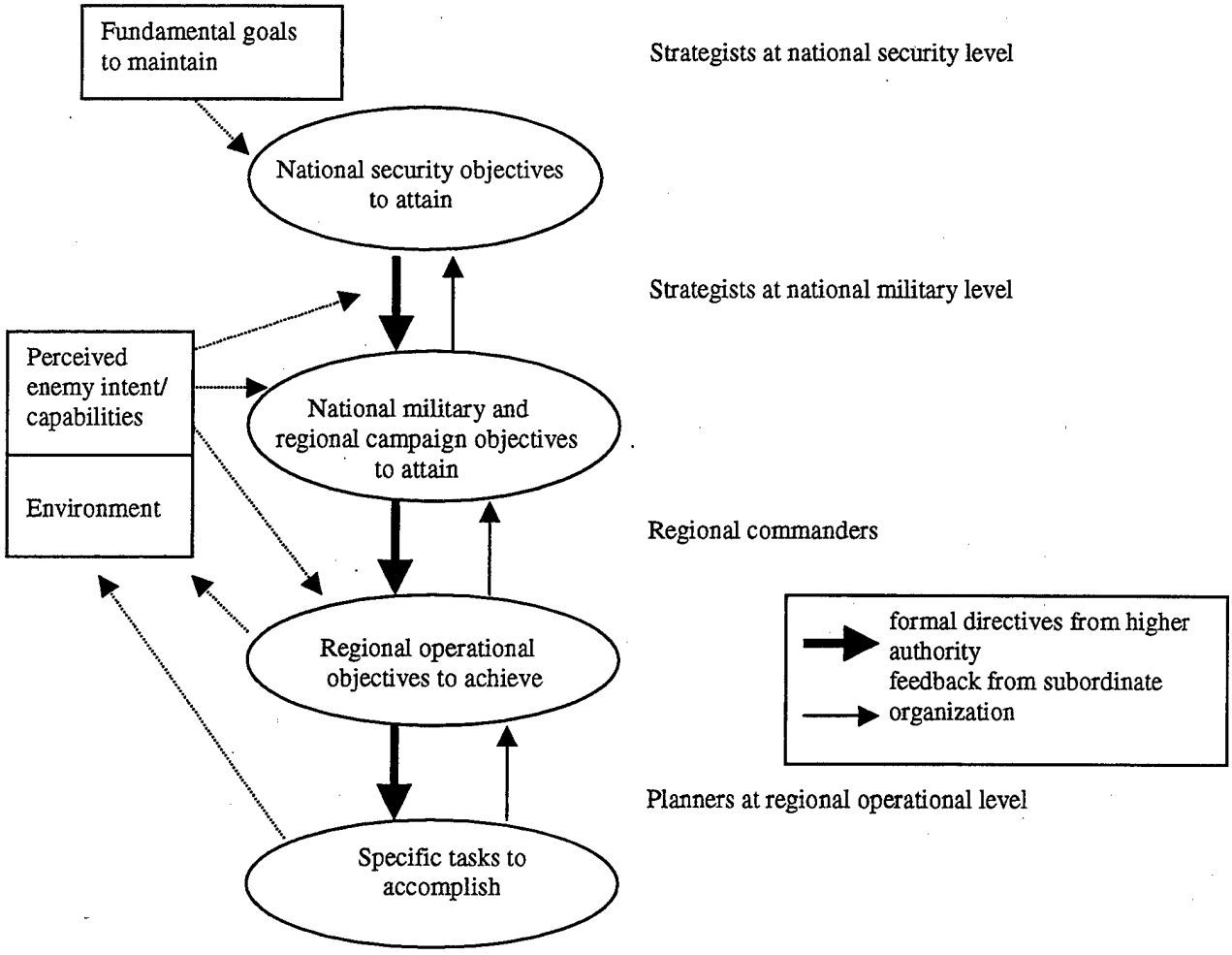


Figure 3. Hierarchy of Objectives Relating to Defense Planning[11]

modifying plans in response to changing fiscal and operational coercion and the altering threat.

[11] Source: Kent, Simons: "Objective-based planning" in *"New Challenges for Defense Planning"*. p. 63.

C. MAJOR LEVELS OF STRM: ANALYSIS OF STRM THROUGH THE CASE OF HUNGARIAN FORCES PARTICIPATION IN NATO PEACE OPERATIONS

This part of the thesis analyzes the major levels of STRM, starting with national security objectives, through missions, and finishing with defense resources. In order to show the practical use of the model; the thesis will focus on how the model could be used for determining defense resources for participation of Hungarian forces in NATO peace operations. This illustrative example does not, however, represent a comprehensive or precise list of Hungarian national security and military objectives.

The model used the structure established in the Joint Exercise Management Package (JEMP) III software, developed by the Dynamics Research Corporation. JEMP draws on Strategy-to-Task framework to connect missions and tasks that can be used in a broader hierarchy of objectives for defense. The software makes it possible for the user, to analyze any mission, operational objective, by breaking down these objectives into different tasks. When these tasks are identified and aligned by the mission phase, then conditions could be described for each task. In the last step, performance standards are assigned for each task to establish a measurable base for task evaluation. JEMP also connects the missions to different doctrines, therefore making possible to connect the missions with higher level objectives.

1. Peace operations and NATO's role in peace operations

Military operations other than war (MOOTW) became a more important mission of the military after the cold war. Besides counter drug and anti-terrorist operations, peace operations are considered the most important missions of the MOOTW. Usually three types of peace operations are differentiated: peacemaking, peacekeeping and peace enforcement. It is important to deeply analyze these different types, because the tasks of the military forces are different in the every case.

a) Peacemaking

Peacemaking is an effort to settle a conflict through mediation, negotiation or other forms of peaceful settlement. Peacemaking is normally carried out by diplomats and politicians. It combines negotiation with nonmilitary tools of coercion to achieve a resolution of a conflict. When these tools are inadequate, military tools may be used to establish and maintain, forcibly if necessary, a cessation of hostilities.

Peacemaking normally goes before the initiation of military operations. Depending on its success, peacekeeping or peace enforcement operation is in place after the peacemaking process. Peacemaking occurs simultaneously with, and continues throughout the duration of, peacekeeping and peace enforcement operations. The political goals and objectives established for the peacemaking effort help define the military objectives of the intervening forces and provide the commander parameters within which to develop supporting operational planning and execution. Thus,

peacemaking constitutes the political framework for application of military force. Without a peacemaking effort, peacekeeping and peace enforcement operations will always fail.

b) Peacekeeping

Peacekeeping includes the prevention, containment, moderation and termination of hostilities between or within states, through peaceful third-party intervention organized and directed internationally, using multinational forces of soldiers, police and civilians to maintain peace. There are two important factors to be aware of concerning peacekeeping operations:

- Peacekeeping forces must be perceived as neutral by all disputing parties.
- Peacekeeping forces must always be prepared for a quickly changing environment in which peace enforcement or combat may occur.

Peacekeeping operations are military operations conducted with the consent of the belligerent parties to maintain a negotiated truce and to facilitate a diplomatic resolution. Peacekeeping operations may take many forms of supervision and monitoring:

- Withdrawals and Disengagements
- Cease-fires
- Prisoner-of-War Exchanges
- Arms Control
- Demilitarization and Demobilization

These operations, therefore, require only passive participation from the forces. Peacekeeping operations support diplomatic efforts to achieve, restore, or maintain the peace in areas of potential or actual conflict. The greatest military consideration in peacekeeping is the political objective of the operation.

Normally, a peacekeeping force will deploy after the fighting has ceased. The nationality of the force is agreed to by the belligerents. The typical peacekeeping force has historically been a lightly armed, defensively oriented observer force that physically separates former combatants. It observed and reported its adherence to the cease-fire while negotiations for peace occurred. Its mission usually involves monitoring and supervising a cease-fire agreed to by two or more former combatants.

Peacekeeping forces assume that use of force will not be required to carry out their tasks, except in self-defense. Therefore, these operations do not require significant command and control systems. The contribution of independent states may only need to be administratively coordinated by supra-national organizations.

c) Peace enforcement

Military operations by sea, air or land forces as may be necessary to maintain or restore international peace and security, whether or not the belligerents are consenting to the intervention.

By definition: peace enforcement operations are military operations (including possible combat actions) in support of diplomatic efforts to restore peace between belligerents who may be engaged in combat activities. The following factors have to be considered in connection with peace enforcement:

- it does not have to end in combat,
- it is a subset of armed intervention,
- intervention force not perceived as neutral,
- an international mandate is required.

In a situation for which peace enforcement operations are required, armed conflict and not peace best describes the situation. Also, one or more of the belligerents usually prefers it that way. This means that, unlike peacekeepers, peace enforcers are not welcomed by one of the belligerents. Rather, the peace enforcers are active fighters who must force a cease-fire that is opposed by one or both combatants. In this process, they may be unable to preserve their neutrality.

Peace enforcement operations may be beyond the UN s ability to plan, command, and control. If this occurs, they may be carried out by a coalition of countries or by a regional organization such as NATO.

Because the forces involved in peace enforcement may use arms against the belligerents, sufficient military strength must be deployed to achieve the objectives established by political authorities. Unlike peacekeeping, enforcement will require a full

range of military capabilities that has the potential to meet or exceed that of the belligerents. Although the preferred objective is the commitment of superior military force to dissuade belligerents from further conflict, forces deployed for these operations should assume, at least for planning purposes, that the use of force will be necessary to restore peace. But unlike war, enforcement operations are more constrained by political factors designed to bring warring parties to the negotiating table. Settlement, not victory, is the goal.

The peace enforcement units will presumably have to fight its way into the combat zone and use force to physically separate the combatants.

There is a danger in believing that peacekeeping forces can be inserted into peace enforcement situations. Peace enforcement requires very different forces than does peacekeeping. While peacekeeping requires mainly passive force participation, peace enforcement usually demands active military involvement. This active participation makes it much easier to use performance standards for planning and evaluating the implementation of military task for this type of peace operation.

d) Hungary's involvement in NATO peace operations

As peace operations are concerned, Hungary participated in several peacekeeping operations (Cypress, Angola, Mozambique, Bosnia). Her active participation in the Implementation Force (IFOR) and Stabilization Force (SFOR) in Bosnia was considered to be a significant factor of inviting Hungary to join NATO. In her new status, a member

of the NATO Alliance, Hungary's effort in peace operations will probably change. There could be a change that shifts more emphasis from peacekeeping to peace enforcement. On the one hand countries participating in peacekeeping operations make their contribution to international peace with significant autonomy. Therefore, Hungary's NATO membership will not lead to a significant change in its method of operation. On the other hand, because peace enforcement operations will be carried out by groups of states and regional alliances, which have the necessary means to implement the mission, NATO's command and control responsibilities in this type of peace operations will increase. Consequently, Hungary as a member of NATO probably will play a more active role in these operations. Nonetheless, these operations consist of different objectives and require different means from participating forces than peacekeeping operations. The next part of the thesis will study the structure of STRM model, through focusing on Hungary's participation in NATO's peace operations (mainly in peace enforcement).

2. National Security Objectives

National security objectives compose the first level of objectives in the STRM model. These objectives usually contain all instruments of national power, including political, economic, and military power. The new Hungarian national security objectives address security in a broader term, which includes finance, human rights, minority rights, information and technology, environment, and international law.

National security objectives are derived from the threats to the country's fundamental goals. These goals are stated in the country's Constitution. Article V of the Hungarian Constitution states that the State of the Republic of Hungary safeguards the freedom of the people, the sovereignty and territorial integrity of the country, and the national borders registered in international treaties. Based on these basic goals the National Assembly has defined the principles and objectives of the national security of the Republic of Hungary.[12] These objective include:

- to guarantee the independence, sovereign statehood and territorial integrity of the country;
- to create appropriate conditions for enforcing the principles laid down in the Constitution, to promote the predominance of the rule of law, the unperturbed functioning of democratic institutions and market economy and to contribute to the internal stability of the country;
- to promote the full respect of civil and human rights and the rights of national and ethnic minorities in the Republic of Hungary;
- to create appropriate conditions for the assurance of personal, material and social safety of people living on the territory of the Republic of Hungary and the preservation of national assets;

[12] After the end of the Cold War, Resolution 27/1993 (23 April) of the Hungarian National Assembly was issued to define the principles of the national defense of the Republic of Hungary. The first part of the resolution dealt with the principles and objectives of national defense policy. At the end of 1998 these policies had been reviewed according to the fundamental changes in the external security situation of Hungary, mainly because of the achievements made in the field of Euro-Atlantic integration. Resolution 94/1998 (29 December) of the National Assembly on the Principles of the Security and Defense Policy was published to form security objectives to fit to the new security environment.

- to contribute to the implementation of what has been laid down in the North Atlantic Treaty and to the security of its Allies;
- to facilitate the preservation of international peace and the enhancement of the security and stability of the Euro-Atlantic region, Europe and its neighborhood;
- to contribute to the assurance of appropriate conditions for the international economic, political, cultural and other relations and co-operation of the Republic of Hungary.

The following figure shows a possible hierarchy of objectives that describes the relations between national security objectives and defense tasks. The figure focuses on peace operations and contains a more detailed description of the objectives within the peacekeeping and peace enforcement missions.

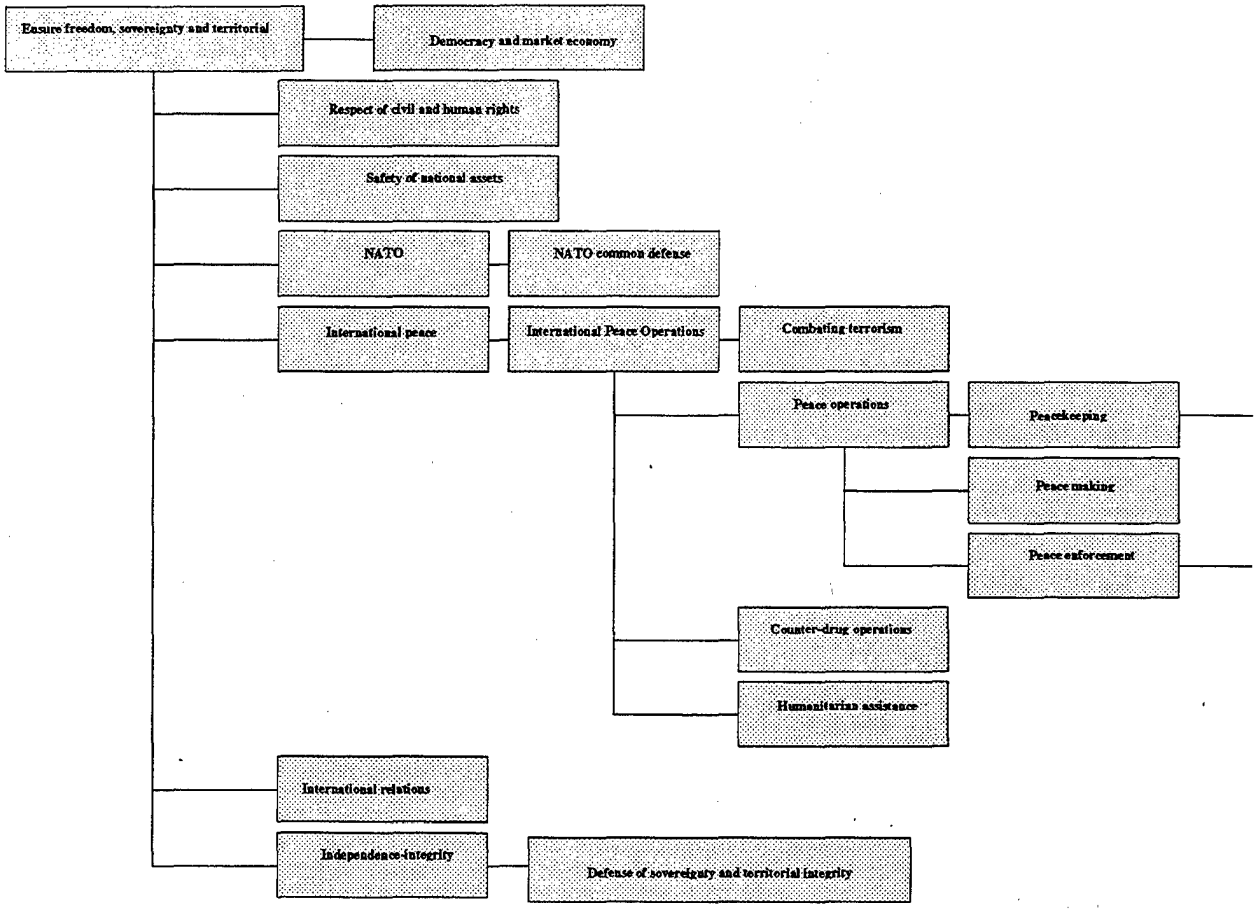


Figure 4. Hierarchy of National Defense of Hungary, Peace Operations

The document states that "the Republic of Hungary wishes to realize the above objectives in accordance with the Constitution, the norms of international law, with special respect to the principles and obligations enshrined in the Charter of the United Nations Organization, in the documents of the Organization for Security and Co-operation in Europe and the Council of Europe, in the North Atlantic Treaty and,

furthermore, in compliance with its obligations undertaken in other relevant international documents, regional and bilateral agreements." [13]

Hungary builds her security on two pillars: the national resources on the one hand, and Euro-Atlantic integration and international co-operation on the other.

3. National Military Objectives

National military objectives constitute the second level of objectives in the model. While national security objectives contain all instruments of national power, national military objectives state those objectives to be achieved through the use of military means. The resolution of the National Assembly also determined the main military objectives of its Armed Forces. The main task of the Armed Forces is the defense of the sovereignty and territorial integrity of Hungary and contribution to the Alliance's collective defense. Furthermore, the Armed Forces are required to contribute to other jointly perceived allied missions of international peace operations, engage in peacekeeping and humanitarian actions carried out under the auspices of international organizations. The next level of the hierarchy will study the missions of these peace operations.

[13] Legal background. http://193.6.238.52/ MOD/jogi_e.htm [Available Online]

4. Missions

Below national military objectives, missions constitute the third level of the model. There are four types of these missions: force employment, military operations other than war, planning and support. Within military operations other than war several operations can be differentiated:

- Combating terrorism (counter-terrorism and anti-terrorism),
- Peace operations (peacekeeping, peacemaking and peace enforcement),
- Counter-drug operations and
- Humanitarian assistance.

The model focuses on peace operations and has a detailed hierarchy of objectives and tasks in this area. Obviously, it is possible to establish such a hierarchy for the other missions. This model intended to demonstrate the idea of Strategy-to-Task model through studying peace operations; however the hierarchical methodology can be applied to other operations and missions.

Peace operations are divided into three types of missions: peacekeeping, peace-making and peace enforcement. Each mission requires implementation of different objectives and tasks from the armed forces.

5. Objectives

At the next level, objectives are formulated by the Major Operational Commands. They are the specific actions that must be performed in order to achieve a mission. Each objective is defined by a concept of employment. This concept of employment interlaces together the different systems, organizations, and tactics required to achieve a particular task in an end-to-end manner.

Tasks are means to achieve objectives. Every theater objective has at least one operational task related to it. Individual tasks could be broken down in order to separate different ways of accomplishing objectives; therefore pinpointing critical activities necessary to achieve an objective. This concept of employment specifies capabilities needed to achieve objectives and allows association of force elements with accomplishing missions.

Tasks cannot be performed unless all of the required capabilities are provided at a minimal level. When assessing the abilities to accomplish a task, concepts of operations (and their required capabilities) and the resourcing of program elements must be considered.

In case of peacekeeping operations, the model identified the following objectives: supervising cease-fires, movements observation, disarming military forces, providing

security to population, training and leading de-mining teams and protecting humanitarian aid convoys.

Peace enforcement requires different objectives. The model includes the following objectives for these operations: force deployment/conducting maneuver, developing intelligence, employing firepower, performing logistics and combat support, exercising command and control and protecting the force.[14]

These objectives consist of several tasks. The importance of the tasks is that they have a more narrow definition and it is easier to create performance standards for them. The model includes several tasks for each objective under peace enforcement. For instance the objective, Perform logistics and combat support, has five tasks: provide personnel, base and mission support, conduct resource management and equipping the force. Other objectives have sequential tasks, which are following each other in the implementation. This results a particular interaction among the different performance standards, which will be discussed in the next chapter.

6. Performance Standards

Performance measures or performance standards contain the last level of the model. Measures of performance simply reflect some aspect of observable performance.

[14] The objectives used for peace enforcement are based on the task list available in the Joint Exercise Management Package III. Developed by the Dynamics Research Corporation.

It is possible to assign several performance standards for each task. The performance standards in the model are developed for this thesis only for demonstration purposes.

It is important to distinguish performance measures, measures of performance from measures of utility. While these terms have often been used interchangeably, there is a significant difference between them. Unlike performance measures, measures of utility directly index the contribution level of task performance to objectives for operations or missions. The utility associated with achieving a particular performance level is measured by using a Single Utility Function (SUF). To compare the utilities determined by the different SUFs, the model uses different weights, which were determined by a consulting group to make the model more realistic. In defense planning these weights could be determined by teams or working groups coming from different parts of the defense establishment, to ensure an acceptable level of reality. Chapter IV includes a detailed description of the methods used for weight setting.

Therefore, performance measures simply describe the levels of performance without attempting to connect them directly to mission success.

7. Resource management in Strategy-to-Task

An end-to-end concept of operations describes capabilities required to accomplish tasks and permits association of force elements, programs, with achieving missions. Assessments of our ability to accomplish the tasks depend on the concepts of operation considered as well as the resources available for the different program elements. There is

an additional category to consider for the model. These are the force elements; most of that may also be called programs. Tasks are accomplished by using force elements. Basically, it is a sequenced application of capabilities. The capabilities can be accomplished by one or more force elements alone or in combination. The different programs would include linkages to capabilities and tasks. For every program an audit trail would be developed to assess the capabilities and the ability to perform certain tasks using these capabilities. Force elements could be the distinct, fundable military programs most visible to the Parliament and to the public. All defense programs should be linked through aggregated capabilities by using a framework to provide a better context for resource decision-making.

The key point of this framework is that resource issues must be addressed by explicitly using linkages of resources to supported objectives in decision-making and in program development. When an issue, such as canceling or cutting funds for force elements participating in peacekeeping programs arises in the budgetary process, the MoD would quickly be able to identify tasks and missions influenced by peacekeeping programs, and assess the effects of the reduction on other high objectives.

Regular reviews of the programs would ensure that updated information is available for decision-making on defense resource allocation and budgeting. During the program review, national and military objectives influenced by the program would be identified. The hierarchy of objectives, the Strategy-to-Task model would help to

determine these linkages. The implication of changes in resourcing on missions would be simply displayed. Assessment of current and future adequacy of the program would be included in the debate. If principal and related higher level objectives and task are not met or supported by the program, then alternatives for achieving these objectives are identified. It is important to emphasize the need to consider tradeoffs at all levels.

D. CHAPTER SUMMARY

This chapter focused on describing the Strategy-to-Task model through the example of Hungary's participation in NATO peacekeeping operation. The model starts with national objectives based on basic national needs, goes through military objectives and missions, and stops at the level of tasks achieved through performance standards. The model drew a map of the hierarchy of objectives in the field of defense and national security. By using this hierarchy basically all military tasks could be linked to military and national security objectives through missions. This linkage would help planners and decision-makers basically in the MoD and the Parliament to understand the consequences of resourcing and budgeting decisions. The model enables decision-makers to understand how a reduction of funds for a certain program would influence attaining higher-level military and national security objectives.

IV. SETTING PRIORITIES IN THE STRATEGY-TO-TASK MODEL

A. INTRODUCTION

The first three chapters described the hierarchy of objectives that can be established for national security planning. This hierarchy goes from the nation's need for defense, through national security, military objectives and missions to the tasks necessary to implement these objectives. For certain tasks, performance standards may be available. This hierarchy of objectives creates a multi-attribute decision making situation for defense planners, where they have to chose between alternatives according to each alternative's contribution to the implementation of the different sets of objectives.

This chapter will study the two well-known methods for decision-making, the Multiattribute Utility Function Analysis (MAUFA) and the Analytic Hierarchy Process (AHP). Benefits and pitfalls and potential use of both methods will be discussed in this chapter. These methods can help decision-makers to understand the relationship between objectives on the same and different levels and use this information in resource management decisions. The same model, the Hungarian participation in NATO peace operations, is used to illustrate these two methods.

The first section will study the situations, where numeric measurements could be applied. In these cases the Multiattribute Utility Function Analysis gives a better approach to foster decision-makers to choose between alternatives.

B. ESTABLISHING PRIORITIES WITH MULTIATTRIBUTE UTILITY FUNCTION ANALYSIS (MAUFA)

Decision-makers in the field of defense always face situations where they are forced to allocate resources between alternatives that differ in many attributes and related different sets of objectives. In comparing the alternatives in the field of defense, the highest question always comes down to study how well the different alternatives influence the ultimate goal of the hierarchy, to sustain the survival of the nation. The decision maker can use the model of hierarchy of objectives, the Strategy-to-Task model, to analyze how strongly the individual factors of the lowest level of the hierarchy, the tasks and the different force elements, affect the objective on the top. By making this comparison, better decisions could be made. However, the comparison of these multi-attribute alternatives requires a stable, consistent and reliable decision-making model.

Usually, it is possible to measure performances of different tasks with one or more standards. For these cases, Multiattribute Utility Function Analysis provides a better approach to the solution.

1. Description of MAUFA

In most cases, when decision-makers face complex situations, they are able to directly assign values to different objectives, their tasks and performance standards. They can determine how much they value a certain amount of the task within a given relevant interval. In economics this value is measured in a common unit, called utility. In a complex situation, when several tasks are connected to objectives, decision-makers have to measure performance and decide how these performances contribute to implement the tasks and the objectives. Therefore, a measure of performance could be used develop the utility of each performance, and weights could be used to determine the importance of the performance in terms of the tasks and the objective. We shall assume that the decision-maker's preferences can be represented by a function of added and weighted utilities. This function is the multi-attribute utility function. [15]

The next section deals with the application of MAUF analysis through the example of participating in peace enforcement operations.

2. Setting priorities with applying MAUFA (peace enforcement example)

According to Figure 4, peace operations consist of peacekeeping, peace making and peace enforcement operations. As described in Chapter III, peace enforcement operations contain several objectives and tasks. There are several performance standards

[15] Appendix B provides a more detailed discussion of the additive multiattribute utility functions.

that could be assigned to these objectives. Figure 5 shows the objectives used for peace enforcement in the model.

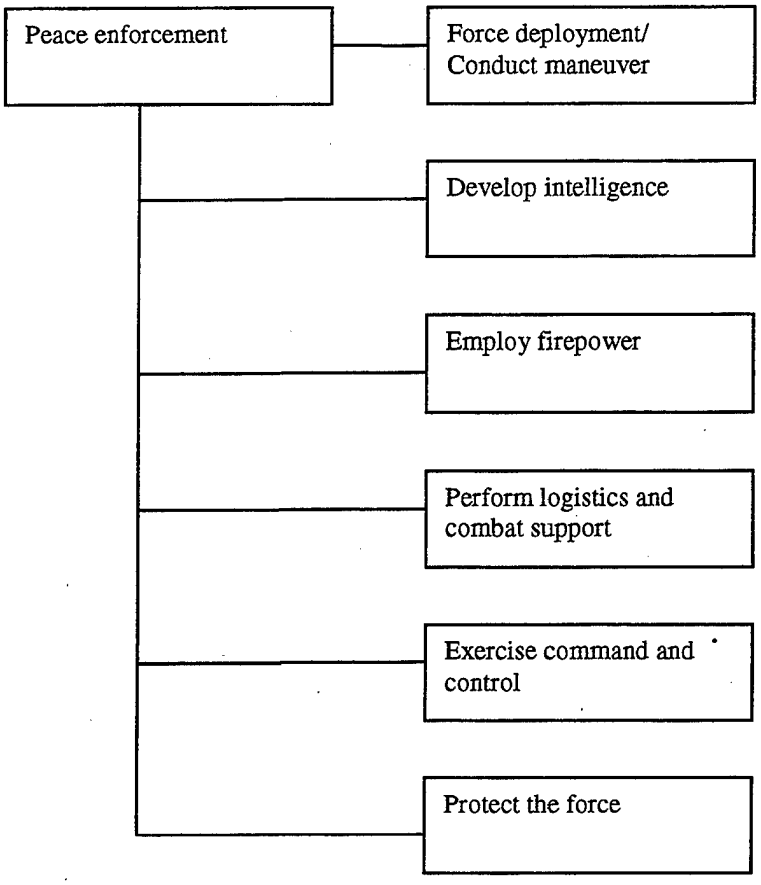


Figure 5. Peace Enforcement Objectives

Table 1 shows the tasks for these objectives and the performance standards associated with the tasks.

Objective	Task	Performance standard
Force deployment/conduct maneuver	Deploy forces	Percent of forces deployed
	Assess area of operations	Area assessed
	Position communication and navigation systems	System positioned
	Redeploy forces	Forces redeployed
Develop intelligence	Plan and direct tactical intelligence activities	Intel implemented vs. planned
	Collect information	Information collected vs. planned
		Information level
	Process information	Information processed
		Number of reports prepared
	Prepare intelligence reports	Number of reports prepared1
Employ firepower	Process targets	Targets processed
	Employ air power	Percent air power employed
	Control forces	Control level
Perform logistics and combat support	Provide personnel support	Level of support provided
	Perform base support	Level of support provided2
	Provide mission support	Level of support provided1
	Conduct Resource management	Level of resource management
	Equip the force	Force equipped
Exercise command and control	Acquire and communicate information	Communication errors
	Assess situation	Accuracy of assessment
	Determine actions	Number of Alternatives
	Direct and lead subordinate forces	Level of leadership
Protect the force	Enhance survivability	Survivability
	Provide force protection	Casualties
	Perform rescue	Forces rescued

Table 1. Objectives, Tasks and Performance Standards for Peace Enforcement

These standards are used to develop a single utility function for each task. These utilities then could be added, by using weights, to determine the utility function for a certain objective, for example developing intelligence, or ultimately, for the goal of peace enforcement.

Single Utility Functions are developed for the different performance standards. The utility ranges between zero and one for each SUF. The least and the most preferred values represent the two endpoints for the horizontal axes. The "knee" of the curve represents the performance standard, at which an incremental increase in performance results in the greatest decrease in the increase in utility. See Figure 6 and 7.

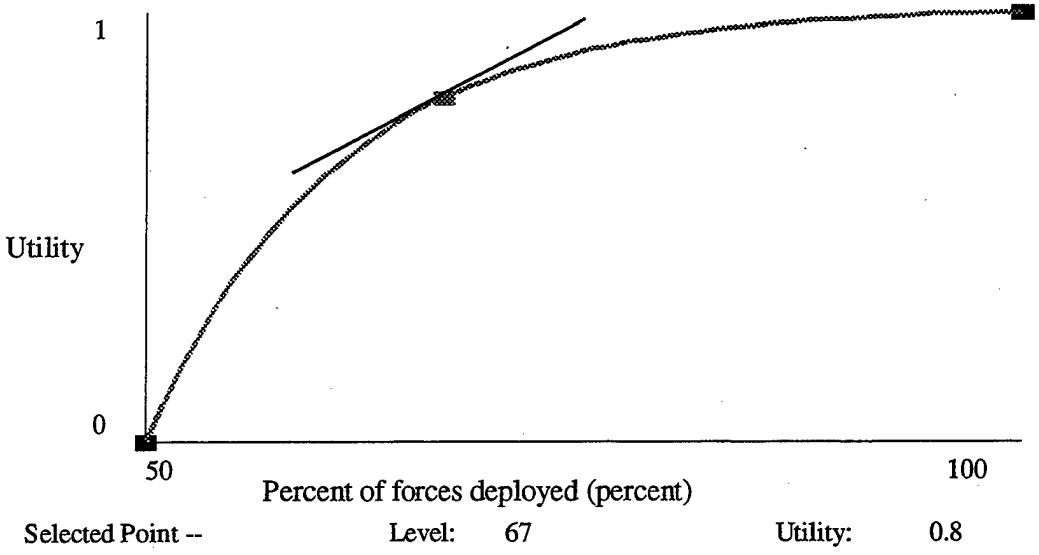


Figure 6. Single Utility Function for Deploy Forces Task

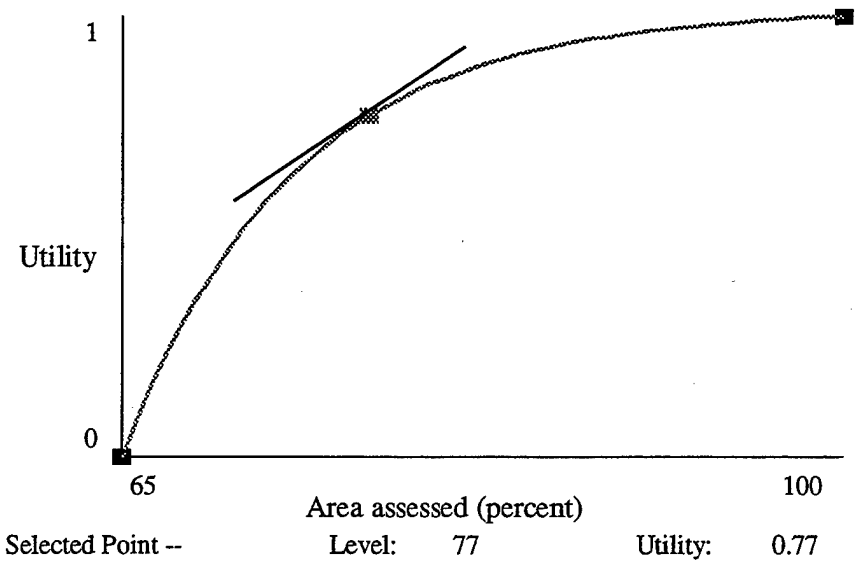
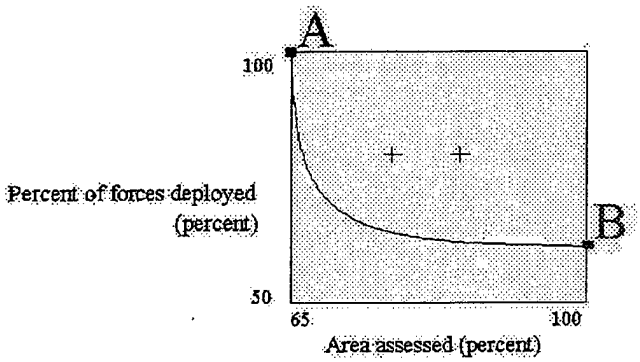


Figure 7. Single Utility Function for Assess Area Task

The model uses tradeoff curves among performance standards under a given objective by weighting the tasks. The tradeoff method defines weights by making pairwise comparisons between measures that define pairs of equally preferred simple alternatives. These tradeoff curves describe how the decision-maker is willing to change one performance, or objective, for another performance, or task. Figure 8 illustrates such a tradeoff curve.

Besides the tradeoff curve the figure also shows the performance for the two alternatives studied in the model (+). The model can show pairwise utility functions curves for the studied performance standards. Figure 9 shows these utility curves.



	A	B	A-B
Area assessed (percent):	65	100	-35
Percent of forces deployed (percent):	100	61.5969	38.4031

Area assessed Measure Weight:Percent of forces deployed Measure Weight = 0.335937:1

Tradeoff computed by Logical Decisions

Preference Set = NEW PREF. SET

Figure 8. Tradeoff Curve for Tasks Deploy Forces and Assess Area

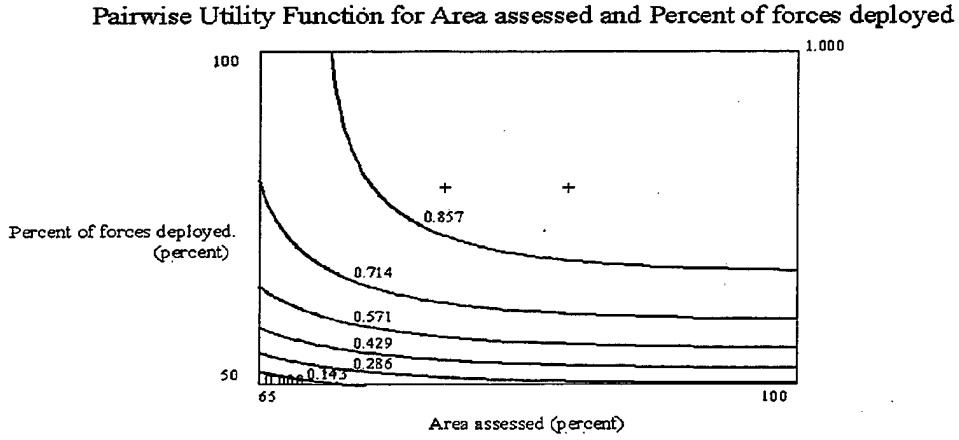
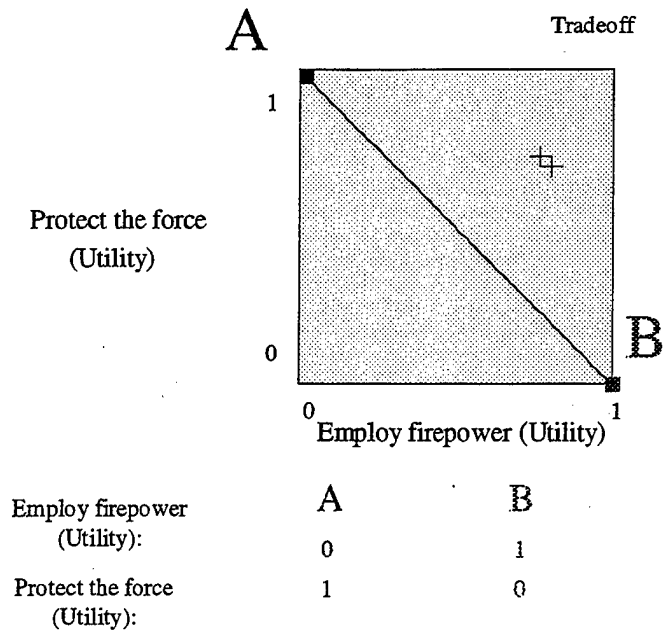


Figure 9. Pairwise Utility Function Curves

Each curve represents a certain level of utility that is the result of the combinations of the two performances. The shape of the curve illustrates the relationship between the two performances. The curvature comes directly from the curvature of the SUFs. Therefore, the shape of the SUFs determines the shape of the pairwise utility function. The model assumes that there is no interaction between the different tasks.

After tradeoff curves have been established for the different tasks, decision-makers have to determine weights for the next highest level in the hierarchy, the different objectives under a given mission, in the model under peace enforcement. The next figure illustrates such a tradeoff curve for two peace enforcement objectives: Protect the force and Employ firepower.



	A	B
Employ firepower (Utility):	0	1
Protect the force (Utility):	1	0

Figure 10. Tradeoffs Between Two Peace Enforcement Objectives

What we are assuming is that the weights at the task level permit the utilities to be compared. At the objective level, therefore, the trade off curve is linear with a slope equal to minus one.

When the weights are defined, decision-makers can analyze force alternatives for the operation. One alternative for the peace enforcement operation is to use general forces, a second is to establish specialized forces for this operation. The model gives an evaluation of the alternatives according to the utility level provided.

In this setting general forces used in peace enforcement and peacekeeping could include a mechanized infantry division, or a light battalion of the army. This general

force would be equipped with weapons and be trained as if it was used for general military operation. The reason for using these troops would be based on their availability and closeness to the peace operations.

The alternative specialized forces refer to forces specially designed for peace operations, such as peacekeeping and peace enforcement. These forces would be specially trained and equipped for the mission of peace operations. Their special training could basically consist of reaction to the typical situations that occur in a peace operation environment. Some of their specialized equipment, such as special boots used for detecting and disabling mines, effectively could not be used for other operations.

For illustrative purposes, the model used the following performance levels for the two alternatives for peace enforcement.

Performance	General force	Specialized force	Unit
Percent of forces deployed	80	80	Percent
Area assessed	85	80	Percent
System positioned	81	92	Percent
Forces redeployed	70	75	Percent
Intel implemented vs. planned	85	90	Percent
Information collected vs. planned	88	95	Percent
Information level	Good	Better	
Information processed	84	85	Percent
Number of reports prepared	3	4	
Number of reports prepared1	2	2	
Targets processed	86	88	Percent
Percent air power employed	85	75	Percent
Control level	Medium	High	
Level of support provided	High	Medium	
Level of support provided2	Medium	High	
Level of support provided1	High	High	
Level of resource management	Medium	Medium	
Force equipped	85	92	Percent
Communication errors	3	2	
Accuracy of assessment	Medium	High	
Number of Alternatives	2	2	
Level of leadership	High	High	
Survivability	83	93	Percent
Casualties	1	1	
Forces rescued	84	90	Percent

Table 2. Performance Levels of the Alternatives

The performance level for each alternative is converted to utilities by using the relevant Single Utility Functions. These single utilities then are aggregated according to their weights. Appendix A contains a detailed description of these weights. The obtained aggregated value of utility describes the alternatives that are comparable by using these

values. In the model, the following utility was obtained in the peace enforcement mission.

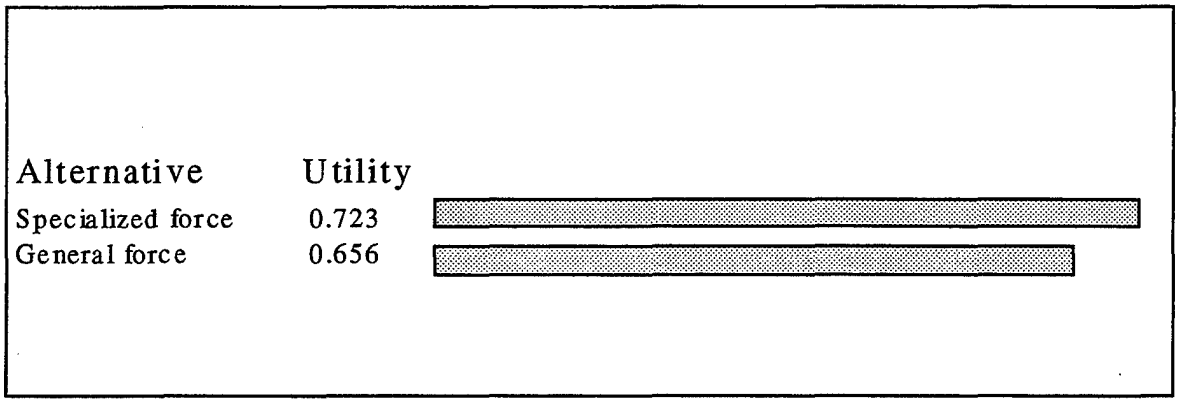


Figure 11. Alternative Utility for Peace Enforcement from Force Alternatives

The utility of the alternatives can provide important information for the decision-maker. The difference in utilities between the two alternatives provides useful information for assessing the two alternatives. The absolute utility received by choosing one alternative is also interesting. This level can be compared to a utility of 1.0, the highest possible utility and 0 the lowest utility level achieved with maximum and minimum performance, respectively, being obtained on all the performance standards.

MAUFA could be used to assess the alternatives up to a certain level in the model. This level is limited partially by the ability to determine performance standards for objectives and tasks, and directly assign utilities to these performance standards. The model, therefore, used Multiattribute Utility Functions up to the level of peace enforcement operation.

3. Advantages and Shortfalls of MAUFA

MAUFA is a useful tool for decision-support in complex situations where attributes with performance measures exist. In the model, these performance standards exist under peace enforcement operations. The MAUFA provides more opportunities for decision-makers, than the last section showed. First, uncertainty could be built into the model to use an approach closer to reality. Appendix B provides a more detailed description of how MAUFA can deal with uncertainty. Second, MAUFA can deal with situations, where there is not only a task-performance standard relationship, but there is a relationship between the performance standards under the same task. For instance, when the tasks follow each other in a sequential manner, the performance of the third in the row depends on the performance of the second that depended on the first. In these situation the performance level on the first task has multiple influence on the utility calculated for the objective.[16] Appendix C of the thesis illustrates this situation.

However, when identifying performance standards is not obvious, like in case of peacekeeping, then using MUAFA to determine the Single Utility Functions is somewhat more difficult. In such cases instead of direct assessment of utility decision-makers may choose to use the Analytic Hierarchy Process method for evaluating the relationship and

[16] Because of the mutual utility dependence, these functions are calculated in different manner, by using multiplicative utility function.

setting priorities among objectives and tasks. The AHP tool could be a useful tool for these situations.

C. APPLICATION OF AHP FOR DEFENSE RESOURCE PLANNING AND ALLOCATION

The previous section studied situations where MAUFA could be used within our model hierarchical objectives. In these situations decision-makers can describe the attributes, measures or performance standards with numeric values. However, in some situations determining numeric values of the objectives is difficult or may not be possible. For instance, going higher on the hierarchy of objectives, decision-makers face more and more complex objectives. The more complex the objective is, the less possible it is to identify a performance standard for this objective. In these situations, pairwise comparison could be used to determine the relationship among objectives, and set priorities. The modified Analytic Hierarchy Process is a well-known analytic tool to use in these situations.

1. Description of the original AHP model

The process of decision-making is concerned with weighting options, all of which fulfill a set of desired objectives. The problem is to choose that alternative which best fulfills the entire set of objectives. The purpose of the process is to derive numerical weights for alternatives with respect to sub-objectives and for sub-objectives with respect

to higher order objectives. These numbers should provide adequate information for decision-makers helping them to allocate resources based on these priorities.

Dr. Thomas L. Saaty, a professor of the University of Pennsylvania, introduced the Analytic Hierarchy Process in 1977. AHP was built to deal with complex real world situations. The method assumes that decision-makers have to face complex situations, where it is hard to assign certain numeric values to describe the different features of alternatives. Making simplifying assumptions about the world to suit the quantitative models is not sufficient. A realistic model should deal with complex situations as they are, and must include and measure all important tangible and intangible, quantitatively measurable and qualitative factors.

According to the AHP model, the determination of the priorities of the lowest factors relative to the goal, could be reduced to a sequence of priority problems, one for each level. The problem can, therefore, be reduced to a sequence of pairwise comparisons. Comparing two objective or attributes has the advantage of focusing exclusively on two objects at a time and on how they relate to each other. The disadvantage of this process is that it generates more information that is really necessary since each objective is systematically compared with every other.

Another feature of AHP is the scaling used for describe the relation between two objectives or attributes. Sometimes it is impossible to assign direct numeric values to

objectives and then make the pairwise comparison. Therefore, during the process of pairwise comparison, decision-makers have to use a scale to express their preferences. This scale could consist of numeric values of (1,3,5,7,9) representing the relationship ranging from equal to extreme. The verbal scale could include equal, moderately more, strongly more, very strongly more and extremely more, standing for the numbers mentioned above.

Hierarchies represent the most important elements in the decision situation and their relationship. However, hierarchies alone do not provide a very powerful tool for decision-making or planning. Decision-makers need a method to determine the potency with which the various elements in one level influence the elements on the next higher level. This method could foster computing the relative strengths of the impacts of the elements of the lowest level, through the hierarchy of objectives, on the overall objective.

To determine the relative strengths, or the priorities, of the elements in one level relative to their importance for an element in the next level, AHP creates a matrix of relationship among the elements. The values of this square matrix represent the relationship between two elements on the same level, one showed in the given row and the other displayed in the column. After the necessary calculations have been implemented, decision-makers obtain information about the relative strengths of the different objectives of one level, concerning an objective on the next level.[17] The process

[17] Appendix D contains detailed description of the calculation.

of creating these weightings through the whole hierarchy of objectives makes it possible to get a numeric value describing the relationship between the lowest level objectives, tasks, and the top goal. Appendix D gives an illustration of AHP through the example of buying a car.

2. Shortfalls and possible modifications of AHP

The AHP contains several possible problems. While two issues, scaling and ordering are serious matters; the problem of rank reversal is seen as the most significant issue regarding the usefulness of AHP.

As James S. Dyer states in his Remarks on the Analytic Hierarchy Process, "The difficulty can be simply stated as follows: The ranking of alternatives determined by the AHP may be altered by the addition of another alternative for consideration." [18]

In some cases, when an additional alternative was to be considered, AHP can give a different result for decision makers, and show that their preference of alternatives has changed, even if the new alternative considered has the same attribute levels as an original alternative. A more detailed description of the rank reversal problem can be found in the literature.[19]

[18] Management Science Vol. 36 No. 3, March 1990 p. 252.
[19] See, for example, Schoner and Wedley, Roper and Sharp and Belton and Gear.

The disregard for measurement units causes the problem of rank reversal; thus eliminating it would abolish rank reversal. Defining an underlying scale based on a standard could be a solution. Both the scale intervals and the standard can be discretionally chosen; however after they exist, measurements must be consistent with this scale. In this case, however, MAUF can be developed.

In AHP, pairwise comparisons are limited to a nine-point integer scale. It leads to inconsistency since no attribute or alternative can be, for example, 2.5, 4.1 or 12 times more important than another. In other cases it is impossible compare alternatives by using AHP's 9-point scale. Suppose, as an example, there are three alternatives, X, Y, and Z with the following comparison results. X has extreme importance over Y that means X over Y is 9, and Y has extreme importance over Z that is Y over Z is 9. The logical relationship between X and Z would be 81. AHP, however, cannot describe consistently the relationship between X and Z, because the value for specify the most extreme relationship is 9.

There is a solution for this problem. First, the decision-maker should identify the extreme, the most and the least preferred, attributes. The least preferred attribute would be defined as one on the scale, and the most preferred would be defined as nine. In this method, all attributes would be within the scale. Following the example above, X, Y and Z might be defined by 9, 3 and 1 accordingly.

The AHP uses the eigenvector method, as illustrated in Appendix D, to determine the weights from pairwise comparisons. According to Hihn and Johnson, there is no reason to believe that AHP generates the most desirable solutions using the eigenvector technique.

Alternatively, using the Least Square Error method to fit weights to alternatives or attributes ensures a more exact solution in the case of inconsistency in the decision-maker's preferences.

3. Applying AHP in the model of Hungarian participation in NATO peace operations (peacekeeping)

As described in the last section, a modified version of the Analytic Hierarchy Process can be a useful tool in assigning weights to the different objectives in complex situations, where numeric evaluation of the objectives is difficult. The following figure demonstrates a possible hierarchy of objectives that was described in the previous chapter. The hierarchy contains a detailed path starting from the top level objective and going down to the different tasks of peace operations, like peacekeeping, peace making and peace enforcement. This hierarchy meets the requirement of complexity described above; therefore AHP could be used for this part of the model. By pairwise comparison of the objectives that are on the same level, decision-makers can identify the relative importance of the objectives and identify their importance in the objective on the next level. For instance this method could be used to determine the relative strengths of the objectives of combating terrorism, peace operations, counter-drug operations and

humanitarian assistance concerning International Peace operations as higher level objective. First, decision-makers have to identify the most and least important of the four lower-level objectives and have to give values 1 and 9 accordingly. Then they have to express how they evaluate the importance of combating terrorism compared to the other three objectives. Then they have to compare peace operations to counter-drug operations and humanitarian assistance. The last comparison would be of counter-drug operations and humanitarian assistance. When the matrix is ready, decision-makers could determine the eigenvector.[20] The eigenvector will determine the priority between the different objectives. It is an important to determine the priority weights for these objectives, because this makes it possible to sum the relative importance of the different tasks and their elements in terms of the top goal of ensuring defense for the nation.

At the lowest level, however, the full process of AHP could be applied to determine the best alternatives. The same process should be followed in order to determine the importance of the different tasks connected to a certain objective, for example peacekeeping. Figure 12 demonstrates the hierarchy used for peacekeeping. The different tasks of peacekeeping could be prioritized according to the value of the eigenvector. Afterwards, a matrix has to be made with the alternatives for each task. The alternatives could be the same that was used in case of peace enforcement operations, to participate in peacekeeping operation with a specialized and exclusive peacekeeping

[20] The eigenvector is determined by squaring the matrix and normalizing it until there is no change in the fourth decimal place between the eigenvectors.

force or to use conventional forces in this mission. By calculating the eigenvectors, the decision-makers can determine the relative strength of the alternatives in each objective. After all the eigenvectors are determined for the tasks, a matrix could be set up where the rows are the different alternatives and the columns represent different tasks. This matrix can be multiplied by the original eigenvector for the tasks and then the decision-maker can get the relative benefits for each alternative.

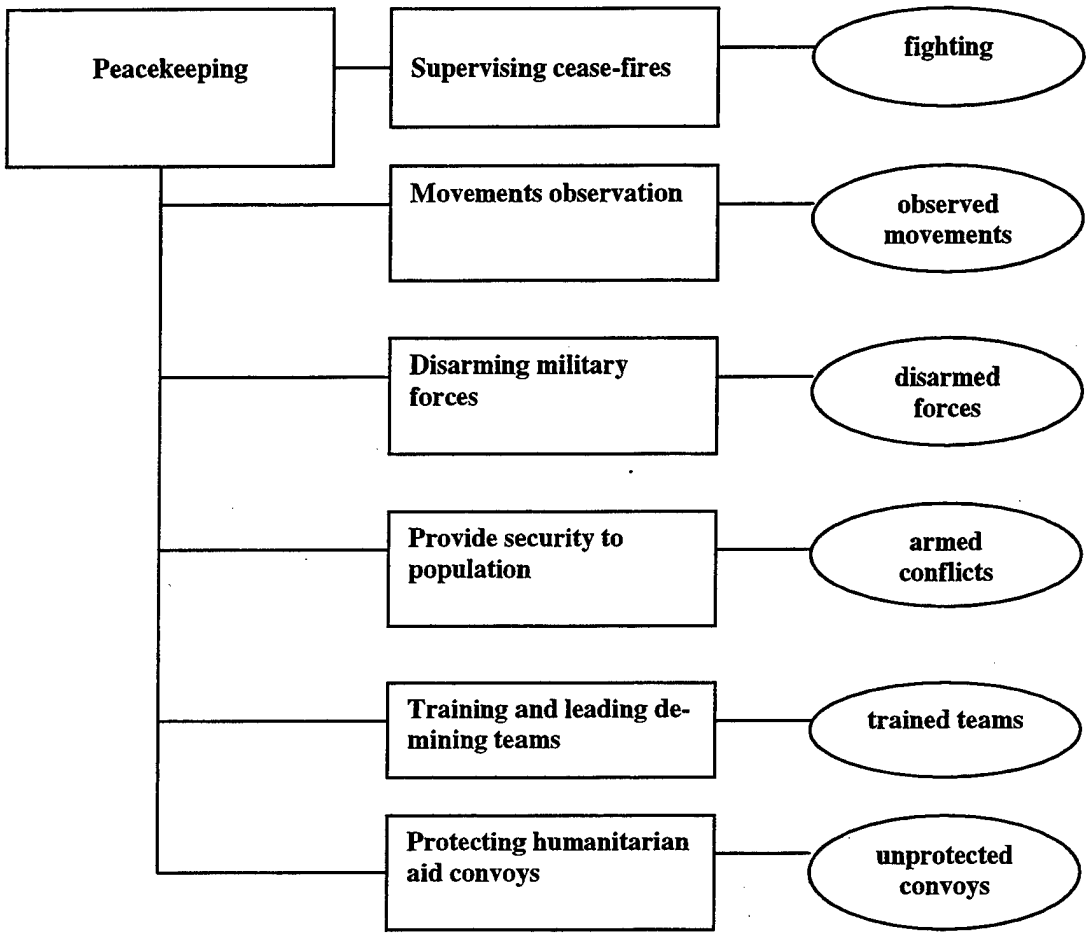


Figure 12. The Hierarchy for Peacekeeping

The process of creating the matrices for both the tasks and the alternatives is complex; therefore the pairwise comparison has to be implemented by a group of experts, representing the different stakeholders. These stakeholders represent different interest groups and have different point of views.

Table 3 illustrates a matrix of pairwise comparison, used for evaluating the relationship among the tasks under peacekeeping. The modified version of the Analytic Hierarchy Process seems to be a useful tool in the case, when numeric measurements for alternatives could not be directly applied because of the specifics of the tasks.

	Supervising cease-fires	**Movements observation**	**Disarming forces**	**Providing security**	**Train de-mining teams**	**Protecting humanitarian aid convoys**
Supervising cease-fires	0.310	2.000	1.000	3.000	3.000	2.000
Movements observation	0.500	0.070	0.250	0.250	0.500	0.500
Disarming forces	1.000	4.000	0.149	0.500	1.000	1.000
Providing security	0.333	4.000	2.000	0.195	2.000	1.000
Train demining teams	0.333	2.000	1.000	0.500	0.101	0.333
Protecting humanitarian aid convoys	0.500	2.000	1.000	1.000	3.000	0.174

Table 3. Pairwise Comparison Matrix Used for AHP for Peacekeeping Operations

For example, in the first row, comparing task Supervising cease-fires to task Disarming forces has the same importance (1.000). In comparing task Movement observation to task Disarming forces, the sample matrix shows, that the latter has more

importance, on our measure between moderate and strong, than Movement observation (4.000 and 0.250).

To measure the alternatives for each task, separate matrices are used, where the alternatives are compared in the same way for a task. By aggregating the weight between the alternatives and the weight among the tasks, the two alternatives can be compared at the level of peacekeeping operations.

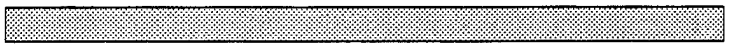
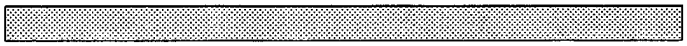
Alternative	Utility	
General force	0.514	
Specialized force	0.486	

Figure 13. Ranking Alternatives for Peacekeeping Operations by Using AHP

After obtaining the utilities for peacekeeping and peace enforcement, it is important to see how the different approaches, the MAUFA and the AHP, could be used at the same time to evaluate alternatives at the higher level of peace operations. The model used AHP to measure the relation between the two objectives. Appendix A contains the weights used in the model for peace operations. After determining the relative importance of peace operations to peacekeeping (0.3333), the weight was used to determine an aggregated value for the alternatives at the level of peace operations. Figure 14 shows these values.

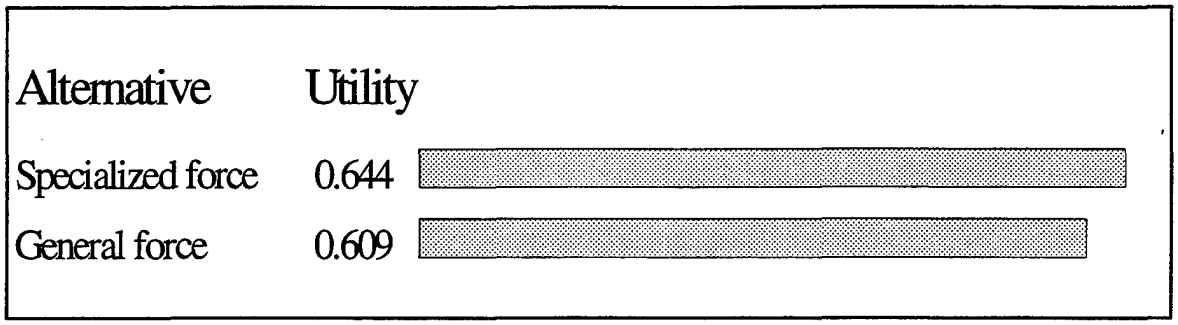


Figure 14. Value of Alternatives at the Level of Peace Operations

As the figure shows, in our model the value of the alternatives in the level of peace operations becomes more balanced. The reason is twofold. First, the ranking of alternatives in the peace enforcement objective evaluation showed a moderately large advantage for using specialized forces (0.723 and 0.656 = 0.067); while in the peacekeeping this was (0.514 and 0.486 = 0.028) advantage for using general forces. While the weights between peacekeeping (0.3333) and peace enforcement (0.6667) indicate that peace enforcement has more importance than peacekeeping. The smaller difference in the peacekeeping utility scores results a more balanced ranking. The same method could be used to determine the ranking of alternatives for higher level objectives. The model could compare peace operations or peace enforcement to other operations in the hierarchy of objectives up to the highest level of national objectives, by using AHP and following the procedure described above. Decision-makers only have to identify the level, where the alternatives are comparable. Because the model focused on peace operations and used detailed information only in this area, it is not possible to show this comparison. However, when several levels of objectives and tasks are established for other branches of the hierarchy, the relevant comparison could be made.

D. CHAPTER SUMMARY

This chapter focused on the two methods that could be used to define priorities, weights, for the different objectives and tasks of the hierarchy. The chapter gave a detailed overview of Multiattribute utility function analysis and its use to calculate utilities for the two alternatives and rank them in connection with the peace enforcement mission operations. The MAUFA was shown to be a useful tool for alternative evaluation in cases, when performance standards could be set up for objectives and tasks.

In other situations, when such performance standards are difficult to establish, the Analytic Hierarchy Process turned out to be a helpful method. The chapter demonstrated the further use of AHP for comparison of alternatives when higher level objectives are taken into account.

V. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

Defense planning can make extensive use of a model directly connecting national security objectives to tasks of the armed forces. Among the different planning approaches, the Strategy-to-Task model may best clarify the hierarchy of objectives in defense planning. The hierarchy consists of several levels. National security objectives constitute the top level. One level below, national military objectives can be found, followed by missions. Objectives and tasks compose the next level, under missions. Performance standards constitute the lowest level of the hierarchy and measure the achievement of the tasks. Performance standards can be used to develop the utility function for a task. The hierarchy helps the decision-maker compare different tasks and objectives that otherwise would be difficult to measure. It also may improve resource allocation decisions by enabling decision-makers to compare the utilities of different alternatives and describe this comparison in different levels of the hierarchy. The process of building the Strategy-to-Task hierarchy enables decision-makers to receive a clear understanding of the relations among the objectives and to connect their decisions to these objectives. The model helps to understand how much influence the tasks of the armed forces have on achieving national military and national security objectives.

The thesis studied two analytic methods for the Strategy-to-Task method to establish utilities at each level of the hierarchy.

Multiattribute Utility Function Analysis was shown to be a useful tool for alternative evaluation in cases, when performance standards can be developed for objectives and tasks. In contrast, the Analytic Hierarchy Process turned out to be a helpful method in situations, when such performance standards are more difficult to establish. The thesis discussed how AHP might be used to make comparisons of alternatives from the angle of higher level objectives.

B. RECOMMENDATION

The Strategy-to-Task planning approach is a useful tool for defense planning. The great benefit it provides for civilian and military decision-makers, through ensuring understanding of the hierarchy of defense related objectives and tasks, is that it leads to better decisions. The Strategy-to-Task model could serve as a useful substitute planning tool in countries where defense resources are planned but there is no clear linkage to national security objectives. In the first step a detailed hierarchy should be worked out by stakeholders, such elected politicians, high-ranking military leaders and representatives of several organizations of the defense sector.

The high-level national security objectives should be based the country's Constitution and on other legislation. The hierarchy should account for the entire defense establishment, in order to see all the relationships among the objectives and tasks.

Senior policymakers should discuss the weights for at least the first two levels of the Strategy-to-Task hierarchy. These weights should be subject of review every year, and needed changes should be taken place.

In the final step, an information technology management system should be set up according to the hierarchy, but should also permit the users to make modification in the structure if it becomes necessary. This system could be used for planning purposes and as a decision-support aid.

APPENDIX A. WEIGHTS USED IN THE MULTIATTRIBUTE UTILITY FUNCTION

This appendix contains information on the weights that were used for the Multiattribute utility function in the Logical Decisions for Windows software. The reader is referred to the Manual of Logical Decisions for Windows pp. 8-18 – 8-20 for a detailed discussion of the meaning of this type of information.

Scaling Constants for the Preference Set.

Peace operations Goal has K = 0, defined by Analytic Hierarchy Process and no interactions

- Peace enforcement Goal weight = 0.6667
- Peacekeeping Goal weight = 0.3333

Combating terrorism Goal members are in International Peace Operations Goal MUF

Counter-drug operations Goal members are in International Peace Operations Goal MUF

Humanitarian assistance Goal members are in International Peace Operations Goal MUF

Peace enforcement Goal has K = 0, defined by direct entry and no interactions

- Employ firepower Goal weight = 0.2056
- Perform logistics and combat support Goal weight = 0.2056
- Exercise command and control Goal weight = 0.2056
- Protect the force Goal weight = 0.2056
- Force deployment/conduct maneuver Goal weight = 0.1222
- Develop intelligence Goal weight = 0.0556

Peacekeeping Goal has K = 0, defined by Analytic Hierarchy Process and no interactions

- Suprevising cease-fires Goal weight = 0.2851
- Providing security to population Goal weight = 0.1989
- Protecting humanitarian aid convoys Goal weight = 0.1746
- Disarming military forces Goal weight = 0.1708
- Training and leading de-mining teams Goal weight = 0.1023
- Movements observation Goal weight = 0.0682

Peace making Goal members are in Peace operations Goal MUF

Employ firepower Goal has K = 0, defined by Smarter method and no interactions

- Process targets Goal weight = 0.4167
- Employ air power Goal weight = 0.4167
- Control forces Goal weight = 0.1667

Perform logistics and combat support Goal has K = 0, defined by Smarter method and no interactions

Equip the force Goal weight = 0.3167
Provide personnel support Goal weight = 0.3167
Conduct Resource management Goal weight = 0.1500
Perform base support Goal weight = 0.1500
Provide mission support Goal weight = 0.0667

Exercise command and control Goal has K = 0, defined by Smarter method and no interactions

Acquire and communicate information Goal weight = 0.5278
Direct and lead subordinate forces Goal weight = 0.1944
Assess situation Goal weight = 0.1944
Determine actions Goal weight = 0.0833

Protect the force Goal has K = 0, defined by Smarter method and no interactions

Perform rescue Goal weight = 0.3333
Provide force protection Goal weight = 0.3333
Enhance survivability Goal weight = 0.3333

Force deployment/conduct maneuver Goal has K = 0, defined by direct entry and no interactions

Deploy forces Goal weight = 0.3750
Position communication and navigation systems Goal weight = 0.3750
Assess area of operations Goal weight = 0.1250
Redeploy forces Goal weight = 0.1250

Develop intelligence Goal has K = 0, defined by Smarter method and no interactions

Collect information Goal weight = 0.3278
Plan and direct tactical intelligence activities Goal weight = 0.2611
Prepare intelligence reports Goal weight = 0.2611
Process information Goal weight = 0.1500

Suprevising cease-fires Goal members are in Peacekeeping Goal MUF

Fighting Measure weight = 0.2851

Providing security to population Goal members are in Peacekeeping Goal MUF

Armed conflicts Measure weight = 0.1989

Protecting humanitarian aid convoys Goal members are in Peacekeeping Goal MUF

Unprotected convoys Measure weight = 0.1746

Disarming military forces Goal members are in Peacekeeping Goal MUF

Disarmed forces Measure weight = 0.1708

Training and leading de-mining teams Goal members are in Peacekeeping Goal MUF
Trained teams Measure weight = 0.1023

Movements observation Goal members are in Peacekeeping Goal MUF
Observed movements Measure weight = 0.0682

Process targets Goal members are in Employ firepower Goal MUF
Targets processed Measure weight = 0.4167

Employ air power Goal members are in Employ firepower Goal MUF
Percent air power employed Measure weight = 0.4167

Control forces Goal members are in Employ firepower Goal MUF
Control level Measure weight = 0.1667

Equip the force Goal members are in Perform logistics and combat support Goal MUF
Force equipped Measure weight = 0.3167

Provide personnel support Goal members are in Perform logistics and combat support Goal MUF
Level of support provided Measure weight = 0.3167

Conduct Resource management Goal members are in Perform logistics and combat support Goal MUF
Level of resource management Measure weight = 0.1500

Perform base support Goal members are in Perform logistics and combat support Goal MUF
Level of support provided2 Measure weight = 0.1500

Provide mission support Goal members are in Perform logistics and combat support Goal MUF
Level of support provided1 Measure weight = 0.0667

Acquire and communicate information Goal members are in Exercise command and control Goal MUF
Communication errors Measure weight = 0.5278

Direct and lead subordinate forces Goal members are in Exercise command and control Goal MUF
Level of leadership Measure weight = 0.1944

Assess situation Goal members are in Exercise command and control Goal MUF
Accuracy of assessment Measure weight = 0.1944

Determine actions Goal members are in Exercise command and control Goal MUF
Number of Alternatives Measure weight = 0.0833

Perform rescue Goal members are in Protect the force Goal MUF
Forced rescued Measure weight = 0.3333

Provide force protection Goal members are in Protect the force Goal MUF
Casualties Measure weight = 0.3333

Enhance survivability Goal members are in Protect the force Goal MUF
Survivability Measure weight = 0.3333

Deploy forces Goal members are in Force deployment/conduct maneuver Goal MUF
Percent of forces deployed Measure weight = 0.3750

Position communication and navigation systems Goal members are in Force deployment/conduct maneuver Goal MUF
System positioned Measure weight = 0.3750

Assess area of operations Goal members are in Force deployment/conduct maneuver Goal MUF
Area assessed Measure weight = 0.1250

Redeploy forces Goal members are in Force deployment/conduct maneuver Goal MUF
Forces redeployed Measure weight = 0.1250

Collect information Goal members are in Develop intelligence Goal MUF
Information level Measure weight = 0.2611
Information collected vs. planned Measure weight = 0.0667

Plan and direct tactical intelligence activities Goal members are in Develop intelligence Goal MUF
Intel implemented vs. planned Measure weight = 0.2611

Prepare intelligence reports Goal members are in Develop intelligence Goal MUF
Number of reports prepared1 Measure weight = 0.2611

Process information Goal has K = 0, defined by Analytic Hierarchy Process and no interactions
Information processed Measure weight = 0.7500
Number of reports prepared Measure weight = 0.2500

APPENDIX B. MULTIATTRIBUTE UTILITY FUNCTION ANALYSIS UNDER UNCERTAINTY

In some cases, decision-makers are not able to identify the attribute values of an alternative as of certain, because there is a possibility of getting different outcomes depending on the situation. Multiattribute Utility Function Analysis can handle these cases of uncertainty.

There are two conditions that the decision-maker's preferences must satisfy. First, the pair of attributes x_i and x_j is preferentially independent of x_k meaning that conditional preferences in (x_i and x_j) space given x_k do not depend on the particular level of x_k. Second, x_i is utility independent of x_j, meaning that conditional preferences for lotteries on x_i given x_j do not depend on the particular level of x_j. Utility independence is important, because each component utility function can be scaled one-dimensionally.

The key theorem states that if for some x_i, the trade-offs between x_i and x_j are independent of the other variables (for all $j \neq i$); and if for that x_i utility independence holds, then U(x) is either additive or multiplicative. The theorem assumes at least three attributes.

The additive form is the following:

$$U(x) = k_1u_1(x_1) + k_2u_2(x_2) + k_3u_3(x_3), \text{ where } \Sigma k_i=1$$

Appendix C provides more details about the multiplicative form.

Under uncertainty, decision-makers assign different probabilities for alternatives. For setting up a multiattribute utility function for a given case, decision-makers have to determine the probability level p at which they are indifferent between, say, an alternative for sure and a lottery of two alternatives with probabilities p and (1-p).

Then depending on the value of Σk_i in the general formula, the multiplicative (if $\Sigma k_i \neq 1$) or the additive (if $\Sigma k_i=1$) formula could be used. By knowing the probabilities of the alternatives, the decision-maker can determine the values of k_i.

A more detailed description of using multiattribute utility function analysis under uncertainty is provided in Raiffa and Keeney.

APPENDIX C. MULTIATTRIBUTE UTILITY FUNCTION ANALYSIS WITH INTERDEPENDENT ATTRIBUTES

This appendix contains the formulas the LDW uses for interdependent attributes in the Multiattribute utility function analysis.

Logical Decisions for Windows uses two formulas for MUFs. It uses the additive formula when there are no interactions between the goal's active members. The second MUF formula is the multiplicative formula. LDW uses it when there are interactions between the goal's active members. The multiplicative MUF formula requires an additional scaling constant called Big K. The value of Big K indicates the degree of interactions between the goal's active members. The multiplicative MUF formula can be written as follows:

$$Ug(X) = ((1+Kk1U1(x1))*(1+Kk2U2(x2))*...*(1+KknUn(xn)) - 1)/K$$

where U(X) = the Utility of Alternative X for Goal g,
K = the constant Big K for g,
ki = the constant Small k for Member i of g, and
Ui(xi) = the utility of alternative X for member i

The multiplicative MUF formula has three interesting limits -- If Big K equals 0.0, we get the additive formula. If Big K equals -1.0, we get Ug(X) = (1 - U1(x1))*(1 - U2(x2))*...*(1 - Un(xn)) + 1, which equals 1.0 if Ui(xi) = 1.0 for any i. As Big K gets very large, we get Ug(X) = U1(x1)*U2(x2)*...*Un(xn), which equals 0.0 if Ui(xi) equals 0.0 for any i. Intermediate values of Big K have intermediate degrees of interaction. Big Ks less than 0.0 mean that a high utility on an individual member can result in a high goal utility (constructive interaction), while Big K greater than 0.0 indicates that a low utility on an individual member can result in a low goal utility (destructive interaction).

In the peace enforcement mission example, Develop intelligence Goal has four objectives: Plan and direct tactical intelligence activities, Collect information, Process

information and Prepare intelligence reports. There is interaction among these objectives. The information collected influences the outcome of the information process and the latter two influence the prepared intelligence reports. In this case the multiplicative formula could be used to determine the multiattribute utility function.

APPENDIX D. APPLYING AHP FOR A CAR PURCHASING PROBLEM

This appendix contains an example for applying AHP in a car purchasing problem.

For this decision to buy a new car, the objective of purchasing a car is placed at the top of the hierarchy. Attributes of the car that influence the decision, such as dependability, comfort and cost, are placed in the next level of the hierarchy, and the various car alternatives, such as BMW, Toyota and Pontiac, are listed at the lowest level. In the second step, pairwise comparisons are made about the factors of one level that contribute to achieving the objective of the next higher level, using the following pairwise comparison scale.

Importance	**Definition**	**Explanation**
1	Equal importance	Equal contribution to the objective
3	Moderate importance of one over the other	Slightly favoring one element over the other
5	Essential or strong importance	Strongly favoring one element over the other
7	Very strong importance	One element is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The favoring of one element over the other is the highest possible
2,4,6,8	Intermediate values	Compromise between two judgments
Reciprocals	When attribute i compared to j one of the above numbers is assigned, when attribute j is compared to i, reciprocals are assigned	
Ratios	Ratios coming from forcing consistency of judgements	

The next step is to construct a comparison matrix including all alternatives and comparing them in connection with a given attribute. The following table shows such an example for the dependability of the three alternatives.

Dependability	BMW	Toyota	Pontiac	*Total*
BMW	1	½	¼	*1.75*
Toyota	2	1	½	*3.5*
Pontiac	4	2	1	*7*
			Total	*12.25*

Similar matrix could be used for the other two attributes, comparing the alternatives and showing them in connection with cost and comfort.

In the third step, the relative weight of each element in a level is computed using the eigenvalue[21] solution technique. These weights are obtained by normalizing the pairwise comparison matrices, summing over the rows and getting an average row sum. These sums are the values of the priority vector, the eigenvector. The priority vector of dependability of the car purchasing example is [0.143, 0.286, 0.571], where the values are obtained by dividing the sum of each row by sum of the elements of the whole matrix (0.143=1.75/12.25).

The fourth step aggregates the relative weights of the various levels from the previous step to construct a vector of composite weights. This vector actually is the weighted rankings of the alternatives with respect to the attribute being analyzed. This step starts with the top of the hierarchy determining the weights at this level that then are multiplied by the eigenvectors at the next lower level. The next table contains the calculation of the weights for level 2. This procedure is repeated at the lower levels and resulting in relative weights of the elements at the lowest level of the hierarchy.

[21] Readers are referred to the following web site for more information on eigenvectors and eigenvalues: http://www.cs.ut.ee/~toomas_l/linalg/lin1/node16.html#eigenvalue

Pairwise Comparison Matrix on Level 2

	Cost	Comfort	Dependability	*Sum*	*Weight*
Cost	1	5	2	*8*	*0.570*
Comfort	0.2	1	3	*4.2*	*0.299*
Dependability	0.5	0.33	1.00	*1.83*	*0.131*
		Total:		*14.03*	

The figure shows that by summing the rows of the matrix (8, 4.2, 1.83) and counting their ratio to the sum of the whole matrix (14.03), the following weights are obtained for cost, comfort and dependability: (0.570, 0.299, 0.131)

Assuming that the eigenvalues are the following for the second and third levels, based on the tables above, the composite priority of the cars would be: BMW=0.307, Toyota=0.295 and Pontiac=0.398.

Level 2 eigenvalues	Cost	Comfort	Dependability
	0.570	0.299	0,131

Level 3 eigenvalues			
Attributes	BMW	Toyota	Pontiac
Cost	0.400	0.400	0.200
Comfort	0.200	0.100	0.700
Dependability	0.143	0.286	0.571

BMW priority	(0.570)(0.4)+(0.299)(0.2)+ (0.131)(0.143) = 0.307
Toyota priority	(0.570)(0.4)+(0.299)(0.1)+ (0.131)(0.286) = 0.295
Pontiac priority	(0.570)(0.2)+(0.299)(0.7)+ (0.131)(0.571) = 0.398

As the table shows that the Pontiac should be purchased based on the buyer's preferences regarding cost, comfort and dependability.

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