Military Utility, a proposed concept to support decision-making

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Abstract A concept called Military Utility is proposed for the study of the use of technology in military operations. The proposed concept includes a three-level structure representing key features and their detailed components. On basic level the Military Utility of a technical system, to a military actor, in a specific context, is a compound measure of the military effectiveness, of the assessed technical system's suitability to the military capability system and of the affordability. The concept is derived through conceptual analysis and is based on related concepts used in social sciences, the military domain and Systems Engineering. It is argued that the concept has qualitative explanatory powers and can support military decision-making regarding technology in forecasts, defense planning, development, utilization and the lessons learned process. The suggested concept is expected to contribute to the development of the science of Military-Technology and to be found useful to actors related to defense.

Keywords Military, decision-making, concept analysis, operational research, Systems Engineering

1 Introduction

> *For Clausewitz, in his masterly analysis of the mental and physical spheres of war, neglected the material--man's tools. If he thereby ensured to his work an enduring permanence, he also, if unwittingly, ensured permanent injury to subsequent generations who allowed themselves to forget that the spirit cannot win battles when the body has been killed through failure to provide it with up-to-date weapons.*
> [1, p. 158]

New requirements and challenges are born from strained military budgets and a rapidly changing world, as well as from the fact that the time when the military industry was in the forefront of technological development has passed in most areas. In Sweden, and probably in most other democratic states, the question of how limited resources should be put to best use is more relevant than ever before. In general, a military system is complex and already its early life cycle stages, from R&D to initial operation, span over several years and often a decade. After that a typical platform on land, at sea or in the air has an operational lifetime of perhaps thirty years or more. Hence, decisions today may influence warfighting capacity for decades.

Our first case of a decision situation is *the technology forecast*. Even before the technical system is born as a concept, armed forces have to make decisions about what technologies to invest their limited R&D budget in. This means there is a need to forecast and predict the utility of technologies as part of a potential technical system in some far away uncertain future.

The second case is *defense planning*. In short to midterm defense planning, i.e. the next ten-year period, decision makers are faced with the question of when and with what technical systems to replace those currently in operation, while keeping within budget restraints. Furthermore it has to be done taking requirements from interdependent capabilities and foreseen doctrinal, tactical and organizational development into account – optimizing the whole capability system.

The third case is *development*. Once in the concept, development and production life cycle stages of a technical system, the question of how to build a technical system of maximum utility to the customer, the armed forces, within a limited time frame and budget, is addressed using requirement management within the systems engineering process.

The fourth case is *use*. In the utilization and support stage of a materiel system, military commanders and their staffs plan the best use of their limited resources in order to maximize the probability of mission success. Concretely, during planning, a staff is typically required to assess what capability systems, i.e. units and technology, the opponent is likely to use based on their strengths and vulnerabilities. Assessing own strengths and weaknesses in the situation the staff is likewise asked to recommend the best use of own available capabilities, not least based on expected technical performance.

The fifth case regards *lessons learned.* This is the long-term review of systems and capabilities throughout all stages from technology forecast, development, defense planning and use. The lessons learned process must be executed in close collaboration with the system stakeholder in order to be accurate in validation of system performance and capability but also to be accurate in the time domain helping decision makers get near-real time information regarding the utility development of the system-in-focus.

In light of the above illustrated incentives for competence in decision making, *Military-technology* is developing as an academic subject at the Swedish National Defence University, SEDU, defined as:

> "Military- Technology is the science which describes and explains how technology influences military activity at all levels and how the profession of an officer affects and is affected by technology" [2]

It seems, though, that in every project similar analytic constructs have to be defined over and over with moderate adjustments to application. And evidently there are similarities between central questions in all the presented use cases from decision situations above. But, is it then possible to form a common theory, to support decision-making regarding use of technology in military affairs, from R&D investments to military operational planning? A more complete Military Technology conceptual apparatus would make it easier to relate to theories across academia, e.g. to economics or management sciences. It would certainly aid effective communication across disciplines within the defense community, i.e. between actors within military research agencies, the armed forces, procurement agencies and industry.

With this paper we intend to propose a concept with potential for both qualitative and quantitative analysis to support decision-making in military technology. The concept is named *Military Utility*. The starting point is a presentation of the postulates of Military Technology and the theory of concept analysis. After that an applied method for concept analysis is presented followed by a description of the resulting concept. The center of gravity is the following discussion on the concept dimensions and indicators. The paper ends with an example, final conclusions and proposed future work.

2 Military-Technology

The technology the military profession chooses, and how it uses that technology, will affect the outcome on the battlefield and the sustainment of capabilities over time. This phenomenon is at the centre of interest here. Our viewpoint originates from postulates in military-technology [3]: the character of war change in pace with the development of technology, technology has influence on all military command levels, and a lack of understanding of technology causes diminishing military opportunities. Consequently, for an analyst in military-technology it is essential to understand what is important to the military decision-maker - i.e. what constitutes military utility?

In an article on the military-technological perspective on Geographical Information Systems, Åke Sivertun finds that maximizing military utility, (translated from Swedish “Militär nytta”) of the technology, is the core question. He stipulates a definition of the concept - how to in an effective way and at a minimum cost, in human life as well as materiel, reach the military mission objectives [4]. This definition is here regarded as a first iteration of the concept.

Military-technology is cross-disciplinary covering engineering as well as both natural and social sciences. The terminology used originates from these and the aim is to propose a concept in harmony with the use of related concepts within these disciplines. Coming from a Systems Engineering tradition viewing problem phenomena as *Systems* is fundamental. A System should be understood as “an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements”[5]. In the military domain, *Capability* is a key concept. Our understanding of capability is that it is being able to do something and being able to do it well [3]. With *Military capability* an actor can solve military tasks and thereby achieve desired effects.

Using a systemic approach military capability can be viewed as a system composed of interacting elements, as thoroughly discussed by Jukka Anteroinen [6]. We can choose to sort these elements into categories of Personnel, Organization, Methods and Technology (POMT) or into Doctrine, Organization, Training, Personnel, Materiel, Facilities, Leadership and Interoperability (DOTPMLFI), as in NATO publications. Regardless of categorization we realize that any component in a system, e.g. the technology element, has dependencies to other elements. Hence, a component has military utility only if it is viewed as a contributing element in a *Capability system*.

The prefix *Technical* system is used to label the technical element in an operational military capability system when it is beneficial to view the element in itself as a system. In this paper the object for the assessment is an element in the capability system and it is labeled the *Element of Interest (EoI),* following the Systems Engineering tradition.

3 Concepts development and Concept Analysis

The above identified need for a concept is based on the view of them fulfilling several important functions within the scientific community. Frankfort-Nachmias and Nachmias states that a concept: provides a common language; provides a perspective to understand the phenomena; allows classification and categorization of different phenomena and; finally, it is the fundamental building block of theories[7, p.2 8]. Goertz submits that concepts are essential theories about ontology [8, p. 5]. Govanni Sartori even claims that "*concepts are not only elements of a theoretical system but equally tools for fact-gathering, data containers*"[9]. A conclusion is that how a concept is designed constitutes not only the building blocks of theories, but also affects how the phenomena are measured and examined. Concept analysis is a process where the characteristics as well as the relations to other relevant concepts are made clear. It can be argued that in fields directly connected to a profession the need of concept analysis increases. A comparison can be made to nursing science where concepts analysis has a given role and where several methods have been developed [10].

There is a lack of lexical definition of the phenomena indicating that the concept is underdeveloped. Two approaches can be used in support of concept development. One is traditional Concept Analysis where the aim is to capture how the concept is used. The other approach is to focus on the phenomena, developing the concept, sometimes referred to as Concept Formation. Which approach is used is primarily dependent on the purpose of the concept in question. The difference between developing a concept for broader usage, through concept analysis, and providing a stipulative definition of a word is minimal according to Goertz [8, p. 3].

There is a fundamental difference in views on concepts, and how to measure them. Goertz and Mahoney conclude that quantitative scholars primarily "*use indicators and the aggregation of the indicators that are causes or cause the concepts"*[11] to construct the concept in question. Qualitative scholars on the other hand use a semantic process identifying the attributes that constitutes the concept. Goertz and Mahoney argue that which approach to use depends on whether reliability or validity is central for the research in question. Since, in most cases, we cannot choose one over the other, we need a method to build concepts that both capture a specific phenomenon and allow measurement with a level of reliability permitting a systematic comparative and causal analysis.[11]

Since this study aims to find a concept aiding communication in the discourse of military technology and supporting evaluation of artifacts we find Goertz's ontological, causal and realist approach to concept analysis beneficial. Goertz's view of concept analysis has been used in several different papers, e.g. Belich (2011)[12] and in Rapkin and Braaten (2009)[13]. How to operationalize the concept in a framework for evaluation of any given EoI is left for future work.

Goertz advocates structuring concepts in multiple levels, or at minimum three levels, much like Sartori´s "ladder"[9]. Below the *basic level*, i.e. the *concept* labelling the phenomena, a *secondary level* consisting of the concept *dimensions* is formed. When for example Arat, in 1991, states that democracy consists of 'participation', 'competitiveness' and 'coerciveness' he defines the constitutive three dimensions of the concept democracy at the secondary level. The next level down Goertz calls the *indicator*- or the *data level*. The intention of this level is to operationalize, i.e. to identify specific measures of how to decide whether a studied phenomenon falls under the concept, or to what degree. For the concept to be complete it has to describe how to combine indicators to form the secondary level dimensions and how to combine secondary level dimensions to get the basic level concept. Goertz concludes that "the basic and secondary levels are really the theory of the concept, while the indicator level is the connection to measures and data collection"[8, pp. 5–10].

Several guidelines exist on how to conduct Concept Analysis [14]. The methods, however, take on the form of checklists rather than a structured and stringent research method usually required for reliability within academic work. The subsequent concept analysis was conducted roughly according to the guidelines provided by Goertz [8, Ch. 2]. Goertz's guidelines have similarities to Sartori´s ten rules for concepts analysis as well as to part of Walker's and Avant's method[10].

At the basic level the negative pole of the concept is analysed and it is also determined whether the concept as such is to be considered dichotomous or continuous. At the secondary level, the dimensions are listed and all necessary conditions are explicitly given. At the indicator level the theoretical relationship between the basic and the secondary level are clarified. According to Goertz's guidelines the causal relationship between the different levels should be examined at the indicator level. In our work generic indicators are suggested. But since the identification of detailed indicators is closely connected to constructing a more formal theory or framework this level will be further investigated in future research, for example theory building case studies.

In accordance with Sartori's eighth rule a search for related concepts was performed in the fields of War Studies and Systems Engineering (SE). The rule states that when selecting the term that designates the concept, it needs to be related to and controlled against the "semantic field to which the terms belong"[9]. For this text the tentative concepts were identified using an initial common requirement from the cases used in the introduction: a measure of the concept should support an Armed Forces's decision about which candidate for an EoI to choose, seen as a component in a capability system, while balancing desired effect against limited resources.

The analysis evolved in a series of seminars held at the SNDU Division of Military Technology during an extended period of time.

4 The Concept Of Military Utility

The concept analysis resulted in a proposed concept labeled "Military Utility"; where the conceptual definition is captured in a Goertz-diagram, see figure1.

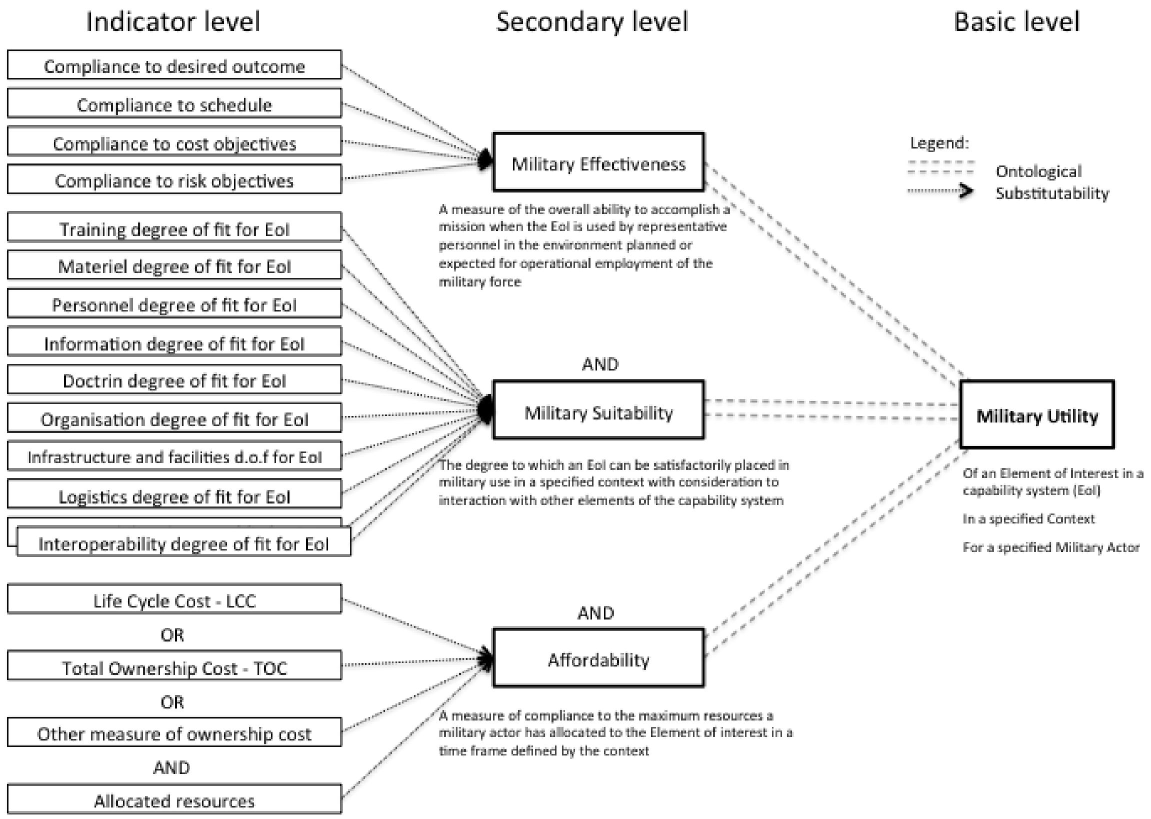

Fig. 1 The resulting Military Utility concept modeled in a Goertz-diagram

An assessment of Military Utility requires knowledge of three situational variables: the Element of Interest, the Military Actor and a specified Context. The Military Actor being any part of a military organization having military capabilities and organizational objectives.

Military Utility consists of three dimensions: *Military Effectiveness, Military Suitability* and *Affordability*. These are not substitutable. That is, for an Element of Interest to have Military Utility to a Military Actor it has to be effective, suitable *and* affordable to that Military Actor in a specified Context.

Military Effectiveness is a measure of the overall ability to accomplish a mission when the EoI is used by representative personnel in the environment planned or expected for operational employment of the military force. Military Effectiveness is operationalized using measures of the degree to which the mission objectives are, or can be expected to be, fulfilled. There are four substitutable indicators at this level, mirroring different characters of objectives: Compliance to *desired outcomes*, *schedule*, *cost* and *risk*. Desired outcomes constitute the purpose of the mission. Schedule, cost and risk objectives are boundary conditions.

Military Suitability is the degree to which an EoI can be satisfactorily placed in military use in a specified context with consideration to interaction with other elements of the capability system. Military Suitability in turn is operationalized using measures of the degree to which the EoI fits together with other elements of the resulting capability. In the model above, indicators corresponding to TEPIDOIL (Training, Equipment, Personnel, Infrastructure, Concepts and Doctrine, Organization, Information and Logistics) illustrate possible elements on this level. The indicators are chosen from an analysis of the situational variables.

Affordability is a measure of compliance to the maximum resources a military actor has allocated to the EoI in a time frame defined by the context. Affordability is operationalized using LCC (Life Cycle Cost), TOC (Total Life Cycle Cost) or other measures of ownership cost and allocated resources in the budget.

5 Dimensions and Indicators

The Military Utility concept should support a stakeholder's decision-making concerning the use of technology in military activities. The concept is hence typically to be used to answer generic questions like: *Is there Military Utility in this emerging technology?* Or -*What is the Military Utility of system X compared to system Y?* Or - *How should this technical system be used to maximize Military Utility?* In this section a discussion on the constituent parts of the concept, i.e. the dimensions and indicators, is presented capturing the most important argumentation from the concept development seminars. The starting point is, however, the top most level and a discussion on the input to an assessment, the situational variables.

5.1 Military Utility - Basic level

´Utility´ was considered a plausible best fit to the proposed concept, since it is used throughout the three domains covered by military-technology with a general sense of supporting decisions. According to the Oxford Dictionary, Utility means "the state of being useful, profitable, or beneficial"[15]. The word has, according to the Oxford Political Dictionary, transformed from a general sense of Usefulness and has today a more specific meaning when used in social science [16]. Its primary meaning in economics is the cognitive process that leads to a decision to choose one thing over another. In the military domain, according to the American Glossary of Defense Acquisition Acronyms & Terms, Utility is defined as "The state or quality of being useful militarily or operationally. Designed for or possessing a number of useful or practical purposes rather than a single, specialized one."[17] This definition indicates that the multipurpose aspect is essential. However, this does not always have to be true in our intended application, at least not when the artifact or technical system is analyzed within a given environment. If, on the other hand, the purpose or the context in which the artifact is going to be used is unknown, the multipurpose criterion becomes more relevant. In the Systems Engineering (SE) domain the closest fit is a definition of Operational Utility, "the degree to which the system in focus enables users to accomplish organizational missions and achieve stated goals and objectives, while posing no unacceptable safety, environment or health hazards or risks to its operators or public" [18, p. 50]. There is however a need to develop the limited resources dimension and to specify the concept from a specifically military organizational viewpoint.

There are other related concepts plausible for the basic level. 'Value', used in SE or 'Value Engineering' [5, p. 36], has a focus on a supplier-customer relation and is therefore not suitable. The concept is also too intertwined with monetary profit [19] to be used as is. SE concepts like 'Operational Effectiveness' [17] or 'Cost Effectiveness' [18] were discarded because they are considered special cases of Military Utility. 'System Acceptability' [18] was discarded since it is considered to be defined from a supplier's perspective.

Faced with a problem concerning military utility we argue that an analyst first has to find the answers to three questions: What is the System of Interest?; Who is the military actor using it?; and in what context is it used? These are referred to as the three situational variables.

5.1.1 What is the Element of Interest?

From a military-technology viewpoint an assessed object has military utility only if it is viewed as a contributing component in a capability system. Consequently, if we want to assess the utility of a technical system we will have to analyze the effects produced by the whole capability system, i.e. when asked what the military utility is of this or that artifact an analyst always has to ask - as an element of what capability system?

If we use a field artillery unit as a system example, the resulting military utility of one unit is dependent on the capability system that it is a part of. The technical specification is one factor as well as the military context. Field artillery is a highly demanding weapon system regarding ammunition and intelligence. To obtain military utility during a battle the artillery gun needs a functional logistic system as well as a functional communication system between the target acquisition system and the fire unit (e.g. an artillery observation team). The artillery gun does not exist in a vacuum and therefore its utility cannot be assessed as a single unit. The ability of the crew to operate the gun, the ability to receive and understand information regarding the location of the target, the ability to maintain ammunition and spare parts during combat are all needed to receive any utility.

Another consequence of the system approach is that the component of military technological interest is not always the technical element itself but an element interacting with the technical element, e.g. the doctrine or the organization. This is for instance the case when developing and evaluating new ways of how to use existing materiel resources. An analyst typically compares the effect delivered by alternative systems as a whole but keeps the technical system unchanged and alternates the doctrine or the tactical procedures.

A technology, on the other hand, underpins system performance but cannot really be viewed as a system element in itself. Therefore, in order to forecast the military utility of a technology, using the proposed definition, an analyst has to first apply the technology to a technical system, which then in turn is viewed as an element in a capability system. A challenge is that the same technology could appear in multiple technical systems. Furthermore, the more generic the technology is, e.g. miniaturization of electronics, the more difficult it will become for an analyst to assess the military utility with any precision. Such an assessment is probably done supporting decision-makers on strategic level, where the technology can be seen having influence on a wide range of systems.

5.1.2 Who is the military actor using the EoI?

The prefix "Military" is used to signal the use of the concept to support military decision-makers – having military capabilities, goals and objectives. As a consequence the military utility of a technical system is not the same for all user organizations, since they have neither the same capability systems to integrate the EoI into, nor the same goals or objectives.

As an example, only a few of the richest nations in the world can afford to have specially designed aircrafts for all types of missions. For example, the US stealth aircraft F-117 Nighthawk proved to be valuable to the coalition forces during the First Gulf War in 1990-1991 [20], [21]. It had a modest payload capacity and a limited maneuverability but was designed for low probability of intercept (LPI). The F-117 was used for Suppression of Enemy Air Defenses and Command and Control facilities. The Swedish Armed Forces on the other hand, prioritizing the defense of Swedish territory, has chosen the JAS39 Gripen multipurpose aircraft. It is designed to balance the requirements from air defense, air to ground as well as reconnaissance missions. In order to fulfill those requirements the LPI concept has to be balanced as well. Hence, though the military utility of the F-117 was great to the coalition forces during the First Gulf War it is safe to conclude that the military utility of the F-117 to the SwAF would be small. It is only rational to have highly specialized military means if you have the overall capacity to shape the battlefield in favor of that capability.

A military organization is hierarchical and composed of units at different levels[†], with different tasks and objectives. In our proposed definition of the concept it is for example possible to find that the military utility of a EoI is great at the tactical level while at the same time small at the operational or strategic levels. One example is assessing the military utility of a patrol vehicle in an expeditionary mission. A tracked and armored personnel vehicle is perhaps the first choice of the land component commander whereas transportability and maintainability weigh in favor of a soft skin wheeled vehicle at an operational or strategic level. Hence, if the military utility concept were only to be used at the highest organizational level it would not be useful for supporting assessments and discussions within the military organization. Consequently, the military technology analyst has to identify not only the military organization, but also to what service, unit or task force within that organization the EoI should be of use. At higher command levels the Military Utility at lower command levels

[†] Top down the levels in a military command hirarchy are usually referred to as: the strategic, the military-strategic, the operative, the tactical and the war-fighting levels.

will have to be included, though, making this a more complex assessment. It should be possible to add an attribute to the concept to mark this distinction, e.g. military *warfighting* utility, military *tactical* utility, military *operational* utility, military *strategic* utility etc.

Finally, the proposed concept is designed from a military actor point of view. Thus, it can be used by the Armed Forces to support decision-making within their organization, but also to understand the capabilities of other military actors. This point of view also makes it useful to other actors supporting military organizations, since when discussing military utility there is no question of who the stakeholders are. When used by, for example, procurement agencies or the industry, the concept should be understood as being their assessment of the utility from a specific military actor's point of view.

5.1.3 In what context is the EoI used?

From the discussion of the ”for what?” and ”for whom?” aspects of Military Utility it is already clear that an analyst needs to understand a military actor's purpose for using the EoI and the status of the surrounding capability system to make an assessment. A military purpose is typically composed of military objectives stated within a mission planned for a specific operational environment. Hence, in order to assess the military utility of an EoI, within a capability system, an analyst has to account for all (or the most important) situational variables that influence the military actor's ability to be successful in the specific context, such as opposing forces' capabilities, climate, terrain, international law etc., i.e. the assessed Military Utility of an EoI only has meaning if related to the planned use – either expressed as requirements on the EoI planned contribution to military capabilities or within a planned mission.

5.1.4 Concept level measurement considerations

Bernoulli assumed already in the 18th century through the St Petersburg paradox that maximizing an individual's income is not the same as maximizing the utility (Bernoulli 1738). The utility one person can have of a specified amount of money is consequently not the same as that of the next person. If using the taxonomy proposed by Stevens [23] on types of scales , i.e. the nominal, the ordinal, the interval, or the ratio scale, Bernoulli thereby also showed that utility cannot be measured on a ratio or interval scale.

Neither can the Military Utility be a linearly proportional product of the number of EoI units available to a military actor, e.g. two JAS39 Gripens do not double the amount of military utility compared to one. The system in which the specific EoI exist offers constraints as well as possibilities. In economics this is called the law of diminishing marginal utility (also known as Gossen's first law) [24]. This demonstrates that the military utility curve has a roof where no more utility can be gained from the system without external changes. When some kind of cost dimension is included, there is a tipping point regarding the maximum utility gained from X number of units. The example of the field artillery can be used again. The military utility of artillery is related to the combined armed forces. Having two artillery battalions when there is only one company of infantry in the operation area is not a maximum use of resources, and therefore the military utility of the artillery is limited. Military Utility consequently needs to be in relation to something, another alternative or a minimum status quo.

When making choices, ranking one option over another, it is often desirable to compile the result of the evaluation process into one number, a scalar assessment. It seems reasonable to say that if having technical system 'A' available in a given context, as compared to having technical system 'B', yields a slightly better chance of achieving stated goals (assuming they come to the same cost). System A has arguably greater Military Utility than system B in this context and hence a continuous scale can be applied to the concept. Correspondingly, in a scenario where two alternatives yield the same probability of success but one comes at a lesser cost – that alternative has the greater military utility. Examining the scale further we find that an alternative EoI that yields no better probability of achieving the organizational goals than status quo, nor at a lower cost, should be considered 'useless'. And since there are probably even worse choices a decision-maker can make there is evidently a negative pole to military utility, i.e. 'inutility' or even 'harm'.

5.2 Military Utility – Secondary level

5.2.1 Military Effectiveness Dimension

The first dimension of a utility concept has to account for the purpose of using the assessed EoI at all, i.e. the military mission. Hence, it is only meaningful to discuss military utility if the capability, to which the EoI contributes, has any potential of being effective in a given context.

In the SE and Military Domain *Operational Effectiveness* is a "Measure of the overall ability of a system to accomplish a mission when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, supportability, survivability, vulnerability, and threat" [17], [18]. Wasson explains this concept as the requirement of a system to be able to support missions "to a level of performance that makes it operationally effective in terms of accomplishing organizational goals and objectives, namely outcomes, cost, schedule, and risk."[18] That is, achieving an effect is usually not enough for a system to be operationally effective, the effect must be delivered at the right time and at the right cost and at acceptable level of risk.

The Prefix "Operational" signals that the measure is assessed when the EoI is used operationally in the context for which it was intended, not to be confused with operations performed at a joint command level. As stated earlier the military utility of an EoI has to be assessed separately at different command levels. This logic still holds if using Effectiveness at the secondary level, since an EoI can have different effects on the different objectives at different command levels. The prefix is however changed to 'Military´ Effectiveness, to make it clear that this dimension is assessed from a military perspective as well as to broaden the scope of use to any command level.

The definition of operational effectiveness is assessed assuming the best possible fit of the EoI into the capability system, using trained and experienced personnel, applying the capability according to the doctrine and the plan etc. As a consequence the Military Effectiveness dimension mirrors the full potential of the EoI. Hence, a possible mismatch between the EoI and interacting elements of the capability has to be accounted for in another dimension (See Suitability). Another consequence is that there is an implied best possible doctrine supporting the plan. Hence, when assessing an entirely new technology or revolutionary technical system an analyst first has to assume a new tentative doctrine bringing out the potential in the EoI.

Furthermore, since the concept is aimed to be open to operationalization, it is not beneficial in the definition to specify all factors that possibly affect Military Effectiveness. Consequently consideration of "organization, doctrine, tactics…" etc. has to be done at lower levels of the concept model. In summary *the Military Effectiveness dimension is a measure of the overall ability to accomplish a mission when the EoI is used by representative personnel in the environment planned or expected for operational employment of the military force*.

5.2.2 Military Suitability Dimension

The second dimension of Military Utility produces the means to analyze the relation between the EoI and the other elements of the capability system.

In the SE and Military Domain *Operational Suitability* is "The degree to which a system can be satisfactorily placed in field use with consideration to reliability, availability, compatibility, transportability, interoperability, wartime usage rates, maintainability, safety, human factors, habitability, manpower supportability, logistics supportability, documentation, environmental effects and training requirements" [17], [18]. In consequence Operational Suitability answers the question of how well suited a system is to a specific application for a particular user in a given operating environment. Thus, it can be used to characterize how well the EoI fits within this user's existing capability system, or how well it fits after development. The Prefix "Operational" is exchanged with 'Military' with the same logic as above..

Some degree of Military Suitability is necessary for an EoI to have any Military Utility. An EoI with low suitability to the other components in the Armed Forces capability system would arguably be of little use, e.g. there is no trained personnel to use the system, the Command and Control system is not compatible, there is no doctrine for how to utilize possible benefits, there are no facilities to maintain the EoI etc. If, on the other hand, a perfect suitability is assumed the capability system can benefit from the full potential of the EoI. Analyzing the Suitability dimension of an EoI is thus beneficial when answering questions like – how should a unit be organized for the organization to get the most out of this EoI? Or – how should the tactics be developed for the organization to benefit the most from this EoI? Or – what changes are necessary in order to maintain the capability if buying this new system? etc. In other words, the Military Suitability dimension is important for understanding the system effects of replacing technical systems.

If the military utility concept is used to study military adversaries, the suitability dimension is often very informative. If a military actor understands under what circumstances the adversary has best possible suitability of his weapon systems, efforts should of course be made to shape the battlefield in a less favorable direction.

Opposite to the definition of ‘Operational Suitability’ above, the definition of Military Suitability should be kept generic allowing modifications on the indicator level. Though the list of affecting factors in Operational Suitability is extensive it is probably not exhaustive. For instance, it should very well be possible to add suitability from national or international law to the list. Instead the following definition is chosen: *Military Suitability is the degree to which an EoI can be satisfactorily placed in military use in a specified context with consideration to interaction with other elements of the capability system.*

5.2.3 Affordability Dimension

The third dimension of the Military Utility concept accounts for the consequences of having limited funding.

For SE and the Military Domain DoD defines Affordability as “ 1. A determination that the Life Cycle Cost (LCC) of an acquisition program is in consonance with the long-range investment and force structure plans of the DoD or individual DoD components. 2. Conducting a program at a cost constrained by the maximum resources the DoD or DoD component can allocate to that capability” [17].

‘Affordability’ is hence more suitable than ‘Cost’ to represent the limited resources dimension of the concept, since it has a positive direction, like effectiveness and suitability.

As an illustration, assume that a military actor tries to find the solution with maximum military utility. An analysis of the problem, e.g. a military mission, will then result in requirements of desired effects delivered by the solution. But for that solution to be possible the military actor needs to be able to afford it – otherwise no effect will be delivered. Hence the solution delivering the most possible of the desired effect, while still being affordable to the military actor, has the greatest military utility.

In use cases where the Military Utility of an EoI is assessed supporting a specific military operation the affordability dimension is omitted. The rationale is that a military actor does not plan for using an EoI if it is not available. Any limitations in resources affecting the use of the EoI are instead accounted for in the mission cost objectives as indicators of the military effectiveness dimension.

The DoD definition, transformed into a measure, yields the definition for Affordability used in the proposed concept. *A measure of compliance to the maximum resources a military actor has allocated to the system of interest in a time frame defined by the context.* The last additional condition makes it possible to use the concept in other time frames than the system lifecycle.

5.3 Operationalization – Indicator level

The operationalization of the dimensions of military utility is the bridge between the conceptual-theoretical and the empirical-observational level. What can be measured and how? During concept development the ambition was to find generic clusters of indicators, rather than indicators themselves. The indicators finally chosen for an assessment will be dependent on use case and context.

5.3.1 Indicators to Military Effectiveness

Leaning on existing definitions the effectiveness of a capability relates to the ability to reach desired effects stated in objectives for “outcomes, cost, schedule, and risk”[18].

The Oxford Dictionary defines *Effect* as: ”A change which is a result or consequence of an action or other cause”[25], i.e. there are potentially both positive and negative consequences of an effect, pending on viewpoint. From a military perspective US DoD states that Effect is: ” 1. The physical or behavioral state of a system that results from an action, a set of actions, or another effect. 2. The result, outcome, or consequence of an action. 3. A change to a condition, behavior, or degree of freedom.”[26].

Here it is interpreted as if the outcome objectives constitute *all desired effects* for which the EoI is to be assessed. This can be exemplified using the aircraft decision situation again. Military-Technology analysts in the SwAF were probably once in the late 1970s faced with a question similar to – What combat aircraft system should the SwAF choose for the next 30-40 years, within a given budget? They came up with a recommendation to buy 200+ JAS 39 multirole aircrafts. This seems rational since this aircraft type is effective in all types of combat air operations needed to defend Swedish territory: counter air, air strike or reconnaissance – probably weighted in that order. If the F-117 ever was on the table, it was probably found very effective for nightly air strikes but not very effective for anything else.

The former reasoning is logical if the assessment of military utility is done at the military strategic command level. Acquisition of complex, expensive, military technical systems is however often decided at a strategic level viewing the EoI as a component in the ‘security policy system’, achieving more abstract effect objectives. Similarly, the greatest military effectiveness of nuclear weapons might not be in the warfighting capacity, but rather for achieving a deterring effect.

The interpretation of the cost, schedule and risk objectives is that they constitute the boundary conditions for using the EoI in the utilization stage of the specified context. There is a limit to acceptable additional costs for using the EoI in the operation, there is a schedule for when the outcome-objectives have to be achieved to reach a desired end-state, and there is a limit to acceptable risk for undesired effects.

The planned ownership cost of a technical system is included in the affordability dimension. All other limiting resources for using the capability have to be accounted for in the effectiveness dimension, and they have to be defined as cost objectives. Some examples could be: in this operation the daily consumption of diesel for this capability A must not exceed 10 tons; or there are only one hundred troops available for this capability B, or the number of spare parts of type X is limited to Y, etc.

Any effect not contributing to achieving the mission objectives may add to undesired effects, e.g. a risk of a sensor system revealing its own position, a risk of a weapon system with low precision resulting in collateral damage, or a safety risk to personnel operating the EoI. The risk of undesired effects hence has to be accounted for in mission risk objectives. This is the boundary condition that, for example, limits the use of weapons delivering more effect than needed.

The most straightforward way to make a compound quantitative measure of Military Effectiveness is to transform all indicators into probabilities of achieving the respective objectives, multiply them with weights and sum up. The operation is allowed since Military Utility can only be assessed on an ordinal, i.e. a rank order, scale. This is however one of those things easier said than done and there are a multitude of textbooks in the field of operational research describing general cases and how to tackle the problem [27], [28].

In the scope of this paper it is sufficient to state that there are typically four types of substitutable indicators contributing to Military Effectiveness: *Compliance to desired outcomes*, *Compliance to Cost*, *Compliance to Schedule* and *Compliance to Risk*. If they are not relevant to the assessment at hand they do not all have to be represented in the compound measure (meaning that they are assessed to be the same for all alternatives).

5.3.2 Indicators to Military Suitability

According to Wasson Measures of Suitability (MoS) are “Objective performance measures derived from subjective user criteria for assessing a system’s operational suitability to the organizational and mission applications”[18]. When used within the Systems Engineering domain these measures quantify issues like supportability, human interface compatibility, maintainability etc., in order to answer questions of how well the technical EoI fits into the user’s organization, mission applications and operating environment.

As Anteroinen states in *Enhancing the Development of Military Capabilities by a Systems Approach* USA, UK, Australia, Finland and NATO among other military actors “view capability as a system of interlocking and interdependent components” [6]. They do, however, choose to categorize their system elements differently from each other. USA uses DOTMLPF: Doctrin, Organisation, Training, Materiel, Leadership and Education, Personnel and Facilities. NATO uses DOTMLPF with an additional I for Interoperability. UK uses TEPIDOIL: Training, Equipment, Personnel, Infrastructure, Concepts and Doctrine, Organisation, Information and Logistics, Etc. The Swedish Armed Forces have chosen the British view for assessing technical systems [29]. Evidently, there are different ways of how to view capabilities and hence the concept should not dictate which architecture to use and thereby what indicators of military suitability to include.

For the continued discussion the TEPIDOIL architecture for capabilities is adopted. The Doctrine measure should then quantify how well the EoI is supported by the Doctrine and the tactical and technical procedures (TTPs), the Organizational measure should quantify to what degree the military force is organized to make the most of the EoI etc. etc. If, for example, the British army had made a correct analysis of the Military Utility of the battle tank before they used it for the first time in World War I perhaps the outcome would have been another [30]. The initial success when the tanks broke through German lines could not be exploited since there was no doctrine developed for how to combine them with infantry, i.e. the Doctrine Measure of Military Suitability was close to nil.

To conclude, a compound measure of Military Suitability is suggested in percent of maximum expected Military Effectiveness. If zero, the EoI has no Military Utility, since no capability is developed, due to no doctrine, no training of operating personnel and/or no logistics etc. If the compound measure on the other hand is 100%, the full potential of the EoI is developed. The compound measure is in turn a function of indicators quantifying the EoI fit with other elements of the capability. A product of the constituent indicators, individually expressed in percent, meets our need of a function, but is not the only way to calculate a scalar assessment.

5.3.3 Indicators of Affordability

In a study of concepts for future military technical systems it is nowadays more or less mandatory to take into account the system's life cycle cost to the owner. "Life cycle cost (LCC) represents all the costs that will be borne during the life of a System (Main System and Support System) to acquire, operate, support it and eventually dispose of it. The list of costs items to be considered in a project is defined and organized in a Life Cycle Cost Breakdown Structure (LCCBS) also referred to as a cost breakdown structure (CBS)"[31]. The Swedish CBS is described in a handbook on technical systems in SwAF [29].

There are other measures of ownership cost than LCC. Total Ownership Cost (TOC) adds indirect, fixed, linked costs to LCC, e.g. like common support equipment, common facilities, personnel required for unit command, administration, supervision, etc. NATO concludes that TOC is a better measure for budgeting purposes, determining the use of services between systems, for optimization purposes and for financial analysis [31].

In conclusion, measures for ownership cost are very well examined and if having a budget of reference and an estimated ownership cost it should be rather straightforward to obtain a measure for Affordability. The Affordability must, ultimately, be weighed together with the Military Effectiveness and Military Suitability in order to form a balanced measure of Military Utility.

5.3.4 Measurement considerations

However, though the concept allows a scalar assessment this is not necessarily the best way to present an assessment of military utility. The compounding process would assumedly involve assigning weighting factors to dimensions on the secondary level and then summing globally to get the result. The advantage is that it is easy to rank the different options - on the other hand, the disadvantage is that information from the different dimensions is lost. The opposite of the scalar assessment is the matrix assessment, where e.g. the dimensions of the secondary level (Military Effectiveness, Military Suitability and Affordability) are presented in a matrix. Alternatively, as long as the dimensions of Military Utility are positive numbers, they could be presented in a polar diagram. Or the elements of the matrix need not even be numbers. In fact they might as well be colors representing how well a certain requirement is fulfilled in some situation. Expressing assessments in scalars has advantages, e.g. when doing multiple simulations or doing some sensitivity analysis of the results. But an analyst has to keep in mind that humans are never unbiased, why the quality of the decision does not necessarily improve with a seemingly neutral scalar assessment. In fact, in a decision process the most important thing is often that the assessment is transparent to the decision-maker. Military utility is a subjective measurement and the need for an assessment can only be seen from a decision maker's perspective. Finding a transparent framework for doing the assessment is, however, not in the scope of this paper. It is enough to state that the concept in itself allows scalar assessment but is not limited to such a measure.

5.3.5 The new Swedish Armored Wheeled Vehicle (AWV) decision situation

But is there an example from reality indicating a need of the military utility concept, and perhaps illustrating the possibility to measure? As it turns out procurement is a grateful example of the sought for decision situation, since Swedish law require a documented unclassified model for evaluating tenders. In 2009, in the example chosen, the Swedish procurement agency, FMV, issued a Request For Quotation[32] for the acquisition of new armored wheeled vehicles.

In their defense planning process the Swedish armed forces, SwAF, had identified a need to replace their armored wheeled vehicles in two infantry battalions, in total 226 vehicles. There was also a requirement for delivery in time to reach initial operating condition for the first battalion in December 2014. The RFQ had one annex stating operational conditions and constraints, including organization of a mechanized infantry battalion, how it operates, expected enemy and typical missions.[32, Pt. C.4]

A decision-maker, using the military utility concept as a guideline, has thereby defined the situational variables; *of what?* – Of a combat vehicle in an infantry capability system, *for whom?* – For the land component commander in Sweden, and *in what context?* – As described in the annex operational conditions and constraints. Hence, it can be argued that the problem for a decision-maker to solve in this situation can be written: - *What concept has the greatest potential military utility to the land component commander in replacing the combat vehicles of the Swedish army, given the schedule and operational context described?* The next step in a decision process, using the military utility concept for support, should be to operationalize the three dimensions; Military Effectiveness, Military Suitability and Affordability.

In the evaluation model[32, Pt. E] enclosed with the request for quotation FMV instead defined six evaluation parameters and a function for how to make a compound measure. The total grading of a tender was obtained as a weighted sum of the identified parameters, see table 1. Each parameter were to be assessed on a scale from zero to ten corresponding to 'no commitment' and 'very good'. Furthermore they were broken down into sub-parameters, with weights, on one or two more detailed levels. 'Survivability' is for example an important sub-parameter in 'System performance' having a weight of 0,25. Survivability in turn is the weighted sum of mine protection, ballistic protection, signature management (camouflage, red. remark), etc.

Evaluation parameter	**W.**	**Comprises assessments of the following sub-parameters**
System performance	0,26	Variant performance, Mobility, Survivability, Command and communication, Availability, Support system performance, Usability, Flexibility and growth
Costs	0,28	Procurement, life operation and life support costs

Through-life responsibilities	0,08	System change, upgrades, governmental work load, disposal solution effectiveness
Contractual conditions	0,23	Title and right of use, fulfillment, liabilities, overall commission, effective cooperation
Implementation	0,09	Schedule, confidence in planning, confidence in system maturity
Program management	0,06	Project-, system engineering-, logistics-configuration-, quality and economic management

Table 1 presents the evaluation parameters, with weights on the top indicator level, in the evaluation model for tenders in the procurement of new armored wheeled vehicles for the Swedish army [32, Pt. E].

Using the vocabulary proposed for the military utility concept it can be argued that 'Survivability' is a measure of compliance to desired outcome on the battlefield and hence one of the indicators needed to assess the Military Effectiveness dimension. In analogy it is easy to see that the sub-parameters of 'Costs' are indicators related to the Affordability dimension. The Military Suitability dimension is about how well the vehicle fits the users existing capability system. This dimension seems to be addressed in the 'Implementation' parameter, measuring the quality of the plan for obtaining full operation, and in the 'Through-life responsibilities' parameter, measuring benefits for the logistic concept and governance. The remaining sub-parameters, constituting 'Program management', is really about managing the risk of not obtaining the desired outcome objectives in time and within budget and can be regarded indicators of Military Effectiveness and Affordability respectively.

In the end there were two remaining concepts competing for the contract, the Patria and the Nexter concepts. The evaluation ended in favor of the Patria tender, see table 2 [33].

Evaluation parameter	**W.**	**Patria**	**Nexter**
System performance	0,26	5,20	4,43
Costs	0,28	9,18	6,80
Through-life responsibilities	0,08	8,82	4,77
Contractual conditions	0,23	7,14	5,48
Implementation	0,09	8,00	7,50
Program management	0,06	8,00	7,80
Figure of Merit:		7,47	5,84

Table 2 presents the resulting evaluation of the two final competing tenders for the new Swedish AWV. The compound figure of merit for the two concepts, calculated using the evaluation model enclosed in the RFQ, is presented on the bottom line. [33]

The example with the new Swedish Armored Wheeled Vehicle (AWV) decision situation thus shows that there is a need for a quantitative concept capturing the phenomena described by the Military Utility concept. It also shows that there are decision-situations were it is both necessary and possible to quantify the assessments. One could say that the evaluation model in the example is one operationalization of the Military Utility concept fitted for administration of an acquisition program. A more straightforward application of the concept would be for Armed Forces to feed such an evaluation model with attributes and weights. That decision-model, for the example above, was however not available for scrutiny.

6 Conclusions

A concept called *Military Utility* is proposed for the study of a central phenomenon in military-technology. This phenomenon, dealing with the technology the military profession chooses, and how it uses that technology, affects the outcome on the battlefield and the sustainment of capabilities over time. The concept is needed to aid effective communication within the defense community and to support decision-making. It was derived through conceptual analysis according to Goertz and is based on related concepts used in social sciences, the military domain and Systems Engineering.

Military Utility is a function of three situational variables: the Element of Interest, the Military Actor and the Context. The concept has three dimensions. The *Military Effectiveness* dimension is a measure of the overall ability to accomplish a mission when the EoI is used by representative personnel in the environment planned or expected for operational employment of the military force. The *Military Suitability* dimension is the degree to which an EoI can be satisfactorily placed in military use in a specified context with consideration to interaction with other elements of the capability system. The *Affordability* dimension is a measure of compliance to the maximum resources a military actor has allocated to the EoI in a time frame defined by the context. In summary, the Military Utility of an EoI, to a military actor, in a specific context, is a compound measure of the military effectiveness, of the EoI's suitability to the military capability system and of the affordability.

By using the proposed concept and a system approach it is possible to explain how military capabilities are constituted and affected by: developments in technology; by different use of technology and how military actors and command levels are affected differently. It becomes clear that there are many factors influencing the assessment and apart from providing a common language, which is likely the biggest contribution to theory - Though assessing Military-Technology is still not easy, it becomes evident which primary factors and relationships must be considered in a quality assessment.

The discussion also indicates that the concept has explanatory abilities, i.e. it supports qualitative analysis of technology in military capabilities. This is important to actors in the defense sphere doing technological forecasts, doing defense planning, developing technology or tactics, using it, or analyzing lessons learned. Hence the concept, accompanied by appropriate frameworks and methods, can support military decision-making regarding technology in these areas.

7 Future research

Though examples of Measures of performance are suggested for the indicator level, indicating support for quantitative analysis, the concept in itself does not stipulate specific frameworks or methods. Future research is needed to further validate the concept. This will be done addressing relevant decision situations and fitting frameworks of indicators and methods to specific problems and applications.

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