ESTIMATION OF LOGISTIC CONSUMPTION FOR THE NORWEGIAN ARMED FORCES

Presented at 23ISMOR August 29th – September 1st 2006

by

Terje Nilsen

Norwegian Defence Research Establishment

P O Box 25

NO-2027 KJELLER

NORWAY

Tel: +47 63 80 77 85

Fax: +47 63 80 77 15

E-mail: Terje.Nilsen@ffi.no

ABSTRACT

As a consequence of new security challenges The Norwegian Armed Forces are transforming to adapt to the new security environment involving different types of missions where the areas of operations usually are a long way from the home base. Effective logistics is recognized as crucial to the success of this kind of missions. This paper presents the ongoing work at FFI to establish estimates of logistic consumptions in future operations. Understanding of logistic consumption is a prerequisite for the analysis supporting the development of a new operational logistic concept and a cost/effective logistic system.

This paper explains the two faced estimation approach chosen in order to obtain a framework for quick consumption assessment of different missions expressed in terms of consumption profiles reflecting consumption as well as variation of consumption over time. A major challenge in consumption estimation is to obtain good input data. This paper presents the type of data sources used in the study, and discusses problems related to the acquisition of input data.

Prognostication of consumption in operations is an important part of the analysis. It is argued that the prognosis is a vital part of the important concept labelled *"Sense and Respond Logistics"* to be studied. The paper discusses important issues related to applying the estimation method in a *"Sense and Respond Logistics"* context.

Finally some methodological challenges are presented.

1 INTRODUCTION

FFI is a governmental research organisation supporting the Norwegian Defence. Among other tasks, FFI has for more than 25 years supported the Norwegian long term defence planning. This planning has in the past not been focussed on cost/effectiveness of the combat service support. With a more varied range of missions in international operations usually a long way from the home base, more emphasis is placed on effective logistics. FFI has for about 6 years, run a series of projects focussing on logistic issues. One of the main activities of these projects has been, and is, estimation of logistic consumption.

Consumption is the most important precondition for evaluation of logistic systems. The main objective of logistic systems is to maintain an appropriate supply level for the force over time. Consumption is the main factor reducing the supply level. Hence in order to study the performance of logistic systems, understanding of the characteristics of consumption and consumption rates is necessary.

In long term planning, several factors make estimation of consumption difficult. Some of these difficulties will be discussed later in this paper under the heading "challenges". Although our main focus is long term planning, our estimation method and results also seem to be of interest for more short term work, like planning national logistic stocks and operational planning. The possibly most interesting applications of our estimation effort are listed below.

- **Force structure planning:** The main reason for calculating consumption estimates is to support a long term planning study on operational logistics. The final result will be presented in the form of advice on future operational concept and the acquisitions of logistic materials (trucks etc.) which this implies. The results will be used as an input to the next long term planning document for the Norwegian Armed Forces being developed in a study called FS-07.
- **Logistics planning of stocks:** As part of the ongoing transformation within the Norwegian Armed Forces, there is a need to identify surpluses and shortages of the present logistic holdings. Hence FFI is also asked to support a study on future logistic stock requirements of the Norwegian Armed Forces.
- **Operational planning:** The consumption estimates are also believed to be useful in the early phases of an operation to obtain a quick first order of magnitude impression of the expected supply requirement of a real operation
- **Prognosis:** We also believe better prognosis will be essential in future operations if "Sense and Respond Logistics" philosophy is implemented. Then reliable consumption rates in the "right" measure will be essential to obtain.

The calculations of consumption estimates are described in chapter 2, followed by a discussion in chapter 3 of the consumption rates used in the calculations and their usefulness in prognosis. In chapter 4 the methodological challenges are discussed, and finally some conclusions are given in chapter 5.

2 CONSUMPTION ESTIMATES – METHOD, INPUTS AND RESULTS

Faced with the problem of estimating the consumption for a period measured in months, when the consumption rate may vary considerably from one hour to the other, we landed on a two phased approach. First we calculated the consumption of a selected set of 7 days operation types. Our final estimates are based on an appropriate sequence of 7 days operation types chosen from the set. In order to achieve a certain degree of consistency in the activities performed by one unit to another during an operation, and to be certain to have taken all the important factors into considerations, a particular scenario was selected and the possible roles of each force component in the scenario was examined. Then we calculated the consumption estimates for each 7 days period for each force component in each of these roles. The method for calculating consumption estimates of a 7 days period is illustrated in figure 2.1. The calculation procedure is implemented in Excel, making it more accessible to military personnel.

2.1 Method of calculation

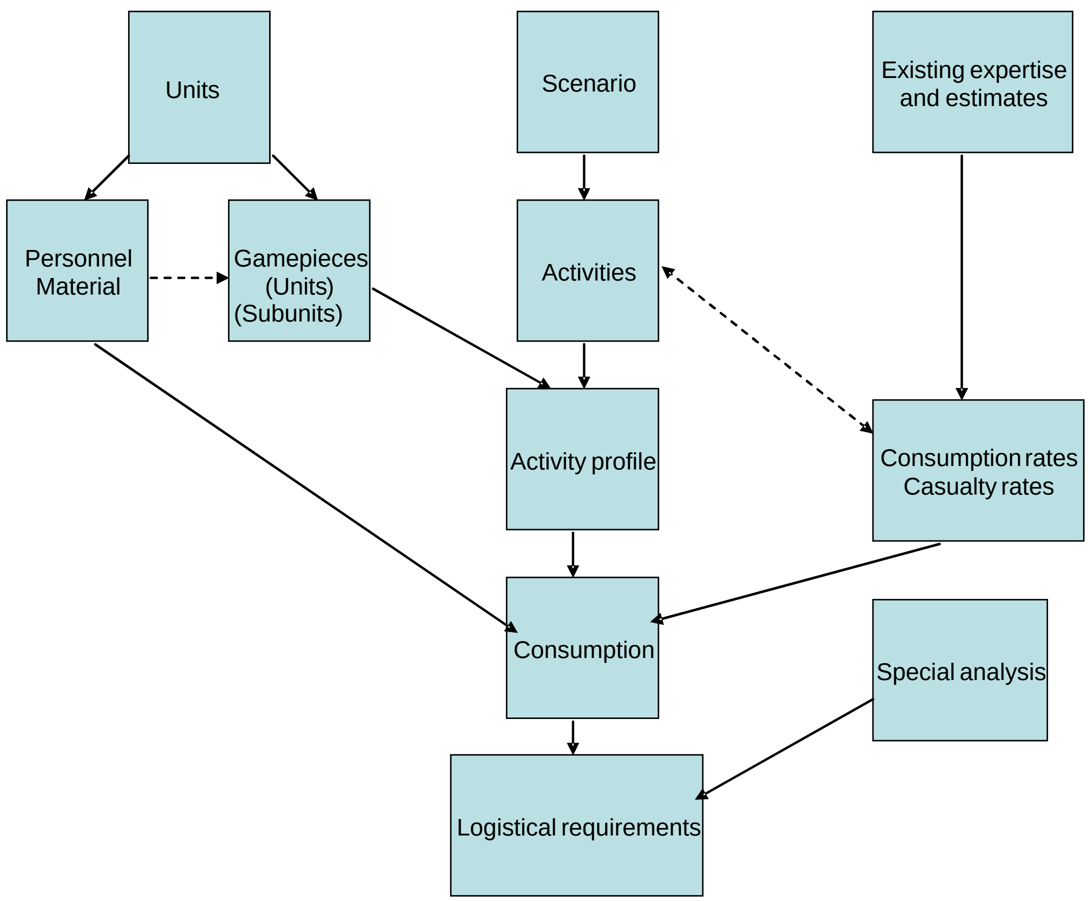

Figure 2.1: An overview of the method used for calculating consumption estimates

In brief, the consumption estimates are calculated by specifying an **activity profile** and sum up the consumption for all the **consumers** in the unit that is to be estimated according to this **activity profile**. For this calculation each unit (e.g. mechanized battalion) is divided into subunits (e.g. tank), called **game pieces**, with the granularity of this subdivision determined by accuracy considerations. For each game piece an activity profile is defined. This profile describes the main activity of the game piece at any time during the seven days period constituting the standard duration of an operation type (e.g. training, defensive combat). It consists of a sequence of activities chosen from a set of predefined **activities** together with the duration of each activity in the sequence. In each game piece the consumers of the supply type (e.g. fuel) to be estimated are specified in terms of number and type of consumer (e.g. tank and armoured field vehicle are two types of consumers for estimating fuel consumption). For each type of consumer there are specified **consumption rates** which vary according to activity type. The consumption rate multiplied by the duration of the specified activity, and summed over all the activities specified for the seven days period results in the total consumption. The equation below gives the expression of the calculation of the total consumption:

$$Consumption = \sum_{j \in Game\_pieces} \left[\sum_{i \in Consumer\_type} \left[\int_0^T \left(Consumer_{i,j}(t) \cdot Consumption\_rate_{i,j}(t) \cdot dt \right) \right] \right]$$

$Consumer_{i,j}(t)$: the number of the i-th type of consumer in the j-th game piece at time t
$Consumption\_rate_{i,j}(t)$: is the consumer rate for the i-th type of consumer at time t, given the activity for the j-th game piece at time t
Game pieces: is the collection of subunits in the total force in question
Consumer types: is the collection of personnel and material types consuming supplies

The method assumes that the consumption is calculated based on consumption rates (consumption per time unit). In many cases the consumption will not be time dependent, for instance consumption of ammunition. Calculation of ammunitions consumption is based on the number of combat incidents/engagements. The consumption of ammunition in each engagement results from detailed simulations and/or qualified evaluations. Ammunition consumption rates are adjusted to correspond with the estimated combat duration.

2.2 Calculation inputs

The choice of **units**, **scenarios, activities** and **activity profiles** were all done in close cooperation with military expertise. We chose a scenario based on the following three criteria: 1) How relevant the scenario was in the political/security climate, 2) that all the services were involved (the scope of the scenario), and 3) that the scenario should be representative in terms of extrapolating the results to other relevant scenarios. Before we defined the **activities** we mapped all the different tasks that the units were to do in the different missions. When setting up the **activity profiles** for all the missions, we defined for each time step the activities of the different units. We used **existing expertise and estimates** from NDLO, staff handbooks, maintenance databases, and combat simulations as basis for our **consumption rates**. In order to define the **logistical requirements**, **special analyses** should be undertaken (e.g. loss of supplies (accidents, theft etc.), to which extent the units have filled up their fuel tanks, loaded their weapons etc.). Consumption estimates should ideally take into account the reduced consumption due to casualties**.** Although our method can incorporate casualties into the calculations, it was for different reasons decided to set the **casualty rates** to zero.

Consumption estimates were calculated for the supply types: water, provisions, fuel, ammunition, and spare parts for the primary missions: training, defensive combat, offensive combat, normal and high stabilization. The measures used for the different consumption rates were:

- Water: Litre per man per day (varies according to unit and mission)
- Provisions: Kilo per man per day (varies according to unit and mission)
- Fuel: For all the fuel consumers an average value for each activity based on litre per consumer per hour.
- Ammunition: Number of rounds/weapon per incident.
- Spare parts: Norwegian kroner per type of material per hour, e.g. one hour use of F-16 will consume spare parts for X thousand kroner. Studies have been undertaken to get both more reliable numbers and a more practical metric in terms of knowing what spare part is needed, see below.

The rates of spare parts for sea and air were mainly based on historical information about the expenditure related to maintenance both “in-house” and when repairs was carried out in commercial dockyards and by commercially hired fly mechanics. To obtain more reliable rates for air and sea, we analysed two maintenance databases, one for air and one for sea in more detail. The results (1) from the maintenance database for air consisted of data on electronic components in the F-16. The analysis resulted in numbers for Mean Time Between Failure (MTBF), work hours and work cost for different categories of electronic systems in the F-16. The results (2) from the maintenance database for sea resulted in numbers for Mean Time Between Failure, work hours and materials cost for the following vessel types: Mine sweeper, missile torpedo boat and submarine.

Rates of spare parts consumption for land were based on an analysis of a maintenance database. The results (3) from the analysis suggested “distance covered” as a measure for vehicle use. Linear relationship has been found to exist between distance covered and each of the three maintenance parameters; failure rate, repair time, and spare part cost, in rough estimates of maintenance requirements. These relationships are so far studied for the vehicle types: Leopard 1, CV9030, M113, BV206, “standard” truck, utility vehicle and drop truck. The analysis of different vehicles has also supported a hypothesis stating a correlation between spare part cost and acquisition cost. Such correlations will enable us to calculate the spare part cost of one vehicle type from the spare part cost of another vehicle type, when the acquisition prices and MTBFs are known. In this way, rough estimates of spare parts costs may be calculated for vehicle types not analysed.

2.3 Results

The results (4) for the consumption estimates were made for the following supply types: provisions, water, fuel, spare parts and ammunition and for each of the primary missions: training, defensive combat, offensive combat, normal and high stabilization. Consumption estimates in terms of weight, volume and cost has been calculated for a standard seven days period of each of the primary missions. The results of these calculations were used to estimate the consumption of the totality of an operation of 6 months duration.

3 CONSUMPTION RATES AND PROGNOSIS

Prognosis has always been important and will probably be more so in the future since the focus is directed towards decreasing stocks. In the future, logistics could look like figure 3.1. The figure is based on the US concept “Sense and Respond Logistics” that is promoted by The Office of Force Transformation (OFT) (5).

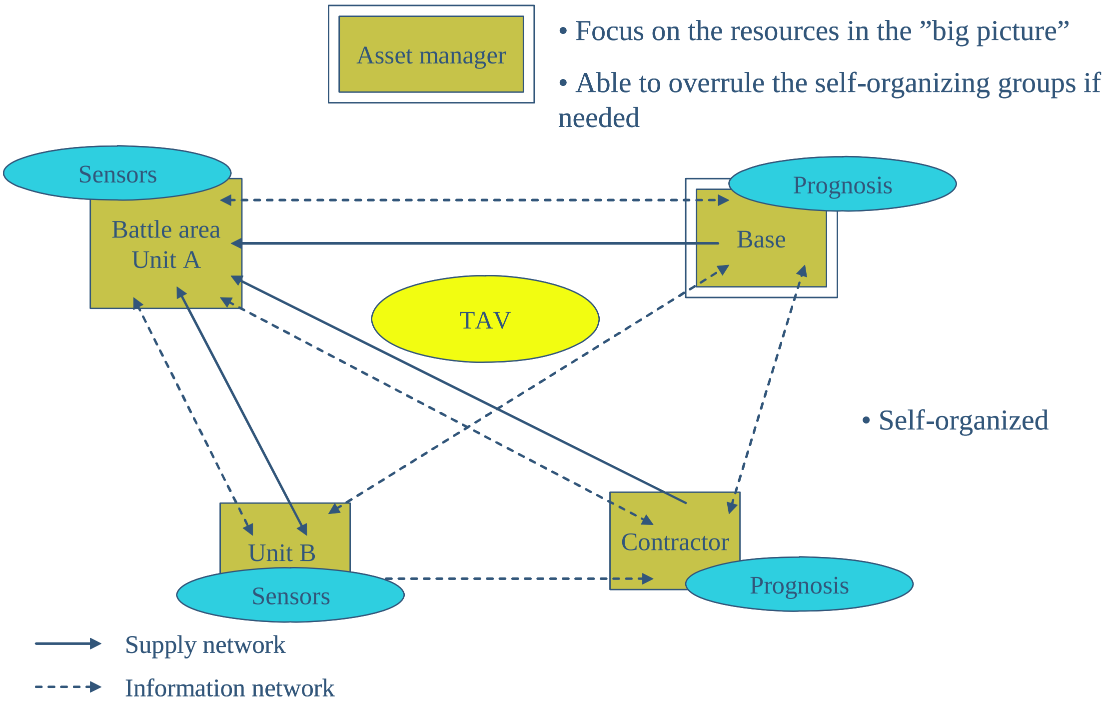

Figure 3.1: The figure is based on the concept “Sense and Respond Logistics” (US) (source (6))

The “Sense and Respond Logistics” concept has a network centric structure regarding information flow and supply routes as opposed to traditional logistic concepts where hierarchical structures prevailed. In the S&RL-concept all the players have Total Asset Visibility (**TAV**), which means that they know at all times (near real-time) where (at a warehouse, in air, on road etc.) all the supplies are in the network. Groups **self-organize** via a common environment and set of shared objectives, e.g. commander’s intent. The **Asset Manager** has focus on all the resources in the network, and has the power to redirect supplies if necessary.

One of the objectives of the S&RL-concept (7) is to decrease stock levels (reduced “footprint”), and one way of doing this is to get as accurate prognosis as possible. To get reliable prognosis it is imperative that the prognoses tools for supplies have the best possible input numbers: Sensor information (status), and consumption rates, e.g. that the number of litres consumed by a soldier during a given condition is as accurate as possible.

Mapping the measures for the consumption rates which we used in our estimations (see page 5) with the measures that are required from a prognosis/suppliers view, we get the following table:

	Number of	Weight	Volume	Price
Water			X	
Provision		X		
Fuel			X	
Spare parts				X
Ammunition	X			

Table 3.1: A comparison of the measures of the actual consumption rates (X) and the desired measures in prognosis/suppliers view (green)

The supply types of water, fuel and ammunition all have the measure that are in line with the measure a prognosis/suppliers wishes. To get the "right" measure for the supply type provision is easy: Number of provisions = number of men. For spare parts the measure is given in price, but from a prognosis/suppliers view, knowledge of what spare part is requested. In the studies we undertook regarding spare parts (see page 5), we did find results in MTBF for some systems for air, sea and land. But the results are not in such a detail as to conclude on the break down probability of different parts of the system (e.g. the main engine).

From the above discussion, the consumption rates for water, provision, fuel and ammunition have the "right" measures to be implemented in a prognosis tool, but not the consumption rates for spare parts. However, it should be mentioned that the consumption rates used in our estimations for the supply types: water, provision, fuel and ammunition does not include all the rates necessary to make a good prognosis tool (a tool that can be used in other scenarios). For instance, it probably will be necessary to adjust the rates for water according to climatic condition in other scenarios. But such adjustments should generally be possible by the support of military expertise. However, to obtain valid rates there is a big challenge particularly for spare parts and ammunition.

4 METHODOLOGICAL CHALLENGES

There are at least four challenges connected to our consumption estimates: Verification of the level of accuracy, representativity of results, area of application, and deaggregation of results.

Verification of the level of accuracy

The accuracy of the consumption estimates has so far just been validated through the presentations of the results to military experts who intuitively thought them to make sense. Since it is not possible to test the estimates empirically, one solution could be to compare the results with an actual operation that has as many similarities as possible to the scenario in this study.

Representativity of results

The most generic scenario available was used because we wanted to have the possibility to extrapolate the results to other scenarios. The challenge in extrapolating the results is that every operation/scenario has its own attributes, which makes it necessary to get support from military expertise to establish the differences between the generic scenario and the scenario at hand, and only then does it make sense to try to extrapolate the results.

Area of application
Until now our work has four areas of application as we see it: Force structure planning, logistics planning of stocks, operational planning and prognosis (see page 2). If the estimates are to be used by the military in operational planning, then it is important that the assumptions of the calculations are known to the operational planner in such detail that proper adjustments in line with the characteristics of the actual operational theatre can be made, to get a best possible first order magnitude of the expected supply requirements.

Deaggregation of results
The results for the supply types: water, provisions, fuel, ammunition and spare parts can all be deaggregated down to each consumer (e.g. Leopard, F-16, submarine etc.), where the results for the first four types have the “right” measure form a supplier point of view (see page 6). The challenge consists of getting the results for the supply type spare parts from the measure: Norwegian kroner per hour (for each consumer) to the measure: Number of per hour (for each spare part). A solution to this problem could be to get a fixed distribution of spare parts being used by each consumer corresponding to a certain amount measured in Norwegian kroner.

5 CONCLUSIONS

In this paper a method for calculating consumption estimates is presented. This method is validated through the presentation of the results to military experts, and the results seem to agree with the intuitive judgements of the logistic experts. A set of calculated basic 7 days operations that can be used for quick estimates of different operations are available. Further work could be to examine present operations in order to compare the results with experienced consumptions in real operations. Through the study with consumption estimates we have also found consumption rates for the supply types: Water, provision, fuel, spare parts and ammunition. The consumption rates for all of the above supply types, except spare parts, will constitute a good basis as input numbers to prognoses tools. Some work has been done to improve rates for spare parts, but more work is needed to make it a useful tool for prognosis.

REFERENCES

(1) BORGE Anette (2004): Feilhyppigheter og vedlikeholdsbehov for noen elektroniske systemer – analyse av IMAS-data for F-16, FFI/Notat-2004/02666, classified. (Maintenance requirements for electronic systems – analysis of IMAS-data for F-16). (In Norwegian)

(2) MOE Christian Rørholt (2005): Feilhyppigheter og vedlikeholdsbehov for noen marinefartøyer – analyse av VEPOST99-data, FFI/Notat-2005/02234, classified. (Maintenance requirement for some navy vessels – analysis of VEPOST99-data). (In Norwegian)

(3) LANGSÆTER Tor et. al.(2003): Feilhyppigheter og vedlikeholdsbehov for noen militære kjøretøytyper – analyse av EDBVT-data, FFI/Rapport-2003/01339, classified. (Estimates of failure rates and maintenance cost for selected military vehicles – analysis of EDBVT-data). (In Norwegian)

(4) NILSEN Terje et. al.(2005): Forbruk av forsyninger i utenlandsoperasjoner – beregninger knyttet til MFU03-scenario S14, FFI/Rapport-2005/03537, classified. (Consumption of supplies in international operations – estimates in connection with MFU03-scenario S14). (In Norwegian)

(5) SHRADY David (2005): Sense and Respond Logistics, Proceedings of the 22nd ISMOR, UK, unclassified. http://www.dcmt.cranfield.ac.uk/ismor

(6) NILSEN Terje et. al. (2004): The future of military logistic concepts, FFI PP-presentation, classified.

(7) OFFICE OF FORCE TRANSFORMATION (OFT) (2004): Operational Sense and Respond Logistics: *Coevolution of an Adaptive Enterprise Capability*, Concept Document (Long Version), unclassified. http://www.oft.osd.mil/initiatives/srl/family.cfm