NORTH ATLANTIC TREATY ORGANIZATION

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STO TECHNICAL REPORT **TR-SAS-132**

Models and Tools for Logistics Analysis

(Modèles et outils d'analyse logistique)

Final report of Research Task Group SAS-132.

Published July 2020

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

AAP	Allied Administrative Publication
AJP	Allied Joint Publication
AMSP	Allied Modelling and Simulation Publication
DOTMLPF-I	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities and Infrastructure
ET	Exploratory Team
LOC	Line of Communication
OA	Operational Analysis
OR	Operations Research
PfP	Partnership for Peace
POL	Petroleum, Oil and Lubricants
RTG	Research Task Group
SAS	System Analysis and Studies
V&V	Verification and Validation

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Models and Tools for Logistics Analysis

(STO-TR-SAS-132)

Executive Summary

This report summarizes the findings from working group SAS-132 on Models and Tools for Logistics Analysis. This activity had three primary objectives with associated deliverables. The first one was to develop an information collection template (Deliverable D01) to inventory and characterize models and tools of interest. This template is fairly detailed, with over 90 fields for each tool, and is documented according to standard NATO terminology and NATO logistic doctrine. The second one, based on D01, was a survey of the participating nations and organizations in order to develop a catalogue (matrix) of models and tools used by NATO nations and PfPs to analyse military logistics (Deliverable D02). This catalogue can serve as a reference for the participating nations and more broadly for operational research analysts across the Alliance. The third one (Deliverable D03) is the present report. It uses the information collected in the catalogue to identify gaps in terms of analytical capabilities, overlaps, and areas for potential collaboration, and documents them, along with D01 and D02, in a final activity report.

The SAS-132 working group surveyed over 100 models and tools used for logistics analysis within SAS-132 participating nations, namely CAN, CZE, DEU, GBR, NLD, SWE, TUR and NATO NCIA. We identified 75 tools with a strong logistics analysis focus for which we collected additional information. The information collection template was in the form of a spreadsheet containing over 90 fields. It captured various aspects of the models and tools of interest, such as the area(s) of sustainment logistics analyzed by each tool, the area(s) of procurement logistics analyzed, the context of the analyses, information requirements, etc. The collected information was then reviewed and collated into a single catalogue of models and tools. This catalogue can now serve as a reference for logistics analysts within the Alliance and can also help us identify gaps in terms of logistics analysis capabilities, overlaps, as well as areas for sharing and future collaboration. It presents, in a structured way, which Logistics models are used in the participant countries and this catalogue of national models in Excel format can be used as is by any NATO or Partner nation to determine which Logistics models are available and being used in other nations.

The analysis revealed that individual participating nations have different approaches to conduct logistics analysis using modelling and simulation tools. Some nations mainly use broad, institutionally recognized models as standard supporting tools for logistics considerations. Others mainly use fit-for-purpose models designed to handle specific problems, while some nations rely on NATO recognized software (e.g., LOGFAS) only. Despite these differences, the wide and deep potential of the set of tools and instruments identified creates a solid foundation for future cooperation between NATO and PfP nations for logistics analysis and also provides opportunities to share existing models.

Modèles et outils d'analyse logistique

(STO-TR-SAS-132)

Synthèse

Le présent rapport résume les conclusions du travail du SAS-132 sur les modèles et outils d'analyse logistique. Cette activité avait trois principaux objectifs, accompagnés d'éléments livrables. Le premier consistait à élaborer un modèle de collecte de données (élément livrable D01) pour inventorier et caractériser les modèles et outils concernés. Ce modèle est assez détaillé, puisqu'il comporte plus de 90 champs par outil et est documenté conformément à la terminologie standard de l'OTAN et à la doctrine logistique. Le deuxième objectif, fondé sur le D01, était une étude portant sur les pays et organismes participants, afin d'établir un catalogue (matrice) des modèles et outils utilisés par les pays de l'OTAN et du PPP pour analyser la logistique militaire (élément livrable D02). Ce catalogue peut servir de référence aux pays participants et plus généralement aux analystes de recherche opérationnelle de toute l'Alliance. Le troisième objectif (élément livrable D03) est le présent rapport. Il utilise les informations recueillies dans le catalogue pour identifier les lacunes en matière de capacités analytiques, les chevauchements et les domaines de collaboration potentielle et les documenter, avec le D01 et le D02, dans un rapport final d'activité.

Le groupe de travail SAS-132 a étudié plus de 100 modèles et outils servant à analyser la logistique parmi les pays et organismes participant au SAS-132, à savoir l'Allemagne, le Canada, les Pays-Bas, la République tchèque, le Royaume-Uni, la Suède, la Turquie, et l'Agence OTAN d'information et de communication. Nous avons identifié 75 outils très axés sur l'analyse logistique, pour lesquels nous avons recueilli des données supplémentaires. Le modèle de collecte de données se présentait sous la forme d'une feuille de calcul contenant plus de 90 champs. Il enregistrait divers aspects des modèles et outils concernés, tels que le/les domaines de logistique de soutien analysés par chaque outil, le/les domaines de logistique d'acquisition analysés, le contexte des analyses, les besoins en termes de données, etc. Les informations collectées ont ensuite été examinées et collationnées en un seul catalogue de modèles et d'outils. Ce catalogue peut maintenant servir de référence aux analystes de la logistique au sein de l'Alliance. Il nous a également aidés à identifier les lacunes en matière de capacités analytiques, les chevauchements et les domaines de partage et de collaboration future.

L'analyse a révélé que chaque pays participant avait une approche différente de l'analyse logistique, à l'aide d'outils de modélisation et de simulation. Certains pays utilisent principalement des modèles généraux, reconnus par les institutions, qui leur servent d'outils standard de soutien à des fins logistiques. D'autres pays utilisent des modèles sur mesure, conçus pour gérer des problèmes particuliers, tandis que d'autres encore ne s'appuient sur les logiciels reconnus par l'OTAN (par exemple, LOGFAS). En dépit de ces différences, le vaste potentiel de l'ensemble d'outils et d'instruments identifiés crée des fondations solides pour une future coopération entre les pays de l'OTAN et du PPP au sujet de l'analyse logistique. Il offre également l'occasion de partager les modèles existants.

MODELS AND TOOLS FOR LOGISTICS ANALYSIS

1.0 INTRODUCTION

1.1 Background

The cost of military logistics and support typically represents a large proportion of a nation's defence budget. Small investments in logistics analysis can enable significant savings, reduce the deployed footprint, increase efficiencies and flexibility, ensure required military effect and support declared mission goals. For that reason, most nations spend considerable effort in developing models and tools for military logistic analysis, for example to support deployment planning and course of action consideration, analyze the support chain, reduce logistics costs, increase operational effectiveness, and analyze life cycle costs. The analytical methods being employed range from simple spreadsheet calculations and soft analysis workshops, to sophisticated mathematical models and simulation software. These analytical methods are generally developed and implemented through in-government capabilities – in particular, Operations Research (OR) / Operational Analysis (OA) capabilities and Life Cycle Management (LCM) analysis – and are often supported or supplemented by private companies with specific tools or expertise. The development of these methods may also involve collaboration with other nations' defence research organizations in the field of OR/OA and LCM.

1.2 SAS-132 Objectives

To that end, a NATO System Analysis and Studies (SAS) Exploratory Team (ET) was formed in 2016 to explore how NATO nations and NATO Partners for Peace (PfPs) could collaborate in terms of logistics analysis. This ET led to the establishment of SAS-132, a two-year Research Task Group (RTG) on *Models and Tools for Logistics Analysis* [1]. The RTG included CAN, CZE, DEU, GBR, NLD, SWE, TUR and NATO NCIA.

SAS-132 had three primary objectives and associated deliverables:

1) Develop a information collection template (Deliverable D01) to inventory and characterize models and tools of interest. This template is fairly detailed, with over 90 fields for each tool, and is documented according to standard NATO terminology and NATO logistic doctrine. The template can be found in Annex A of this report.
2) Survey the participating nations[1] and organizations in order to develop a catalogue (matrix) of models and tools used by NATO nations and PfPs to analyze military logistics (Deliverable D02). This catalogue could be used as a reference by the participating nations and more broadly by OR/OA analysts across the Alliance.
3) Use the information collected in the catalogue to identify gaps in terms of analytical capabilities, overlaps, and areas for potential collaboration and document them, along with D01 and D02, in a final activity report (Deliverable D03, the present report).

Another objective of SAS-132 was to use the forum as a means to exchange knowledge about the specifics of certain tools, models, techniques or approaches, through focused presentations by national experts, and also through the exchange of scientific papers.

[1] TUR participated in two meetings and some of the discussions but did not provide input on models and tools for the D02 catalogue.

By learning from other countries' analytical capabilities and experience in studying similar logistics problems, NATO nations, bodies and PfPs can save a significant amount of effort, time and money in the development of new analysis models and tools. They can also find opportunities to compare, contrast and cross-validate different tools and analytical approaches. Furthermore, the catalogue and conclusions of SAS-132 can help focus the development of new models and tools on capability gaps and areas of mutual interest to the defence logistics analysis community, across NATO bodies and within each nation.

1.3 Definitions

Since there are minor differences in how different nations define and interpret terms related to logistics, NATO terminology and definitions were used by SAS-132. Specifically, for the purpose of this work, the following definitions of "logistics", "model" and "tool" are used:

- **Logistics** is defined in its most comprehensive sense, i.e., "the aspects of military operations which deal with:
  - Design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposal of materiel;
  - Transport of personnel;
  - Acquisition or construction, maintenance, operation, and disposition of facilities;
  - Acquisition or furnishing of services; and
  - Medical and health service support." [2]
- A **model** is defined here as "a physical, mathematical or otherwise logical representation of a real system, entity, phenomenon, or process." [3]
- A **tool** is defined here as the implementation of a model (as defined above) or other analytical approach. A tool can take the form of a software application, web application, spreadsheet, simulation software, or other form.

Additional definitions related to specific logistics terms are given in Annex A describing the information collection template.

1.4 Outline

Following this introduction, Section 2 describes the RTG SAS-132 general work process. Section 3 describes the views from participating nations (NATO NCIA's views are also included). Section 4 analyses information from the catalogue (D02), including a discussion of the analytical gaps in the tools surveyed and opportunities for potential collaboration. Section 5 describes general conclusions and a potential way ahead for NATO with respect to logistics modelling and analysis.

2.0 APPROACH

2.1 General Timeline

The Exploratory Team meeting took place in September 2016 in Paris, where a Technical Activity Proposal (TAP) was produced to document the activity's objectives, deliverables and timelines. The denomination of the deliverables (D01-D03) previously listed follows their denomination in the TAP.

SAS-132 is a two-year Research Task Group (RTG) that has held five physical meetings: the first in Stockholm, SWE, in April 2017; the second in The Hague, NLD, in September 2017; the third in Wilhelmshaven, DEU, in March 2018; the fourth in Prague, CZE, in September 2018; and the final meeting in Ottawa, CAN, in March 2019. Between meetings, a significant amount of collaboration and coordination was conducted virtually through emails and NATO's Science Connect portal.

2.2 Information Collection Template

The first meeting focused on generating a template (D01) to survey of models and tools for defence logistics analysis being used within countries participating in the activity. This template, in Microsoft Excel, is largely inspired from a catalogue of logistics models developed by the United Kingdom [4]. Multiple fields are also borrowed from a Canadian compendium of OR tools [5].

The template produced by SAS-132 contains over information 90 fields and is described in Annex A. Most of them are multiple choice fields that can be filled out relatively quickly by subject-matter experts. A descriptor aligned with NATO terminology and doctrine is provided for each information field. An example of input for a materiel repatriation simulation [6] is also provided to illustrate the type and amount of information expected by SAS-132 for each field.

2.3 Catalogue of Models and Tools

Starting mid-2017, members of SAS-132 began collecting information using the template within their respective nations and organizations. The models and tools of primary interest were those that have been used (or are expected to be used) by analysts in the participating nations for providing logistics analysis and decision support to NATO bodies, NATO nations and PfPs. The information was reviewed by SAS-132 during follow-on meetings and collated into a single catalogue (D02). Some models are included more than once because they are used by more than one nation.

2.4 Catalogue Analysis

Around mid-2018, the group started to use the catalogue to identify gaps in analytical capabilities, overlaps and opportunities for collaboration. Examples of such opportunities include, for example, tools or report sharing. Another example is the comparison or cross validation of models/tools used for similar purposes by different nations.

To make this analysis repeatable as the catalogue potentially evolves in the future, different analysis features and macros were directly incorporated into the catalogue. They allow the models and tools of different nations to be compared, filtered or analyzed from specific angles. Examples of such analyses are presented later in this report.

2.5 Knowledge Exchanges

During each physical meeting of SAS-132, a small amount of time was reserved to exchange knowledge and national experiences surrounding specific tools or models. This was an opportunity to do a "deep dive" into a particular method, model, and the context for which they are aimed to be used. Specifically, SWE made a demonstration of PVL, a logistics forecasting and analysis tool. NLD made a presentation on the AMICO logistics analysis tool. DEU arranged a visit to Wilhelmshaven harbour and the frigate Hamburg which offered several insights regarding logistics at sea. CZE hosted the meeting at the Multinational Logistics Coordination Centre (MLCC) where a presentation of MLCC was given. CAN presented on vehicle routing optimization conducted for the Canadian Material Support Group, a study about optimizing the supply chain for disaster relief, applications of information analytics to spare parts forecasting, and a summary of logistics analysis work done under the Technical Cooperation Program (TTCP) Land Systems Group (TP6).

2.6 Life Cycle Management Considerations

Life Cycle Management (LCM) is an important aspect of logistics in the context of national procurement and maintenance processes. LCM, among other issues, explains the importance of the Integrated Logistics Support (ILS) process for complex and costly materiel systems. ILS is of high importance and seamless connected to reliability, maintenance, logistics, cost effectiveness and military success in the field. Modelling and simulation tools can be extremely useful for LCM and ILS. The LCM analysis (and here we include ILS/LSA analysis) may or may be not considered as OR/OA depending on the purpose and on the ambition of the analyst. But without any doubts, most OR/OA related to logistics would benefit from including complete LCM analysis, or at least the outcome of such analysis.

As part of our approach, LCM was considered when capturing tool characteristics. In fact, some national toolsets are analyzing logistics largely from an LCM process perspective, whereas other participants approach logistics more from a methodological OR/OA perspective.

OR/OA generally deals with the application of various analytical methods to help make better decisions. But the term “operational analysis” is often used in the military as an intrinsic part of capability development, management and assurance. In the UK for instance, operational analysis forms part of the Combined Operational Effectiveness and Investment Appraisals (COEIAs), which support the UK Ministry of Defence capability acquisition decision making. Operational analysis is conducted in order to understand and develop operational processes and aims to determine whether each area of analysis is contributing effectively to overall performance and the furthering of the military strategy adopted. LCM analyses are doing the similar job but focus on one particular system or product. It is clear that when operational analysis involves one or many systems, it will be beneficial if LCM analyses are also conducted and taken into considerations. In the same way OR/OA can include LCM analysis the LCM process can include operational analysis. For example, in performance engineering, an integral part of LCM, operational analysis involves a set of basic quantitative relationships between performance quantities based on operational laws used to predict the response time, throughput, availability, reliability, etc.

A more detailed discussion on LCM is given in Annex B.

3.0 NATIONAL PERSPECTIVES

3.1 United Kingdom

3.1.1 British Perspectives

The United Kingdom (UK) perspective is limited to the contents of the Defence Science and Technology Laboratory (Dstl) Logistics Model Catalogue (LMC), and therefore does not represent a complete view of all UK defence-related logistics modelling capabilities.

The LMC contains a much wider selection of tools and models for logistics analysis, however these include tools and models which are no longer in use, alongside models from industry about which Dstl are aware. These have been excluded from the NATO catalogue (D02) on the basis that these would not be suitable for collaboration with other nations without further understanding of specific requirements. As such, the UK models in the D02 are limited to Dstl-owned or -developed tools and models that are currently in use, and therefore have the most potential for collaboration opportunities and ongoing user support. Where classification permits, all actively used logistics models recorded within the Dstl LMC have been included in the D02. These entries have been included based on the best available knowledge of the model or tool's owner.[2]

Dstl conducts a wide range of modelling and analysis across the breadth of logistics and medical areas which includes the deployment and sustainment of our military forces, along with casualty estimation and the transportation of casualties in the battlefield. Dstl has undertaken an investigation into the strengths of their modelling capability which they steward on behalf of MOD and identified gaps with respect to these areas of logistics. The findings are summarized below.

3.1.2 Strengths

The UK is able to access a range of logistics models through those models owned by Dstl or via Dstl's strong links across MOD and Industry. These models cover the following areas of logistics:

- Provision of supplies (Class I-V);
- Materiel;
- Medical;
- Movement and transportation (Airlift, Sealift and inland surface);
- Maritime, Land, Air and Joint domains; and
- Strategic, operational and tactical levels.

3.1.3 Gaps

It has been assessed that the UK lacks access to models in the areas of:

- Equipment support;
- Asset tracking;
- Consumption, usage and stock level tracking;
- Maintenance and repair;
- ILS;
- LCM phases;
- Procurement; and
- Leadership.

There is clear opportunity for collaboration with other nations that have access to modelling capability covering the above areas, depending on the specific question to be answered. The D02 catalogue provides an opportunity for the UK to identify nations that have expertise in the above areas of modelling, in order to reduce duplication of effort and promote information sharing.

[2] Known within Dstl as a Software Model Custodian – SMC.

3.2 Sweden

3.2.1 Swedish Perspectives

The models and tools documented in Swedish version of the D02 catalogue are presently available for use within the Swedish Defence Materiel Administration (FMV) or the Swedish Armed Forces (SwAF). Inquiries were made within FMV as well as the Swedish Defence Research Agency (FOI) about others, for the Swedish SAS-132 representatives potentially unknown models, but no one could contribute anything more in this field of expertise. Therefore, the tools presented here probably do not represent the whole picture of all SwAF-related logistics models.

The FMVs approach through the LCM and explicitly ILS process, as well as other logistics processes in general, has led to that the development of a more generic type of models at FMV. The models are mostly connected with the general problem of spare parts inventories optimization, which requires that three basic attributes are involved:

1) The materiel configuration of the system in use;
2) Its operational profile, how it is supposed to be used, and in which environment; and
3) The maintenance/logistic organization meant to support and sustain the specific system.

When applied in analysis, they are tailored to the explicit purpose of the case. It is always easier to create a case using a model having the main attributes already described. Also, the general characteristics of steadiness in the logistics processes are improved by a model for which the basic aspects are already developed.

3.2.2 Background to Swedish Models and Tools

From experience, we assume that other tools than those presented in the D02 catalogue exist within the Swedish defence authorities. However, it is fair to presume that they are in many aspects obsolete or that the people running them have left the organization. This was also partially confirmed by the survey.

Not all models ultimately become obsolete: the PVL model, presented in D02, is an exception. It is a revived method further developed from one widely used during the 90s. One of the main reasons that it became possible to revive it is that the people having developed the old model were still active in companies close to FMV and SwAF. Other tools such as Astor have been in constant use since the late 80s. Astor, like PVL, is entirely owned by the FMV/SwAF, but developed by private companies with specific competencies. The other tools are acquired as licenses and are owned and developed by private firms.

FMV is a government authority mainly focused on the acquisition of materiel systems, various equipment and services for the SwAF. It is following the Life Cycle Management (LCM) process as mentioned before. This involves, among other things, a focus on spare part optimization and simulation of maintenance and support resources. Connected (or better, included) in LCM is the Life Cycle Cost (LCC) Analysis. The LCC and LCM work within FMV has inspired and led to development of CATLOC, as well as other models.

The models that FMV uses all have one common feature: they are developed and supported by private companies with specific competencies. There are ideas and initiatives to develop models by FMV’s personnel, but those often end up with a company that continues to develop the model and also becomes the provider for analyses. This has some benefits because the models and the analyses become properly developed, professionally performed and well supported. It also results in a more general model, which can be improved by other companies as well. But this reduces the incentives to make in-house model changes and questions the ability of making models the organization's own personnel. At the same time, the personnel lose the necessary insight on how the models really work and the skills to run them. The latter is a less of a problem when the government is the owner of the model, but still is. There is a need to keep a balance between models a nation can afford to let to the industry, and models that are retained in-house, not only for security reasons but for the level of competence needed.

3.2.3 Lessons from SAS-132

There are important and beneficial experiences by participating in this type of forum that goes beyond the exchange of knowledge about the methodological aspects of models and tools.

For example, there are many different mathematical and methodological ways of approaching a logistics analysis. OR/OA can be regarded as an established example of the diversity in the field of analysis of military context. There are also other factors that constrain how analysis processes are decided and performed, such as organizational and financial conditions.

In opposition to the discussion above (in Section 3.2.2), it is sometimes best to engage highly skilled people to develop models in-house for specific purposes, which is often the case for more research-oriented authorities. Models developed in this way can be very advanced, yet relatively easy to control and modify. However, there are difficulties in keeping them alive and developing them professionally as a functional, continuously used product. They are also dependent on skilled people remaining in the organization.

Other factors of importance for success regarding logistics analysis are in general the support for the analysis process, such as support from the management of the organization. It is important for decision makers to be willing to seek knowledge about the effects different decisions may cause *before* entering the process of implementing them. Logistics analyses are one of the key factors regarding such knowledge.

Accessibility of input information is a well-known topic for discussion, especially in field of logistics analysis. In the preparations of an analysis case, tailoring information is essential, regardless if it comes from reporting systems or judgements from experienced staff. This work, together with the analysis itself, makes a solid base for further analysis work. Therefore, it is important that the organization collects and stores information appropriately and makes it available for analysis purposes. At FMV, there are ongoing attempts to make this easier in the future.

3.3 Dutch Perspectives

The Netherlands' (NLD) contribution to the catalogue was focused on evaluating and determining the characteristics specifying the functionality of the models. It is not complete: the NLD models included in the catalogue are limited to the models known to the participants in the working group and should not be considered as covering the complete NLD logistic modelling capability.

The Netherlands' point of view is that the catalogue is a source of information regarding logistic modelling and is providing insight in logistic modelling capabilities that was not available before. Also, the catalogue provides a useful overview of the logistic areas to possibly considered in analyzing logistic problems.

To further enhance the usability of the catalogue in the future, it would be advisable first to include more standardized characteristics regarding the type of model (e.g., deterministic, discrete event simulation, continuous simulation, regression, etc.) and second to highlight the specific logistic area(s) the models are designed for. The latter helps to select the most suitable models for a specific task. If, for example, one is looking for a model to support a particular LCC analysis, not all models that cover LCC aspects are suitable to perform a complete LCC analysis.

As for further development: during the creation of the catalogue it was noted that some characteristics are not describing logistic models, but logistic doctrine (areas sustainment logistics analyzed). For example, "Asset Tracking" is not included in the models, even though it is generally recognized that the added value of asset tracking can be modelled in most relevant models by changing the associated parameters, such as service levels of spare parts. Also, the "partially or potentially" rating generates uncertainty as to what extent an area is currently covered by a model.

3.4 Canadian Perspectives

Canada has developed several models and tools for military logistics analysis over the years. They were mainly developed internally to the Department of National Defence (DND) by Defence Research and Development Canada (DRDC), and in some cases in collaboration with industry and academia. Generally, they are fit-for-purpose models that have been developed for specific applications, specific studies, or specific operational planning activities rather than multi-purpose analysis tools.

Because of their specialized nature however, many of them have not been reused after the studies were completed. As a consequence, they have not been systematically maintained or updated. Most of their custodians have move to other teams, or even outside DRDC, which will delay any reuse or modification in the future. One notable exception is Omega-PS Analyzer, a tool originally developed in-house that is now commercially sold and maintained, and is used extensively for Logistics Support Analysis (LSA).

The sample of tools identified by Canada may not be fully representative of all the tools and models currently in used by Canada's logisticians. Nevertheless, it appears that nearly all aspects of logistics have been analyzed at some point or another by Canadian models or tools, in particular the provision of supplies, materiel, and movement/transportation. All domains have been covered (maritime, air, land, joint). Most models have been used for operational and strategic decision support, although some models cover tactical aspects of logistics as well.

Like many other NATO nations, Canada is increasingly relying on commercial Enterprise Resource Planning (ERP) systems. Such systems typically contain large amounts of historical information related to materiel, movements, finances, human resources, and related transactional information. The Defence Resource Management Information System (DRMIS) is a customized SAP ERP system used by DND and the Canadian Armed Forces to transact the business of supporting operations and training, act as the materiel and financial system of record, and report on performance.

Such information can be very useful for descriptive analysis of a wide range of logistic processes, for planning, reporting and for decision support. The collection of large amounts of information in ERPs like DRMIS can also be exploited through more advanced analytics techniques such as machine learning, and make predictions useful to planners (for instance, on the timely delivery of materiel items [7] or predictive maintenance). It is expected that, in the future, more advanced analytics products of that nature (e.g., statistical models in R, Python, or built-in statistical libraries) will be developed and integrated into ERP systems for real-time decision support related to logistics-related issues. This will have the advantage of making model outputs more directly available to planners and decision makers, so that they can be used on a routine basis.

However, there is a disadvantage to statistical models relying on ERP information. These models are mainly useful to analyze assets and processes that are already existing and for which a sufficient amount of representative information has been collected. They have limited utility to make inference about platforms or assets that have yet to be procured. As such, they are of limited utility for “what if?” analyses where there is a need to compare hypothetical platforms, processes or scenarios. Furthermore, the validity of any analysis is dependent on the information quality. Many participating nations in SAS-132, including Canada, have noted major shortfalls in the quality and completeness of their ERP information that limits what can be achieved in terms of logistics analysis.

3.5 Czech Perspectives

The Czech contribution to the catalogue was primary focused on institutionally recognized tools and applications, which are widely and permanently used within Czech Armed Forces (CAF). The presented point of view did not cover the individually or one-purpose created analytical instruments, and for this reason presented point of view could not be considered as a complete overview of simulation and modelling logistics capabilities.

The Centre of Simulation and Training Technologies in Vyskov, which is a part of the Military Academy in Vyskov, is the main body applying a modelling and simulation approach for training within the Army of the Czech Republic. This Centre is led by the Capability Planning Division of the General Staff of the Army of the Czech Republic. Furthermore, there exists several particular analytics tools, especially to support strategic management and long-term project management of the armament programs and LCM of military systems and materiel. The University of Defence in Brno also contributes to the educational and analytical application of models and simulation tools.

The main logistic system used by the CAF is Information System of Logistics (ISL), which is used mainly for evidence and statistics reports about materiel and services. It consists of a wide range of reporting functions, but its possibility for modelling and simulation for decision making is limited. At the same time, the outputs from this system can be used as a valuable source of information for further analysis. The CAF, mainly within its logistic structure, uses submodules of the LOGFAS system, namely SPM, SDM, ADAMS and CORSOM.

Today, the idea of institutionalizing the usage of sophisticated analysis tools for decision making within logistic processes exists. That creates opportunities for collaboration in modelling and simulations of logistic solutions. Regarding this fact, the work of SAS-132 should be seen very positively due to the increased visibility of existing tools through the survey and identification of gaps and areas for future collaboration.

3.6 German Perspectives

German armed forces made a survey through the Planungsamt der Bundeswehr (German Armed Forces Office for Defence Planning) about tools used for logistic analysis in July 2017. All military command authorities (Navy, Army, Airforce, Cyber, Joint Support, Medical) and Bundesamt für Ausrüstung, Datastechnik und Nutzung der Bundeswehr (Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw)) have been surveyed. The result of the survey is that logistics models and tools of interest mainly focus on procurement.

It has been decided not to fill in single excel sheets and so called “SinN” (System in Nutzung / “Systems in Use”) legacy models or tools that are being superseded by the SAP System “SASPF” (Standard-Anwendungs-Software-Produkt-Familien) with all its modules and components. Quite a few SASPF components – already decided – have yet to be introduced. Only already existing and already available/implemented tools were entered in this template.

There are two main focus points for future improvements: projects have been started and efforts are being taken to improve the status by the Ministry of Defence. Agenda Rüstung ("Agenda Armament") is implemented with measures. Agenda Nutzung (Agenda In-Service) has been started and tools are under development like the "forecasting ability main weapon systems" as a part of Agenda Nutzung.

Another important project of the federal government and the Ministry of Defence is "Digitization". As part of this project, a digital situation report is currently being created, which includes a logistics situational report (sitrep).

3.7 NATO Perspectives

To inform D02 catalogue, information was provided on two main models that are used to inform logistics analysis within NATO. The first of these was the Joint Defence Planning Analysis and Requirements Toolset (JDARTS), which is used to undertake logistics requirements analysis in support of the NATO Defence Planning Process (NDPP). Secondly, information was provided on the LOGFAS suite of models, which is used to support logistics analysis throughout NATO.

The catalogue includes separate descriptions for the following LOGFAS modules:

- Allied Commands Resource Optimization System Software (ACROSS);
- Sustainment Planning Module (SPM);
- Supply Distribution Model (SDM);
- Allied Deployment and Movements System (ADAMS);
- Coalition Reception, Staging and Onward Movement (CORSOM); and
- Effective Visible Execution (EVE).

Of course, many nations also use the LOGFAS suite of tools and provided information to the catalogue regarding how these are used within their specific nations. However, the description in catalogue D02 was based on the NCIA input. It should be noted that the future LOG FS system was not included in the catalogue, as this is currently under development.

A survey was sent out to the NATO analytical community to determine if other logistics models were used to support analysis. However, no other major models were identified.

4.0 ANALYSIS

4.1 Approach

Members of SAS-132 collected information using the template in Annex A (D01) within their respective nations and organizations. The models and tools of primary interest were those that have been used (or are expected to be used) by participating nations for logistics analysis and decision support. The information was reviewed by SAS-132 during follow-on meetings and collated into a single catalogue (D02). Some models are included more than once because they are used by more than one nation.

This analysis of the D02 catalogue aims to identify gaps in analytical capabilities, overlaps and opportunities for collaboration. The analysis was mostly conducted in quantitative fashion by filtering the information from D02 across multiples dimensions. This approach was selected to make the analysis repeatable in case the catalogue evolves in the future. The analysis was partially done through macros that were directly incorporated into the catalogue.

4.2 Constraints and Limitations

The results are representative of information SAS-132 members were able to gather in their respective organizations. Not all models and tools being used across NATO are included. Nor that all tools from the participating countries are necessarily represented.

A total of 75 models and tools were inventoried. Over 100 were initially identified, but only logistics-centric models were retained. For example, war gaming simulations with limited logistics features were excluded.

Furthermore, because no participant had a complete understanding of all the tools used in their participating nations, the completeness and accuracy of the information was also limited to a degree. In some cases, the information was validated by national subject-matter experts. In other cases, it was only representative of the information available through the group's participants.

It is worth noting that some of the models presented in the catalogue can only be used by their originating countries due to classification, policy, customization, or other constraints. They were inventoried, nonetheless.

4.3 Areas of Logistics Analyzed

The following logistics functional areas were analyzed based on catalogue information:

- Sustainment logistic (e.g., supply and service function);
- Procurement logistics;
- Context of analysis:
  - Level of analysis (Strategic, Operational, Tactical);
  - Environment (Maritime, Air, Land, Joint);
  - LCM Phases; and
  - Capabilities and DOTMLPF-I areas;
- Requirements Status and Details of the tool; and
- Collaboration opportunities.

An overview of the analysis is presented in Figure 1, which shows the percentage of models covering different areas of logistics.

The logistics areas and categories on y-axis are aligned with the D01 template in Annex A and mainly derived from NATO logistics doctrine. In Figure 1, green represents the fraction of the tools that are covering a logistics area ("Yes" in the catalogue), yellow represents the fraction of tools "partially or potentially" covering the area, and red represents the fraction of the tools not covering the functional area ("No"). Categories not easily amenable to modelling (e.g., contracting, asset tracking) or for which an answer could not be determined are in grey.

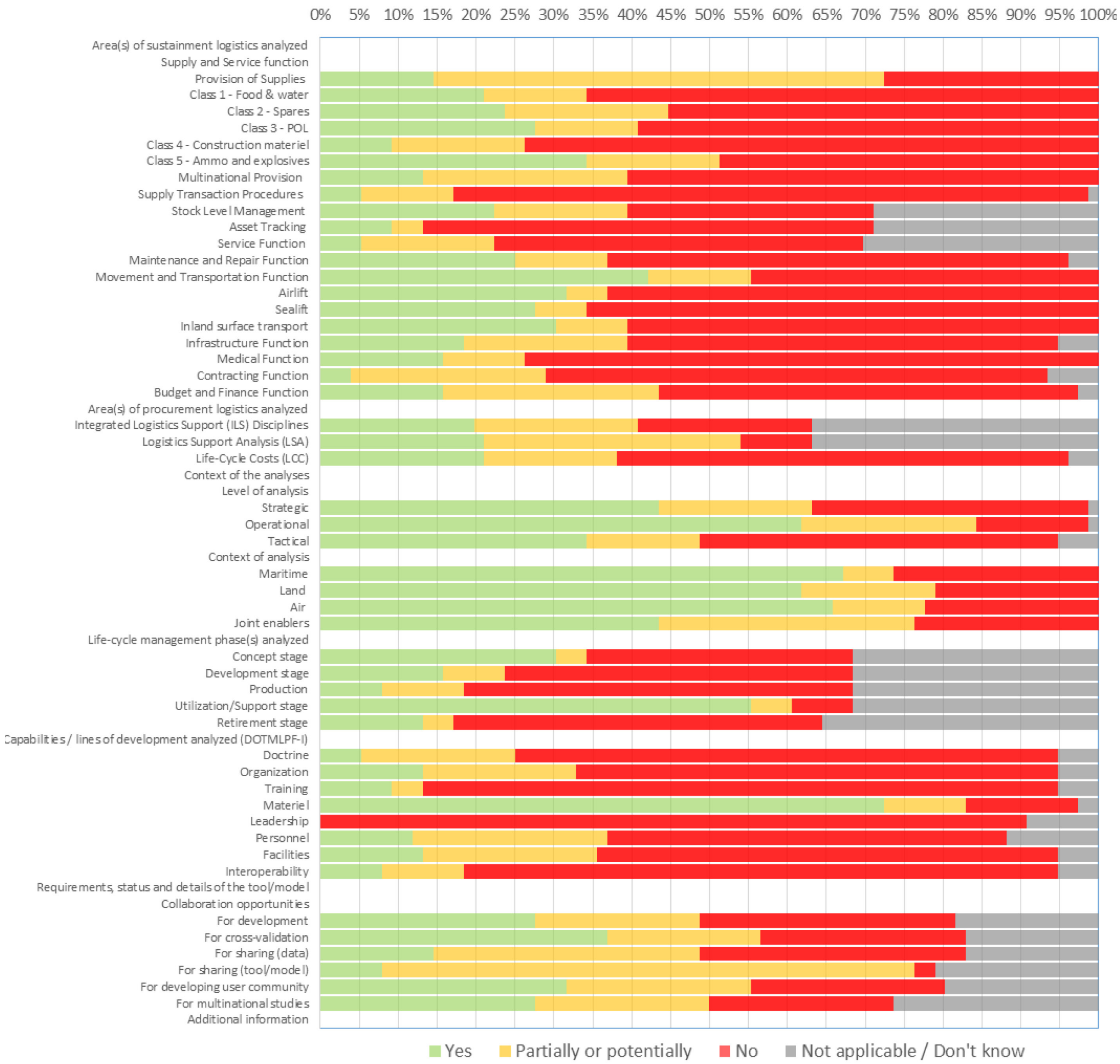


Figure 1: Overview of the Logistics Areas Covered (by Percentage of Models and Tools).

A more detailed review of the D02 catalogue is presented further in this section, but a few general observations can already be made from Figure 1. First, there is a disparity of model coverage between categories. Some categories of analysis (e.g., operational-level analysis, materiel analysis) are covered by most models, whereas others are covered only by a small fraction of them. Notably, the Leadership area of DOTMLPF-I is not covered by any of the models or tools, which might represent a gap in terms of analysis capability. We can also see a lot of grey in LCM phases, an indicator only of subset of tools and models include LCM as part of their analyses.

SAS-132 did not comment on the quality of the models. The appearance of a green bar or green rating does not necessarily mean that the model is of good quality and could still result in a gap.

4.4 Closer Analysis by Function

The following subsection further details the analysis by functional areas of logistics.

4.4.1 Supply and Service Function

Figure 2 provides further details regarding the Supply and Service function, which is one of the most covered area, especially the Supply Function for Class 5 – Ammo and explosives. Meanwhile, the Movement and Transportation Function is also well represented (airlift modelling in particular).

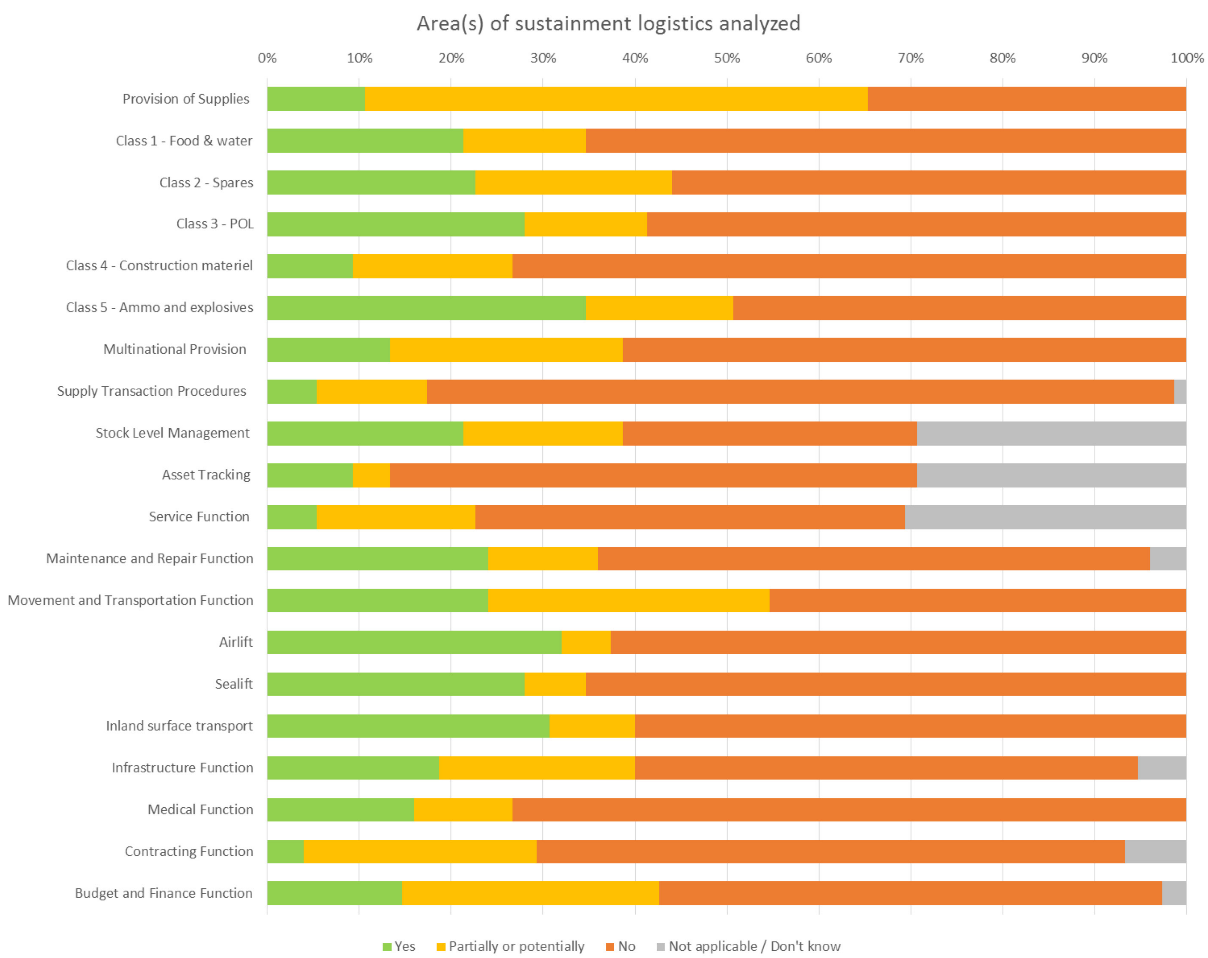


Figure 2: Percentage of Models per Area of Supply and Service Function.

4.4.2 Procurement Logistics

Based on Figure 3, it is striking that for over 50% of the models it is explicitly stated that they do not cover/address LCC. This suggests that LCC analysis is often done independently of logistics analysis. Tools and models for LSA is often identified as a more encompassing of different aspects of logistics. The LCC area is usually covered by only a few tools and models, usually with special purpose or analytical outcome in mind.

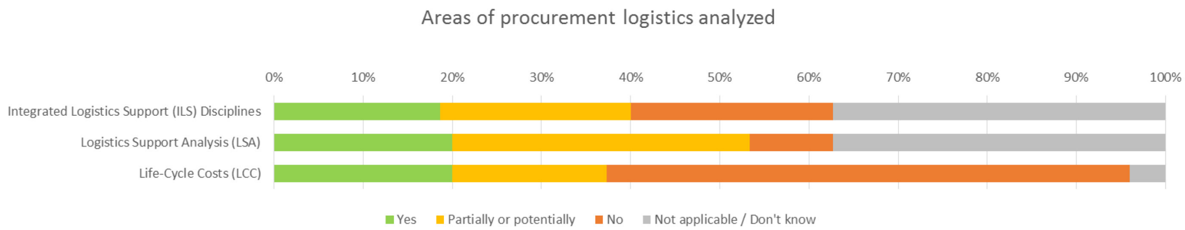


Figure 3: Percentage of Models per Area of Procurement Logistics Analyzed.

4.4.3 Context of Analysis

As shown in Figure 4, most of the models and tools inventoried have been developed for operational-level analysis. This was expected from an OR/OA perspective: much of logistics analysis has to be conducted in advance of operations, or with operational scenarios in mind. At a tactical level, it is often more challenging to employ models in theatre to optimize logistics processes and develop solutions, although near-real-time ("just-in-time" / "just-enough" / "just-in-case") logistics is increasingly becoming of interest. Some logistics models can be used for strategic-level decision support, especially for comparing different alternatives with respect to major components of the supply chain.

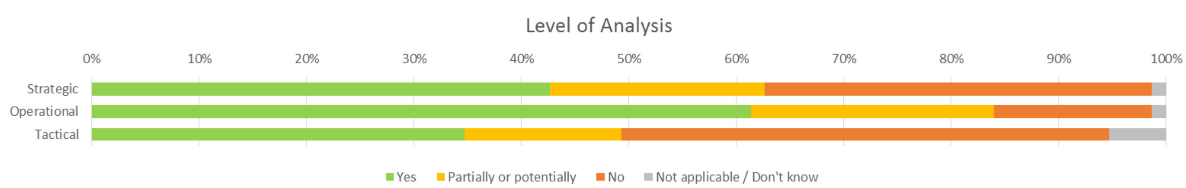


Figure 4: Percentage of Models per Level of Analysis.

Figure 5 shows the context (or environment) of the analysis done using the models and tools.

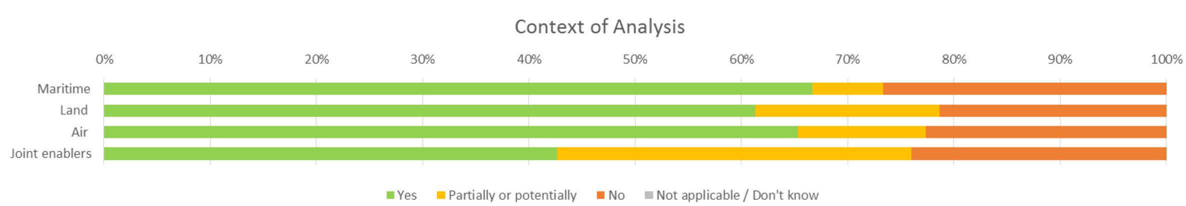


Figure 5: Percentage of Models per Context Analysis.

Table 1 shows details as to how the context of analysis and level of analysis intersect. In addition to this it was also investigated whether the level of analysis was comparable for all domains (Maritime, Land, Air or Joint Enablers).

What is not shown in this table but revealed by closer analysis of the catalogue is that of the 33 tools potentially useful for strategic-level analysis (green ratings), 16 of them apply to all four domains. Of the 47 tools for the operational level, 18 apply to all domains. And of the 26 tools for the tactical level, only six apply to all domains, which was expected given the specificities of tactical applications. There are seven tools that apply to all domains and three that apply to all domains AND analysis levels.

Table 1: Logistics Domains Coverage (Number of Models).

	Strategic	Operational	Tactical
Maritime	25	33	15
Land	24	30	18
Air	29	34	17
Joint Enablers	19	23	12

There are six tools that focus only on strategic-level analysis (one for the maritime domain, one for air, and one for land). The others apply to all domains. None of these strategic-level tools is specifically built for joint enablers.

At the operational level, nine tools apply to this level only, and six of them are specifically designed for the maritime domain. Only one is specifically built for the land domain. The other two apply to all domains. There is only one tool in the catalogue specifically designed for the tactical level and it applies to the maritime domain.

The relative number of models (see Figure 6) covering the LCM phases are poorly represented in the catalogue, with the exception of the Utilization/Support stage, which is close to 50%. Meanwhile, the "Not applicable / Don't know" has almost a constant number of models (24) in each stage. That reflects in a way that the catalogue depends very much on who filled in the models included and the knowledge of the participants in the working group about how the model has been used. For example, MILO was not categorized as a LCM tool whereas PVL was, even though the two tools have many similarities.

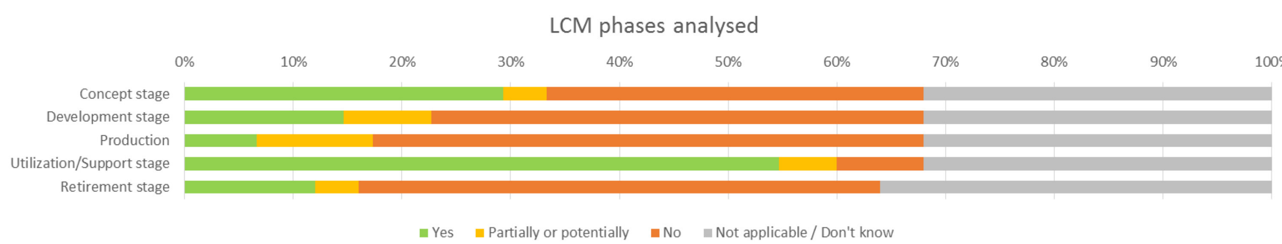


Figure 6: Percentage of Models per LCM Phase.

Bear also in mind that the LCM process is a very complex one covering the entire life of a system, and can have different definitions depending on the viewer's considerations, from a simple system to systems-of-systems, or even military units.

4.4.4 Streamgraph Analysis

The information from the master catalogue can also be visualized using a streamgraph to better show the strengths of individual models and national tool sets. In this visualization, a tool or model is attributed points based on the extent to which a catalogue field is covered by a tool or model, based on an arbitrary point system presented in Based on this system, all models get a minimum of one point, so that each model represents a stream in the graph. The width of a stream for each catalogue field is determined by the points given to the model. If a stream is representing an aggregation of fields (e.g., "Movement and Transportation") then the stream width is based on the average of the entries on the fields underneath (Table 2).

Based on this system, all models get a minimum of one point, so that each model represents a stream in the graph. The width of a stream for each catalogue field is determined by the points given to the model. If a stream is representing an aggregation of fields (e.g., "Movement and Transportation") then the stream width is based on the average of the entries on the fields underneath.

Table 2: Point System for Tools and Models Ratings.

Rating	Points
"Yes"	10
"Partially or potentially"	3
"No"	1
"Not applicable / Don't know"	1

Such streamgraphs tend to show more prominently the nations that have inventoried more tools than others (because at least one point is given by tool), but it is the thickness of each model stream that is an indicator of capability.

From Figure 7, for example, it is possible to identify that Canada and the UK have the largest amount of models, but these models cover "area(s) of sustainment logistics" and "area(s) of procurement logistics" to a lesser extent than the models from Germany, Sweden and the Netherlands (smaller band per model). This may be explained by the possibility that more tools/models also imply more specialized models, as mentioned in earlier national perspectives. Furthermore, the results show that Germany, Sweden and the Netherlands seem to have a bigger focus on "area(s) of procurement logistics", while Canada, Czechia, NATO and the UK seem to put more focus on "area(s) of sustainment logistics".

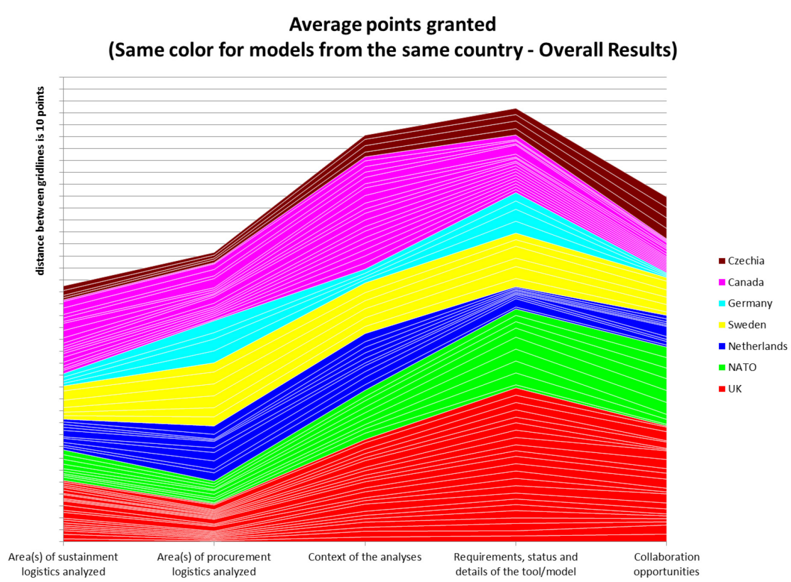


Figure 7: Models Coverage by Project-Participating Countries.

If we look at the more detailed results in Figure 8, we get the following results for "area(s) of sustainment logistics".

It appears that UK models are the most specialized models. A relatively large part of Canada, UK and NATO models cover the "Movement and Transportation" function, while the Sweden and Netherlands models seem to have a larger focus on the "Maintenance and Repair" function. The "Contracting" function is the one that is covered the least by models. This was perhaps to be expected: output may be used as inputs in contracting functions, or the type of contracts might influence the input of the models. However, this does not mean that the "Contracting" function itself is fully included in the models or tools.

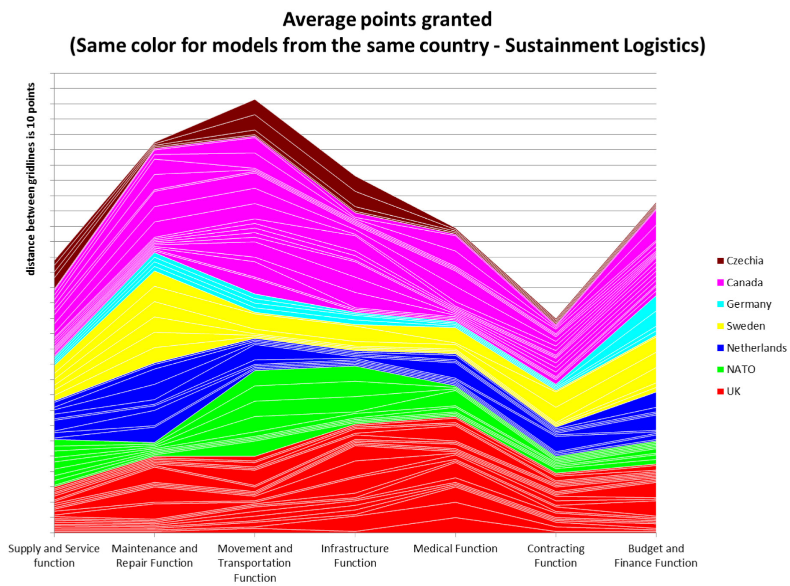


Figure 8: Areas of Sustainment Logistics Analyzed.

The detailed results for "area(s) of procurement logistics" are shown in Figure 9.

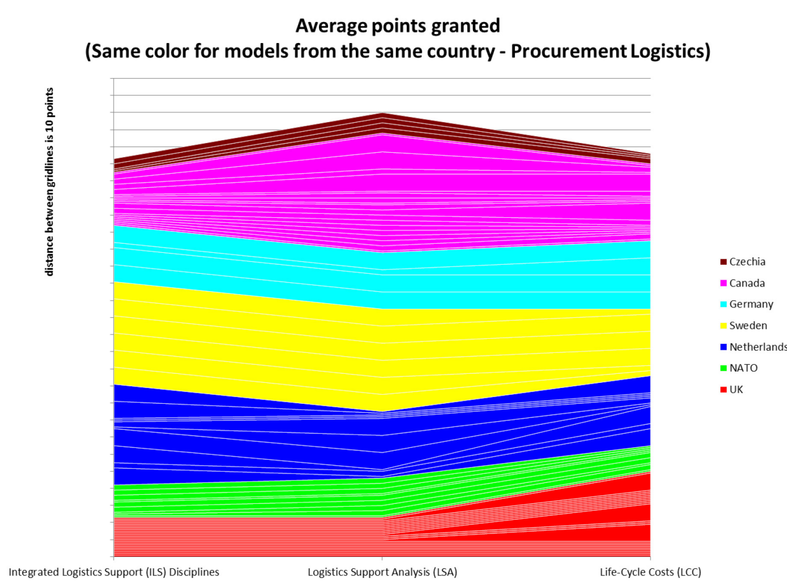


Figure 9: Areas of Procurement Logistics Analyzed.

With regard to "area(s) of sustainment logistics", it can be seen that UK models only cover LCC. ILS and LSA are generally not covered by the UK models. Czechia, Germany and Sweden models cover all three topics (although LCC is covered to a slightly lesser extent by the Czech and Sweden models). The Netherlands models all seem to be more specialized in one or two of these three items. Canadian models appear more focused on LSA, although Canada seems also to have some models especially focussing on LCC.

These results are somewhat contradicting those of Figure 3 where LCC analysis appeared to be done more independently than other types of modelling. This might be due to the different interpretations made of ILS, LSA and LCC by the participants, and the extent to which these areas of procurement were deemed covered by the models.

The detailed results for "context of the analysis" are shown in Figure 10.

Most models – and especially UK models – are covering LCM phases the least. Exceptions are the Germany and Sweden models.

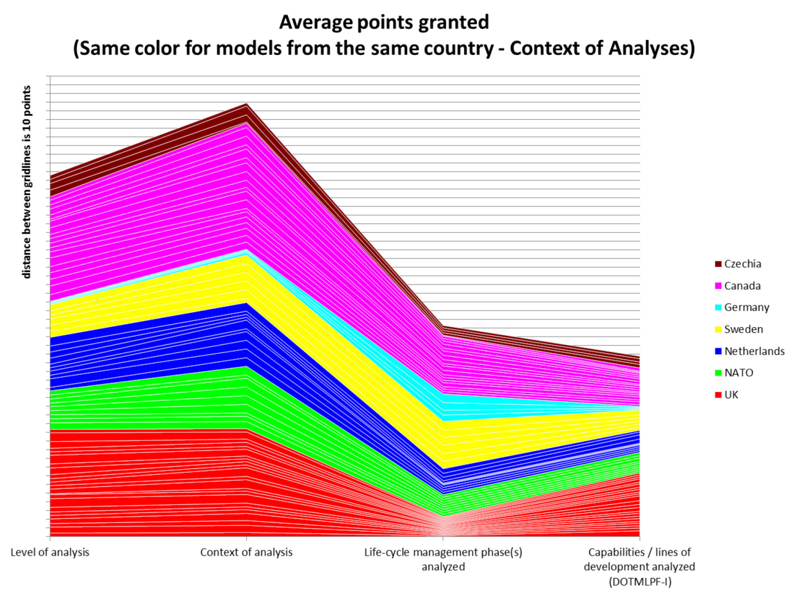


Figure 10: Analyzed Areas of Context Analysis.

Figure 11 shows the streamgraph for LCM phases. What comes out is that models and tools are largely focused on the utilization and support phases, which was expected of logistics models. Two exceptions are the German and Swedish toolsets which tend to cover all phases.

The results for additional details of the tools are shown in Figure 12.

The results show rather large differences between countries. The UK models are relatively strong on "Existing user community". Most nations however have limited technical support available for their models and tools.

The results for "Collaboration Opportunities" are as follows, Figure 13. It can be seen that generally the most opportunities are within development, cross validation and developing a user community.

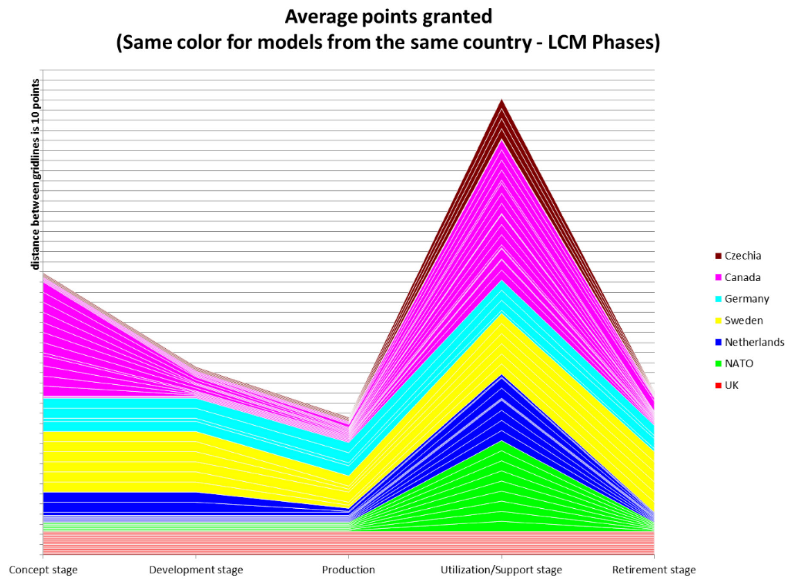


Figure 11: Streamgraph for LCM Phases.

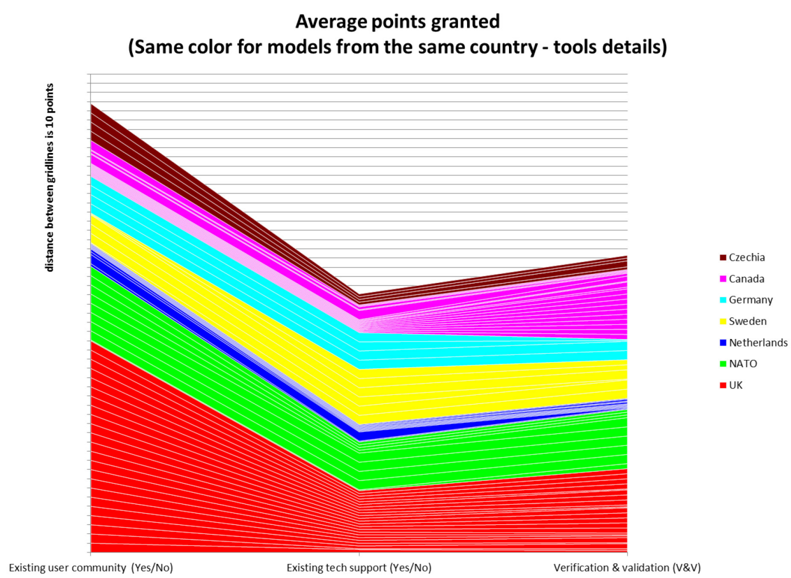


Figure 12: Additional Details of the Models and Tools.

4.5 Pair-Wise Comparison of Model and Tool Capabilities

A feature was added to the catalogue to assess the capabilities of the set of models and tools inventoried. Specifically, the feature allows the user to select two specific fields of the catalogue and performs a pair-wise comparison on them.

For example, a user can compare the ability of the models and tools to analyze "airlift" and "sealift". As shown in Table 3, out of 75 tools in the catalogues, 25 of them are applicable to airlift analysis. Out of these 25, there are 19 models and tools that are also applicable to sealift. We note as well that five models are applicable to sealift but not airlift, whereas the opposite occurs for three models. These pair-wise comparisons can be done for any catalogue field with multiple input choices in the D02 catalogue.

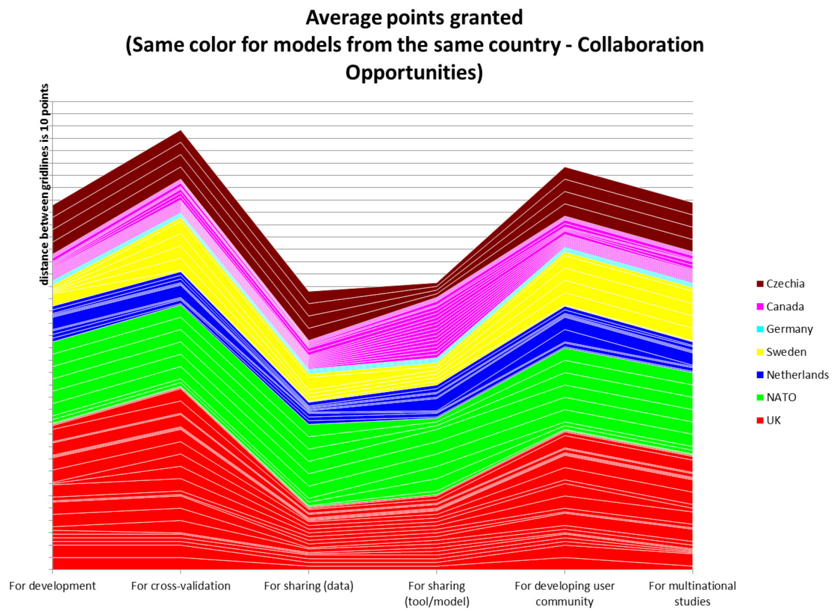


Figure 13: Streamgraph for Collaboration Opportunities.

Table 3: Models Coverage of Analyzed Sealift Area.

			Sealift			
			Yes	**Partially or potentially**	**No**	**Not applicable / Don't know**
			21	5	49	0
Airlift	Yes	24	18	1	5	0
	Partially or potentially	4	0	4	0	0
	No	47	3	0	44	0
	Not applicable / Don't know	0	0	0	0	0

4.6 Gap Analysis

No significant gaps seem to exist with regard to the topics covered by the models, with the exception of Leadership where it appears none of the participating nations have models which consider this field. Some countries appear to have more specialized models, while other countries appear to have fewer but more generic models. Topics that are the least covered by models are often also not relevant from a modelling perspective – however, existing models may be used to perform analysis supporting those topics without requiring the topic itself to be included in the models. An example is the Contracting function or Asset Visibility. With regards to collaboration opportunities, sharing (information and models) is generally not considered as being the most feasible collaboration opportunity (with an exception for the NATO models).

There are no apparent gaps with regards to the domains (maritime, land, air and joint enablers) or the levels of analysis (strategic, operational, tactical). When these two criteria are combined, there seems to be a gap when it comes to tools designed specifically for the tactical level. Especially when it comes to other domains than the maritime domain. However, one could argue that at a tactical level, tools may not be of the same use than on the other levels.

Whilst there are no obvious gaps in any single field, gaps may be apparent when fields are combined together – for example, a cost model at the tactical level. There are many possible field combinations, but using a pair-wise comparison (as shown in Table 3) in the D02 catalogue can help to identify these gaps.

4.7 Overlaps

The toolsets of the participating nations overlap to some degree across all areas. This means that at least two countries have recorded a model or tool in the catalogue against each of the specific fields, however, this does not mean that each nation has its own capability to model every aspect of logistics surveyed in this study. As a result, some nations may be reliant on models from other nations to be able to conduct analysis in specific areas, which may not always be possible. Similarly, some models may be developed by a nation for a specific purpose, and may not be appropriate for other nations.

A pair-wise comparison (as shown in Table 3) in the D02 catalogue can also be used to identify where overlaps exist when comparing multiple fields.

4.7.1 Collaboration Opportunities

The survey of models shows there is strong appetite for nations to use existing models and tools collaboratively, since for all collaborative categories, at least 50% of the models listed scored "yes" or "partially or potentially" (as shown in Table 4).

Table 4: Collaboration Opportunities of the Analyzed Tools and Models (Number of Models).

	Yes	Partially or potentially	No	Not applicable / Don't know
For development	28%	21%	33%	18%
For cross validation	37%	20%	27%	16%
For sharing (information)	15%	35%	35%	17%
For sharing (tool/model)	8%	69%	3%	20%
For developing user community	32%	24%	25%	19%
For multinational studies	28%	23%	24%	25%

The highest scorer in this category was for model sharing between nations, with 77% of models (8% yes, 69% partially or potentially) potentially available. Given the high proportion of this figure being partially or potentially, it will be important for the nations collaborating to discuss the exact requirements to ensure that the model does what is required. Only a very small percentage (3%) of models were listed as having no availability in terms of sharing with other nations. The remaining 21% of models were listed as “don’t know”, where it may not have been possible to determine information sharing availability with the model owner prior to inclusion in the catalogue.

The next highest proportion of collaborative tool usage was for cross validation, with 57% of models (37% yes, 20% partially or potentially) being potentially available for this purpose. Cross validation allows one nation to use the results from another nation’s model to validate its own results, which may be useful for new models that have been developed where the first nation cannot share (or can only partially share) the original model or its underlying information. Use of models for cross validation would also help to develop user communities for these models in different nations; 55% of all models were identified as having the potential (32% yes, 24% partially or potentially) to develop a user community internationally.

The highest proportion of “No” was for information sharing (35%). This is expected since often the information within these models is classified or nationally sensitive, and therefore it would not be appropriate to share with other nations. This is complemented by the 76% of models that can potentially be shared without the information. Whilst the information itself is classified or sensitive, often the methods are not, meaning these models and tools could be shared without their underpinning assumptions information.

4.8 Discussions

This report has presented many examples of how the information from the D02 can be extracted and further analyzed. However, as the various analysis above shows that one cannot draw any obvious and determined conclusions, since the information in the D02 catalogue can be interpreted differently by both those completing it, and by those viewing it. The aim of this report is also to present, in a structured way, which Logistics models are used in the participant countries. The reader can explore which model to use for a specific task. The D02 is a catalogue of these national models in Excel format and can be used as is by any NATO or Partner nation to determine which models are available and being used in other nations. The accuracy of the information is also open to input error.

Care should be taken when selecting a model based on its categorization within the catalogue. Where a model or tool is said to cover a specific area of logistics (for example, ILS) it may not be able to cover every aspect of that area. Furthermore, different nations may have different interpretations of logistics terms.

The purpose of this catalogue is to reduce duplication of effort and to encourage nations to collaborate and thereby avoid having multiple models within the NATO community that serve the same purpose, where possible. There are of course circumstances where collaboration may not be possible: e.g., for classified scenarios or if using nationally sensitive information, but Table 4 shows us that there is definite opportunity for collaboration within the NATO community.

Some models have been developed by nations for a specific purpose, and therefore when considering collaboration opportunities, it is important to determine whether these models will be able to answer logistical questions posed by other nations. There may also be commercial, licencing or intellectual property limitations that must be considered.

One other, often underestimated, obstacle for collaboration is the access to input information. Information availability and information structure can vary very much between different nations. It is common to focus mainly on analytical methods, but in practice the input information often dictate which method(s) can be applied. Searching for suitable input information and information preparation can be very demanding and time-consuming, but remain essential steps to provide an accurate output.

5.0 CONCLUSIONS AND WAY AHEAD

5.1 Summary

We surveyed over 100 models and tools used for logistics analysis within SAS-132 participating nations, namely CAN, CZE, DEU, GBR, NLD, SWE, TUR and NATO NCIA. We identified 75 tools with a strong logistics analysis focus for which we collected additional information. The information collection template was in the form of a spreadsheet containing over 90 fields. It captured various aspects of the models and tools of interest, such as the area(s) of sustainment logistics analyzed by each tool, the area(s) of procurement logistics analyzed, the context of the analyses, information requirements, etc. The collected information was then reviewed and collated into a single catalogue of models and tools. This catalogue can now serve as a reference for logistics analysts within the Alliance, and also helped us identify gaps in terms of logistics analysis capabilities, overlaps, as well as areas for sharing and future collaboration.

The analysis revealed that individual participating nations have different approaches to conduct logistics analysis using modelling and simulation tools. Some nations mainly use broad, institutionally recognized models as standard supporting tools for logistics considerations. Others mainly use fit-for-purpose models designed to handle specific problems. Some nations rely on NATO-recognized software (e.g., LOGFAS) only. Despite these differences, the wide and deep potential of the set of tools and instruments identified for logistics analysis creates a solid foundation for future cooperation between NATO and PfP nations and opportunities to share existing models.

Of note, in most of the participating nations, logistics models are increasingly relying on ERP information. These are useful for analyzing logistics assets and processes that already exist, and for which a sufficient amount of representative information has been collected. However, they have limited utility to make inference about platforms or assets that have yet to be procured or have yet to be used in particular scenarios. As such, they are of limited use for “what if?” analysis where there is a need to compare hypothetical platforms, processes or scenarios.

In general, the work of SAS-132 can be described as successful by the participants. Members were focused, motivated and have collaborated well to reach the objectives of the RTG. They contributed much of their experience and knowledge, despite other work commitments. Members of the group recognized the importance of increasing and sharing their knowledge of logistics analysis modelling internationally for the greater benefit of the Alliance. Rightly used, the knowledge gathered and generated by SAS-132 can enable significant savings and provide potentially significant impact on military logistics and military planning.

5.2 Way Ahead

In order for the catalogue to remain a living document, SAS-132 recommends that there should be a new SAS activity (e.g., a specialist team) a few years from now to review and update the catalogue. This activity could also explore how to leverage some in-depth information from the catalogue and individual models, beyond the high-level analysis conducted as part of SAS-132. To further exploit the products of SAS-132, it is recommended that the catalogue and report be shared within the NATO logistics community, including analysts, practitioners and educators. In fact, some of the members have already shared the catalogue within their respective nations.

A follow-on SAS activity would also be an opportunity to expand the catalogue, which now remains limited to tools identified by members of the participating nations. The sample provides a good picture of the Alliance's logistics modelling capabilities, but is not fully representative the tools existing within NATO. Furthermore, although the catalogue captures over 90 information fields per model, there is still scope to expand the amount and level of detail of the information being captured.

Moreover, the work of SAS-132 mainly offers an "as is" picture of NATO's capabilities for logistics analysis. Follow-on activities should look at the "to be" state of these capabilities and inform how to develop them. For instance, the development of future NATO tools such as LOG FS could be informed by the findings of SAS activities.

In the interim, SAS-132 recommends that the SAS panel identifies a custodian within NATO or a participating nation to maintain and update the catalogue as required (custodianship with NCIA and NATO standard organization are potential options; leveraging NSMG's "Modelling as a Service" effort is another one). SAS-132's recommendation is that the D02 catalogue should be made available in the simplest possible way that supports its maintenance and further development.

6.0 REFERENCES

[1] "Models and Tools for Logistics Analysis", Technical Activity Proposal (TAP) for NATO STO Activity SAS-132, September 2016.

[2] "NATO Glossary of Terms and Definitions", NATO Allied Administrative Publication AAP-06 (Edition 2013), http://www.dtic.mil/doctrine/doctrine/other/aap6.pdf, Accessed 18 April 2017.

[3] "NATO Modelling and Simulation – Glossary of Terms", Allied Modelling and Simulation Publication AMSP-02, 2014, https://www.sto.nato.int/publications/Pages/ModellingandSimulationGlossary.aspx?FilterField1=Starts_x0020_With&FilterValue1=MN, Accessed 18 April 2017.

[4] Lawrence, A. "NATO SAS: Methods and Models for Logistics Analysis – UK Brief", presentation to NATO SAS Exploratory Team SAS-ET-DK, Paris, FR, September 2016.

[5] Gauthier, Y. "Cataloguing Models and Tools for Logistics Analysis – CA perspective", presentation to SAS-132 Initial Meeting, Stockholm, SWE, April 2017.

[6] Kaluzny, B.L., and Pall, R. "Simulating the Repatriation of Canadian Forces Materiel from Afghanistan", DRDC CORA TM 2013-032, March 2013.

[7] Gauthier, Y. et al. 2018. "Predicting the Responsiveness of the Royal Canadian Navy's Supply Chain", Proceedings of the 17th IEEE International Conference on Machine Learning and Applications.

Annex A – D01, INFORMATION COLLECTION TEMPLATE

A.1 BACKGROUND

This annex (which also defines Deliverable 01, D01) describes the template developed by SAS-132 members to collect information on models and tools used for military logistics analysis within their respective nations and organizations. The template is in the form of a Microsoft Excel spreadsheet containing over 90 information fields. They capture various aspects of the models and tools of interest, including general information, areas of sustainment logistics analyzed, areas of procurement logistics analyzed, the context of the analyses, data requirements, collaboration opportunities and several other pieces of information. Most fields are multiple choice fields that can be filled out fairly quickly by subject-matter experts. A descriptor aligned with NATO terminology is provided for each field. Examples of input for a materiel transportation model are also provided to illustrate the type and amount of information expected by SAS-132.

Members of SAS-132 have used the template to survey models and tools employed within their respective nations and organizations, starting mid-2017. The information was then reviewed, collated into a single catalogue, and analyzed in D02.

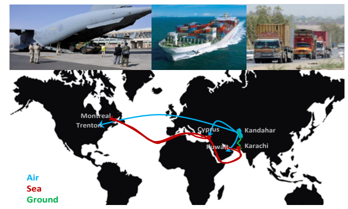
A.2 TEMPLATE DESCRIPTION

Table A-1 describes the template produced by members of SAS-132 to collect information on logistics analysis models and tools within their respective nations and organizations. It is largely inspired from a catalogue of logistics models developed by the United Kingdom [1]. Multiple fields are also borrowed from Canadian compendiums of OR tools [2]. See in the Catalogue the final version of Table A-1.

The template produced by SAS-132 contains over 80 data fields. Most of them are multiple choice fields that can be filled out relatively quickly by subject-matter experts. A descriptor aligned with NATO terminology is provided for each information field. An example of inputs for a materiel repatriation simulation [3] is also provided to illustrate the type and amount of information expected by SAS-132 for each field.

Table A-1: Information Collection Template with Example.

Field	Descriptor	Example
General Information		
Name	Name of model or tool in national language.	Simulation of the Repatriation of CAF Materiel from Afghanistan
English name	Name in English (if any).	Simulation of the Repatriation of CAF Materiel from Afghanistan
Acronym	Acronym (if any).	SimRetro-Afg

Field	Descriptor	Example
Logo or image (if any)	Logo or representative image (if any).	
Country	Country contributing the information about the model or tool.	Canada
Language	Language of the model or tool interface and related documentation (NOT the programming language in which a tool was developed).	English
Typical type(s) of questions analyzed	Types of questions/problems typically answered or analyzed using the model or tool.	• What is the estimated time required to repatriate materiel through a particular LOC (or combination of LOCs), given certain numbers of lift assets (e.g., number of trucks available) and schedules (e.g., number of flights per week) and associated uncertainties in lift asset availability? • What would be the effect of certain events (e.g., closure of a LOC)? • What are the estimated costs of repatriating materiel for different combinations of LOCs?
Type of modelling or analysis	The underlying modelling technique or analytical approach being employed (e.g., deterministic calculation, simulation, optimization, soft analysis, etc.).	Discrete-event simulation
General description	A short paragraph providing a high-level, general description of the model or tool.	Discrete-event simulation used to analyze the repatriation of Canadian equipment from Afghanistan via different Lines Of Communication (LOCs). Entities in the simulation represent the lowest level of items to repatriate (e.g., containers, vehicles, air pallets). Resources are the various modes of shipment govern the aircraft used for the air LOC, the contracted trucks for the ground LOC, and the ships used for the sea LOC. Costs and time for usage of each type of resource are determined stochastically.
Key limitations and dependencies	The main limitations of the tools or its dependencies upon other tools or assumptions.	Materiel and vehicle processing at origin (e.g., Afghanistan) and destination (e.g., Canada) are not modelled. Disposal, transfers, and sales of non-essential items that are not being repatriated after an operation are not modelled.

Area(s) of sustainment logistics analysed	The functional areas of sustainment logistics being analyzed. These are based on areas described in the ALLIED JOINT LOGISTIC DOCTRINE AJP-4(A) **[4].**	
Supply and Service Function	Supply covers all materiel and items used in the equipment, support and sustainment of military forces. The supply function includes the determination of stock levels, provisioning, distribution and replenishment. The service function covers the provision of manpower and skills in support of combat troops or logistic activities [4].	No
Provision of Supplies	Ensuring the provision of sufficient supplies and services to adequately sustain forces [4].	No
Class 1 - Food and water	Covers Class 1 supplies: items of subsistence, e.g. food and forage, which are consumed by personnel or animals at an approximately uniform rate, irrespective of local changes in combat or terrain conditions [4].	No
Class 2 - Spares	Covers Class 2 supplies: supplies for which allowances are established by tables of organization and equipment, e.g. clothing, weapons, tools, spare parts, vehicles [4].	No
Class 3 - POL	Covers Class 3 supplies: petroleum, oil and lubricants (POL) for all purposes, except for operating aircraft or for use in weapons such as flame-throwers, e.g., gasoline, fuel oil, coal and coke [4].	No
Class 4 - Construction materiel	Covers Class 4 supplies: supplies for which initial issue allowances are not prescribed by approved issue tables. Normally includes fortification and construction materials, as well as additional quantities of items identical to those authorised for initial issue (Class II) such as additional vehicles [4].	No
Class 5 - Ammo and explosives	Covers Class 5 supplies: ammunition, explosives and chemical agents of all types [4].	No
Multinational Provision	Covers co-operative or multinational arrangements for the provision of services [4].	No
Supply Transaction Procedures	Supply transactions between nations or national forces may take the form of pre-planned logistic assistance, emergency logistic assistance in crisis and conflict, multinational support, or redistribution [4].	No
Stock Level Management	Management of stocks for sustained operations, including organic stocks of units plus additional stocks, maintained at support levels, necessary to cover the order and shipping time for supplies [4].	No
Asset Tracking	Logistic asset tracking information for the efficient management and co-ordination of support to forces [4].	No
Service Function	Covers the provision of manpower and skills in support of combat troops or logistic activities. This includes a wide range of services such as combat re-supply, map distribution, labour resources, postal and courier services, canteen, laundry and bathing facilities, burials, etc. [4].	No

Maintenance and Repair Function	Maintenance means all actions to retain materiel in, or restore it (repair) to a specified condition. Repair includes all measures taken to restore materiel to a serviceable condition in the shortest possible time [4].	No
Movement and Transportation Function	Covers infrastructure, organizations, facilities and equipment necessary for the deployment, sustainment and re-deployment of forces during the execution of a mission [4].	Yes
Airlift	Covers movement and transportation by sea.	Yes
Sealift	Covers movement and transportation by air.	Yes
Inland surface transport	Covers land movement and transportation.	Yes
Infrastructure Function	Covers the co-ordination of infrastructure for operational and logistic purposes, and infrastructure provision if mission critical infrastructure has to be constructed, adapted, altered or repaired [4].	No
Medical Function	Covers the provision of a medical support system that includes the maintenance of health and the prevention of disease, the holding, treatment and evacuation of patients, the re-supply of blood and medical materiel, to minimise man-days lost due to injury and illness, and the return of casualties to duty [4].	No
Contracting Function	Covers contracting relevant to the conduct of operations, for example to gain access to local resources, and other necessary materials and services [4].	Partially or potentially
Budget and Finance Function	Covers budget, finance and costing aspects of sustainment [4].	Partially or potentially
Area(s) of procurement logistics analysed	The functional areas of procurement logistics analyzed, or logistics support activities considered, as per NATO LOGISTICS HANDBOOK [5].	
Integrated Logistics Support (ILS) Disciplines	ILS is the deliberate integration of systems/equipment logistic support considerations into the system's life cycle management during the outset of the programme/project. ILS prescribes that all elements of logistic support be planned, acquired, tested and provided in a timely and cost-effective manner [5].	Not applicable / Don't know
Logistics Support Analysis (LSA)	LSA is a structured process intended to define, analyze and quantify logistic support requirements and to influence design for supportability, throughout system development. LSA stresses simplicity by identifying an optimal level of logistic requirements. The objective of LSA is to enable optimum system performance and availability at minimum life cycle cost. LSA is conducted on an interactive basis throughout the acquisition cycle [5].	Not applicable / Don't know

Life-Cycle Costs (LCC)	LCC is the total sum of direct, indirect, recurring, non-recurring and other related costs incurred, or estimated to be incurred, in the design, development, production, operations, maintenance and support of a major system over its anticipated life span. LCC analysis is an iterative process that starts at the beginning of the programme/project life cycle and continues throughout the life cycle of the system [5].	Not applicable / Don't know
Context of the analyses	**Describes the context of the analyses conducted using the tool or model and its various dimensions (level of analysis, environment, relevant life cycle phase(s), lines of capability development, etc.).**	
Level of Analysis		
Strategic	Used to analyze issues of a strategic nature.	Yes
Operational	Used to analyze issues of an operational nature.	Yes
Tactical	Used to analyze issues of a tactical nature.	Partially or potentially
Context of Analysis		
Maritime	Used to analyze maritime logistics issues/scenarios.	Yes
Land	Used to analyze maritime logistics issues/scenarios.	Yes
Air	Used to analyze air logistics issues/scenarios.	Yes
Joint enablers	Used to analyze joint logistics issues/scenarios.	Partially or potentially
Life-cycle management phase(s) analysed	**Life cycle management phases analyzed, as defined in NATO SYSTEM LIFE CYCLE STAGES AND PROCESSES (AAP-48) [6].**	
Concept stage	The Concept Stage starts after the decision to fill a capability gap with a materiel solution and ends with the requirements specification for this materiel solution [6].	No
Development stage	The Development Stage is executed to develop a system-of-interest that meets user requirements and can be produced, tested, evaluated, operated, supported and retired [6].	No
Production	The Production Stage is executed to produce or manufacture the product, to test the product and to produce related supporting and enabling systems as needed [6].	No
Utilization/ Support stage	The Utilization/Support Stage is executed to operate and support the product at the intended operational sites to deliver the required services with continued operational and cost effectiveness. This stage ends when the system-of-interest is taken out of service [6].	Yes
Retirement stage	The Retirement Stage provides for the removal of a system-of-interest and related operational and support services and to operate and support the retirement system itself [6].	No

Capabilities / lines of development analyzed (DOTMLPF-I)	Describes the capabilities (or lines of development) considered by the analysis model or tool, as per NATO's DOTMLPF-I spectrum of capabilities (Definitions adapted from [7]).	
Doctrine	A doctrine analysis examines the way the military fights its conflicts to see if there is a better way that might solve a capability gap [7].	No
Organization	An organization analysis examines how we are organized to fight and see if there is a better organizational structure or capability that can be developed to solve a capability gap [7].	No
Training	A training analysis examines how we prepare our forces to fight, from basic training, advanced individual training, various types of unit training, joint exercises, and other ways to see if improvement can be made to offset capability gaps [7].	No
Materiel	A materiel analysis examines all the necessary equipment and systems that are needed by forces to fight and operate effectively and if new systems are needed to fill a capability gap [7].	Yes
Leadership	A leadership and education analysis examines how leaders preparation and their overall professional development [7].	No
Personnel	A personnel analysis examines availability of qualified people for peacetime, wartime, and various contingency operations to support a capability gap [7].	No
Facilities	A facilities analysis examines military property, installations and industrial facilities (e.g., government owned ammunition production facilities) that support forces to see if they can be used to fill in a capability gap [7].	No
Interoperability	An interoperability analysis examines the ability to be interoperable with forces throughout the NATO alliance [7].	No
Requirements, status and details of the tool/model		
Data	A brief description of the data required to employ the model or tool.	Historical or hypothetical data comprising item weights (containers, vehicles, and air pallets), flight times, aircraft loads (weight and number of items), aircraft availability (schedule), and the LOC chosen for each item shipped.
Hardware	Minimum computing hardware and exploitation required (if any).	Windows PC

Software / Platform	Additional software packages or environment required (if any).	Arena simulation environment
Level of expertise and knowledge to use tool	Particular knowledge or competencies required to gather the input data, run the tool or model, and interpret the output (if any).	Knowledge of Arena and logistic movements
Existing user community (Yes/No)	Existence of any user community for the tool/model of interest.	No
Existing tech support (Yes/No)	Existence of any technical support for users of the tool/model of interest.	No
Latest version number (if any)	Latest version number (if any).	N/A
Current status	Current status of the tool.	Not actively used
Verification & Validation (V&V)		
Formal V&V or accreditation	A formal validation and verification or accreditation process was followed.	No
Peer-review	Underlying logic/approach of the model or tool was peer-reviewed by subject-matter experts.	Yes
Other	Other means of V&V.	Comparison with actual operational data.
Authorities and Points of Contact		
Intellectual property rights	The person and/or organization owning Intellectual Property rights.	Crown / Gov. of Canada
Details of custodian / POC	The person and/or organization that controls the structure and maintenance of the tool/model.	Raman Pall – DRDC CORA
Release authority	The person and/or organization that controls the release and use of the tool/model.	DRDC
Available documentation	References to relevant documentation, in hyperlink format whenever available on the web.	B. L. Kaluzny and R. Pall, Simulating the Repatriation of Canadian Forces Materiel from Afghanistan, DRDC CORA TM 2013-032, March 2013

Collaboration opportunities through NATO, if any. (NOTE: this information may be filled but will be revised by NATO SAS-132 national representatives).		
For development	Collaborative development of the model or tool.	No
For cross-validation	Validation of the model/tool's results against results from a model or tool from another nation.	No
For sharing (data)	Sharing of the data used or produced by the model/tool.	No
For sharing (tool/model)	Sharing of the model/tool and associated documentation with other nations.	Partially or potentially
For developing user community	Developing a community of analysts using the model/tool or variations of it.	No
For multinational studies	Collaboration on the conduct of studies using the model or tool.	No
Additional Information		
Experience	A short paragraph describing how the model/tool has been used by the nation in the past, with emphasis on the impact and benefits of the analyses conducted (e.g., cost savings, efficiency increases, decisions supported).	Results informed key DND decisions related to Op ATTENTION mission transition and termination plan.
Additional comments, suggestions or recommendation(s)	Any additional comments with respect to the information above, suggestions or recommendations for SAS-132.	None.
Keywords	Up to 5 keywords that best describe the tool or model (comma-separated).	Movement, transport, simulation, costing, retrograde

A.3 REFERENCES

[1] Lawrence, A. "NATO SAS: Methods and Models for Logistics Analysis – UK Brief", presentation to NATO SAS Exploratory Team SAS-ET-DK, Paris, FR, September 2016.

[2] Gauthier, Y. "Cataloguing Models and Tools for Logistics Analysis – CA Perspective", presentation to SAS-132 initial meeting, Stockholm, SWE, April 2017.

[3] Kaluzny, B.L., and Pall, R. "Simulating the Repatriation of Canadian Forces Materiel from Afghanistan", DRDC CORA TM 2013-032, March 2013.

[4] "Allied Joint Logistic Doctrine", NATO Allied Joint Publication AJP-4(A), December 2003.

[5] "NATO Logistics Handbook", November 2012 http://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2016_03/20160303_2012-logistics_hndbk-en.pdf, Accessed 18 April 2017.

[6] "NATO System Life Cycle Stages and Processes", NATO Allied Administrative Publication AAP-48 (Edition 1), February 2007, NATO/PFP UNCLASSIFIED.

[7] Definitions adapted from "Joint Capabilities Integration Development System (JCIDS) Process – DOTMLPF-P Analysis", http://www.acqnotes.com/acqnote/acquisitions/dotmlpf-analysis, Accessed 18 April 2017.

Annex B – LCM CONSIDERATIONS: SWE PERSPECTIVE

Systems Lifecycle Management (SLCM) is the concept that lies behind the Swedish FMV's values, with a focus on knowledge and qualitative assessment. It therefore deserves to be explained in more detail.

FMV defines a system as a combination of interacting elements organized to achieve one or more specified targets. Systems can be technical as well as organizational. In this context, they are always designed by the people for the people. All systems have a life cycle. A system is born as an idea; it is matured, developed, realized, used, dismantled, and replaced by something new. A system considers technologies as well as organizations. Neither the systems nor their life cycles operate in isolation, which gives us a complex and dynamic mesh (i.e., network) of collaborative but also often competing systems.

It is difficult to manage these systems and life cycles in the specific context in which they are created and maintain a balance between different needs and perspectives without over-exploiting, sacrificing, or cannibalizing other systems or resources. And everything must be done at the same time, while increasing the number of requirements for efficiency, outcomes, and innovations, which does not make things easier.

For us at FMV, these aspects together make up SLCM. We offer a wide range of skills, techniques, and tools that help Swedish Defence manage the complexity of all the steps in its system's life cycle, irrespective of whether this system is technical or organizational.

One can argue that Lifecycle Management (LCM) and its analyses do not cover the whole spectrum of logistics analyses, which is undoubtably true. But everybody agrees that LCM and its analyses outcomes provide fundamental input to all the other kinds of logistics analyses, because what would a supply chain or deployment analysis be without a spare parts optimization?

LCM is often referred to as Total Life Cycle System Management (TLCSM). LCM is the implementation, management, and oversight by the program manager of all activities associated with the acquisition, development, production, fielding, sustaining, and disposal of a system. In addition, "the tenets of life cycle management emphasize sustainment planning early in the capability solution's life cycle, to include requirement generation activities." [1]

The definition above is as good as any definition of LCM, and there are many definitions around, but it still does not answer the questions a system engineer encounters when starting to work with the LCM of a system. These questions are:

> **How to shape, acquire, develop, implement, maintain, and dismantle a complex system so that it becomes and remains cost-effective?**

In our view, the answer is simple: do your analyses continuously at all stages of the LCM process and scientific evidence will hopefully succeed. It may sound simplistic, but this is the quintessence of the work within the LCM process. The analyses give you the necessary and appropriate information in order to be able to take the right decision at the right time. In this pamphlet we intend to show this.

In this report we have gathered many tools for analyses, and we assume that everybody knows why. Everybody agrees that analyses are important for logistics and for LCM but still, analyses are too often requested on an ad hoc basis, or when an emergency occurs.

The following guidance is given for LCM. It shall:

1) "Maximize competition and make the best possible use of available DoD and industry resources at the system, subsystem, and component levels; and
2) Maximize value to the DoD by providing the best possible product support outcomes at the lowest operations and support cost." [2]

The above citation from the Department of Defence, US (DoD) illuminates the very equation for military logistics. Slightly changed, the meaning of the above can be written:

Find maximum of E(x, y) when C(x, y) is minimum

where E is the capability needed and C will be the cost of it. The vectors x and y refer to respective operational logistics properties.

This is nothing new! It was stated by Blanchard 40 years ago[1]. The logic of it is natural:

- A Defense, any Defense, has a **need** that will be fulfilled by a capability.
- How will the capabilities meet the needs – in other words, the operational requirements? You will need a "**needs analysis**", which should find the abilities, interests, values, level of production, revenues for the system to be, because you will need a system.
- Then you will have to study how the technical system is used to meet the needs, a so-called "**use study**", another kind of analysis, which will give you the type, character, volume, profile, location/environment of the operational concept.

Once the system is decided, system engineering takes over and makes a multitude of analyses to tell you how to design and specify the technical components of the system and to find what, which, how many you need, and the nature of their functional properties (for example, speed, range, capacity).

At the same time, logistics engineering defines the needs/requirements of the support; the Reliability, Availability, Maintainability, and Supportability (RAMS) properties of the technical system; and how we will design/detail the support system (for example, reliability, spare parts, maintenance). This task is carried out using many analyses:

- Failure Modes Effect and Criticality Analysis (FMECA);
- Reliability Analysis/Prediction;
- Scheduled Maintenance Analysis (SMA) – Reliability-Centered Maintenance (RCM);
- Testability Analysis;
- Maintainability Analysis;
- Maintenance Task Analysis (MTA); and
- Level of Repair Analysis (LORA).

[1] Benjamin Seaver Blanchard, Jr. was an American Systems Engineer and Emeritus Professor of Industrial and Systems Engineering at Virginia Tech.

All this is done while keeping in mind the total cost (LCC) that can be expected for the system. In addition, everything must be done in parallel, at the same time, iteratively, so that system and logistics engineering, and cost analyses are integrated (see Figure B-1). Because of this approach, and the goals it sets, LCM can be seen to be a program (system, product) of management that operates in all phases of a given system/product life cycle – "over time", in order to ensure **maximum system effectiveness at minimum cost (**Figure B-2**).**

The key to LCM is the analyses, including the methods, models, and tools to understand, predict, monitor, optimize, and improve system effectiveness (dependability, RAMS) and total costs (LCC) – analyses that have to be performed continuously throughout the system life cycle. Not sporadically, not ad hoc, but continuously.

Of course, all analyses need information (i.e., data), and this is usually a problem. However, this issue is not assessed here, but may be the subject of another pamphlet.

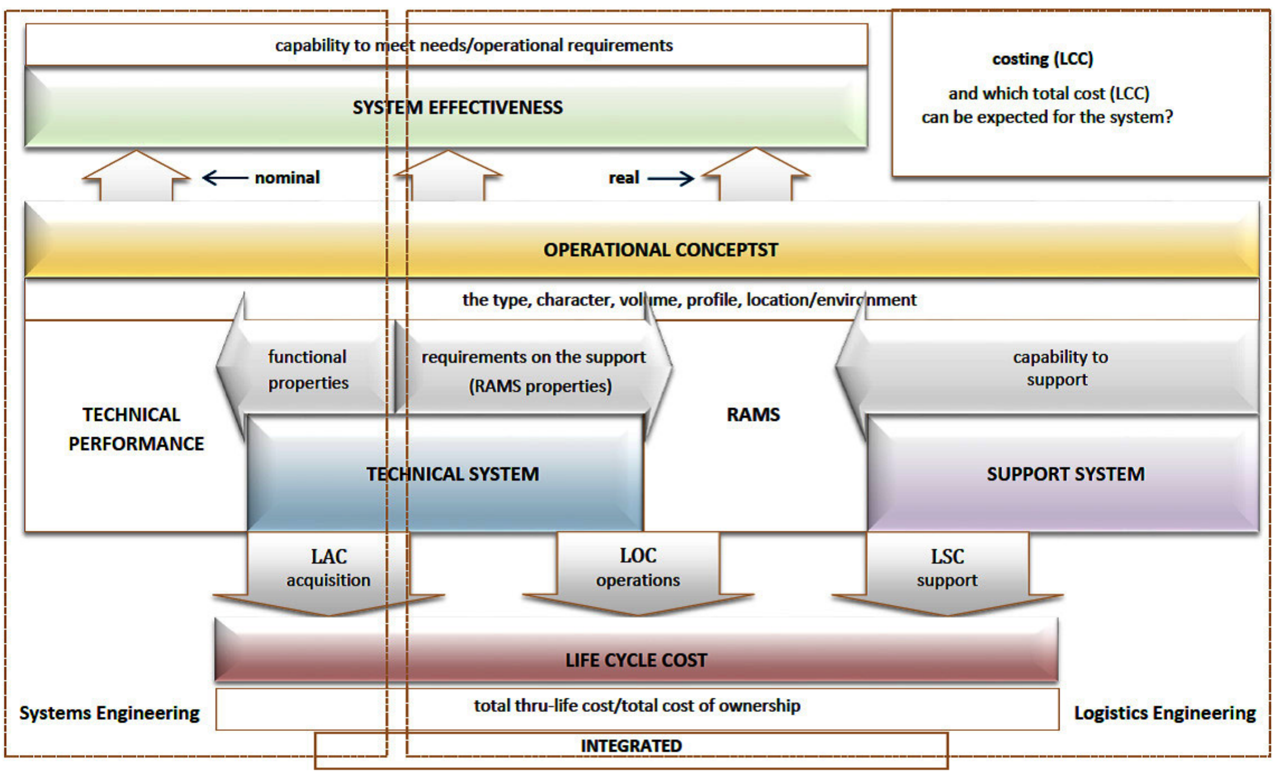


Figure B-1: LCM Framework Logistics Engineering, and Cost Analyses.

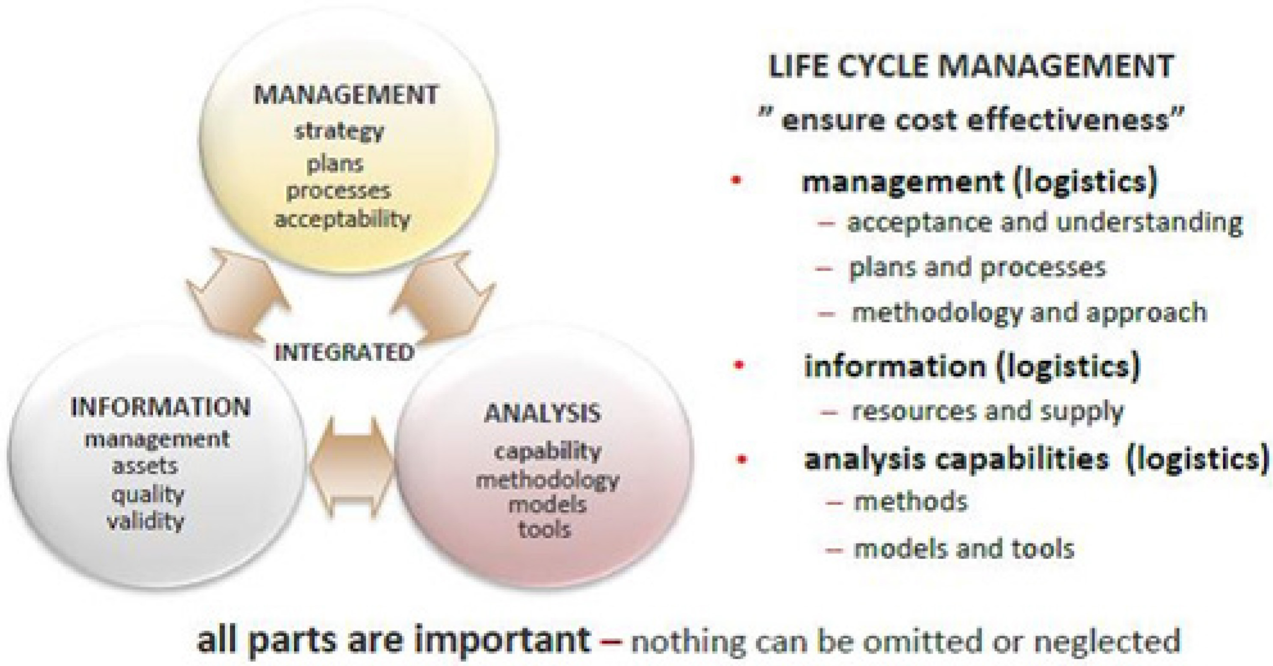


Figure B-2: LCM: The Road to Success at Minimum Cost.

B.1 REFERENCES

[1] Manual for the Operation of the Joint Capabilities Integration and Development System, JCIDS, Appendix D to Enclosure D, Paragraph 2, 2015, DoD.

[2] 10 U.S.C. 2337 Life-Cycle Management and Product Support, General Military Law, Part IV-Service, Supply, and Procurement, Chapter 137 – Procurement generally, 2013, USG.

ANNEX C – SHORTLIST OF MODELS AND TOOLS ARRANGED BY ORDER OF APPEARANCE IN D02

United Kingdom:

Strategic Evacuation, Analysis of Requirements Tool for Hospital Utilisation and Resources, Afloat SUPport (AfSUP) Demand and Profiling Tool, Alligator, Amphibious Offload Simulator, APOTHECA, Battlefield Support Aviation (BSA) Suite, Concurrency Analysis Tool, Deployment, Equipment and Sustainment Logistics Evaluator, Defence Support Cost Model, Dynamic and Readiness Concurrency Tool, Fleetflow, Force Structures Cost Model, Land Systems Theatre Ammunition Requirements / MASD Ammo Tool, Maritime Stockpile Analysis Tool, Model of Integrated Logistic Operations, NATO Reference Mobility Model, Object-Orientated Supply Chain Analysis, Rapid Maritime Casualty Estimation Tool, Ship Scheduler, Strategic Maritime and Air Lift Tool, Strategic Balance of Investment Linear Programme, Support Ship Optimiser.

Netherlands:

RAM Tool, Every Angle, Tools4LCM, SLIM4, Land Command & Control Information Services, Logistic Functional Services, SALOMO Single Airbase Logistics Model, MxMP Model, Planningstool modulair helikopter detachementen, Life Cycle Costing Tool.

Sweden:

ASTOR, SIMLOX, OPUS10, CATLOC, Monterey Activity-Based Analysis Program, PVL.

Germany:

LSA Bench, ASSET 3000, OPUS 10, ILS Viewer.

Canada:

Simulation of the Repatriation of CAF Materiel from Afghanistan, Readiness-Based Ammunition Allocations Requirements, Distribution Network Topological Resilience Model, Operational Support Hubs Model, Operational Support Hub Location Selection Approach, Northern Reception-Staging and Onward Movement Hub Model, Ground Transportation Distribution Network Model, Canadian Forces Operational Energy Consumption Model, Fully Burdened Cost Model for Military Operational Energy, Model of Northern Operations and Their Staging, Three-Echelon Supply Chain Model for Disaster Relief Operations, Design of Robust and Effective Supply Network for Engineering Tools for Military Operations, Supply Chain Network Studio, Multi-Objective Genetic Algorithm for Stockpile Planning, OmegaPS Suite, RCN Supply Chain Predictive Analytics Logistic Functional Services, Recognized Operational Support Picture, Ship Scheduler.

Czech Republic:

Sustainment Planning Module, Supply Distribution Model, Allied Deployment and Movements System, Coalition Reception-Staging and Onward Movement.

NATO:

Simulation of the Repatriation of CAF Materiel from Afghanistan, Allied Commands Resource Optimisation System Software (Air Defence / Air to Ground / Land Equipment Munitions Expenditure Model), Allied Commands Resource Optimisation System Software (Maritime Munitions Expenditure Model), Sustainment Planning Module, Supply Distribution Model, Joint Defence Planning Analysis and Requirements Toolset, Allied Deployment and Movements System, Coalition Reception-Staging and Onward Movement, Effective Visible Execution.

REPORT DOCUMENTATION PAGE

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14. Abstract
The SAS-132 Research Task Group surveyed over 100 models and tools used for logistics analysis in CAN, CZE, DEU, GBR, NLD, TUR, SWE and NATO NCIA. They identified 75 tools with a strong logistics analysis focus for which we collected additional data. The data collection captured various aspects of the models and tools of interest, such as the area(s) of sustainment logistics analysed by each tool, the area(s) of procurement logistics analysed, the context of the analyses, data requirements, etc. The collected information was reviewed and collated into a single catalogue of models and tools. The analysis revealed that individual participating nations have different approaches to conduct logistics analysis using modelling and simulation tools. Some nations mainly use broad, institutionally-recognized models as standard supporting tools for logistics considerations. Others mainly use fit-for-purpose models designed to handle specific problems, while some nations rely on NATO-recognized software (e.g., LOGFAS) only. Despite these differences, the wide and deep potential of the set of tools and instruments identified creates a solid foundation for future cooperation between NATO and NATO's Partnership for Peace Nations for logistics analysis and also provides opportunities to share existing models.

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