SYM-AM-17-088

Proceedings of the Fourteenth Annual Acquisition Research Symposium

Thursday Sessions Volume II

Acquisition Research: Creating Synergy for Informed Change

April 26–27, 2017

Published March 31, 2017

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School

A Systemic Analysis of Military Equipment Acquisition Among NATO Suppliers: A Proof of Concept Based on a Multi-Layered DSS Approach

Martin Zsifkovits—University of the Federal Armed Forces Munich, Germany [martin.zsifkovits@unibw.de]

Gonzalo Barbeito—University of the Federal Armed Forces Munich, Germany [gonzalo.barbeito@unibw.de]

Dieter Budde—Major General (Ret.), German Armed Forces [dibu11@gmx.de]

Max Krüger—University of Applied Sciences Furtwangen, Germany [max.krueger@hs-furtwangen.de]

Stefan Pickl—University of the Federal Armed Forces Munich, Germany [stefan.pickl@unibw.de]

Abstract

The analysis of military weapon or equipment acquisition is facing numerous challenges, such as rapidly changing and advancing technologies, several cost dimensions—including investment costs, maintenance, or upgrading—as well as public interests. Due to the significant monetary investments required, a transparent and understandable acquisition process is needed. Therefore, especially defense acquisition among NATO partners for the increase of overall efficiency is a desirable goal. We propose a systemic approach, conceptualized under NATO supplying regulations, capable of analyzing the acquisition process of military equipment over multiple layers among NATO partners. The layers differ in their dimensions of analysis. The approach is demonstrated in the paper at hand based on a proof of concept, using artificial data.

Introduction

The NATO Defence Planning Process (2014) describes armaments planning as follows:

> Armaments planning focuses on the development of multinational (but not common-funded) armaments programs. It promotes cost-effective acquisition, cooperative development and production of armaments. It also encourages interoperability, and technological and industrial cooperation among Allies and partners.

Military procurements from allied nations and vice versa are embedded in a complicated network of foreign politics and home affairs, as well as preceding prospective acquisitions' decisions. State armaments procurements are not intended for primary economic purposes. Armaments are given priority in order to fulfill constitutional and political tasks of defense, as well as to safeguard national security and foreign policy interests. Procurement is usually the subject of social and economic policy controversies. Therefore it is necessary to make the underlying considerations and objectives clear within a transparent decision-making process. Future challenges call for cooperation to achieve financial, technical, and/or industrial benefits within the field of acquisition. This requires the possibility of objectively assessing the cooperation in an acquisition. This concept can make complex acquisitions more transparent, effective and more modern. As a result, the capabilities of the armed forces can be further developed through continuous modernization.

In order to meet the requirements of transparent and well informed military acquisition, we introduce the proof of concept for a multi-layered systemic approach that combines qualitative and quantitative methods. As this paper at hand only focuses on proving this concept, we introduce a simplified, artificial acquisition process as use case.

In the last years, acquisition processes became more and more complex and sensitive, as indicated in actual press releases and forum discussions. The report of the NATO-Industry Forum on November 9, 2016, stated: “NATO should further deepen its engagement with Industry through joint concept development, involvement in exercises, experimentation and war gaming, in order to design future solutions together.” Additionally, “The length of the NATO acquisition processes was criticized. One-size-fits-all procurement strategies may no longer (in fact, already does not) address NATO needs adequately” (NATO, 2016). NATO is making efforts to improve the acquisition process. SHAPE Allied Command Operations (ACO) Acquisition Management is an organization that deals with acquisition and is responsible for developing, coordinating, promulgating, and implementing acquisition policies and procedures ACO-wide and may conduct centralized acquisition initiatives. This year for instance, for the procurement of vehicles for the HQ KFOR fleet in Kosovo, Human Resources Data Services (HRDS) support at SHAPE Headquarters and Electronic Warfare Services for ACO Training and Exercises (NATO, 2017). In order to understand and to improve these acquisition processes several description layers should lead to a better understanding. In each layer quantitative and qualitative modeling aspects will be embedded and should be analyzed.

As a first approach a specific normalization procedure might help to generalize such a holistic acquisition process. Our acquisition model is characterized by a multilayered and multistage architecture:

- Multi-layered addresses the different sectors being involved.
- Multistage covers the dynamic behavior of the time-dependent process.

It is the focus of our approach to identify, characterize, and predict the distinguished interfaces. In order to characterize them, we are starting from classical best-practice examples and specify the interfaces more and more.

The resulting management cockpit is characterized by our “Big Five of an Advanced Acquisition Architecture”:

- better coordination,
- better monitoring,
- better interpretation,
- better services, and
- better process-stability.

This should be elaborated in the future to develop a comfortable Decision Support System (DSS) as expert analytic framework. The main reason, therefore, is the potential reduction of complexity via such an approach to an acceptable minimum in order to focus on the process itself instead of interpretations of concrete numbers. However, at the end of this article we will discuss the possibility of increasing complexity for real-life evaluations and the automation within a management cockpit as part of a DSS.

This paper is structured as follows: In the next section (Multi-Layered Systemic Acquisition Evaluation: Management Cockpit) we introduce the multi-layered systemic approach for a transparent and understandable acquisition process of drones, comparing several suppliers and their offers on the same scale. The following two sections (Qualitative Analysis [Layer 1] and Quantitative Analysis [Layer2]: System Dynamics) describe the qualitative and quantitative analysis steps of this approach which provide an executable

System Dynamics model (Sterman, 2000). The results of the corresponding simulation are provided in the Simulation Execution (Layer 3) section and discussed in the Validation and Expert Evaluation (Layer 6) section. Possible future work and conclusions are given in the final section.

Multi-Layered Systemic Acquisition Evaluation: Management Cockpit

Due to the high complexity and multiple dimensions of acquisition processes, as discussed above, we propose splitting evaluation of suppliers' bits into several layers. Hereby, every layer represents one step in the evaluation process. We start with a qualitative analysis that brings together experts' opinions with previous best practice examples. This allows us to create a checklist of aspects to be considered in the acquisition evaluation. Furthermore, we propose a visual presentation (e.g., a Mind Map) in order to visualize the interconnections and dependencies between these aspects. This quantitative information is used in a subsequent step for quantitative analysis. Here we suggest the methodology of System Dynamics modelling in order to quantify the previously detected dependencies in the system. For a user-friendly representation of the model and its results, a management-cockpit is suggested. This management cockpit allows the simulation to tackle various research questions at the same time and represents the results adequately. Before taking the final decisions, the qualitative analysis experts from Layer 1 judge the model's output for validation and verification of the results. A graphical representation of this proposed approach is shown in Figure 1.

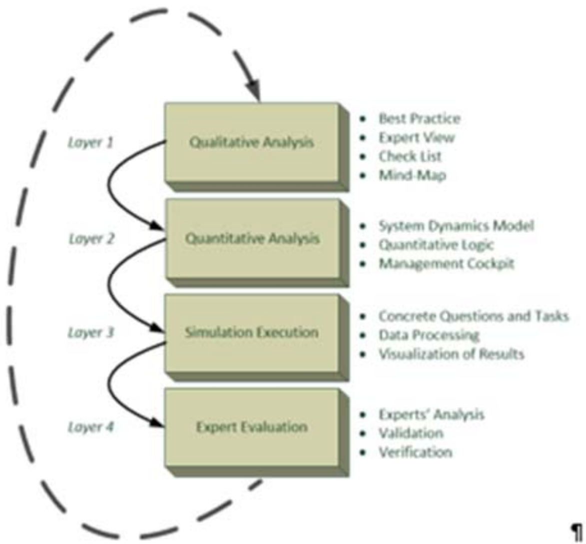

Figure 1. Complex DSS-System Analysis Over Multiple Layers

These four layers form the main part of the Multi-Layered Systemic Acquisition evaluation and are explained in the following sections in more detail. For demonstration purposes, we provide and use a fictive example of a weapon system acquisition.

Let us consider the acquisition of a novel drone fleet as running example. There might be 10 different suppliers on the national and international market offering such assets. Thereby, prices, technologies, maintenance, and possibilities for upgrades differ among all suppliers. A table of the most important key-parameters for the existing suppliers on the market is shown in Table 1.

Table 1. Key-Parameters of Suppliers’ Tender Offers

SUPPLIER	TECHNICAL ATTRIBUTES				MAINTENANCE ATTRIBUTES			SUPPLY SIDE ATTRIBUTES			Cost Upgrade	Price/U
	Equip	Range	Versatility	Load	length	cost/rev	r	n lines	time/unit	stock T(0)		
1	3	6	8	3	20	€ 50.000	2	2	5	10	€ 150.000	€ 1.000.000
2	6	3	7	7	25	€ 70.000	3	4	6	5	€ 50.000	€ 1.200.000
3	8	7	8	5	30	€ 100.000	2	2	4	8	€ 200.000	€ 1.300.000
4	4	4	5	7	10	€ 50.000	2	5	7	5	€ 150.000	€ 800.000
5	4	6	8	7	20	€ 150.000	1	10	12	10	€ 60.000	€ 1.100.000
6	5	5	10	1	30	€ 220.000	1	8	3	0	€ 130.000	€ 900.000
7	4	4	3	6	20	€ 75.000	2	6	5	2	€ 200.000	€ 700.000
8	2	7	4	4	15	€ 75.000	3	7	4	15	€ 80.000	€ 800.000
9	8	8	6	8	10	€ 100.000	3	3	7	4	€ 320.000	€ 2.200.000
10	5	4	6	4	20	€ 80.000	2	3	6	7	€ 120.000	€ 1.100.000

Here, the technological parameters are normalized values on a scale from 0 to 10, with 10 representing the best value. We compare each drone system with respect to equipment, maximum range per flight, versatility, and maximum payload. Furthermore, the average duration per maintenance, the number of maintenances needed per year, and the average cost per maintenance are listed. Suppliers’ offers also include information on how many drones are in stock and how many can be built in a given time period and in how many production lines. Even though we are using a simplified scenario with fictive numbers in order to prove our concept, one can see the high degree of complexity underlying to this acquisition decision problem.

Using the systemic multi-layer approach, we demonstrate, subsequently, how the acquisition process can be processed in a transparent way. This should lead to adequate decision support. Therefore, we will use different ways of analysis for a deeper understanding of every offer.

Qualitative Analysis (Layer 1)

Let us assume that the intended useful life of the new drone fleet is 20 years. In the first layer of analysis, decision makers should evaluate best practice acquisitions from the past. This helps to find important aspects in prior cases and allows for learning from prior mistakes. Additionally, experts should be contacted in order to identify a successful acquisition’s key issues of assets of this or similar type. The evaluation of these experts’ views and best practice examples results go into a checklist that contains relevant factors, such as technological parameters, performance indicators, maintenance circles, upgrade possibilities, or delivery dates. In addition, the checklist should include relevant constraints for these factors, drawn from the call for tenders, for example. In more detail, the checklist may specify upper or lower bounds (e.g., for prices). This allows for reducing the quantity of offers in a first step. With respect to our running example, we assume the following checklist with desired attributes and constraints:

- Minimum level of equipment, range, and load is 3.
- Minimum level of versatility is 5.
- Annual maintenance costs should not exceed €210,000.
- Four drones are needed immediately.
- Acquisition costs should not exceed €1,300,000.

Applying this checklist to the existing offers in Table 1, the number of valid offers substantially reduces. Table 2 shows the suppliers’ tender offers with every value outside defined boundaries marked in red. These offers are excluded from further consideration.

Table 2. Reduction of Offers Based on Checklist's Application

SUPPLIER	TECHNICAL ATTRIBUTES				MAINTENANCE ATTRIBUTES			SUPPLY SIDE ATTRIBUTES			Cost Upgrade	Price/U
	Equip	Range	Versatility	Load	length	cost/rev	r	n lines	time/unit	stock T(0)		
1	3	6	8	3	20	€ 50.000	2	2	5	10	€ 150.000	€ 1.000.000
2	6	3	7	7	25	€ 70.000	3	4	6	5	€ 50.000	€ 1.200.000
3	8	7	8	5	30	€ 100.000	2	2	4	8	€ 200.000	€ 1.300.000
4	4	4	5	7	10	€ 50.000	2	5	7	5	€ 150.000	€ 800.000
5	4	6	8	7	20	€ 150.000	1	10	12	10	€ 60.000	€ 1.100.000
~~6~~	5	5	10	1	30	€ 220.000	1	8	3	0	€ 130.000	€ 900.000
~~7~~	4	4	3	6	20	€ 75.000	2	6	5	2	€ 200.000	€ 700.000
~~8~~	2	7	4	4	15	€ 75.000	3	7	4	15	€ 80.000	€ 800.000
~~9~~	8	8	6	8	10	€ 100.000	3	3	7	4	€ 320.000	€ 1.200.000
~~10~~	5	4	6	4	20	€ 80.000	2	3	6	7	€ 120.000	€ 2.200.000

Application of this first analysis step resulted in a reduction of relevant offers by 50%. However, the remaining offers and their underlying information need further analysis. In the following step we outline the individual influences previously evaluated in a graphical representation (e.g., a mind map). This illustration helps to understand interdependencies among various factors and might already provide a qualitative idea of preferences. For our running example in drone acquisition, this presentation is given in Figure 2.

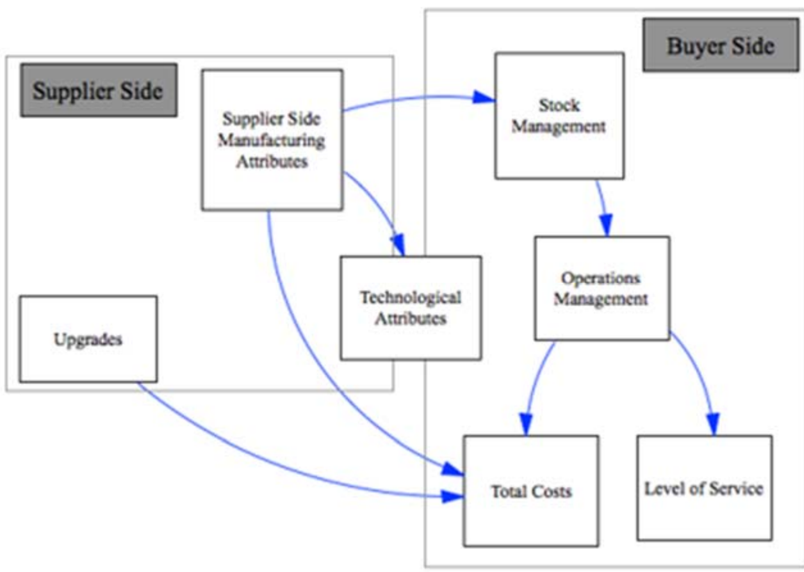

Figure 2. Graphical Representation of Relevant Acquisition Factors

This graphical representation sketches a first qualitative impression of various values' relations, such as monetary costs, service levels, technological attributes, or waiting time according to the stock management. All these factors are of importance for the acquisition and therefore demand for further analysis. In order to make all these values more concrete and comparable among each other, in the next section we transfer the mind map into a quantitative model.

Quantitative Analysis (Layer 2): System Dynamics

Many methodologies for quantitative analysis exist. We decided to apply System Dynamics, which is a computer-aided approach to policy analysis, design, and the definition of corporate strategies. System Dynamics (SD) was developed by Jay W. Forrester at the Sloan School of Management of the Massachusetts Institute of Technology in the 1950s (System Dynamics Society, 2017).

System Dynamics is an established methodology, which has been applied in various areas before. Coyle (1996) provides a practical oriented introduction in qualitative and quantitative modelling with Systems Dynamics. For example in military context, Minami and Madnick (2009) apply System Dynamics for the analysis of combat vehicle accidents in Afghanistan. Fan, Fan, and Chang (2010) provide a modeling of military weapon maintenance supply systems for the analysis of the bullwhip effect in military supply chains, and in Adamides, Stamboulis, and Varelis (2004) System Dynamics is used to support a procurement decision of military aircraft engines.

Considering the given information from our running example and the designed mind map, we construct a System Dynamics model for numerical analysis. In a nutshell, System Dynamics is a modeling and simulation technique for analyzing the behavior of systems over time. Plenty of sources exist with detailed descriptions and information on the methodology, and with a broad audience considered, (e.g., Sterman, 2000; Meadows & Wright, 2008; Pruyt, 2008). All System Dynamics models are formed of three major entities, as described in Zsifkovits et al. (2016):

- **Stocks or levels:** These elements are the foundation of every system. Their main behavior is to accumulate or deplete over time. They can act as delays, lags, buffers, ballast, and sources of momentum in a system. Furthermore, these entities allow inflows and outflows to be decoupled and independent and temporarily out of balance with each other.
- **Material and information flows:** Material flows are the elements that modify the value of a stock: inflows add to the stock and outflows subtract from it. Despite their name, they don’t necessarily need to carry physical elements. For example, information flows are a representation of who has access to determined information on the system.
- **Delays:** These entities represent the lengths of time relative to the rates of system changes. These delays may be inherent to the system structure, as the rate on which a stock changes, acting as buffer of the system, or explicitly added, by introducing a time delay entity in the model. (Zsifkovits et al., 2016)

These simple elements all can be composed in such a way that complex systems are easily represented.

Even though that System Dynamics is well suited for qualitative behavioral analysis of systems and policies over time, System Dynamics is not to be used as method for forecasting particular future events, but to provide decision makers and experts a better intuitive feel for improving judgment on the factors influencing success (Forrester, 1961; Forrester, 2007). This is also what we are aiming for in this paper.

For the example at hand, the overall structure of the proposed model is shown in Figure 3. The structure is divided into sub-models in order to make the model more clear and easy to understand. It demonstrates all observed interactions on basis of eight different sub-models and their interactions, separately for each supplier. The sub-models represent the acquisition costs, the total costs (including acquisition, maintenance, and upgrading), technological aspects, stock management, maintenance, upgrades, supplier side conditions, and the level of service. The sub-models are interacting at various points, which is represented by variable names in grey (in Figure 3), which means that they are used in more than one sub-model at the same time. The individual sub-models are subsequently described in more detail.

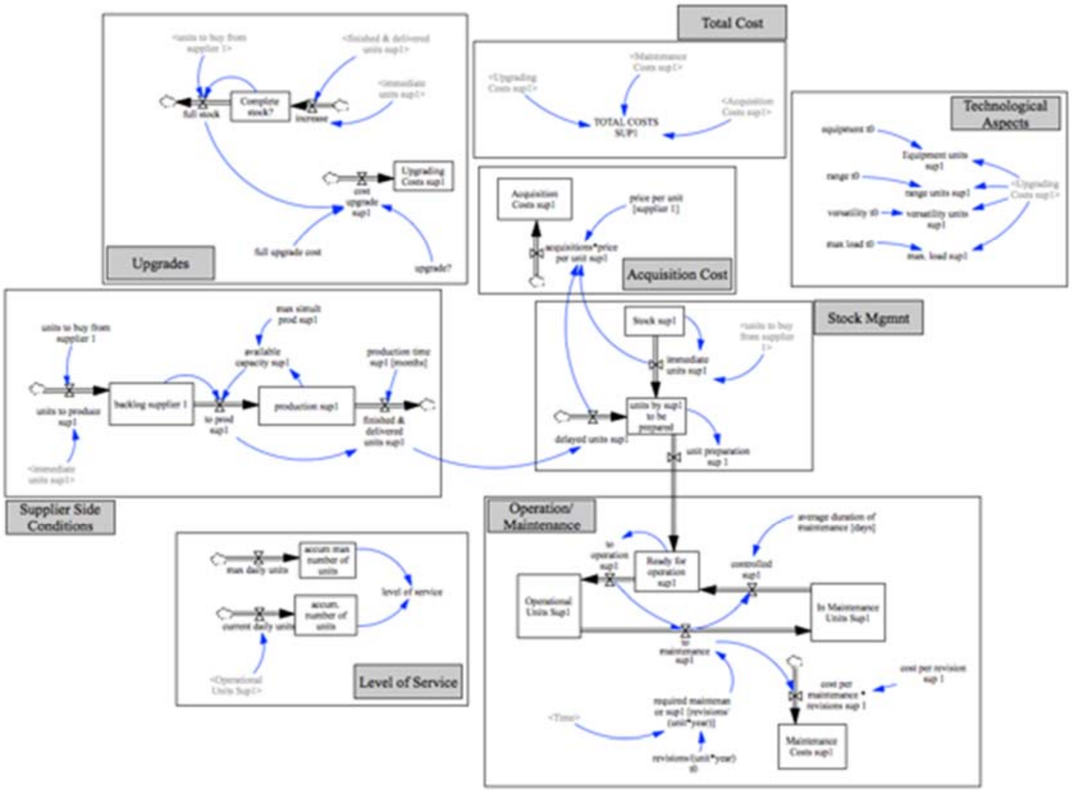

Figure 3. System Dynamics Model

Sub-Model: Acquisition Costs

The first sub-model is very small and counts the overall acquisition costs by simply multiplying the price per unit by the number of ordered units (summing up the immediately delivered and the ones that need to be produced as explained in the sub-model "Supplier Side Conditions"). The interaction of the acquisition costs with the stock management and the maintenance is shown in Figure 4.

Sub-Model: Supplier Side Conditions

As soon as a special quantity is ordered, this model checks how many quantities are available in stock and how many have to be produced. Thereby, the model considers the production time per unit and the existing production lines per supplier. This shows finally, when the quantities in production are available.

Sub-Model: Stock Management

This sub-model combines the existing units in stock and the supplier side conditions in order to see in which time steps which quantities can be delivered.

Sub-Model: Maintenance

The maintenance sub-model considers the different annual service intervals, their individual duration in days, and the costs per maintenance. Every supplier has different maintenance circles, durations of maintenance, and different costs caused by maintenance. Additionally we assume that after 10 years, every product needs an additional maintenance per year. The sub-model as well as its connection to the previously mentioned sub-models is shown in Figure 4.

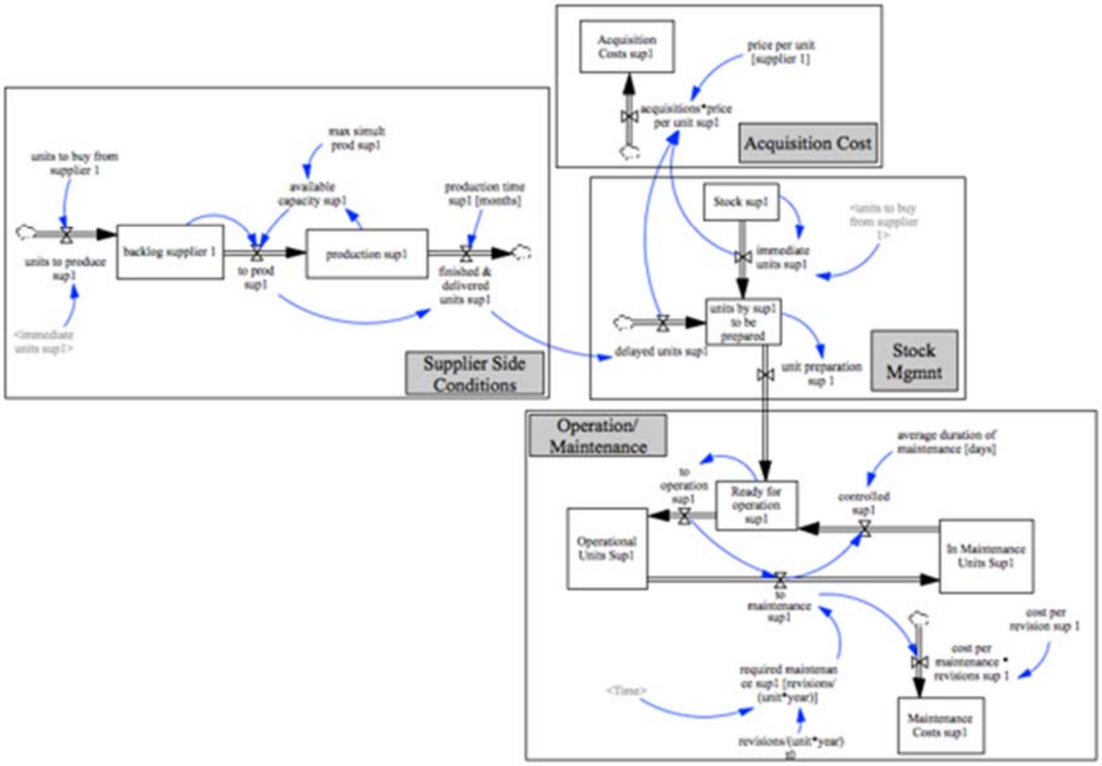

Figure 4. Core Sub-Models

Sub-Model: Total Cost

In this sub-model the total costs are summed up, resulting from acquisition, maintenance, and technological upgrading. Each supplier offers supplementary upgrading, which is considered in future. This upgrading would increase technological parameter and is at cost (as also shown in Table 1). This sub-model is shown in Figure 5.

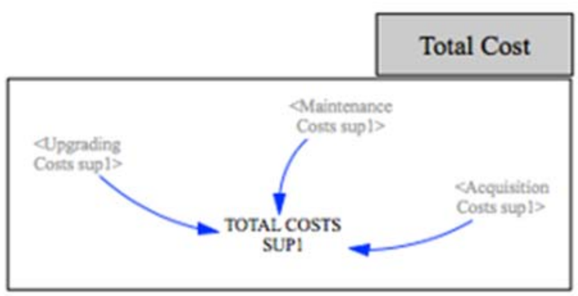

Figure 5. Sub-Model Total Costs

Sub-Model: Technological Aspects

Every product is facing several technological parameters: equipment, range, versatility, and maximal loading capacity. Different suppliers have different views and therefore their products differ in those ranges. For a comparison of their capabilities we normalized the technological values on a scale of 0 to 10. These levels can be improved by technological upgrading at cost in the future, which is explained in the sub-model “upgrading.” Initial values are used from the input sheet in Table 1. The sub-model is illustrated in Figure 6.

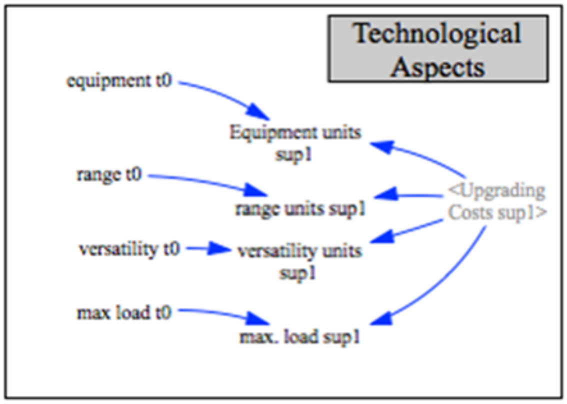

Figure 6. Sub-Model Technological Aspects

Sub-Model: Upgrades

When upgrading the technology of a product, this improves the technological capability by a special amount. To simplify things we assume in this proof of concept, that each technological parameter (equipment, range, versatility, and maximal loading capacity) can always be improved by two units, but keeping the upper bound of 10 units. For a more complex analysis of real cases this would of course differ. However, just for proving the concept suggested in this article, the simplification seems to be adequate. We assume that the upgrades of the fleet are executed as soon as all items are delivered by the supplier. This sub-model is illustrated in Figure 7.

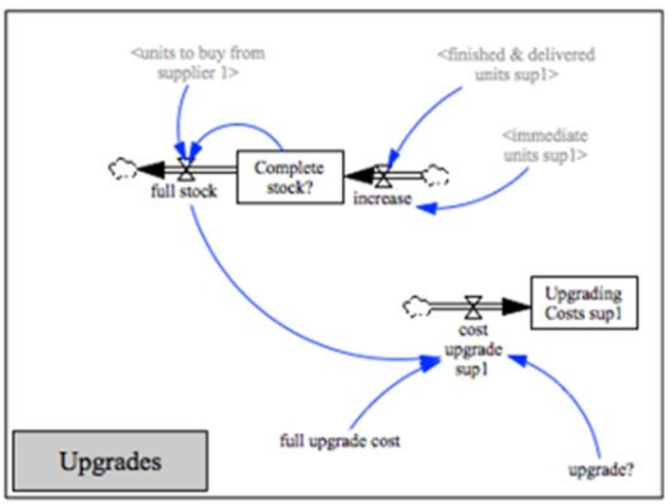

Figure 7. Sub-Model Upgrades

Simulation Execution (Layer 3)

For the remaining five suppliers, which met the constraints in our example, we executed simulation runs and evaluated the results in comparison amongst each other. This should help the decision maker to rank the options for a purchasing decision. We execute the simulations over 20 years in order to project the impact of the acquisition over the full-time horizon of the intended system's use. For the analysis, we tackle three main questions of interest:

- What is the technological status and potential of each product?
- What is the overall cost of acquisition over 20 years, including all relevant factors?
- What is the service level of each supplier over the planning time horizon?

In order to help the decision maker answer these questions, the following results were performed and visualized for the planning horizon of 20 years. However, as different suppliers deliver the orders (at least partly) at a later stage, an analysis over 20 years after delivery of the last piece might also make sense and could be executed.

Decision's Dimension: Technology

The technological parameters in our example are not parameterized dynamically over time. Technological improvement is possible in the same volume over all parameters and suppliers. We introduced this simplification in order not to make this proof of concept too complex. However, results might become far more extensive for real-life scenario analysis if this simplification is omitted. In the scenario at hand we see the initial values and their potential equal improvement over time and parameters in Figure 8.

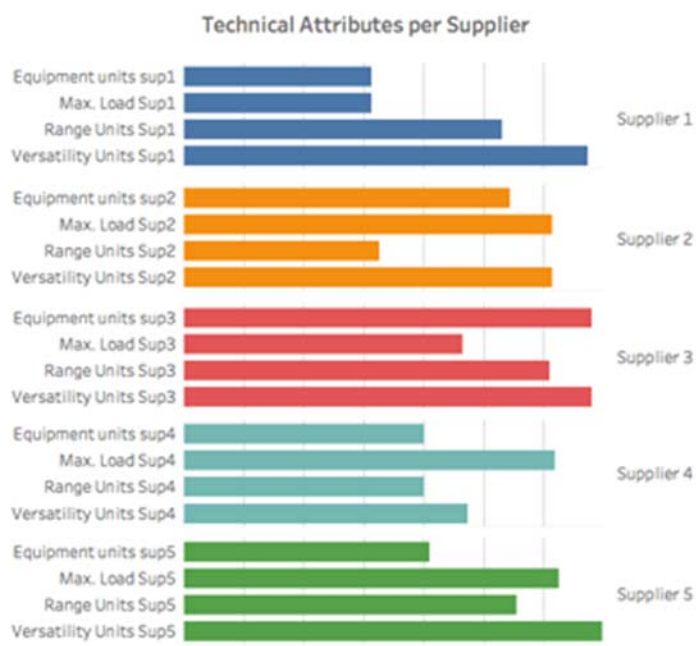

Figure 8. Technological Attributes per Supplier

Decision's Dimension: Costs

Figure 9 shows the results of simulated cost evolution over several dimensions. On top, the overall costs per supplier are accumulated over a 20-year time horizon. It is shown very clearly that the overall acquisition costs vary in a range from about €120 million to over €200 million for the different suppliers. Suppliers 1 and 4 are amongst the cheapest overall, while acquisition from supplier 3 would lead to the highest overall costs. A surprising aspect of this analysis is that suppliers 1 and 4 are amongst the most expensive suppliers in terms of upgrading. However, as these are costs that occur only once, and as these costs are comparably low, this does not influence the overall costs negatively compared to the other suppliers. In the analysis at hand we assume that costs incur after delivery. This leads to different rises of costs over time. First of all, this is essential in order to see when the products are delivered, secondly it might become relevant when discounting the interest to t=0. When having a detailed look at the cost curves, one can see a slight turn upwards at the overall costs, but especially for the maintenance costs. This is caused by the additional annual maintenance needed after 10 years. Several mid- and long-term effects can be analyzed using this systemic approach. Especially with an increase in complexity, these dynamics become increasingly important. The time point when all 40 items are delivered can be easily seen in the costs of upgrading, as all drones are upgraded as soon as they are all delivered from each supplier. This also explains why upgrade costs are a rather sharp increase and therefore leads to the increase in total costs for all suppliers.

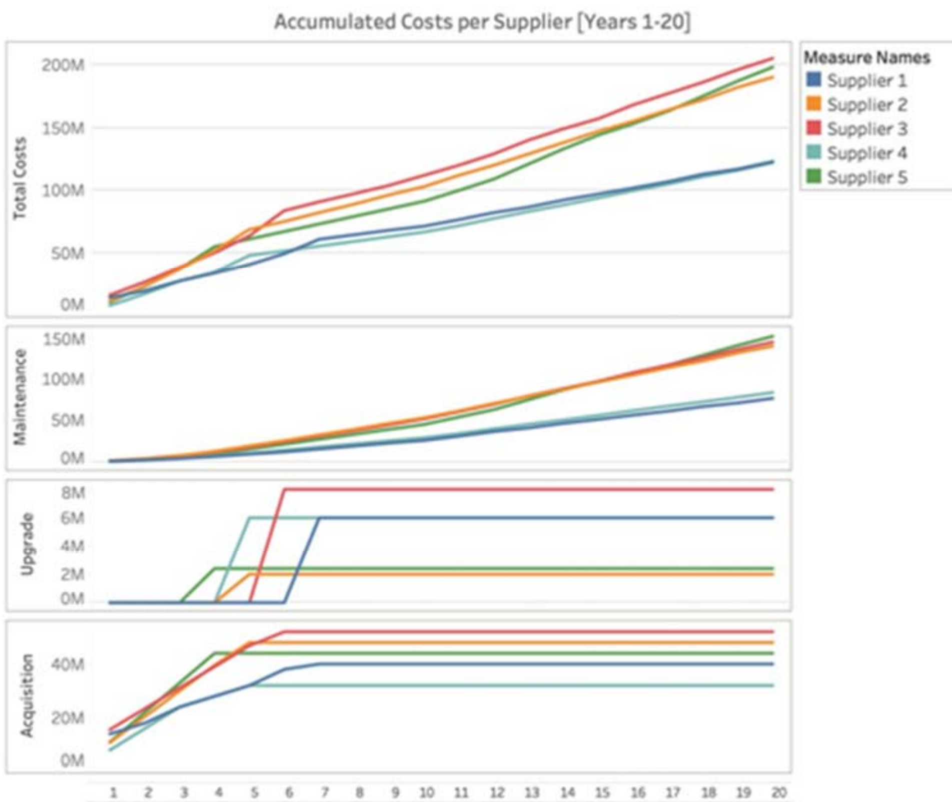

Figure 9. Accumulated Costs per Supplier

Decision's Dimension: Service Level

Another analysis aspect is the degree of expected service by each provider. We define the service being higher if all desired drones can be delivered immediately at t=0. Furthermore, we define a higher degree of service when a system does not have to undergo maintenance too often, the maintenance is shorter, or the unavailability of drones is low. Thus, receiving all 40 drones at t=0 and having no maintenance over the planning horizon, the service level would be 1. We introduce this measure in order to have more information on the offer than only monetary costs and technological parameters. In this case, the highest degree of overall service can be expected by suppliers 4 and 5. While supplier 5, holding the highest degree of service, is amongst the most expensive providers, supplier 4 is the second best in service and is amongst the cheapest suppliers. The service levels of the rather expensive suppliers 2 and 3 are amongst the lowest. The results of the analysis for service levels can be seen in detail in Figure 10.

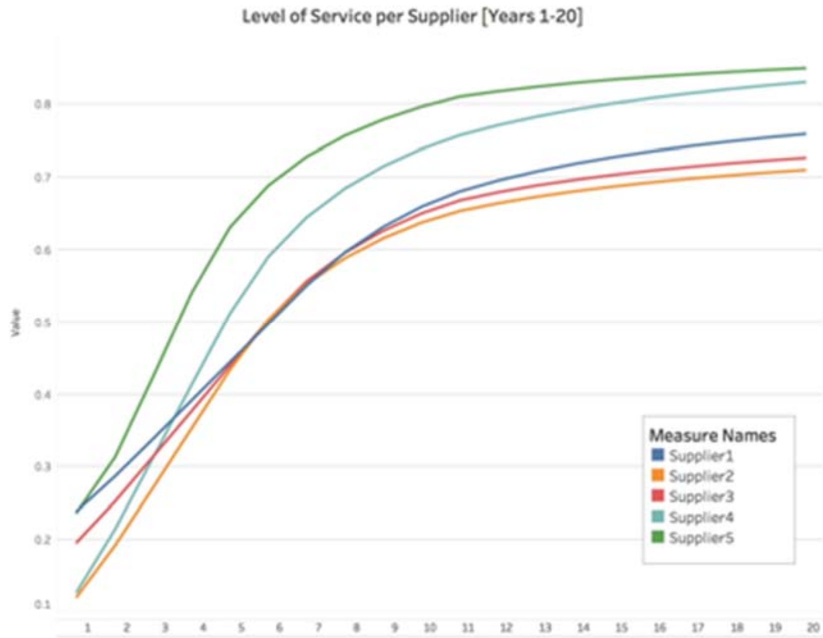

Figure 10. Level of Service per Supplier

The presented model with its eight sub-models was validated and verified in a multiple step approach, combining partial (sub-model) tests and full tests, fixed number execution, and scenario evaluation. At a certain level of abstraction, the model with all its sub-models can be seen as valid for the fictive running example and can be easily modified or extended. This would allow executing simulations for real-life acquisitions beyond this proof of concept.

Validation and Expert Evaluation (Layer 6)

The results of the model executions are finally presented to experts. From a modeler's or analyst's point of view, it is important not to evaluate the results, as this should be done unbiased by the subject matter expert, not by the analyst. The expert is now able to compare all the supplied products over various dimensions. Here it must be noted, that it is not possible to include all possible dimensions in the quantitative analysis. Thus, the decision maker needs to combine quantitative results with other dimensions, such as public interest.

For validation and expert's evaluation of our example, the objective analysis of acquisition allows rationality of procurement programs and thus joint procurement. It is about equipment, weapon systems, and services. The clear definition of common service time and cost parameters allows an economical procurement of armament. The different costs, such as investment, introduction, maintenance, up-grading, and new procurement, as well as technological and organizational support for an acquisition can be better estimated. In addition, cost increases and possible additional costs can be recognized at an early stage. The frequent "low demand for high-quality weapon systems" can be tackled this way.

Investments can be reduced by reviewing existing policies, structures, and procedures for armaments cooperation and acquisition. Furthermore, it can support managing a reduction of forces and a rationalization of military infrastructure or a build-up of new forces and the required equipment, thereby supporting a transformation of forces.

The political, social, and economic interests of states can be bundled through joint acquisition. Thus, synchronizing and utilizing the relevant national line organizations that are in charge of the procurement processes. Using common acquisition deep-rooted national traditions, bureaucratic inertia, diverging industrial interests, and different procurement philosophies might be overcome. This model supports a possible effort for armament cooperation and standardization in bilateral and multilateral bodies and a broad range of armaments programs. This paves the way for technological security, industrial consolidation, and the harmonization of military requirements for systems to be procured. Thus, world-marketable military products can be procured. Joint acquisition of equipment can ensure the required military capabilities, security of supply, cooperative research, and development. Furthermore, unified requirements and capabilities enable cooperation and help to achieve commonality in equipment, support, and usage.

The application of the model can lead to better coordination of procurement procedures for defense and security and better monitoring of supply and service contracts. In particular, a close professional collaboration between the client and the contractor is crucial for success, especially in large projects. The aim of a subsequent phase of realization is to provide the armed forces with timely, ready-to-use products and services for their operations.

This model is used to assess the entire life-cycle of ordnance from the initial stage of research, to propose solutions for their realization and use of the control system, and to separate and exploit them according to rational processes. The different layers of the model, Qualitative Analysis, Quantitative Analysis, Simulation Execution, and Expert Evaluation, and their interdependencies enable an expert to survey the background of the preparation of an acquisition. There are several different areas in which the analysis can be influenced by the provision of expertise. This is particularly true in the context of layer 4. The qualified view of experts in layer 1 is of particular importance, where different experts are required to present their ideas. However, the different perceptions of experts should then be harmonized within the framework of setting key parameters.

Through the model, the decision maker gains the opportunity to get an overview of the entire process of acquisition. Through the objectivity of the processes, the possibility of comparing the parameters and the alternatives, the decision maker finds the basis for a decision. It is possible for him or her to estimate costs and risks and to analyze vulnerabilities. It also ensures early planning security and the possibility of early coordination of further structural and personal measures as well as for training. Overall, the effectiveness and efficiency of the procurement of materials and services, and thus of the armed forces, can be increased by means of the model.

Conclusion and Future Work

The analysis of previous armament projects and armament acquisitions has shown that an improvement in armament acquisition management is required in national and international projects. Acquisition and management of armament projects calls for a culture of leadership in which transparency, integrity, initiative, and responsibility of all project participants are required. With the approach provided in this paper, possible deficiencies can be overcome. The framework conditions for future equipment and procurement to ensure necessary military capabilities and security of supply can be improved. Cooperation efforts and joint defense efforts become more transparent. Common projects such as "Smart Defense" and "Pooling and Sharing" provide the necessary force resources for states who can no longer afford the independent military capabilities through appropriate acquisition. Using the model, possible national selfishness and unwillingness to make necessary investments in the future military capability can be reduced through shared knowledge, parameters for acquisition, and common procurement. All these aspects are candidates to be included in a possible refinement of the proposed acquisition decision support model.

In the current state of this research we introduced only a proof of concept for the systemic analysis of military acquisitions based on a multi-layered decision support system (DSS) approach. In doing so, we introduced an artificial example with reduced complexity. In a further step, we propose to increase complexity in applying the concept to real cases and analyzing real data from historic (or current) acquisition processes. The increase in complexity would also increase dynamics in the simulation and demonstrate the importance of our approach even more. The reason is that several medium- and long-term effects might differ strongly over several suppliers.

A further step in this research might be the concentration and standardization of several groups of cases. For example, weapon acquisitions, vehicle acquisitions, drone acquisitions, or helicopter acquisitions seem to have very individual characteristics, but seem rather homogeneous within these groups. Several DSS for each group of acquisitions might increase the acceptance of our solution for practitioners as it improves the applicability in daily work.

Furthermore, this standardization of the DSS would allow bundling the whole process in a management cockpit. The greatest benefit is thereby the automation of several steps such as the modeling or representation and visualization of results. The management cockpit should be user-friendly software that allows for testing various scenarios or settings within a group of acquisition projects. It should guide the user to an adequate analysis using predefined and dynamic variable inputs. In general, a fully working DSS prototype over all layers is characterized and proposed for future research.

References

Adamides, E. D., Stamboulis, Y. A., & Varelis A. G. (2004). Model-based assessment of military aircraft engine maintenance systems. The Journal of the Operational Research Society, 55(9). 957–967.

Coyle, R. G. (1996). *System dynamics modelling—A practical approach.* Boca Raton, FL: Chapman & Hall/CRC.

Fan, C. -Y., Fan, P. -S., & Chang, P. -C. (2010). A system dynamics modeling approach for a military weapon maintenance supply system. *International Journal of Production Economics, 128*(2). 457–469.

Forrester, J. W. (1961). *Industrial dynamics*. Cambridge, MA: MIT Press.

Forrester, J. W. (2007, June). System dynamics—The next fifty years. *System Dynamics Review, 23*(2–3). 359–370.

Meadows, D. H., & Wright, D. (2008). *Thinking in systems: A primer*. White River Junction, VT: Chelsea Green.

Minami, N. A., & Madnick, S. (2009). Dynamic analysis of combat vehicle accidents. *System Dynamics Review, 25*(2), 79–100.

NATO. (2014). *The NATO Defence Planning Process*. Retrieved from http://www.nato.int/cps/en/natohq/topics_49202.htm

NATO. (2016). *NATO-Industry Forum report*. Retrieved from https://diweb.hq.nato.int/indrel/Shared%20Documents/NIF16_Report_final.pdf

NATO. (2017): *Supreme Headquarters Allied Powers Europe—Acquisition management*. Retrieved from http://www.shape.nato.int/financeandacquisition

Pruyt, E. (2013) *Small System dynamics models for big issues: Triple jump towards real-world complexity*. Delft, Netherlands: TU Delft Library.

Sterman, J. D. (2000) *Business dynamics: Systems thinking and modeling for a complex world* (Vol. 19). Boston, MA: Irwin/McGraw-Hill.

System Dynamics Society. (2017). *U.S. Department of Energy's introduction to system dynamics: Origin of system dynamics*. Retrieved from http://www.systemdynamics.org/DL-IntroSysDyn/start.htm

Zsifkovits, M., Barbeito, G., Pickl, S., & Pauli, G. (2016, July). System dynamics modeling for analyzing business model innovation. In *Proceedings of the First International Conference on Business Management of Technology*. Kumamoto, Japan.

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net