Evaluation of New Technologies

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Introduction

Dornier, a Division of the Daimler-Benz Aerospace (DASA) is an internationally reputed Aerospace Enterprise, working successfully in Satellite and Defence Technology and in the Consultancy field. The Company is located in Friedrichshafen at Lake Constance in the south of Germany.

The military branch of Dornier's Management Consulting Division serves as an independent Operations Research Group of the German Ministry of Defence for more than thirty years. With a long experience in systems analysis this branch performs OR-studies

- for the Army,
- for the Navy,
- in the field of Logistics (Army and Navy),
- on issues of C^3I and Modelling Theory.

The following short list of subjects of OR studies already performed and/or currently under way will give an impression of the versatility of the Operations Research Groups work:

- Military Bridges
- Mine Warfare
- Countermining
- Terrain Management
- Reconnaissance/Command and Control
- NBC-Reconnaissance and Protection
- Field Fortifications
- Artillery
- Infantry
- Evaluation Models.

1. Evaluation of New Technologies

In 1994 our Department of Systems Analysis won a contract from the German MOD in order to perform an OR study for the "Evaluation of New Technologies". The overall reason for launching this study was the problem to find a reliable way to evaluate the influence of technologies on the combat strength of the Army.

Therefore a computerized model should be developed within the study to be used in the future by the Army Staff in order to support the selection of New Technologies for upcoming Research and Development Programs (R&D).

To achieve this goal the cost-effectiveness of New Technologies to be applied in weapon systems and/or their components had to be assessed while paying attention to significant limitations of budget for funding of these technologies. Accordingly, it seems appropriate to split the required evaluation procedures into two separate parts:

1. evaluation of cost ,
2. evaluation of effectiveness.

The cost evaluation follows general ideas as used typically with the calculation of Life Cycle Cost. The cost model as a part of the entire model system connects R&D cost, investment cost and operational cost of weapon systems and/or their components to their total cost. The procedures to calculate the Life Cycle Cost are well known so that this point can be skipped here.

Therefore, the main focus of the study had to be given on the development of a standard procedure in calculating a measure for the effectiveness of the Army in total, which until then had not been feasible in a concise and comprehensive way.

Here, the effectiveness of the introduction of New Technologies is expressed in terms of the relative increase of the combat strength of the Army compared to the situation without application of these technologies. In order to calculate this effectiveness, a model system and a computer-aided procedure was developed under the logo MARCANT which stands for:

Model for the analysis of the relative change of the combat strength of the Army by introduction of New Technologies.

Furthermore the OR model MARCANT covers - in addition to the ability to assess the influence of New Technologies on the combat strength of the Army - some other important features:

By means of integrated submodels of MARCANT it is possible to calculate the effectiveness of all weapon and employment and support systems of the Army and, in a further step to be taken next, of all related systems of the different forces. For simplicity in this paper all these systems will be condensed within the expression "weapon systems".

In the following the structure of MARCANT and its most important parameters will be explained.

2. Model System MARCANT

In MARCANT the influence of New Technologies on the combat strength of the Army is calculated in several phases. The procedure is shown in figure 1 "The Pyramid of

Interrelations as covered by the Model System MARCANT" (see appendix) following these steps:

- The **first phase** is the assessment of the influence of New Technologies on the technical performance of the components of weapon systems;
- then the components are grouped to weapon systems, their technical performance is converted into a military effectiveness;
- the weapon systems are representatives of weapon categories, belonging to 13 functional sectors with the same military main tasks given below;
- in the **second phase** the effectiveness of these thirteen functional sectors is calculated;
- then the influence of the effectiveness of the functional sectors on the four capabilities of the Army is assessed;
- finally, the values of these capabilities are combined to get the "combat strength of the Army".

Usually, OR studies and systems analysis deal with one or at most with two of these phases. A method to process **all** these phases in only one step was not known before. Conventional methods, e. g. simulations, would require an intolerable high expenditure. Hence it was the fundamental brainwork of the study to find a new method for this pretentious task.

MARCANT is a closed system with two subsystems, each subsystem containing several phases:

- Subsystem 1 for "Performance Evaluation" (named **MALAGA**):

  MALAGA is the model to calculate the performance of weapon systems when New Technologies are introduced, and to calculate the resulting effectiveness in the functional sectors.

- Subsystem 2 for "Combat Strength Evaluation" (named **MADEIRA**):

  MADEIRA is the model to analyze the influence of an enhancement in weapon systems performance and therefore of an increase of the effectiveness of the functional sectors to get the integral improvement of combat strength of the Army.

The intersection between the two subsystems is marked by the functional sectors. They represent the total of all weapon, employment and support systems of the Army.

We have the following functional sectors (FS):

FS 1: C^3I-Means

FS 2: Reconnaissance Means

FS 3: Electronic Warfare Equipment

FS 4: Firepower

FS 5: Self Protection of complex Weapon Systems

FS 6: Mobility of complex Weapon Systems, subdivided into

FS 6B: Mobility of Ground based complex Weapon Systems
FS 6L: Mobility of Air based complex Weapon Systems

FS 7: Means for collective Protection

FS 8: Mobility Means

FS 9: Countermobility Means

FS 10: Transport Means, subdivided into

FS 10B: Ground based Transport Means
FS 10L: Air based Transport Means

FS 11: Maintenance Means

FS 12: Means for Storage and Reloading

FS 13: Technical Training Systems.

2.1 Subsystem 1 "Performance Evaluation" (MALAGA):

The lower part of the pyramid of interrelations is covered by the subsystem MALAGA.

The **first work package** of this subsystem was the design of the basement for the evaluation. All weapon categories which are found in the Army are defined and assigned to the corresponding functional sectors. A weapon category contains all weapon systems which can be engaged for the same purpose.

In addition to the definition of weapon categories, technical properties and military main tasks were assigned to the functional sectors:

- Technical properties describe the performance of the weapon systems in the functional sector. They depend on the technical design of the weapon system, especially on the introduction of New Technologies;
- military main tasks characterize the application of the weapon systems belonging to the functional sector.

The last point of this work package was the definition of scenarios. The effect of the technological performance of a weapon system on the combat strength of the Army can be different, depending on the scenario for the engagement of the weapon system.

At present, MARCANT contains parameters for two scenarios:

Scenario 1 "Central Region": A scenario in the middle of Germany;

Scenario 2 "Out-of-Region": A scenario for Rapid Reaction Forces.

The **next work package** of the subsystem MALAGA consists of basic investigations for the above given thirteen functional sectors:

- The relative importance of weapon catagories to their individual functional sector must be assessed. A small value e. g. for the relative importance results in a small effect of this category at the calculation of the effectiveness of the functional sector.

  The values for this relative importance factor depend on the scenario.

- The technical properties of each functional sector have a different importance. This fact is taken into account by introduction of weighting factors for the technical properties.
- The suitability of a weapon category for an individual military main task is expressed by a suitability value.
- The last factors to mention in this context are the significance values. They refer to the military main tasks of a functional sector, and they depend on the scenario.
- A very extensive part of the basic investigations for the functional sectors is the elaboration of efficiency functions. The purpose of these functions is the conversion from the technical performance data of a weapon system or one of its components into a military effectiveness. The efficiency functions must be defined individually for each functional sector, for each weapon category, for each military task and for each technical property.

  As the result, a very high number of efficiency functions is needed for MALAGA, more than 3,000!

Prior to the application of MALAGA the user has to quantify the performance data of the weapon systems or its components referring to the predefined technical properties. All other parameters are included already in the model so that the user can start processing the data of all technologies under investigation.

MALAGA yields the effectiveness values of the functional sectors. These values serve as input for the second subsystem named MADEIRA.

2.2 Subsystem 2 "Combat Strength Evaluation" (MADEIRA):

Now attention is given to the upper part of the pyramid of interrelations.

By use of the subsystem MADEIRA different weapon systems or its components can be compared with regard to their influence on an improvement of the combat strength of the Army:

- The weapon systems or components can be part of the same functional sector, e. g. a comparison of a new reconnaissance equipment with an introduced one;
- on the other hand, the weapon systems or components can also be part of different functional sectors, e. g. asking wether a new gun is better for a tank than a new reconnaissance equipment.

A tank is an example of a complex weapon system. These systems are characterized by the fact that they have components belonging to different functional sectors. For example, the components of a tank belong to the functional sectors FS 1, 2, 4, 5, and 6B.

Using MARCANT it is possible to investigate all weapon systems of the Army as complex as they ever might be!

In the upper part of the pyramid the features of the interrelations are critical: the correlation between the functional sectors and the connections between the levels.

The correlation matrix represents the synergism effect between the functional sectors. The elements of this matrix indicate the influence of an improvement of the effectiveness of each functional sector on the effectiveness of the respective other functional sectors.

The values of the correlation matrix are the most important parameters of MADEIRA. Therefore, these have been determined by consultation of about sixty experts of the German MOD.

By means of the correlation matrix the primary and secondary indirect correlations resulting from the improvement of the effectiveness of a functional sector are calculated. The indirect correlations are damped compared to the direct influence on a functional sector. This damping is realized by introduction of a so-called "damping coefficient".

A second pre-set parameter of MADEIRA is "status of Technology". This parameter serves as a substitute for the effectivenesss of a weapon category or a functional sector in the case that no performance data are available.

The next level in the pyramid of interrelations is represented by the capabilities of the Army. Four capabilities have been defined:

- capability to estimate the situation,
- capability to take the initiative,
- capability to push through and
- capability to hold out.

The relative influence of all functional sectors on these four capabilities results in the influence matrix.

At the highest level of MADEIRA the values of the four capabilities are combined by means of the weighting factors of the capabilities with regard to the combat strength of the Army.

Influence matrix and weighting factors were determined by consulting experts again.

The last step in the application of the model system MARCANT is the processing of the results gained from MALAGA by use of MADEIRA with its manifold interrelations.

3. A typical application of MARCANT

A typical application of the model system MARCANT with its subsystems MALAGA and MADEIRA is shown in figure 2 (see appendix).

For example three weapon systems have to be considered:

- weapon system A is introduced in the Army;
- weapon system B is like weapon system A, but improved by technology #1. The Life Cycle Cost of weapon system B is LCC1;
- weapon system C is like weapon system A, but improved by technology #2. The Life Cycle Cost of weapon system C is LCC2.

The technical performance data of these weapon systems are the inputs for three

runs of MALAGA. This results in the effectiveness values E of the functional sectors by using the weapon systems A, B, and C, respectively: E(A), E(B), and E(C).

Two cases are examined now:

- case 1: Replacement of weapon system A by weapon system B. Here, the inputs for MADEIRA are E(A) and E(B), the result of the run is the relative increase of the combat strength of the Army, called ΔCS1.
- case 2: Replacement of weapon system A by weapon system C. The values E(A) and E(C) result in ΔCS2 by the next run of MADEIRA.

The answer to the question which Technology is the better one can be found now by comparing the relative increases ΔCS1 and ΔCS2 and the respective cost figures LCC1 and LCC2 calculated before.

4. MARCANT - different purposes of use

The model system MARCANT can be utilized for different tasks, also beyond the evaluation of New Technologies. It is not a substitute for more detailed simulations, but it is a new and unique method of military Operations Research for analysis, prognostics and trend predictions:

- Analysis: MARCANT can be used when actual problems concerning the effectiveness of weapon systems are to be solved within a short time.
- Prognostics: MARCANT can be used when a prediction is required on the influence of improvements in the performance of existing weapon systems or introduction of new weapon systems on the combat strength of the Army.

  The evaluation of New Technologies is a special case of prognostics.
- Trend predictions: MARCANT can be used to find and to indicate those areas in which technical innovations could bring a maximum of improvement to the combat strength of the Army in total.

The technical requirements for the application of MARCANT are very simple: a Personal Computer and the runtime version of the database system Microsoft-ACCESS.

Since 1996 MARCANT has successfully been used to solve some real problems:

- Investigation and comparison of all weapon systems which can be used to fight tanks: mines, tanks, missiles, helicopters etc.,
- Comparison of several proposals for an improved armoured infantry fighting vehicle (MARDER)
- Investigation of future combat identification systems of four nations: US, UK, FR and GE.

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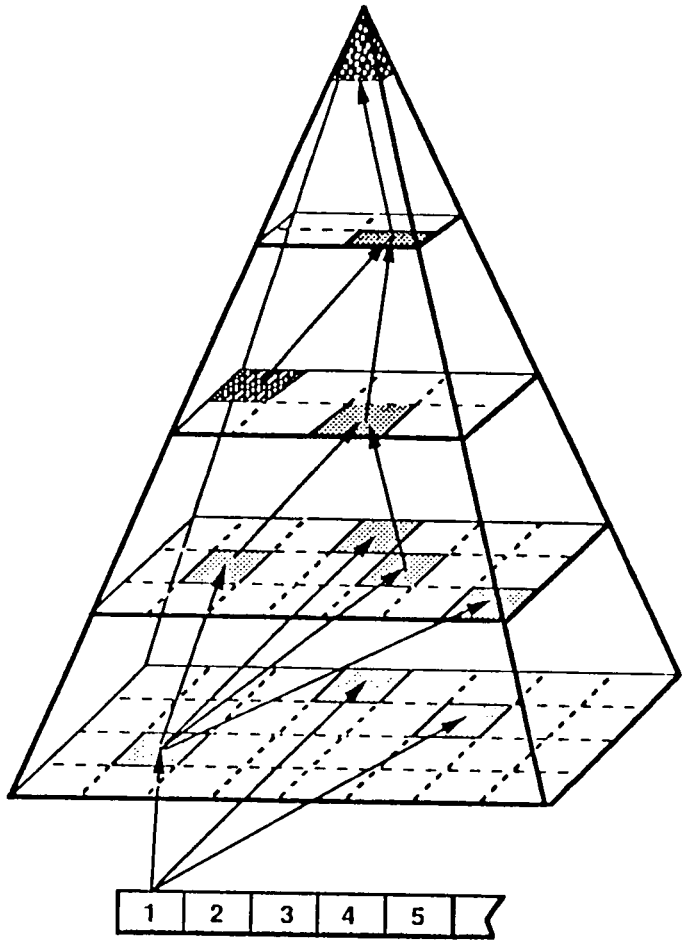

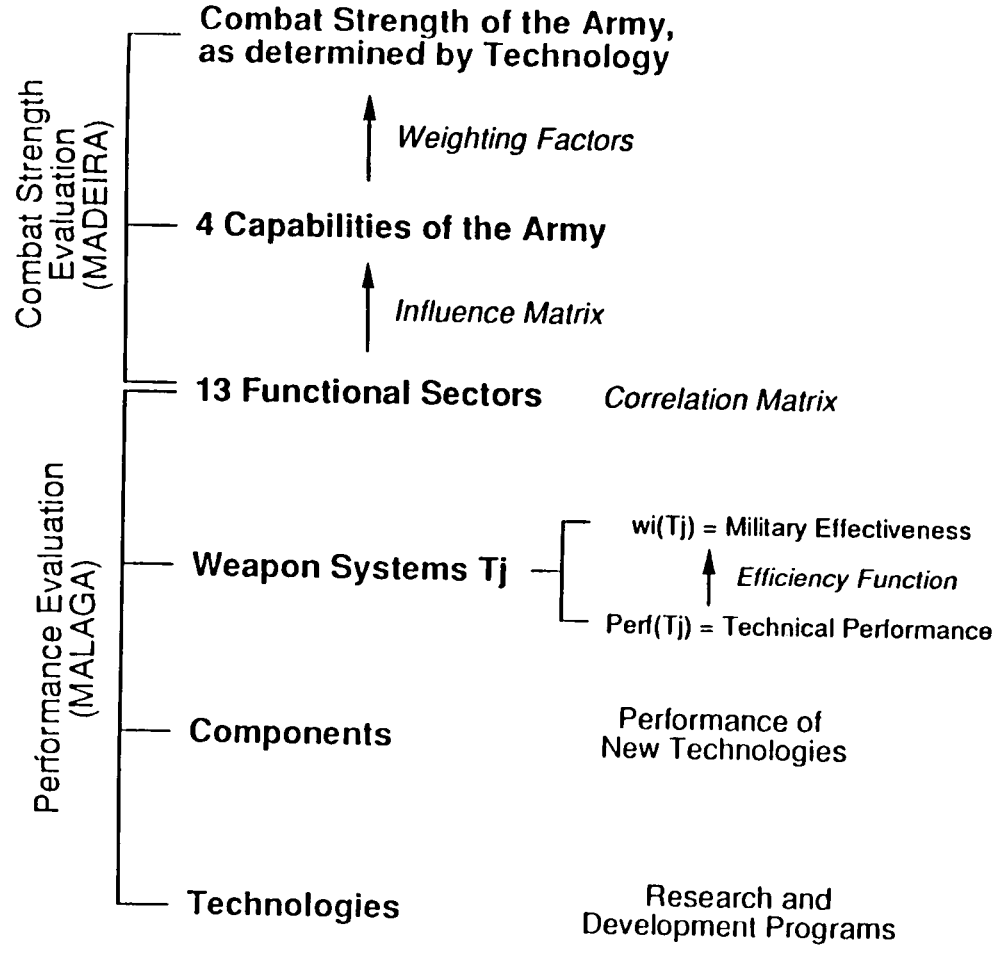

The Pyramid of Interrelations as Covered by the Model System MARKANT

Figure 1

A typical Application of the Model System MARKANT

WS A:
Weapon system introduced in the Army

MALAGA

E(A) = Effectiveness of 13 FS by using WS A

WS B:
Weapon system A improved by Technology #1.
Cost of WS B: LCC1

MALAGA

E(B) = Effectiveness of 13 FS by using WS B

WS C:
Weapon system A improved by Technology #2.
Cost of WS C: LCC2

MALAGA

E(C) = Effectiveness of 13 FS by using WS C

Case 1: WS A is replaced by WS B

MADEIRA --> Relative increase of the Combat Strength: ΔCS1

Cost Model --> Life Cycle Cost: LCC1

Case 2: WS A is replaced by WS C

MADEIRA --> Relative increase of the Combat Strength: ΔCS2

Cost Model --> Life Cycle Cost: LCC2

To compare the Technologies #1 and #2 we compare ΔCS1 : ΔCS2 and LCC1 : LCC2

Figure 2