E-MODELS AND METHODS FOR PROJECT MANAGEMENT IN THE PUBLIC AREA

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Project management is a problem-solving process studied by behavioural, management, engineering, information, and mathematical sciences. In the public area, and in particular in defence, the process involves a logical sequence of activities and decisions transforming a mission need into operational requirements, description of system performance parameters and a preferred system configuration.

System engineering provides for application of scientific and engineering efforts in order to [1]:

(a) Transform operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation;

(b) Integrate related technical parameters and ensure compatibility of all physical, functional, and program interfaces in a manner that optimises the total system definition and design;

(c) Integrate reliability, maintainability, safety, survivability, human, and other requirements into the total engineering effort to meet cost, schedule, and technical performance objectives.

Key for effective implementation is the careful choosing of:

- Methodology and approaches for the project management;
- Measures for assessing project management decisions;
- Methods and tools in support of project management.

Figure 1 present a possible interpretation of a methodology to support project management life cycle. In principle, the system life cycle should be regarded as a living model. New steps may be added, new methods can be inserted and more stringent requirements for upgrade might be specified. Over time, the project team learns from the design and development experience and feeds important lessons back into the next iteration of the project life cycle.

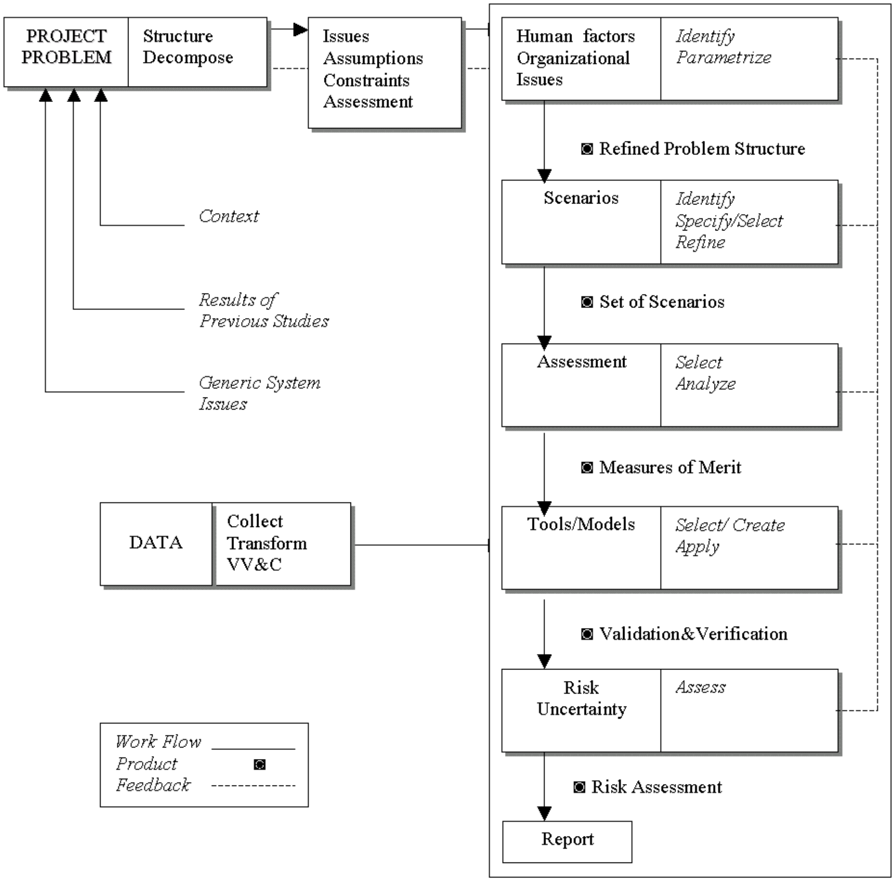

Figure 1: Methodology for management of a project life cycle.

The decomposition of a project provides possibilities to relate project activities to models and methods used to solve arising issues. Each activity requires that tasks and sub-tasks to be performed. Each step has a gate at the end of its implementation process that determines if the next step should be taken.

Simultaneously, the model development at each project stage is accompanied with a measure of merit; assessments of this measure are made in order to accept or reject proposed solutions.

Many authors [2] propose schemes and approaches for the creation a flexible iterative and explicit life cycle, which can adapt to several design situations, organizations, and management styles. The idea is to create opportunity for future application and reuse of the main life cycle backbone when new methods, tools and techniques are available. A variety of approaches and project life cycle representations (one example is given on Figure 2) have been applied in support of project management.[3] Recently, technology and especially computer and communications technology is the leverage that stimulates the progress in this area.

Currently, several means and ways are extensively used in support of project design. Among these are modelling languages that implement software realizations of mathematics methods and their applications, as well as tools in support of project design, analysis and assessment of alternative variants according to defined criteria.

Advanced approaches are used not only to suggest the life cycle steps, but also to propose methods, models and tools for use in support of these decision steps. They also suggest what the “output” along the way should look like. The achievements of the Multiatribute Utility Theory, Evolution Theory, Multidisciplinary Information System Engineering, Computer Aided System Engineering, Cost-Effectiveness Assessment, etc., provide only a sample of expedient approaches. We consider the full range of models, including performance and effectiveness models, object-oriented, procedure-oriented and agent-oriented models, hierarchic, stochastic and deterministic models, etc.

This activity is a distillation of the best approaches and methods that are implemented successfully in the practice and are perceived by the experts. The code of best practice (COBP) is the precious warehouse for developers and designers.[4] The well-known taxonomy of G.W. Hopple,[5] even if not complete, represents very well the way methods, tools and techniques can be categorized and assessed and provides for future extension. In addition, Sage and Rouse show how several classes of methods can be described and assessed.[6] Finally, Andriole showed how to rank-order methods against a set of requirements.[7]

In recent years, a number of additional tools, methods, techniques, devices and architectures became available in support of decisions made by project teams. The challenge lies in the extent to which designers can match the right tool or method with the problem at hand.

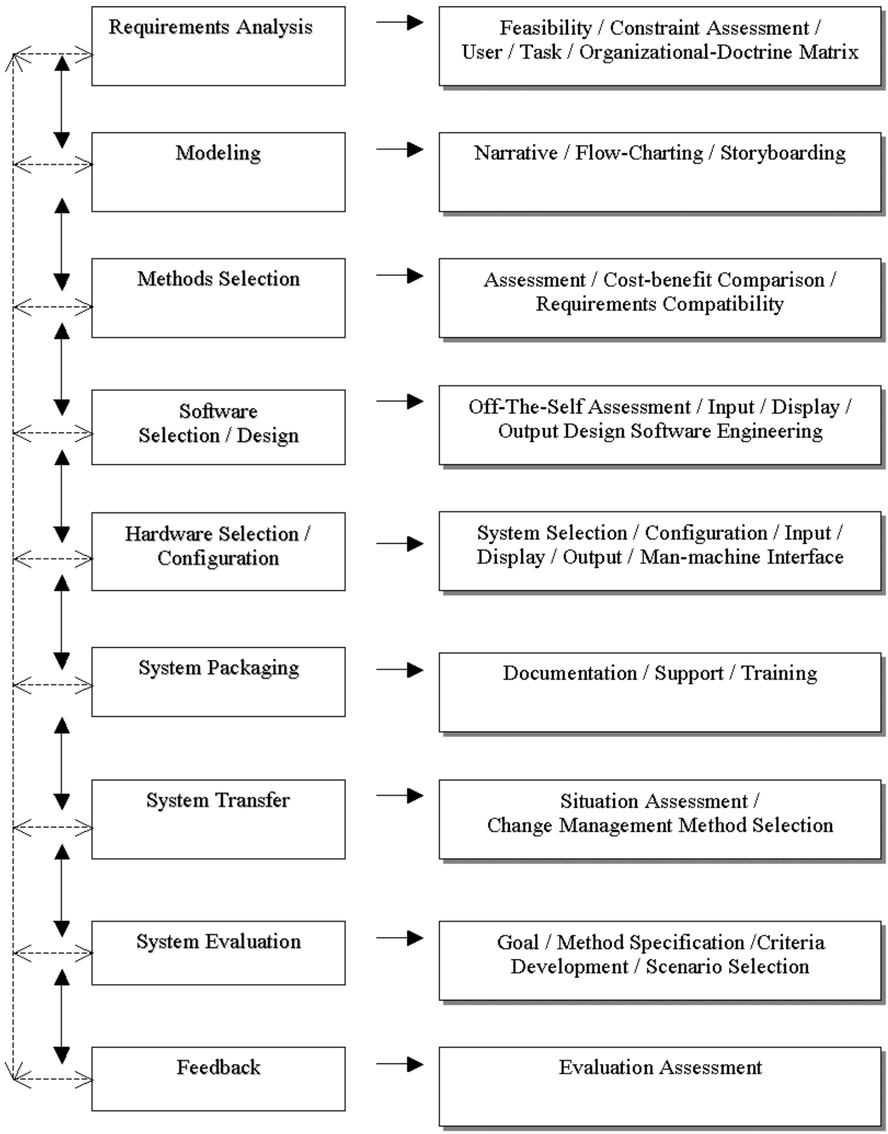

Figure 2: Project life cycle management process.

The authors' idea is to create a resource depot for scientific and applied tools intended to assist users in decision-making. Hence, each user who would like to use the system could turn to an "Analytical Centre" for an expert opinion. For public projects that Centre may be part of a governmental or non-governmental non-for-profit organisation, contributing to transparency of project management and providing impartial assessment of the way project resources are being used. In addition to the analytical activity of the Analytical Centre, an Engineering Centre may provide for technical support in the implementation of a particular tool.

The work of these centres involves a number of steps. A preliminary phase includes four steps in order to:

1. Present successful approaches;
2. Select the best practice (The expert team discusses the merit of each approach and whether it guarantees inclusion in the code of best practice);
3. Develop a general set of modelling requirements;
4. Assess current strengths and weaknesses; Compare the requirements to the current approaches to identify strengths and weaknesses in current capabilities; Identify remaining challenges.

A number of approaches to support of project management are based on artificial intelligence (AI) methods and expert system. These represent the decision-making process by a set of interacting decision rules. Such approaches are based on sound AI principles. However, their practical implementation leads to models which are large, complex and slow. The decision rules themselves are, in many cases, too dependent on a scenario; human involvement and considerable organisational expertise may be needed to treat these issues correctly.

The complexity of the projects requires multicriteria assessment. There is an increasing requirement to consider large numbers of scenarios and to perform a wide range of analyses. This has led to a requirement for "lightweight," fast running models, which can easily represent a wide range of scenarios. To this purpose a number of authors explore advanced algorithmic tools based on modern mathematics such as catastrophe theory and complexity theory.

A number of approaches employ "human in the loop" techniques in order to ensure realistic human performance or to check assumptions and parameters. However, these techniques are expensive and require inclusion of soft factors and their attendant measure of merit. The introduction of human factors also raises the level of uncertainty as these factors are difficult to integrate and are not necessarily well understood in the system specific context. The increased cost, complexity, and uncertainty of a "human in the loop" demands analyst to use this approach for small portions of the overall problem structure, rather than as the primary analytical method.

Frequently the dilemma is to create (a) a homogeneous model or (b) hierarchy (federation) of models (Figure 3). The detailed modelling of the supporting activities or functions is necessary to establish constraints on decision-making and the impact of some additional aspects. These supporting models could be run off-line, providing sets of input data to the main model (raising the model hierarchy) or they could be run in real time interaction with the main model (as federation of models). This approach can generate valuable analytical insights, but becomes critical in case of a large number of system parameters or a long scenario.

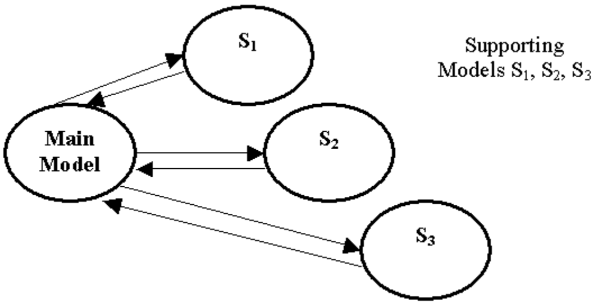

Figure 3: Hierarchy of models.

Another approach,[8] applied in many cases, is to use a structured hierarchy of models to create an audit trail from systems, processes, and organizations through to their outcome. The idea is to create supporting performance level models of particular aspects of the process, which can be examined at this level. Linking performance models with effectiveness models directly or through off-line approaches gives better possibilities during the project life cycle.

An approach adequate to the modern methodology is the agent-based modelling. A key aspect is the description and representation of the project design process through agent modelling and programming techniques. Modelling this activity as a group of agents based on artificial intelligence concepts favours the capture of the cognitive aspects of project tasks. Agents can be implemented in an object-oriented environment as either objects (e.g. actor or "applet" type) or aggregates of objects (coarse grain agents). Such agents interact with each other through a messaging infrastructure.[9]

Well known systems reveal how natural language interfaces evolve over time, of how users are able to communicate with databases and knowledge bases in ways that are compatible with the natural way to address data, information and knowledge.

The systematic collection and cataloguing of data generated by analytic tools adds to the available body of analytical data and knowledge bases. By tapping into these resources, analysts can develop more representative tools and validate the results. Sharing data among analysts may reduce the resources required to develop sufficiently sophisticated tools by reducing the degree of necessary repetition in the development and selection of appropriate analytical tools. Finally, the application of tools and the improvement of theory and the tools themselves, helps the analyst to better answer the requirements and to identify the key uncertainties and limitations of the findings of their analysis.

One way to create a relevant environment for project management is to describe formally the correlation between the problem—to make a decision—and methods and models appropriate to support this decision. The Engineering Centre in the proposed organisation maintains an information depot for the methods, models and approaches available to users with their features, capabilities and cost-effective rating according to known criteria (Table 1). The user could obtain necessary information for the characteristic features through software agent as a verbal reference reports – the records K_i, T_i, P_i, S_i, W_i.

Table 1. Notional ratings of groups of methods

Method / Criteria	Expert Systems	Cognitive Science	Decision Analysis	Operational Research
Objectives/ Expectations	K1	K2	K3	K4
Type of Methods *Typical* *Analytical* *Other*	T1	T2	T3	T4
Products	P1	P2	P3	P4
Strength	S1	S2	S3	S4
Weaknesses	W1	W2	W3	W4

Table 2. Notional ratings of methods’ applicability to particular tasks

Method / Activity/Task	Expert Systems	Cognitive Science	Decision Analysis	Operational Research
A1	x		x	
A2	x	x		x
A3			x	x
A4	x	x		x
A5		x		x

Further, it is suitable to consider the methods and models in accordance with the task-solving process. A useful approach is to constitute a matrix with rows describing the kind of project activity (stage or phase) and columns related to a method or a model (Table 2). If several methods and models are considered, as candidates for task-solvers, they shall be assessed according to appropriate criteria. Competent experts applying any of the multicriteria methods/models assessment approaches in the 3D-space (Figure 4) could propose most appropriate solutions for the user problem.

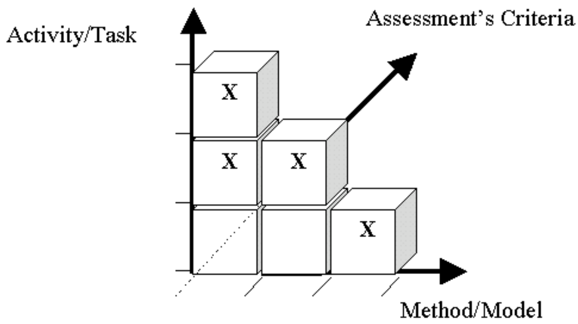

Figure 4: 3-D presentation of method and model "ratings."

A number of authors have proposed algorithms to provide the best solution in support of the project management process.[10] As a rule, they search an optimal package of models and methods to solve the project management problems. The requirements to the project become constraints of the objective function. Usually the solution corresponds to the minimal expenses of resources and to the application of generic methods and models. Solving a general optimisation task, authors propose a package of methods and models that 'optimally' supports project management throughout.

Such approach is suitable in some cases but, on the other hand, it gives a quite common solution. As a result, the project team selects a package of methods and models frequently applied to similar tasks. The same package is used in dealing with more than one subtask. In this case, the basic requirement is the economy of resources. However, the project team cannot apply methods and models of specific strength that would be more suitable to support decision-making during particular activity or in solving a sub-task.

Personnel working in the area of public projects must be familiarised with the methodology and its potential to meet their planning and decision-making requirements. Additional technical expertise, when needed, shall be provided by the

Engineering Centre (EC). EC may support the project team also in defining requirements to supporting models and method, identifying a number of criteria and arranging the criteria. A multi-objective approach to the assessment is appropriate in this case.

The problem becomes somewhat more complicated when budget constraints are added. The preferred package of models and methods shall be identified so that the cost of each does not exceed available funding. A number of complications arise here. First the number of feasible packages can be large even though the number of the stages appears reasonable. Second complication involves the existence of synergistic effects among the alternatives. In addition this process is continuously connected with rapidly changing technology and needs in the public area.

The authors suggest the following methodology to deal whit these challenges. The input information includes a list of project activities (stages, phases), a list of alternatives – methods and/or models, and a list of attributes for the evaluation of each alternative. A total ordering of the alternatives may then be derived using simple weighted linear combination of the scores for each alternative.

The methodology requires definition of the following inputs:

S - a finite set of activities; Card S = M;

A - a finite set of alternatives, in our case methods, approaches; Card A = N;

I - a finite set of additively independent attributes;

$\{ u_i(\alpha) \}$ - a set of value scores, giving the value associated with attribute I for selecting method α.

The following information may also be entered if available:

$\{ w_i \}$ - a set of attribute trade-off weights, for one or more I.

The usual preferences for alternative X to alternative Y can be described by X>Y, based on the definite set of orders applied to definite set of alternatives. This statement creates the input for the application. For example, the statement “attribute 1 is more important than attribute 3” has a simple translation to input information in the form “$w_1 \geq w_2$”. Thus, some natural language formulations are represented adequately as trivial logical assignments. With three relationships allowed ($\leq$, $\geq$, and =), the analyst could make every possible statement.

The objective of the analysis is to determine any dominance relation that can be inferred between the alternative and method/model. The methods are performed by the attributes: cost, parameter 1 (“less is better“), parameter 2 (“more is better”), parameter 3, etc. Table 3 lists four methods with their 3 attributes, presented as absolute values.

Table 3. Structured description of methods/models

Method \ Attribute	Par 1	Par 2	Par 3
A1	A_{11}	A_{12}	A_{13}
A2	A_{21}	A_{22}	A_{23}
A3	A_{31}	A_{32}	A_{33}
A4	A_{41}	A_{42}	A_{43}

Table 4. Description of methods/models with ranked attributes

Method \ Attribute	Par 1 V_1	Par 2 V_2	Par 3 V_3
A1	$V_1(A_{11})$	$V_2(A_{12})$	$V_2(A_{13})$
A2	$V_1(A_{21})$	$V_2(A_{22})$	$V_2(A_{23})$
A3	$V_1(A_{31})$	$V_2(A_{32})$	$V_2(A_{33})$
A4	$V_1(A_{41})$	$V_2(A_{42})$	$V_2(A_{43})$

Table 4 gives the attribute scores, where $0 \leq Vj(Akj) \leq 1$. The value shows the difference between the best and the worst alternative scores on each attribute. At this point, one could elicit statements from the user regarding the relative importance of the attributes. They could assign a value score of “1” to the best and a value score of “0” to the worst alternative score on each attribute and assign all other attribute value scores in a linear fashion.

A software agent, deriving mathematical implications form the tables, supports the analyst so that he or she infers at least one additional alternative dominance relation for the possible choice of method or model the user might make. Additionally, the agent generates a directed graph indicating the dominance relationships that could be inferred among the alternative methods. Thus, the software agent 1 (SA_1) will be used to generate packages of methods and models and to determine their scores. The software agent 2 (SA_2) will be used for comparative evaluation and selection of a ‘best’ package.

The main steps to use the special software agent in support of project management are to:

- Define hierarchy of activities (tasks) and attributes;

- Identify methods and models that may contribute to solving the tasks;
- Assess individual scores for methods (models);
- Assess synergy scores (optional);
- Specify rules for package generation;
- Generate feasible packages.

In conclusion, the proposed methodology may be implemented through software agents based on the commercial-off-the-self products. Such approach provides familiar graphical user interface and easier access to large problem-oriented databases. Besides, it allows for straightforward communication of the project team, i.e., through video teleconferencing, arranging for electronic payment, etc. As a whole, it improves the capabilities of decision makers to understand the impact of a particular decision, to generate options and assess alternatives, thus improving decision-making capacity and transparency of the decision making process.

Notes:

1 For examples the reader may refer to Stephen J. Andriole, *Handbook for Decision Support Systems* (Blue Ridge Summit, PA: Tab Books, 1989).

2 See for example Leonard Adelman, *Evaluating Decision Support and Expert Systems* (John Wiley & Sons, 1992).

3 Stephen J. Andriole, *Information System Design Principles for the 90s: Getting it Right!* (Fairfax, VA: AFCEA International Press, 1990).

4 *NATO Code of Best Practice for C2 Assessment*, NATO COBP AC/243 (Panel 7) TR/8 (1998), <http://www.dodccrp.org/2000CCRTS/cd/html/nato/nato_cobp.pdf> (15 June 2003).

5 G.W. Hopple, “Decision Aiding Dangers: The Law of the Hammer and Other Maxims,” *IEEE Transactions on Systems, Man and Cybernetics* SMC-16, 6 (November-December 1986): 948-963.

6 Andrew P. Sage and William B. Rouse, “Aiding the Decision-Maker through the Knowledge-Based Sciences,” *IEEE Transactions on Systems, Man and Cybernetics* SMC-16, 4 (July-August 1986): 511-521.

7 Stephen J. Andriole, *Handbook for the Design, Development, Evaluation and Application of Interactive Military Decision Support Systems* (New York: Petrocelli Books, 1989).

8 *NATO Code of Best Practice for C2 Assessment.*

9 For an overview and results in implementing agents in support of the defence procurement the reader may refer to Jay Liebowitz, Monica Adya, *et.al.*, "MACS: Multi-Agent COTR System for Defense Contracting," *Knowledge-Based Systems* 13, 3 (October 2000): 241-250, Available also online at <http://userpages.umbc.edu/ ~buchwalt/papers/multijour.htm> (12 May 2003). A variety of additional issues in using agents in defence and security are covered in Petya Ivanova, ed., *Agent-based Technologies, Information & Security* 8 (2002), <http://www.isn.ethz.ch/onlinepubli/ publihouse/infosecurity/volume_8/Content_vol_8.htm> (12 May 2003).

10 See for example Peter Pavlov, *Scientific and Applied Methods and Tools for Developing and Managing Public Projects* (Sofia: Prisma, 2001).

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