Industrial Project Management:
A Handbook of Planning, Scheduling & Evaluation Techniques

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Chapter 1 Decision modelling in management

1.1. Decision Modelling

Modelling decisions in management is a process of developing models reflecting the interrelations between relevant factors in a real situation. The model is reality presented in a simplified form. Modelling is a specific method and means of comprehension. It is applied in company management to study various activity alternatives using developed models. Every individual model comprises various components, variables, parameters, relations, limitations and criteria [1].

- Components correspond to the elements of the system under study.

- Variables are used to describe the relations between individual components of the model. They can have more than a single value [2].

- Parameters characterize the influence that various variables have in the model. They are constant for every individual model, i.e. they have just a single value [2].

- Relations reflect the links, relations and interaction between various components, variables and parameters in the model [3].

- Limitations point out the variation limits and can be either placed in space and time, can be single-value or multi-value, one-sided or double-sided, global or local, etc [4].

- Criteria are means of evaluation, comparison and selection. They are objective and subjective, qualitative and quantitative [4].

The model reflects the nature, structure and functions of the original. It is its imaginary or real duplicate. Its resemblance to the original is used as a basis of building up the model and at the same time, a prerequisite for transferring the results of the experiments carried out with the model to the original. According to their form of comprehension models are classified as theoretical and empirical. Depending on the chances of implementation models can be fictional and material. According to the degree of quantification models can be divided into qualitative and quantitative [5]. According to the factors being reflected there are models based in space and time. Depending to the structure being reflected models can be schematic, physical and mathematical.

i). Schematic models

In schematic models a logical correspondence between activities, tasks, executives, time schedules and resources is created, which is later easily transferred into a graphical relation. The graphical relation allows the manager to follow directly and observe the logical links in time, to control the performance of individual tasks with respect to time schedules and consumption of resources [6]. And to look for additional provisions in both re-distribution of tasks between executives and it reducing the time needed for the performance of individual activities as a result of which the overall time is thus reduced [7].

The Gantt chart method is a typical representative of graphical models. Gantt charts represent charts spread out in time giving the relevant indications of tasks to be executed. These chronograms, along with activity planning make it possible to give graphical indications of activity work progress. Thus, process management is largely visualized and allows the manager not only to control performance but also find out when (in what time intervals) he can expect piling up of several parallel activities and hence, some organisational and technical difficulties that might occur [7]. This enhances the search for possibilities for re-distribution of tasks or avoiding difficulties by advancing or moving some activities back in time. It can be noted here that Gantt charts are a good graphical technique allowing the manager to both plan and control task execution [7].

Network models (CPM, for example) are some of the most widely used graphical models. Network analysis is a technique for planning and control of complex projects and developing time schedules for resources needed for products to be manufactured. It achieves this aim by analyzing the component parts of a given product and evaluating the consecutive interrelations between each event [8]. The results of this analysis are presented as a network diagram of internally linked activities.

The idea in the contents of the network planning is close to that of programmed-goal planning (or the linear programming methods) but the technique for the realization of the process of implementation of the method is different. Here, again the basic thing is to break down the process of implementation of the decision into separate elementary tasks or operations that have to be performed in time and pointing out their interrelation and logical link in time and space in a connected graph (network) in which the separate elements could represent events or obtained partial results and the links between them (the columns in the graph) represent operations, activities.

The advantage of this process is that the final result features good visual presentation and systematical analysis of the process of implementation of decisions and the sequence for accomplishing individual tasks. Also, numerical characteristics for the overall duration, the total resources required and last but not least – for those routes in the network that are critical for the accomplishment of the overall program are obtained. Critical here means that every extension of activities or every increase in resources consumption along the critical path would lead to overall increase in the duration of the performance or overall increase in the cost of the entire program [8].

Another advantage is that some very well developed application software packages are available for using computer equipment for building and calculating network graphs. With the help of this software one can plan the accomplishment of individual opera-

tions, activities and tasks in time and in a logical link and sequence that is objectively dictated by the nature of the work being performed, as well as to evaluate the necessity of resources and time needed for the accomplishment of the complex of tasks.

Also widely used are conformance tables, which actually present always two-dimensional matrices. The rows in them are used to indicate the names of individual executives and the columns are used to indicate the set of tasks to be performed. Then various letters or other graphical characters can be used to indicate the cross-points that correspond to, for example the degree of competence of a give executive in solving a certain task [8]. This matrix provides for the correct distribution of executives in performing a complex of activities. Other such matrix diagrams could be made to indicate the correspondence between tasks and resources (and, for example technical means, financial means, etc.)

Plotting various diagrams and curves indicating the rate and degree of resources consumption in time and allowing the manager to control the spending of these resources can plan the time and resources compliance.

Technological block-diagrams are another common graphical technique used for planning and control purposes. These diagrams visualize the performance of certain administrative and managing activities and the accomplishment of a complex of activities for the implementation of a certain decision [8]. These block-diagrams are called technological because they literally interpret the logics and sequence in the management process and in the technology for the realization of the process of implementation of decisions made. Various sets of graphical characters that in their content correspond to various activities and operations are used for the graphical and symbolic indications in these diagrams. All these symbols are used to shorten the written description and to visualize the overall process and also, point out the logical link between individual operations and activities in the form of individual procedures. With the help of the block diagrams and organigrams the manager is capable of making a visual representation of the process of implementation of decisions made and control the work progress for this decision using simple and clear graphical indications [8].

ii). Physical models

Physical models differ from analytical models in that they are not a system of formal mathematical records but spread-out diagrams that give detailed description of the structure of the subject matter being studied. The methods of imitation and acting modelling are among the most powerful analysis tools available to people, who are responsible for the development and functioning of complicated processes and schemes. The idea of imitation modeling provides a possibility for experimenting with the system (existing or imaginary one) in cases when doing so with the real object would be impossible and purposeless. Individual persons, groups, etc. could act the role of such elements [9].

When building up such models some basic blocks imitating the behaviour of individual elements of the modelled system are actually built up. Individual persons, groups, etc. could act the role of such elements. Moreover, it is very important to define the time scale in every individual imitation and acting model.

The difficulties in obtaining analytical solutions to ordinary mathematical models come primarily from the interference of the "uncertainty" factor. Hence, the necessity for including complicated statistical relations in the model that involve the usage of the theory of probability instrument and mathematical statistics. It is exactly these difficulties that cause and encourage the idea of creating imitation models. The existing uncertainty in them is achieved not by looking for descriptions using complicated mathematical formulas but by imitating actual reality [9]. Therefore, imitation modeling is experimentally applicable method that attempts at describing the behaviour of the system, building up theories and hypothesis, which in turn are capable of explaining the observed behaviour and applies these theories to forecast future behaviour of the system and defines those actions that could cause changes in the structure of the system or changes in the manner it functions.

iii). Mathematical models

The term mathematical modeling indicates the mathematical formulation of a given problem. Actually, it is an abstract form of description of the phenomena and processes actually taking place, which gives many advantages for the analysis and solving various problems. These advantages are based on using the methods of applied mathematics, which make it possible to process, compare and calculate following strictly defined procedures large quantities of data featuring the problematic situation [9].

- Practically, this means that problems could be solved mathematically if the following conditions are available:

- The processes and subjects could be quantitatively described;

- The relations existing between them could be interpreted using functional relations and mathematical values;

- The results could be studied and interpreted from the real practical situation point of view in other words the mathematical results are adequate with respect to existing actual reality.

Therefore, the advantages to this effect lie in the wide variety of mathematical methods applicable to the given problematic situation for searching definite solutions or the new problem formulation opens new possibilities for solving it.

The second advantage of the mathematical models used is in the fact that a large part of repeating problematic situations can be qualified and defined through them. Moreover, conditions are now available to look for routine solutions in determining how given situations belong to the corresponding group using developed models and respective program and technical means [10]. The use of computer equipment largely assists this as it can be used to create not only databases for solving problems but also, model databases that have been classified and defined for certain types of problematic

situations. These databases could help derive final or intermediate alternatives to be discussed as possible solutions quickly and efficiently.

Along with defining and sorting problematic situations and relevant models for solving them, the practical application of mathematical models in economy in the recent forty years made it possible to define and sort individual stages of making up and solving the models, which besides of having educational importance helps the managers in organizing correctly the usage of mathematical models in practice [10].

To answer the question about the procedures involved in the process of building up and applying mathematical models we should give a short explanation of these defining stages that the process involves:

- The Initial Stage is always linked to creative analytical activities that run along with recognizing the problematic situation despite of the type of solution method to be applied later. Of course, it is from this very stage that in cases where the problematic situation could be given sufficiently good quantitative characterization it becomes quite clear that mathematical methods are going to be used. This means that along with recognizing the problem itself at this initial stage it is also determined here if the problem has been sufficiently structured to be given quantitative description and eventually applying a model for solving it [10].

- During the Second Stage all necessary information is gathered in the form of data referring to the individual quantitative characteristics of the problem. These could include certain quantitative parameters featuring the activities of the organization but could also include parameters or variables introduced by the subject for describing a certain problem situation. However, these parameters should also be given quantitative characteristics. Compiling numerical data is a difficult and tedious activity especially when no continuity has already been created in solving problem situations such that there is already sufficient information that has been acquired and stored in some form for certain parameters [10]. In this sense, data to be later included in the model should have comparative character, should also be sufficiently and precisely defined and derived from reliable sources.

- The Third Stage is practically the assembly of the model. Here modeling experts provide the mathematical form of the relations between individual characteristics, values and model parameters. And basing on these mathematical relations they make analytical calculations where possible, mainly for simplifying the mathematical formulae working with abstract mathematical symbols. At this stage the way of solving the model also becomes clear because in many cases it turns out that the final result cannot be calculated just on the basis of some analytical transformations. Also defined here is the algorithm for calculating the mathematical model itself. Algorithm is a logically described sequence of elementary operations that have to be carried out to find the final solution [10]. These operations can have either computing, logical or purely informational character (data recording, data transfer, etc.). Every individual logarithm corresponds to an exactly defined procedure for finding the solution.

- The Fourth Stage comprises the finding of the solution. Once that the algo-

rithm for solving the model has been defined the solution itself can be calculated either by using computer equipment (then it would be necessary to transform this algorithm into a software program for this equipment) or conventional calculation means (hand calculator, small-sized calculator, etc.). Very often in modeling it is necessary to iteratively perform previous stages depending on the results from the calculation of the model itself (when changes are necessary, additional clarification in the model contents, its variables, parameters, values, etc.). When the second stage is repeated the model is additionally clarified and when the third stage is repeated, changes in the relations are usually made aimed at making the calculation of the model easier. For example, it is often necessary for given non-linear and complex relations to be replaced with simpler linear ones for the needs of simplification or to reduce the variety of parameters and variables making the model large in size and difficult to solve through aggregating and summarizing parameters and variables. A certain mathematical result claiming to be the solution of the initially set problem is obtained at the end of the Fourth stage [11].

- The Fifth Stage covers the answer to the question: how far the result obtained by purely mathematical means is an adequate solution to the actually existing problematic situation? The problem with the adequate solution is solved by means of analyzing the sensitivity of the result obtained when changing the conditions in the actual problematic situation being solved. The validity tolerance of the result thus obtained is determined with respect to the real situation. In other words, here again we proceed with the creative analysis. At this point again we go from the mathematical model to the actual reality and the exact practical task that has to be solved. Sometimes it is exactly at this stage when one has to return back to the very beginning of the process described so far because the results obtained are not adequate or do not exactly reflect existing processes and phenomena. [11] This could either be due to mistakes in the very definition of the situation and building up the model or in the description given in mathematical form of the relations between individual variables and parameters.

Specialists in the application of mathematical models in economy are very well aware that the boundaries of these stages are largely provisional and that this is actually one continuous process of building up the model and its calculation followed by evaluation of the obtained results. It is important for the manager to have a general knowledge of the contents of this process to be able to get the idea and to control the activities of the teams that perform the modeling.

The process of defining and sorting models in groups of problematic situations that are similar in type has formed certain directions in modeling that have acquired their own names and individual significance. Such are: modeling and distribution of resources, mass services modeling, exchange modeling, modeling the formation of reserves and modeling conflicting situations [11].

These modeling directions actually comprise the contents of an independently formed applied scientific subject – operations studies.

The models for planning and distribution of resources from the first type are most widely used since the very appearance of operations studies. These are mainly applied in two situations characteristic of the economy:

- A fixed amount of resources is available (this is usually insufficient). A certain kind of activities is necessary to be performed aimed at achieving optimum effect (maximum income or profit from the activities performed or minimum expenses).

- The second group of problematic situations involved in the models for the distribution of resources could be characterized as follows: it is necessary to perform a certain volume of work (the work is fixed) and the usage of a certain resource should be minimized or maximized.

The areas where such problematic situations arise and the models for the distribution of resources are applied are mainly related to the defined production programs and the personnel and other material resources support provided. A number of other tasks also exist that at first sight seem too irrelevant to the above area but still use the same models to solve them as a result of the fact that similar relations occur during the analysis [11]. For example, determining the optimum route for transportation vehicles intended to serve a specified number of terminals is again solved using models from the planning and distribution of resources area.

Mathematical modeling is aimed at increasing decision rationality through applying mathematical methods and modern computer equipment. Mathematical models include several methods from mathematics, statistics, linear programming, dynamic programming, analysis, the theory of probabilities and other applicable when the factors influencing managing decisions can be quantitatively expressed [11]. Adopting these methods when giving grounds for the suitability of various alternatives and the choice for one of them increases the reliability and quality of decisions made.

The application of mathematical methods for modeling economy activities is constantly widening its boundaries covering new areas and solving new problematic situations. It is important for the manager to understand that this is an exceptionally wide and dynamically developing area for the development of the tools and means and applying the methods in solving problematic situations. That is why he should encourage the positive attitude of the specialists he is working most closely with in using this kind of models. It is very essential that he take care to train these specialists, as investment in such training will be generously repaid later.

Comment on the following statement of Barholdi and Platzman and explain how it refers to mathematical modelling:

" A heuristic could be regarded as an information processor who deliberately but judiciously disregards certain information. Ignoring this information the heuristic is relieved of any effort that would have been needed to read this data and make computations with it. Moreover, the decision this heuristic is going to make would be independent of the ignored information and, hence would not be influenced by any changes it might be subjected to. Of course, the art of heuristic design is about knowing exactly which information to ignore. Ideally, one tends to disregard the information that is ex-

pensive to acquire and maintain, hard to operate with in calculations and that would have little significance to the additional precision of the decision."

Barholdi and Platzman, 1988

We know from the company management theory and the cybernetics that management and information are closely and deeply connected. Practically, it is impossible to perform management without having the relevant information available. In essence, the management process is a constant process of compiling, recording and transferring various facts, data and reports and transforming them into management decisions. The information that has been received, considered and processed by the human intellect results in creating new ideas, knowledge and experience, i.e. new information originates. It is exactly getting the experience that helps create in the human brain a database, which in the case of Barholdi and Platzman statement is referred to by the human processor. This is a process of mathematical modeling that utilizes the principles of linear programming. When a certain number of predictable variables and limiting requirements is available a heuristic would either include or ignore certain information in the limiting requirements basing on the result obtained after said database has been consulted [12]. If this particular information has not been useful to him in solving a similar problem in the past then all further detailed familiarization with this information is cancelled and it is pushed aside from the scope of the current problem. Or we could say here that all data that his personal experience tells him would not be necessary in solving a certain problem situation will be ignored. It will be disregarded judiciously as a result of a sensible and mathematically modeled evaluation. This data will be thrown outside of the scope formulated by the limiting requirements in the form of equalities and inequalities and thus it will not affect the definition of an extreme limit for the linear function. The heuristic will act like this after he has analyzed the secondary information provided by his own database (his own experience). This secondary information has been caused as a result of the logical comparison (reference) related to the fact whether (and how much) this information has been useful in solving a similar problem in the past experience of that person [12]. It is exactly here where the results of his inductive thinking are shown because the evaluation should be made quickly and completely so disregarding this information would help save whatever efforts that would be needed to read this data and make calculations with it. As a result of a correct synthesis of obtained analytical results it will be necessary to provide sufficient confidence that the decision this heuristic is going to make would be independent of the ignored information and hence, would not be influenced by any changes in this information. I.e. presumably, this would involve mathematical modeling by adopting the methods of linear and dynamic programming, statistics, etc.

There is no doubt the statement of the art of heuristic design being in knowing exactly which information to ignore is true. Information is a resource that similar to all other resources has its own cost. It is necessary to gather and process the data using minimum materials, financial, credit, etc. expenditure and using available information sources and equipment [12]. This is the reason why human tendency for ignoring the information that is expensive to gather and maintain, hard to handle in calculations and that would have insignificant effect on the additional precision of the decision is understandable.

We could say that this is a tendency for the ideal case, which is actually similar to searching for the optimum solution of a mathematical model, which analyses a list of actions the consequences of which are known for certain and chooses the combination of actions that would maximize profit or minimize expenses.

1.2.   Network planning techniques

Network planning techniques find wide application in project management. The usage of these models relates to the application of system methodology, which stresses on the importance of the links between individual activities as a necessary condition for achieving the set objectives. The CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) are among the most widely known methods. They are used for developing determined and stochastic network charts. The network chart is a set of performed activities and operations in a given project that are graphically presented in the form of a network where their sequence and interrelation is indicated [10].

The basic elements of network charts are the activities (operations) and the events in them. Every individual operation could express: a work process that involves time and resources consumption; a stand-by process that only requires time; a relation (a fictitious work) that shows the logical link between two events and does not require time or resources consumption. The events show the beginning or end of work (operations) [11]. They are performed momentarily, have no duration and do not require spending time or resources.

According to the CPM and PERT methods the tips represent the events and the arrows – individual work activities. Every individual work activity is performed in between two events called the initial event, when it starts and the final event when it ends. No work activity can start before its initial event has occurred. One and the same event can be the final event for one or several work activities [12]. Every individual network chart has an event that indicates its start and this event is not preceded by other work activities. The final event in the network chart is called finishing event and indicates the completion of work activities. It is not followed by other work activities. Events are linked according to the sequence of performed work activities and thus form the network chart. A numbered circle indicates events and continuous lines indicate operations. The length of the arrows is randomly selected, not to scale and does not indicate the duration of work activities. In the network chart they follow an order that indicates the sequence of performing them.

Before we proceed with the development of network charts we should first clarify the technological sequence in performing the activity works and the links between them. Once we have established this we start making the network chart from the left to the right the number for the initial event of every individual work activity being smaller than the number of the final event. We recommend events to be numbered after the complete network has been made.

Network charts differ in the number of events and work activities. The larger the number of work activities and the more links are available between them, the more complicated will the network chart be. The number of work activities would depend on the degree of detailing, which is defined by the level of the managing body [12]. The

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