

The morphological analysis as a tool for handling complexity in management sciences

Michał Trocki

Department of Project Management,
Warsaw School of Economics (SGH)
Warsaw, Poland
michal@trocki.info

Paweł Wyróżębski

Department of Project Management,
Warsaw School of Economics (SGH)
Warsaw, Poland
pawel@wyrzezbski.org

Abstract— The complexity of problems of management science resulting from various approaches, number and diversity of sub-components requires researchers to employ methods allowing them to comprehensively describe observed phenomena or object, as well as to perform reduction and indication of their key components. Therefore the goal of the authors of the article is to present one of the methods that meet the above mentioned demands i.e. "morphological method". This paper presents its genesis, recommendations on how to employ the method, as well as discuss its application in cases of management sciences.

Keywords- management methodology, morphological method, morphological analysis

I. INTRODUCTION

An important, and perhaps the most important feature of the management is the complexity of managerial issues and problems imposed by the various aspects and approaches, the number and variety of components and internal relationships between these elements. As the result two methodological problems emerge. The first is the need to recognize this complexity and the second - its reduction or simplification to the most important elements. There are many methods of varying effectiveness and popularity to solve these problems. "(...) a particular interest in the so-called combinatorial methods that combine an element of intuitive and analytical has been noticed. (...) Among them the morphological analysis pulls ahead"[1]. The goal of the paper is to discuss the principles and possibilities of using this method in management sciences.

II. THE ORIGIN AND ESSENCE OF THE MORPHOLOGICAL ANALYSIS

The concept of morphology is used mainly in biology, geology, and linguistics. It means the knowledge of a form and construction of a particular class of objects, such as animals or plants in biology, fossils in geology, as well as words in linguistics. In a broader sense, introduced by F. Zwicky morphology is defined as the "total methodology of thinking and acting" consisting of "spotting the picture of reality, which would clearly address all the major structural relationship between objects, events, ideas and actions"¹ [2], [3], [4].

¹ The inventor of the concept - F. Zwicky – was a prominent Swiss astrophysicist working in the United States. He was the discoverer of dark matter and supernovae, as well as a participant for the construction of space rockets

The concept of morphology by F. Zwicky enjoys considerable popularity among the specialists in various fields, both researchers and practitioners. The development and popularization of the concept is supported by Fritz Zwicky Foundation (Fritz-Zwicky-Stiftung) and Morphological Society (Morphologische Gesellschaft Zürich) both operating in Switzerland.

As part of the idea of methodological morphology F. Zwicky developed a number of methods: method of morphological analysis, morphological box method, the method of sequential morphology, the method of systematic coverage of the fields, the method of analysis functions, etc. [5]. The most common approach is the method of morphological analysis [6],[7] which enables seeking resolution of issues through a systematic analysis of all the elements defining the solution to the problem. Morphological analysis has been successfully applied in all fields of human activity, both practical and scientific.

Morphological analysis involves the following stages of the procedure: [8],[6]

1. Defining a problem,
2. Defining problem variables, i.e. the key elements/dimensions of the solution and determining their value (conditions),
3. Arrangement and combination of problem variables and the corresponding values in a table called a morphological table (or morphological matrix),
4. Creating variants of solutions to the problem through a combination of relevant values of problem variables.
5. Evaluation of developed alternative solutions and selecting the best solutions to further, detailed studies.

The formulation of the problem in morphological analysis should include the determination of: the object of problem, the goal to achieve through a solution of the problem and so-called inviolable conditions, relevant to the problem being solved, independent from investigator. Definition of the problem should be generalized as far as it is possible and beneficial. Later, it is necessary to define problem variables i.e. phenomena that are affected by the problem solver and are significant for the overall resolution [9]. The following requirements are posed in relation to the problem variables:

1. variable must have a significant impact on the solution of the problem,
2. must be mutually separable and independent,
3. they are coherent as a whole and must ensure good (and above all full) solution to the problem.

Each problem variable can be assigned specific values that this variable can take. If the problem variables are treated as subproblems, then the values of the problem variables can be treated as variants of subproblems solutions. The following requirements are posed in relation to the values of problem variables:

1. values should be clearly separated from each other, when the variable is a continuous it needs to create ranges of variation,
2. values should be in a clear, direct relationship with the described variable
3. in case of a large number of variable values it is necessary to reduce them by eliminating the solutions less useful or difficult to implement in practice, as well as combining the individual solutions, etc.

Defined values of the problem variables should be afterwards evaluated by specialists. In the further course of the proceedings the problem variables and their corresponding values are structured in the form of morphological table (table 1). It is one of three types of morphological order, a two-dimensional one with different number of possible values for each problem variable. When the number of values is the same for all problem variables, then the table is called a morphological matrix. The third order, referred to as a morphological box, occurs when a third dimension to the analysis is added to the morphological matrix.

TABLE I. THE EXAMPLE OF MORPHOLOGICAL TABLE

| Problem variables | Values of problem variables | | | | |
|-------------------|-----------------------------|-----------|-----------|-----|----------------|
| | 1 | 2 | 3 | ... | m |
| A: | A1 | A2 | A3 | ... | A _m |
| B: | B1 | B2 | B3 | ... | B _m |
| C: | C1 | C2 | C3 | ... | C _m |
| . | . | . | . | . | . |
| N: | N1 | N2 | N3 | ... | N _m |

Source: own study

Morphological table provides a detailed definition of the problem and contains all it possible solutions. They may be determined on the basis of morphological table as a combination of values adopted by problem variables. This combination is called a morphology chain. Theoretical number of solutions contained in the morphological table equals to:

$$L_r = \prod_{i=A}^N l_i \tag{1}$$

where: l_i – numer of values of problem variable i ,
 $i=A...N$ - subsequent problem variables

Since this is usually a very large number, it is necessary to reduce the set of solutions designed for the detailed analysis by

selecting the most promising sets. This problem is mostly solved by the logical analysis based on the expert judgment of team members. It can be also achieved by employment of a method of discovery matrix by Moles [10]. Refined solutions are evaluated: lesser solutions are eliminated and the solutions with higher values are transferred for further detailed studies. Evaluation and selection may be made by means of general and special methods of assessment [11],[12].

The value of morphological analysis derives from a variety of functions: methodical - involving the ordering of thinking processes; heuristic - consisting of creating a complete picture of potential solutions; creative - involving the creation of innovative solutions, critical - consisting of a comprehensive - external and internal - evaluation of solutions to problems.

III. THE USE OF MORPHOLOGICAL ANALYSIS IN MANAGEMENT SCIENCES

The concept of morphological research and its main method of morphological analysis was developed by E. Zwicky by the way of his study of astrophysical and space projects. Soon, the concept was introduced to astronomy, space research, power industry, engineering and technology. Morphological analysis for a long time has been used in economics for the research of economic systems and forms of markets (M. Weber, von Stackelberg, H. W. Eucken, Lhomme, J., E. Boettcher, H. Leipold and others).

In the field of the management sciences the morphological analysis was used in the following research cases: [13],[8]

- organizational and legal forms of various types of organizations (F.Lehmann , G. Weisser , B. Tietz)
- particular areas and functions of the organization (W.W. Engelhardt)
- external and internal organizational structures,
- organizational forms of organizations operating in different sectors (E. Castan)
- forms of interaction between organizations (P. Schwarz)
- management processes.

In Poland, morphological analysis is poorly widespread and rarely used as a research method. Some of the examples of its application includes:

- research of methods for solving organizational issues (Z. Martyniak) [14]
- examination of the problems of integration and disintegration in the company (M. Trocki) [15] ,
- research of management systems (M. Trocki) [16]
- research of project tasks in order to choose the form of project organization (M. Trocki) [17] ,
- research of organizational knowledge management and project knowledge management (P. Wyrozębski) [18]
- research of means of methodological support for project management (P. Wyrozębski) [19]

- research of forms of project management offices (P. Wyrozębski) [20]
- research of the communication issues in project management (K. Kandefer-Winter) [21]

The experience of the application of morphological analysis is positive. Given the usefulness of this method and, to date, its weak popularization it is justified to promote it by describing examples of its application.

IV. EXAMPLES OF THE USE OF MORPHOLOGICAL ANALYSIS IN MANAGEMENT SCIENCES

Because the essence of management concerns the structural problems the morphological analysis is a useful method in most areas of management in both practical and scientific approach. The use of the method allows not only to perform analysis but also, as is apparent from the description presented above, to combine and to synthesize solutions. It is particularly useful as the tool for systematization and modeling of complex phenomena, developing common solutions, making a complex, multi-criteria ratings, analysis, case studies, etc.

The first example presents a study of management systems diversity [15]. The main differentiating features (problem variables) were established in accordance with the concept of situational management by W. Hill, R. Fehlbau and P. Ulrich [22]. There were: tasks breakdown and grouping, the type of management structure, delegation of authority, style of management, regulation/standardization and division of labor and the expressions of those characteristics (values of problem variables). As the result the picture of diversity of management systems have been achieved. The morphological table of concept of situational management covers 6000 theoretically possible cases. After rejecting solutions internally contradictory the significant number of solutions still remained. The procedure allowed identifying individual of practical cases on a wide spectrum of possibilities.

TABLE II. THE MORPHOLOGICAL TABLE OF CONCEPT OF SITUATIONAL MANAGEMENT

| Problem variables | Values of problem variables | | | | |
|---------------------------------|-----------------------------|----------------------------------|---|---------------------------------------|----------------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| A: Task breakdown | A1: functional | A2: results-based | A3: territorial | A4: mixed | |
| B: Type of management structure | B1: linear structure | B2: linear structure with staffs | B3: linear structure with staffs and functional units | B4: functional | B5: matrix |
| C: Delegation of authority | C1: none | C2: weak importance | C3: average importance | C4: great importance | |
| D: Managerial style | D1: autocratic | D2: participatory | D3: autonomous work teams | | |
| E: Regulation / standardization | E1: detailed, unambiguous | E2: detailed, alternative | E3: frame | E4: heuristic | E5: none |
| F: Division of labor | F1: elementary partial work | F2: interchangeable partial work | F3: sequences of operations | F4: natural parts of the work process | E5: execution of the entire work |

| | | | | | |
|--|--|--|--|--|---------|
| | | | | | process |
|--|--|--|--|--|---------|

Source: according to the concept of situational management by Hill, R. Fehlbau, P. Ulrich, *Organisationslehre I*, Paul Haupt, Bern 1974

The second example relates to the use of morphological analysis for the analysis of project management tasks for the organization of the project [23]. There are six characteristics of the project management tasks that form six problem variables significant from the point of view of project organization design: the frequency of the projects, the number of simultaneous projects, interdependencies between projects (none, programs, portfolios of projects), the size of projects (aggregated time, budget and workload), the scope of the project in relation to the organization activities and compliance of competence requirements of a project and organization capabilities. Each of these features has the same number of values, thereby forming the morphology matrix (table 3). The matrix allows to assess characteristics of project environment and the influence of organization on project management and in result leads organizations to identify appropriate solution (structure/form) for project organization.

TABLE III. MORPHOLOGICAL MATRIX OF PROJECT TASKS INFLUENCING THE CHOICE OF FORM OF PROJECT MANAGEMENT ORGANIZATION DESIGN

| Problem variables | Values of problem variables | | |
|---|-----------------------------|----------------------------------|--------------------------|
| | 1 | 2 | 3 |
| A: the frequency of the projects | A1: occasionally | A2: regularly, from time to time | A3: constantly |
| B: the number of simultaneous projects | B1: one | B2: several | B3: several dozen |
| C: interdependencies between projects | C1: none | C2: programs | C3: portfolio of project |
| D: the size of projects | D1: small | D2: medium | D3: large |
| E: the scope of project in relation to the organization activities | E1: fragmentary | E2: partial | E3: complex |
| F: compliance of competence requirements of a project and organization capabilities | F1: full | F2: partial | F3: none |

Source: Trocki M., *Organizacja projektowa* [in] *Nowoczesne zarządzanie projektami*, praca zbiorowa pod red. M. Trockiego, PWE, Warszawa 2012, p. 332

The third example illustrates the use of morphological analysis in the field of knowledge management [24]. Because of its value as a tool for ordering complex, often very diverse phenomenon, it is an excellent method for the arrangement of the process of collection of knowledge within the organization. In view of the multiplicity of approaches, resources, tools and methods used in this field as well as multiplicity of actually used solutions the morphological table allows to keep them organized by four problem variables derived from the literature (table 4). The theoretical maximum number of combination of the table variables equals to $2 \times 2 \times 3 \times 2 = 24$ methods of knowledge accumulation in the organization. Some examples of these methods are described by combination of the variables shown in table 5.

TABLE IV. MORPHOLOGICAL TABLE OF PROCESS OF ACCUMULATION OF KNOWLEDGE WITHIN THE ORGANIZATION

| Problem variables | Values of problem variables | | |
|---------------------------------------|-----------------------------|---------------------|----------------|
| | 1 | 2 | 3 |
| A: Type of knowledge source | A1: external | A2: internal | |
| B: Knowledge type | B1: explicit knowledge | B2: tacit knowledge | |
| C: Level of knowledge accumulation | C1: organization | C2: team | C3: individual |
| D: Method of preserving the knowledge | D1: codification | D2: personalization | |

Source: own study

TABLE V. SELECTED APPROACHES AND TOOLS FOR THE ACCUMULATION OF KNOWLEDGE WITHIN THE ORGANIZATION

| | | | | | |
|----|----|----|----|--|--|
| A1 | B1 | C1 | D1 | Knowledge acquisition from available publications, studies, reports and reports, open standards, imported to the organization in documented form | Traditional "knowledge markets": the purchase of publications, books, training materials, licenses, patents, standards, best practices etc. |
| | | C2 | | | |
| | | C3 | | | |
| A2 | B1 | C2 | D2 | Knowledge sourced by employees and teams from codified internal sources of knowledge stored in their minds and work practices | Learning by individuals and teams from internal publications, studies and reports, organizational and process documentation, internal knowledge bases etc. |
| | | C3 | | | |

Source: own study

Similar approach can be used for other knowledge management processes. The following example concerns the description of the tools of knowledge transfer within the organization. In the process of knowledge transfer organization can use various tools such as a simple correspondence between employees, traditional training programs addressed to large groups, individual coaching and mentoring programs, intranet portals, dedicated, comprehensive information systems to support knowledge sharing or even strategic partnerships and developing a joint venture. Like the previously presented case the multiplicity of possible tools can hinder proper analysis and evaluation of available solutions, hence the need for systematic approach and their description by six problem variables: type of knowledge, process structure, participants of knowledge transfer and occurrence of the time and place of the transfer (table 6 and 7).

TABLE VI. MORPHOLOGICAL TABLE OF PROCESS OF KNOWLEDGE TRANSFER IN THE ORGANIZATION

| Problem variables | Values of problem variables | | |
|-----------------------|---|---|------------------|
| | 1 | 2 | 3 |
| A: Knowledge type | A1: explicit knowledge | A2: tacit knowledge | |
| B: Process structure | B1: process is organized and structured | B2: process disordered, lack of a clear structure | |
| C: Knowledge sender | C1: individual | C2 team | C3: organization |
| D: Knowledge receiver | D1: individual | D2: team | D3: organization |

| | | | |
|--------------------------------|---|--|--|
| E. Time of knowledge transfer | E1: same time of sending and receiving | E2: different time of sending and receiving | |
| F. Place of knowledge transfer | F1: same place of sending and receiving | F2: different place of sending and receiving | |

Source: own study

TABLE VII. SELECTED APPROACHES AND TOOLS FOR THE KNOWLEDGE TRANSFER WITHIN THE ORGANIZATION

| A | B | C | D | E | F | Tools/methods |
|---------|-----|--------|--------|-----|-----|---|
| A1. | B2 | C1/2/3 | D1/2/3 | E2 | F2 | E-mail |
| A1 | B2 | C1/2 | D1/2 | E2 | F2 | Mailing lists, newsgroups, internet forums, |
| A1 | B2 | C1/2 | D1/2 | E1 | F2 | Chats, tele- / video-conferences |
| A2 (A1) | B2 | C1 | D1 | E1 | F1 | Coaching, mentoring, shadowing, (OJT) |
| A2 (A1) | B2 | C2 | D2 | E1 | F1 | Communities of practice |
| A1 | B1 | C3 | C3 | E2 | F2 | The document workflow, groupware |
| A1 | B1 | C1/2 | D3 | E2 | F2 | Knowledge base, best practices database |
| A1 | B1 | C1 | D2 | E1 | F1 | Traditional training programs |
| ... | ... | ... | ... | ... | ... | |

Source: own study

The last example of the use of morphological analysis as a tool for analysis and the creation of complex solutions deals with the evaluation and selection of forms of methodological support for project management [25]. Various undertakings aimed at identifying, collecting, and then choosing the set of the best practices, proven tools, approaches and methods of managing the projects has led to the development of numerous project management methodologies [26]. The diversity of offered solutions and an irrepressible interest from organizations wishing to organize their project management processes resulted in popularization of methodological solutions in project management and showed strong need for analysis of the factors and conditions for the proper implementation of project management methodologies.

The purpose of the study, which employed the morphological method, was the identification of the areas significant from the point of view of methodological support for project management and exploration of factors influencing needs of methodological support among Polish organizations [19]. Also, one of the research goals was to meet the needs of methodological support reported by surveyed organizations by the selection and adaptation of the solutions proposed by the universal project management methodologies.

Intermediate result of the research was to develop and apply a model that would become a common reference point, a framework, to determine the needs of methodological support of organizations, and at the same time, that could be used for a comprehensive and comparable representation of available solutions (project management methodologies). These assumptions were perfectly satisfied with the morphological table used by the author as a research tool.

The initial study together with the analysis of methodologies and project management standards allowed to

prepare an unified combination of 18 variables – criteria for the analysis of the needs and for project management methodology support² According to the method of morphological analysis, the corresponding values were defined and prepared for each variable. The adopted scale of assessment of methodological support solutions was based on standardized forms of activities put in an order in conformity with the increasing scope and accuracy of problem solving methods used in a given area (variable).

TABLE VIII. MORPHOLOGICAL MATRIX OF METHODOLOGICAL SUPPORT FOR PROJECT MANAGEMENT (SAMPLE)

| Problem variables | Values of problem variables | | | |
|---|--------------------------------|---|---|--|
| | 1 | 2 | 3 | 4 |
| A: Stages and Life Cycle of the project | A1: insignificant /not present | A2: Determining different project stages | A3: Determining different project stages and a description of the main milestones | A4: Complete and detailed description of the stages and processes in the Project Life Cycle |
| B: Initiating a project | B1: insignificant /not present | B2: General rules of project initiation | B3: General rules of project initiation with the main decision points | B4: Detailed procedures and Project Initiation Documentation |
| C: Project definition, setting the goals, defining limits and requirements of the project | C1: insignificant /not present | C2: General guidelines for project goals | C3: General definition of the project goals | C4: Detailed and precise definition of goals, basis and requirements related to project realization |
| D: Project environment and context | D1: insignificant /not present | D2: Low degree of susceptibility to project environment | D3: Moderate degree of susceptibility to project environment | D4: High degree of susceptibility to project environment, taking into account correlations and mutual dependence |
| | ... | ... | ... | ... |

Source: Wyrozębski P., *Research of the needs of methodological support in project management*, Organization and Management, No. 5 (148) 2011, The Committee on Organizational and Management Sciences & Warsaw School of Economics

The use of a morphological matrix as a research tool permits to conduct a complex and detailed analysis of needs concerning particular problem areas in an organization, and to compare the profile of needs with the profile of solutions offered by respective methodologies (Figure 1). Thanks to the morphological matrix it was possible to define combinations of various support levels for each variable, what contributed to the elaboration of all possible variants of solutions to the problem.³

² The scope of the study consisted of preliminary empirical study of project management professionals' expectations with respect to the methodological support for projects, as well as detailed analysis of 16 international standards and models of project management.

³ For 18 variables and 4 values of each of them it is possible to define $4^{18} = 68.719.476.736$ potential variants (profiles) of the needs for project management methodological support.

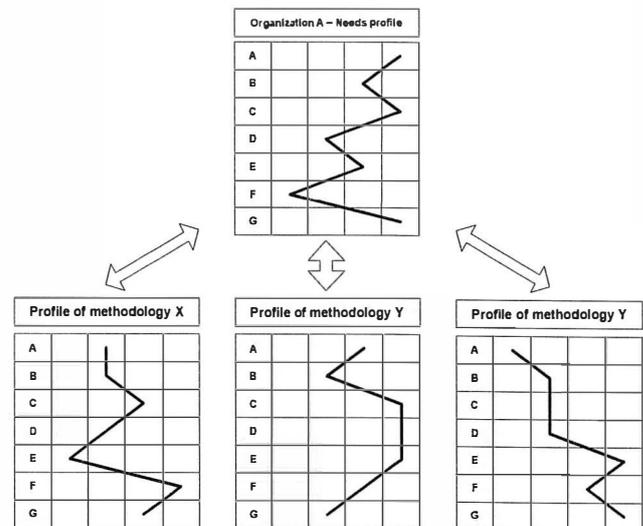


Figure 1. Use of the morphological matrix in choosing the proper project management methodology in a particular organization

The developed tool has been used to create profiles of the most popular, universal project management methodologies (PMI: A Guide to the Project Management Body of Knowledge [27], PRINCE2 [28] and PCM: Project Cycle Management [28]) and to empirically examine the needs of methodological support of selected group of specialists in project management.⁴

Profiles of the methodologies were developed using the method of expert judgment of experienced practitioners, professionals characterized by a remarkable knowledge of and proficiency in the use of various project management methodologies.

TABLE IX. MORPHOLOGICAL MATRIX OF METHODOLOGICAL SUPPORT FOR PROJECT MANAGEMENT

| Problem areas / variables | Profile of the needs for the methodological support | | | |
|--|---|---|------------------|-------------------------|
| | 1 | 2 | 3 | 4 |
| A Stages and Life Cycle of the project | | | | PMBOK PRINCE2 PCM |
| B Project Initiation | | | PMBOK PCM | PRINCE2 |
| C Project definition, setting the goals, defining limits and requirements of the project | | | | PMBOK PRINCE2 PCM |
| D Project environment and context | | | PMBOK PRINCE2 | PCM |

⁴ Detailed description of a study may be found here: Wyrozębski P., *Research of the needs of methodological support in project management*, Organization and Management, No. 5 (148) 2011, The Committee on Organizational and Management Sciences & Warsaw School of Economics

| Problem areas / variables | | Profile of the needs for the methodological support | | | |
|---------------------------|---|---|-------------------------|----------------|----------------|
| | | 1 | 2 | 3 | 4 |
| E | Giving structure to the project and scope management | | PMBok | PCM | PRINCE2 |
| F | Project time management | | | PRINCE2 PCM | PMBok |
| G | Organizing and leading a project team | | PCM | PMBok | PRINCE2 |
| H | Monitoring and control of project | | PCM | PMBok | PRINCE2 |
| I | Closeout and project evaluation | | | PMBok | PRINCE2 PCM |
| J | Risk management | | PCM | PRINCE2 | PMBok |
| K | Quality management | | | PMBok PCM | PRINCE2 |
| L | Communication management | | PCM | PMBok | PRINCE2 |
| M | Project cost management | | PMBok PCM | PRINCE2 | |
| N | Project resource management | | PMBok PRINCE2 PCM | | |
| O | Project procurement management | | PRINCE2 PCM | PMBok | |
| P | Change management (attitude towards changes, flexibility) | | PMBok PCM | | PRINCE2 |
| R | Project documentation | | | PMBok PCM | PRINCE2 |
| S | IT support for the methodology | PCM | PRINCE2 | PMBok | |

Source: Wyrozębski P., Model oceny i doboru metodycznego wsparcia dla zarządzania projektami, Warsaw School of Economics 2008, p.74-76

V. SUMMARY

In view of the progressive complexity of phenomena and problems in organizations, it is necessary to provide a systematic approach to analysis and design of their solutions. The number of possible options and their complexity makes it impossible to intuitively navigate among the multitude of available options. Importantly, in course of the analysis investigators are often not aware of many of available solutions, because they have never been reported for consideration. Morphological analysis is a simple and effective tool to support both the creative search for solutions and the process of organizing collections of phenomena and problems. Therefore, efforts should be made to wider dissemination of the morphological analysis among practitioners and theoreticians of management..

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