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Fractal approach for manufacturing project management

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1. Introduction

This research paper is focused on the planning problems of production processes in manufacturing for small and medium enterprises (SMEs), which practice business activities that are performed based on integrated multiple projects management. These problems have received a major attention from researchers and practitioners over the last decade. The reason is an exceptional importance for non-single project implementations to reach total profitability, while complexity of the project environment keeps increasing.

Individual projects management is usually a difficult task. The situation becomes much more complicated when there are multiple on-going projects within an organization. Projects need to be considered as an integrated portfolio, rather than a disjointed collection. The process of managing multiple projects requires maintaining control over a varied range of projects, in order to balance the concurrent demands with limited resources and to coordinate the project portfolio to achieve the optimal outcome for organisation.

The multiple projects management (MPM) requires an efficient, dynamic process for determining how to allocate resources and set a realistic delivery schedule for new projects, especially when new project is added to an existing portfolio. Besides the problem of scarce resource allocation among the projects and their tasks, one of the important challenges in any multi-project environment is the coordination of the different tasks comprising those projects. Coordination is especially difficult in situations where the complexity of the comprised projects leads to their separation into concurrent and interrelated tasks, the results of which must be integrated dynamically into an entire portfolio of a satisfactory solution.

Practically every manufacturing enterprise manages a number of projects or multiple projects. One of the major problems is dealing with the complexity resulting from the multifunctional aspect of the projects, which needs a clear definition of the objectives and the roles of each manager on an enterprise.

The aim of the current research is to work out the method and principles of multi-project management targeted to maximization of existing resources utilization within a separate manufacturing enterprise in the projects management environment.

1.1. MPM as a complex system

Projects are characterized by complexity (they include many components and dependencies), uncertainty (availability of resources and task durations), dynamic behaviour (changes in the scope of the project, adding or removing unexpected tasks, re-scheduling processes) and are inherently heterogeneous (each task may be completed by different resources or in different geographical locations). In the case of a multi-project environment, each one of these characters is severely intensified.

Any project is a complex system with a lot of interconnected tasks, number of targets and participants. The nature of the project is characterized as an open system, due to interrelations with internal and external environments. At the same time it causes interdependencies among different components of the project in different scales and on different levels.

Complex systems are never completely predictable, even if the working principles are known. Managers should be prepared to deal with the unexpected events that complexity most certainly will bring forth, and should be able to correct any deviation from the planned course of action as soon as possible. To achieve this kind of error-based regulation they should not try to predict or determine the behaviour of a complex system, but to be prepared for the most probable scenarios. It will make easier to adapt when things go off-course [1]. Complexity is an important criterion in selection of an appropriate organisational form and inputs of the project.

There is hard base that enables to suppose that MP system may be considered as a complex system. Complex system has multiple interacting elements whose collective behaviour cannot be simply inferred from the behaviour of its elements [2]. Therefore, MP system can be similarly described by the means of complexity theory:

1. Complex systems consist of a large number of elements which could be simple. A single project consists of a number of tasks; portfolio consists of a number of projects.
2. The elements interact dynamically by exchanging resources or information. These interactions are rich. Even if specific elements only interact with a few others, the effects of these interactions are propagated throughout the system. It means that the tasks and/or projects are usually connected via the input/output chain with each other, and any change of information may affect the whole task and/or project.
3. The interactions are nonlinear. There is no confidence that a double change in one project will cause the same change in other projects [3].
4. There are many direct and indirect feedback loops. The application of the system dynamics to project management has been significant, especially in order

to understand the feedbacks [4].

5. Complex systems are open systems – they exchange information with their environment, where all processes are irreversible. Success of a project depends on endogenous and exogenous factors, such as market situation with all participants on it, supplier's operability, contractor's prosperity, fund sources credibility and many others.
6. Complex systems have memory that is not located at a specific place, but distributed throughout the system. Any complex system thus has a history, and the history is of cardinal importance to the behaviour of the system. Under the history in projects we understand an experience, skills, and action policies of all participants.
7. The behaviour of the system isn't determined by the content of the components, but by the nature of the interactions. Since the interactions are rich, dynamic, fed back, and above all, nonlinear, the behaviour of the system as a whole cannot be predicted from an inspection of its components. The notion of 'emergence' is used to describe this aspect. The presence of emergent properties does not provide an argument against causality, only against purely deterministic forms of prediction. It supports the synergy/cannibalization nature in the multi-project (portfolio) environment [5, 6].
8. Complex systems are adaptive. They can (re)organize their internal structure without the intervention of an external context. Principles of adaptive management are strongly endorsed and actively used in many industries, such as information technology and environmental protection.

Definitely, all these properties may exist or not in the system and may affect it in a different manner. But few of them appear to be very important in terms of validation of any scientific approach to studying multi-project environment. They are: dynamic exchange in an open system and nonlinearity.

There are several traditional approaches to modelling in dynamic multi-project environment with respect to above discussed complexity properties:

1. Discrete event (linear feedback modelling) and continuous simulation (Simulink) [7].
2. Markov chains (sequence of random variables corresponding to the system state; transition matrices) [8].
3. System dynamics (top-down view, feedback loops, etc.) [9, 10].
4. Agent-based modelling (autonomous rule-based agents) [11].

This research covers the overview of various complexity types and measures. The fractal idea is applied and transformed into a framework for production planning in MPM environment.

1.2. Theory of fractals in project management

Usually fractal is considered as geometric concept introducing the quantity fractal dimension or the concept of self-similarity [12]. Fractal is a model of the modular component used to design, implement, deploy and reconfigure any project context. It has a hierarchical structure, and put an emphasis on reflexivity in order to support adaptation and reconfiguration. It has to be more and more adaptive and must perform reconfigurations in reaction to changes in its environment. Indeed, when additional ideas or requirements appear during the project portfolio implementation, new tasks or even projects are created in order to adapt to changed environment.

Any project consists of at least one task, which includes one operation or procedure (transportation, welding, machining, etc.). When a project contains a single operation it is possible to magnify the scope and scale of this operation in order to receive a number of various tasks (sub-tasks) in it.

The use of fractal approach has been applied in a number of different contexts: manufacturing, physics, biology, artificial intelligence, and etc. [13-15]. The key to the project-based fractal enterprise is establishing client–server relationships between an "ends-manager" who manages projects and a "means-manager" who ensures the resource usages as scheduled while maximizing resource utilization over time (in an open market economy) [16]. The fractal enterprise idea is the most appealing one from the standpoint of the management tasks modelling since self-organizing and self-optimizing unit characteristics allow to differentiate goal management from resource management in the network of SMEs.

1.3. Entropy theory of project management

The "entropy theory of project management" approach is based upon analogies with the discipline of statistical thermodynamics. This is an emergent theory of project management. The primary objective is to reduce the inherent chaos and uncertainty associated with every lifecycle stage of the project, by the transformation of information into highly structured (i.e., low entropy) products or services.

Multi-project entropy is presented as follows. Each organization has a limited amount of the liability that it can undertake. The entropy helps a project manager to calculate the total amount of the uncertainty for all the projects running in his company.

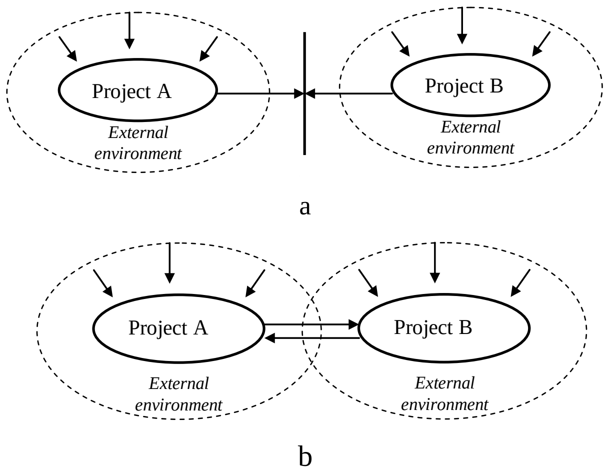

Fig. 1 Two project system: a) isolated and b) open system

Project A may be in states (A_1, A_2,…, A_n) with probabilities (p_1, p_2,…, p_n) respectively. Project B can occupy states (B_1, B_2,…, B_m) with probabilities (q_1, q_2,…, q_m) respectively. If the projects are considered as isolated from each other the information flow, i.e. influences, changes, etc. (designated as arrows) is coming from the external environment only, without exchanges between project environments (Fig. 1). In the a) example a system is subject to exchange only with its environment. In b) example the system is in exchange with environment and another subsystem.

Projects A and B are then defined by their respective entropies:

$$H(A) = -\sum_{i=1}^{n} p_i \log_2 p_i \ ; \tag{1}$$

$$H(B) = -\sum_{j=1}^{m} q_j \log_2 q_j \ . \tag{2}$$

The joint (multi-dimensional) entropy of the Projects A and B is:

$$H(A,B) = H(A) + H(B) - I(A,B), \tag{3}$$

where $I(A, B)$ is the average mutual information entropy measures how knowledge of the value of one random variable reduces the uncertainty about another:

$$I(A,B) = -\sum_{i=1}^{n}\sum_{j=1}^{m} p_i q_j \log_2 (p_i q_j). \tag{4}$$

According to the second law of thermodynamics, if the system is in the initial state Σ_b then, in the absence of any further constraint, it will tend to converge to the state Σ_a. Clearly, the system is then disorganizing.

A system would be organized mainly because there is creation of constraints that reduce its informational entropy. In the same way, it would be self-organizing whenever there is self-creation of constraints. In other words, the level and the grade of the organization capability of the system would be directly characterized by the constraints [17].

2. Fractal structure for MPM

Fractal approach organizes the complex system that can be generated through the iteration and integration of the simple units and the common control rules. Fractal system possesses some advantageous features:

- Self-similarity (in terms of modality, information, function or time, etc.).
- Simple, recursive and iterative structure (maybe the most needed features for multi-project management).
- Adaptability and self-organization (finds popularity in rapid exchanging highly competing environments).

Fractal approach is based on the assumption that there is a single activity in the project, which is the smallest and similar part of the whole project. Based on the same logic an elementary operation within an activity is a component, which is similar to the entire activity; or project is similar to the project portfolio (Fig. 2).

Similar feature of these parts (sub-parts, sub-sub, etc) that they all contain three evolutionary stages: preparation (‘Prep’), realization (‘Realization’), and finalization (‘Finish’). Therefore we obtain a fractal structure of the project regardless of its size and type. Square of rectangular is proportional to the product of parameters N (number of people) and T (parameters of time).

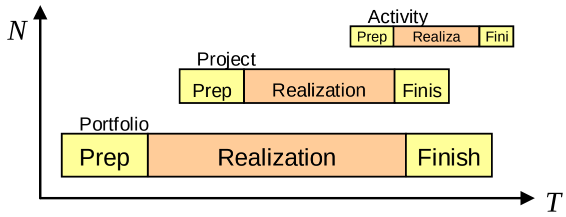

Fig. 2 Graphical concept of project fractal

Depending on the magnitude of these values we can build a parametrically scalable picture of a fractal. The underlying notion in the fractal project (FP) is Effort, E. It could be defined by Eqs. 5 and 6. Constraints are: project time, which is limited by the contracted due date T_{lim} and resources in use N_{lim}. The latter includes equipment, machines, and staff. Schematic representation of the fractal is given in Figs. 3 and 4.

$$E = N\,T\ ; \tag{5}$$

$$E = W / P\,, \tag{6}$$

where W is the project work amount needed for the completion of project; P is team productivity.

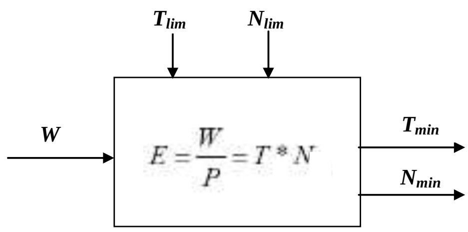

Fig. 3 Mathematical model of FP

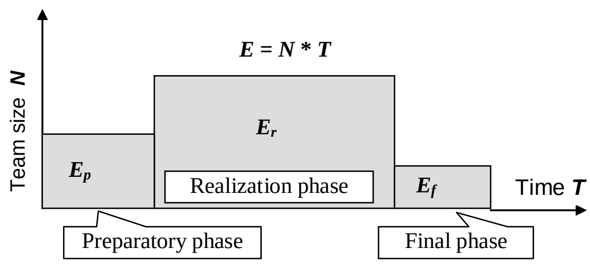

Fig. 4 Components of FP

Number of simultaneous projects represents a system with properties of self-organization. Using the proposed fractal approach allows the manager to direct human resources, approaching the maximum use of their effort. Principally, the effect of self-organization causes the existence of synergy:

$$E_{PR1} + E_{PR2} + E_{PR3} ... \geq E_{MP}\,, \tag{7}$$

where E_{PR1}, E_{PR2}, and E_{PR3} indicate the effort (which is a function of time and people involved) required to performing three separate projects; E_{MP} is a total effort in multi-project realization.

The main part of the fractal, namely Realization takes, as usual, most of the time from the whole activity. This is the phase, which adds the value to our project as a whole, and to the goods, in particular. Other phases, Preparation and Finishing are non-value-added, but they are necessary in terms of technological and production requirements. The former involves processes such as parts cleaning, drying, mounting and others where the detail is involved. The latter includes local enterprise features (e.g. long logistics chain, no painting chamber, etc). Therefore, we suppose that ideally all these 0-value processes should be conjugated (or combined) and proceeded during value-added processes (Fig. 5).

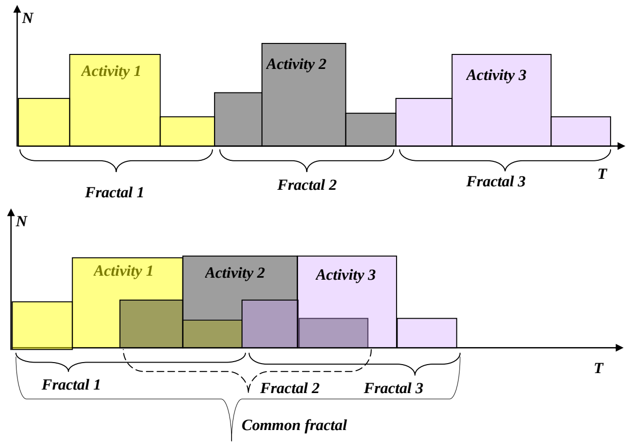

Fig. 5 Logic of FP combinations

3. Algorithm for FP output parameters definition

The project effort and its distribution over time can serve as a basis for the obtaining of the total number of human actions and their distribution over time (Fig. 6).

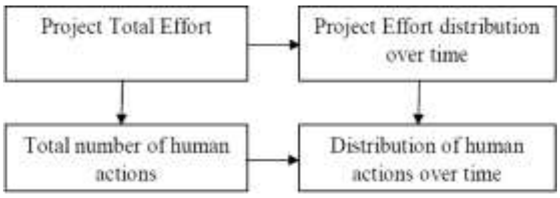

Fig. 6 Interrelationships between project parameters

The basic objective of the proposed fractal approach is to determine the minimal amount of resources required for the minimal duration of project. The following algorithm is elaborated for this purpose (Fig. 7).

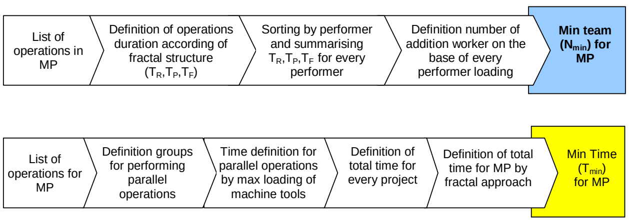

Fig. 7 Algorithm of $N_{\min}$ and T_{min} definition for FP

The determination of N_{min} begins with a description of each project operations. For every operation the main manufacturing, preparation and finishing time (T_P, T_R, T_F) must be defined. For the information processing it necessary to sort the data based on different parameters, which could be performed in Excel or Access tables. The realization time T_R is used in order to calculate the resource (machine + operator) utilization.

4. Realization of FP approach

In order to consider the real application of multiple project management framework the local company has been chosen as a practical example. The selected company is a small partner of ABB, which is one of the largest enterprises in Estonia. It specializes in metal constructions for huge equipment in various industries – forest, mining, electrics, etc.

Table 1

Basic parameters of projects

Project 1	Order	Activities	Performer	Time, hours			TOTAL
				TP	TR	TF	
P1	1	Cutting Tubes	Carver	4	16	1	21
P1	2	Cutting Shafts	Carver	4	22	1	27
P1	3	Cutting Plates	Carver	4	16	1	21
P1	4	Machining Tubes	Turner	2	24	2	28
P1	5	Machining Shafts	Turner	2	24	2	28
P1	6	Machining Plates	Turner	2	28	2	32
P1	7	Welding Plat-Tub-Shafts	welder	8	42	2	52
P1	8	Welding Surface	welder	4	16	2	22
P1	9	Welding Spikes	welder	4	16	2	22
P1	10	Machining roller end	Turner	2	18	2	22
P1	11	Assembling	Worker	6	16	2	24
P1	12	Painting	Painter	4	36	2	42
P1	13	Greasing	Worker	2	18	2	22
P1	14	Packing	Worker	4	32	2	38
P1	15	Delivery	Manager	2	6	0	8
Project 2		Activities	Performer	TP	TR	TF	TOTAL
P2	1	Cutting Tubes	Carver	2	8	1	11
P2	2	Cutting Shafts	Carver	2	12	1	15
P2	3	Cutting Plates	Carver	2	8	1	11
P2	4	Machining Tubes	Turner	2	12	1	15
P2	5	Machining Shafts	Turner	2	12	1	15
P2	6	Machining Plates	Turner	2	14	1	17
P2	7	Welding Plat-Tub-Shafts	welder	4	20	1	25
P2	8	Welding Surface	welder	2	8	1	11
P2	9	Welding Spikes	welder	2	8	1	11
P2	10	Machining roller end	Turner	1	8	1	10
P2	11	Assembling	Worker	3	8	1	12
P2	12	Painting	Painter	2	18	1	21
P2	13	Greasing	Worker	1	10	1	12
P2	14	Packing	Worker	2	16	1	19
P2	15	Delivery	Manager	2	4	0	6
Project 3		Activities	Performer	TP	TR	TF	TOTAL
P3	1	Cutting of Materials	Carver	2	15	1	18
P3	2	Sharp edge carping	Carver	1	2	1	4
P3	3	Drilling	Turner	2	16	1	19
P3	4	Milling	Turner	2	20	2	24
P3	5	Sand blasting	Painter	1	4	1	6
P3	6	Sharp edge removing	Carver	1	2	1	4
P3	7	Assembling	Worker	2	8	2	12
P3	8	Packing	Worker	2	4	1	7
P3	9	Delivery	Manager	2	6	0	8

The average number of employees in case study company is about 12-14 persons. Two of them are managers; others are welders, metal cutters, and technicians. There are about 3-4 projects in progress simultaneously with an average duration of 6 weeks. This case-study includes 3 projects with a brief description of the specifics of each: Project 1 - Spike rollers (Type A, 34 pcs.); Project 2 – Spike rollers (Type B, 17 pcs.); Project 3 – Stator bars, 72 pcs.

Next step – is sorting by performer, which enables to see how much work each performer of the project has to do. This data is summarised in Table 2. From this data could be calculated the amount of work to be distributed among non-specialized professionals (not working on machines, i.e., turner, welder, carver). This amount is equal to the sum of preparation and finishing times. For example, if we require one month 160 hours to completing all three projects, it is evident that there is no problems in resources besides the CNC machine resource capacity, since it has 176 working hours.

Table 2

Sorted parameters of the projects

Sum of Realization				
Performer	Project 1	Project 2	Project 3	Grand Total
Carver	54	28	19	101
Manager	6	4	6	16
Painter	36	18	4	58
Turner	94	46	36	176
Welder	74	36		110
Worker	66	34	12	112
Grand Total	**330**	**166**	**77**	**573**
Sum of Preparation				
Performer	Project 1	Project 2	Project 3	Grand Total
Carver	8	12	4	24
Manager	2	2	2	6
Painter	4	4	1	9
Turner	8	8	4	20
Welder	16	16		32
Worker	12	12	4	28
Grand Total	**50**	**54**	**15**	**119**
Sum of Finishing				
Performer	Project 1	Project 2	Project 3	Grand Total
Carver	3	3	3	9
Manager	0	0	0	0
Painter	2	2	1	5
Turner	8	8	3	19
Welder	6	6		12
Worker	6	6	3	15
Grand Total	**25**	**25**	**10**	**60**

Visual presentation of workloads in all projects allows the manager to conveniently distribute the non-value-added operation stages among general workers Fig. 8.

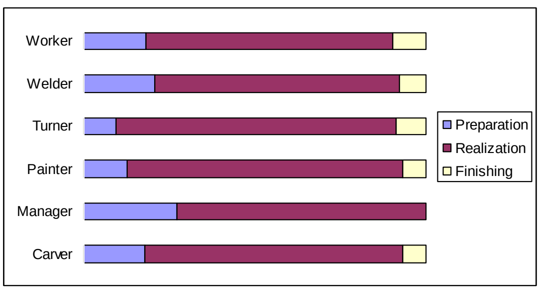

Fig. 8 Fractals for every performer

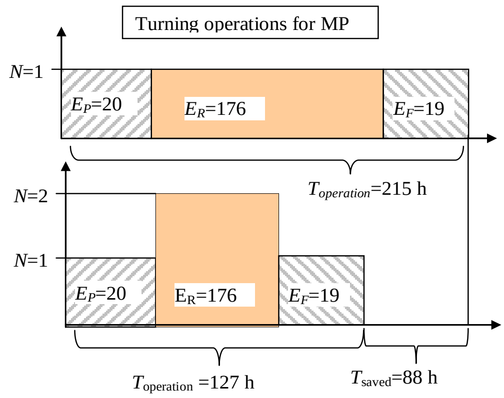

Fig. 9 Changes in CNC machining operation fractal

The distribution of effort among the team members is given in Table 3. Notice that 3 general workers were have been added to last row as well as one person that help "Worker". The total effort added by 4 workers is 235 (hour/person).

Table 3

Effort distribution among the team members

Performer	Effort	Persons	Time
Carver	101	2	50.5
Manager	16	1	16
Painter	58	1	58
Turner	176	2	88
Welder	110	2	55
Worker	112	2	56
General worker	179	3	60
TOTAL	**752**	**13**	

It is possible to build the complete fractal structure for three projects. The sequence of operations for one project is introduced in Figs. 10 and 11. There following work-groups are defined: WG1 – turning, WG2 – welding, WG3 – cutting, WG4 – painting, WG5 – others.

Fractals visually demonstrate ways of possible combinations of activities, allow grouping and distribution of concurrent operations between the simultaneously available resources, and enable to identify the milestones in switching between different projects and different stages. Depending on the established technological routing the total project time may be changed. Duration of a project is limited by a contract.

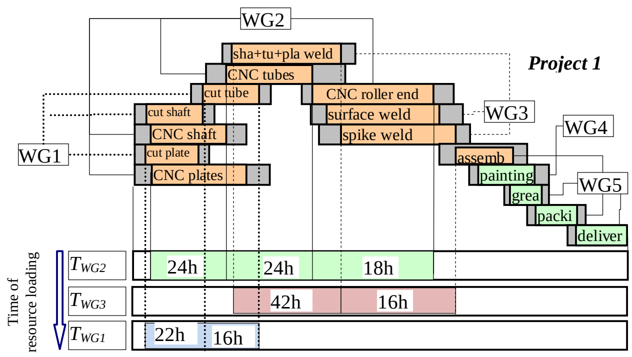

Fig. 10 Fractal structure for the first project

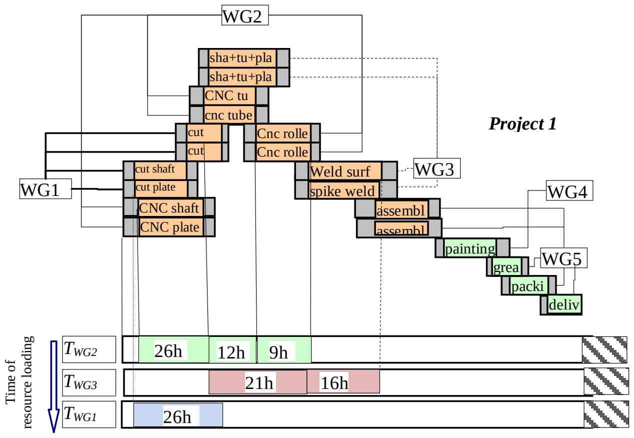

Fig. 11 Fractal structure for the first project by using self–organisation in Work-Groups

Naturally, the results of the approach implementation depends on many factors such as the size and the complexity of projects, capacity of resources (for machines) and their skills (for human), time limits and number of projects, and so on. But no result could be achieved without a proper integration of the FP approach in enterprise engaged in MP.

5. Self-organization in MPM

The goal of FP approach is to provide general worker involved in projects the possibilities for deployment of self-organization capabilities into the MPM. Therefore, a measure of entropy or disorder may be decreased by involvement of few general workers, who would be sharing information about available tasks between each other. Of course, the considerable directing work is performed by a manager [18, 19]. But case study does not include his contribution to self-organization in the MPM environment.

The calculation steps for the Project 1, see Table 4:

- No general workers were added in Project 1. Total effort is 405. Entropy is maximal (but not absolutely, since realizes that it is impossible).
- One general worker was added. He brings an effort level of the carver ($E_P + E_F$) equalled 11. Calculate entropy, mutual information and create plot.
- Two general workers were added

Table 4

Efforts in Project 1

	Carver	Turner	Welder	Worker	Remained effort	Shared effort	Remained effort, %	Shared effort, %
No workers	-	-	-	-	405	0	100.0	0
General worker	11	-	-	-	394	11	97.2	2.8
General worker	11	16	-	-	378	27	92.9	7.1
General worker	11	16	22	-	356	49	86.2	13.8
General worker	11	16	22	18	338	67	80.2	19.8

Logarithmic measures of different states and their total entropy are calculated and results are demonstrated in Table 5. Graphical expression is presented in Fig. 12.

Table 5

Self-organization in Project 1

(remained) * (shared)	log (remained)* log(shared)	*I* (remained * shared)	Self-organization (*H-I*)
0.000	-	-	-
0.027	-5.203	0.141	0.039
0.066	-3.914	0.260	0.093
0.119	-3.075	0.365	0.167
0.159	-2.654	0.422	0.225

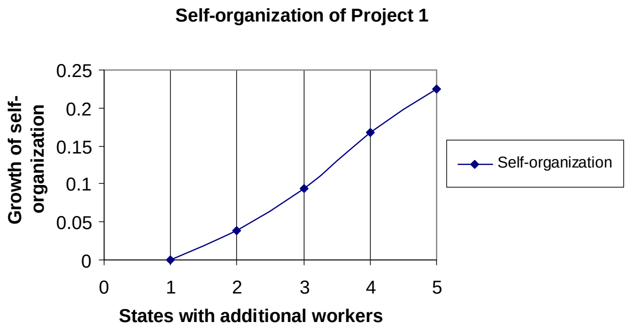

Fig. 12 Self-organization in Project 1

The total values of self-organization measures in the project are presented in Table 6 and plot is depicted in Fig. 13.

Table 6

Self-organization in three projects

	Number of state	Project 1	Project 2	Project 3
Nobody is added	1	0	0	0
Carver + worker	2	0.038781	0.095434	0.107178
Turner + worker	3	0.09338	0.196654	0.212512
Welder + worker	4	0.167051	0.319341	0.212512
Worker + worker	5	0.225271	0.399081	0.306378

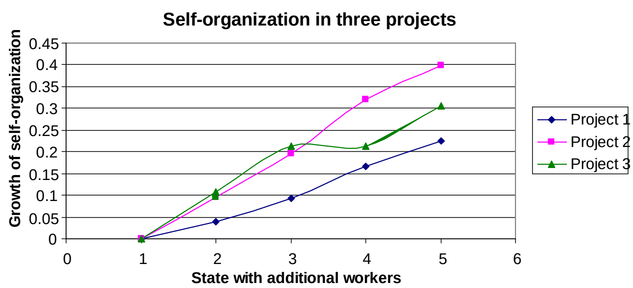

Fig. 13 Self-organisation in three projects

To sum up the description of self-organization in the projects should say that there is no infinite entropy decrease and no limit points in the mutual information. Hence, one can't expect a considerable self-organisation growth by adding more general workers to the project. In current consideration the average number of additional workers to be added in the projects is 3 persons.

6. Conclusions

The production activities in numerous manufacturing companies around the world are handled as separate projects. Specifically, the success of projects performing depends on skills and techniques used by the project manager. In the current research the new approach for maximisation of existing resources utilization within a separate manufacturing facility in the MPM environment was considered. The Fractal approach was used for this purpose. It includes several methods for calculation purposes, which are based on characteristics of complex systems, such as entropy, self-organization, and adaptability. Moreover, and more importantly, this approach is a novel way of thinking, fresh point of view on processes within an enterprise.

In the case study, it was verified that the use of fractal approach reduces the total production time, which enabled to add additional project to existing multi-project portfolio and to decrease the total cost of multi-project for 15%. The advantages are as follows: better distribution of activity’s main processes, higher productivity of the qualified workers (welders, turners, etc.), and improved utilization of machines during the value-added process. Entropy theory allows to measure uncertainty and complexity in managing projects.

The more information is available, the better is picture received about projects that will be implemented.

Acknowledgements

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References

1. **Gershenson, C.; Heylighen, F**. 2001. How can we think complex? In: Richardson, Kurt (ed.), Managing Organizational Complexity: Philosophy; Theory and Application 1: 47-62.
2. **Smith, J.B**. A 2003. Technical report on complex systems, Villanova University, USA.
3. **Richardson, K.** 2005. Managing organizational complexity: philosophy, theory and application, Information Age, 301-311.
4. **Lyneis, J.M.; Ford, D.N**. 2007. System dynamics applied to project management: a survey, assessment, and directions for future research, System Dynamics Review 23(2-3): 157-189. http://dx.doi.org/10.1002/sdr.377.
5. **Evaristo, R.; van Fenema, P.C**. 1999. A typology of project management: emergence and the evolution of new forms, Int. J. Proj. Manag. 17(5): 271-281. http://dx.doi.org/10.1016/S0263-7863(98)00041-6.
6. **McDermott, C.M.; O’Connor, G.C**. 2002. Managing radical innovation: an overview of emergent strategy issues, J. Prod. Innov. Manag 19(2): 424-438. http://dx.doi.org/10.1016/S0737-6782(02)00174-1.
7. **Majak, J.; Pohlak, M.** 2010. Decomposition method for solving optimal material orientation problems, Composite Structures 92(8): 1839-1845. http://dx.doi.org/10.1016/j.compstruct.2010.01.015.
8. **Kulkarni, V.G.; Adlakha, V.G**. 1986. Markov and Markov-regenerative pert networks, Oper. Res. 34: 769-781. http://dx.doi.org/10.1287/opre.34.5.769.
9. **Abdel-Hamid, T.K**. 1993. A multi-project perspective of single-project dynamics, J. Syst. Soft. 22(3): 151-165. http://dx.doi.org/10.1016/0164-1212(93)90107-9.
10. **Kavadias, S.; Loch, C**. 2003. Optimal project sequencing with recourse at a scarce resource, J. Prod. Oper. Manag. 12(4): 433-444. http://dx.doi.org/10.1111/j.1937-5956.2003.tb00213.x.
11. **Shevtshenko, E.; Küttner, R.; Karaulova, T.** 2006. Using of Multi-Agents in Intelligent Decision Support System for Collaborative SME –s, In: NordPLM´06, 123 - 134.
12. **Takayasu, H.** 1990. Fractals in the Physical Sciences, Manchester University Press, Manchester, 170 p.
13. **Polyantchikov, I.; Shevtshenko, E.; Kramarenko, S**. 2010. Fractal management approach for the manufacturing projects in the collaborative networks of SME-s. Journal of Machine Engineering 9(4): 81-93.
14. **Ramanathan, Y**. 2005. Fractal architecture for the adaptive complex enterprise, Communications of ACM 48(5): 51-67. http://dx.doi.org/10.1145/1060710.1060739.
15. **Ryu, K.; Jung, M**. 2003. Fractal approach to managing intelligent enterprises, Creating Knowledge Based Organisations, In: Gupta and Sharma (Eds.), Idea Group Publishers, 312-348.
16. **Canavesio, M.; Martinez, E**. 2007. Enterprise modeling of a project-oriented fractal company for SMEs networking, Computers in Industry 58(8-9): 794-813. http://dx.doi.org/10.1016/j.compind.2007.02.005.
17. **Jumarie, G**. 2000. Maximum Entropy, Information without Probability and Complex Fractals, Kluwer Academic Publishers, Dordrecht. http://dx.doi.org/10.1007/978-94-015-9496-7.
18. **Karaulova, T.; Kostina, M.; Sahno, J.** 2012. Framework of reliability estimation for manufacturing processes, Mechanika 18(6): 713-720. http://dx.doi.Org/10.5755/j01.mech.I8.6.3168.
19. **Kramarenko, S.**; **Shevtshenko, E.** 2009. Decision support system for multi-project cash-flow management, Annals of DAAAM For 2009 & the 20th International DAAAM Symposium Book Series: Annals of DAAAM and Proceedings, 20: 1111-1112.

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FRAKTALŲ TAIKYMAI GAMYBOS PROJEKTŲ VALDYMUI

R e z i u m ė

Šis straipsnis siejamas su gamybos procesų planavimu mažose ir vidutinio dydžio įmonėse, kuriose visa verslo perspektyva susijusi su projektų valdymo patirtimi. Šio tyrimo tikslas perduoti informaciją apie naują greitą susietų projektų parametrų valdymo planavimo ir vertinimo būdą. Šis būdas siūlo naujus metodus leidžiančius didinti turimų resursų panaudojimą vienoje gamybinėje įmonėje.

Tikslas pasiektas remiantis prielaida, kad eilė susietų projektų yra kompleksinė sistema, kuri yra siejama su kompleksiškumo teorijos dėsniais. Fraktalai simbolizuoja ryšius su kompleksiškumu, apjungia kompleksinę sistemą per pavienių vienetų iteraciją ir integraciją ir bendrąsias valdymo taisykles. Naudojant fraktalus susietų projektų valdyme nereikalaujama specialių kompleksinių sistemų teorijos žinių. Fraktalų idėja yra integruota į gamybos planavimo susietų projektų valdymo aplinkoje struktūrą.

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FRACTAL APPROACH FOR MANUFACTURING PROJECT MANAGEMENT

S u m m a r y

This paper is focused on the planning problems of production processes in small and medium manufacturing enterprises, where all business activities are performed based on project management practice. The aim of this research is to deliver the new approach for rapid planning and assessment of parameters for the case of multi-project management (MPM). The novel approach that suggests new methods for maximizing utilization of existing resources within a single manufacturing enterprise was proposes in current research.

The aim was achieved based on assumption, that multi-project is a complex system, which is directed by laws of the complexity theory. Fractals represent a way of dealing with complexity; organize the complex system through the iteration and integration of the simple units and the common control rules. Using of fractal approach in MPM does not require special knowledge of complex system theory. The fractal idea is integrated into the framework for production planning in MPM environment.

Keywords: multi-project management, complex adaptive system, fractal, entropy, self-organisation.

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