P2P Outsourcing Model for Agile Project Tasks Allocation

Anton Ivaschenko
Samara State Aerospace University
Samara, Russia
anton.ivashenko@gmail.com

Andrey Lednev
Haulmont Development Ltd
Samara, Russia
andrey.lednev@gmail.com

Alfiya Diyazitdinova
Povolzhskiy State University of Telecommunications and Informatics
Samara, Russia
dijazitdinova@mail.ru

***Abstract*—P2P outsourcing model is introduced to describe an interaction process of project tasks distribution between employees as a part of the enterprise project management system that supports decision-making process within the company. The proposed solution provides an agile technology of tasks allocation in enterprises with matrix organizational structure. The described approach was implemented using multi-agent technology. The resulting solution was implemented in oil-and-gas industry using CUBA platform**

I. Introduction

Modern trends in agile project management at enterprises with distributed structure require the process of adaptive project tasks allocation to be organized in highly flexible and interactive manner. Due to high variability of business processes, complexity and uncertainty of project tasks, rigid requirements to project team members' pro-activity and motivation, the role of tasks executors becomes critical at all stages of the project. This requires new approaches for project tasks allocation and scheduling software solutions using modern algorithms and systems of decision-making support, multi-agent technologies and knowledge bases.

One of such approaches that can be implemented to provide an efficient solution for project execution and control is the use of P2P outsourcing model, which is formed, based on classical project scheduling: the tasks are preliminarily distributed between the most appropriate staff. According to this initial distribution lately, the tasks are being decomposed and partially shared in real time using P2P model. In practice it means that current task owner can have a little expertise the work he will delegate (outsource) and he needs an efficient tool for decision making support.

Assuming a high motivation of staff, it can be inferred to solve this problem by auctioning. The approach was first presented in papers [1], [2], and lately developed to a practically useful solution implemented in intelligent systems for supply chain management and decision making support.

II. Motivation

Modern enterprises are going through the period of hard business competition that compels the companies to increase the number of complex innovative projects minimizing operational expenses and thus reducing production costs.

These aims are tightly coupled with the management efficiency, which is highly dependent on IT technologies used within the companies.

P2P model of actors' interaction and cooperation at distributed enterprises is based on high autonomy of organizational units and even exact employees. Professional, qualified and highly motivated employee usually becomes self-sufficient and is being involved in project tasks distribution getting the most profitable job and sharing it with colleagues.

To enforce this trend and encourage such a behavior pattern, which is generally positive for enterprise performance and competitiveness, the capability to capture and share project tasks should be provided on the level of project management automated decision making support. The process of task transfer from initially assigned executor to another one can be treated as outsourcing (see Fig. 1).

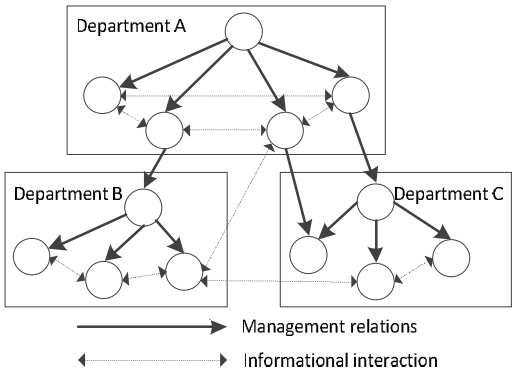

Fig. 1. Internal outsourcing at a modern enterprise

The executor is being selected according to his competences with time and cost criteria taken into consideration. P2P outsourcing management system can improve the quality of complex projects' managing.

According to the proposed approach, the scheduling system should support a P2P network in an actual stage, create initial project schedule and help employees decompose and distribute tasks between each other by carrying out a series of auctions.

III. STATE OF THE ART

Management strategies of enterprises in production, transportation or mining industries are concerned with a combination of vertical integration and implementation of matrix organizational structures. Vertical integration implies organizational and financial unions under a single management company covering all stages of business processes [3].

Matrix organizational architectures are most commonly used to improve the production efficiency by reducing the variety of services throughout the whole enterprise and thus increasing the labor productivity. The use of matrix models is also determined by a big number of projects as this organizational structure is considered to be the best to support project management activities and share resources between functional structures [4].

According to best project management practices [5], [6] the quality of the project plan plays a vital role in the success of the whole project. Work Breakdown Structure (WBS) of the project is used to split the whole work into smaller equal parts (packages) [7]. The packages are presented in a hierarchical view to define the sequence of tasks. This approach works during the project initiation but can be hardly applied to the project execution due to high complexity of tasks, uncertainty of requirements and constant changes.

Project management strategies implementation in practice is complicated by a large number of interactions between the parties involved apart from relations defining the management hierarchy between the departments and head-daughter companies.

Informational interaction usually duplicates management links but as a rule, it is much wider as follows direct communication between employees working on complex projects affecting transparent business processes of the enterprise. This informational links can be described in a form of a network:

$$M = (U_M, V_M), \quad (1)$$

where U_M is a set of employees working on complex projects in different departments of the enterprise;
V_M – existing informational links between employees.

A number of management theories are studying the network organizational structures, for example the theory of hierarchical management describing the problems of decision making under the circumstances of unpredictability [8], [9]. Self-organization in networks applicable for enterprise management is investigated using bio-inspired approach [10].

Classical project management approaches are hardly applied in the areas of high uncertainty. Modern models of interaction management in solid information environment of network structures must be applied [11].

Peer-to-peer (P2P) networks are used in practice to simulate the work inside matrix organizational structures. P2P models [12] are frequently used to describe and simulate interaction processes in organizations with network structure and autonomous decision makers. Actors, representing employees in integrated information space, are the peers of the network as they are enough autonomous enough to make decisions and to use their own resources for project execution.

Key features of P2P networks making them applicable for modeling matrix management systems are:

- decentralization that assumes the distribution of responsibility between the actors.
- resources sharing, meaning that employees are sharing their knowledge and skills during project execution.
- autonomy: actors are taking decisions in respect of the tasks they are executing.

Different strategies and rules can be applied to study the employees' interactions in organizations with matrix structure are reviewed in game theory [13]. P2P network representing the matrix structure of the enterprise can flexibly adapt to the incoming flow of complex projects' tasks using the principles of network interaction.

On the basis of the existing approaches we propose a P2P outsourcing model for agile project management that considers the features of various strategies combination.

IV. PROJECT MANAGEMENT IN P2P NETWORKS

The formal model of P2P interaction network can be presented as the following:

$$S_{P2P} = (U_{P2P}, V_{P2P}, F_{P2P}), \quad (2)$$

where U_{P2P} – a set of actors, V_{P2P} – a set of P2P communications, $F_{P2P} : U_{P2P} \times U_{P2P} \to V_{P2P}$ – function, defining the communication between the actors.

The transformation of previously defined Enterprise structure into P2P network $M \to S^0_{P2P}$ is implemented by the project management Centre of the Enterprise which builds the initial network of actors. At this stage the set of all possible actors $U^0_{P2P} \subseteq U_M$ is generated including any potential resource that will be involved in project implementation.

It should be also considered that the number of complex simultaneously running projects can be very high depending on the size of the enterprise and these projects can have interdependencies. Thus the flow of tasks coming from different complex projects $P_k(t)$ must be executed in a flexible organizational structure of P2P network $S_{P2P}(P_k(t))$, which can constantly adopt to new projects: $F_{P2P}(P_k(t)) : U_{P2P} \times U_{P2P} \to V_{P2P}(P_k(t))$.

To manage the incoming flow of complex projects flow in vertically integrated companies the following algorithm is proposed (see Fig. 2). The algorithm consists of initiation and dynamic scheduling stages. During the initiation stage the P2P network is defined and the initial schedule is built. While new projects arrive, the P2P network is constantly changing together with corresponding staff changes. Dynamic scheduling in its turn provides an efficient tool for operational project management.

Stages 4 – 6 of the algorithm are based on the classical project management approach.

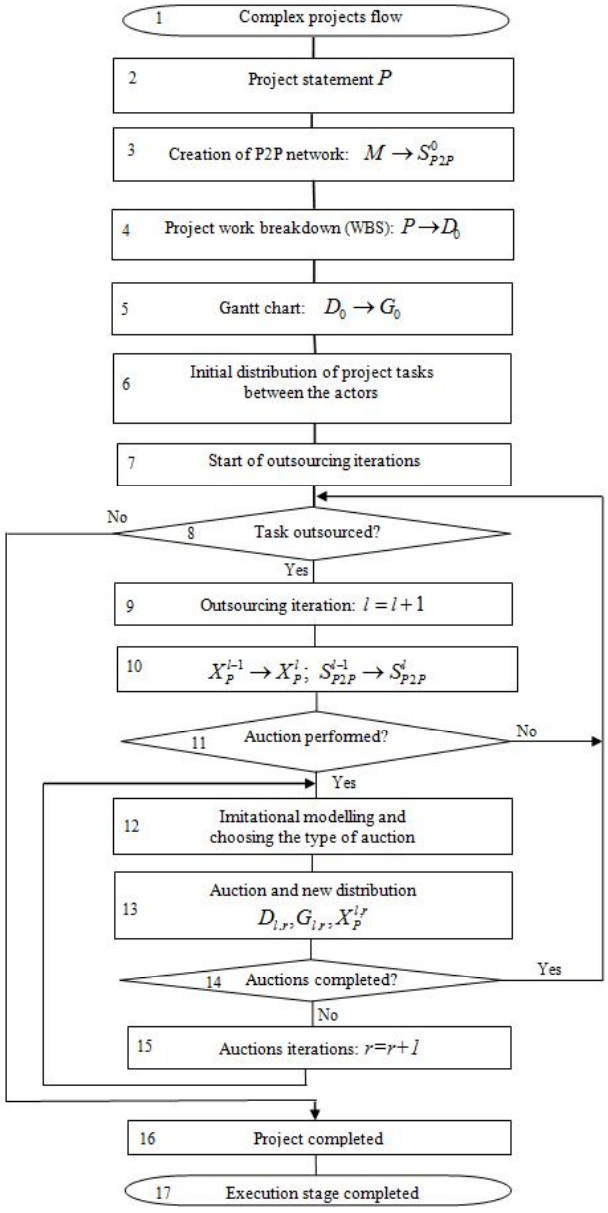

Fig. 2. Algorithm of projects' tasks flow management in P2P nets

At the input we are getting the complex project:

$$P = (Z_P, T_P, C_P), \tag{3}$$

where $Z_P = \{z_1, ..., z_{N_Z}\}$ – the set of complex project tasks, $T_P = \{(t_1^*, \Delta t_1^*), ..., (t_{N_Z}^*, \Delta T_{N_Z}^*)\}$ – the set of deadlines defined for each tasks and the timeframes of their execution; $C_P = \{c_1, ..., c_{N_Z}\}$ – the costs of each task which can be defined at the current level of project decomposition.

The schedule of the project after the initial decomposition can be presented in a form of Gantt chart to define the timelines and logical sequence of the tasks

$$G = (Z_P, T_P, V_G), \tag{4}$$

where V_G – predecessor/successor connections between the tasks.

When the project work breakdown is completed and Gantt chart with critical part flow is built the project tasks must be initially distributed between appropriate executors who can compile with this tasks. For this purpose they are divided into groups according to their project roles $L = \{L_1, L_2, ..., L_{10}\}$.

To enable more or less accurate distribution information about employees' competences, qualification, working experience, personal characteristics, aims and goals within the company is required. This information can be acquired from HR service or motivational programs.

Employee qualification $u_n \in L_n$ is characterised according to their experience of previous similar job execution and it can be measured by the following parameters:

- performance w_n – an approximate number of tasks executed during the month;
- quality q_n – a number of corrections to already executed tasks.

The set of required qualification requirements $q_i^{\det} = (w_i^{\det}, q_i^{\det})$ is used to select the executor.

There is a number of other restrictions affecting the allocation process should be considered. In general it can be formulated as the following:

$$\sum_{n=1}^{N_U} b_{ni}^k x_{ni} \;\; \omega \;\; 0; \quad \omega \in \{=, \le\}, \quad k = \overline{1, K} \tag{5}$$

where b_{ni}^k – are the constant coefficients, K – the number of such coefficients.

To build the initial schedule a discrete optimization problem with the minimal project cost criteria must be solved:

$$C = \sum_{n=1}^{N_U} \sum_{i=1}^{N_Z} c_{ni} x_{ni} \to \min \tag{6}$$

where c_{ni} is the cost of the task defined according to its capacity and qualification requirements,

and $x_{ni} = \begin{cases} 1, \text{if task is allocate to actor,} \\ 0, \text{if task is not allocated.} \end{cases}$

This is a complex problem which in practice is usually solved by the methods of nonlinear programming for example using branch and bound algorithm.

V. AGILE TASKS DISTRIBUTION IN MATRIX ORGANIZATIONAL STRUCTURES

When the initial schedule is received and P2P network is already formed the process of proactive tasks' distribution between actors in P2P network is started. To manage this process the following approach is proposed based on P2P interaction, outsourcing and virtual auctions [14, 15].

The aim of actor's interaction in P2P network is to enable timely project implementation with minimal cost. This goal is achieved by providing the actors with a certain level of autonomy enabling them to manage their project tasks. Actor owns a set of tasks after initial distribution and decides which tasks he would like to outsource.

Throughout the outsourcing process the task exchange mechanism is started. It enables the actors to accept new tasks to their existing pool. Tasks can be also decomposed into simple subtasks and fully or partly outsourced to other actors, who will execute these tasks for lower cost.

These basic principles of outsourcing mechanism inside P2P network can be described in a form of events.

1) Event e_{ni} defines the allocation of the task to the actor:

$$e_{ni}(z_i, u_n, t_{ni}), \tag{7}$$

where z_i – the assigned task, $i = \overline{1, N_Z}$ – task index, u_n – actor, $n = \overline{1, N_U}$ - actor index, t_{ni} – the time of the event.

Directive allocation is required to perform initial distribution and to manage conflict situations when there are no actors accepting the tasks during the outsourcing process.

2) Event e^d_{ij} defines decomposition of task z_i into a set of subtasks $\{z_{ij}\}$, which is made by actor u_n:

$$e^d{}_{ij}(z_i, \{z_{ij}\}, u_n, t''_{in}), \tag{8}$$

where $\{z_{ij}\}$, $j = \overline{1, J_{nj}}$, – is a set of subtasks received in the result of decomposition, J_{ni} – the size of the set.

3) Event e_{nijm} corresponds to transfer of task z_{ij} to actor u_m for outsourcing:

$$e_{nijm}(z_{ij}, u_n, u_m, t'_{ijm}) \tag{8a}$$

where u_n – are the actors, $n, m = \overline{1, N_U}$.

The aim of task decomposition is to receive the tasks of smaller size what will make them more clear and attractive for other actors. Actors that do not have certain competencies cannot execute complex tasks for the reason of their limited experience, but they can take the arts of these tasks what guaranties the quality and the time of their work.

In other words, the proposed approach helps to reduce the level of uncertainty and minimize the costs of the whole project, what can be formulated in a form of non-linear optimization problem the mathematical presented objective function:

$$\sum_{n=1}^{N_U}\sum_{i=1}^{N_Z}\sum_{j\in J_{ni}}\sum_{m=1}^{N_U}(c_{nij}\cdot x_{ni} - (c_{nij}x_{ni} - c_{nijm})y_{ijm}) \to \min, \tag{9}$$

with the following restrictions:

$$\forall z_i, u_n : t^{\lambda}_{i,n} \le T_i, \quad i = \overline{1, N_Z}; \quad n = \overline{1, N_U}; \tag{9a}$$

$$c_{nij}x_{ni} - c_{njim} \ge 0; \quad \forall i, n, j, m; \tag{9b}$$

$$\sum_{j\in J_{ni}} c_{nij}x_{ni} - \sum_{j\in J_{ni}}\sum_{m=1}^{N_u} c_{nijm}y_{nijm} \ge c^D_{ni}; \quad \forall i, n; \tag{9c}$$

$$\sum_{n=1}^{N_U} x_{ni} = 1; \qquad \sum_{m=1}^{N_U} y_{ijm} = 1; \qquad i = \overline{1, N_Z}, \quad j \in J_{jn}, \tag{9d}$$

where c^D_{ni} – is the size of actors income organizing the outsourcing, including the overheads; x_{ni}, y_{ijm} – Boolean variables; $c_{ni}, c_{nij}, c_{nijm}$ – the initial cost of corresponding project tasks.

VI. IMPLEMENTATION RESULTS

The described above approach was implemented in P2P outsourcing management system and was approbated by Haulmont Development Ltd as a part of ERP system automating the business process of Alliance Oil Company Ltd, a vertically integrated oil company with matrix organizational structure.

Most of oil companies are vertically integrated, which means that they have a large number of departments and organizational units working together on same projects, such as design of new facility for oil extraction and processing, geologic exploration, business processes reengineering, IT projects, etc. To manage the process of complex projects execution in vertically integrated oil companies the modern agile methodologies including the set of optimization tasks, models of P2P interaction, outsourcing procedures and virtual auctions are being developed and approbated nowadays.

Vertical integration in oil industry implies organizational and financial union under single management of companies covering all stages of technological stages from oil prospecting and extraction – transportation – refining – and sales.

Interaction between the actors takes place in multi-agent integrated information environment [16], which receives defectively appointed tasks from scheduling modules and returns back the updated information on executor change and new timeframes and cost of the task. Software agents simulate the behavior of actors: receive the tasks, decompose them as part of the scheduling procedure and produce auctioning to allocate the decomposed subtasks that do not fit into the schedule.

The resulting solution produced by the agents is presented to each actor for approval. In case of any manual changes, additional scheduling procedure is performed in order to coordinate tasks allocation and bring the schedule to a consistent state. Therefore, the same approach is used for manual outsourcing and its simulation in multi-agent software.

The architecture of P2P outsourcing management system is based on open interfaces (see Fig. 3). The system is using Enterprise Service Base to work the ERP system of the Company. Information about the projects and employees is received as the input and in the output the concrete tasks are generated and update that can be reviewed using classical task management module of the ERP. Auctions playgrounds module is used to outsource projects tasks and thus solving the objective function (9).

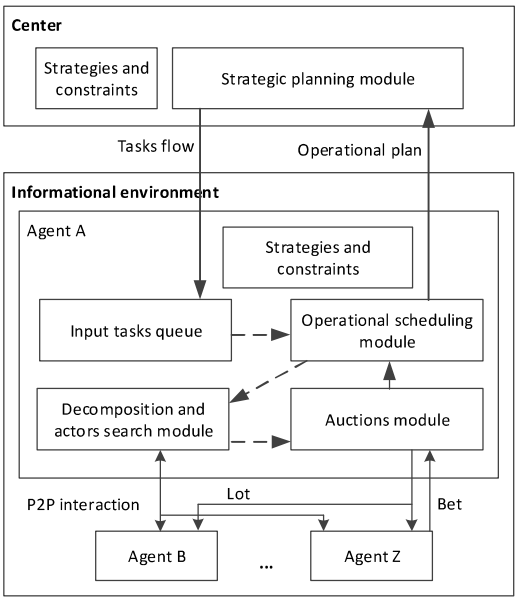

Fig. 3. P2P outsourcing management system

The described above solution was implemented based on CUBA platform [17]. CUBA platform is a high level Java framework designed for fast enterprise software development built on industry-leading open source technologies. CUBA addresses generic enterprise software requirements with numerous pre-built features like data-aware visual components, universal data filter, reports, charts, fine-grained access control, user actions audit, full-text search, credit cards processing, etc.

CUBA applications can be seamlessly integrated into most IT environments thanks to rich web interface, generic REST API, support for the most popular databases and application servers. Cluster support ensures that applications can scale to the needs of the business. With all the efficiencies of a high level framework, CUBA is an open and developer-friendly platform. It comes with open source code and any part of the platform can be overridden to match the needs of your project. The applications have a transparent DB structure and are developed purely in Java.

P2P network service module supports the P2P infrastructure representing the matrix organizational structure of the company. It updates information about the actors and their skills, which is stored in Knowledge Base (see Fig. 4).

Quantitative and timing characteristics have been chosen as the initial parameters to perform system analysis of employees' interaction within the company. Three complex IT projects of different scale have been chosen for approbation purposes:

1) *Financial service automation.* Project workload – 11 400 hours. Involved resources described by Table I.
2) *Procurement service automation.* Project workload – 5 700 hours. Involved resources described by Table II.
3) *Automation of human resource efficiency management.* Project workload – 3 200 hours. Involved resources described by Table III.

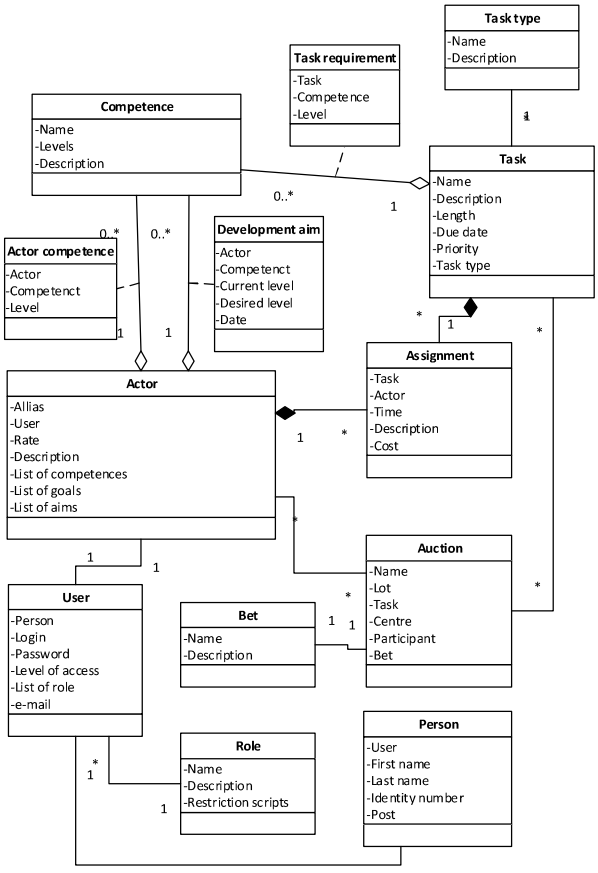

Fig. 4. The Knowledge Base structure of P2P outsourcing management system

TABLE I. RESOURCES IN FINANCIAL SERVICE AUTOMATION

Role	Number of actors
Financier	8
Analyst	3
Developer	4
Quality assurance	2
System administrators	4

TABLE II. RESOURCES IN PROCUREMENT SERVICE AUTOMATION

Role	Number of actors
Procurement manager	4
Economist	2
Analyst	2
Developer	3
Quality assurance	1
System administrators	2

TABLE III. RESOURCES INVOLVED IN AUTOMATION OF HUMAN RESOURCE EFFICIENCY MANAGEMENT

Role	Number of actors
HR manager	3
Analyst	1
Developer	2
Quality assurance	1
System administrators	2

To measure the efficiency the projects with similar participants, workload and timeframes implemented in the company during the last years have been chosen. Projects were compared in the speed ratio of their implementation, what characterizes how faster the project using P2P outsourcing approach is being implemented. Percentage of project plans execution has been captured during 20 check points as a speed ratio (see Fig. 5).

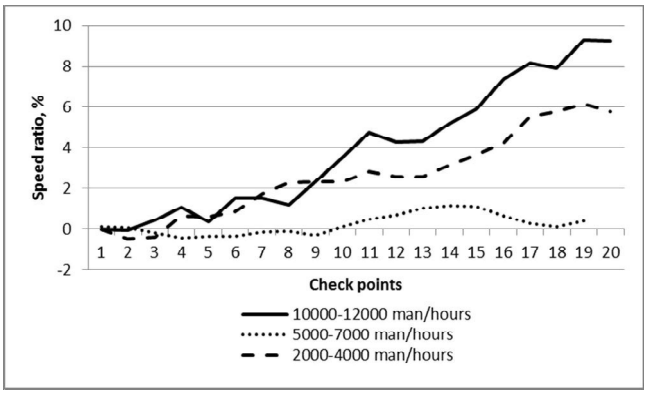

Fig. 5. Efficiency of P2P for projects with different labor workload

The provided comparison demonstrates that the efficiency of P2P outsourcing approach increases in accordance with project complexity. The greater number of tasks the project has, the harder it is to manage them what actually provides the field for optimization. It is proven by Fig. 6. The performed comparative analysis has also shown that the number of decompositions is mostly affected the number of tasks then the overall workload.

Application of P2P outsourcing management system in the process of task distribution for the mentioned projects as part of agile project management system enabled to improve the project conversion on 10-15%.

VII. CONCLUSION

The solution of P2P outsourcing for agile project tasks allocation can be useful for intelligent scheduling of projects at different enterprises that require high autonomy and motivation of executives that can participate in project management processes as valuable decision makers.

Implemented by a multi-agent technology this solution becomes a powerful tool of project management as part of a workflow system, enterprise resources planning system or product lifecycle system at enterprises with distributed or matrix organizational structure.

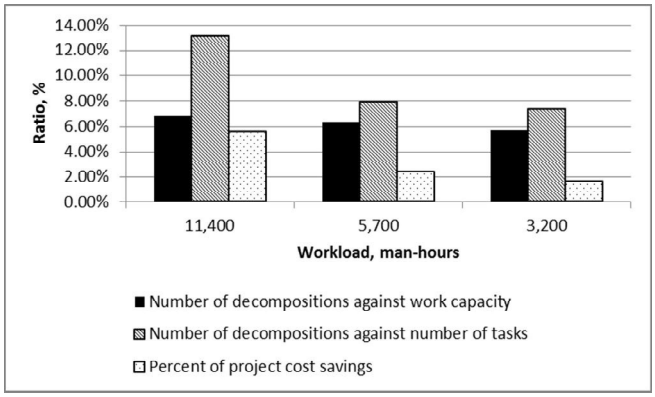

Fig. 6. Decompositions and cost savings for projects with different labor workload

REFERENCES

[1] A. Ivaschenko and A. Lednev, "Auction model of P2P interaction in multi-agent software", *Proceedings of the 5th International Conference on Agents and Artificial Intelligence*, ICAART 2013, Barcelona, Spain, Vol. 1, 2013, pp. 431-434.

[2] A. Ivaschenko and A. Lednev, "Time-based regulation of auctions in P2P outsourcing", *Proceedings of the 2013 IEEE/WIC/ACM International Conferences on Web Intelligence (WI) and Intelligent Agent Technology (IAT)*, Atlanta, Georgia, USA, 2013, pp. 75 – 79.

[3] Cole. "General discussion of Vertical Integration". Bereau Economy and Business Research, U. III., No. 74, 1952.

[4] R.C. Ford and W.A. Randolph, "Cross-functional structures: A review and integration of matrix organization and project management" *Journal of management*, 18.2, 1992, pp. 267-294.

[5] C. Larman, "Agile and iterative development: a manager's guide", Addison-Wesley Professional, 2003, 368 p.

[6] IEEE Guide – Adoption of the project management institute (PMI(R)) Standard A Guide to the Project Management Body of Knowledge (PMBOK(R) Guide) – Fourth Edition IEEE, 2011, 508 p.

[7] M. Servello and M.W. Evans, "Work breakdown structure. Encyclopedia of Software Engineering", John Wiley & Sons, 2002

[8] N. Minar, "Distributed systems topologies: Part 1", 2001, http://www.openp2p.com/pub/a/p2p/2001/12/14/topologies_one.html>

[9] N. Minar, "Distributed systems topologies: Part 2", 2002, http://www.openp2p.com/pub/a/p2p/2002/01/08/p2p_topologies_pt2.html>

[10] P. Leitao, "Holonic rationale and self-organization on design of complex evolvable systems", *HoloMAS 2009*, *LNAI 5696*, Springer-Verlag Berlin Heidelberg, 2009, pp. 1-12

[11] J. Broberg, S. Venugopal and R. Buyya, "Market-oriented grids and utility computing: The state-of-the-art and future directions", *Journal of Grid Computing – GRID*, vol. 6, no. 3, 2008, pp. 255-276

[12] D. Schoder and K. Fischbach, "Peer-to-peer prospects", *Communications of the ACM*, vol. 46, no. 2., 2003, pp. 27-29

[13] R.M. Myerson, "Game theory: analysis of conflict", London: Harvard University Press, 1997, 568 p.

[14] P. Bolton and M. Dewatripont, “Contract theory”, Cambridge: MIT Press, 2005, 688 p.

[15] V. Krishna, “Auction theory”, 2nd edition, Burlington, MA: Academic Press, 2009, 336 p.

[16] A. Ivaschenko, “Multi-agent solution for business processes management of 5PL transportation provider”, *Lecture Notes in Business Information Processing*, Vol. 170, 2014, pp. 110-120

[17] CUBA platform [Online], https://www.cuba-platform.com/