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**BUILDING AN INNOVATIVE PROJECT TEAM USING
COMBINATORIAL ANALYSIS**

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Abstract

This study is devoted to the development of an algorithm for creating a temporary (2–5 years) project group to solve problems dictated by the innovative vector of business development. The authors have noted that knowledge workers are the main factor of any design and innovation activity. It has been shown that methods for assessing the competence of knowledge workers should differ materially from those used to evaluate “manual“ workers or clerks. Search, selection, and management of professional skills and professionals in the field of professional development, as well as retaining the most useful and experienced knowledge workers with a company are the key activities of a Human Resources Department. The authors have substantiated the need to automate the assessment and selection of knowledge workers as a basis for the implementation of innovative projects. The developed algorithm takes into account the different qualifications of specialists engaged in a particular project, as well as the forced employees’ dead time at certain stages of job performance. To illustrate the algorithm operation, we have given a numerical example of creating a team. Based on the suggested algorithm, we have highlighted the prospect of creating a software which automates all stages of creating a team including knowledge workers. The use of such software simplifies the procedure for creating teams to implement innovative project and increases the knowledge workers’ productivity.

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1. Introduction

The human capital is a key and a system-forming factor of any business system's activity and viability. All productive resources of an enterprise are implementation of the personnel's experience and knowledge in material or intellectual form. Search, selection, recruiting, adaptation, and training of personnel; management of their professional development and working efficiency, as well as retaining the most useful and experienced professionals are the key activities of a HR department (Shahbazov, 2016).

One of effective ways to do modern business is carrying out design and innovation activities. Successful implementation of this activity requires planning, evaluation, management, retention, and training of knowledge workers (Martin, 2013). This category of workers is characterized by their research and creative competences, the apparatus for assessment of which has not been sufficiently developed to date (Soo, Tian, Teo, & Cordery, 2017). There are some studies (Lysenko & Kovaleva, 2016; Lysenko & Sereda, 2018) devoted to the management of talented workers. Talented workers undoubtedly belong to the category of knowledge workers. In a project, they usually act as ideological generators. They can be referred to as top managers. Each worker of the "talent" category is unique, but this sub-group of knowledge workers is small enough. Today, effective implementation of innovative projects requires managers and experts of the middle management level, who are able to work simultaneously on several projects.

HR planning, including knowledge workers, can be divided into three types: planning of HR requirements, planning of staff recruiting (hiring), and planning of staff costs. Such important types of planning as the planning of staff training, staff retention, the planning of HR use, and the planning of layoffs. Traditionally, the the notion of "competence" includes the field of knowledge, skills, and practical experience of a worker, that are required to solve specific tasks with an enterprise. This notion also includes the scope of the employee's responsibility for solving issues related to business tasks. In fact, competence implies the suitability of an employee to perform specific business tasks. The task of assessing the competence of knowledge workers or, as stated in (Soo, Tian, Teo, & Cordery, 2017), the task of managing knowledge workers is rather difficult. The knowledge workers' competence assessment cannot be carried out by testing. The knowledge workers' competence can be reliably assessed in the interview with an employee who has a greater competence in the relevant field. Therefore, knowledge workers should not be treated as "manual" or "paper" workers, performing everyday routine jobs within their competences.

There are works that suggest evaluating the competence of specialists (including knowledge workers) on the basis of an expert evaluation based on objective data, for example, identifying trends in the development of innovative technologies and determining their respective competencies based on the analysis of trends in patent activity (Nikulchev, 2017), or based on the data of professional social networks, analyzing which you can assess the communication competence in the professional field (Plokhov, 2016).

2. Problem Statement

The traditional measure of the effectiveness of the project is the costs, time, schedule and scope of work. An innovative project is usually an interdisciplinary one; it can last for several years with or without breaks; therefore, its successful implementation requires enough knowledge workers who, probably, will not be engaged in the project implementation for a time all their working hours, and they will not necessarily have the required set of competences. Hence, the practice of productive and seamless transfer of employees

within an enterprise, who have experience and knowledge, to create temporary (for a period of 2–5 years) teams for addressing specific project or innovation tasks, is becoming more relevant.

In the modern human resources management systems (HRM-system), all processes of operational management of human resources (hiring, dismissal, timesheets, personnel transfers, etc.) are fully automated. The functions of planning, selection, and training are available only in multifunctional expert systems that are developed immediately (directly) for large business systems, taking into account the subject area of their business. For example, Oracle Human Resources Analyzer (Stephan & Gretczko 2017) plans the career development of business system's employees. The module SAP Human Resources Management System (SAP, 2018) automates the planning of staff costs, their working hours, and their use. The use of an integrated system IEX TotalView (FutureSoft, 2018) allows for creating staff's timesheets, tracking the job distribution effectiveness, determining the requirements for the level of employees' professional knowledge level and skills, but also for a contact center. Note that these solutions deal with the competence of employees engaged in routine operational activities.

3. Research Questions

This paper discusses the following issues:

- developing a sufficiently general algorithm for the formation of a team to implement an innovative project, which will take into account the competence of knowledge workers;
- showing the reduction in the timing of an innovative project, based on a concrete numerical example.

4. Purpose of the Study

The goal of this paper is developing a sufficiently general algorithm for the formation of a team to implement an innovative project with regard for the competence of knowledge workers and proving the efficiency of the algorithm for a concrete numeric example.

5. Research Methods

The algorithm is developed on the basis of combinatorial analysis methods.

6. Findings

Assuming that implementation of design and innovation activities requires performing several individual jobs A_i , let us designate them as a set of $A_1, \dots, A_i, \dots, A_N$ (1), where N is the total number of predefined separate jobs or stages thereof.

6.1. Mathematical statement of the problem

First, we will compile a correspondence table, i.e. we will define the employees who are able to perform at least one of the jobs A_i from the total set of planned jobs. In the explanatory correspondence table in Fig. 1, an “asterisk” is conditionally assigned to each participant of the job.

	A ₁	A ₂	A ₃	A _N
1	*			*	*
2			*		
3	*	*		*	*
4		*			*

Figure 01. Correspondence table of n-employees to the number of jobs N

The table in Fig. 1 shows that, for example, employee No. 1 (in the first line) is able (has the relevant skills and qualification) to perform three jobs, whereas employee No. 2 is able to perform only one type of job, etc. In other words, although the employees of this team have different skills and qualifications, they can perform a specific job by joint efforts. However, let us assume that one employee cannot perform two or several jobs simultaneously. It is also presumed that, if m employees perform job A_k , this job will be performed m times faster: T_{A_k}/m .

Our goal is minimizing the timing of performing jobs $A_1, \dots, A_i, \dots, A_N$.

Further, we introduce time values $T_1, \dots, T_j, \dots, T_N$ (2), where T_k is the time required to perform the i^{th} job by one employee. The time spent by employee i for job j shall be described as ∇t_{ij} . Thus, the total

worktime of the i^{th} employee shall be $t_i = \sum_{j=1}^N \Delta t_{ij} + \Delta t_{id}$ (3), where ∇t_{id} is the time of the possible dead

time of the i^{th} employee (the index “d” comes from English “dead time” or “delay”). We assume that the employee’s dead time can be included in the main time of his or her activity.

Given that, according to the condition above, one employee cannot perform two or several jobs simultaneously, $\nabla t_{ij} \cap \nabla t_{ik} = 0, j \neq k$ (3a) (here \cap is the sign of intersection).

Let us denote $t_i^* = \max t_i$ as the largest total worktime of the i^{th} employee. The following problem arises: we have to find a distribution of employees by all jobs for the planned time J to be minimum, i.e. we shall introduce an optimization criterion: $J = \min T^*$ (4).

6.2. Solving the Problem

Let us start from the question whether there is at least one variant where all planned jobs under the project can be performed by the available staff? Only in this case, we can consider the problem of minimization (4). Let us show that there is a solution that is far from the optimal one. For this purpose, it is sufficient to agree upon a stage-by-stage implementation of all jobs. At first, the stage of job A_1 is implemented by one employee (while the others are waiting). Then, job A_2 is implemented by the same or another employee (according to table in Fig. 1) and so on, in the same order. Then, the total time of implementing all jobs under the project shall be $\sum_{i=1}^N T_i$ (5).

Therefore, there is a trivial solution of the problem. Let us remind that T_i is the time of implementing the i^{th} job by one employee. Here, we should also note that finding a well-formalized procedure for solving

the optimization problem is rather difficult. With a high dimension of the problem, the exhaustive search method is hardly acceptable in our case. In addition, do not forget that we are dealing with a discrete problem: an employee who started a specific job, necessarily ends it. Let us show that, based on heuristic considerations, the above trivial solution (5) can be significantly improved.

The basis for further consideration is the following “stage-by-stage” approach: at each stage k, we try to use the minimum number of workers, as well as the time that was not used at the previous stages.

Assume that job A_1 can be performed by m_1 employees of the team from the total number n (see Fig. 2). Then, job A_1 can be performed for a time $T_1/m_1 = T_1^*$. Similarly, job A_i will be performed in this case for a time $T_i / m_i = T_i^*$.

	A_1	A_2	A_3	\dots	A_n
m_1 {	T_1^*				
	T_1^*	T_2^*			
	T_1^*				
		T_2^*			
		T_2^*			
	T_1^*	$T_1^* + T_2^*$			

Figure 02. Correspondence table “Job – Time” for the first two jobs. For this example, we assume that each of these two jobs can be performed by three employees

We pre-rank the timing of jobs in the table in Fig. 2 according to the following rule:

$$T_1^* \geq T_2^* \geq \dots \geq T_N^* \quad (6)$$

In our example, the second job will be started at the moment T_1^* . Therefore, jobs A_1 and A_2 will be performed for a time $T_1^* + T_2^*$, after which the third job will be started, etc.

Let us mention an important point for further consideration. As can be seen in our hypothetical case, there are employees in the team, who are free from job A_1 , being able to perform job A_2 (the two lower employees in the second column). Therefore, these two employees can perform their part of job A_2 in advance, as shown by arrows in Fig. 3. Note also that, taking into account (6), transferring these employees for implementation of their jobs at the stage A_1 would result in dead time $\Delta t_{id} = T_1^* - T_2^*$, that is included by us in the optimization criterion (4).

	A_1	A_2	\dots	A_N
T_1^*				
T_1^*	T_2^*			
T_1^*				
T_2^*	←			
T_2^*	←			
	T_1^*	$T_1^* + T_2^*$		

Figure 03. Correspondence table “Job – Time” for the first two jobs with transferring two specialists for advanced performance of job A_2

Further, the procedure continues in the same way for jobs $A_3 \dots A_N$. As a result, we find the time of performing all jobs A_1 to A_N . For more clarity of this procedure, we will consider below a simple example of solving the problem for the selected optimization criterion.

Note: Given that, in our case, specialists can have different qualification, the time of performing job A_i by employee “k” shall be equal to T_{ik} , where $k = 1 \dots n$. For example, let us assume that job A_1 can be performed by “ m_1 ” employees having different qualifications. Then, time T_1^{**} of performing this job, instead of T_1/m_1 , as previously assumed with an equal qualification of employees, shall be equal to:

$$T_1^{**} = \frac{1}{\frac{1}{T_{11}} + \dots + \frac{1}{T_{1m}}} \quad (7)$$

In this case, we shall add the values of time T_1^{**} , calculated according to (7), to the relevant cells of the tables in Figs. 2 and 3.

6.3. Numerical example

Let assume that five jobs $A_1 \dots A_5$ ($N=5$) shall be performed by four employees ($n=4$). In this case, according to (6), we assume that $T_1 = 5$ months (m), $T_2 = 4$ m, $T_3 = 3$ m, $T_4 = 2$ m, and $T_5 = 1$ m. Presume that specific workers (marked by asterisks), who implement an innovative project, are ranked in the table in Fig. 4 in the same order as the project manager has ranked them, given their qualifications and skills.

	A_1	A_2	A_3	A_4	A_5

Figure 04. Example of specialists’ distribution by jobs

From the table in Fig. 4, we can see, in particular, that the job is performed in the conditions where specialist n_1 is able to perform jobs on four sites; worker n_2 can be engaged in three jobs, etc. At the same time, job A_1 can be performed by three people (for example, programming specialists), whereas job A_4 can be performed only by two of four persons. It is assumed that,

$m_1 = 3$, $m_2 = 3$, $m_3 = 3$, $m_4 = 2$, and $m_5 = 3$. From the table in Fig. 4, let us find the time values T_i^* : $T_1^* = 5/3$ m, $T_2^* = 5/3$ m, $T_3^* = 4/3$ m, $T_4^* = 2/2 = 1$ m, and $T_5^* = 1/3$ m. As we can see, condition (6) is met in our case.

Stage 1: Let us redraw the table in Fig. 4 for jobs A_1 and A_2 :

	A_1	A_2	A_3	A_4	A_5
	5/3		*	*	*
	5/3	4/3			*
	5/3	4/3	*		*
	←	4/3	*	*	
	5/3	$5/3 + 4/3 = 3$			

Figure 05. Table to determine the completion time of jobs A₁ and A₂

As we can see, the fourth specialist in job A₂ can perform his or her job A₂ for a time T₁^{*}, as he or she is not engaged in job A₁. Thus, jobs A₁ and A₂ have been performed for a time T₁^{*} + T₁^{*} = 3 months.

Stage 2: Let us redraw the table in Fig. 5 for jobs A₁, A₂, and A₃:

A ₁	A ₂	A ₃	A ₄	A ₅
5/3	3/3	←	*	*
5/3	4/3			*
5/3	4/3	3/3		*
4/3	3/3	←	*	
5/3	3 + 1 = 4			

Figure 06. Table to determine the completion time of jobs A₁, A₂, and A₃

From the table in Fig. 6 in our example, we determined the completion time of the third job: 4 months. According to (6), for all “transferred” employees, there will be a certain dead time: a “transferred employee” can idle until his or her colleagues in the previous job have completed their, more long job.

Continuing in the same way, we get the correspondence table in its final form.

A ₁	A ₂	A ₃	A ₄	A ₅
5/3	3/3	←	1/3	
5/3	4/3	←	←	
5/3	4/3	3/3	←	
4/3	3/3	←	←	
5/3	3	4	4½	

Figure 07. The final form of the correspondence table to calculate the completion time of all jobs

As follows from the table in Fig. 7, all jobs under the project can be completed for 4½ months. Let us remind that, in our example (5), the trivial solution of the problem, based on a stage-by-stage (consecutive) performance of jobs A₁ ... A_N makes the implementation time of all the project which is equal

$$\text{to } \sum_{1..5}^5 = 15 \text{ months.}$$

7. Conclusion

Based on a combinatorial analysis, the suggested general algorithm to create a team for an innovative project, including knowledge workers, makes it possible to significantly reduce the implementation timing of innovative projects, based on a minimization criterion as defined in this study. The suggested algorithm takes into account different qualifications of employees engaged in a particular project, as well as the forced dead time of employees at various stage of job performance. The further development of this study presumes creating a software implementation based on this algorithm, which could simplify the procedure

for creating teams of knowledge workers, as well as to increase their productivity in design and innovation activities in the research, engineering, and education fields.

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