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# CALCULATION OF TIME TO COMPLETE A TASK BY A GROUP OF EMPLOYEES USING FUZZY SETS FOR THE SUSTAINABLE DEVELOPMENT OF THE ENTERPRISE*

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**Abstract.** The article considers the use of fuzzy sets in determining the execution time of tasks. An approach is proposed that makes it possible to obtain an expert estimate of the time taken to complete a task by a specific employee in the form of a fuzzy set. A procedure is proposed for generalizing fuzzy sets defined on different bearing sets. To apply the proposed procedure, fuzzy sets are subject to continuity and monotonicity restrictions. The generalization procedure is based on the process of finding the value of a fuzzy set for a certain value of its membership function. For piecewise linear functions, the operation of calculating the points of the resulting function is defined. Piecewise nonlinear functions are considered and an algorithm for searching for individual values of the generalized membership function is described. In addition to generalizing fuzzy sets, an approach to calculating the interaction time of workers is proposed. Various approaches to defuzzification of fuzzy sets of task execution time are considered. The proposed approach will improve the work planning for sustainability of enterprise.

**Keywords:** fuzzy set; execution time to task; membership function; generalization procedure; interaction time for workers

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**JEL Classifications** A31, C41, M12

**Additional disciplines:** mathematics; information and communication

## 1. Introduction

Determining the time to complete a task is one of the main problems in planning work. Currently, approaches are being applied related to expert estimates of the time taken to complete the task. In this case, the expert is usually the leader, who, based on his experience in carrying out such projects, splits it up into tasks and estimates the time

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it takes to complete them in the form of a certain value. In addition, the leader sets the sequence of tasks in terms of the logic of their possible implementation (Fridlyanov, 2017).

Information on estimating task execution time and their relationship is used in the CPM (Critical Path Method) method (George E. 2016, Kiran D.R. 2019), which allows one to single out tasks of the so-called "Critical Path", i.e. tasks, changing the runtime, which will lead to a change in the runtime of the entire project. But this algorithm lacks the visibility and ability to manage resources. To eliminate the shortcomings of CPM and attract the leader directly to the calendar distribution of tasks, Gantt charts (Nahmias S. 2013, Wilson J.M. 2003) are used, which are primarily aimed at visualizing the process of performing work and occupying individual resources. At the same time, in Gantt charts, in addition to automatic task setting by the CPM method (for early start and finish positions), there is the possibility of manually changing the task start time. But it is worth noting that the number of allocated resources, for example, employees, can also change the duration of work, which is not taken into account either in the CPM method or in Gantt charts.

When developing science-intensive projects, the evaluation of the duration of individual tasks is impossible by the leader, since such work has not been carried out before. For such cases, an estimate of the time taken to complete the task directly by the employee or the leader of a small working group is used. But such an assessment is almost impossible to give in cases when several workers perform the same task at the same time. For such cases, they try to provide employees with smaller tasks designed for a short time of their implementation. For example, when developing software, the SCRUM methodology (Bott 2019, Darshita K.2019, Levine M.K.2019, Marques R. 2020, Ridewaan 2020) is used, which splits work up into weekly stages (sprint) with daily status checks.

Modern work on the use of fuzzy sets in task planning is usually based on the task of fuzzy resource allocation and the possibility of mathematical work planning taking into account these resources. (Stephen W. 1986, Piegat A. 2001, Wen-Xiang 2006, Zatsarinny A. 2019) At the same time, works devoted to fuzzy execution time of tasks are based mainly on triangular fuzzy sets. (Didier 2010, Kanmohammadi 2004, Matthew 2008, Nasution 1994, Mohammad 2008, Shih-Pin 2008) For the fuzzy set "employee performing the task", it is necessary to set the membership function $\nu_{i,j}(t)$ with saturation, for the fuzzy variable $t_{i,j}$, which determines the execution time of the task of the j-th type for the i-th employee. If several employees are assigned to a single task, then the time to complete this task will be shorter, and to evaluate this time, the concept of employee productivity is often used, which is calculated as the inverse of the time to complete the work, i.e. $p_{i,j} = 1/t_{i,j}$. The membership function $\mu_{i,j}(p_{i,j})$ with saturation, for the fuzzy variable $p_{i,j}$ is determined by the formula $\mu_{i,j}(p_{i,j}) = 1 - \nu_{i,j}(t_{i,j})$. To obtain the total productivity of all the workers assigned to the task, it is necessary to carry out the operation of generalizing the fuzzy productivity sets of these workers. But the generalization operation is defined for fuzzy numbers or for fuzzy functions defined on identical bearing sets. The paper proposes an algorithm for performing the generalization operation for fuzzy functions defined on various bearing sets under certain restrictions.

## 2. Description of the method of obtaining membership function

The membership function $\nu_{i,j}(t)$ can be defined as a piecewise function. In this case, to set the piecewise membership function, you can use the PERT method (Carl 2008, Ganesan 2019, Goman 2019, Kanmohammadi 2004) etermining the time to complete each work using a formula that uses optimistic, pessimistic, and expected time to complete the work: $t_w = {}^{1}/_{6} * (t_o + 4 * t_e + t_p)$. Pessimistic and optimistic terms can be calculated based on statistical methods or forecast. The expected time to complete the work can be determined by expert assessment, including with the involvement of the employee. In the general case, it is not necessary to be limited to 3 values. But the function $\nu_{i,j}(t)$ must be continuous and monotonic. For an optimistic period, the value of the membership function $\nu_{i,j}(t) = 1$, and for a pessimistic one, $\nu_{i,j}(t) = 0$.

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When assessing, in addition to the time it takes to complete the task, it is advisable to identify the positive and negative risks associated with the task. Negative risks are those that can increase the duration of the task, and positive risks – can reduce. For the time proposed by the employee to complete the task, we determine the probability of its completion. If the employee finds it difficult to give an assessment, then it can be suggested to determine several times and indicate for them the probabilities of the task. Notice that with an increase in the task time, the probability of its completion should not decrease.

## 3. Calculation of overall performance

For all employees assigned to this task, calculate their total productivity by the formula:

$$p_j = \sum_{i \ni I_j} p_{i,j}, \quad (1)$$

where $p_j$ – is the performance when performing the j-th job; $I_j$ – the set of all employees assigned to the j-th job; $p_{i,j}$ – productivity when performing the j-th job by the i-th employee.

The sum of the fuzzy sets $p_{i,j}$ is based on the principle of generalization.

$$\mu_j(p_j) = \max_{p_j = \sum_{i \ni I_j} p_{i,j}} (\min_i(\mu_{i,j}(p_{i,j}))) \quad (2)$$

Similar formulas are used when combining fuzzy numbers, and for fuzzy sets, the union procedure is used only in the case of identical bearing sets (Annaxsuel 2020, Bhowmik 2017). In our case, both workers have different, continuous bearing sets. If we carry out the generalization procedure by nodal points, then the generalized function loses its monotony (Fig. 1, red graph). If you sort through all possible combinations of points, you can get the graph, marked in Figure 1, with a blue function. From the analysis of the graph it is clear that sorting by nodal points does not allow us to calculate the generalized function. And the process of exhaustive search, in addition to computational complexity, requires setting the step accuracy (Kolesnik 2020, Formalev 2019).

For a more efficient procedure for calculating the values of the membership function, we use the properties superimposed on the function $\nu_{i,j}(t)$: continuity and monotonicity. The transformations that are carried out to obtain $\mu_{i,j}(p)$, preserve the properties of continuity and monotonicity for this function as well. The continuity properties and boundary conditions that determine the values of $p_{i,j}$, in which the value of the membership function $\mu_{i,j}(p)$ takes on the values 0 and 1, guarantee that after the generalization procedure, the calculated membership function $\mu_j(p)$ will take all values are from 0 to 1, i.e. for $\forall \mu \in (0..1)\ \exists p: \mu_j(p) = \mu$. The monotonicity property of membership functions of fuzzy employee productivity functions $\mu_{i,j}(p)$ allows us to conclude that the generalized membership function $\mu_j(p)$ will also be monotonic and the condition will be satisfied for it: $\forall p1, p2: p1 > p2\ \mu_j(p1) \geq \mu_j(p2)$.

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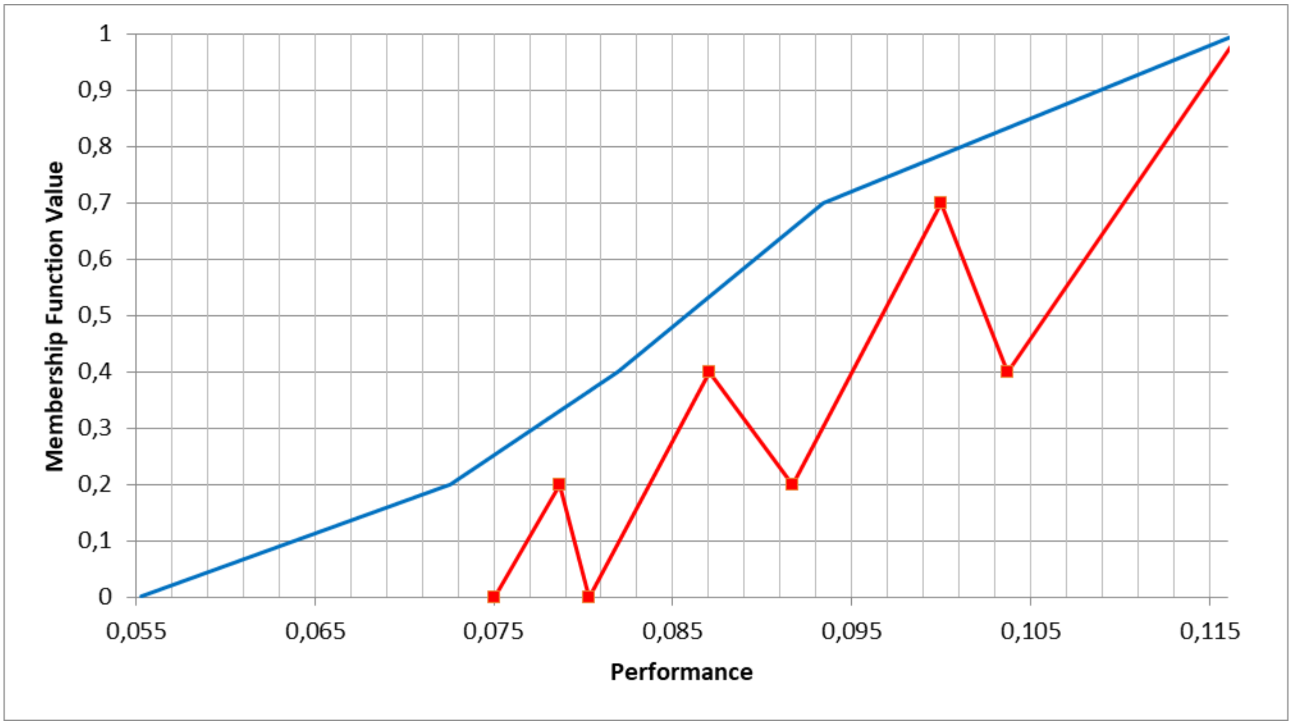


**Figure 1.** The membership function of the overall performance

Proposes to search not for the value of the membership function for a specific performance value, but for solving the inverse problem. From the generalization formula (2), we can conclude that the maximum value of the membership function will be equal to the values of all membership functions of individual workers $\mu_{i1,j}(p_{i,j}) = \mu_{i2,j}(p_{i,j})$. Since in this case the best value $\min_i(\mu_{i,j}(p_{i,j}))$ is achieved. An increase in at least one of the values $\mu_{i,j}(p_{i,j})$ will lead to a decrease in other values provided that the productivity value is constant $p_j = \sum_{i\ni I_j} p_{i,j} = \text{const}$. This conclusion can be made due to the properties of monotonicity and continuity of membership functions of fuzzy functions.

$$\mu_{i1,j}(p_{i,j}) = \mu_{i2,j}(p_{i,j}) = \max_{p_j=\sum_{i\ni I_j} p_{i,j}} (\min_i(\mu_{i,j}(p_{i,j}))) = \mu_j(p_j) \colon \forall i1, i2 \quad (3)$$

$$p_j = \sum_{i\ni I_j} p_{i,j} \colon \mu_j(p_j) = \mu_{i,j}(p_{i,j}), \text{для } \forall i \ni I_j, \forall \mu_j(p_j) \in (0..1) \quad (4)$$

Based on the fact that the generalized function is piecewise linear, it is possible to consider not all the values of the generalized membership function, but only the values equal to the inflection points of the membership function of the fuzzy function of each employee assigned to work, since the derivative between them does not change.

For nonlinear monotonic, continuous functions, the rules for calculating the generalized membership function (3, 4) will be similar. An algorithm for passing along the points of change in the graph of the membership function is suitable, since between these intervals the formula of the generalized function remains undefined, but the equation of the generalized function will not change. In calculations (3, 4), it is necessary to determine the productivity value for a given value of the membership function. Since the value of the membership function is the ordinate, it is necessary to use a pre-calculated inverse function. This approach is not always possible, since some functions, for example parabolas, have rather complex inverse functions, moreover, having several abscissa values accuracy (Formalev 2019, Formalev 2020). In this case, it is necessary to impose restrictions on a complex analytical

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function that will leave one solution. This problem must be solved before the calculations of the "common" functions themselves, when forming the initial membership functions of the employee's execution time of the task and their parameters.

## 4. Employee interaction

If the interaction is determined by a scalar value, possibly depending on the quantity and quality of workers, then the lead time must be shifted by an appropriate amount. In the case when the time spent on interaction is specified in the form of a fuzzy function with a piecewise membership function, it is necessary to carry out the procedure of generalizing the membership function of the total time of the work and the time spent on the interaction of workers.

Since the main problem of fuzzy sets is the complexity of their task, it is worth giving an example of the procedure for determining the time of interaction between employees. If you imagine the most non-optimal case of interaction, then it can be described by the phrase: "If you want to do well, do it yourself." In this case, a more experienced worker, i.e. the worker who does the work faster educates the inexperienced to a conditional level. In this case, you can choose a clear number equal to the difference in the pessimistic time of the work performed by the employees or as a maximum of the membership function $\gamma_{i1,i2,j}(t)$ of the fuzzy interaction function of two workers, calculated by the generalization principle (5). It should be noted that this time is quite large and should be taken with the interaction coefficient $k_{\text{itr}} \in (0{,}1..0{,}3)$.

$$t_{itr} = \max_t(\gamma_{i1,i2,j}(t)) = \max_t(\nu_{i1,j}(t_{i1,j}) - \nu_{i2,j}(t_{i2,j})), \text{for } \forall\, i1, i2 \ni I_j \quad (5)$$

If we consider all the possible interactions between employees, then this time will greatly affect the overall time of the task. The interaction between employees can be represented as a fully connected interaction graph G (V, E), where V is the set of vertices corresponding to the workers, and E is the set of arcs corresponding to the interactions between them and determining the necessary time. For example, Figure 2 shows a graph of the interaction of six workers. The total time required for interaction is equal to the sum of all values of the graph arcs, and for our example it is equal to 77. In this case, we should set low $k_{itr} = 0{,}05$ since the time 77 is very excessive and most likely exceeds the time required to complete the work. Another case, we can consider only the arcs that form the Hamiltonian path (Chartrand 1983) (marked in bold lines in Figure 2). The Hamilton path in this case will describe only communication between employees of the same "skill" and will be a rather optimistic time, since most other types of communication in the group are most often required. In this case, the interaction time will be equal to 14 and $k_{itr}$ should be taken in the interval (0.1; 0.5). But calculating the Hamiltonian path is a very laborious task.

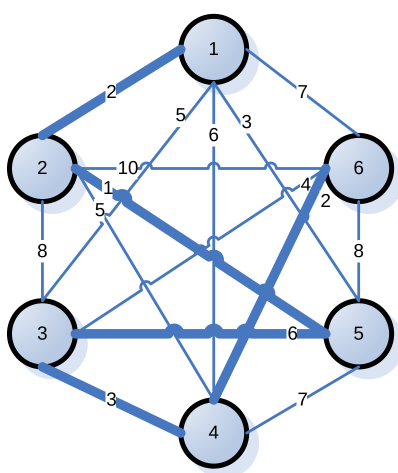


**Figure 2.** Graph of interaction between employees

As an adequate estimate of the interaction time, you can use the estimate of the interaction time of each employee only with the employee who has the most experience, i.e. performing this work in the least amount of time. This approach is similar to the interaction of the department head with his subordinates and, on the whole, with a fairly small error can describe all the necessary interactions in the team. In addition, this approach is quite simple to implement and calculate. For Figure 2, employee No. 2 will be the best employee, and the time required for interaction is 26. The interaction coefficient $k_{itr}$ should be taken from the interval (0.1; 0.3).

## 5. Calculating Work Lead Time

All values of membership functions and coefficients are set during the statement of the problem, but the process of determining the set of employees assigned to the task has not been determined yet. To solve such a problem, it is very difficult to choose a criterion, because the execution time is set in the form of a fuzzy function. It is necessary to carry out the operation of defuzzification of a fuzzy function to calculate the value of the criterion.

The easiest way to defuzzify a fuzzy run-time function is the right modal value method. This method is used for convex membership functions. If the membership function is monotonous and continuous, it is proposed to use the value of the time at which the work will be exactly performed, i.e. the minimum time value at which the membership function of the task execution time will take a value of 1. This point will in any case be obtained as a result of calculating the generalized function. In this case, the nature of the membership function is inessential and may not be considered at all. In a similar way, one can use the method of left modal value, which will consider the most optimistic deadlines for completing all tasks. With such methods of defuzzification, the calculation of a generalized fuzzy function is not required, which greatly simplifies the work, for example, with nonlinear membership functions, but at the same time, all the advantages of using fuzzy sets are lost.

Another possible defuzzification method is to decompose a fuzzy set into regular sets using the $\alpha$ – level (Bayoumi 2000, Debnath 2018). For this, it is necessary to determine the level value from the interval (0; 1). This level shows the value of the task execution time, with the membership function value equal to the value of $\alpha$. The physical meaning of this level can be explained as follows: the reason why the value of the membership function is not equal to 0 is the hope of employees to complete the task fully, provided that they do not have unforeseen difficulties in its implementation. In the event of some difficulties, it can be safely assumed that at this point in time the task will not be completed in full or of poor quality, but will be close to completion. For example, when developing a software product, it is possible to obtain an early, partially working version. As a result, in the process of defuzzification, it is possible to calculate several different values of the execution time of the work, presumably at various stages of its completion. To calculate the α level, it is necessary for each generalized fuzzy function to add a point corresponding to the value of α for the membership function and calculate the corresponding values of the execution time and productivity. Moreover, for nonlinear functions it is necessary to use a pre-calculated inverse function.

Other defuzzification methods cannot be applied to the proposed membership functions for which the conditions of continuity and monotonicity are satisfied even if they are specified in the form of piecewise linear functions. To expand the capabilities of defuzzification, it is proposed to calculate the derivative of the membership function:

$$\varphi(t)_j = \frac{d\nu(t)_j}{dt} \qquad (6)$$

The resulting function can be considered as a fuzzy function "task execution time". This function contains properties and, in limiting values, has a membership function value of 0. For such functions, other classical defuzzification methods can be used: the membership function maximum method, the center of gravity method,

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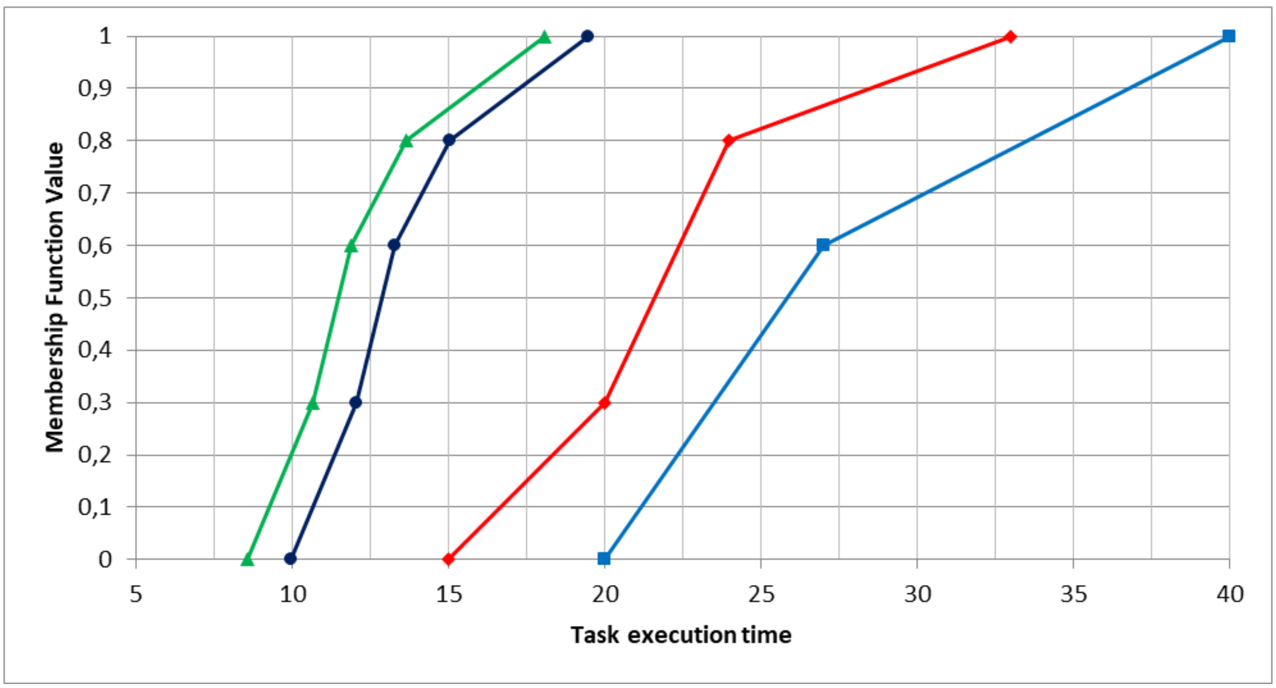
the median method, the center of maximum method, etc. (José 1995, Kumar 2017) These methods require knowledge of the function to calculate its various characteristics. In the case of piecewise linear functions, to determine the value of the derivative, it is necessary to calculate only the angle of inclination of the line. For nonlinear functions, the calculation of the derivative, within the framework of a software implementation, is difficult. It should be noted that in most cases, as a result of the generalization procedure, the calculation of the nonlinear function itself in an analytical form is not feasible, especially the calculation of its derivative.

All the proposed values cannot fully reflect the completeness of the fuzzy function of the time taken to complete the work and, therefore, optimization according to the calculated times (pessimistic, integral or mathematical expectation of the time to complete the work) can give various solutions to the task of appointing workers.

## 6. An Example

Suppose, a survey of two workers was made to assess the time taken to complete one specific task (Fig. 3, red and blue graphs).



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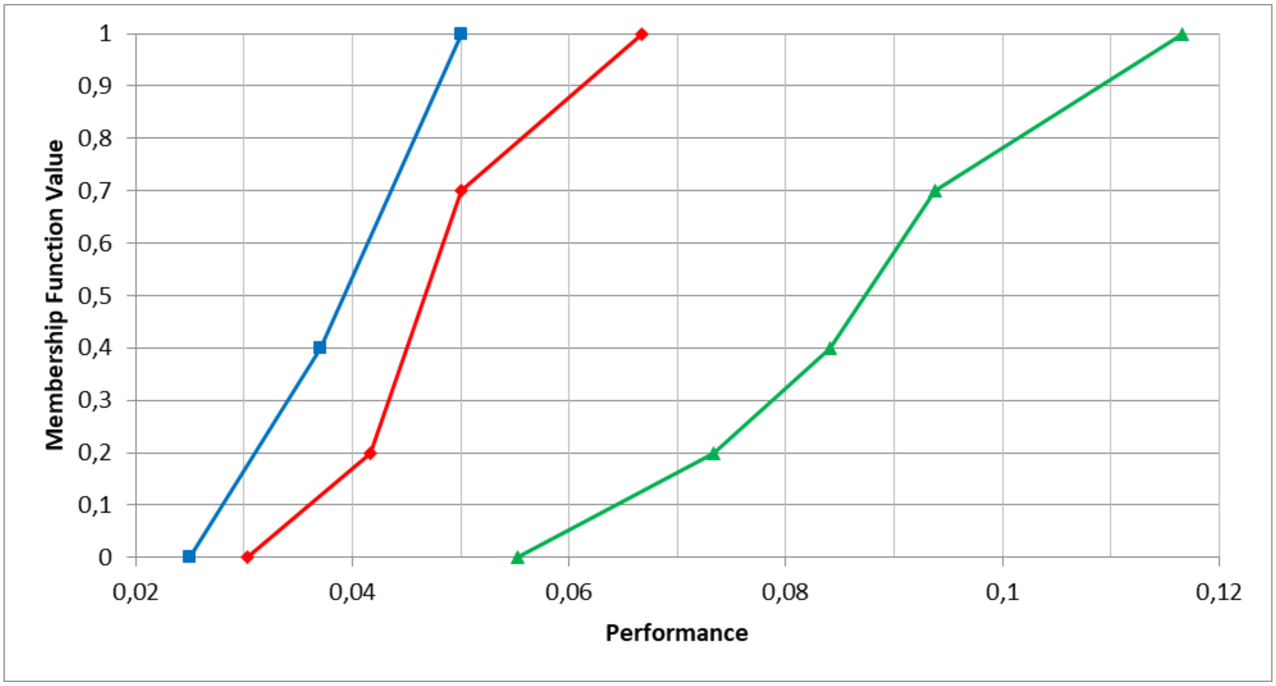


**Figure 3.** Graphs of fuzzy functions for an example. Red - employee number 1, blue - employee number 2, green - a generalized function, purple - a generalized function, taking into account the interaction of workers.

According to the results of calculations of the fuzzy set “total productivity of employees assigned to the task”, 5 total inflection points corresponding to the following values of the generalized membership function can be identified: 1; 0.7; 0.4; 0.2; and 0. Points 1; 0.7; 0.2; 0 belong to the first employee and 1; 0.4; 0 to the second. The value of the membership function will take a value equal to 0 to the point 0.0303 + 0.025 = 0.0553. Further, the membership functions of fuzzy productivity functions of workers No. 1 and No. 2 change the values of derivatives, which leads to a change in the derivative of the generalized membership function. For the value of the membership function $\mu_{1,j}(p) = 0{,}2$ for employee No. 1, the productivity value p = 0.0417 is known. For employee No. 2, the productivity value must be calculated based on linear interpolation of two points: (0; 0.025) and (0.4; 0.037). The value of the membership function of the fuzzy productivity function of employee No. 2 takes the value $\mu_{2,j}(p) = 0{,}2$ at the point p = 0.0316. The value of the membership function of the fuzzy function of generalized productivity is $\mu_j(p) = 0{,}0417 + 0{,}0316 = 0{,}0733$. Changing the derived membership function of the fuzzy productivity function of employee No. 1 makes it necessary to search for the next point. The result of calculating the membership function of the fuzzy function of generalized performance is shown in Figure 3 in the form of a green graph.

For the proposed example of the interaction of two workers, the time difference is 40-33 = 7. In the general case, this is a rather pessimistic assessment of the interaction time of workers. For our example, the time for interaction between two employees is more than 20% of the time it takes to complete the task alone. But this time is the most unfavorable option for communication between employees. It is proposed to multiply it by the coefficient of communication ($k_{itr}$), which determines how tightly it is necessary to interact. $k_{itr} = 1$ for the case of constant interaction of employees, for example, according to the principle of two employees at the same computer, and $k_{itr} = 0$ for the case when interaction between employees is not required. In addition, this coefficient describes the interaction between all employees assigned to work, and can describe various methods of interaction of a whole group of employees. An example of changing the task execution time when taking into account the interaction of employees is shown in Figure 3, the purple line.

## Conclusion

The article considers the process of appointing employees to certain tasks and determining the time to complete all work by this group of workers. It is proposed to set the execution time for a specific task for each employee in the form of a fuzzy function. The algorithm is proposed that allows one to calculate a fuzzy function of the task execution time if several employees are assigned to it. It is proposed to consider the operation of generalizing continuous membership functions of fuzzy functions defined on various bearing sets by searching for time values in which the membership function will take certain values. This approach required the imposition of restrictions on the membership functions of the times of work: continuity and monotony. In the case of assigning workers to tasks, these restrictions can be easily satisfied. Algorithms for accounting the time required for the interaction of workers assigned to one task are determined.

This technique was applied to determine the time to complete the work when solving the problem of compiling teams of programmers in the development of a software product. At the same time, about 15 tasks and 35 programmers with various qualifications were considered. The obtained solutions made it possible to sustain sprint planning using the SCRUM methodology.

To appoint workers in enterprise, it is recommended to use algorithms that allow you to quickly find rational solutions that can be equally good by various criteria. One of these algorithms can be considered the ant colony method, which, based on the probabilistic nature of the search for solutions, allows you to quickly find rational solutions. In addition to the proposed algorithms, it is worth considering the possibility of using linguistic variables for setting the time to complete the work and for evaluating the results obtained both.

## References

Annaxsuel Araujo De Lima, Eduardo Silva Palmeira and ect. (2020) Multidimensional Fuzzy Sets. IEEE Transactions on Fuzzy Systems, 99, 1-1. https://doi.org/10.1109/TFUZZ.2020.2994997

Bayoumi Fatma Mahmoud (2000) The α-levels of a fuzzy uniform structure and of a fuzzy proximity. Fuzzy Sets and Systems, 116(3), 421-428 https://doi.org/10.1016/S0165-0114(98)00133-X

Bhowmik Monoranjan, Pal Madhumangal (2017) Emerging Research on Applied Fuzzy Sets and Intuitionistic Fuzzy Matrices Retrieved from https://doi.org/10.4018/978-1-5225-0914-1.ch001

Bott M. Mesmer B. (2019) An Analysis of Theories Supporting Agile Scrum and the Use of Scrum in Systems Engineering. Engineering Management Journal, 76-85, https://doi.org/10.1080/10429247.2019.1659701

Carl L. Pritchard (2018) The Project Management Drill Book Retrieved from https://doi.org/10.4324/9780203741764-11

Chartrand Gary, Kapoor S. F., Nordhaus E. A. (1983) Hamiltonian path graphs Journal of Graph Theory, 7(4), 419-427 https://doi.org/10.1002/jgt.3190070406

Darshita K., Devarshi M. (2019) Study of Agile Scrum and Alikeness of Scrum Tools. International Journal of Computer Applications 178(43), 21-28, https://doi.org/10.5120/ijca2019919318

Debnath Shyamal, Rakshit Debjani (2018) On Rough Convergence of Fuzzy Numbers based on α-level sets. Journal of the Indian Mathematical Society 85 (1-2), 42, https://doi.org/10.18311/jims/2018/17869

Didier Dubois, Hélène Fargier, Philippe Fortemps (2010) Production Scheduling. Retrieved from https://doi.org/10.1002/9780470611050.ch11

Formalev V.F., Kartashov É.M., Kolesnik S.A. (2020) On the Dynamics of Motion and Reflection of Temperature Solitons in Wave Heat Transfer in Limited Regions. Journal of Engineering Physics and Thermophysics 93(1), 10-15, https://doi.org/10.1007/s10891-020-02085-9

Formalev V.F., Kartashov É.M., Kolesnik S.A. (2019) Simulation of Nonequilibrium Heat Transfer in an Anisotropic Semispace Under the Action of a Point Heat Source. Journal of Engineering Physics and Thermophysics 92(6), 1537-1547, https://doi.org/10.1007/s10891-019-02074-7

Formalev V.F., Kolesnik S.A. (2019) On Thermal Solitons during Wave Heat Transfer in Restricted Areas. High Temperature 57(4), 498-502, https://doi.org/10.1134/S0018151X19040047

Formalev, V.F., Kolesnik, S.A., Garibyan, B.A. (2019) Mathematical modeling of heat transfer in anisotropic plate with internal sinks. AIP Conference Proceedings. 2181, 020003. https://doi.org/10.1063/1.5135663

Fridlyanov M.A. (2017) Methods and techniques of project management in the field of industrial production. Problems of a market economy, 3, 17-24. https://doi.org/10.29030/2309-2076-2017-10-3-39-44

Ganesan Ramesh, Sudha G., Ganesan Kandasamy (2019) A study on interval PERT/CPM network problems. The 11th national conference on mathematical techniques and applications. https://doi.org/10.1063/1.5112308

George E. (2016) Project Management in Product Development. Retrieved from https://doi.org/10.1016/B978-0-12-802322-8.00003-6

Goman Maksim (2019) Research and Practical Issues of Enterprise Information Systems Retrieved from https://doi.org/10.1007/978-3-030-37632-1_10

José Valente de Oliveira, (1995) A set-theoretical defuzzification method Fuzzy Sets and Systems 76(1), 63-71, https://doi.org/10.1016/0165-0114(95)00002-3

Kanmohammadi S., Rahimi F., Sharifian M.B.B. (2004) Analysis of different fuzzy CPM network planning procedures. 10th IEEE International Conference on Electronics, Circuits and Systems, 2003. ICECS 2003. Proceedings of the 2003, 3, https://doi.org/10.1109/ICECS.2003.1301696

Kiran D.R. (2019) Production Planning and Control. Retrieved from https://doi.org/10.1016/B978-0-12-818364-9.00032-9

Kolesnik S.A., Bulychev N.A. (2020) Numerical analytic method for solving the inverse coefficient problem of heat conduction in anisotropic half-space. Journal of Physics: Conference Series 1474(1), 012024, https://doi.org/10.1088/1742-6596/1474/1/012024

Kumar H. (2017) Some Recent Defuzzification Methods. Retrieved from https://doi.org/10.4018/978-1-5225-1908-9.ch044

Levine M.K.(2019) People over Process. Retrieved from https://doi.org/10.4324/9780429324758-16

Marques R. and ect. (2020) A gamification solution for improving Scrum adoption. Empirical Software Engineering https://doi.org/10.1007/s10664-020-09816-9

Matthew J. Liberatore (2008) Critical Path Analysis With Fuzzy Activity Times. IEEE Transactions on Engineering Management, 55(2), 329-337 https://doi.org/10.1109/TEM.2008.919678

Mohammad S., Fariborz J., Seyed H. I., Morteza H.(2008) A Model for Project Scheduling with Fuzzy Precedence Links. Australian Journal of Basic and Applied Sciences, 2, 1356-1361 https://www.researchgate.net/publication/228889527_A_Model_for_Project_Scheduling_with_Fuzzy_Precedence_Links

Nahmias S. (2013) Encyclopedia of Operations Research and Management Science. Retrieved from https://doi.org/10.1007/978-1-4419-1153-7_375

Nasution S.H. (1994) Fuzzy critical path method. IEEE Transactions on Systems Man and Cybernetics, 24(1), 48-57 https://doi.org/10.1109/21.259685

Piegat A. (2001) Fuzzy modeling and control. Retrieved from https://doi.org/10.1007/978-3-7908-1824-6

Ridewaan H. and ect. (2020) Advances in Agile and User-Centred Software Engineering. Retrieved from https://doi.org/10.1007/978-3-030-37534-8_5

Shih-Pin Chen, Yi-Ju Hsueh (2008) A simple approach to fuzzy critical path analysis in project networks. Applied Mathematical Modelling, 32(7), 1289-1297, https://doi.org/10.1016/j.apm.2007.04.009

Stephen W. Choate, Abraham Kandel (1986) Fuzzy resource management analysis. Fuzzy Sets and Systems, 20(3), 291-316 https://doi.org/10.1016/S0165-0114(86)90041-2

Wen-Xiang Gu, Fang Wang, Jia-Yue Ren, Gang Hou (2006) Fuzzy Resource Constraints Graphplan. 2006 International Conference on Machine Learning and Cybernetics https://doi.org/10.1109/ICMLC.2006.258323

Wilson J.M. (2003) Gantt Charts: A Centenary Appreciation. European Journal of Operational Research, 149 (2), 430-437, https://doi.org/10.1016/S0377-2217(02)00769-5

Zatsarinny A. A., Korotkov V. V., Matveev M. G. (2019) Modeling of network planning processes of a portfolio of projects with heterogeneous resources in the conditions of fuzzy information. Informatics and its applications, 13(2), 92-99. https://doi.org/10.14357/19922264190213

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