AHP analysis of need factors for development of Machine Learning Based system for Monitoring of Employee Digital Activities

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Abstract — **In this paper, the need for development of a system for Machine learning (ML) based monitoring of employee digital activities is analyzed. The need is evaluated through the benefit factors for development and introduction of ML based remote employee monitoring system in companies. Development of such a system would involve the implementation of ML methods and techniques, as well as appropriate prediction models. To assess the need for the development of such a system, a multi-criteria analysis is performed on a sample of 102 superiors from IT (53 participants) and non-IT (49 participants) companies, which offer the option of remote work to their employees. By applying the multi-criteria Analytic Hierarchy Process (AHP), it is noticed that in the group of participants from IT companies the most important factor for development and introduction of this kind of system is the improvement of work quality of remote employees. On the other hand, participants from non-IT companies emphasized the employee productivity growth as the most important benefit of the system introduction.**

Keywords – AHP analysis; machine learning; monitoring system; remote employee; benefit factors.

I. Introduction

To develop a system for monitoring remote employees in companies that offer remote work to their employees, the need for such a system is assessed.

The assessment is performed through an analysis of benefits that superiors from companies that would potentially introduce such a system see from its introduction. Superiors in the role of respondents were given a survey through which they evaluated each of defined benefits on a nine-point scale [1]. System, which would include the implementation of ML algorithms in the analysis of collected data from monitoring process, were explained in detail to the respondents in the survey itself.

The benefits evaluated using Saaty's nine-point scale [1] are actually factors that are most important to the respondents for the introduction of the ML-based remote employee monitoring system. Below is a list of benefits that have been evaluated:

1. *improving productivity* - productivity implies the improvement of ongoing work - to achieve the best possible results with the least amount of work invested [2]. In the context of non-IT companies, respondents see productivity as a quantitative expression between the volume of production, services or turnover and the amount of labor employed. Respondents from IT companies pointed out that under the benefit of productivity they mean successfully completed planned tasks of employees during one sprint, i.e,. in the medium term during one cycle of 5 sprints – Program Increment (PI).
2. *improving quality* - the benefit of increasing quality for non-IT respondents implies that, through constant monitoring, the system should ensure that there are as few deviations in the work of employees as possible, concentration on work, and therefore an increase in customer satisfaction [3]. For IT respondents, the benefit of quality implies that the monitoring system would enable not only the timely completion of tasks, but also an increase in the quality of those tasks. Here, quality means reducing the percentage of open bugs after each closed feature and customer satisfaction with each newly developed and released functionality.
3. better efficiency - reduction of task solving time regardless of quality [4]. The emphasis is on timing and fulfillment of plans.
4. reducing wasted time - eliminating the possibility of performing private or non-productive activities (reading newspapers, playing games, social networks) during the working hours.

The analysis of factors that are most important to participants from the point of view of introducing mentioned system in their companies is performed by

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applying the AHP method. Therefore, the data obtained by evaluation through a nine-point scale by each respondent, are further processed using the AHP method. The goal of applying this methodology is to obtain results in the form of a ranking list of benefits to see which benefits are the most important for superiors from different companies.

The AHP methodology is applied in three occasions. First, weight coefficients are determined for answers of all 102 respondents. After that, as the respondents were clearly divided into the group of those from IT (53 respondents) and those from non-IT (49 respondents) companies, the results for each group are also considered separately. From this approach, the goal is to see if there is a difference in opinion between superiors from IT and non-IT companies.

II. LITERATURE OVERVIEW

The applied AHP analysis methodology is based on previously studied works on a similar topic.

In the research [5], the development principles of the methodology of the Analytic Hierarchy Process (AHP) are presented. The significance of the paper [5] for the needs assessment research is reflected in defining steps of implementation of the AHP method. Authors have proposed principles for AHP methodology implementation in public work contract. In contrast to the full implementation of the AHP methodology proposed in paper [5], the multi-criteria factor analysis of remote employee monitoring system implementation used only the step of defining the AHP structure and comparing factors in relation to the goal. Therefore, the aim was to determine the weight coefficients of each factor and to define the matrix of priority factors according to weights.

It should be emphasized that Saaty's nine-point intensity scale [6] is used during the pairwise comparisons, i.e., comparing benefit factors of the monitoring system development and implementation in companies. The scale is presented in Saaty's research paper on various examples of AHP and Analytic Network Process (ANP) methods implementation [6, 7].

In the publication [8] an integrated methodology for evaluating existing legacy systems and migrating their architectures to modular and open ones is presented. Proposed model integrates open systems strategies with Analytical Hierarchy Process (AHP) and Goal Programming (GP) and is useful because steps of AHP implementation are also used in this paper.

A very important aspect in the AHP methodology is determining the degree of consistency. The paper [9] explains the importance of consistency degree and indicates that if the degree is greater than 0.10 (10%), the results should be reanalyzed and reasons for the inconsistency established and removed by partially repeating the comparison in pairs. If repeating the procedure in several steps does not lead to a lowering of the degree of consistency to the tolerance limit of 0.10 (10%), all results should be rejected and the whole procedure should be repeated from the beginning [9].

III. THEORETICAL ASPECTS

A. Description of remote employee monitoring system

This chapter contains the analysis of the ML-based Remote Employee Monitoring System (REMS) that will be developed. This system's objective is to daily monitor remote workers employed by businesses that give their employees the option of working remotely.

The system's objective is to monitor employee performance as well as to provide early warning to company superiors in case of excessive levels of employee stress, falling performance, or employee dissatisfaction.

The Client-Server architecture model [10] will serve as the basis for the suggested system. Installed on users' PCs, the client application (CA) aims to gather pertinent data about users' behavior and transmit it to the server side.

Monitoring Module (MOM) [11], a component of CA, would be tasked with gathering information regarding the behavior of remote employees: 1) mouse moves, clicks, scrolls and mouse trajectory, 2) memory and Central Processing Unit (CPU) data; 3) time tracking data; 4) keyboard hook data.

A Data collection module (DCM) [11] will be tasked with responding to external events and accepting all information from the MOM in callback methods to relieve threads of the MOM. DCM would also be responsible for the client-side temporary data storage.

Representational state transfer (REST) [12] endpoints would be used for data transmission and communication between the client and server sides.

The server side will accept unprocessed data about the behavior of remote employees and store in a non-relational database. Additionally, the REMS architecture will comprise a relational database that contain business logic, users' data, as well as raw user activity data that was gained by using ML algorithms from the Machine learning module (MLM) [11]. The MLM module will set REMS apart from other systems on the market that do not have deeper ML examination of the gathered data. Based on employees' actions throughout the monitoring phase, the MLM module would be able to classify employees according to their roles (developer, administrative worker). The MLM module would also be tasked with the responsibility of analyzing employee behavior data to extract information regarding the employee's degree of stress and emotional state and to inform superiors about it.

The Data visualization Module (DVM) [11] and the Admin Single Page Application (SPA) [11] application will be used to carry out the process of visualizing the processed data. JavaScript Object Notation (JSON) Web Token implementation will maintain the security of data and their transit (JWT) [13].

B. Analytic Hierarchy Process (AHP) method

Comparisons of benefit factors for development and introduction of ML based monitoring system are based on Saaty's nine-point scale and the analysis and determination of weight coefficients of factors is performed by the AHP method. AHP is a strong and flexible multi-criteria decision analysis approach. AHP helps decision makers set priorities and choose the best alternative when both qualitative and quantitative aspects are considered [14]. AHP is an intuitive method for formulating and analyzing decisions, based on hierarchical problem structuring (see the Figure 1), and making pairwise comparisons [15].

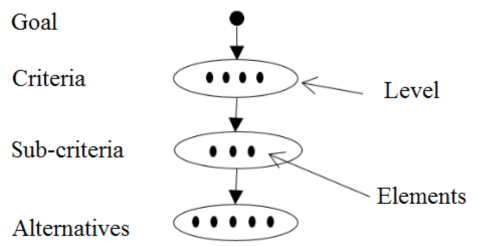

Figure 1. AHP hierarchical structure [16]

Making pairwise comparisons is based on the 1-9 comparison scale (see the Table 1) [15].

TABLE I. SAATY'S FUNDAMENTAL SCALE [17].

Numerical scale	Verbal scale
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

The procedure of implementation the AHP method will be carried out through the following steps [18]: 1) developing the AHP hierarchy, 2) comparing pairs of decision-making elements, 3) determining the local weight coefficients and consistency verification (weights based on each individual participant's response), 4) determining the overall priority vector based on geometric means of all comparisons of all participants. The AHP method will be applied in such a way that comparisons will be made only at the first level of the hierarchy, i.e., in relation to the goal. To obtain consistent and relevant results, each comparison of factors by the participants will be used to obtain the overall priority vector and finally determine the weighting coefficients of the consideration factors. The overall priority vector is obtained as the geometric mean of all comparisons of all 102 participants (53 from IT companies and 49 from non-IT companies). In this way, the subjectivism that may be present in the AHP methodology has been eliminated.

C. Structure of the survey

The AHP method is used without determining certain comparison criteria, but exclusively in comparing alternatives (factors in the form of system benefits) in relation to the goal. Saaty's nine-point scale is used for comparison, and the answers are collected through the survey. Survey is based on the survey of the author Yuji Sato, who collected data using a nine-point scale and included them as inputs into the AHP method for determining the weighting coefficients [19]. Below is a set of questions answered by all 102 respondents:

Q1: Choose which benefits of introducing the system are more important to you: productivity (better results in realization of employee tasks and higher percentage of finished tasks) or improving quality (higher quality of the work of employees when they know that someone is interested in their work).

Q2: Choose which benefits of introducing the system are more important to you: productivity or efficiency (faster execution of tasks if supervision exists).

Q3: Choose which benefits of introducing the system are more important to you: productivity or reducing wasted time (reducing time spent on activities unrelated to work tasks).

Q4: Choose which benefits of introducing the system are more important to you: improving quality or reducing wasted time.

Q5: Choose which benefits of introducing the system are more important to you: efficiency or reducing wasted time.

IV. RESULTS

The basic alternatives between which will be determined the priority ranking list are defined as follows: $\mathbf{A_1}$ – productivity, $\mathbf{A_2}$ – improving quality, $\mathbf{A_3}$ – efficiency, $\mathbf{A_4}$ – reducing wasted time on non-business activities.

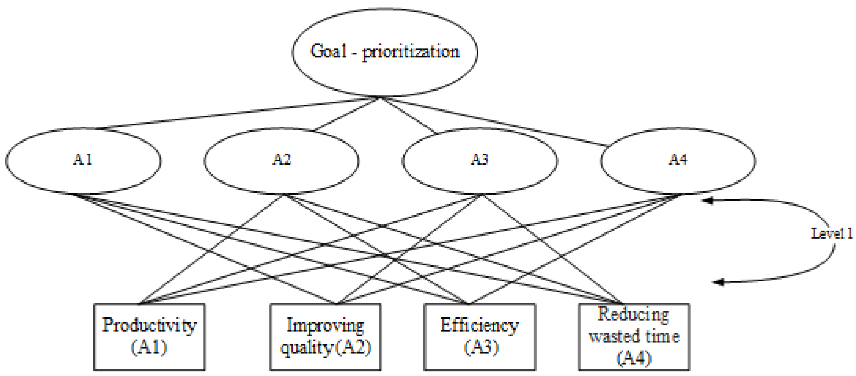

Figure 2. AHP structure

The structure of the first level of comparison in relation to the goal is shown in the Figure 2.

Therefore, the prioritization is performed at the first level of comparison and is based on the obtained weighting coefficients.

This AHP structure is used with the aim of obtaining weight coefficients and prioritization of system benefit factors in the mutual comparison of alternatives in relation to the goal. The overall weight vector is based on the expert decision-making of 102 experts in front of different IT and non-IT companies and it is determined by using the geometric mean of the comparisons of these 102 experts. Overall weights based on the geometric mean of responses of 102 superiors are shown in the Table 2.

TABLE II. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEANS – ALL PARTICIPANTS.

Goal	**A1**	**A2**	**A3**	**A4**	w_j
A1	1.0	1.04100	1.99947	2.32923	0.33519
A2	0.96061	1.0	1.95195	2.29157	0.33836
A3	0.50013	0.51231	1.0	2.08061	0.19915
A4	0.42933	0.43638	0.48063	1.0	0.12730
Degree of consistency: CR = 0.01582 < 0.10					

After analyzing comparisons of all 102 participants and defining the overall comparison matrix and based on geometric means of all comparisons of superiors, the weight coefficients of the system benefit factors (alternatives) are obtained.

$$w_{all} = \begin{pmatrix} 0.33519 \\ 0.33836 \\ 0.19915 \\ 0.12730 \end{pmatrix} \quad (1)$$

Also, by calculating the CR index the AHP method can identify and analyse inconsistencies in the process of comparing pairs of alternatives. If the degree of consistency (CR) is less than 0.10 (10%), the result is sufficiently accurate and there is no need for corrections in comparisons and repetition of calculations [20]. In this case, degree of consistency CR=0.01582 is less than the specified threshold of 0.10, so there is no inconsistency in comparisons.

The obtained results of the overall priority of the considered alternatives are given in descending order: A_2 (Quality) → A_1 (Productivity) → A_3 (Efficiency) → A_4 (Reducing wasted time). Therefore, it can be concluded that in the total sample of 102 participants, the *quality factor* is the most important, i.e., the development and introduction of such system would contribute to the growth of the quality of the work of remote employees.

If the data are analysed separately by groups into which participants are divided (those from IT companies and those from non-IT companies), results of comparisons are as follows (Tables 3 and 4).

TABLE III. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEANS – 49 PARTICIPANTS FROM NON-IT COMPANIES.

Goal	**A1**	**A2**	**A3**	**A4**	w_j
A1	1.0	1.23396	2.98408	3.55676	0.41604
A2	0.81039	1.0	1.81527	2.59529	0.30329
A3	0.33511	0.55089	1.0	2.37699	0.17934
A4	0.27367	0.38531	0.42069	1.0	0.10133
Degree of consistency: CR = 0.01953 < 0.10					

The obtained results of the overall priority of the considered alternatives are given in descending order for non-IT group: A_1 (Productivity) → A_2 (Quality) → A_3 (Efficiency) → A_4 (Reducing wasted time).

$$w_{non\text{-}IT} = \begin{pmatrix} 0.41604 \\ 0.30329 \\ 0.17934 \\ 0.10133 \end{pmatrix} \quad (2)$$

Therefore, it can be concluded that in the sub-sample of 49 respondents from non-IT companies, the *productivity factor* is the most important, i.e., the development and introduction of such an information system would contribute to the growth of the productivity of the work of remote employees. Also, it can also be concluded that the degree of consistency CR = 0.01953 is less than the specified threshold of 0.10.

TABLE IV. OVERALL WEIGHT VECTOR BASED ON GEOMETRIC MEANS –53 PARTICIPANTS FROM IT COMPANIES.

Goal	**A1**	**A2**	**A3**	**A4**	w_j
A1	1.0	0.88957	1.38083	1.53608	0.27802
A2	1.12414	1.0	2.08744	2.04249	0.35296
A3	0.72420	0.47905	1.0	1.83957	0.21467
A4	0.65101	0.48959	0.54360	1.0	0.15435
Degree of consistency: CR = 0.01808 < 0.10					

The obtained results of the overall priority of the considered alternatives are given in descending order for the IT group: A_2 (Quality) → A_1 (Productivity) → A_3 (Efficiency) → A_4 (Reducing wasted time).

$$w_{IT} = \begin{pmatrix} 0.27802 \\ 0.35296 \\ 0.21467 \\ 0.15435 \end{pmatrix} \quad (3)$$

Therefore, it can be concluded that in the sub-sample of 53 participants from IT companies, *quality factor* is the most important, i.e., development and introduction of such information system would contribute to the growth of the quality of the work of remote employees.

V. Discussion

If results of the AHP analysis are considered, in a total sample of 102 participants, without division into two groups, *quality* is marked as the factor with the highest weight coefficient. This means that participants recognized the importance of the system in the fact that it can contribute to the growth of the quality of work of remote employees. It should be noted that productivity is also a very important system benefit in the overall sample, with slightly less weight than quality factor.

If the separate results of the AHP analysis are analyzed, it can be noticed that the results of the IT group coincide with the results of the whole sample in prioritized order of system benefit factors. Therefore, for the superiors from IT companies, the *quality factor* is recognized as the most important benefit of development and introduction of such a system.

Unlike the IT group, participants from the non-IT companies consider that the *productivity* is the greatest benefit that the development and introduction of the system for employee monitoring and ML based clustering contributes.

So, in terms of the benefit factors, there is a certain difference in opinions of participants from the IT and non-IT group.

The results might have been different if the sample had been larger, and the questionnaire included superiors from even more different companies. Also, the fact that the ratio of participants from IT companies is slightly higher compared to participants from non-IT companies may have an impact on validity of results in the sense that they could be different if the number in both groups was the same.

On the other hand, the applied methodological procedure contributed to the results being valid and free of any dose of subjectivism. In the applied AHP methodology, any subjectivism is eliminated by summing all results into a common comparison matrix, where each value in the matrix represents a geometric mean of all values of participants' comparisons.

VI. Conclusion

It can be concluded that superiors from non-IT companies emphasize the growth of employee productivity as the main benefit of such a system. On the other hand, for superiors from IT companies, quality is the most important benefit, which is expected, because today's IT companies invest a lot of effort and money in quality improvements of their projects. So, it can be said that participants from both groups recognized two important benefits of the system introduction and development – productivity and growth of work quality of remote employees.

This research paper results show that there is a need to develop ML-based system for monitoring remote employees, i.e., that ML based algorithms in data processing are welcome for the purpose of deeper analysis of employee behavior. This is confirmed precisely because the superiors expressed through their answers and later AHP analysis that they clearly the benefits of such a system.

As a plan for further research is to extend the AHP methodology using Fuzzy logic and thereby reduce the subjectivism expressed by the comparison of benefits, as well as to analyze results comparatively. Authors plan the application of Fuzzy AHP (FAHP) Yüskel's matrix calculation [21], based on triangular Fuzzy numbers. The plan is to extend the matrix calculation procedure by Cheng's extent analysis and Wang's corrective procedure [22] and by applying the optimism index, for each of the matrices with triangular Fuzzy values, a system of formulas will be used to directly calculate the exact values of the weighting coefficients and continue with the classic matrix calculation. In this way, the results of the vector of weighting coefficients of benefits of the applied FAHP methodology would be obtained, which would be suitable for a detailed comparative analysis with the results generated by the classic AHP approach.

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