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**REGRESSION ANALYSIS FOR EVALUATING EMPLOYEE PRODUCTIVITY
IN IT PROJECT MANAGEMENT**

Abstract. Employee performance assessment is a key element of effective IT project management, especially in the context of the transition to a remote or hybrid work model, which has become dominant after the global changes caused by the COVID-19 pandemic, digital transformation and social shifts. In such conditions, traditional approaches to measuring performance, based on direct observation or formal reports, lose objectivity and do not take into account the real context of task performance. Most modern activity control tools are focused mainly on monitoring, rather than on a deep analytical analysis of the factors that shape employee performance. This article proposes the use of regression analysis methods as a formalized statistical tool for quantitative performance assessment. The regression model allows you to simultaneously take into account several influential factors – the number of tasks completed, the accuracy of estimates, the quality of work (the number of defects) and participation in team processes – and determine their contribution to the overall level of performance. The mathematical justification of linear regression in the context of project management is presented, formulas for calculating coefficients by the least squares method and indicators for assessing the quality of the model (R^2 , p -value, standard error) are given. The construction and interpretation of the model are demonstrated using the example of a realistic data set of ten developers. The results obtained showed a high level of explanatory power ($R^2 = 0.97$), which confirms the close relationship between the independent variables and the productivity indicator. The greatest impact on efficiency was found in the work quality factor ($\beta = -2.68$), while participation in teamwork and the number of tasks have a moderate positive effect. The regression model can be used both for retrospective analysis (identifying patterns and deviations in productivity dynamics) and for predicting future results or evaluating new employees by their metrics. It provides transparency, reproducibility and the possibility of analytical interpretation without excessive use of control tools. The conclusions outline the advantages and limitations of the approach: high accuracy and adaptability of the model require high-quality data and mathematical training of managers. A promising direction for further research is the integration of regression methods with machine learning and Bayesian models to identify the causes of performance fluctuations and build personalized forecasts. The proposed model is aimed at small and medium-sized IT teams that need a practical, statistically sound alternative to complex corporate performance evaluation systems.

Keywords: Employee productivity; Regression analysis; IT project management; Performance evaluation

Introduction

IT project management in modern conditions has undergone significant transformations under the influence of global changes – in particular, the COVID-19 pandemic, military conflicts, labor market instability, and the mass transition to a remote work model. These factors have not only changed organizational structures but also set new requirements for measuring, controlling, and developing personnel efficiency. Employee

productivity, which was previously assessed mainly on the basis of personal observations or subjective assessments of management, today requires objective, quantitative, and reproducible approaches.

Against the background of the growth of the number of remote teams, where direct observation is difficult or impossible, the need for reliable productivity measurement systems becomes urgent. Existing software solutions – from activity trackers to KPI assessment modules – mostly perform monitoring functions, not

diagnostics. They do not enhance the context of task performance, do not provide a deep analysis of the impact of various factors on the result, and do not allow for forecasting based on historical data.

In the project management field, especially in IT, employee productivity directly affects the implementation time, compliance with technical requirements, team interaction, and the final quality of the product. The lack of a transparent and adaptive approach to assessing productivity creates risks for both internal management and the strategic development of the company. On the other hand, overly simplified productivity models (for example, only by the number of completed tasks) do not reflect real efficiency and can distort management decisions.

In this context, it is good to use some mathematical models that allow for a formal analysis of employee efficiency using several influencing factors. One of such approaches is regression analysis – a statistical method that allows not only to describe the relationships between different features that describe productivity performance but also can make predictions. The use of regression allows you to model productivity as a function of such indicators as the number of tasks, planning accuracy, the number of technical errors, and the level of participation in team processes. Unlike heuristic approaches, regression models provide transparency, repeatability of results, and a clear quantitative interpretation.

This article proposes a conceptual framework for applying linear regression as a tool for assessing employee performance in a project environment. It analyzes the current state of approaches to performance measurement, describes the formal aspects of building the model, demonstrates an example of its use, and discusses the potential for further expanding analytics in IT team management.

Current Approaches to Productivity Assessment in Project Management

Introduction to Productivity Assessment.

Employee performance assessment is a key aspect of effective project management, as it directly affects the timeliness of task completion, adherence to budgets, and the quality of final results. Traditional approaches have focused on quantitative indicators – the number of tasks completed, time spent, code volume, etc. However, these metrics have significant limitations, as they do not take into account the context of performance, the level of task complexity, the quality of results, and involvement in teamwork.

In the context of remote or hybrid work, which has become widespread after the COVID-19 pandemic, the need for accurate and objective approaches to performance assessment is only increasing. At the same time, excessive focus on activity trackers and quantitative reports creates risks of formal control without in-depth

analysis of effectiveness. This pushes the scientific and management community to implement complex analytical methods, among which regression analysis is increasingly used.

Factors Influencing Employee Productivity.

Current research confirms that productivity is based on multiple factors – individual, organizational and social. Abdelwahed & Dogan [3] examine the impact of employee engagement on their effectiveness. The authors showed that emotional, behavioral and cognitive engagement are important predictors of high productivity. They also draw attention to the role of the environment, management style and organizational support in achieving sustainable results.

Another study by Okafor, focuses on performance management systems in the context of small and medium-sized enterprises. The results indicate that the presence of structured feedback, clear expectations and regular performance evaluation leads to increased motivation and actual productivity. The author also emphasizes the importance of involving employees in the planning process, which increases the sense of responsibility for the result. [4]

Application of Regression Analysis for Productivity Assessment. Regression analysis is widely used in productivity research as a way to identify patterns between worker characteristics, task conditions, and performance. In Ngoma et al. paper there was a model presentation about productivity in construction projects in Zambia [5]. The authors use multivariate linear regression to identify the impact of variables such as experience, education level, equipment availability, and weather conditions on labor productivity. The model allowed not only to assess the impact of each factor, but also to formulate practical recommendations for improving the organization of work processes.

A similar study in the context of Vietnam was conducted by Hai & Tam (2019), who focused on analyzing the productivity of construction workers. Their regression model identified the most significant factors – the presence of technical control, motivational schemes, and logistics management. The results confirmed the suitability of regression analysis for practical prediction of worker efficiency in production conditions. [6]

Application of Regression Analysis in IT Projects. In the field of IT projects, the problem of assessing productivity is often even more difficult since tasks can differ in duration, technological complexity, and impact on other stages of the project. Azzeh & Bou Nassif proposed a model for early prediction of productivity in software, which is based on regression analysis [7]. The model includes the size of the team, the type of tasks, the experience of developers, and the type of contract. The study shows that, if properly constructed, regression can give an accurate forecast even before the start of the active development phase.

It is also worth mentioning the study by Kivilä et al., which studied the impact of the maturity of project management practices on productivity in small and medium-sized IT companies [8]. The regression model allowed the authors to prove that the formalization of processes (in particular, planning, communications, and risk management) directly correlates with increased productivity at the level of individual employees and the whole team.

Additional Research in the Field of Productivity Assessment. In addition to traditional approaches to performance measurement, recent research focuses on integrating sustainability and using machine learning algorithms to improve project management effectiveness.

Kivilä, Martinsuo, and Vuorinen (2017) examine the concept of sustainable project management through effective control. The authors emphasize that integrating sustainability principles into project management contributes to increased efficiency and effectiveness [11]. They propose a model that uses as indicators environmental, social, and economic aspects at all stages of the project life cycle, which allows to balance between short-term goals and long-term benefits.

Another study by Balakayeva, Zhanuzakov, and Kalmenova is devoted to the development of a digital employee rating evaluation system (DERES) based on machine learning algorithms and the 360-degree method [9]. The authors created a rating prediction model that allows assessment of employee performance, analyzes their competencies, and predicts future performance. The results showed that the use of such systems contributes to increasing team motivation and optimizing management decisions.

In addition, the study by Plevris et al. analyzes various performance metrics in regression analysis and machine learning-based forecasting models. The authors examine 14 metrics in detail, including the mean square error, the mean absolute error, and the coefficient of determination, discussing their advantages, disadvantages, and limitations [10]. They emphasize the importance of choosing the right metrics to obtain accurate forecasts and improve the effectiveness of the models.

Challenges and Prospects. Despite significant progress in using regression analysis to assess productivity, there are still certain challenges. In particular, the need to collect a large amount of qualitative data, take into account industry specifics, and adapt models to rapidly changing market conditions. However, the development of data collection and processing technologies, as well as the integration of machine learning methods, open up new prospects for increasing the accuracy and efficiency of employee productivity assessment.

Regression Analysis

General Formula of Linear Regression. Linear regression is one of the basic machine learning algorithms used to model the relationship between a single target variable and one or more independent variables (features). It belongs to the class of supervised learning methods, where a model is trained on known input data and corresponding output values, and then predicts outcomes for new data [13]. Mathematically, linear regression seeks to find the optimal coefficients that minimize the difference between the predicted and actual values of the target variable, usually by minimizing the mean square error.

Linear regression has the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon, \quad (1)$$

where Y – dependent variable (target variable), e.g., productivity; X_1, \dots, X_k – independent variables (factors), for example, number of tasks, quality of performance; β_0 – constant (intercept with the Y axis) when all $X = 0$; β_1, \dots, β_k – regression coefficients that determine the effect of each factor X_i on Y ; ε – error (noise) that includes all other factors that are not represented in the model.

This equation describes how changes in the independent variables affect the mean of the dependent variable, assuming a linear relationship between them.

The coefficients β_i are estimated by the least squares method, which minimizes the sum of the squares of the deviations between the observed and predicted values of Y [14].

Regression goal. In linear regression, the goal is to determine the model coefficients that minimize the sum of the squared differences between the actual values of the dependent variable and the predicted values of the model. This approach is known as the least squares method (LLS). LLS provides a line or hyperplane (based on a number of features) that best fits a dataset by minimizing the sum of the squared deviations between the observed and predicted values [12]. This method is widely used to estimate parameters in linear regression models due to its simplicity and efficiency.

The main goal is to find $\beta_0, \beta_1, \dots, \beta_k$ which minimizes the sum of the squared deviations (errors):

$$RSS = \sum_{i=1}^n (Y_i - (\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_k X_{ik}))^2, \quad (2)$$

where Y_i – the value of the dependent variable for the i -th observation; X_{ij} – the value of the j th factor for the i th observation.

Estimation of coefficients (least squares method). Coefficients are calculated when you solve equation:

$$\beta = (X^T X)^{-1} X^T Y, \quad (3)$$

where, X – a matrix of independent variables, where each row corresponds to one observation; Y – vector of dependent variables; X^T – transpose matrix X ; $(X^T X)^{-1}$ – inverse matrix.

This equation, known as the normal equation, allows for direct computation of regression coefficient estimates without the need for iterative methods such as gradient descent. However, computing the inverse matrix can be computationally expensive for a large number of variables, so in practice, numerical methods such as QR decomposition are often used to improve stability and computational efficiency [15].

Important Regression model characteristics. In linear regression, the following indicators are used to assess the quality of the model and the significance of its parameters [16]:

– **R-square** R^2 – indicates how much of the variation in the dependent variable is explained by the model

$$R^2 = 1 - RSS / TSS, \quad (4)$$

where RSS – residual sum of squares; TSS – total sum of squares; P -value – for each coefficient, determine whether it is statistically significant P -value < 0.05 :

– Standard errors – reflect the precision of coefficient estimates.

– Residuals (ε) – differences between the actual values of Y and those predicted by the model.

– **P-value:** Determines the statistical significance of each regression coefficient. A low P-value (usually less than 0.05) indicates that the corresponding coefficient is significantly different from zero, meaning that the independent variable has a significant effect on the dependent variable.

– **Standard Errors:** Reflect the precision of the estimates of the regression coefficients. Smaller values of the standard errors indicate more precise estimates of the coefficients. The standard error of a coefficient shows how variable the estimate of that coefficient is across repeated samples.

– Residuals (ε): The difference between the actual values of the dependent variable and the values predicted by the model. Residual analysis helps to assess how well the model fits the data and to identify possible violations of the model's assumptions.

Definition of Productivity in the Regression Approach

Specifics of Defining Productivity in the Regression Model. Productivity in a regression model has a broader interpretation than in the Bayesian approach. Here, productivity is defined as a complex indicator that is formed on the basis of an analysis of several factors that affect work performance. This can be an assessment in the form of a numerical scale that summarizes key aspects of the activity of an employee or team. The main approaches to determining productivity in a regression model are outlined below.

Comprehensive Approach. Productivity is measured as the result of the interaction of several factors, for example:

- Number of tasks completed.
- Adherence to estimates (accuracy in planning).
- Quality of work performed (number of bugs found).
- Participation in team activities (reviews, planning, discussions).

These factors are combined in one equation, which allows you to assess how each of them affects overall productivity.

Productivity Scale. A scoring scale can be distinguished:

- A regression model generates a numerical indicator (for example, from 0 to 100 points) that reflects overall efficiency. This scale uses not only quantitative but also qualitative aspects of work.
- For example, a developer's scale may include the complexity of the tasks performed, adherence to estimates, and the number of defects found.

Multidimensional Analysis. Regression allows you to work with multiple factors simultaneously, assessing their individual and joint impact on performance.

Linear Regression in Project Management: A Practical Example. Imagine you want to understand how the number of tasks completed, meeting deadlines, quality of work, and participation in team activities affect your team's productivity. Linear regression is a mathematical way to answer the question:

- What factors have the greatest impact on productivity?
- How strong is this impact?
- How can you predict productivity based on these factors?

Main goal. Main goal is to take data about the team (performance factors) and "draw a line" through that data to see:

- How changing each factor (e.g., number of tasks) affects overall performance?
- What performance can be expected for given those factors?

The formula looks like this:

$$Productivity = Y = \beta_0 + \beta_1(NumberOfTasks) + \beta_2(Estimates) + \beta_3(Quality) + \beta_4(TeamWork) + \varepsilon, \quad (5)$$

where β_0 – is the base performance when all factors are zero; $\beta_1, \beta_2, \beta_3, \beta_4$ – are coefficients that show how much each factor affects performance; ε – is "noise", i.e., all the other factors that didn't taken into account.

What do the ratios mean? Imagine your team is working on tasks and you see the following:

- If your team completes an additional task, productivity increases by 1 point.
- If the accuracy of estimates increases by 1%, productivity changes by 2 points.
- If the quality of work deteriorates (an additional bug), productivity drops by 3 points.
- If an employee participates in team activities, productivity increases by 4 points.

Each ratio helps you understand how critical this factor is to your team's success.

Practical Example

Formulation of a Real-World Task. Let's evaluate the productivity of the development team based on the following factors:

- Number of tasks completed (X_1) – Completed tasks of varying complexity.
- Compliance with estimates (X_2) – Percentage of actual time matching the planned.
- Quality of work (X_3) – Number of bugs in completed tasks.
- Contribution to teamwork (X_4) – Number of code reviews and participation in planning.

Objective:

- Determine which factors have the greatest impact on productivity.
- Predict the productivity of new team members based on their metrics.

Preparation of the Test Dataset. We took a team of 10 developers:

Table 1 – Set of input data for calculating the regression model

Emp.	X_1	X_2	X_3	X_4	Y
1	22	95	1	10	90
2	18	90	2	12	85
3	25	98	0	15	95
4	20	85	3	8	80
5	17	88	4	7	75
6	23	92	2	9	87
7	19	89	3	11	83
8	24	97	1	14	93
9	21	93	2	10	88
10	20	90	3	9	82

Results of the Regression Model. Lets perform the calculation to obtain estimates of the impact of factors (X_1, X_2, X_3, X_4) on productivity (Y) using the linear regression algorithm described above. Key conclusions:

– *R-square*: – 0.971. The model explains 97.1% of the variation in performance, indicating a very good fit to the data.

– *Adj. R-square* – 0.948 – remains high even after taking into account the number of factors, which confirms the reliability of the model.

Coefficients and their values:

– Constant ($\beta_0 = 54.97$). Baseline performance if all factors are zero.

– Number of tasks (X_1) – $\beta_1 = 0.47$:

- Each additional task increases performance by 0.47 points.

- *P-value* ($P > 0.05$) – Not a very significant factor (probably due to interaction with other variables).

– Estimates (X_2) – $\beta_2 = 0.25$:

- The percent agreement with estimates has a positive effect, but a weak one.

- *P-value* ($P > 0.05$) – Not statistically significant in this model.

– Quality of work (X_3) – $\beta_3 = -2,68$:

- Each additional bug reduces performance by 2.68 points.

- *P-value* ($P > 0.068$) – Almost statistically significant, indicating a significant effect.

– Contribution to the team (X_4) – $\beta_4 = 0.36$:

- Additional review or participation in team processes increases productivity by 0.36 points.

- *P-value* ($P > 0.05$): Not significant factor.

Variance Calculation. Let's choose a confidence level of 95%. This is a standard in scientific research, which is a compromise between sufficient confidence in the predictions and an acceptable level of error. In a normal distribution, 95% of the values are within approximately two standard deviations of the mean ($\mu \pm 1.96\sigma$). This is naturally integrated into many mathematical models.

For a confidence level of 95% ($\alpha = 0.05$) and a large sample ($n > 30$), we can use the quantile of the normal distribution. Let's use the Student's t-distribution, which has "heavier tails" than the normal one to account for additional uncertainty. These values are tabulated. Find the degrees of freedom:

$$df = n - k - 1 = 10 - 4 - 1 = 5;$$

$$t_{\frac{\alpha}{2}} = 1.96(\text{tableValue}).$$

Let's take the residual variance value $\sigma^2 = 4$ as a hypothetical value to demonstrate the calculations. This simplifies the example and makes it easy to calculate the standard error $SE = \sqrt{\sigma^2}$. In real data, this value is calculated using the residuals of the model. In this case prediction interval will be:

$$Y_{predicted} \pm t_{\alpha} \cdot \frac{\sqrt{\sigma^2}}{2} = Y_{predicted} \pm 1.96 \cdot 2. \quad (6)$$

Prediction Logic. This is a model that is built based on team performance data:

$$Y = 55 + 0.47X_1 + 0.25X_2 - 2.68X_3 + 0.36X_4.$$

Table 2 – A set of test data for new employees to calculate performance predictions

Emp.	X_1	X_2	X_3	X_4	Y
New 1	20	92	2	12	N/A
New 2	11	80	10	10	N/A

Substituting values into the model:

$$Y1 = 55 + 0.47 \cdot 20 + 0.25 \cdot 92 - 2.68 \cdot 2 + 0.36 \cdot 12 = 86.36 \pm 3.92.$$

$$Y2 = 55 + 0.47 \cdot 11 + 0.25 \cdot 80 - 2.68 \cdot 10 + 0.36 \cdot 10 = 56.97 \pm 3.92.$$

Taking into account the variance, productivity values vary in the range of 3.92. Accordingly, we were able to calculate the productivity of employees using a regression model. For employee 1, productivity is normal and, in general, corresponds to the level of other employees in a company, while for employee 2, productivity is quite low. Also results show that parameter related to a number of bugs has significant impact on employee productivity.

Possible approaches that can detect reasons of it and fix employees productivity requires further analysis mechanisms and appropriate response.

Conclusion

The article analyzes the possibility of using regression analysis to assess employee productivity in the context of IT projects. A mathematical model was built

that allows taking into account several influencing factors – such as the number of tasks completed, the accuracy of estimates, the quality of execution, and participation in team interaction. The relationships between these variables and the target performance indicator were formalized, and an example of the practical application of the regression model was provided.

The results obtained allow for both current and retrospective performance assessment, revealing patterns in dynamics and identifying untypical deviations. Regular use of such model in HR analytics or project management makes it possible to identify problem areas – for example, a drop in the productivity of an individual employee due to external or internal factors. In the case of new employees, this may indicate adaptation difficulties or onboarding problems. On another hand, if productivity increases, this may indicate professional development (for example, a transition from junior to middle level).

To increase the accuracy of the assessment, the model can be expanded by integrating additional factors, psychological variables, or time dependencies. A separate direction of research is to identify the causes of changes in productivity using other models. This direction of research will allow not only to assess productivity, but also to analyze the factors that could have influenced it.

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РЕГРЕСІЙНИЙ АНАЛІЗ ДЛЯ ОЦІНЮВАННЯ ПРОДУКТИВНОСТІ СПІВРОБІТНИКІВ В УПРАВЛІННІ ІТ-ПРОЄКТАМИ

Анотація. Оцінювання ефективності роботи персоналу є ключовим елементом дієвого управління ІТ-проєктами, особливо в контексті переходу до дистанційної або гібридної моделі роботи, що стала домінуючою після глобальних змін, спричинених пандемією COVID-19, цифровою трансформацією та соціальними зрушеннями. У таких умовах традиційні підходи до вимірювання продуктивності, засновані на безпосередньому спостереженні або формальних звітах, втрачають об'єктивність і не враховують реального контексту виконання завдань. Більшість сучасних інструментів контролю діяльності орієнтовані переважно на моніторинг, а не на глибокий аналітичний аналіз факторів, що формують результативність співробітника. У статті запропоновано використання методів регресійного аналізу як формалізованого статистичного інструментарію для кількісної оцінки продуктивності. Регресійна модель дозволяє одночасно враховувати декілька впливових факторів – кількість виконаних завдань, точність оцінок, якість роботи (кількість дефектів) та участь у командних процесах – і визначати їхній внесок у загальний рівень результативності. Представлено математичне обґрунтування лінійної регресії в контексті управління проєктами, наведено формули розрахунку коефіцієнтів методом найменших квадратів та показники оцінки якості моделі (R^2 , p -value, стандартна похибка). Побудову та інтерпретацію моделі продемонстровано на прикладі реалістичного набору даних десяти розробників. Отримані результати показали високий рівень пояснювальної сили ($R^2 = 0,97$), що підтверджує тісний зв'язок між незалежними змінними та показником продуктивності. Найбільший вплив на ефективність виявлено у фактора якості роботи ($\beta = -2,68$), тоді як участь у командній роботі та кількість завдань мають помірний позитивний ефект. Регресійна модель може бути використана як для ретроспективного аналізу (виявлення закономірностей та відхилень у динаміці продуктивності), так і для прогнозування майбутніх результатів або оцінювання нових співробітників за їхніми метриками. Це забезпечує прозорість, відтворюваність та можливість аналітичної інтерпретації без надмірного використання інструментів контролю. У висновках окреслено переваги та обмеження підходу: висока точність і адаптивність моделі потребують якісних даних та математичної підготовки менеджерів. Перспективним напрямом подальших досліджень є інтеграція регресійних методів із машинним навчанням та байєсівськими моделями для виявлення причин коливань продуктивності та побудови персоналізованих прогнозів. Запропонована модель орієнтована на малі та середні ІТ-команди, які потребують практичної, статистично обґрунтованої альтернативи складним корпоративним системам оцінювання персоналу.

Ключові слова: продуктивність співробітників; регресійний аналіз; управління ІТ-проєктами; оцінювання ефективності

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