Jurnal Sosial dan Sains (SOSAINS)
p-ISSN 2774-7018 e-ISSN 2774-700x

Improving Project Time Estimation in Game Development: Rayleigh Distribution and Program Evaluation and Review Technique Approach

Mochamad Haikal Ghiffari[1], Nur Budi Mulyono[2]
[1,2] Institut Teknologi Bandung, Indonesia
E-mail: mhaikalghiffari@gmail.com

ABSTRACT

The video game industry has grown exponentially over the past few decades, becoming a dominant force in the global entertainment sector. Despite its rapid growth, the game development process remains highly complex and distinct from traditional software development, requiring a creative and agile approach. This paper addresses the challenge of inaccurate time estimation in game development projects, which often results from the inherent uncertainty inherent in the iterative and creative nature of the industry. This study integrates the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) with the Rayleigh distribution to improve the accuracy of time estimation in the context of high uncertainty. Data from a completed game development project by an Indonesian game company is analyzed using this methodology. The results show that the Rayleigh-PERT model, with 70% confidence and an expert quality estimate of 0,3, provides the most accurate time estimation, showing only a 4,26% deviation from actual project performance, compared to 20% for CPM and 15,2% for traditional PERT. This research contributes to improving project management in the video game industry by incorporating uncertainty into time estimation, offering more realistic schedules for game development projects, and improving overall project execution.

Keywords: *game development project, project management, project scheduling management, rayleigh distribution*

INTRODUCTION

Video game industry is an entertainment industry that has been around since 1960s. Video game industry is much younger Industry compared to another entertainment industry like the film, literature and music industries, that has been around for centuries (Malliet & De Meyer, 2005; Stanton, 2015; Wardyga, 2023) Over the past few decades, video game industry has grown exponentially to becoming a major sector within the entertainment industry. In 2022, the global gaming industry generated an estimated $184.4 billion (Hsiung et al., 2023; Kokkonen & Holmlund, 2023; Kumar, 2024; Wijman, 2022), generating more revenue than the global music industry ($26.2 billion) (IFPI, 2023) and the global movie industry ($26 billion in box office revenue) (Frater, 2023). Games have become more popular with each passing year, evidenced by the fact that in 2018 there were 7.934 games on steam, and in 2023 the number grew to 12.068, averaging about 33 games every day (Clement, 2024). This growth highlights the increasing competitiveness of game development, which requires game studio to continue innovate in creating video game (Hsiung et al., 2023).

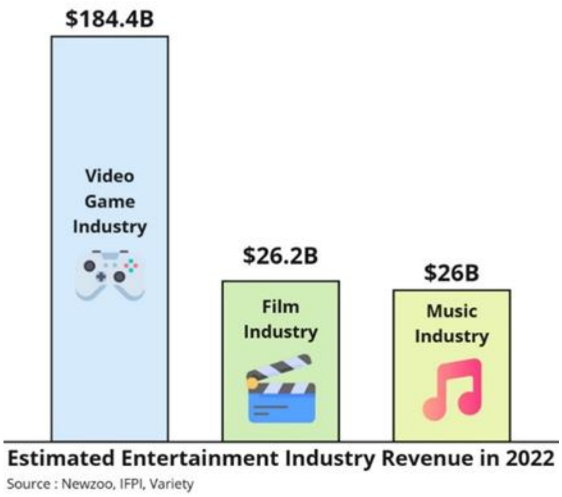

Figure 1. Estimated Entertainment Industry Revenue in 2022

A video game is a software application that allows one or more players to make decisions by manipulating game objects and resources to achieve certain goals (Chugai, 2023; Legerén Lago, 2017). However, video games cannot be viewed solely as software products; they can also be viewed as creative works, cultural expressions, or even art (Wolf, 2021) (Engström et al., 2018). The process of developing a video game differs significantly from ERP systems or other business-oriented software, requiring a different approach that reflects the creative and dynamic nature of the medium.

Because of these differences, simply applying the traditional Software Development Life Cycle (SDLC) to game development is not sufficient (Petrillo et al., 2009) (Islam & Ferworn, 2020; Maryani et al., 2022). To address this, the Game Development Life Cycle (GDLC) has been introduced as a specific framework to guide the game development process (Pandey et al., 2018; Wibowo et al., 2025; Wibowo & Hermanto, 2022). Several studies have proposed GDLC models that offer guidelines for the industry (Ramadan & Widyani, 2013). Each game studio or publisher develops its own unique methodology for creating games. In game development, agile approaches, with flexible requirements, diverse teams, and a strong emphasis on creativity, are valued more than (Higuchi & Nakano, 2017).

Agile methodology is the best choice for Game Development as this approach encourage the use of heavy iteration and allows flexibility during every stage of development (Archontakis, 2019). Agile project management also can be developed to foster creativity in the project teams (Olszewski, 2023). The frequent feedback and iterative changes are a way to facilitate the creativity.

However, due to its constant feedback, the video game development is filled with uncertainty in the scope because of future change that may happen.

As video game development embraces creativity, there will be cases where plans are ignored for the sake of project success, as described by the hiding hand principle (Flyvbjerg, 2016). However, planners and managers may display optimism bias during the framing and valuation phases of projects, a phenomenon known as the planning fallacy. The challenge then becomes how to facilitate creativity within project planning while acknowledging these uncertainties, ensuring that the iterative process is balanced with realistic time and resource estimations (Ika et al., 2020).

According to research conducted by Ardianti, F. (2017). Parameter Estimation in Rayleigh Distribution using Maximum Likelihood Method and Bayes Method. This study aims to compare the Maximum Likelihood method and Bayes method in estimating Rayleigh Distribution parameters. The prior distribution for the Bayes method used in this study is Jeffrey's prior. Comparison of the two methods is done through data simulation on various parameter conditions and sample sizes. Evaluation of the two methods is done through observation of the resulting bias and MSE values. Based on data simulation from the estimator obtained using the R program, it is known that the bias values of the two methods show the same pattern, namely the bias value is getting smaller with the larger sample size. The bias value in the Bayes method with the kegurian loss function-L1 shows a smaller number compared to the Maximum Likelihood method and the Bayes method with the precautionary loss function, entropy loss function, and loss function-L1. Meanwhile, the MSE value shows an error that is getting bigger with the condition of the larger sample size. The MSE value of the Maximum Likelihood method is smaller than the MSE value of the Bayes method with the precautionary loss function, entropy loss function, and loss function-L1. This study shows that the Bayes method is not always better than the Maximum Likelihood method in estimating parameters.

This study aims to integrate Rayleigh distribution and PERT techniques to improve the accuracy of time estimation in game development projects that have a high level of uncertainty. Meanwhile, the benefits of this study are to provide a tool that can be used by project managers to improve the accuracy of time planning, thus helping in managing resources more efficiently.

RESEARCH METHODS

This data will be sourced from game development projects, which called Project Black, that have been completed by undisclosed game companies based in Indonesia. Key internal documents will include project reports, development schedules, and task plans, all of which are created periodically by the company. These materials provide comprehensive insight into the company's past operations, strategies and results, providing a solid basis for comparing and analyzing specific aspects of current projects.

The game development project game data will be analyzed using a project management framework such as CPM to outline planned project tasks and can effectively determine critical paths to project completion. Additionally, by combining PERT and Rayleigh Distribution, project uncertainty can be accurately measured and quantified. Accurate estimates are anticipated results obtained from problem formulation and schedule re-evaluation procedures.

In the Eastern-European Journal of Enterprise Technologies, V. Litvinov & A. Moskaliuk (2018) explored the implementation of Rayleigh Distribution in the Program Evaluation and Review Technique for taking into account unexpected delays. The traditional PERT method uses a three-point estimation (optimistic, pessimistic, and most likely durations) and assumes that project durations follow a Beta distribution. However, this method does not adequately address unforeseen delays, particularly in projects with a high degree of uncertainty.

The proposed modification involves using Rayleigh Distribution instead of the Beta distribution, allowing the model to account for probabilistic delays by emphasizing the most likely duration while incorporating unforeseen time deviations. The Rayleigh distribution is ideal in this context as it aligns with the cumulative effect of independent delays that are common in highly detailed, complex project structures. The study highlights the use of Rayleigh distribution to estimate the maximum time and minimum. The calculation for maximum time and minimum time is as follows:

$$T_{min} = T_{exp} - a \quad (3)$$

$$T_{min} = T_{exp} - b \quad (4)$$

$$a = \sigma * \sqrt{-2\ln(p)} \quad (5)$$

$$b = \sigma * \sqrt{-2\ln(1-p)} \quad (6)$$

Where Texp is the expert's estimate of the most likely completion time, σ is the quality of the expert making the estimate, and p is the probability that the project will be get delayed within the estimated time. In this context, if p is equal to 10% (0.1), it means that 90% of the project will be completed. With p and σ determined before the calculation, the formulas for a and b can be simplified as in formula (7) and (8) below. Data on the changes in the coefficients Ka and Kb in the calculation of a and b are shown in Table 1.

$$a = \sigma * \sqrt{-2\ln(p)} \quad (7)$$

$$b = \sigma * \sqrt{-2\ln(1-p)} \quad (8)$$

Table 1. Coefficients for calculation of minimum and maximum time

p	K_a	K_b
0.1	0.459043605	2.145966026
0.2	0.668047231	1.794122578
0.3	0.844600431	1.551755654
0.4	1.010767653	1.353728726
0.5	1.177410023	1.177410023
0.6	1.353728726	1.010767653
0.7	1.551755654	0.844600431
0.8	1.794122578	0.668047231
0.9	2.145966026	0.459043605

RESULTS AND DISCUSSION

The researcher will begin the Project Black critical path analysis by defining all activities using the Work Breakdown Structure (WBS) method. Project Black consists of 14 activities that are clearly defined in the Work Breakdown Structure (WBS). These activities serve as the foundation for achieving the overall objectives of the project. The researcher has been concluded that there are 10 critical activities with an estimated project completion time of 205 working days.

PERT analysis will then be employed to determine the time and cost estimates in three scenarios: Optimistic, Most Likely, and Pessimistic. The Most Likely Time Estimate (M) is based on expert estimates provided in the project plan. The Optimistic Time Estimate (O) is derived from historical data and past experiences. Experts at PT. ABC have stated that successful project completion is typically 25% faster than the Most Likely Time prediction. Conversely, the Pessimistic Time (P) estimate accounts for delays, such as a week or an extra sprint, based on historical trends. As a result, the Pessimistic Time is expected to be roughly 1.5 times the Most Likely Time. These estimates are then used to calculate the Expected Time (ET) for each task through a weighted average formula:

$$P = M * 0,75 \quad (9)$$

$$O = M * 1,5 \quad (10)$$

$$TE = \frac{(O + 4M + P)}{6} \quad (11)$$

In addition to estimating task durations, PERT incorporates the concepts of Standard Deviation and Variance to assess uncertainty and variability in time estimates. Standard Deviation (σ) provides a measure of the spread of possible durations, indicating how much the time estimates deviate from the Expected Time. Variance (σ2) measures overall variability and is valuable for combining uncertainty across multiple tasks to assess the total variability in project duration. By combining these measures, PERT provides a comprehensive framework for estimating project durations while accounting for uncertainty and variability

$$\text{Standard Deviation} = \sigma = \frac{(P - O)}{6} \quad (12)$$

$$Variance = \sigma^2 = \left(\frac{(P - O)}{6}\right)^2 \quad (13)$$

Table 2. PERT Calculation

Activity	**Optimistic Time (O)**	**Most Likely Time (M)**	**Pessimistic Time (P)**	**Expected Time (ET)**	**Standard Deviation**	**Variance**
1	7,5	10	15	10,417	1,25	1,563
2	30	40	60	41,667	5	25
3	7,5	10	15	10,417	1,25	1,563
4	11,25	15	22,5	15,625	1,875	3,516
5	15	20	30	20,833	2,5	6,25
6	7,5	10	15	10,417	1,25	1,563
7	26,25	35	52,5	36,458	4,375	19,141
8	15	20	30	20,833	2,5	6,25
9	7,5	10	15	10,417	1,25	1,563
10	26,25	35	52,5	36,458	4,375	19,141

Table 2 presents the PERT calculations for the project activities, incorporating the updated time estimates specifically for the critical path. The revised PERT analysis estimates the total project completion time to be 213.5 days, which is approximately 8 days longer than the initial project plan. This difference is primarily due to the quantification of uncertainty inherent in the PERT model, which accounts for variability in the optimistic, most probable, and pessimistic time estimates.

As already explained in the previous chapter, the implementation of Rayleigh distribution and PERT Analysis involves using Rayleigh Distribution instead of the Beta distribution. Beta distribution is restricted by the interval from an optimistic to a pessimistic evaluation of execution time. The Rayleigh distribution is ideal in this context as it aligns with the cumulative effect of independent delays that are common in highly detailed, complex project structures.

In this model, the key factor influencing estimates is the quality of input from experts (σ) and possible project delays (p). To explore different scenarios, researchers will experiment with different combinations of expert quality and project delay probabilities. This will help assess how changes in these parameters affect the overall time estimate.

The researcher will calculate the time estimation using expert quality $\sigma = 0.3$ and $\sigma = 0.1$, with probabilities of 90% completion ($p = 0.1$) and 70% completion ($p = 0.3$). By adjusting these parameters, we can analyze how varying levels of expert accuracy and potential delays impact the overall project timeline, providing valuable insights for project planning and risk management.

Table 3. Rayleigh Distribution Model with σ = 0,1 & p = 0,1

Activity	Workdays Plan	Time Maximum	Time Minimum
1	10	10,46	7,85
2	40	41,84	31,42
3	10	10,46	7,85
4	15	15,69	11,78
5	20	20,92	15,71
6	10	10,46	7,85
7	35	36,61	27,49
8	20	20,92	15,71
9	10	10,46	7,85
10	35	36,61	27,49
Total	**205**	**214,41**	**161,01**

Table 4. Rayleigh Distribution Model with σ = 0,1 & p = 0,3

Activity	Workdays Plan	Time Maximum	Time Minimum
1	10	10,84	8,45
2	40	43,38	33,79
3	10	10,84	8,45
4	15	16,27	12,67
5	20	21,69	16,90
6	10	10,84	8,45
7	35	37,96	29,57
8	20	21,69	16,90
9	10	10,84	8,45
10	35	37,96	29,57
Total	**205**	**222,31**	**173,19**

Table 5. Rayleigh Distribution Model with σ = 0,3 & p = 0,1

Activity	Workdays Plan	Time Maximum	Time Minimum
1	10	11,38	3,56
2	40	45,51	14,25
3	10	11,38	3,56

4	15	17,07	5,34
5	20	22,75	7,12
6	10	11,38	3,56
7	35	39,82	12,47
8	20	22,75	7,12
9	10	11,38	3,56
10	35	39,82	12,47
Total	**205**	**233,23**	**73,02**

Table 6. Rayleigh Distribution Model with σ = 0,3 & p = 0,3

Activity	Workdays Plan	Time Maximum	Time Minimum
1	10	12,53	5,34
2	40	50,14	21,38
3	10	12,53	5,34
4	15	18,80	8,02
5	20	25,07	10,69
6	10	12,53	5,34
7	35	43,87	18,71
8	20	25,07	10,69
9	10	12,53	5,34
10	35	43,87	18,71
Total	**205**	**256,94**	**109,57**

The researcher will use historical project performance data to assess how close the estimates of each method are to actual progress. This analysis will include a comparison between CPM Analysis, PERT Analysis, and PERT with Rayleigh Distribution. The actual progress is documented through project documents containing team performance, details of the scope, labor documentation, et cetera. The actual time of the game development project is shown in the following table.

Table 7. Game Development Project Actual Time

No	Activity	Planned Time	Actual Time
1	Project Initiation	10	10
2	Game Design Documents	40	40
3	Minimum Viable Product	10	10
4	Client System Integration	15	18
5	Client Feature Implementation	20	25

6	3rd Party Integration	10	16
7	Beta Test Build	35	44
8	Beta Testing	20	30
9	Beta Testing Feedback	10	10
10	Release Build	35	43
Total		**205**	**246**

After completing the time estimation calculations for each approach, the researchers have compiled the results into a table to simplify the comparison between each estimate and the actual value. The researchers have chosen to directly compare the accuracy of each model's progress analysis. This approach allows for a more detailed and contextual assessment of the project status. By focusing on direct comparisons, the researchers aim to obtain a clearer and more accurate picture of each model's performance.

Table 8. Time Estimation Method Comparison

No	Method Estimation	Time Estimation (Days)	Variance to Actual (Days)	Variance to Actual (%)
1	Critical Path Method	205	41	20%
2	PERT Method	213,54	32,46	15,2%
3	Rayleigh Time Maximum with σ = 0,1 & p = 0,1	214,41	31,59	14,73%
4	Rayleigh Time Maximum with σ = 0,1 & p = 0,3	222,31	23,69	10,36%
5	Rayleigh Time Maximum with σ = 0,3 & p = 0,1	233,23	12,77	5,47%
6	Rayleigh Time Maximum with σ = 0,3 & p = 0,3	256,94	10,94	4,26%

The findings suggest that Rayleigh Distribution with 70% confidence and 0,3 expert quality estimation closely aligns with the actual progress of the Game Development Project, exhibiting the lowest deviation of only 4,26% in comparison to other estimation methods. On the other hand, the CPM estimation deviates the most from the actual development, with a variation of 20%. This is mainly due to the fact that the CPM technique does not consider uncertainties in its model estimation (deterministic plan). The PERT estimation, which considers uncertainty, lies between the CPM and Rayleigh PERT estimations in terms of proximity to the real progress, with a variance of 15.2%.

The results of this research gap are that traditional time estimation methods such as the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) often do not consider the high level of uncertainty inherent in game development projects. Most previous studies have only relied on the Beta distribution in PERT, which has limitations in handling significant variations and unexpected events in project duration.

Based on previous studies, such as those conducted by Litvinov and Moskaliuk (2018), it has been shown that the Rayleigh distribution has the potential to improve the accuracy of time estimation. However, its application is still limited to projects with certain specific characteristics, such as engineering or construction projects. There has been no comprehensive research testing this distribution in the context of game development which has unique creative and technical dynamics.

CONCLUSION

The primary objective of this research is to resolve the significant issue of inaccurate time estimations affecting Game Development Project. To address this issue, the researcher has developed a comprehensive set of analytical methods aimed at improving the accuracy of these estimates. These methods include Critical Path Method (CPM) Analysis and Program Evaluation and Review Technique (PERT) Analysis. In addition, an innovative approach has been used by integrating Rayleigh distribution with PERT. These methodologies are designed to enhance the estimation process by integrating a deeper understanding of the project's complexity and uncertainty, thereby improving the overall project management and execution. The following is a summary of the analyses performed: The integration of Rayleigh Distribution and PERT has improved the accuracy of time estimation based on direct comparison with actual project performance. The use of Rayleigh distribution is an appropriate approach for Game Development Projects due to its uniqueness compared to other projects such as high uncertainty and ambiguity, complex decision environment from all aspects, and dynamic conditions. The findings suggest that Rayleigh Distribution with 70% confidence and 0,3 expert quality estimation closely aligns with the actual progress, exhibiting the lowest deviation of only 4,26% in comparison to other estimation methods. On the other hand, the CPM estimation deviates the most from the actual development, with a variation of 20%. The PERT estimation, which considers uncertainty, lies between the CPM and Rayleigh PERT estimations in terms of proximity to the real progress, with a variance of 15.2%.

DAFTAR PUSTAKA

Archontakis, I. S. (2019). *Agile Development In The Video Game Industry: Examining The Effects Of Iteration And Methods Of Limiting It*.

Chugai, O. (2023). The Power Of Games: What, Why And How To Employ It In Education. *European Science*, *Sge18-02*, 52–82. https://doi.org/10.30890/2709-2313.2023-18-02-024

Higuchi, M. M., & Nakano, D. N. (2017). Agile Design: A Combined Model Based On Design Thinking And Agile Methodologies For Digital Games Projects. *Revista De Gestão E Projetos*, *8*(2), 109–126. https://doi.org/10.5585/gep.v8i2.528

Hsiung, H.-H., Lin, C.-Y., & Zhu, G.-Y. (2023). The Impact Of Intellectual Capital Efficiency On Value Creation In Video Game Industry—An Evidence From Taiwan. *Journal Of Infrastructure, Policy And Development*, *7*(3), 2340. https://doi.org/10.24294/jipd.v7i3.2340

Islam, A., & Ferworn, A. (2020). A Comparison Between Agile And Traditional Software Development Methodologies. *Global Journal Of Computer Science And Technology*, *20*(2), 7–42.

Kokkonen, A., & Holmlund, J. (2023). *The Future Of Gaming?: A Study On The Effects Of Cloud Gaming On Traditional Game Purchase And Engagement*.

Kumar, A. (2024). Copyright Protection Of Video Games In The Era Of Artificial Intelligence. *Sports Laws In India (University Book House Pvt. Ltd., Jaipur 2024 Forthcoming)*.

Legerén Lago, B. (2017). Al-Kimia: How To Create A Video Game To Help High School Students Enjoy Chemistry. *Serious Games And Edutainment Applications: Volume Ii*, 259–272.

Malliet, S., & De Meyer, G. (2005). The History Of The Video Game. *Handbook Of Computer Game Studies*, 23–45.

Maryani, H. P., Gaol, F. L., & Hidayanto, A. N. (2022). Comparison Of The System Development Life Cycle And Prototype Model For Software Engineering. *Int. J. Emerg. Technol. Adv. Eng*, *12*(4), 155–162.

Olszewski, M. (2023). Agile Project Management As A Stage For Creativity: A Conceptual Framework Of Five Creativity-Conducive Spaces. *International Journal Of Managing Projects In Business*, *16*(3), 496–520.

Pandey, J., Singh, A. V., & Alabri, A. A. (2018). Proposing A Hybrid Methodology For Game Development. *2018 7th International Conference On Reliability, Infocom Technologies And Optimization (Trends And Future Directions)(Icrito)*, 142–146. 10.1109/ICRITO.2018.8748360

Ramadan, R., & Widyani, Y. (2013). Game Development Life Cycle Guidelines. *2013 International Conference On Advanced Computer Science And Information Systems (Icacsis)*, 95–100.

Stanton, R. (2015). *A Brief History Of Video Games*. Robinson Londres, Reino Unido.

Wardyga, B. J. (2023). *The Video Games Textbook: History• Business• Technology*. Crc Press.

Wibowo, T., Adnas, D. A., Mulyanto, M., & Marvel, A. A. (2025). Crafting An Interactive Video Game Court System For Moral Development And Legal Insight. *Zonasi: Jurnal Sistem Informasi*, *7*(1), 85–94.

Wibowo, T., & Hermanto, E. (2022). Development Of Global Warming Themed

Video Games: Implementation Of Game Development Life Cycle (Gdlc) Framework. *Combines-Conference On Management, Business, Innovation, Education And Social Sciences*, *2*(1), 365–372.

Wijman, T. (2022). The Games Market In 2022: The Year In Numbers. *Newzoo Url: Https://Newzoo. Com/Resources/Blog/The-Games-Market-In-2022-The-Year-In-Numbers (Дата Обращения: 15.02. 2023)*.

Wolf, M. J. P. (2021). *Encyclopedia Of Video Games: The Culture, Technology, And Art Of Gaming [3 Volumes]*. Bloomsbury Publishing Usa.