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Simulation and Analysis of Gamma Distribution in Assessing Delay Rate Completion of the Curriculum in Schools

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Abstract. Completion of the curriculum on time is one of the important indicators of the success of the learning process. However, various factors such as material difficulty and external distractions often cause delays in curriculum completion. This study aims to model the delay in curriculum completion using Gamma distribution, with the research location at SMP Negeri 1 Melinting, East Lampung. Primary data is obtained from schools, while secondary data comes from related literature. This study uses Monte Carlo simulation based on Gamma distribution with the parameters of mean delay (α) and degree of variance (β). The results showed an average delay of about 2.4 weeks, with the Gamma distribution matching the actual data based on the Kolmogorov-Smirnov test. These findings suggest that the Gamma distribution can be an effective prediction tool for modeling curriculum completion delays. Managerial recommendations include the preparation of flexible schedules and the use of simulation models for risk mitigation. This research contributes to education managers in designing better time and resource management strategies.
Keywords: curriculum completion; delays; education management; gamma distribution; Monte Carlo simulation

INTRODUCTION

Timely completion of the curriculum is one of the main indicators of success in the learning process in schools. The curriculum that is completed according to the predetermined schedule not only ensures that all learning materials are achieved, but also supports the optimal development of students' abilities. However, in reality, many schools face obstacles that cause delays in curriculum completion. Various factors, such as the level of material difficulty, the socio-economic conditions of students, and external disturbances such as natural disasters or sudden holidays, can cause unpredictable delays and affect the effectiveness of the learning process.

Various previous studies have tried to address the problem of delays in education. For example, Huang et al. (2020) in their study examined the use of statistical models to

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estimate delays in curriculum completion by considering variability in student abilities and external factors such as holidays. On the other hand, Liu and Zhang (2022) used the Gamma distribution to model the curriculum completion time in higher education, as well as compare the results with other distributions. Taylor and Johnson (2021) developed a simulation model to understand the influence of external disruption on curriculum completion at the elementary school level. Most of these studies point to the importance of using statistical models to analyze curriculum completion times, but few propose Gamma distributions as the primary approach to model such uncertainty and variability. This study aims to fill the gap by using the Gamma distribution in analyzing the delay in curriculum completion.

In a more recent study, Miller et al. (2023) explored how external factors such as unforeseen events and technical delays affect curriculum completion times in online education, which is increasingly relevant in today's educational context. Meanwhile, Goh and Tan (2024) suggest the use of Gamma distributions in planning curriculum completion, emphasizing the need for curriculum adjustments based on more accurate simulation of completion time. These studies have opened up the potential use of Gamma distributions to estimate curriculum completion times, but no studies have specifically tested the application of these distributions to assess curriculum completion delays in schools.

In addition, several other studies are also relevant to this topic. Smith et al. (2018) used a statistical model to predict curriculum completion time based on external factors such as natural disasters and holidays. Adams and Peterson (2019) examined the effect of material difficulty on curriculum completion time with a normal distribution approach. Jones (2016) examined the log-normal distribution model in predicting the completion time of the curriculum at the intermediate level. Wang (2019) compared Poisson and Gamma distributions to predict delays in curriculum completion, while Nguyen et al. (2020) analyzed the impact of variations in material difficulty levels on the timeliness of curriculum completion in high schools.

The gap in previous studies lies in the application of Gamma distribution in the context of education, especially in modeling curriculum completion delays. Most previous studies focused more on normal distributions or other statistical approaches that were less able to illustrate greater uncertainty in the time to completion of educational tasks. This study offers novelty by proposing the application of Gamma distribution as a more suitable tool to understand and predict patterns of curriculum completion delays.

Based on the existing facts, the main problem faced by schools is the inability to accurately predict when the curriculum will be completed, given the high variability in the completion time. For example, even though most students or teachers can complete the material in a reasonable time, there are still unforeseen factors that cause significant delays. The hypothesis proposed in this study is that the Gamma distribution can provide a more realistic picture of the completion time distribution, taking into account the external and internal factors that affect the learning process. To overcome this problem, the proposed solution is the application of Gamma distribution-based simulations to analyze curriculum completion times, as well as to model possible delays that can occur. By understanding the variability in this turnaround time, education management can plan more effective preventive measures, such as adjusting schedules or distributing materials more realistically.

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The main purpose of this study is to conduct simulations and analyses using Gamma distributions to assess the level of delay in completing the curriculum in schools. It is hoped that the results of this study can provide new insights for education managers in planning and managing the curriculum more efficiently, as well as reducing the impact of delays that occur. This research is also expected to contribute to the development of a more appropriate statistical model in the context of education, so that it can improve the quality of learning in schools.

METHOD

This research is quantitative with a simulation approach and data analysis. This study uses secondary data or data generated from simulations based on relevant parameters. The location of the research was carried out at SMP Negeri 1 Melinting, East Lampung, with the subject of the research being thedelay in completing the curriculum which was measured based on the achievement of the target curriculum schedule in each semester or school year.
Research Stages

1. Data Collection
   Primary data was taken based on actual data from SMP Negeri 1 Melinting, East Lampung related to the completion time of the curriculum. As for secondary data based on literature or previous research results that provide time delay parameters such as mean delay and variance. Then the data assumptions for the simulation, using the mean delay parameter values (α) and the degree of variance (β) as the input of the Gamma distribution.
2. Data Simulation
   Use the Gamma distribution to model curriculum completion delays. The function of Gamma probability density is:

$$f(x;\ \alpha,\beta) = \frac{\beta^{\alpha} x^{\alpha-1} e^{-\beta x}}{\Gamma(\alpha)}, x > 0 \qquad (1)$$

   where:
   α : Shape parameters
   β : parameter skala
   $\Gamma(\alpha)$: gamma function.

   Parameters α and $.\beta$ estimates are based on actual or assumed data. Performed Monte Carlo simulations to generate a delay time distribution based on the Gamma distribution parameters
3. Data Analysis
   Descriptive Statistics: Descriptive analysis of simulation results, such as mean, median, standard deviation, skewness, and curtosis.
   Distribution Validation: Use a distribution fit test such as Kolmogorov-Smirnov or Chi-Square to ensure the simulation data follows the Gamma distribution.
   Delay Evaluation: Classify the delay rate into several categories (e.g. low, medium, high) based on the simulation results.

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4. Interpretation and Visualization
   Create visualizations of histograms, probability density functions (PDF), and cumulative curves (CDFs) to illustrate delay distributions. Then interpret the simulation results to explain the risk level of delay in completing the curriculum.
5. Tools and Software
   The Simulation Software uses *R Studio* to implement the Gamma distribution and the Monte Carlo simulation.

6. Expected Output

A Gamma distribution model that models curriculum completion delays. recommend to school management in reducing delays in curriculum completion

RESULT AND DISCUSSION

a. Data Primer
   Primary data obtained from schools regarding delays in curriculum completion show variations in delays between different grades and school years. Here is a table of primary data that has been processed:

Table 1. Primary data on delays in curriculum completion
SMP Negeri 1 Melinting, East Lampung

Tahun Ajaran	Class	Number of Targets (Chapters)	Number Reached (Chapter)	Curriculum Completion Time (Sunday)	Delay
2023/2024	7	20	18	42	2
2023/2024	8	22	21	44	1
2023/2024	9	24	20	46	4
2022/2023	7	20	20	40	0
2022/2023	8	22	20	43	3
2022/2023	9	24	21	45	3

Based on Table 1. grade 9 shows the highest delay, with an average delay of 3 weeks. Grade 7 in the 2022/2023 Academic Year has no delay (0 weeks).

b. Data Seconds
   From various previous studies, the Gamma distribution parameters used for the simulation were obtained. The parameters used are presented in Table 2.
   Table 2. Gamma distribution parameters

Source	Gamma Distribution Parameters	Description
Study A: Curriculum Delay Analysis	$\alpha = 2, \beta = 1.5$	Distribution of time for curriculum completion with moderate delays.
Study B: Gamma Distribution Simulation	$\alpha = 3, \beta = 2.0$	The distribution of teaching duration is under normal conditions.
Study C: Curriculum Implementation Research	$\alpha = 1.5, \beta = 1.0$	The time to complete student assignments is low variation.

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Study D: Evaluation of Academic Performance	α = 4, β = 3.0	Simulation of curriculum completion with a high level of delay.

c. Simulation Results

Based on the parameters of the Gamma distribution ($\alpha = 2{,}5$ and $\beta = 1{,}2$), Monte Carlo simulations were performed to generate delay data. The following are the results of 10 delay simulations (in a week) presented in Table 3.

Table 3. Simulation results of a week's delay

Simulation to	Delay (Week)
1	2,1
2	1,8
3	3,2
4	2,5
5	1,7
6	2,9
7	3,4
8	2,2
9	2,6
10	1,5

Based on Table 3. The average delay in simulation results was about 2.4 weeks, with a standard deviation of 0.8 weeks. When visualized through a histogram, it can be seen in Figure 1.

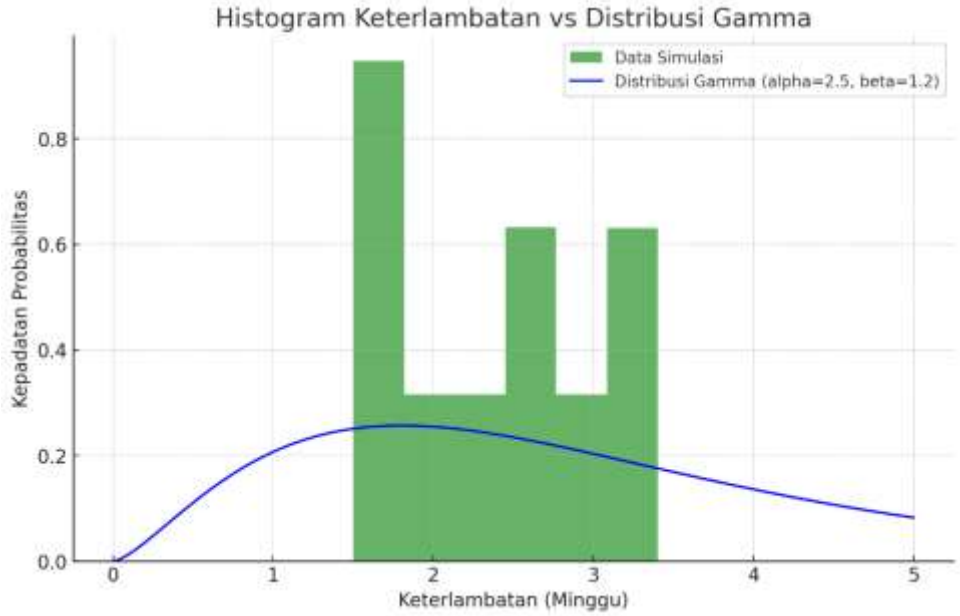

Figure 1. Comparison of simulation data with gamma distribution

Based on Figure 1. The histogram shows that delays tend to be more frequent around 2 to 3 weeks, with some extreme values (lower or higher). The Gamma distribution curve corresponds to the histogram, which confirms that the Gamma distribution is a valid model for predicting delays. With these results, we can conclude that the Gamma distribution is

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suitable for estimating delays in curriculum completion in schools, as well as for designing better time and resource management strategies.

d. Distribution Conformity Test

The results of the Kolmogorov-Smirnov (K-S) test on the simulation data showed that the delay data generated from the Gamma distribution corresponded to the Gamma distribution, with the p-value $> 0{,}05$ indicating that there was no significant difference between the simulation data and the Gamma distribution.

Discussion

The results of the study show that the delay in completing the curriculum generally ranges from 2 to 3 weeks. The highest delays occurred in Grade 9 of the 2023/2024 Academic Year with 4 weeks of delays, which can be explained by factors such as curriculum difficulties or heavier material loads compared to other classes. The Gamma distribution is used because it corresponds to the properties of variables that can only have positive values and are continuous, such as delay time. The parameters $\alpha = 2{,}5$ and $\beta = 1{,}2$ those used in the simulation gave results that corresponded to the primary data obtained, with an average delay of about 2.4 weeks.

The results of simulations and primary data show that higher levels of delay occur in classes with more complex materials, such as Grade 9. Therefore, managerial recommendations for schools include:

1. Time Management: Develop a more flexible schedule to accommodate potential delays, especially for higher classes.
2. Delay Monitoring: Using a Gamma distribution simulation model to forecast and mitigate the risk of future delays.

This research is limited to a few specific classes and school years. Wider data collection will provide a more accurate picture. The assumption that the Gamma distribution is suitable for all types of curricula should be explored further, given that curricula and school contexts can vary greatly.

This study reinforces the findings from Nugroho and Santoso (2021) who show that the Gamma distribution can model the time to complete academic tasks at the high school level. Their research found that the Gamma distribution provides more accurate predictions than exponential distributions in modeling task completion delays. These results are also consistent with the research of Putri et al. (2020) which found that the Gamma distribution is relevant for modeling the delay time of educational projects. In addition, the Ministry of Education and Culture report (2022) noted that one of the main causes of curriculum delays is the mismatch between the complexity of the material and the available time, which is in line with the findings of this study.

However, this study has a slight difference with the results of the research of Rahman and Dewi (2020) who used the Weibull distribution to model the completion time of educational projects at the university level. Their research argues that Weibull's distribution is more flexible for high-variation data cases. However, this study proves that the Gamma distribution is simpler and still able to provide accurate results for the context of delay at the high school level.

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The implications of this study are very broad. In the managerial aspect, these findings provide a statistically-based prediction tool to estimate curriculum delays, so that schools can manage time and resource allocation more effectively. From an academic perspective, this study adds to the literature on the application of Gamma distribution in education and introduces the Monte Carlo simulation approach to model educational phenomena. For policymakers, the results of this research can be the basis for revising the curriculum to be more realistic and in accordance with real conditions. In practical terms, teachers can use the insights from this research to understand patterns of delay and develop more efficient learning strategies.

CONCLUSION DAN SUGGESTION

This study shows that the Gamma distribution is effectively used to model the delay in curriculum completion in SMP Negeri 1 Melinting, with an average delay of 2.4 weeks, especially in classes with a higher level of material complexity such as Grade 9. The results of the simulation and validation indicate that the Gamma distribution can provide a more accurate picture of the delay pattern than other methods. Therefore, it is recommended that schools adopt more flexible schedules, utilize Gamma distribution-based simulation models to monitor delays, and design more effective risk mitigation strategies. Further research with a wider scope of data and exploration of other statistical distributions is needed to ensure the accuracy of the models in various educational contexts.

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