

Analysis of New Student Admission Dynamics Using SPMA Model

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Abstract

This study proposes an SPMA (Skeptical–Persuaded–Motivated–Applicants) model to analyze the dynamics of student enrollment at SMP Negeri 3 Langsa during 2015–2025. The model divides prospective parents into four compartments: skeptical, persuaded, motivated, and applicants. Transitions between compartments are governed by media influence, social interaction, motivation formation, enrollment conversion, and attrition rates. Parameter estimation was performed using least-squares curve fitting through piecewise and piecewise-continuous simulations. The results indicate that social interaction plays a more important role than media exposure in influencing parental decisions. The conversion rate from motivation to actual enrollment is relatively high, suggesting that motivated parents are likely to complete the enrollment process. However, the transition from persuasion to motivation remains low, while attrition is still significant. These findings highlight the importance of strengthening parent–school communication, alumni networks, and community engagement rather than relying solely on media promotion. The proposed SPMA model provides a useful analytical framework for understanding enrollment dynamics and supporting more effective student recruitment strategies.

Keywords: *Compartmental Model; Dynamics of Enrollment; Epidemiological Approach; New Student Admission; Secondary School.*

Abstrak

Studi ini mengusulkan model SPMA (Skeptis–Terbujuk–Termotivasi–Pelamar) untuk menganalisis dinamika pendaftaran siswa di SMP Negeri 3 Langsa selama tahun 2015–2025. Model ini membagi calon orang tua menjadi empat kompartemen: skeptis, terbujuk, termotivasi, dan pelamar. Transisi antar kompartemen diatur oleh pengaruh media, interaksi sosial, pembentukan motivasi, konversi pendaftaran, dan tingkat putus sekolah. Estimasi parameter dilakukan menggunakan metode kurva kuadrat terkecil melalui simulasi bertahap dan bertahap kontinu. Hasil menunjukkan bahwa interaksi sosial memainkan peran yang lebih penting daripada paparan media dalam memengaruhi keputusan orang tua. Tingkat konversi dari motivasi ke pendaftaran aktual relatif tinggi, menunjukkan bahwa orang tua yang termotivasi cenderung menyelesaikan proses pendaftaran. Namun, transisi dari persuasi ke motivasi tetap rendah, sementara putus sekolah masih signifikan. Temuan ini menyoroti pentingnya memperkuat komunikasi orang tua-sekolah,

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jaringan alumni, dan keterlibatan masyarakat daripada hanya mengandalkan promosi media. Model SPMA yang diusulkan menyediakan kerangka analitis yang berguna untuk memahami dinamika pendaftaran dan mendukung strategi perekrutan mahasiswa yang lebih efektif.

Kata Kunci: Model Kompartemen; Dinamika Pendaftaran; Pendekatan Epidemiologi; Penerimaan Siswa Baru; Sekolah Menengah.

INTRODUCTION

The choice of favorite schools is a significant phenomenon in the Indonesian education system. This phenomenon is influenced by various factors. Parents' habit of choosing quality schools during the new student enrollment season is understandable, as they certainly have compelling reasons (Arliansyah & Muslimah, 2020). Parents are the first school where children get good grades or otherwise (Buseri, 2014). Parents play a very important role in making decisions about choosing school levels for their children (Ervina I et al., 2019). Parents and students tend to choose schools with a good reputation, high exam results, and academic and non-academic achievements (Naqvi & Naqvi, 2021). Factors such as income level, social background, distance and location, teacher quality, school performance, school environment, and school syllabus are dominant factors that influence parents' decision-making when choosing private schools for their children (Yaacob et al., 2015). The zoning system encourages school selection based on distance from home to school, but many still prioritize their favorite schools even though they are further away (Hayati et al., 2023; Purwanti et al., 2019). The zoning system aims to reduce the gap between favorite and non-favorite schools, but the label of favorite schools is still strongly attached in society (Arlinwibowo et al., 2024; Widyastuti, 2020). Favorite or flagship schools typically use the flagship class program as a strategy to improve student achievement and build a positive image of the school in the eyes of the community and parents. This has proven effective in attracting parents to enroll their children in favorite or flagship schools (Fauzi, 2024).

Schools tend to attract students from low-income and low-education families, especially in rural areas. Conversely, favorite or flagship private schools

are more attractive to highly educated and economically strong families, especially in urban areas (Asadullah & Maliki, 2018). Parents expect preferred or top schools to provide a better learning environment, adequate facilities, and opportunities for higher achievement. Parents' interest in preferred or top schools is influenced by various factors, ranging from the quality of service and the school's reputation to alignment with their values and hopes for their child's future. Parents tend to choose preferred or top schools based on perceived quality, social environment, and school image, rather than solely on academic effectiveness. The quality of service, promotion, and organizational image of a school significantly influence parents' interest in choosing preferred or top schools or private schools. Efforts to strengthen these aspects, such as a school's reputation, identity, and values, have proven effective in attracting parents' interest (Yuliarsi et al., 2023). Parents prefer schools with high-achieving students and a positive social environment. However, this preference is more related to the quality of peers than the school's effectiveness in improving learning outcomes (Abdulkadiroğlu et al., 2020; Tarkhnishvili et al., 2022). Parents tend to choose schools that reflect their family's values and identity. A sense of connection and comfort with the school's values is an important consideration (Keynes et al., 2024). Parents with higher levels of education tend to be more active and interested in choosing and being involved in their children's schools (Vera et al., 2016).

The diffusion of innovative state policies in favored or superior schools is one example of the spread of innovation in education. The widespread adoption of favored or superior education is a complex process that requires synergy between individual, institutional, and social factors (Menzli et al., 2022). Factors such as institutional support, infrastructure readiness, training, and strategic leadership are crucial in facilitating the adoption and spread of favored or superior education (W. Porter & Graham, 2016). Furthermore, public perception of the benefits of superior education, ease of access, and the availability of concrete examples of success (observability) also accelerate the adoption process (Ali, 2024). Obstacles often encountered include resistance to change, lack of information, limited

resources, and policies that do not optimally support innovation (W. W. Porter et al., 2016). Effective communication, collaboration between stakeholders, and a community culture open to change play a crucial role in accelerating the spread of favored or superior education (Giger et al., 2024). Research on school choice tends to focus on the reasons parents choose schools or programs. (Burgess et al., 2015) stated that there are three most important factors: academic achievement, school socioeconomic composition, and travel distance. Teacher quality and class size were reported (Stewart & Wolf, 2014) as relevant factors chosen by parents in choosing a school. Several studies have also reported that the academic quality of a school is an important selection criterion for parents when choosing a school. Researchers of private school choice hypothesize that "market-oriented programs will have a positive impact on student achievement" (Sude et al., 2018).

Conventional approaches to analyzing educational preferences typically employ psychological or sociological approaches. Rational choice theory posits that rational parents choose the best school based on their personal preferences and values (utility), as well as the constraints they face (Egalite & Wolf, 2016). Parents use decision rules to process all available information and maximize their utility by making trade-offs among the attributes that characterize the alternatives. Aggregate behavior is the sum of each parent's behavior and is a function of the frequency with which they choose this school over others in repeated choices. This focus on utility maximization is theoretically sound and robust; it provides a good description of choice behavior, even if parents use different rules. Discrete choice models are widely used to investigate individual-level decision-making (Chorus, 2015). In traditional approaches, decision-makers are asked to choose only one—the most preferred—option from a set of available alternatives. In such cases, researchers have the option of estimating school demand using standard discrete choice models. In more dynamic and collective contexts, such as choosing a favorite or top-tier school, a social epidemiological approach becomes relevant and powerful. Information about a new school can spread through indirect interactions as well as direct contact. Models that assume homogeneous mixing among individuals, in other words, random contact, are called population

models. Population models divide the population into classes that reflect the status of individuals within the population. The epidemic model has been applied to problems in education studies; (Anwar et al., 2021) proposed the SEIRS epidemic model for the problem of online gaming addiction in mathematics students. (Teklu & Terefe, 2022) proposed a deterministic model for the dynamics of student hostility towards mathematics. Recently, (Side et al., 2024) also used the SEIRS epidemic model to address the problem of online gaming addiction among junior high school students in Makassar City. In this study, we will introduce a social context-based epidemiological model based on a system of differential equations that maps the parent population into several compartments based on their preference tendencies. Of the aforementioned works, mathematical modeling research in education, particularly on the spread of social fever, has used an epidemiological approach to our knowledge. Therefore, our study aims to develop a model for the spread of fever at SMPN 3 Langsa among parents in Langsa City. The development of a more complex model, yet appropriate to the local context, in this study adapts the compartmental structure of epidemiology. Borrowing a framework from the infectious disease transmission model, the preferences of prospective students and parents for the school can be modeled as a social fever, which spreads from one individual to another through social contact and interaction.

RESEARCH METHODS

a. Model Formulation

This study adopts an epidemiological approach in the form of a system of differential equations to model the adoption process of a leading educational institution by parents, with a case study of SMPN 3 Langsa. This adoption process is analogous to the spread of infection, where "infection" is represented as the interest and decision of parents to send their children to the school. We adapt SPMA (*Skeptical–Persuaded–Motivated–Applicants*) model framework, where the parent population is divided into four compartments based on their level of knowledge and interest in the school, namely: $S(t)$ is the population of

parents who are not yet aware or have not been exposed to information about school; $P(t)$ is the population of parents who have been persuaded to information about school but have not shown active interest; $M(t)$ is the population of parents who have shown motivated in sending their children to school and $A(t)$ is the population of parents who have taken concrete applicants such as registering their children to school. This model is developed based on several assumptions as follows: the transition from S to P occurs through two main mechanisms, the influence of media/public information (β_1), and social interaction (β_2), through direct contact with parents who have already sent their children to the school (A); parents in P can be more motivated and move to M at a rate of σ ; and parents in M can make a decision and move to A at a rate of γ ; each compartment has the possibility of losing members (leaving the system) at a rate of μ , either due to external factors or internal factors; and The total population of prospective parents is bounded and may decrease over time due to attrition. Thus, $N(t)=S(t)+P(t)+M(t)+A(t)$, where the total population is not necessarily constant because individuals may leave the system at rate μ .

The diagram of transition between compartments is given in Figure 1:

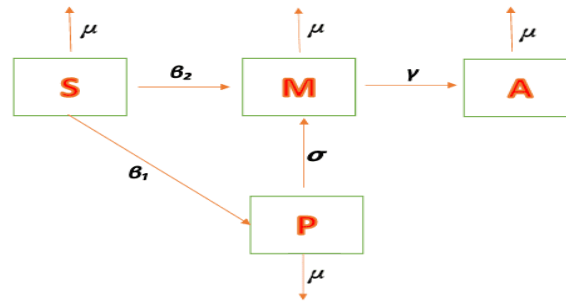


Figure 1. The Diagram of Transition between Compartments

The system dynamics model is:

$$\frac{dS}{dt} = -\beta_1 S - \beta_2 SA - \mu S \quad (1)$$

$$\frac{dP}{dt} = \beta_1 S + \beta_2 SA - \sigma P - \mu P \quad (2)$$

$$\frac{dM}{dt} = \sigma P - \gamma M - \mu M \quad (3)$$

$$\frac{dA}{dt} = \gamma M - \mu A \quad (4)$$

Where: β_1 is general information diffusion rate; β_2 is influence of interactions from registered parents; σ is parent interest rate; γ is interest conversion rate to action (registration); and μ : attrition rate (leaving the system).

b. Mathematical Analysis

Positivity of Solutions

Theorem 1

Let $S(t), P(t), M(t), A(t) \geq 0$, then the solutions of the SPMA model remain nonnegative for all $t \geq 0$.

Proof

Consider the first equation (1), its solution is: $S(t) = S(0) \exp \left[- \int_0^t (\beta_1 + \beta_2 A(\tau) + \mu) d\tau \right]$.

Since the exponential function is always positive, $S(t) \geq 0$. Similarly, $\frac{dP}{dt} |_{P=0} = (\beta_1 + \beta_2 A)S \geq 0$, $\frac{dM}{dt} |_{M=0} = \sigma P \geq 0$, and $\frac{dA}{dt} |_{A=0} = \gamma M \geq 0$. Therefore, trajectories cannot cross the coordinate planes and all state variables remain nonnegative for all $t \geq 0$. So, $S(t), P(t), M(t), A(t) \geq 0$, for all $t \geq 0$.

Boundedness of Solutions

Theorem 2

The feasible region: $\Omega = \{(S, P, M, A) \in \mathbb{R}_+^4 : S + P + M + A \leq N_0\}$ is positively invariant.

Proof

Define: $N(t) = S(t) + P(t) + M(t) + A(t)$. Adding all equations yields: $\frac{dN}{dt} = -\mu N$.

This equation shows that the total population decreases exponentially over time due to attrition. In the context of school enrollment, attrition represents prospective parents who leave the decision-making process because of relocation, preference for other schools, quota limitations, or other external factors. Consequently, the total population remains bounded and nonnegative throughout the observation period. The solution is: $N(t) = N(0)e^{-\mu t}$. Hence

$0 \leq N(t) \leq N(0)$, Therefore, $S(t) + P(t) + M(t) + A(t) \leq N(0)$, which implies that all solutions remain bounded inside Ω . So, Ω is positively invariant.

Equilibrium Point

The equilibrium point is obtained by setting: $\frac{dS}{dt} = \frac{dP}{dt} = \frac{dM}{dt} = \frac{dA}{dt} = 0$. From $0 = -(\beta_1 + \beta_2 A^* + \mu)S^*$, we obtain $S^* = 0$. Substituting into $0 = (\beta_1 + \beta_2 A^*)S^* - (\sigma + \mu)P^*$, gives $P^* = 0$. Similarly, $M^* = 0$, and $A^* = 0$. Thus, the SPMA model possesses the equilibrium $E_0 = (0, 0, 0, 0)$. This equilibrium represents a situation in which no parents remain in any stage of the enrollment process.

Local Stability Analysis

To investigate local stability, the Jacobian matrix of the system is constructed as:

$$J = \begin{pmatrix} -(\beta_1 + \beta_2 A + \mu) & 0 & 0 & -\beta_2 S \\ (\beta_1 + \beta_2 A) & -(\sigma + \mu) & 0 & \beta_2 S \\ 0 & \sigma & -(\gamma + \mu) & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix}.$$

Evaluating at the equilibrium point $E_0 = (0, 0, 0, 0)$ gives:

$$J(E_0) = \begin{pmatrix} -(\beta_1 + \mu) & 0 & 0 & 0 \\ \beta_1 & -(\sigma + \mu) & 0 & 0 \\ 0 & \sigma & -(\gamma + \mu) & 0 \\ 0 & 0 & \gamma & -\mu \end{pmatrix}.$$

Because this matrix is lower triangular, its eigenvalues are: $\lambda_1 = -(\beta_1 + \mu)$, $\lambda_2 = -(\sigma + \mu)$, $\lambda_3 = -(\gamma + \mu)$, and $\lambda_4 = -\mu$. Since $\beta_1, \sigma, \gamma, \mu > 0$, all eigenvalues satisfy: $\lambda_i < 0, i = 1, \dots, 4$. Therefore, the equilibrium point E_0 is locally asymptotically stable.

The local asymptotic stability of E_0 indicates that, in the absence of sufficient persuasion and motivation mechanisms, the numbers of persuaded, motivated, and applicant parents eventually decline toward zero due to attrition. Consequently, sustained enrollment growth requires continuous information dissemination and social interaction among parents.

RESULTS AND DISCUSSION

RESULTS

The data on the number of applicants for SMPN 3 Langsa (last 11 years) that we collected can be seen in Table 1. The data pattern indicate that the dynamics of parental interest in SMPN 3 Langsa can be adequately explained by SPMA model. Descriptively, the annual number of applicants fluctuates throughout 2015–2025, with an increase in 2015–2017, a sharp decline around 2019, and a recovery until 2023 before weakening again in 2025.

Table 1. Data of Applicants for SMPN 3 Langsa

No	Year	Number of Applicants
1	2015	368
2	2016	406
3	2017	435
4	2018	434
5	2019	321
6	2020	344
7	2021	351
8	2022	363
9	2023	397
10	2024	384
11	2025	352

The data pattern appears to fluctuate with a peak around 2017–2018, then declines, then rises slightly again towards 2023, and declines again in 2025. This data can be linked to changes in the values of β_1 (campaign media) and β_2 (alumni/old parent effect) from year to year.

To connect the model simulation results with the actual number of applicants, a scaling factor k was used so that $A(t) \times k \approx$ the annual number of applicants. The parameter estimation process was performed through curve fitting using the least squares method, which minimizes the squared difference between the number of applicants from the model simulation and the actual PSB data for the 2015–2025 period. The estimation focuses on five main parameters: β_1 , β_2 , σ , γ , μ , and an additional parameter in the form of a scale factor k . Two fitting

schemes were applied: piecewise fitting (three separate phases): phase 1 (2015–2018), phase 2 (2019–2021), and phase 3 (2022–2025). Each phase was treated independently with its own parameter estimates, thus capturing variations in parental behavior between periods; and piecewise fitting with continuity (2015–2025): the simulations were conducted continuously from 2015 to 2025, but parameters were allowed to change at phase boundaries. Thus, the initial conditions for each phase were derived directly from the final results of the previous phase, maintaining the continuity of the S , P , M , and A compartments. We consider this approach more realistic because it takes into account the interconnectedness between periods and allows for the interpretation of differences in parameter values across phases. The result of estimate the parameters of SPMA model, we then fitted it based on the annual number of applicants at SMPN 3 Langsa using the least squares fitting method directly to the series $A(t_i)$ at annual time points, adding one scale parameter k so that: $A_{model}(t) \times k \approx A_{observation}(t)$, which represents the effective market size of prospective parents. The estimated parameters are: β_1 , β_2 , σ , γ , μ , and k . The initial conditions are set so that: $A(2015) = A_{data}(2015)/k$; and the other compartments are proportional (conservative). Summary results can be seen in Table 2:

Table 2. Results of SPMA Model Parameter Estimation

Parameter	Description	Estimated value
β_1	The rate of transition S to P due to the influence of media/public information	≈ 0.000
β_2	The rate of transition S to P due to the influence of social interaction (contact with parents in A)	≈ 0.237
σ	Rate of increase in motivation (M) after being persuaded (P)	≈ 0.0228
γ	The rate of conversion of motivation (M) into concrete registrations (A)	≈ 0.372
μ	Member loss ratio of each compartment	≈ 0.108
k	Scale factor to relate the model to real data (number of applicants)	$\approx 1,167$ people

Based on Table 2, it can be observed that each parameter of SPMA model shows significant variation in explaining the dynamics of applicants at SMPN 3 Langsa. The value of β_2 is relatively higher than β_1 , indicating that the influence of parents and social networks is more dominant than promotion through public media. On the other hand, the value of σ is still low, while γ is quite high. This condition indicates that once parents are motivated, the chance of actually registering their children is quite high. However, the biggest obstacle still lies in the initial stage, namely how to change parents from merely being persuaded to being truly motivated. To better understand how these parameters operate in each period, a piecewise fitting approach was conducted by dividing the data into three phases. Figure 2 presents the fitting results for phase 1, which demonstrates the fit of the model's simulation curve to the actual number of applicants. These results serve as a basis for assessing the effectiveness of the promotion in the initial period and the extent to which social interactions and media played a role in increasing the number of applicants during that phase.

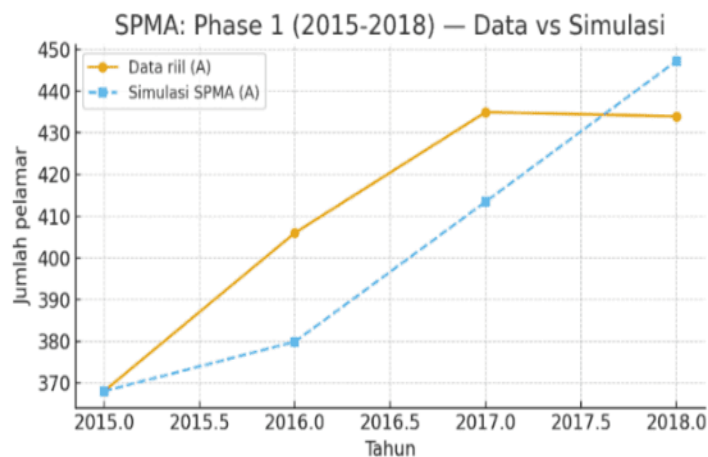


Figure 2. Fitting Piecewise Phase 1

Based on the graph, it can be interpreted that, $\beta_1 > \beta_2$ and σ, γ are quite large; μ is small. This period appears to be campaign/media-driven (β_1), and the conversion process from P to M to A is progressing well (σ & γ are high). During this period, investing in measurable media will effectively maintain the increase in registrations. Phase 1, β_1 is high while β_2 is moderate. γ is relatively large and μ is

small. This means this period was driven by media/promotion and an effective conversion (M to A) process. Effective policies include continuing measurable media campaigns and focusing on calls-to-action that lead directly to registration.

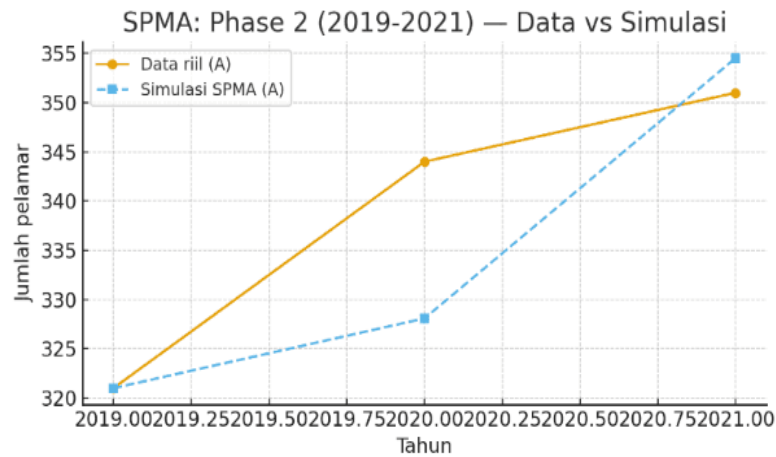


Figure 3. Fitting Piecewise Phase 2

Based on the graph, it can be interpreted that, $\beta_2 > \beta_1$, high γ , medium σ , moderate μ . This period is more influenced by β_2 . Alumni empowerment strategies and parent testimonials can be very effective. Phase 2, β_1 remains high and β_2 increases. σ is high, but γ is very small, and μ increases. This means that although many people are converting to P (high σ), final conversions to A plummet ($\gamma \approx 0$), resulting in stagnant real signups; the exit rate is also higher.

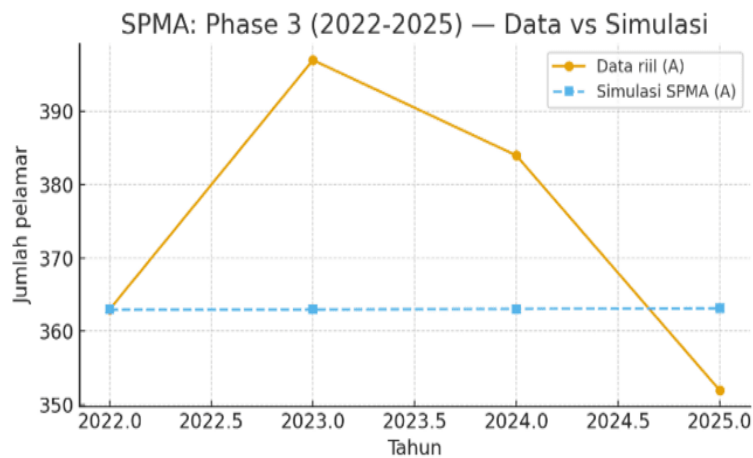


Figure 4. Fitting Piecewise Phase 3

Based on the graph, it can be interpreted that, $\beta_1 > \beta_2$, but $\sigma \approx 0$ and γ is very small, μ is higher - the model indicates a difficulty at the end of the funnel (from P to M to A). Despite some “reach” (large k), exposure does not translate into motivation/registration. This indicates a conversion funnel problem (a strategy is needed to increase σ and γ and suppress μ) before simply increasing promotional costs. Without improving the funnel, simply increasing β_1 will not increase actual applicants. Phase 3, low β_1 and moderate β_2 ; γ close to zero; high μ . This means low reach/promotion, high churn (high μ), and almost no motivation become registration conversion. In this phase, increasing of β_1 alone is not enough; the focus must first be on reducing μ and improving γ and σ , so that promotions result in actual registrations.

Next, we ran piecewise with continuity (one simulation 2015-2025; parameters change at phase boundaries, but the S/P/M/A state persists between phases). Below is a summary of the results, interpretations, output files, and policy/technical recommendations.

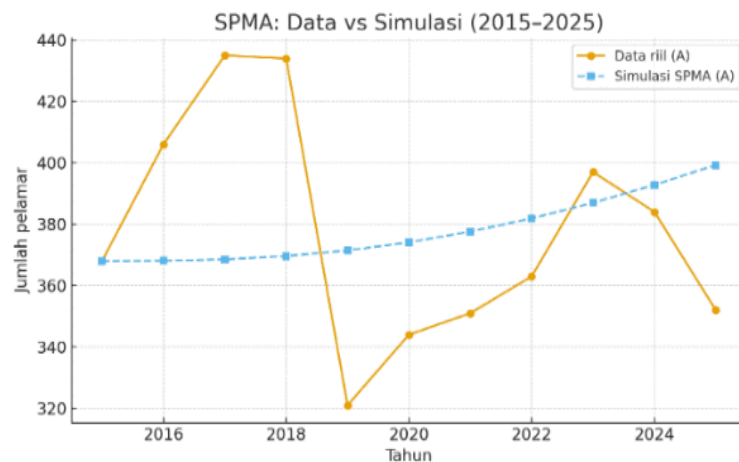


Figure 5. Number of Applicants

Based on the graph, it can be interpreted that:

- With a constant parameter configuration, the model relies more heavily on β_2 than on β_1 . This is consistent with effective influence occurring through parent/alumni conversations rather than generic campaigns.

- b. The interest activation rate of σ is relatively low $\rightarrow$ many drop out at the "persuaded" but not yet strongly motivated phase, necessitating content reinforcement and follow-up in P phase.
- c. The conversion rate of γ is quite high; the main bottleneck is before M phase.
- d. The system drop-out rate of μ is moderate; improvements in quota information, services, and follow-up have the potential to lower μ .
- e. The effective market scale of k provides an estimate of the target community size "reached" by the current strategy.

CONCLUSION

This study developed SPMA (Skeptical–Persuaded–Motivated–Applicants) model to analyze the dynamics of parents' interest in enrolling their children at SMP Negeri 3 Langsa. Based on parameter estimation results, it can be concluded that: social interaction is more dominant than public media in encouraging parents to shift from skepticism to interest. The conversion from motivation to enrollment is relatively high, so school efforts should focus on increasing the persuasion-to-motivation ratio; the attrition rate indicates structural and perceptual barriers that need to be addressed to prevent prospective applicants from switching to other schools. SPMA model is able to capture the general pattern of enrollment numbers and provides an analytical basis for developing more targeted promotional strategies and interventions. Therefore, the implementation of promotional policies at the school should emphasize strengthening the parent community, alumni, and social networks, as well as improving the information and support system to motivate more parents and ultimately enroll their children.

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