



Forecasting Batam City Secondary School Enrolments in 2035: Implementing Double Brown Exponential Smoothing

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Abstract: Batam City, an industrial hub in the Kepulauan Riau Province, Indonesia, boasts a significant immigrant population. The city experiences one of the fastest population growth rates in Indonesia, including a surge in student numbers. The current number of elementary school students and the projected number of junior high and high school students in the next few years play a crucial role in sustainable development, aligning with the government's Golden Indonesia Vision 2045, which aims to cultivate a high-quality and productive generation. To support this initiative, accurate projections of student numbers, particularly in high schools, are essential. This study focuses on forecasting the number of senior secondary school students in Batam City for 2035. Utilizing data from the Batam City Statistics Agency spanning 2019 to 2022. To achieve the research goals, data collection uses secondary data. The authors employed the Smoothing Exponential Brown Parameter to project figures for 2023-2035. The optimal projection was achieved with $\alpha = 0.99$, estimating 29.988 high school students in Batam City by 2030 and 34.775 by 2035. The research findings indicate that the Batam City government is highly recommended to formulate policies and plan to establish 18 new secondary schools, addressing potential shortages in classrooms and educational institutions. Additionally, the study urges the local government to ensure the availability of 1.879 secondary school teachers in Batam City by 2035. These projections can help the administration plan effectively for educational resources to deliver quality education by 2025, contributing to the realization of the Golden Indonesia Vision 2045.

Keywords: exponential smoothing, forecasting, elementary school students, Golden Indonesia visions

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Introduction

Batam is experiencing rapid population growth driven by migration and urbanization factors. The population of Batam City has increased significantly since 1970, when the city was transformed into an industrial area. In 2020, the population of Batam reached 1.196.396. The population of Batam City in 2024 is expected to increase to 1.294.548 people. The annual population growth rate of Batam City was 1.72%. This growth was influenced by the development of the industrial sector, which attracted workers both within the country and abroad. As a result, many families choose to migrate to Batam in search of employment. This condition results in a very high number of marriages in Batam, which increases the number of new students entering school every year. According to the Indonesian Ministry of Education and Culture's student base data, by 2024, the number of students in Batam City is expected to reach 281.280. Of which 136.663 are students in elementary school. In particular, the number of students at the senior high school level in Batam City reached 32.803. Every year, the estimated percentage increase

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in the number of students entering high school is 8.20%. Meanwhile, regarding the forecast of the number of students in Batam, no research has been conducted to date to project future trends, especially for the year 2035.

Elementary School students today will become High School students or their equivalent in 3 to 9 years, and they will be part of the next generation of the nation. Population growth in Batam is partly attributed to the number of elementary school students. The increase in the number of students in Batam City has caused various problems, both within educational institutions, the government, and society. One of the serious problems that occurs every year is that many junior high school graduates do not have the opportunity to enter state senior high schools because of school quotas and limited study space. This is evident in the student base data of the Indonesian Ministry of Education and Culture. By 2024, the number of junior high school students is expected to reach 61.675, and the number of high school students will be 32.803. From the figures presented above, it can be predicted that 30% of the 61.675, or approximately 18.505, who graduate from junior high school will continue to high school.

Meanwhile, the capacity of high schools in Batam City to accept new students is only 10.934, of which 20.558 junior high school graduates will continue to high school. The gap between entry and capacity was 9.624. Every year, this problem becomes an annual problem during the admission of new students and the beginning of the new school year in Batam. Many parents of students who did not attend state schools held demonstrations, making demands on the school, the government, and all interested parties. In response, the Batam City government needs to prioritize the provision of quality educational services, including the availability of school buildings and infrastructure, facilities, and the ideal number of teachers in relation to the number of schools, study groups, and students. The increase in the number of new students poses a significant challenge for the Batam City government in terms of providing education with adequate facilities, particularly at the upper secondary education level.

The growth in the number of students in Batam City is in line with the city's very high population growth. This results in a reciprocal relationship in which the current growth of students will correlate with the number of workers in the future. Andersson and Bergman (2011) stated that adolescent age is a significant predictor of income and employment levels in middle adulthood, controlling for several childhood factors, including intelligence and educational attainment, which typically occur around the time of junior high school and high school. In line with this, Arnett (2001) also stated that adolescence is likely an important marker of the transition to adulthood, particularly in accepting responsibility for one's actions, which is a crucial factor to consider. Rudolph et al. (2001) added that the importance of academic success in adolescent students lies in measuring perceptions of academic control in the future. Leventhal et al. (2001) also stated that teenagers who enter the world of work successfully earlier will have a greater chance of completing high school than their peers. From this, it appears that adolescence is an age when education requires attention, both in terms of quality and educational facilities.

Projections are important to see the future of elementary school students today. Forecasting from various sides, such as from the psychological side. As stated by Prananto et al. (2022), responding to these demands appropriately can support the future psychological development of students. One aspect of the psychological future is motivation. Habibullah et al. (2022) stated that motivation plays a crucial role in encouraging students to learn with full attention and concentration during lessons, thereby achieving the expected learning objectives, one of which is marked by increased learning outcomes.

Analysis of the projected number of students at the public high school level is crucial in assisting the government with educational planning. Azhari et al. (2016) also stated that in optimizing the quality of good schools, not only the quality of teachers and students, but also educational facilities and financing, are considered to make a significant contribution. Shaturaev (2021) stated that state schools are fully owned by the government, meaning that the land, buildings, and facilities are fully subsidized. The school's teachers and staff are partly civil servants, which affords them a certain status, relatively reasonable salaries, and pension schemes. This facility will become one of the benchmarks in state schools for supporting student success. The number of state high school students in Batam is increasing year after year; therefore, it is necessary to improve the facilities at schools. Jhon et al. (2021) stated that not only are elementary school character education programs in Indonesia lacking, but the lack of support, such as socialization, training, facilities, and infrastructure, is the main challenge that comes from state schools. BPS data indicate that 12 sub-districts in Batam City have several students who continue to increase in number from year to year.

Table 1. Number of Students in 12 Sub-Districts in Batam City

Subdistrict	Number of Students Per Year			
	2019	2020	2021	2022
Belakang Padang	762	769	783	800
Bulang	179	196	203	208
Galang	560	619	641	655
Sungai Beduk	1.195	1.303	1.498	1.653
Sagulung	4.217	4.538	4.921	4.216
Nongsa	1.296	1.406	1.484	1.554
Batam Kota	2.241	2.542	2.786	3.253
Sekupang	2.861	3.319	3.669	3.914
Batuaji	416	792	985	1.206
Lubuk baja	647	664	697	720
Batu Ampar	917	917	958	989
Bengkong	2.354	2.512	2.763	3.160
Total	17.645	19.577	21.388	22.328

According to Table 1, the number of public high school students in 2019 was recorded at 17.645, and then increased by 10.95% in 2020. Similarly, in 2021, it increased by 9.25% compared to 2020. For the four years, the average increase in the number of students in public high schools was 8.20%. This is not in line with the number of existing schools; in 2019 and 2020, the number of state high schools was 26, and in 2021 and 2022, the number of schools was 28, with an average of 749 students/school. Not only is it related to welfare, but the higher the number of high school students, the higher their life expectancy. Lutz and KC (2013) stated that in almost all societies, more educated adults have lower death rates and better chances of survival for their children. Therefore, the projection of the future distribution of educational attainment is also important because education has a significant influence on almost every aspect of human development. Meanwhile, the Central Bureau of Statistics data states that the number of public high school teachers in Batam in 2022 will be 957.

The Government's Role in Achieving Vision 2045

To create a quality-productive generation, the government must invest in educational infrastructure and human resources. Alignment between the projected number of students and the development of infrastructure, school policies, and teacher policies is crucial. Teacher training programs and the construction of new schools in the strategic areas of Batam need to be prioritized. Through collaboration between government, society, and the private sector, it is hoped that Batam will manage student growth well, in line with the ideals of the Golden Indonesia Vision 2045, while simultaneously responding to global challenges in the future. Malihah (2015) stated that the presence of ideal Indonesian people will contribute to high national growth and development. This depends on understanding multiculturalism and the cooperative attitudes of Indonesian citizens in the future. In such a situation, there is a need for information on the projection of the number of students at the state high school level from 2025 to 2030; by 2045, they will be the age of Indonesian youth as potential leaders of the nation in the future.

From this, it appears that the importance of population prediction information for the development of infrastructure, as well as school services and facilities, is especially at the public high school level. Huang and Wey (2019) stated that secondary schools and elementary schools facing urgent challenges suggest that they can not only help the local public sector encourage a policy of adaptive reuse of excess school land development, but also serve as an appropriate urban sustainability measure for the central government. Démurger (2001) also states that infrastructure support has a significant influence on development. Kawuryan (2024) adds that to create a quality and productive generation, the government must invest in educational infrastructure and human resources. Alignment between the projected number of students and the development of infrastructure, schools, and teacher policies is very important. Meanwhile, education also needs to be understood by parents, as mentioned by Mumpuniarti et al. (2019), who emphasize the importance of understanding inclusion correctly and discussing parental perspectives to contribute to the success of learning in elementary schools. The study's objective is to generate data that can inform educational policy decisions, particularly regarding the number of

schools and educators needed at the state high school level. This information is crucial for supporting Indonesia's vision of becoming a golden nation by 2045.

Methods

The forecasting method was implemented using the Smoothing Exponential Brown Parameter method, and student data from 2016 to 2022 were used as the basis for projecting the number of students by 2030 and 2035. These data have time-series characteristics or variables that are related to the time series. The aim of describing time series data analysis, as outlined by Esling & Agon (2012), is to extract all meaningful knowledge from the data and explore it further to provide a broad understanding. Fu (2011) added that time-series analysis is an important class of temporal data objects and can be easily obtained from scientific applications. A time series is also a collection of chronological observations. The characteristics of time-series data include large data sizes, high dimensions, and the need for continuous updates. In addition, time-series data, characterized by their numerical and continuous nature, are always considered as a whole, rather than as individual numerical fields. Relevantly, this research aims to project the number of students in special high schools by 2035.

The projection of the number of students at the Batam City public high school level was carried out using a method, namely single exponential smoothing and double exponential smoothing with one brown parameter, where single exponential smoothing was carried out using five trials, namely using $\alpha = 0.1$; $\alpha = 0.3$; $\alpha = 0.7$; $\alpha = 0.9$; $\alpha = 0.99$, Single exponential smoothing has the form of an equation.

$$F_{t+1} = \left(\frac{1}{N}\right)X_t + \left(1 - \frac{1}{N}\right)F_t$$

Where F_{t+1} based on weighting the last observation with a weight value and weighting the last previous forecast or F_t with a weight $\left(1 - \frac{1}{N}\right)\left(1 - \frac{1}{N}\right)$. Because N is a positive number, $\frac{1}{N}$ will be a number between 0 and 1; then, the notation $\frac{1}{N}$ can be replaced with α , so that the equation.

$$F_{t+1} = \left(\frac{1}{N}\right)X_t + \left(1 - \frac{1}{N}\right)F_t$$

$$F_{t+1} = \alpha X_t + (1 - \alpha)F_t$$

This equation is a general form of single exponential smoothing, which is considered to significantly reduce the problem of data deviation because it no longer needs to involve old or historical data, and the equation $F_{t+1} = \alpha X_t + (1 - \alpha)F_t$ can be expanded by replacing F with components as follows:

$$F_{t-1} = \alpha X_t + (1 - \alpha)[\alpha X_{t-1} + (1 - \alpha)F_{t-1}]$$

$$F_{t-1} = \alpha X_t + (1 - \alpha)\alpha X_{t-1} + (1 - \alpha)^2 F_{t-1}$$

To determine the best projection for 2023, attention is paid to the Mean Square Error (MSE) between $\alpha = 0.1$, $\alpha = 0.3$, $\alpha = 0.7$, $\alpha = 0.9$, and $\alpha = 0.99$, as well as the delta of the percentage of forecast results that match the realization.

$$\text{Second column: } S'_t = \alpha X_t + (1 - \alpha)S'_{t-1}$$

$$\text{Third column: } S''_t = \alpha S'_t + (1 - \alpha)S''_{t-1}$$

Where S'_t is the single exponential smoothing value while S''_t is the double exponential smoothing value.

$$\text{Fourth column: } \alpha_t = S'_t + (S'_t - S''_t) = 2S'_t - S''_t$$

$$\text{Fifth column: } b_t = \frac{\alpha}{1 - \alpha}(S'_t - S''_t)$$

$$\text{Sixth column: } F_{t+m} = a_t + b_t m$$

Pamungkas (2012) stated that selecting the best model can be done using one of three methods: the Quadratic Mode Estimator (QME) Method, the Symmetrically Trimmed Least Squares (STLS)

Method, and the Left Truncated (LT) Method. However, in this forecasting method, the smallest error is observed. Where m is the number of periods predicted or projected, and column 2 shows the double exponential smoothing of one Brownian parameter. Single exponential smoothing yielded the best results at $\alpha = 0.9$, then approached again between 0.9 and 0.99, and the best results were obtained with $\alpha = 0.99$. The forecast results are listed in Table 2 below.

Table 2. Prediction of the Number of Students in Batam City in 2030 and 2035

Years	Number of students	Single exponential smoothing	Double exponential smoothing	a	b	$a + bm$
2019	17.645	17.468.55	17.293.86	17.643.24	17.293.86	
2020	19.577	19.555.92	19.533.29	19.578.54	2.239.43	
2021	21.388	21.369.68	21.351.32	21.388.04	1.818.02	
2022	22.328	22.318.42	22.308.75	22.328.09	957.43	
2030						29.988
2035						34.775

From Table 2, it can be seen that the projection for the number of public high school students in Batam City in 2030 is $\alpha = 0.99$, namely 29.988 students, which indicates a 34.30% increase compared to 2022. Meanwhile, the projected number of students in Batam City using double exponential smoothing with one Brown parameter for 2035 is 34.775, indicating an increase of 55.74% compared to 2022. This figure is also in line with the birth rate from 2017 to 2019, where these babies will be at the high school level or equivalent by 2035. The birth rates of these babies are shown in Table 3 below.

Table 3. Live Birth Babies in Batam City in 2017 – 2019

Years	2017	2018	2019
Mother giving birth	14.292	16.136	15.042
Baby born alive	14.191	16.045	14.942

Table 3 shows that it can be seen that the total number of live births during the period 2017–2019 was 45.178. These individuals will become high school students or their equivalent by 2035, and among them will make their choice of public high schools.

Results and Discussion

Results

According to Table 2, the results of the analysis in the research methodology state that in 2030, there will be 29.988 students; in 2035, there will be 34.775 public high school students, which shows a significant increase and requires careful anticipation and planning to improve the quality and facilities of education, in addition to the importance of buildings, infrastructure required and adequate number of teachers. By 2022, the number of public high schools in Batam is expected to be 28, with a proportional distribution, and an average of 749 students/school. If this reference is used in 2035, 46 public high schools will be needed, which means that an additional 18 new public high schools will be required in 2035. The number of teachers is also an important factor that must be considered. Ajani and Akinyele (2014) stated that the ratio of teachers to students supports academic achievement. These findings also show that years of teacher experience and qualifications have a significantly positive relationship with academic achievement.

Additionally, the Batam City government must provide land for the construction of 18 new schools in various sub-districts and regions within Batam City. Planning needs to be formulated through relevant policies to provide other supporting resources, such as road access, permits, and school land acquisition, in relation to local residents, the government, and other stakeholders. The issue of land acquisition often becomes a dispute not only between families and neighbours, but also between the community and the government because the land dispute conflicts that occur are motivated by the complexity of land acquisition, and the community feels that they have no benefit from land acquisition (Djanggih & Salle, 2017; Rohaedi et al., 2019; Maulidah et al., 2023; Masyhur, 2022; Sahara et al.,

2023). The results of this prediction are very crucial and important for the Batam City government to anticipate future problems in the context of adding school units and building new school buildings in various areas of Batam City.

Apart from the aspects above, the results of this forecasting are also important for the Batam City government to prepare competent school principals as top management of education units and professional teachers. The school principal plays a central role in managing all school resources to improve the quality of education (Neel et al., 2024; Dor Haim, 2022; Connor et al., 2025). For this reason, preparation for the recruitment system and increasing the capacity of school principals must begin from an early age. The research results indicate that the performance of the education unit, teacher performance, student learning outcomes, and stakeholder trust in the school are influenced by the principal's competence, leadership, and exemplary behaviour in managing the educational unit (Alsaleh et al. 2017; Horner et al. 2020; Karakose et al. 2021, 2022; Kafa, 2023; Alladatin et al. 2024).

Discussion

The results of the student projection indicate an increase in quantity, which is also an indicator of the need for an education policy. One of the policies that can be implemented is the addition of facilities and infrastructure to support the quality of education. Additionally, the number of teachers needs to be aligned. Regarding facilities and infrastructure, Rofiah et al. (2024) also stated that future teachers need to understand their roles and functions in adapting to developments in technology and information, to align their readiness with professional teacher competency standards. In addition to these abilities, according to Brilatin et al. (2024), a future teacher also needs to emphasize and foster the self-confidence of graduates in strategic leadership positions within their respective institutions. With a good understanding of technology, a teacher is expected to be able to help students in providing a better understanding as well. Firdaus et al. (2022) in their research also stated that mastery of Macromedia-based learning can help improve learning outcomes in mathematics.

After considering the principal's provision, the forecast results above confirm that the most important point is to prepare professional teachers. Professional teachers are the key to success in organizing the Education process to respond to the future (Haverly et al., 2020; Schawarz et al., 2021; Anderson & Dobbie, 2022). Next, Aaronson et al. (2007) noted that teachers are also crucial in enhancing the learning outcomes of students, particularly those with lower academic abilities. Fry (2005) stated that 10% of U.S. high schools had 22 or more students for every teacher hired in the 2002-2003 academic year. While the rest are less than 22 students per teacher, Nishom and Wibowo (2018) stated that it is very important to pay attention to the ratio of students to teachers, because based on data from the UNESCO Institute of Statistics, the ratio of teachers to students in Indonesia is the lowest in the world. Based on the forecasted data for the number of students in Batam City in 2035, if we use the ideal student-to-teacher ratio of 18 to 1, we will need to prepare 1.879 public high school-level teachers with quality and integrity in Batam City in 2035. The importance of the availability of the number of teachers, teacher competence, and teacher readiness are determining factors in producing quality education (Fletcher & Zucollo, 2020; McKeown et al. 2022; Skousen et al. 2024).

Policies in the world of education are necessary to improve the quality of education in Indonesia by 2045. This finding is also in line with the research conducted by Hanushek (2005), who found that education can contribute to economic growth. Governments around the world have played a crucial role in educating their citizens, and "providing education for all" is a key pillar of the Sustainable Development Goals. In line with Golden Indonesia 2045, it is hoped that all levels of society will have access to education. To support a better future, in addition to policy strategies, there is a need for guidance on student career development. Saptono (2022) also stated that school policies need special attention, especially regarding child-friendly policies. In future policies, planning is also necessary. Lidyasari et al. (2022) stated that career development facilitates easier planning, understanding, and achieving a clear career identity. Education management also plays a role in determining teacher-ratio policies. Chapman and Adams (2002) noted that the role of educational management will continue to evolve, directly influencing teaching and the quality of student outcomes.

The results of this study indicate that the number of new high school students in Batam City is expected to reach 29.988 by 2023 and 34.775 by 2035. These projections indicate that the local government should establish 18 new high schools and hire 1.879 additional qualified teachers. Based on these findings, the researcher recommends further investigation of the city's student admission policies

and their alignment with these forecasts. Additionally, the researcher suggests conducting similar predictive analyses for kindergarten, elementary, and junior high school enrolment up to 2030 and 2035. This comprehensive approach would provide the government with crucial information for developing regional policies, planning infrastructure, and allocating educational resources in Batam. The researcher also proposes future studies to forecast the quantity and conditions of school buildings that may deteriorate by 2023 and 2035. This information would enable the city government to formulate policies and plans based not only on projected student numbers but also on anticipated structural needs. By considering both factors, the educational system in Batam City can operate more effectively and efficiently in 2023 and 2035, contributing to the development of high-quality human resources in Indonesia's projected golden era in 2045.

Conclusion

Forecasting student enrollment in Batam City is essential to support Indonesia's Golden Vision 2045, especially given the city's rapid population growth and the corresponding need for equitable, high-quality education. Using the Brown Exponential Smoothing method, the study projects 29.988 public high school students in 2030 and 34.775 in 2035, leading to recommendations for 18 new schools and the recruitment of 1.879 additional teachers. These projections aim to guide more effective government planning in educational infrastructure, staffing, and resource allocation. The study also calls for further research on student-teacher ratios, facility adequacy, and the condition of educational infrastructure to ensure policies reflect both growth and maintenance needs. Ultimately, the findings highlight the importance of data-driven planning to build a strong educational foundation and produce future-ready human resources for national development.

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