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Forecasting and Policy Optimization for The Enrollment of State University in Bulacan: A System Dynamics Approach

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ABSTRACT: This study develops a system dynamics model to support enrollment forecasting and policy optimization for a State University in Bulacan. State universities and colleges increasingly face fluctuating demand, resource constraints, and policy shifts, yet decisions on admission quotas and capacity are often reactive and based on fragmented analyses. Using five years of historical data on applicants, qualifiers, new enrollees, program-level enrollment, and student retention, dropout, and graduation, the study constructs causal loop and stock-and-flow diagrams that capture key feedbacks between demand, institutional capacity, and student success. The model will be calibrated and validated against historical trends, then used as a “flight simulator” to test alternative admission and capacity policies, such as changes in grade cutoffs, expansion of high-demand programs, or improvements in retention. Scenario results will provide multi-year enrollment projections by college and reveal leverage points where targeted interventions can stabilize growth, prevent capacity overload, and align enrollment with strategic objectives and budget constraints. By integrating forecasting and policy analysis in a single dynamic framework, the study aims to offer state universities a practical decision-support tool for evidence-based enrollment management. More broadly, the framework can be adapted by other regional higher education institutions confronting similar uncertainties in student demand and capacity elsewhere.

KEYWORDS: System Dynamics, Forecasting, Enrollment Management, Policy Analysis, Digital Transformation

I. INTRODUCTION

Enrollment data is a crucial part of a university strategic plan, especially in the aspect of resource allocation [1]. In the Philippines, state universities and colleges faces challenges with regards to adequate resources such as facilities, intellectual capacity, and funding resources [2]. These institutions often operate within organizational frameworks that prioritize stringent capital accumulation over generous resource allocation, resulting in tight management approval processes that create operational bottlenecks [3]. Facility management plays a vital role in keeping educational institutions safe, reliable, and conducive to learning. One study assesses the maturity and effectiveness of an institution’s facility management processes and recommends a digital reporting system to improve efficiency and strengthen safety. Ongoing issues—such as limited space, aging equipment, and irregular maintenance—continue to disrupt operations and reduce user satisfaction [4]. State universities also face the challenge from the national government agencies such as the Commission on Higher Education to maintain the absorptive capacity of the SUCs in the 98% - 101% only. While former and recent studies have analyzed enrollment trends using multiple methods including descriptive methods or time series analysis, these methods often fail to capture the complexity of interconnective loops that really drives the enrollment behavior over time [5-6]. These loops includes the graduation rate, dropout rate, admission rate, as well as the academic reputation of the university itself. This study addresses this gap by applying system dynamics to model and simulate the enrollment level at Bulacan State University, aiming to provide an evidence-based and data-driven tool to develop effective admission policies.

II.CONCEPTUAL FOUNDATIONS OF ENROLLMENT MANAGEMENT

Enrollment management (EM) is a crucial strategic process in higher education designed to influence the size, shape, and characteristics of the student body by coordinating efforts in areas like recruitment, admissions, financial aid, and retention [7-8]. The decision for a student to enroll is a complex, multi-stage process influenced by both student characteristics and external factors [9]. Hossler and Gallagher introduced a three-stage model of how students choose a university or college that they want to join; the predisposition stage, where students are heavily influenced by their socioeconomic status, parental guidance, and perceived academic ability; the search phase, where students focus on gathering information about their university choices such as location, academic reputation, and perceived cost; and lastly, choice phase, where students weigh available financial aids and career progression options before making their final enrollment decision. Building on these models, a research by David W. Chapman [10] identified a comprehensive set of variables that influences a student's choice. These factors includes the student's academic ability and their personal motivation. Also, external factors are considered such as the institution's academic reputation, program offerings, and the quality of facilities. However, the student's socioeconomic background, in particular, remains a strong predictor of the student's institutional selection and the probability of their attendance to a university. This leads to students from lower-income backgrounds to confront greater financial barriers that may cause them to steer away from higher-cost, higher standard of education [11-12].

III. TRADITIONAL APPROACHES TO ENROLLMENT FORECASTING

Enrollment forecasting is central to effective budgeting and program planning in higher education. The comprehensive enrollment forecasting model developed in this study deepens our understanding of the factors that influence student enrollment and improves forecasting accuracy. As in other forecasting applications, conventional statistical techniques have long been used to estimate and model enrollment levels in higher education institutions [13]. Extending this perspective beyond education, similar forecasting capabilities are critical in supply chain management, where demand forecasting enables businesses to anticipate customer needs and align inventory, production, and logistics decisions. Traditional forecasting methods, including ARIMA and exponential smoothing, remain widely used because of their simplicity and interpretability. However, increasing market complexity and richer data patterns have exposed limitations in their accuracy and adaptability. In response, research by Tulli et.al. presents a comparative analysis of traditional and AI-based forecasting models, examining accuracy, computational efficiency, scalability, and interpretability. Using diverse datasets from industries such as retail, manufacturing, and e-commerce, the research evaluates the strengths and weaknesses of each approach. The findings identify the conditions under which AI-based models substantially outperform traditional methods and outline the trade-offs involved in resource use and ease of deployment, providing insights that can inform forecasting practice across domains [14]. Returning to the higher education context, prediction is essential for strategic and tactical decision-making that supports efficient and effective management. Within higher education institution (HEI) data mining, prediction enables the ongoing analysis of relationships among historical, current, and future data for specific educational situations. In this study, the forecast indicates an increasing enrollment trend in the succeeding school years. Future researchers may apply additional data mining algorithms and consider predicting enrollment counts at the college level to refine enrollment trend analysis and enhance knowledge extraction [15].

IV. APPLICATION OF SYSTEM DYNAMICS IN HIGHER EDUCATION MODELING

The complexity and dynamic nature of educational systems, characterized by interconnected variables, feedback loops, time delays, and non-linear relationships, make traditional forecasting methods inadequate [13, 15]. System dynamics (SD), a methodology developed by Forrester in 1968 and further formalized by Sterman in 2000, provides a robust framework for framing, analyzing, and discussing these complex issues through simulation modeling. This approach allows for a holistic understanding of how various components interact and how system behavior evolves over time.

Numerous studies have applied System Dynamics modeling to various aspects of educational management to support decision-making. For instance, System Dynamics models have been developed to understand the deployment of instructional resources within academic departments when enrollment levels change. Other research has focused on modeling student flows from high school graduation through enrollment and degree completion to predict potential teacher shortages, demonstrating System Dynamics' utility in long-term capacity planning. In a specific context, System Dynamics was utilized to develop enrollment policies for the private higher education sector in Syria, providing a decision-support system for administrators by presenting simulated data and recommendations regarding enrollment quotas and capacity.

These applications highlight the ability of system dynamics to integrate both quantitative data (e.g., enrollment rates, facilities capacity) and qualitative insights (e.g., reputation effects, student satisfaction) into a cohesive simulation environment [16]. By explicitly modeling causal relationships and feedback loops—using tools like causal loop diagrams (CLDs) and stock and flow diagrams (SFDs)—researchers can explore the impact of various policy interventions before actual implementation. The resulting models help policymakers anticipate unintended consequences, optimize resource allocation, and strategically plan for growth, which is a significant improvement over reactive, short-term planning methods.

V. THE RESEARCH GAP

Despite the proven utility of system dynamics (SD) in various higher education contexts globally, a notable gap exists in its specific application to manage enrollment dynamics within the Philippine state university system, particularly at Bulacan State University (BulSU). While traditional studies often describe enrollment trends using historical data or focus solely on streamlining administrative processes, they lack a holistic, dynamic modeling approach to address the unique policy challenges faced by regional institutions like BulSU [14, 15].

Existing literature demonstrates how SD can model general university capacity or resource allocation, but there is a scarcity of research that integrates BulSU-specific quantitative data (e.g., specific admission test pass rates, GWA cutoffs) and qualitative variables (e.g., local reputation, K-12 transition effects) into a unified simulation model. This study specifically addresses this void by developing and validating a system dynamics model tailored to BulSU's context. The research uniquely aims to simulate the impact of various admission policy changes on long-term enrollment levels, thereby providing BulSU administration with an evidence-based tool for proactive and strategic decision-making, moving beyond reactive management of student intake volatility.

VI. METHODOLOGY

The proposed methodology section outlines the research design, data collection strategy, the specific steps for developing the system dynamics (SD) model, and the simulation and validation procedures. This section will describe how the conceptual framework from the literature review will be translated into a functional model of the Bulacan State University (BulSU) enrollment system.

A. Research Design

This study employs a system dynamics (SD) approach to model and simulate the complex factors influencing student enrollment levels at BulSU. SD is an appropriate methodology for analyzing dynamic systems characterized by non-linear relationships, time delays, and feedback loops (Forrester, 1968; Sterman, 2000). The research design follows a cyclical process of problem identification, system conceptualization, model formulation, simulation, evaluation, and policy analysis.

B. Data Collection

Quantitative data will be collected from the last five academic years and will include several key indicators. These consist of the annual number of applicants, exam takers, qualifiers, and new enrollees, as well as enrollment levels by college and program. Student retention, dropout, and graduation rates will also be gathered to capture progression patterns. In addition, capacity-related data such as the number of classrooms, faculty-to-student ratios, and available budget will be included to understand institutional constraints and resources.

C. System Dynamics Model Development

This model will be developed using specialized system dynamics modelling software such as MATLAB or SciLab, following the structured procedure below:

1) System Conceptualization

System conceptualization will be carried out using the gathered data and insights from the literature review. Causal loop diagrams (CLDs) will be developed to represent the hypothesized feedback loops, such as the "Success Breeds Success" loop and the "Capacity Limit" loop. Through this process, the model's boundaries will be clearly defined.

2) Model Formulation (Stock and Flow Diagrams

Model formulation will be conducted by converting the causal loop diagrams into quantifiable stock and flow diagrams (SFDs). In these diagrams, stocks (levels) will represent accumulations such as the total student population, the applicant pool, and physical capacity. Flows (rates) will describe the inflows and outflows that change these stocks, including measures like the new admissions rate, graduation rate, and dropout rate. Auxiliary variables and converters will specify the mathematical relationships among variables, for example, defining the admission rate as the ratio of new admissions to the number of qualifiers.

3) Model Simulation and Validation

Calibration will involve adjusting the model parameters and equations to match historical data trends for BulSU. After calibration, validation will be carried out using standard tests such as structure verification, boundary adequacy, and sensitivity analysis to ensure that the model behaves realistically and remains robust under extreme conditions.

4) Policy Analysis and Scenario Testing

Based on the system dynamics model developed for Bulacan State University (BulSU), policy analysis will be conducted using the validated Scilab script as a "flight simulator." This approach allows for the evidence-based exploration of various "what-if" scenarios, moving beyond simple projections to understand the complex interactions between admissions, infrastructure, and faculty constraints.

The insights gained from these simulations will inform policy recommendations by examining the effects of:

a) Aggressive Infrastructure Expansion (Scenario 1): Testing the impact of increasing classroom capacity by 30 rooms annually versus the standard 5, analyzing how quickly physical space bottlenecks can be resolved.

b) Stricter Admission GWA Cutoffs (Scenario 2): Simulating the effects of raising GWA standards on the total student population size and the subsequent improvements in student retention and dropout rates.

c) Strict Graduate-Only Faculty Hiring (Scenario 3): Modeling the trade-off between faculty quantity and quality by restricting new hires to only Master's and PhD holders, observing the impact on student-to-faculty ratios and overall student outflow (graduation/dropout).

d) Construction Delays (Scenario 4): Assessing the systemic risks of a five-year freeze in building capacity, demonstrating how quickly such delays force the university to operate above its ideal physical limits.

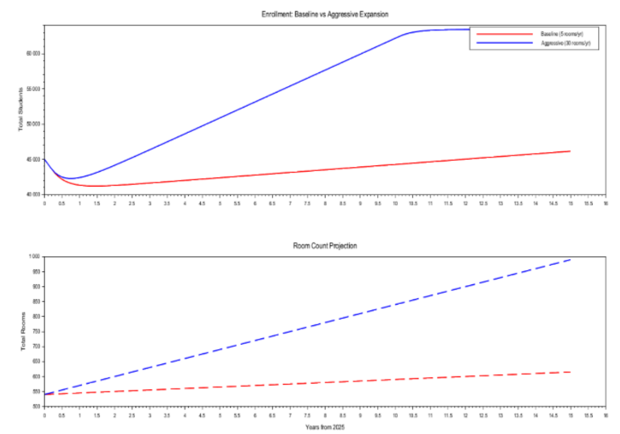
VII. RESULTS AND DISCUSSION

In this section, the results of the four (4) what-if scenarios will be presented and discussed. These simulations will serve as the basis for several policy analysis and possible recommendations for policy amendments of Bulacan State University.

1) Aggressive Infrastucture Expansion (Scenario 1)

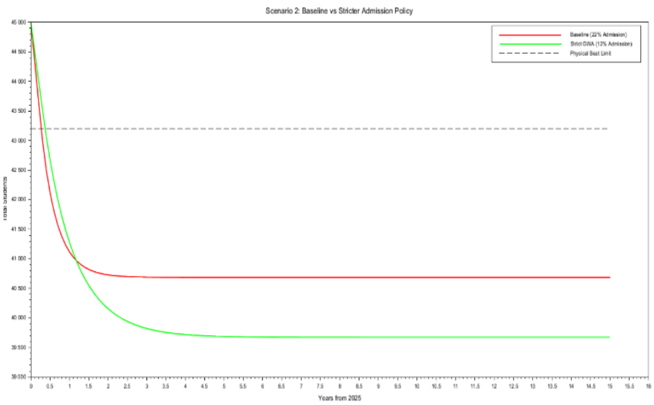
This image shows the result of simulation of system dynamics using Scilab. Under the aggressive growth scenario, student enrollment initially increases due to expanded room capacity, yet eventually plateaus upon reaching the current faculty limit of 1,347. This trend suggests that while physical infrastructure mitigates immediate space constraints, personnel shortages create a secondary ceiling for institutional growth.

Consequently, a dual strategy addressing both facility expansion and faculty recruitment is essential for sustaining long-term enrollment at Bulacan State University.



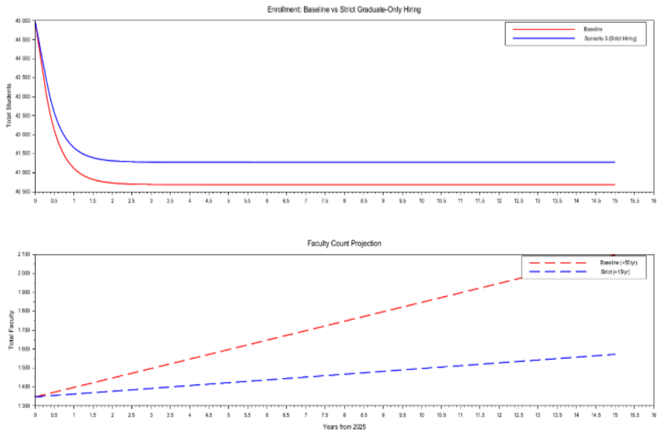
2) **Stricter Admission GWA Cutoffs (Scenario 2)**

In this section, the result of the second simulation using system dynamics shows the effects of stricter admission policy on the enrollment level of Bulacan State University. The strict policy scenario demonstrates slow, stabilized enrollment growth that remains well within physical capacity, prioritizing institutional sustainability over volume. By maintaining enrollment levels below seat limits, this approach prevents the quality factor from declining and ensures the university remains functional without immediate, massive infrastructure investment. Furthermore, this policy enhances student retention and graduation rates, suggesting that controlled growth protects academic integrit andprioritizes long-term student success over rapid expansion.



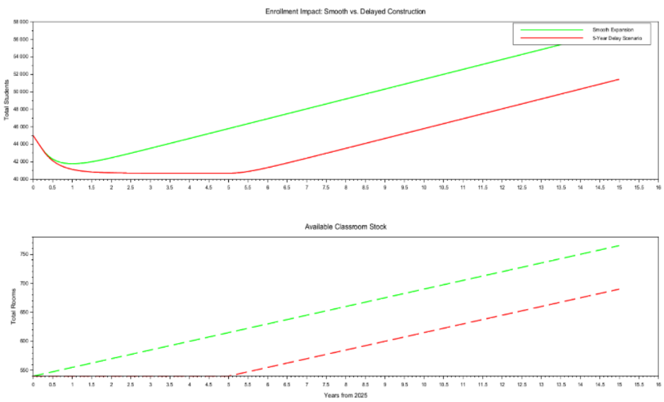
3) **Strict Graduate-Only Faculty Hiring (Scenario 3)**

In this section, the research will show the effect if Bulacan State University will enforce the policy of only hiring faculty with master's degree as entry level. A critical conflict emerges as faculty growth lags behind student enrollment, forcing a trade-off between institutional quantity and academic quality. By maintaining stricter hiring credentials, Bulacan State University (BulSU) may experience more stable enrollment, but this strategy theoretically improves the success rates of admitted students. To resolve this, the university should complement strict hiring with expanded faculty development grants, which provide vital opportunities for permanent staff to advance their careers through graduate studies. Enforcing these grants empowers faculty to enhance their professional competencies, directly elevating the overall quality of education and institutional excellence at BulSU.



4) **Construction Delays (Scenario 4)**

In this section, this simulation will show the potential effects of delays in construction of academic facilities of Bulacan State University. This simulation will show a 5-year delay in construction, citing budget constraints and other construction related problems. In the "delayed scenario," enrollment reaches an immediate plateau because Bulacan State University (BulSU) is already operating at full capacity with its 540 existing rooms as of 2025. Even a short-term postponement in infrastructure development halts the university's ability to admit new students, forcing the institution into a "critical threshold" of overcrowding characterized by strained facilities. To mitigate these effects, research suggests adopting "contingency infrastructure" through flexible learning modalities. For 2025, BulSU has already implemented Alternative Delivery Modes (ADM) and Hybrid Flexible (HyFlex) learning guidelines to maintain quality education during physical capacity constraints or unexpected campus disruptions. These digital strategies allow the university to sustain student success and academic operations without being solely dependent on the immediate completion of physical construction projects.



VIII. CONCLUSION

The simulation results conclude that sustainable growth at Bulacan State University requires a dual-strategy approach that balances physical infrastructure expansion with aggressive faculty recruitment and development. While increasing room capacity provides immediate relief for enrollment demands, the current faculty limit of 1,347 serves as a secondary ceiling that eventually plateaus institutional growth unless addressed. To maintain high academic standards, the university must navigate a critical trade-off between quantity and quality, where stricter admission and hiring policies improve student success and institutional stability at the cost of rapid expansion. Consequently, the enforcement of faculty development grants is essential to empower existing staff to meet higher credential requirements, thereby enhancing the overall quality of education. Furthermore, to mitigate the immediate stagnation caused by potential construction delays, the integration of flexible learning modalities like Hybrid Flexible (HyFlex) learning provides a necessary "contingency infrastructure." Ultimately, BulSU's long-term resilience depends on synchronized investment in both its human and physical capital to ensure educational excellence remains the priority amidst growing student populations.

In summary, the most effective path forward for BulSU involves a balanced, proactive approach that integrates facility expansion, strategic faculty growth and development, and flexible operational strategies to maintain academic quality and ensure sustainable institutional development.

During the preparation of this work the author(s) used CHATGPT and GEMINI AI in order to synthesize certain statements and extract substantial data from the references. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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