

Modeling Graduate Education Management System Using System Dynamics Approach

Nikolay Merkulov, Nasim Nezamoddini, Nasim Sabounchi, PhD

Binghamton University

4400 Vestal Parkway East, Binghamton, NY 13902

607-777-2151, 607-777-5937

nmerkul1@binghamton.edu, nnezamo1@binghamton.edu, sabounchi@binghamton.edu

Abstract:

Graduate education is a complex system with a wide range of dynamics behind it, where any decision affects other parts of system directly or indirectly. Decisions related to admission, funding allocation, resource management, and recruitment are the most important variables in system, which not only influence the internal performance of the school reflected, for instance, in the number of enrolled students, but also indirectly change the image the school has expressed in its ranking and reputation. Accordingly, a more systematic approach is required to consider all these relationships and the effects of various management decisions. This paper studies the basics of such a system instantiated by one of the graduate education programs in the United States, where the main goal of management is to increase enrollment without losing the quality and affordability of education.

Key words: System dynamics, Graduate education, US news ranking, Education management system

I. Introduction:

Higher education has become a necessary condition for successful career advancement, which has created an unprecedented demand on educational services. In an attempt to meet this demand, multiple universities have launched expansion programs, which aim not just at growing the enrollment but also at transforming their image and footprint on the educational market. This market, in turn, has become increasingly competitive due to the fact that each institution is willing to attract the best and the brightest new students.

Binghamton University aspires to become the premier public university of the 21st century. As a premier public, the university intends to produce first-class scholarly and research output that will stimulate economic development and innovation in the Southern Tier and the State of New York. The university already has a significant economic impact on the local community. Recognizing the potential and the current importance of the university, the State of New York has decided to support the university's mission and vision with the NYSUNY2020 plan (Ellis, 2015). As part of

the plan, the State has committed to provide significant financial resources for reinforcing the research infrastructure on campus among other things. In return, Binghamton University has promised to grow its enrollment by 2000 students in six years from fall 2010 enrollment levels, of which at least 400 would be graduate students.

Although the streamlining of administrative practices helped achieve the short-term growth goal, the rate of increase has been subsiding annually since the original surge caused by the enactment of the program. This tendency demonstrates that the current system is exhausting its potential, which necessitates diagnosing the strengths and limitations of the university's policies, in order to formulate a program to improve the situation.

One of the apparent consequences of the rapid enrollment increase is the worsening average quality of the students' pool, as the simplest way to meet the goals is converting as many available applications into students as possible. Sustaining such a growth model requires constant efforts to recruit more applications to choose from. However, this practice creates a vicious circle when lower admission standards from the previous academic period become known to potential applicants, which attracts applications of increasingly low quality and dissuades possible higher quality recruits from applying. Even if the latter submit an application, lower perceived quality of the school will prompt such an applicant to accept an offer from another university if available. The reference mode graph (Figure 1) traces the change in the student enrollment since 2000 and demonstrates two scenarios of future growth: the increase in the enrollment to 6000 students based on the NYSUNY2020 plan and the possible stagnant growth if the expected quality of education declines.

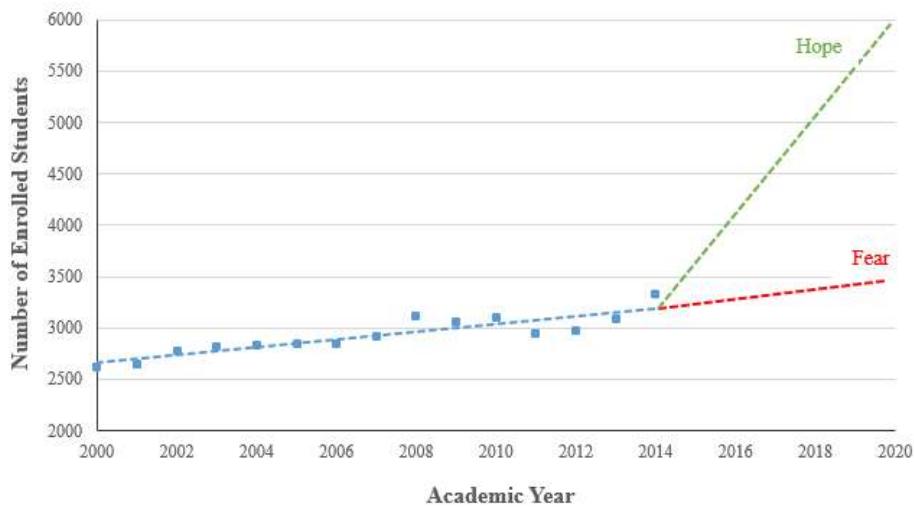


Figure 1: Reference map for number of the enrolled students

One of the salient sources of information about the quality of education is university ranking systems, which are used both by students to screen prospective schools and by universities that are sensitive to this fact. The ranking is a tangible measure of the university's reputation, and if it is updated frequently, e.g. the U.S. News "America's National Universities", it becomes an indicator

of the successfulness of university's enrollment and academic policies. Hence, it is important to analyze the effect of the ranking on the admission and enrollment trends.

Most rankings follow a general system that starts with picking appropriate criteria. The selection of criteria depends on the purpose of the ranking, e.g. comprehensive description or estimating the school's presence in the Internet, etc., the availability of data, the need to use proxies, and so on. After criteria are decided upon, they are weighted such that each contributes a certain percentage to a summary score or rank. After weighting, ranking is fairly straightforward and takes the form of a league table.

This project will examine Binghamton University's place in the U.S. News America's National Universities ranking and its effect on the enrollment patterns using system dynamics approach. It will explore the role of various criteria used to generate the ranking and their connection to the crucial parameters of university's activities using the system dynamics approach. The primary goal of the project is formulating policy suggestions that will enable continuous enrollment growth without compromising the reputation at Binghamton University. The U.S. News America's National Universities ranking has been selected as a proxy for the school's reputation, because it relies on transparent methodology that we can replicate in the model. Furthermore, this is one the few comprehensive rankings that have a section dedicated specifically to graduate programs, which are the focus of this study, with these rankings renewed on an annual basis, generating a constant flow of information on the school's reputation.

II. Related Works:

Wide range of studies targeted the management of education systems using system dynamics approach. One of the main goals considered in these studies is to increase student enrollment through identifying the enforcing variables. Pedamallu et al. (2010) applied system dynamics for managing infrastructure facilities, in order to increase primary education enrollment in a developing country. This model is built based on Cross Impact Analysis method. Akar (2008) proposed a similar model with the main focus on the Turkish educational system. Prior to this research, numerous other attempts were made to model primary education systems using system dynamic models (Terlou et al., 1991). Karadeli et al. (2001) study the relation between the budget and quality of education, with the budget affecting the quality by changing other variables, such as student-to-teacher ratio and student-to-class ratio. Altmirano and van Daalen (2004) examine the effect of policy variables, such as the increasing coverage of educational system, in Nicaragua. Literacy programs, subsides to cover costs, and the increase of teacher salaries are among the considered policy variables. Their findings show that the combination of the policies is required to overcome the complexity existing in the system and to increase the coverage of the educational system in the country.

Apart from the enrollment increase, system dynamics was applied to investigate factors influencing student performances in primary schools. For instance, Pedamallu et al. (2012) study the effect of various factors on improving academic performance of primary school students residing in poor migrant neighborhoods. The model is built based on the perception of the teachers inside the system, with a goal of finding the best public policies for migrant students of the area

under study. Llewellyn and Usselman (2013) present another model with the same concerns. The system considered in their research is the primary school in the inner squatter and outer squatter districts of Turkish cities. The survey data were used to model the causal relations and loops of the system.

System dynamics was also applied to improve higher education systems. The main influencing factor is budget. France et al. (1994) analyze its effect on American higher education exemplified by the University of Houston for the first time. Dahlan and Yahaya (2010) present a system dynamics model for managing university capacities. They mainly focused on balancing available capacities in a system including lectures and facilities and total enrolled students. Different policy factors, such as facility allocations, acceptance policies, and financial aid, were included in their research. Strauss and Borenstein (2014) also try to build a system dynamics model as a learning tool for decision-makers to study the effect of various parameters on increasing higher education enrollment in Brazil. The variables incorporated in the model include regulation, goals, demand, supply, and the balance between public and private sectors. To validate the model, they compare the results of their simulation with real data. Barlas and Diker (2000) present another simulation model for strategy selection in academic systems. Their model also focuses on solving problem of faculty-to-student ratio, education quality, and research productivity. Skribans et al. (2013) create a model to investigate the growth of third generation universities with research and innovation implementation centers. The results show the importance of the ability to develop and manage innovative technologies. Barnabe (2004) studies the reform of higher education system, where system dynamics captures the effect of long-term management policies. The main focus of the model is on teaching and research performance that influence managerialization of the universities.

The quality of higher education was the main research interest for Rodrigues and Leekha (2012). The ABET criteria were considered as the key measures for quality assessments in the presented system. Their research studies such factors as the availability of facilities in the system, faculty contribution, curriculum, and other evaluation factors of teaching and learning process. They demonstrate that the availability of facilities has a small influence on increasing the quality of the education system, and the managements needs to invest on the other factors hidden inside the system. The quality of doctoral education as a part of a broader higher education system is studied in the model prepared by Mikulskiene and Mazrimiene (2013) to find the most relevant factors among state-regulation and self-regulation variables. Oyo et al. (2008) provide another model employing a different approach for studying relevant variables in the Ugandan educational system to increase the quality of higher education.

III. Proposed Model:

The model presented in current research is based on the system dynamic approach, which is known as one of the effective management tools capturing existing dynamics behind the system elements. The basic steps of system dynamic approach is to identify influencing factors and the feedback loops between them. The model is capable of capturing nonlinear behavior of system that will change over time affecting the existing stock and flow in system (Sterman, 2000). The model developed for this project demonstrates a dynamic interconnectedness of the admission and

enrollment process with the parameters influencing the university ranking. The university budget plays a crucial role in the process as well, because changing enrollment directly affects the ability of the institution to collect funds that can be utilized for both the intensification of efforts to increase the enrollment and to improve the characteristics that impact the ranking but are not related to the enrollment. Hence, the model comprises three groups of variables, namely, the admission process, the components of the ranking, and the budget process. Figure 2 shows the system overview.

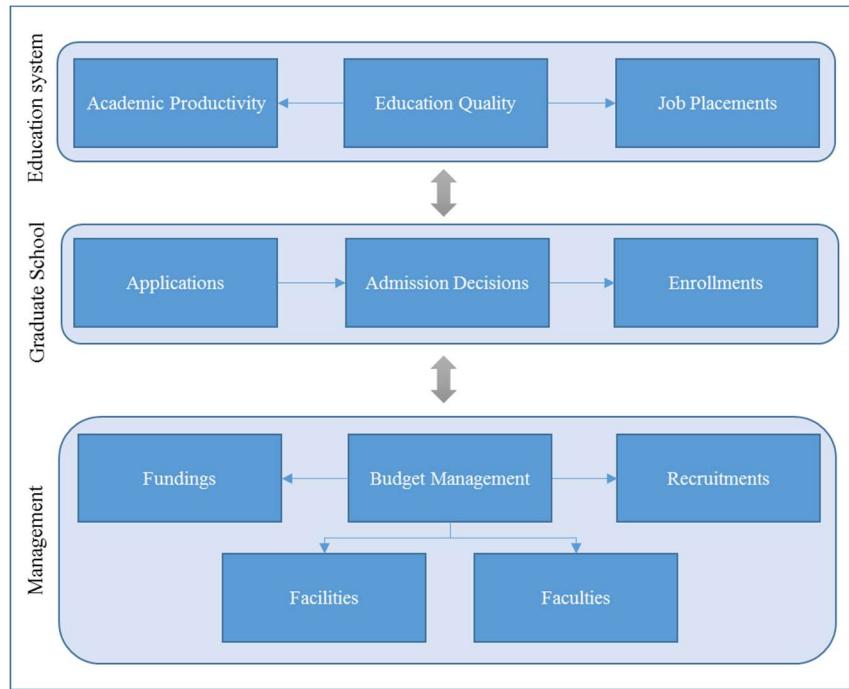


Figure 2: Graduate education system overview

The admissions and enrollment part of the model is based on the admission funnel (also called enrollment funnel), which is a well-established concept in the admissions and enrollment management literature (Burge, 2009). Briefly, the intuitive idea behind the funnel is that applications convert into admissions, and admissions convert into enrolled students, with the number of available potential students decreasing at every stage. The different modifications of the funnel used to describe and highlight various aspects of the admissions and enrollment process. Recently, the idea of the funnel has come under criticism for the lack of relevance to guide the university admissions policy (Noel-Levitz White Paper, 2015). However, this critique is related mostly to the recruitment stage of the admissions process, particularly, the fact that recruits, i.e. potential applicants who demonstrated some interest in joining the program, are not the only source of the application pool. Simultaneously, the conversion rate from recruits into applicants is usually very low, meaning that the use of the recruitment part of the admission funnel is limited and should be removed or supplanted with a more adequate input. Therefore, we do not treat recruitment as a separate stage of the admission process and equate the recruits with the received applications. At the same time, we have elaborated on the enrollment step, which is often treated as the end of the

funnel in the relevant literature, yet we have extended the model to include the graduated, dropped-out, and continuing students into the model.

Figure 3 depicts the admission and enrollment funnel used in the model. The acceptance rate depends on the current number of enrolled students and the enrollment goal, formulated by the university administration in accordance with the internal planning and external commitments, such as the NYSUNY2020 plan, as the university does not have a capacity to accommodate all the students at a time. This goal seeking behavior is captured by the balancing loop B1. For simplicity, balancing loops are labelled with letter B, while reinforcing loops are labelled with letter R in the model description.

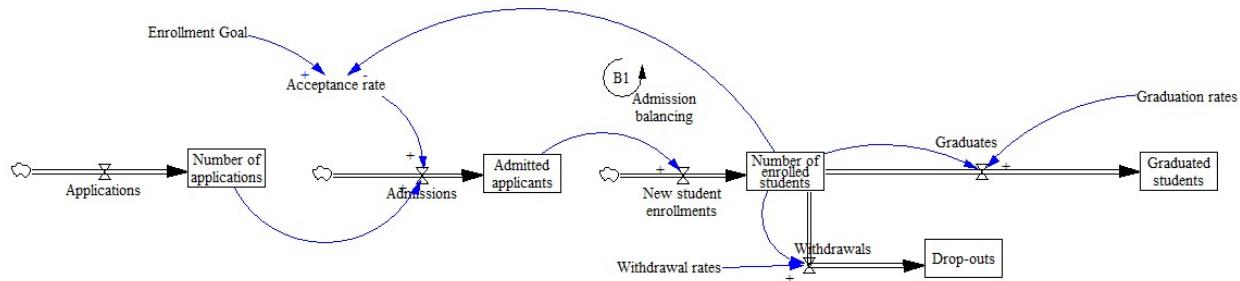


Figure 3. Admission and enrollment funnel

We have followed the methodology of the US News university ranking in order to incorporate the ranking components into our model. The American news magazine US News began publishing its “America’s Best Colleges” report in 1983 and has since become one of the most widely used ranking systems. US News evaluates survey data from over 1800 American colleges, publishing numerical ranks for approximately the top 75%. The US News conducts annual surveys to collect most of the data and relies on third party data when survey data are not available. Reputation criteria are based on surveys sent to high school counselors and university faculty and administration. It uses more criteria than any other ranking system, seeking to take into account as many aspects of a college’s profile as possible, and is explicit about the use of those criteria and their relative weights. The parameters used by the US News National Universities Rankings can be grouped into several categories: assessment by administrators at peer institutions, retention of students, faculty resources, student selectivity, financial resources, alumni giving, graduation rate performance, and high school counselor ratings of colleges (National Universities Methodology, 2015). We will exclude the criteria for high school counsellor reputation and the proportion of freshman class in top 10% of high school class from our model, as they are inapplicable to the analysis of the quality of graduate programs. We will not use the proportions of faculty members with the highest degree in the field and full-time status in the model either, because both these parameters approach 100 per cent at any large research university, and there is very little variation in them.

These ranking components as well as some of the other variables that we deemed directly related to them, e.g. research and academic partnerships, faculty resources, research projects, job placements, were combined in the system dynamics model represented in Figure 4. It is worth noting that three criteria of the rankings, namely, student financial support, faculty salary, and

alumni contributions, were left outside of the scope of this sub-model, as they unequivocally belong to the budget process, which will be described later. As it is obvious from the chart, the ranking of the university has a self-reinforcement mechanism exercised through the university's reputation, which is the second most important component of the ranking. Therefore, a higher ranking should produce more favorable reputational reviews in the future, which in turn make the ranking higher (loop R1), reputation itself leads to a higher number of partnerships and research projects, which consequently make the university more recognizable (loop R2). The same logic is applicable to the relationship between the reputation and job placements (loop R3). Furthermore, as the reputation increases the chances for employment for the university's graduates, the time to finish the degree goes down; hence, the university ranking will go up (loop R4).

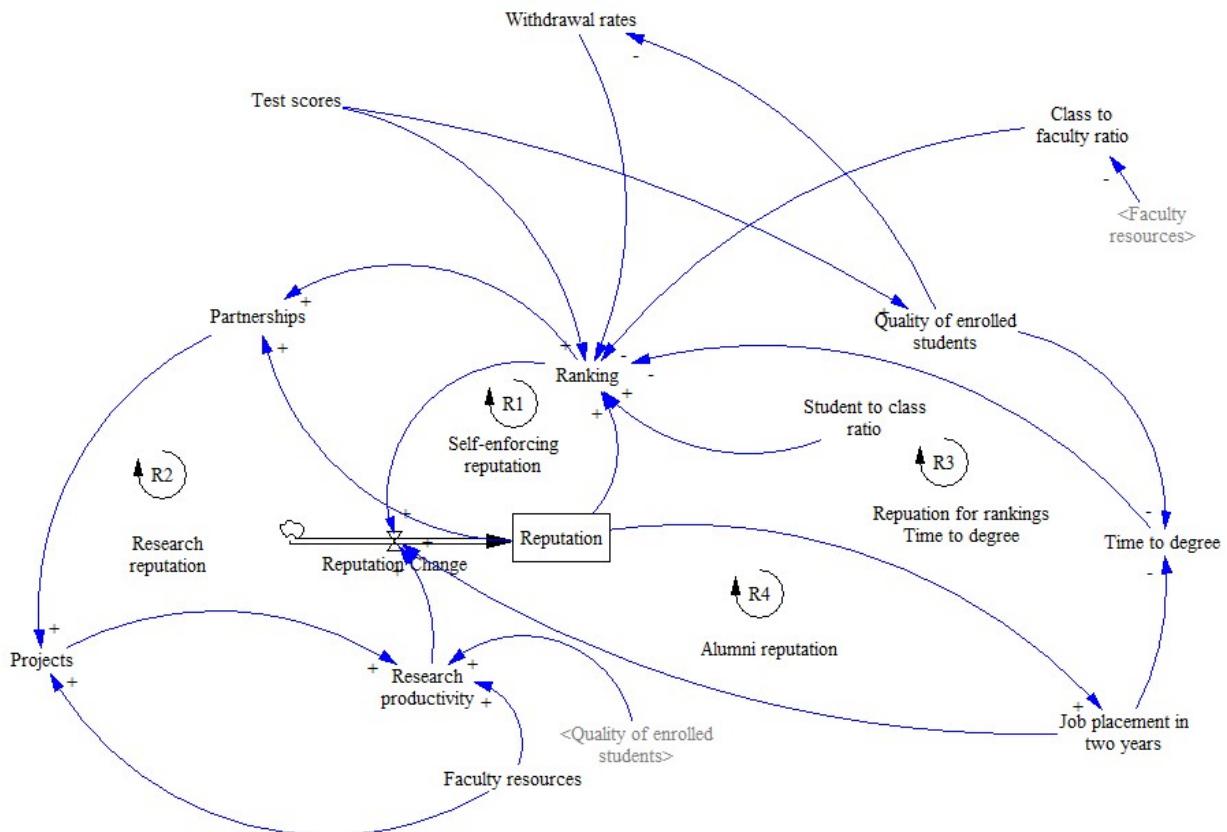


Figure 4. US News Rankings components

We have identified all the components of the Binghamton University budgeting process (Division of Administration. Policies and Procedures, 2015). The main sources of income for the university are tuition payments from the students and the money allocated by New York State. However, several other inputs into the budget are both substantial and relevant for our model, particularly, alumni contributions, application fees, and funds obtained for research projects. The collected amounts of tuition payments and application fees depend upon tuition rates and application fee

rates, correspondingly, which are of special interest to us, as they can be manipulated to obtain the desired state of the system. Furthermore, the tuition rates are directly related to the affordability of the university, which influences the number of applications and thus the size of the enrollment population.

The collected fees and payments increase the budget size which is used for several expenditure categories considered in our model, including investing into recruitment, creating new academic programs, setting up new research and academic facilities, expanding faculty resources, providing students with funding support, and paying salary to the university faculty (see Figure 5).

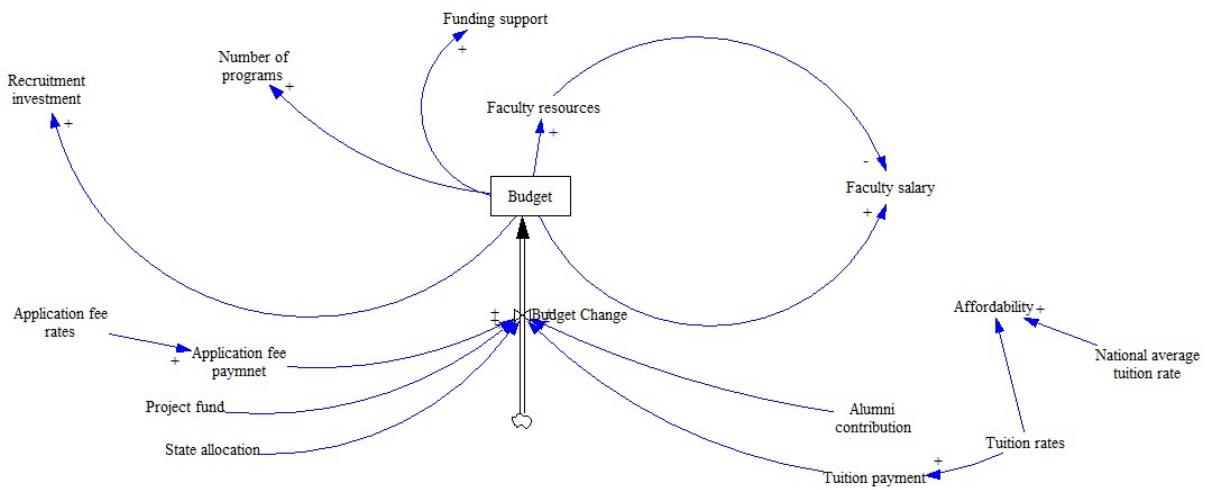


Figure 5. Budget process

Chart 6 demonstrates the unification of all the three sub-systems into one model.

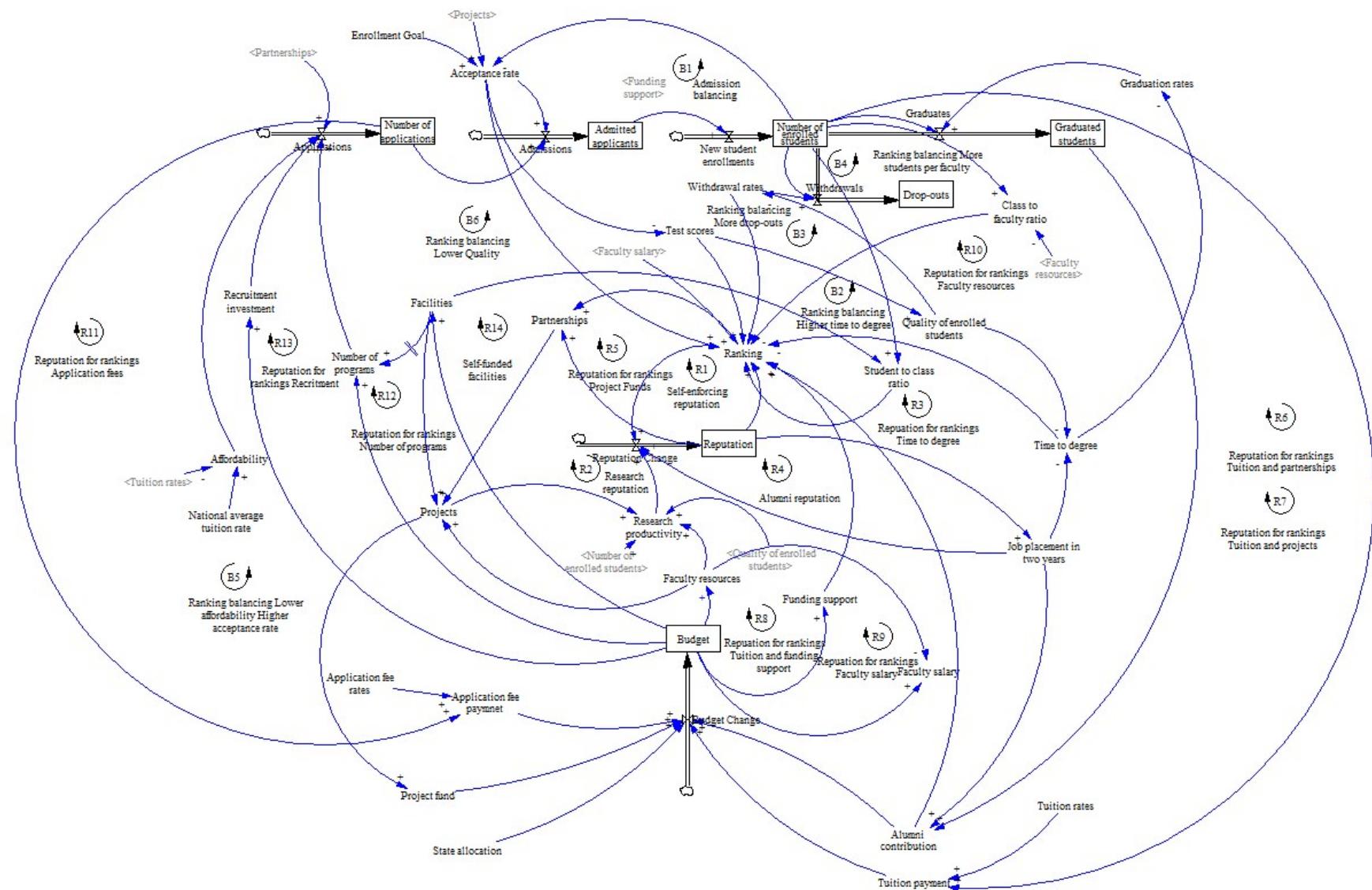


Figure 6. Enrollment and rankings model

The combination of the components of the model provides numerous new insights into the dynamics of the system as a whole. The increase in the ranking leads to the improvement of the university reputation, which is connected to the budget revenue through the number of partnerships and thus research projects that the campus gets. With more projects, more research funds are collected, which improves the university's ability to fund the faculty resources, causing greater research productivity and so improves the school reputation and ranking (loop R5). The number of partnerships per se leads to a larger number of applications, as the awareness of the university goes up on other campuses, triggering the growth on all stages of the admission and recruitment funnel. This in turn leads to the increase in tuition and alumni payments (loop R6), expanding the budget, which produces the increase in the rankings via the mechanisms described for the previous loop. The same way, the number of the projects creates the demand on the number of students; hence, it will lead to higher acceptance rates, growing enrollment, and the subsequent tuition payments and ranking (loop R7).

Generally, a larger budget provides the university with the leverage to increase the enrollment, in order to sustain the budget via tuition payments and simultaneously effect the positive change in the rankings, through several channels, namely, students funding support (loop R8), faculty salaries (loop R9), faculty resources via class to faculty ratio (loop R10), recruitment investment (loop R12), creating new academic programs (loop R13). These efforts result in the growth of the application pool, the budget gets replenished using application fees too, creating another reinforcing loop (R11). Finally, investing in facilities creates more possibilities for research projects generating higher revenue, which can be used to set up more facilities (loop R14).

However, increasing the acceptance rate negatively affects the ranking through lowering average test scores of the admitted applicants, the quality of the enrolled students and then either via longer time to degree (loop B2) or higher withdrawal rate (loop B3) or the lower test scores per se (loop B6). The growth of the enrollment, which is not accompanied by the growth in the faculty resources, shifts the class to faculty ratio higher, which is adversely associated with the rankings (loop B4). Another important consideration for decision-making is the tuition rate. As it goes up, the affordability of programs diminishes, which can necessitate higher acceptance rates, leading to the previously described negative effects for the ranking (loop B6).

IV. Conclusion:

The main goal of the current research is to model the dynamics of graduate education system in which managers try to increase the student enrollment without losing the quality of education as perceived by the potential students, i.e. the university's reputation. The paper presents a detailed overview of the variables influencing the dynamics and highlights factors that affect the university ranking, according to the U.S. News Rankings methodology. The main three components of the model are the admissions and enrollment funnel, the university's ranking, and the budget process. Using these three modules of variables, we have identified several feedback loops that will help us determine the key factors that can be manipulated to achieve the proper balance between increasing enrollment and maintaining the reputation, thus enabling sustainable enrollment growth. Generally, the model demonstrates that the goals set by this project can be attained by addressing the issue via different channels or by different offices of the university.

The feedback loops connecting enrollment, acceptance rates, and the quality of the incoming pool of students with the rankings and reputation are of a particular interest for us, as they can be affected directly by modifying the admissions policy only. However, the effect of these changes will be noticeable throughout the system.

The model proposed in the current research can be applied to solve wide variety of issues in the graduate education system such as:

- Finding best strategies for the acceptance rate considering its long-term effects on the system
- Comparing effects of various budget assignments on the enrollment of graduate students
- Investigating the impact of the change in academic resource of the system
- Obtaining insights into the factors important for quality of the enrolled students

We plan to continue the work on the project, in order to simulate different scenarios using the model and find the best strategies increasing the quantity and quality of graduate education.

References:

- Akar H. 2008. Poverty, and Schooling in Turkey: a Needs Assessment Study, Presentation at Workshop on Complex Societal Problems, Sustainable Living and Development, May 13-16, 2008, IAM, METU, Ankara.
- Altamirano MA, van Daalen CE. 2004. A system dynamics model of primary and secondary education in Nicaragua. 22nd International conference of the system dynamics society, July 25-29, 2004, Oxford, England.
- Barlas Y, Diker VG. 2000. A dynamic simulation game (UNIGAME) for strategic university management. *Simulation & Gaming*, 31(3), 331-358.
- Burge W. 2009. *The Admission Funnel: How to Streamline the Private School Admission Process*. Independent school management, Wilmington, Delaware.
- Dahlan SM, Yahaya NA. 2010, September. A system dynamics model for determining educational capacity of higher education institutions. In *Computational Intelligence, Modelling and Simulation (CIMSiM), 2010 Second International Conference on*, 285-290. IEEE.
- Division of Administration. Policies and Procedures. 2015. *Policy Type: Budget*. Retrieved March 18, 2015, from <http://bingdev.binghamton.edu/administration/procedures/100series/100.htm>
- Ellis K. 2012, April. Binghamton University presents its NYSUNY 2020 plan to governor, legislative leaders. *Inside Binghamton*. Retrieved February 19, 2015, from <http://www.binghamton.edu/inside/index.php/inside/story/2737/binghamton-university-presents-its-nysuny-2020-plan-to-governor-legislative/>

Frances C, Van Alstyne M, Ashton A, Hochstettler T. 1994. Using System Dynamics Technology to Improve Planning and Budgeting for Higher Education: Results in Arizona and Houston, Texas. *Proceedings of the 12th System Dynamics*.

Karadeli N, Kaya O, Keskin BB. 2001. Dynamic modeling of basic education in Turkey. Senior graduation project, Bogazici University, Turkey.

Llewellyn DC, Usselman M, Edwards D, Moore RA, Mital P. 2013. Analyzing K-12 Education as a Complex System. In *120th ASEE Annual Conference & Exposition, Atlanta, GA*.

Mikulskiene B, Mazrimiene D. 2013. Transformative quality of doctoral education: the way new standards are negotiated. System dynamics approach. In *Proceedings of the 31th International Conference of the System Dynamics Society*.

National Universities Methodology. 2015. Retrieved March 17, 2015, from
<http://www.usnews.com/education/best-colleges/articles/2014/09/08/how-us-news-calculated-the-2015-best-colleges-rankings?page=2>

Noel-Levitz White Paper—Retooling the Enrollment Funnel: Strategies and Metrics for a New Era. 2009. Retrieved March 8, 2015, from
https://www.noellevitz.com/documents/shared/Papers_and_Research/2009/RetoolingTheEnrollmentFunnel0109.pdf

Oyo B, Williams D, Barendsen E. 2008. A system dynamics tool for higher education funding and quality policy analysis. In *Proceedings of the 24th International Conference of the System Dynamics Society*.

Pedamallu CS, Ozdamar L, Akar H, Weber GW, Özsoy A. 2012. Investigating academic performance of migrant students: A system dynamics perspective with an application to Turkey. *International Journal of Production Economics*, 139(2), 422-430.

Pedamallu C, Ozdamar L, Ganesh L, Weber GW, Kropat E. 2010. A system dynamics model for improving primary education enrollment in a developing country. *Organizacija*, 43(3), 90-101.

Rodrigues LLR, Hebbar S, Suraj S, Leekha D. 2012, September. Modelling and simulation of quality management in higher education: A system dynamics approach. In *Computational Intelligence, Modelling and Simulation (CIMSiM), 2012 Fourth International Conference on* (pp. 304-309). IEEE.

Skribans V, Lektauers A, Merkuryev Y. 2013. Third Generation University Strategic Planning Model Development.

Sterman JD. 2000. *Business dynamics: systems thinking and modeling for a complex world*. Vol. 19. Boston: Irwin/McGraw-Hill.

Strauss LM, Borenstein D. 2014. A system dynamics model for long-term planning of the undergraduate education in Brazil. *Higher Education*, 1-23.

Terlou B, van Kuijk E, Vennix JAM. 1991. A system dynamics model of efficiency of primary education in Latin America. In: *Proceedings of the international conference of the system dynamics society*, 578-587.