Strategies for University Growth

A System Dynamics Analysis of Organizational Change

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Key words: System Dynamics, Educational Policy, System Dynamics Society Education Special Interest Group, Higher Education Management, Stakeholders engagement, Organizational learning.

Abstract

This paper reports on a study with a real-life client. In response to budgetary difficulties, administration at a tuition-dependent university pushed for growth in student enrollment. The expansion was resisted by the faculty who argued that the quality of education has declined. More students also impacted the use of university infrastructure. By actively engaging key stakeholders, I constructed a dynamic hypothesis and built a small model that captured existing mental models. A working model was used to conduct experiments with the stakeholders. The experiments simulated key policy decisions to gain insights from the resulting behavior. University management is a topic that enjoys active debate and increased attention in the higher education policy and management literatures. The current project could be expanded to include financials, graduate enrollment, and the pressure of academic research.

Introduction

This paper is a result of a term project which was part of a graduate class titled “System Dynamics Modeling for Change”[1]. The class emphasized the role of System Dynamics methodology in the process of organizational change. Its main focus was on helping students learn about the realities of modeling in an organizational context and improves their ability to facilitate change through reflective learning both as modelers and change agents.

John Sterman once wrote*“ The history of decision support tools in all fields is replete with examples of valuable models that failed to have any impact as they are rejected by the organizational immune system..“* yet the challenge is to *“ encourage the use of the model as an engine of inquiry rather than as a tool for performance assessment and employee evaluation”* (Cooper and Lee 2009). The use of the immune system metaphor here is very illustrative of what is going on in organizations. It is ironic to realize that the same protection mechanism could also be the deteriorating mechanism that resists positive change. It is important to keep this issue in mind as success is not measured by the ability to build a high fidelity model that remains as a foreign object and does not promote organizational learning and change.

Another insight came from Karim Chichackly who wrote in response to a question about the effectiveness of management games[2] *“In an ideal world, we use a model first and foremost to communicate our mental models of the system and then, through a possibly collaborative process, improve our shared understanding of the system. Once there is buy-in on the model structure, it is very useful to have a flight simulator to test various policies including the*

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[1] The course was offered as a part of the Advanced Distance Learning Network master program in System Dynamics at Worcester Polytechnic Institute (WPI), based in Worcester Massachusetts.
[2] During a discussion board exchange in a “Project Dynamics” class offered also in WPI’s System Dynamics ADLN professional education and masters program.

identification of unintended consequences and resilience to change." A successful modeling experience goes beyond meeting the modeler's desire to build intricate models to getting people to buy in or at least start a conversation based on a systemic view of how the system works and how the problem exists within that system. This could only happen if the stakeholders agree on the basic model structure. Therefore, to demonstrate the application of system dynamics in facilitating change, the project needed to translate institutional debate about an issue into a system dynamics model that draws upon people's knowledge of the organizational processes, provides a different language for discussing the issues, promote model ownership by working with stakeholders including key decision makers, utilize active participation to grow the model's level of complexity , and most importantly impact the organizational planning process.

The impact of the undergraduate students enrollment growth on quality and resources was modeled. The selection of the topic was fine-tuned after extensive interviews with the project stakeholders. The issue is almost ubiquitous in any tuition dependent educational institution. The university in the past was operating below the profit line. That's why it needed to grow its student enrollment to improve net revenues and improve its financial viability. Net revenues growth would help other areas in the university to grow its facilities and faculty which would attract more applicants. What are the unintended consequences of growth and how to mitigate them is the topic of the debate. University resources, as the definition evolved along the course of the project, are faculty and facilities. Quality also evolved to refer to the faculty academic experience.

The stakeholders have different backgrounds and their involvement in the project varies to a certain degree. Three of them are faculty members with extensive System Dynamics background who are also involved in different committees. One of them is a senior faculty member and an alumnus of the university who has always been the voice of the faculty and exercised dissent with the administration as a member of numerous administrative committees. He has a limited exposure to System Dynamics. The fourth member is a high level administrator overseeing strategic decisions in the institution. Through the project phases, careful attention is paid to the modeling, learning both of the modeler and the clients and real world implications.

The project objective was achieved as the clients' thinking was successfully translated into a small working model that replicated the reference modes and also helped gain some not so obvious insights into some key policy decisions. The project scope is a subset of a larger content that could include finance, administration, graduate enrollment growth, and the associated research focus which could result in showing more interesting behavior to deepen the understanding of the issue in question.

In the next section, we review the existing system dynamic work in higher education management in particular the area of planning, resourcing & budgeting. Then we explore the supporting data of the topic, construct the reference modes, the causal loop diagram, and build the model and the user interface. We then run experiments to test the impact of some policy decisions on quality and resources. We came to find that improvements in one domain could cause unintended consequences in others, which takes considerable time to recover from.

Previous Work in Higher Education Management

For more than a decade, Michael Kennedy (2011) kept his commitment to compile the research in the area of higher education management. The category of interest here is planning, resourcing & budgeting. Over the span of 30 years, Galbraith (2010) focused on publicly funded British and Australian universities. He addressed competition over resources under limited funding conditions where he modeled the decision-making processes of a university and the ramifications of management decisions to stimulate change through incentives on the behavior of faculty staffing and budgeting. His emphasis was on public funding allocation depending on enrollment growth per department and on grants allocation per faculty which is a function mainly of their academic research output. His research had little impact on the planning process of the university because it was conducted in isolation from stakeholders resulting in lack of model ownership. Stakeholder participation is important because they are the best to identify their own relevant problems and to conduct the verification and validation tests (Kennedy 2011).

The virtual university game "Virtual U" is a highly sophisticated higher-education management simulation game that was initially developed by Dr. William F. Massy[3]. It blurs the boundary between a strategy game and a training tool in hope to utilize the strength of gaming to elevate learning and especially strategic learning among players. It contains enormous details and customizations and was used in some 25 master's and Ph.D. programs to train more than 3,000 aspiring university administrators, and some 50,000 copies have been downloaded. (Baker 2005). The impact on universities planning process is not clear though.

Barlas and Diker (2000) developed an interactive dynamic simulation model into a university management game "UNIGMAE" where they generated numerous performance measures and demonstrated the systemic nature of university management in the sense that a single decision in isolation may yield counter-intuitive results, if not coordinated with a number of other related decisions. The model was built without involving multiple clients. Later it was used by both faculty members and high rank administrators but no serious follow up on the

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[3] A former Chief Financial Officer and vice-president of business and finance at Stanford university.

impact of their experiences was pursued according to a recent communication with one of the authors[4].

Vahdatzad and Mojtahedzadeh (2000) addressed growth of the University of Yazd in terms of student numbers, faculty members, and university resources. They identified and modeled only the research function as the means by which revenues could be increased for further expansion. Also the impact of this study is not reported.

The legendary Dennis Meadows (1999) through his productive career created many games to demonstrate the effect of growth among which is the famous "Fish Banks" game was used in a university context. He came up with the insight that growth has now gone on so long that it now generates costs far in excess of its benefits. Meadows also found that the proper game design is very important for its effectiveness and realized after many sessions of gaming that more complication means less learning and kept searching for a simpler way of conveying insights. He states: *"I believe that learning is more effective and permanent if the lessons can be conveyed and anchored through models that are complementary to words"*.

Szelest[5] (2003) explored a range of university enrollment management theories and put them to test through a sophisticated dynamic simulation model. He analyzed several strategic initiatives and confirmed the inherent tradeoffs between competing objectives like teaching and research. At the same time he found out that some seemingly conflicting objectives could be simultaneously achieved. His analysis also emphasizes the role of information delays and loop

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[4] Email exchange in November 2012 with the two authors who generously provided me with the game, the original model, and Diker's thesis. Professor Barlas expressed the intention to update the game in the near future.

5 Bruce Szelest is the Associate Vice Provost for Academic and Resource Planning at the New York University at Albany in Albany, NY where he heads the office of Institutional Research, Planning, and Effectiveness (IRPE) which is responsible for Administrative Information Development, external Reporting, management support, policy analysis, evaluation, and assessment. Many thanks to professor George Richardson who provided the lead to Szelest work.

dominance shifts that governs the financial resources allocation process and the unintended consequences of policy decisions that are made with good intentions. Currently, his office conducts special studies and survey analyses to support campus management where it launched a series of model-driven cohort studies. His research is part of an organizational lifelong commitment towards institutional research that is reflected by the establishment of the Association for Institutional Research and Planning Officers (AIRPO)[6].

The above accounts confirmed our stakeholders' centered approach to involve to consider their priorities, focus on creating a simple model that captures their thinking about the issue, and increase gradually the level of model complexity based on their own discoveries at their own learning pace in hope to leave a lasting positive impression from this experience.

Supporting data

During the interviews, stakeholders pointed out to several references of published data related to the issue of undergraduate enrollment growth. According to a subcommittee report (Hoffman, Tichenor et al. 2011), it was clear that the university went through that growth in enrollment rate from 2005 onward as shown in Figure 1 which resulted in the growth of the undergraduate student body shown in Figure 2.

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[6] This effort placed Albany in the forefront of outcomes assessment research. See (http://airpo.binghamton.edu/)

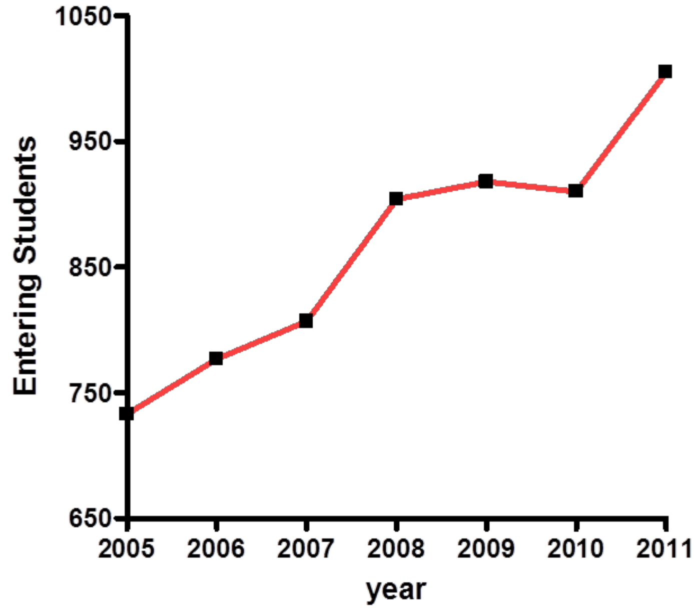

Figure 1: Undergraduate students enrollment rate (Hoffman, Tichenor et al. 2011)

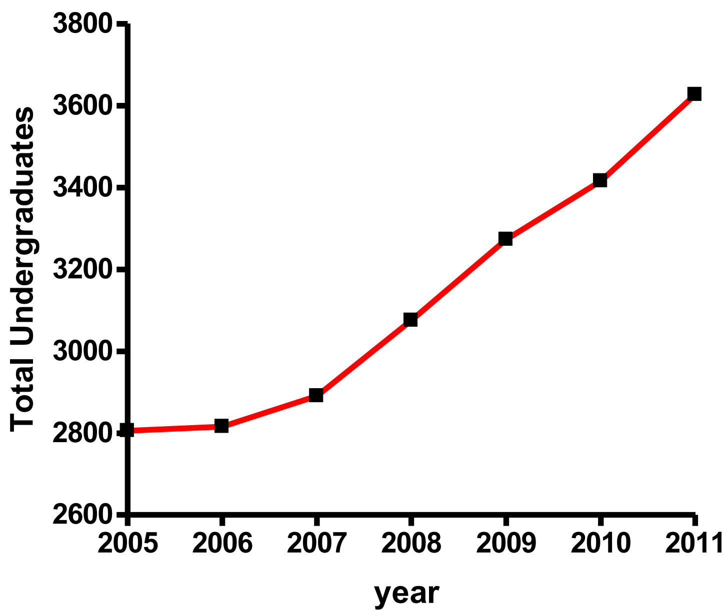

Figure 2: Growth of undergraduate student body (Hoffman, Tichenor et al. 2011)

The number of faculty over the same period is shown in Figure 3. It shows a steady increase of Tenured/Tenure-Track faculty only after 2008. Full Time faculty numbers were oscillating over the years. Part-Time adjuncts numbers declined between 2005 and 2008 only to increase in the last two years. One can notice that during the early years of enrollment growth, faculty numbers did not follow the same trend of continuous growth until four years later which means the faculty were overloaded during that period without an indication for change in the situation.

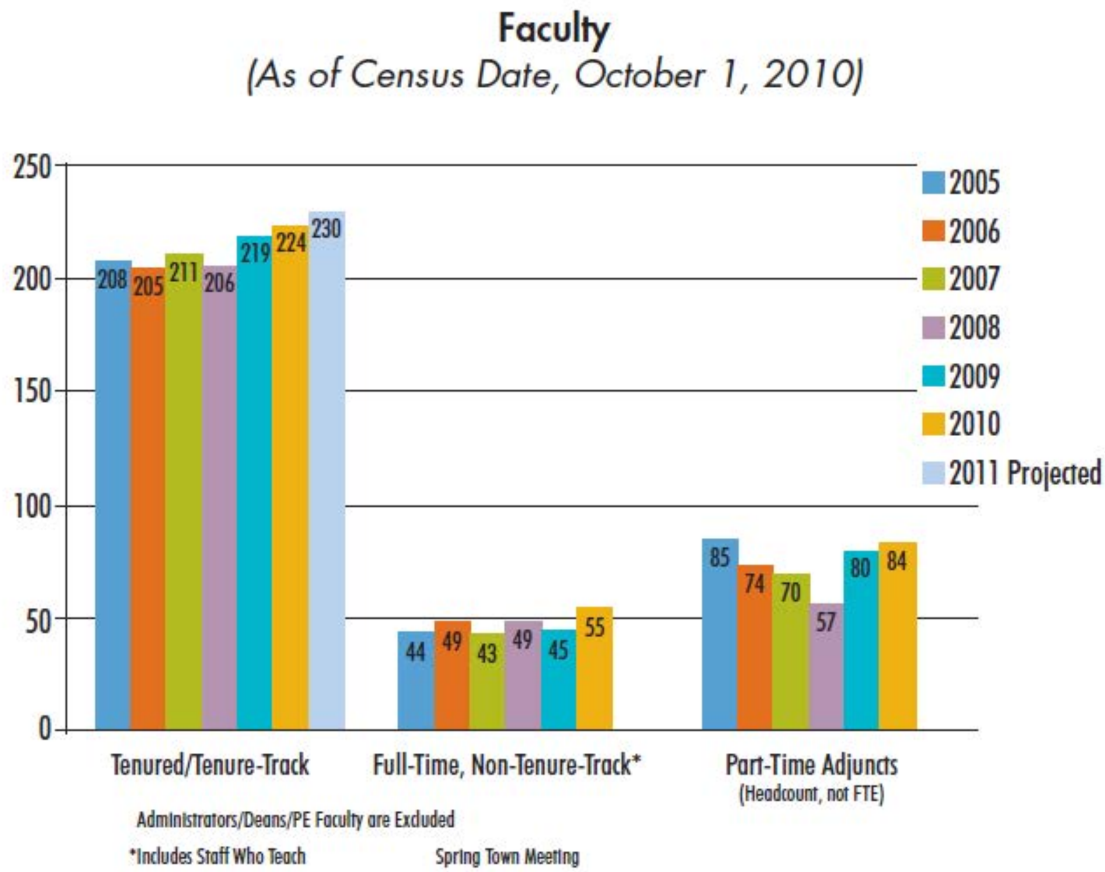

Figure 3: Faculty numbers (NEASC 2011)

According to the New England Association for Schools and Colleges self study (NEASC 2011), the need to develop a new faculty workload model was indicated. The current faculty workload includes teaching, project advising, academic advising, and innovation in courses in advising. The shortage in faculty office space and undergraduate laboratory space was also pointed out. The study referred to campus housing ability to accommodate the growth and, at the same time, the need to provide an additional capacity. Lastly, it showed that the university effort to replace the budget deficit in Fiscal Year 2001 through FY 2005 with budget surplus from FY 2007 through FY 2010 were successful.

Reference modes

After the client's interviews, it was possible to summarize them and construct the reference mode diagram showing the key variables frequently repeated during the interviews and represented the issue in consideration as shown in Figure 4. The continuous growth of undergraduate students UG (green curve) is feared to continue with a hope to stop it at its current value. Faculty members (light blue curve) were growing however at a lower rate in comparison to the enrollment. Their numbers are hoped to increase to meet the enrollment growth and reach equilibrium when the faculty load drops to a reasonable value. There is actually a fear that faculty numbers may drop if they start leaving in response to the continuous load increase and any associated drop in quality (purple curve). Faculty load (red curve) was growing with a hope to drop and reach equilibrium. There is a fear that it will keep increasing as long as the enrollment continues to grow. Quality (purple curve) , defined as faculty academic experience, was dropping there is a fear that it will continue to drop and a hope to restore it back to a higher level and equilibrate. This scenario would materialize if the enrollment remains constant without further increase while faculty numbers does not decrease.

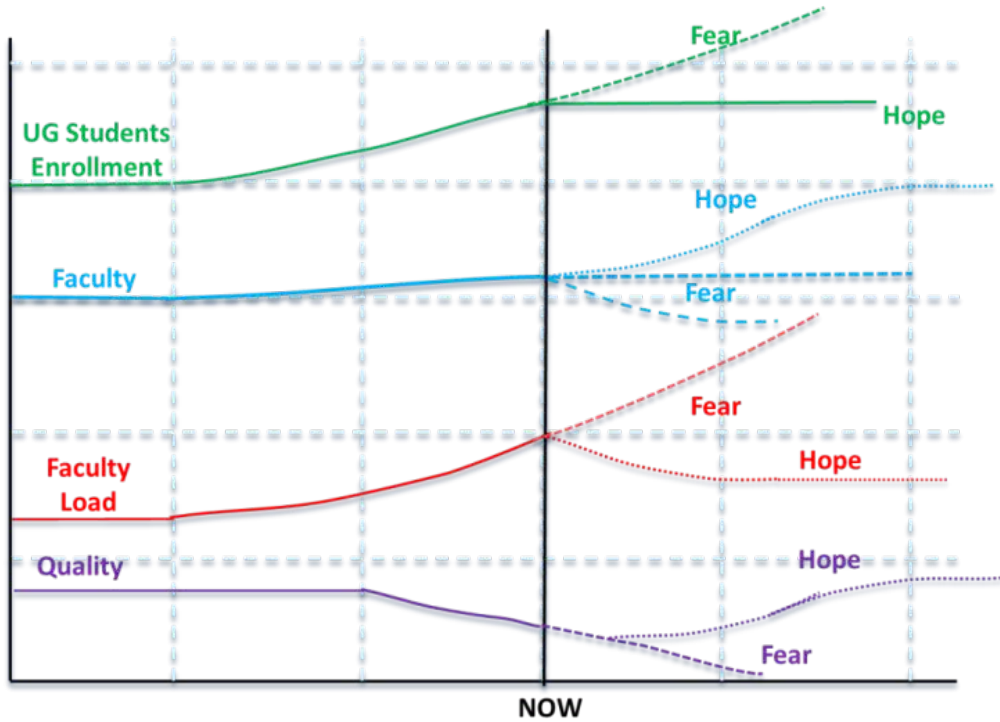

Figure 4: Reference Mode Diagram

Dynamic hypothesis

Although the clients' main concern was the same, that is the impact of enrollment growth on faculty, facilities, and quality, they had different views on how it originated. Figure 5 shows a rather comprehensive causal loop diagram (CLD) that shows the feedback structure generated by enrollment growth. The CLD includes key variables like the enrolled students, full time faculty, part time faculty, administration, revenues , salaries, and research productivity.

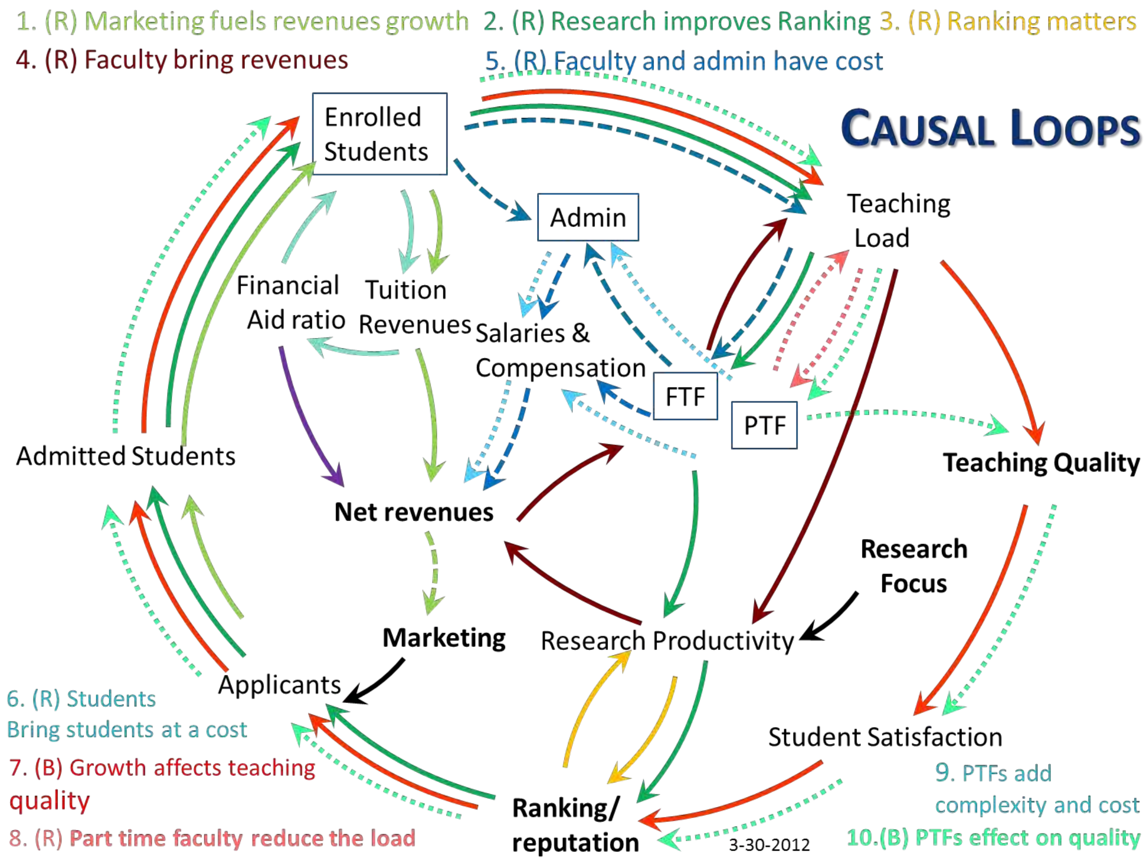

Figure 5: Causal Loop Diagram showing the feedback back loops generated by enrollment growth.

The attempt to make the above CLD easy to absorb through the extensive use of colors for each causal loop, the elimination of the +/- signs to de-clutter the diagram, and the gradual introduction of each loop paid off. The stakeholders were able to quickly prioritize two issues to explore namely; the impact of enrollment on faculty. In addition, they added facilities which was not shown in the above CLD. Accordingly, impact on facilities was added to the CLD while removing other unneeded variables and causal links. The modified CLD is shown in Figure 25.

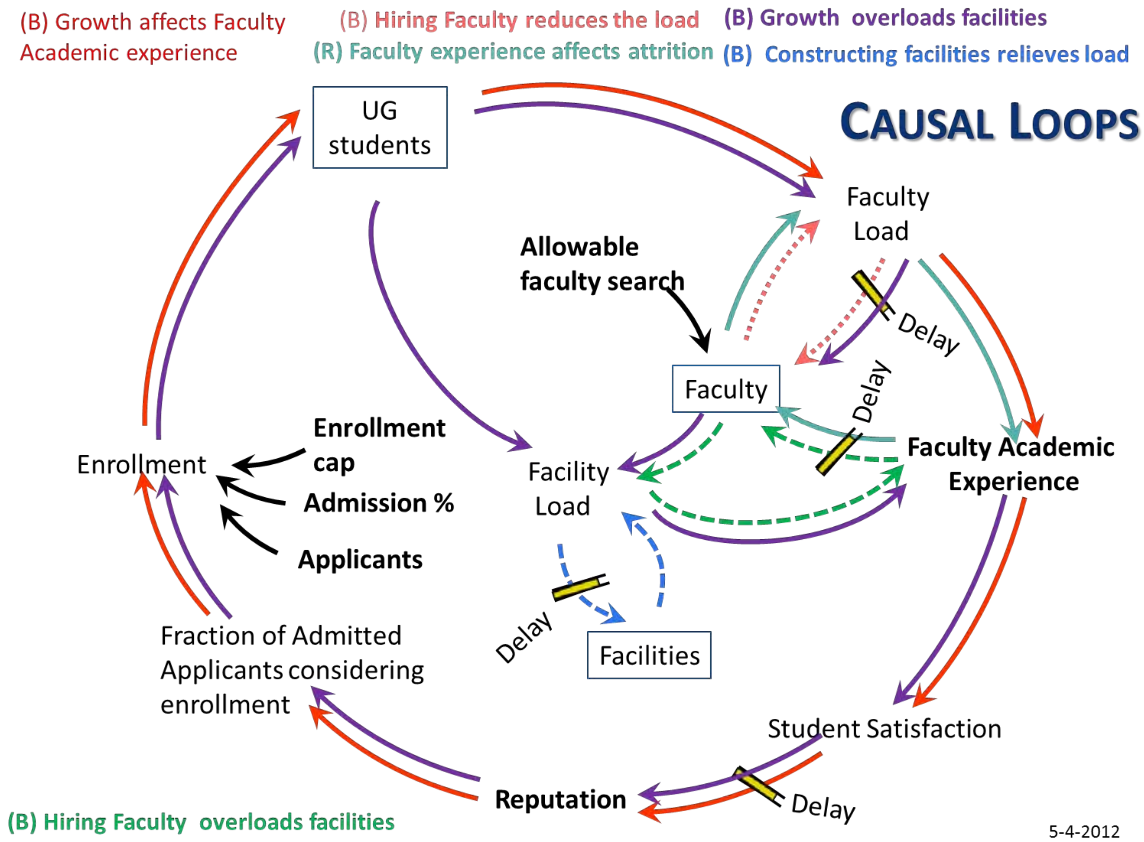

Figure 6: Modified CLD including Facilities sector

The loops description goes as follows where the (B) and (R) at the beginning of each loop title indicate a balancing and reinforcing loop respectively:

1. **(B) Growth affects faculty academic experience (red loop):**

As enrollment increases, student body grows, faculty load increases overwhelmingly leading to a degraded faculty academic experience, lower student satisfaction, and over time, impact negatively the institution reputation as it might come short of fulfilling its commitment to deliver what makes it unique among other schools. This would lead to a reduction in the fraction of admitted applicants considering enrollment.

Delay is shown between student satisfaction and the effect on reputation which is assumed to be the time until students graduate from the university or the time needed for school counselors to learn and talk to their students about the school reputation and hence spreading the word.

2. **(B) Hiring more faculty alleviates faculty load (light green loop)**
   As the faculty load increases, and after a time delay which is the time needed to hire more faculty , the number of faculty increases to reduce the faculty load.

3. **(B) Growth overloads facilities (purple loop)**
   Growth in undergraduate students and faculty puts more load on facilities which could degrade the faculty academic experience, student satisfaction, reputation and the fraction of enrolled students.

4. **(B) Constructing facilities reduces facilities load (blue loop)**
   As facilities load increases, more projects could be initiated to either modify classrooms, laboratories, and dorm rooms to accommodate more students and faculty or start building new facilities which takes time to finish.

5. **(R) Faculty load increases attrition (ocean blue loop)**
   Increase in faculty load degrades faculty academic experience and over time leads to faculty attrition to further increase the load on faculty.

6. **(B) Faculty growth overloads facilities (green loop)**
   As more aggressive faculty hiring takes place, this puts more load on facilities especially when targeting high quality faculty who demand both office and lab space which barely meet the needs of current faculty. This would deteriorate the faculty academic experience for the faculty are overloaded by the academic load, which does not include research in this study, and by facility shortage. Shortage in facilities makes it hard for the faculty to find a proper space to teach, and counsel students. This would lead to further faculty attrition.

Model construction

The model was constructed while refining the dynamic hypothesis and eventually more important feedbacks were identified, like the feedback of faculty growth on facilities and faculty attrition discussed earlier, as the 1st version of the model was demonstrated to the clients in a story telling mode[7]. Story telling enables the presentation of the model one step at a time which proved to be helpful in discussing each variable and feedback as it emerges. This reflected both the clients' understanding of the structure and their engagement in the process.

The model, at an aggregate level, was constructed in 4 sectors namely students, faculty, quality, and facility as shown in Figure 7.

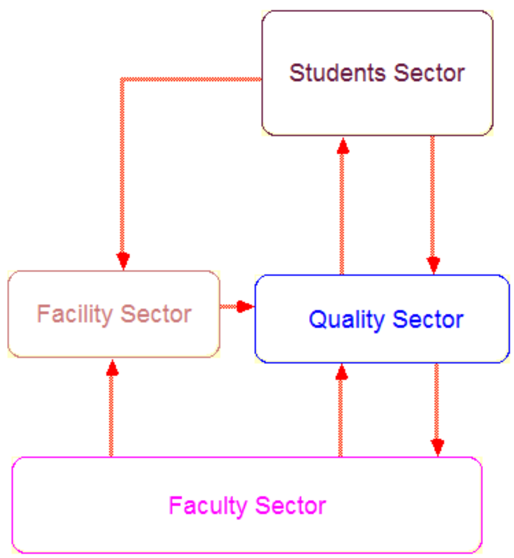

Figure 7: model sectors shown in an aggregate level

A more detailed view is shown in Figure 8. The students sector shows the stock of undergraduate students which grows with enrollment. Enrollment is a function of applicants,

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[7] Story telling is a feature in iThink, the modeling software used to build the model (available from ISEE Systems: http://www.iseesystems.com).

percent admitted of that pool, and the fraction of them who end up enrolling. Enrollment is limited by enrollment cap. Students graduate over an average time of stay in school and accordingly reduce the stock of students.

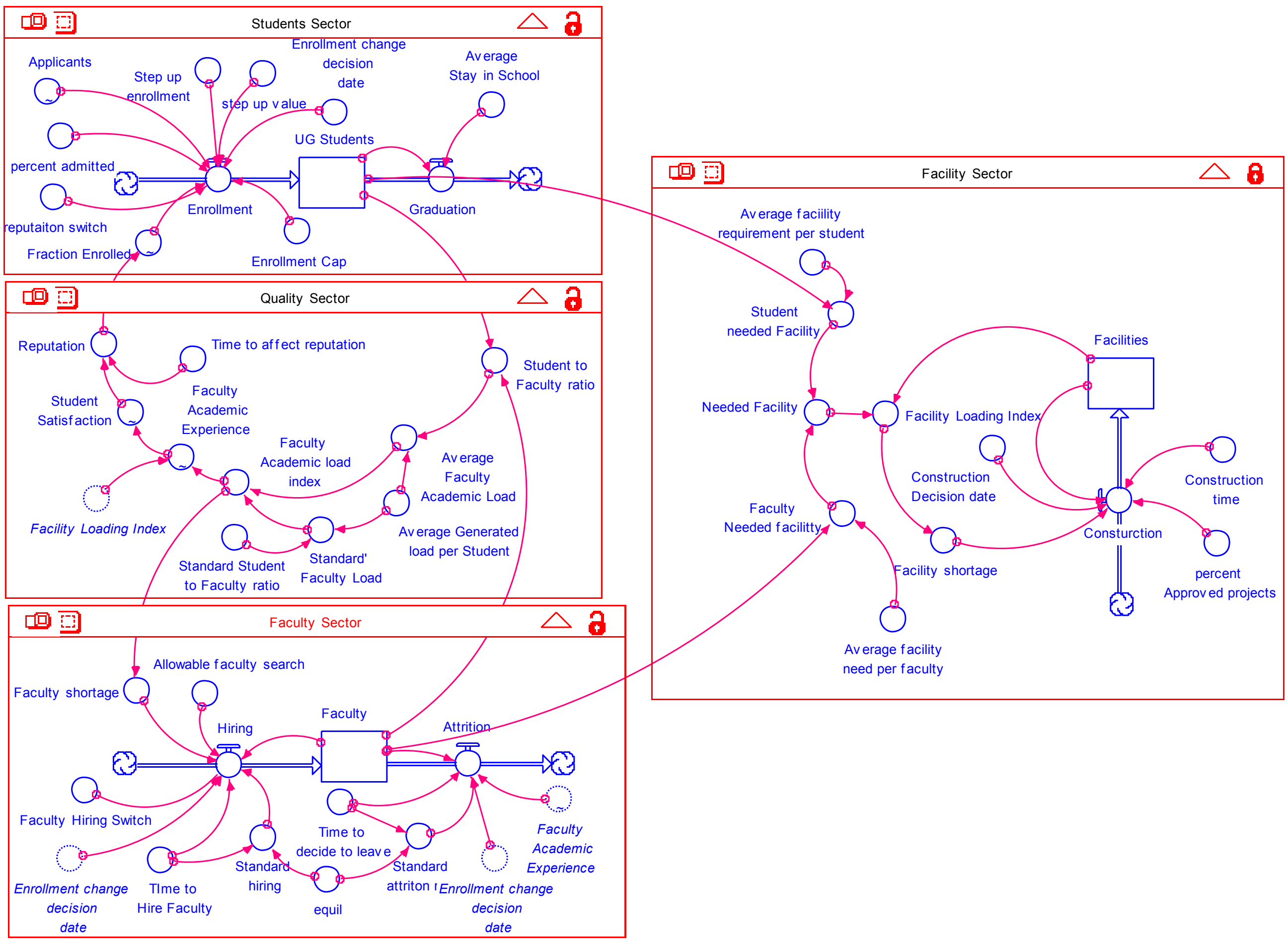

Figure 8: Simulation model shown in sectors

The fraction enrolled is affected by the reputation in the quality sector which takes time to be influenced by student satisfaction. Student satisfaction is a function of faculty academic experience that is affected by faculty academic load index and facilities loading index. Faculty academic load index is the ratio of the average faculty academic load to an assumed standard load. The average faculty academic load is generated by the ratio of students to faculty and multiplied by the load generated per enrolled student.

The faculty sector shows that faculty grows by hiring and reduced by attrition. Faculty hiring takes time driven by faculty shortage, and limited by the allowable faculty search. Faculty shortage is a function of the faculty academic load index from the quality sector. Similarly, attrition is driven by faculty academic experience and the time it takes them to make the decision to leave.

Finally, facilities grow by construction, which takes time to finish. Construction is driven by the facility shortage and is limited by the percentage of approved projects. Facility shortage is determined by the facility loading index. Facility loading index is the ratio of the needed facility to the facilities stock. The facility loading index as mentioned earlier affects the faculty academic experience. The needed facility is determined by both the student and the faculty needed facility. Student needed facility is determined by the number of students multiplied by an average facility requirement per student. The same applies for the faculty needed facility where it is determined by number of faculty multiplied by the average facility need per faculty. The complete model with its equations is provided in the appendix.

Simulation experiments

Two sets of experiments were conducted. One set used the historical data of students enrollment (Figure 1) and faculty numbers (Figure 3) to drive the model. It was used to demonstrate how the situation developed over the past years from 2005 to 2011. Then we switched to a policy testing mode where the model was initiated in equilibrium then disturbed by a step change in students enrollment and different experiments were conducted afterward. This approach was thought to provide for the clients a better base for understanding the impact of different decisions and their interactions.

To conduct the experiments a graphical user interface (Figure 9) was designed to include switches, buttons, and displays that would enable the clients to interact effectively with the model and change the parameter values easily. Both the model and the interface were implemented in the simulation software iThink.

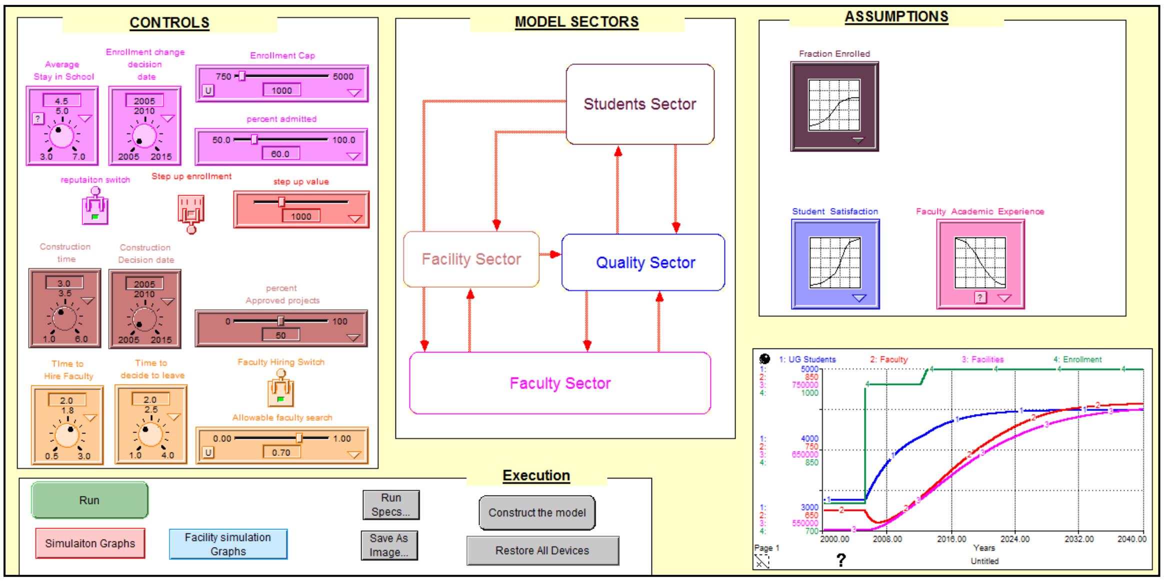

Figure 9: Graphical User Interface GUI for the model

Experiments using historical data

Historical data were used up to the year 2011 then the last enrollment value is kept constant at 950 students per year. A second test was to reduce enrollment to a lower value of 750 students per year to explore the effectiveness of this policy in mitigating faculty load. A third test was to expedite faculty hiring by reducing the hiring from two to one year in order to alleviate the faculty academic load. The previous three tests assumed that faculty allowable search is 1 i.e., the target is to hire all what is requested to compensate for the shortage in faculty which is rarely the case in a real life situation. Running the model with allowable searches of 0.5 would be closer to reality. Notice that all decisions are not influenced by financial performance since the financial sector is not included in this model.

Simulating the four cases, the results are shown in the figures 10 through 17 and will be discussed below. During the discussion, *curve 1* will correspond to the case of freezing enrollment target to 950 students per year, *curve 2* will correspond to the case of reducing enrollment to 750 students per year, *curve 3* will correspond to the case of reducing faculty hiring time to 1 year, and *curve 4* will correspond to the case of reducing the allowable faculty search to 0.5.

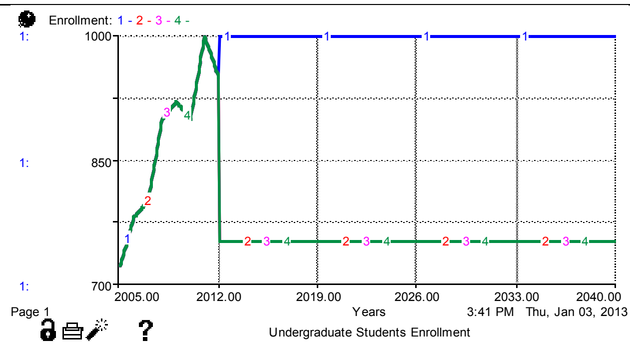

Figure 10: Undergraduate students enrollment

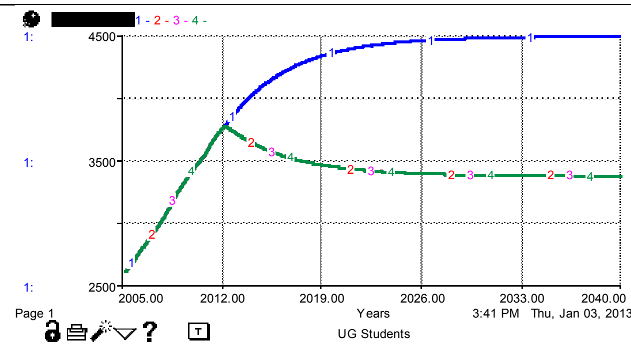

Figure 11: Undergraduate students body

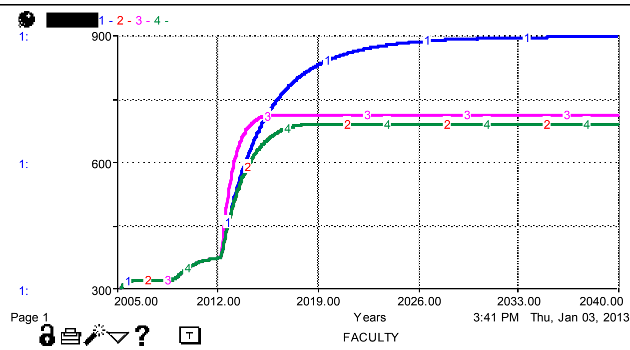

Figure 12: Faculty numbers

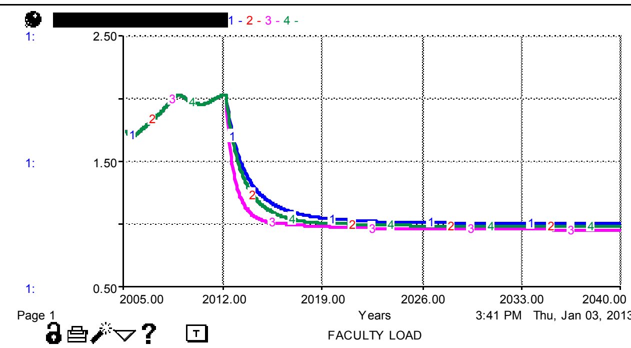

Figure 13: Faculty academic load index

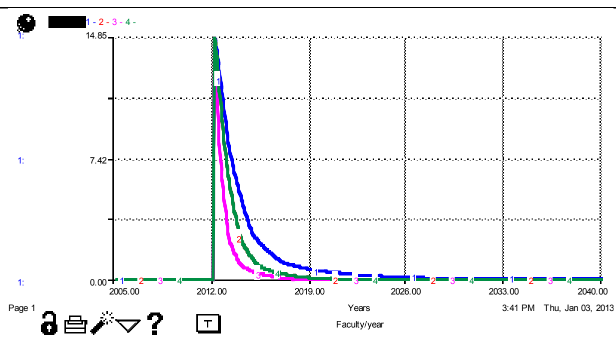

Figure 14: Faculty attrition

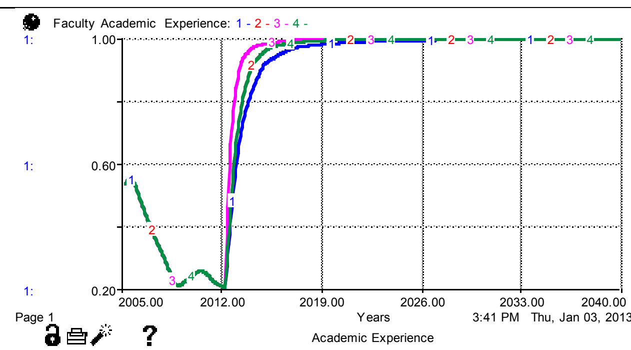

Figure 15: Faculty academic experience

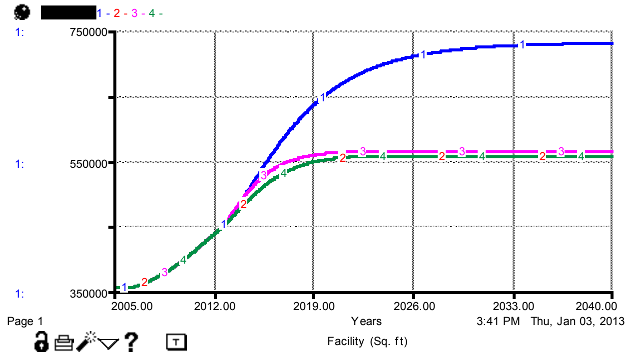

Figure 16: Available Facilities

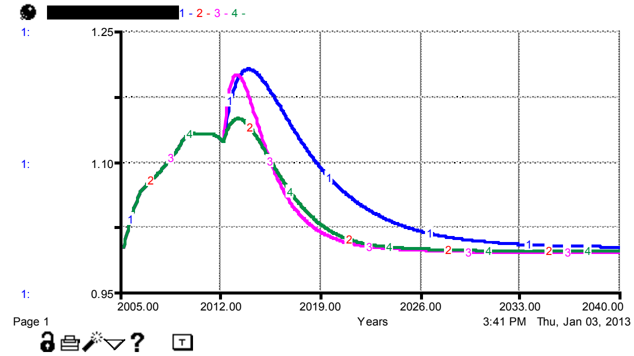

Figure 17: Facility loading index

Figure 10 shows, at the beginning, how the enrollment grew between 2005 and 2011. *Curve 1* shows the 1st test to freeze enrollment at the value of 950 over the coming years up to 2040. *Curves 2,3, and 4* show the implementation of the decision to reduce enrollment to 750 students per year.

Figure 11 illustrates the continuous growth of undergraduate students body as a result of enrollment behavior between 2005 and 2011. *Curve 1* shows how freezing the enrollment would result in a decelerating growth approaching equilibrium (at the value of 4267 students compared to 3774 students in 2012) when graduation equals enrollment around the year 2030. The drop in enrollment would slowly bring the students body to a lower equilibrium level of 3383 students compared to the highest level reached in 2012 before stepping down the enrollment.

As can be seen from Figure 12, if all faculty shortage will be met after 2011, *curve 1* depicts that it will take more than 20 years to be able to satisfy the demand and bring back the ideal situation of faculty load index value of 1 which suggests that all faculty members would work at their “standard” workload as shown Figure 13. *Curve 2* shows a faster recovery since the enrollment is reduced and accordingly the shortage is less and meeting that shortage could be achieved over a short period of time. *Curve 3* simulates the case of hiring time reduction which could be achieved by hiring adjuncts. This would result in a faster growth of the number of faculty but at the same time results in more pressure on facilities as shown in *curve3* in Figure 17. This could lead to higher attrition rate and accordingly higher faculty shortage. The model reaches equilibrium at a higher number of faculty as can be seen in *curve3* in Figure 12. When reducing the allowable faculty search, the number of needed faculty to compensate for the shortage at equilibrium is surprisingly reduced as shown by *Curve 4* in Figure 12. The reason is lower hiring of faculty reduces the facility loading index in curve 4 in Figure 17 resulting in lower attrition and hence a less shortage in faculty.

Facilities are shown to have the highest levels when enrollment is kept at 950 as shown by *curve 1* in Figure 16 and lower levels, as expected, when the enrollment reduces to 750 as shown by *curves 2,3,and 4* in the same figure.

Experiments in a policy testing mode

The purpose of conducting these tests is to improve the understanding of the effect of each policy decision on a system that is not currently under stress of any sort, i.e. in a state of equilibrium which then will be disturbed by stepping up enrollment followed by accelerating faculty hiring and a reduction in the faculty allowable search as we did in the previous section when the model was initiated and driven for a certain period using historical data. In these experiments, the feedback loop of reputation effect on enrollment (loop1in Figure 6) is kept inactive which resembles the prevailed mental model that the university is still and will remain in high demand by prospective students for years to come.

Simulating the four cases, the results are shown in the figures 18 through 25 and will be discussed below. During the discussion, *curve 1* will correspond to the case of initiating the model in equilibrium (parameter values for initializing the model in equilibrium are listed in the appendix) , *curve 2* will correspond to the case of stepping up enrollment to 1000 students per year, *curve 3* will correspond to the case of reducing faculty hiring time to 0.5 year, and *curve 4* will correspond to the case of reducing the allowable faculty search to 0.5.

Figure 18 below shows the model in equilibrium (*curve 1*) and when the enrollment is stepped up (*curves 2,3, and 4*). Figure 19 shows how the number of students grow as a result of the step up in enrollment (*curves 2,3, and 4*). The growth is not linear due to presence of a draining flow of students graduating from the university which takes place over the average time students spend in the university before graduation (around 4.5 years).

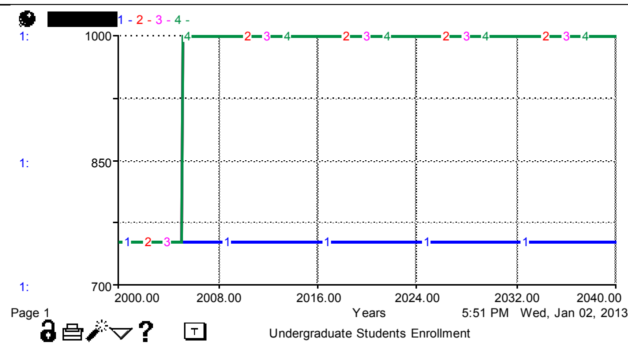

Figure 18: undergraduate students' enrollment

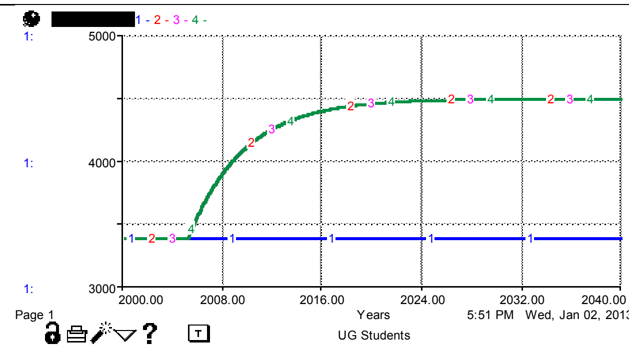

Figure 19: Undergraduate students body

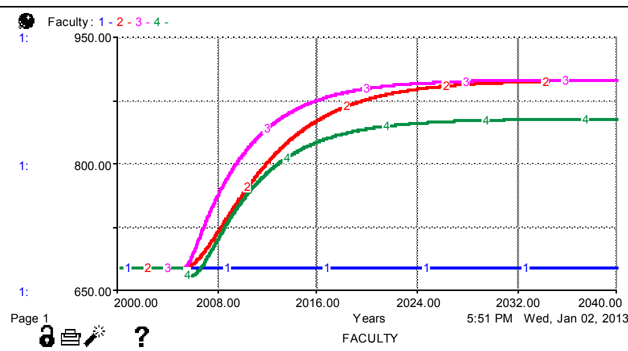

Figure 20: Faculty numbers

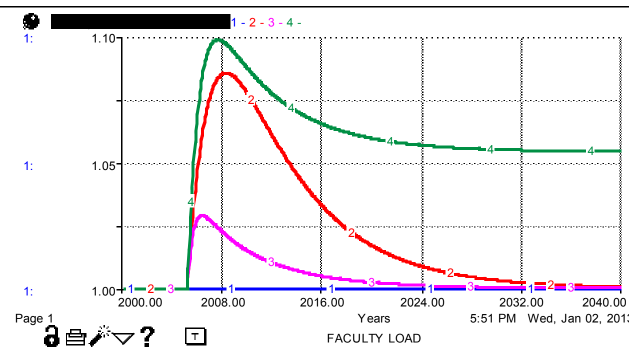

Figure 21: Faculty academic load index

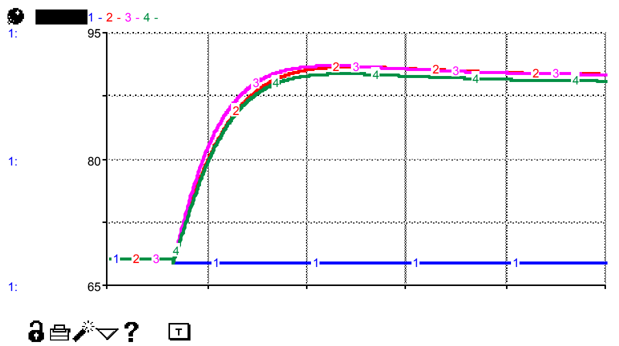

Figure 22: Faculty attrition

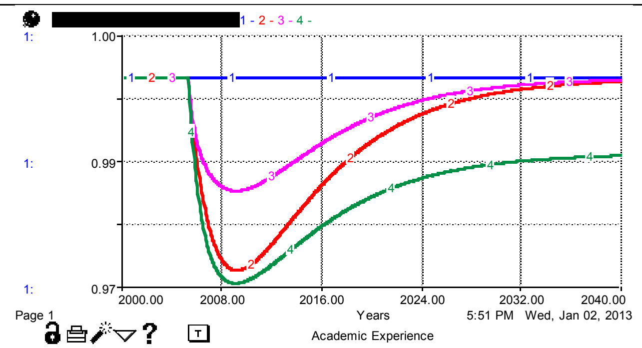

Figure 23: Faculty academic experience

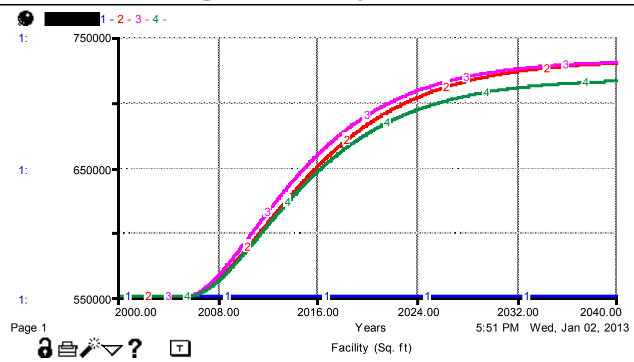

Figure 24: Available facilities

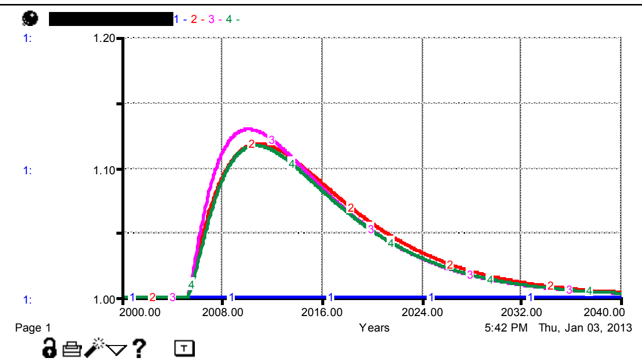

Figure 25: Facility loading index

Speeding up hiring by reducing the hiring time making it 4 times as fast did not improve the faculty academic experience as would have been expected. *Curve 3 and curve 2* in Figure 23 are close to each other as the faculty academic experience shown in *curve* 3 recovers slowly. This is happening since hiring more faculty would increase facilities loading index (*curve 3 in* Figure 25) resulting in a lower faculty academic experience, as explained earlier by the green loop (Faculty growth overloads facilities) in Figure 6, despite the fact of having lower academic load as depicted by *curve 3* when compared to *curve2* in Figure 21.

Finally, the reduction of faculty allowable search would set a new equilibrium level for the school both in faculty academic load (*curve 4* in Figure 21) and faculty academic experience (*curve 4* in Figure 23). This is a result of a decision the organization has consciously made to maintain a certain operational capacity which translates into a new norm for certain faculty load and quality .

Activating the reputation feedback loop to test its effect is of paramount importance since it reflects the faculty mental model which they tried to convey to the administration with no apparent success. Starting from equilibrium (*curve 1*), the experiments are conducted by keeping the enrollment at 1000 student per year and reducing faculty allowable search to 0.5 to be closer to reality (*curve 2*), then allowing a slightly higher faculty search value of 0.75 in an attempt to improve the situation (*curve 3).* The simulation results of the experiments are shown in the figures from 26 to 33.

Enrollment is shown to step up, stabilize for a certain period of time, then drops to a much lower value (*curve 2* in Figure 26). This is translated into a severe reduction in the number of students (*curve 2* in Figure 27), faculty (*curve 2* in Figure 28), faculty academic experience (*curve 2* in Figure 31), and facility loading index (*curve 2* in Figure 33).

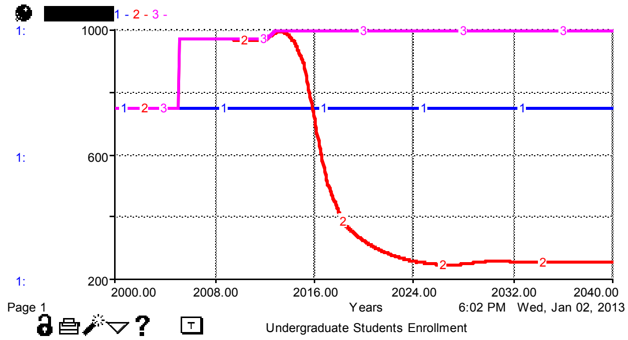

Figure 26: Undergraduate students enrollment

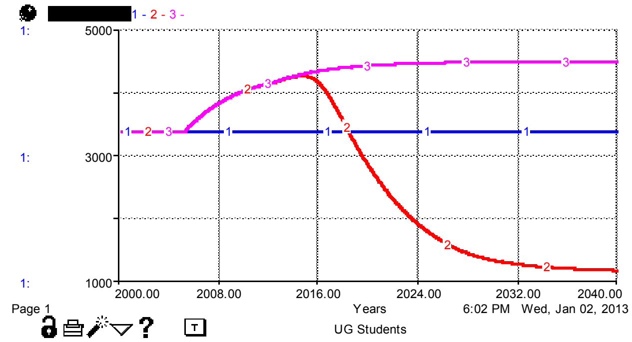

Figure 27: Undergraduate students body

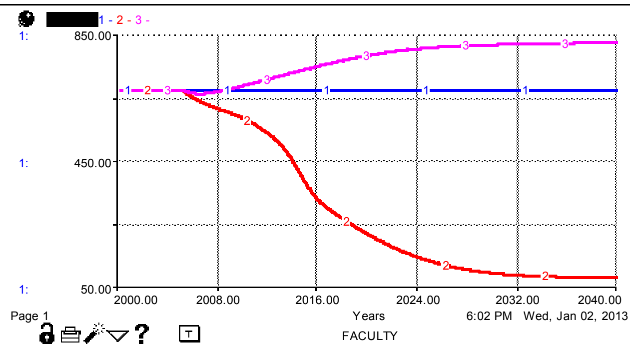

Figure 28: Faculty

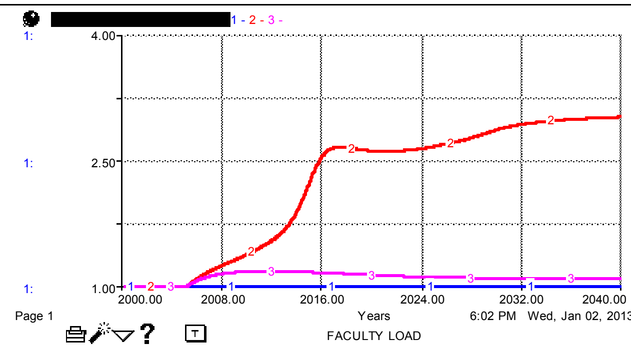

Figure 29: Faculty academic load index

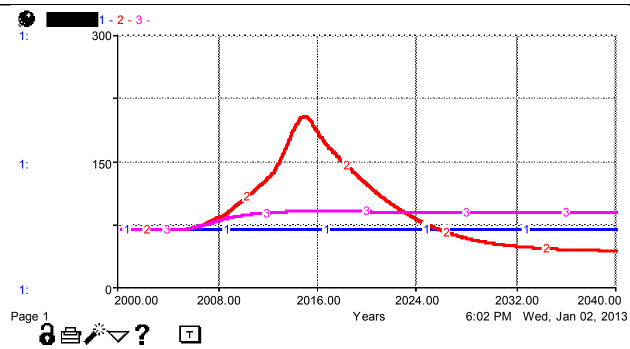

Figure 30: Faculty attrition

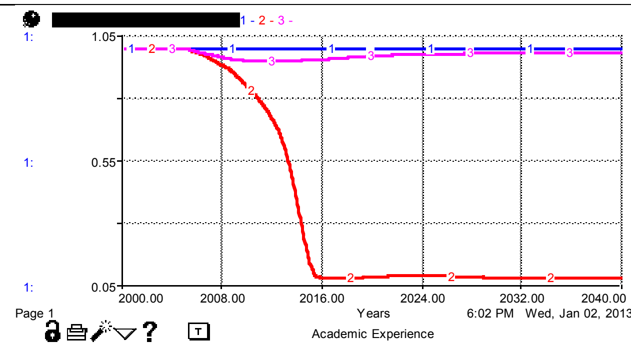

Figure 31: Faculty academic experience

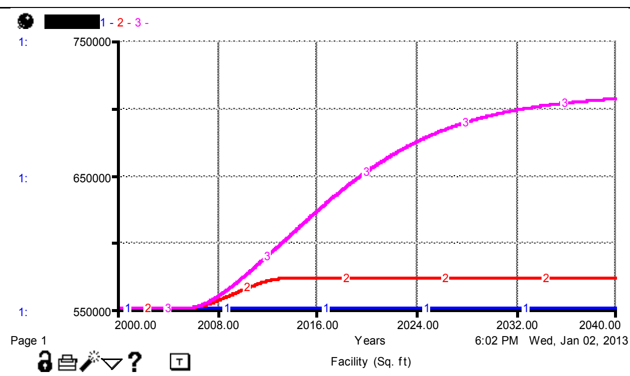

Figure 32: Available Facilities

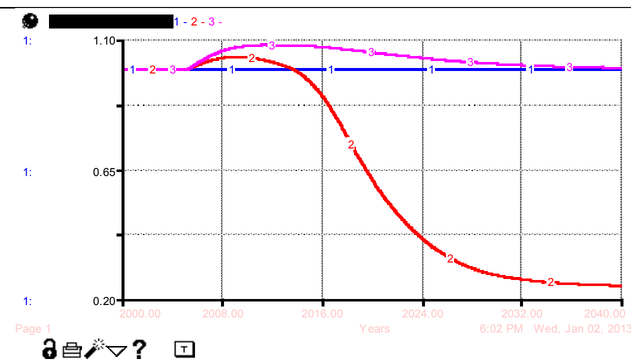

Figure 33: Facility loading index

The reduction in the number of faculty is explained by the high faculty academic load (*curve 2* in Figure 29) resulting in high attrition rate (*curve 2* in Figure 30). This feedback is shown by the balancing ocean blue loop in Figure 6. Facilities construction is slowed down with a delay, however, the financial commitments to the construction projects and their finances were made during the time of student body and faculty growth. Those facilities will not be any more needed and their utilization would fall below 1 which means that there are offices, laboratories, classes, dorms but neither enough students nor faculties are there to ocupy them. Such a university is not economically viable to survive and might have vanished earlier should the financial sector was included in the model.

Raising the allowable faculty search to 0.75 would sustain enrollment as can be seen in *curve 3* in Figure 26 and Figure 27. Although faculty numbers are growing (*curve 3* in Figure 28) the growing attrition rate (*curve 3* in Figure 30) is driven by the degraded faculty academic experience (*curve 3* in Figure 31) which kept the faculty academic load (*curve 3* in Figure 29) at a higher level. This also indicates an operational policy that seeks a certain load to be maintained on faculty and facilities. Including the financials in the model may better explain the reasons behind such policies. The results of the experiments are summarized in Table 1.

Overall, the results are showing that improvements in one domain could create problems in another which is highly probable when departments work in silos and make decisions independently. This could lead to zero sum benefits regardless of how good and sincere the intentions to improve the situations are. Growth decisions made at any time could take a long time to recover from its unintended consequences. Additionally, decisions in the form of long term financial commitment to facilities construction when combined with a limitation on hiring high quality faculty could lead to disastrous consequences to the institution or degrade its status in the best case.

Table 1: Summary of experiments and their reuslts

Experiment	Policy instrument	Original value	Changed to	Results
Using historical data	Enrollment target	950	950 (no change)	Faculty load and facilities load takes a long time to recover.
	Enrollment target	950	750	Less time is needed for recovery, not as fast as anticipated, implementation is questionable as a viable economic policy.
	Faculty hiring time	2	1	Adds more load on the faculty and facilities.
	Allowable faculty search	1	0.5	Sets a new operating standard of higher faculty load and lower academic experience.
Inactive reputation feedback	Enrollment target	750	1000	Long recovery time.
	Faculty hiring time	2	0.5	Higher load on facilities and lower faculty academic experience and high attrition.
	Allowable faculty search	1	0.5	Sets a new operating standard of higher faculty load and lower academic experience
Active reputation feedback	Allowable faculty search	1	0.5	Collapse of the institution by being not economically viable.
	Allowable faculty search	1	0.75	Economically viable yet overloaded faculty and facilities , a question mark over the policy sustainability.

Conclusion

Working with key stakeholders, it was possible to choose a live topic that enjoys active debate and successfully capture and translate their existing mental models into a small working model. Despite the lack of details when compared to the large and extensive models built by other scholars in the domain, the model replicated the reference modes and unveiled the systemic feedback structure that produced them.

High aggregation level in combination with storytelling and proper user interface helped improve both clients' understanding and engagement in experimenting and gaining insight from the model behavior. It also helped gaining insights on how decisions when made in isolation and not coordinated with other related decisions may yield counter-intuitive consequences that takes the organization an extended period of time to heal from.

The slow and gradual progress, as unsatisfying as it might be to a modeler, really paid off and helped gain willingness from the clients to commit for possible future development of the model in a hope to utilize it as a vehicle for communication and exchange of views around delicate organizational issues and high priority topics typically raised when making strategic choices that calls for organizational change and effective collaboration to materialize .

Future expansion of the model could include the financials, graduate students growth, and the associated focus on research. This would enable a more in depth analysis of different growth strategies and their outcomes on the performance of the university.

Acknowledgments

This work could not be accomplished without the ingenuity of professor Oleg Pavlov who, when approached, came up with the initial suggestion of the topic and provided extensive guidance and advice during the process of conducting the project. Many thanks to professor Khalid Saeed with his extensive background and seminal contributions in the area directed me to the proper modeling approach of focusing on a high level of aggregation which proved to be indispensable to meeting the project objective. I take this opportunity to express my profound gratitude and deep regards to professor Michael Radzicki whose extensive knowledge of the organizational processes and the key stakeholders in the organization in addition to his academic reputation, played an instrumental role in connecting me to the right people, initiating, and facilitating the project meetings. Kristin Tichenor helped sharpen the focus of the project and the framing of the model key variables with her amazing attention to details, passion and pride of her role as a vice president for strategy and enrollment. Professor Allen Hoffman deep engagement and expertise in heading several faculty governance committees enhanced the model structure thorough identification of not so obvious feedbacks that gave the model an appreciable added value. I also take this opportunity to express a deep sense of gratitude to both of them. A word of appreciation goes to WPI which provided an atmosphere of transparency through providing accessibility to the timely publications of organizational data and providing access to meeting the New England Association of Schools and Colleges team during their visit to the institution who valued the research project and encouraged its further pursuit. Lastly, I am obliged to professor Jennefer Kemney who taught the course with enthusiasm and passion for her valuable thoughts, encouragement, and the set of needed tools and skills she provided through this course.

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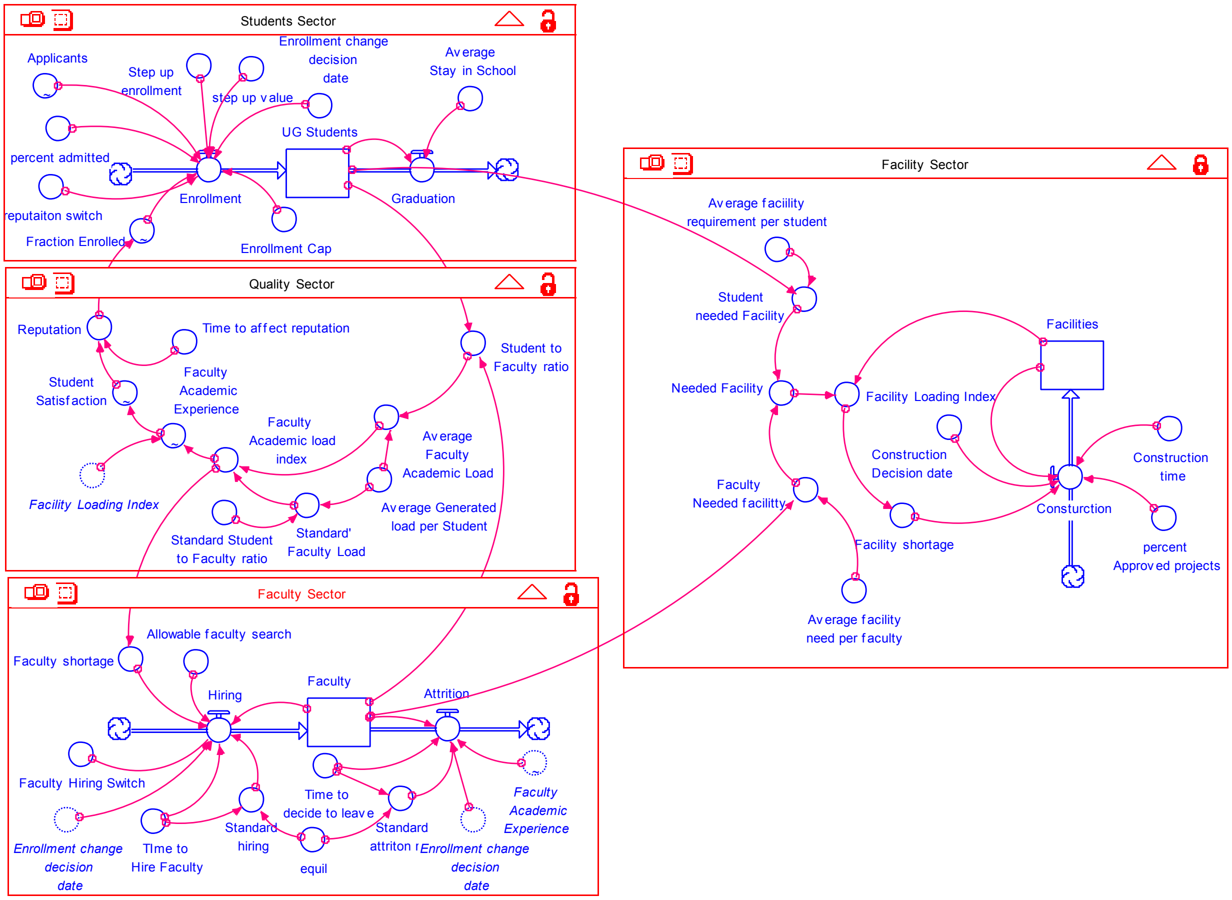
Appendix



Students Sector

UG_Students(t) = UG_Students(t - dt) + (Enrollment - Graduation) * dt
INIT UG_Students = 3375
INFLOWS:
Enrollment = IF (TIME> Enrollment_change_decision__date) and Step_up_enrollment = 1 then step_up_value
ELSE IF TIME> Enrollment_change_decision__date and reputaiton_switch =1 then MIN(Fraction_Enrolled*Applicants*percent_admitted/100,Enrollment_Cap)
else 750
OUTFLOWS:
Graduation = UG_Students/Average__Stay_in_School
Average__Stay_in_School = 4.5
Enrollment_Cap = 750
Enrollment_change_decision__date = 2005
percent_admitted = 60
reputaiton_switch = 0
Step_up_enrollment = 0
step_up_value = 1000
Applicants = GRAPH(TIME)

(2012, 8000), (2014, 8500), (2016, 9000), (2017, 9500), (2019, 10000), (2021, 10500), (2023, 11000), (2025, 11500), (2026, 12000), (2028, 12500), (2030, 13000)
Fraction_Enrolled = GRAPH(Reputation)
(0.00, 0.03), (0.1, 0.033), (0.2, 0.048), (0.3, 0.063), (0.4, 0.09), (0.5, 0.132), (0.6, 0.168), (0.7, 0.185), (0.8, 0.195), (0.9, 0.201), (1, 0.203)

Quality Sector
Average_Generated_load_per_Student = 100
Average__Faculty__Academic_Load =
Average_Generated_load_per_Student*Student_to__Faculty_ratio
Faculty__Academic_load__index =
Average__Faculty__Academic_Load/Standard'__Faculty_Load
Reputation = SMTH1(Student__Satisfaction,Time_to_affect_reputation)
Standard'__Faculty_Load =
Standard_Student_to_Faculty_ratio*Average_Generated_load_per_Student
Standard_Student_to_Faculty_ratio = 5
Student_to__Faculty_ratio = UG_Students/Faculty
Time_to_affect_reputation = 4
Faculty__Academic__Experience =
GRAPH((Faculty__Academic_load__index+0.5*Facility_Loading_Index)/1.5)
(1.00, 1.00), (1.10, 0.975), (1.20, 0.92), (1.30, 0.805), (1.40, 0.68), (1.50, 0.515), (1.60, 0.355), (1.70, 0.23), (1.80, 0.135), (1.90, 0.085), (2.00, 0.075)
Student__Satisfaction = GRAPH(Faculty__Academic__Experience)
(0.00, 0.065), (0.1, 0.075), (0.2, 0.1), (0.3, 0.145), (0.4, 0.22), (0.5, 0.32), (0.6, 0.505), (0.7, 0.815), (0.8, 0.94), (0.9, 0.98), (1, 1.00)

Faculty Sector
Faculty(t) = Faculty(t - dt) + (Hiring - Attrition) * dt
INIT Faculty = UG_Students/Standard_Student_to_Faculty_ratio
INFLOWS:
Hiring = if time > Enrollment_change_decision__date and Faculty_Hiring_Switch = 1then
Allowable_faculty_search*(Faculty*
(Faculty_shortage+Standard__hiring))/TIme_to__Hire_Faculty

else 68
OUTFLOWS:
Attrition = IF time > Enrollment_change_decision__date then
((1-
Faculty__Academic__Experience)+Standard__attriton_rate)*Faculty/Time_to__decide_to_leave
else 68
Allowable_faculty_search = 1
equil = 10
Faculty_Hiring_Switch = 1
Faculty_shortage = Faculty__Academic_load__index-1.0
Standard__attriton_rate = Time_to__decide_to_leave/equil

Standard__hiring = TIme_to__Hire_Faculty/equil
Time_to__decide_to_leave = 2
TIme_to__Hire_Faculty = 2

Facility Sector
Facilities(t) = Facilities(t - dt) + (Consturction) * dt
INIT Facilities =
UG_Students*Average_faciility_requirement_per_student+Faculty*Average_facility_need_per_faculty
INFLOWS:
Consturction = IF(TIME<= Construction__Decision_date) THEN 0.0
ELSE (Facility_shortage*Facilities*(percent__Approved_projects/100))/Construction__time
Average_faciility_requirement_per_student = 100
Average_facility_need_per_faculty = 315
Construction__Decision_date = 2005
Construction__time = 3
Facility_Loading_Index = Needed_Facility/Facilities
Facility_shortage = Facility_Loading_Index-1
Faculty__Needed_facilitty = Faculty*Average_facility_need_per_faculty
Needed_Facility = Faculty__Needed_facilitty+Student__needed_Facility
percent__Approved_projects = 50
Student__needed_Facility = UG_Students*Average_faciility_requirement_per_student

parameter values to initialize the model in equilibrium

Parameter	Value	Unit
Average stay in school	4.5	Years
Enrollment change decision date	2005	
Enrollment cap	750	Student
Percent admitted	60	%
Construction time	3	Years
Construction Decision date	2005	
Percent approved projects	50	%
Time to hire faculty	2	Years
Time to decide to leave	2	Years
Allowable faculty search	1	
Reputation switch	Off	
Step up enrollment	Off	