A DYNAMIC SIMULATION GAME FOR STRATEGIC UNIVERSITY MANAGEMENT (UNIGAME)[1]

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ABSTRACT

We present an interactive simulation model on which the academic aspects of university management can be analyzed and alternative management strategies can be tested. The model focuses specifically on long-term, dynamic, strategic management problems, such as growing student-faculty ratios, poor teaching quality and low research productivity. It yields numerous performance measures about the fundamental activities in a university: teaching, research and professional project activities. The simulation model is built using system dynamics methodology and is validated/verified by standard tests, using data from Boğaziçi University, Istanbul, Turkey. The necessary changes are made to turn the model into an interactive one and the gaming interface is built using VENSIM software. The game has been played and tested by faculty members, managers, teaching assistants and students. The game results generated by these players are compared. Differences in the results reveal that players with different orientations focus on different aspects and performance measures of the university in making decisions. Research results obtained suggest that UNIGAME promises to be not only a useful technology to support strategic decision making, but also a laboratory for theoretical research on how to best deal with strategic university management problems. Further research is being carried out to add enhancements both to the simulation model and the gaming interface.

I. INTRODUCTION

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Contemporary universities worldwide face challenging management problems such as: unbalanced growth in student body in state (public) universities; infrastructures that can not keep up with the enrolment growth; increased student/faculty ratios; concerns about quality of instruction; heavy competition for limited funding for research and heavy competition among private universities for limited student demand. Such problems have been studied both on macro and micro levels by many researchers (Benjamin 1995; Gürüz et al. 1994; Boğaziçi University 1994). While some of these studies have made use of certain quantitative methods (for instance, Galbraith 1998; Mahmoud and Genta 1993; Saeed 1993; Sinuany-Stern 1984; Vemuri 1982), a great portion of the existing research on university problems do not have quantitative foundations, primarily because such problems involve qualitative (human) elements that are difficult to quantify and model. Thus, there seems to be a need for research that can handle simultaneously both the quantitative and the qualitative aspects of the university management problems. In this research we build an interactive simulation model/game that focuses on those university problems that are dynamic and long-term in nature and as such must be addressed by high-level, strategic policy-making mechanisms (the president, the deans, and the main policy-making councils) within the university.

II. MODEL DESCRIPTION

II. 1. Model Overview

The focus of the model is those academic management problems that are dynamic and persistent in nature, such as growing student-faculty ratios, poor teaching quality and low research productivity. As such, the model represents the faculty members' time allocation among the main activity groups, the factors that determine this allocation and various performance measures that result from these -often conflicting- allocations. The major activities of a faculty members are: **(a) graduate instruction, (b) under-graduate instruction, (c) graduate instruction overhead, (d) under-graduate instruction overhead, (e) unsponsored research, (f) sponsored research, (g) income-generating projects, (h) unofficial projects.** With respect to these activities, the faculty members are classified in two groups: **Graduate** faculty members, that are primarily involved in graduate instruction and research (but also involved in some under-graduate instruction.) and **Undergraduate** faculty members, that are involved only in under-graduate instruction and have limited interest in (and background for) research. Thus, graduate instruction and graduate instruction overhead loads apply only to the graduate faculty members.

The **instruction** activities are divided into two groups: (a) in-class instruction and (b) instruction overhead, which includes all out-of-class activities related to instruction. The second main activity group is **research** activities. Research activities are represented in two categories as (a) unsponsored research activities, which are not sponsored financially except for the university's own resources and (b) sponsored research activities, which are supported by governmental or private organizations. The last activity group is **project (consulting)** activities, which are also divided into two: (a) income generating projects, which are activities like seminars, courses or consulting realized through university channels and generate income to the university and (b) unofficial projects, which are activities like seminars or consulting realized through non-university ("unofficial") channels and do not generate any income to the university.

The model is constructed on sector basis. (Figure 1). The sectors of the model are determined so as to represent the dynamics of major activity groups defined above. The model is constructed using Vensim software (Eberlein and Peterson 1994). The basic time unit is a semester and the time step used in the simulation is also 1. (The model is discrete).

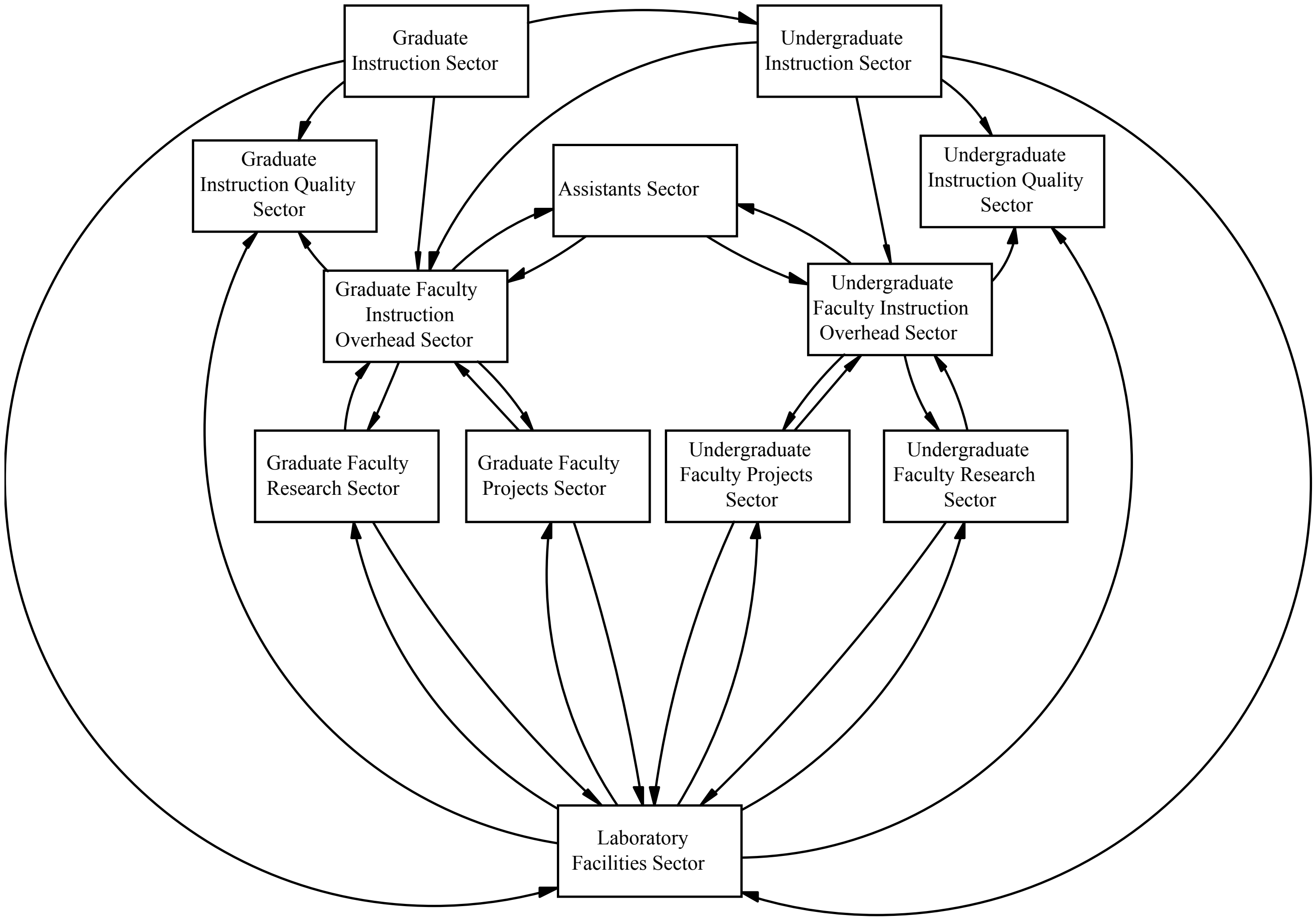

Figure 1. Global Sector Diagram

II. 2. Graduate Instruction Sector

In this sector, the graduate faculty FTE (Full Time Equivalent) that is available for instruction and the need for graduate instruction are calculated and the faculty FTE is assigned to graduate instruction (Figure 2). If the graduate faculty FTE is not enough to meet all the need, the discrepancy is eliminated with some other strategies, like hiring part- time faculty, increasing the class sizes, etc. On the other hand, if the graduate faculty FTE for instruction is more than the need for graduate instruction, the surplus is transferred to 'Under-graduate Instruction Sector'.

The main stock variables in this sector are ‘Number of Graduate Faculty’ and ‘Number of Graduate Students’. ‘Number of Graduate Faculty‘ decreases through ‘GF that Leave’ and increases through ‘New Grad Faculty’. ‘New Grad Faculty’ is determined by ‘GF Hiring Decision’, under the constraints of ‘Vacant Faculty Positions and ‘Indicated GF Supply’. ‘GF Hiring Decision ‘ is a user decision variable in the interactive game version, but in the simulation version, it is computed so as to eliminate the discrepancy between the need for graduate faculty and the existing graduate faculty FTE. ‘GF Supply’ depends on ‘Instruction Load per GF’ and ‘Historical Average GF Salary’. These variables affect ‘GF that Leaves’, as well. (Figure 2). It is impossible to discuss all the variables and equations within the scope of this article. The interested reader is referred to Diker (1995).

II. 3. Undergraduate Instruction Sector

In this sector, the need for undergraduate instruction is determined and met by the “undergraduate faculty time” that can be assigned to instruction and the surplus graduate FTE for instruction, if any, from the Graduate Instruction sector. If the need is more than the total available FTE, some strategies like hiring part-time faculty and increasing class sizes, are used to eliminate the discrepancy. This sector is very similar to the ‘Graduate Instruction Sector’ in many aspects. (The sector diagram is omitted due to lack of space. See Diker 1995).

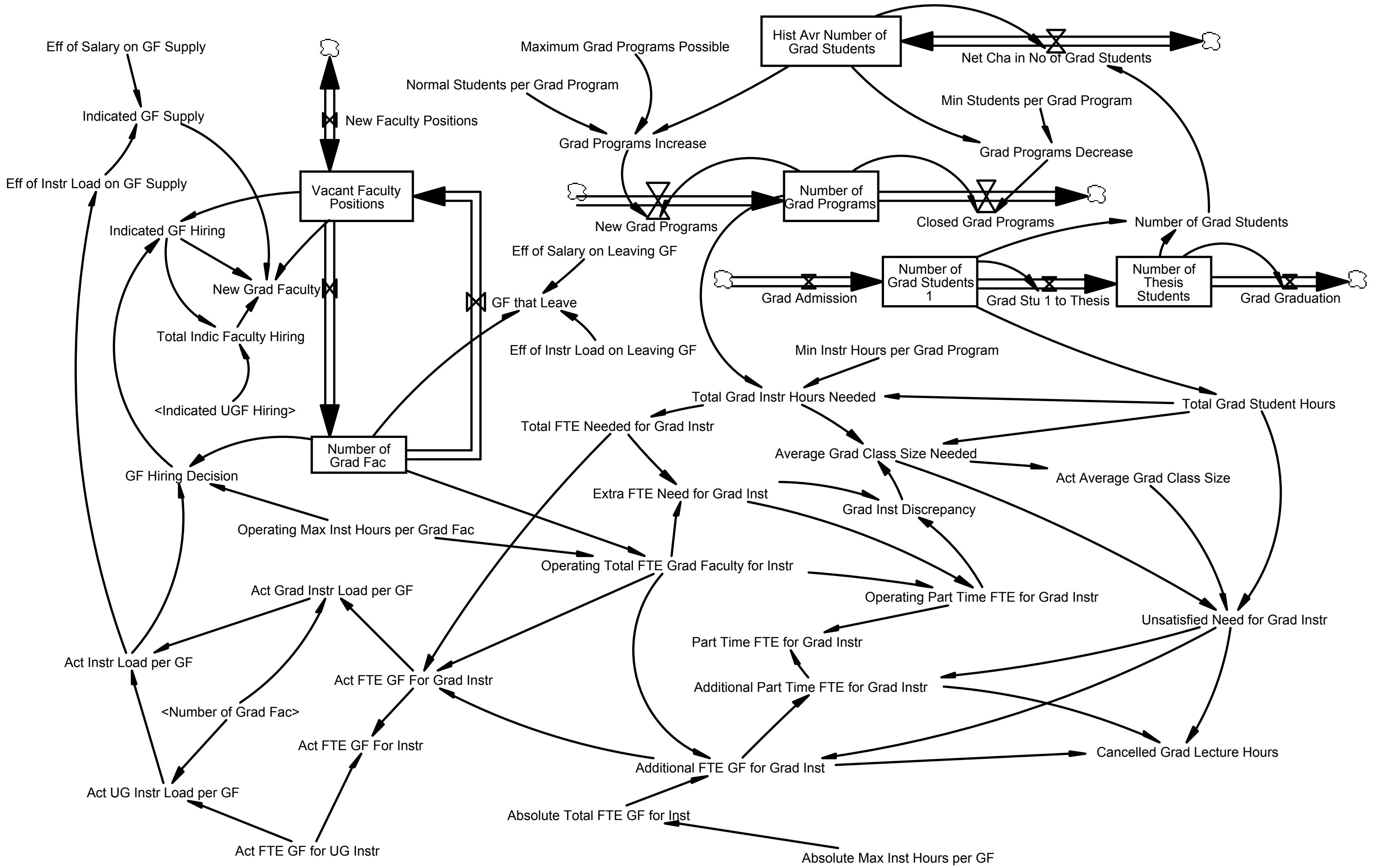

Figure 2. Stock-Flow Diagram of the Graduate Instruction Sector

II. 4. Graduate Instruction Quality Sector

This is the sector where the graduate instruction quality indicators are calculated. (Figure 3). The main instruction quality indicators are 'Graduate Students/Grad Faculty Ratio', 'Actual Graduate Instruction Overhead per Grad Student', 'Actual Average Graduate Class Size' and 'Lab Facilities for Graduate Instruction per Graduate Student'. Graduate Instruction Quality Index in a semester is given by:

f ('Actual Graduate Instruction Overhead per Grad Student', 'Actual Average Graduate Class Size',
'Lab Facilities for Graduate Instruction per Graduate Student',
'Historical Average Research Papers per Grad Faculty')

Each of these factors are functions of other related variables. It is impossible to discuss all the variables and equations in the context of this article. (See Figure 3 for the other variables and Diker 1995 for all equations).

The instruction quality indices are important in determining the "Teaching Commitments" of different faculty members, which are indicators of the long-term attitude of the faculty members about instruction quality. Teaching Commitments of graduate and undergraduate faculty are used as inputs to graduate and undergraduate "Instruction Overhead Sectors" respectively.

II. 5. Undergraduate Instruction Quality Sector

The indicators of "undergraduate instruction quality" are calculated in this sector. The structures of the "undergraduate" and "graduate" Instruction Quality sectors are very similar. In order to save space, the undergraduate sector will not be further discussed. (The reader is referred to the graduate instruction quality sector discussion above and Diker 1995).

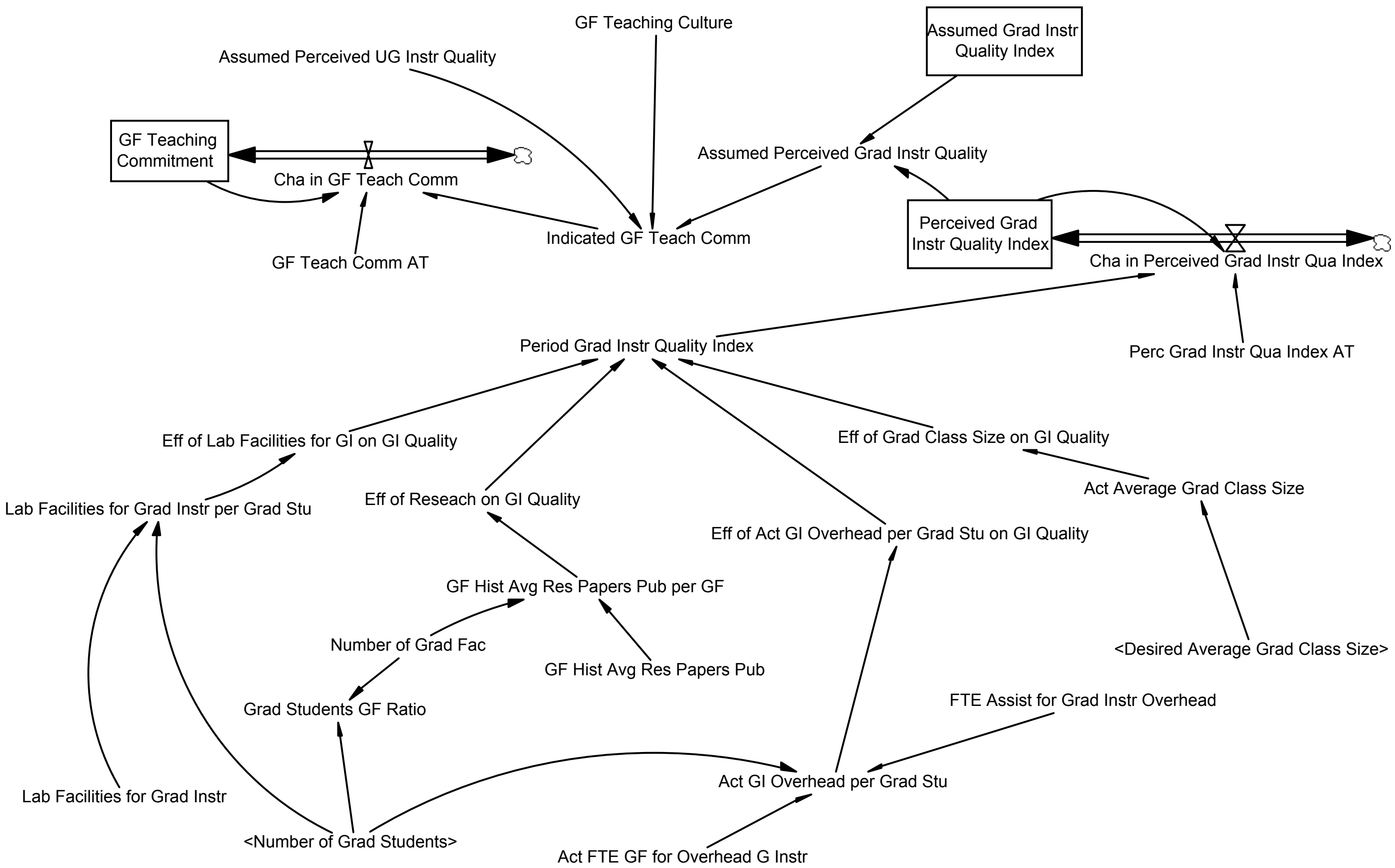

Figure 3. Graduate Instruction Quality Sector

II. 6. Graduate Faculty Instruction Overhead Sector

In this sector, the “instruction overhead loads” of graduate faculty members are first calculated. “Instruction overhead load” is defined to be all out-of-classroom, yet instruction-related work. Two different instruction overhead loads are calculated separately for graduate faculty members: graduate instruction overhead and undergraduate instruction overhead. (See Figure 4). The total “Non-instruction Graduate FTE” is found by subtracting the sum of “graduate faculty instruction total overhead” and “graduate faculty total in-class FTE” from the “total graduate faculty FTE”. This “non-instruction graduate FTE” yields, after some fine adjustments, the “graduate FTE for research and projects”. Finally, this FTE is divided between “research” and “project” activities (‘graduate FTE for Projects’ and ‘graduate FTE for Research’), according to the relative motivations of each (‘GF Financial Pressure’ and ‘GF Research Commitment’). For the purpose of this article, it is unnecessary to discuss all the detail variables and computations. Interested reader is referred to Diker (1995).

II. 7. Undergraduate Faculty Instruction Overhead Sector

This is the sector where the instruction overhead loads of undergraduate faculty members are calculated and the undergraduate FTE for research activities and for project activities are determined. This sector resembles to ‘Graduate Faculty Overhead Sector’ discussed above. The dynamics in both sectors are similar. The main difference is that only undergraduate (no graduate) instruction overhead is assigned to undergraduate faculty, because they are not involved in graduate instruction. In order to save space, the undergraduate instruction overhead sector diagram is not included. The reader is referred to Diker (1995).

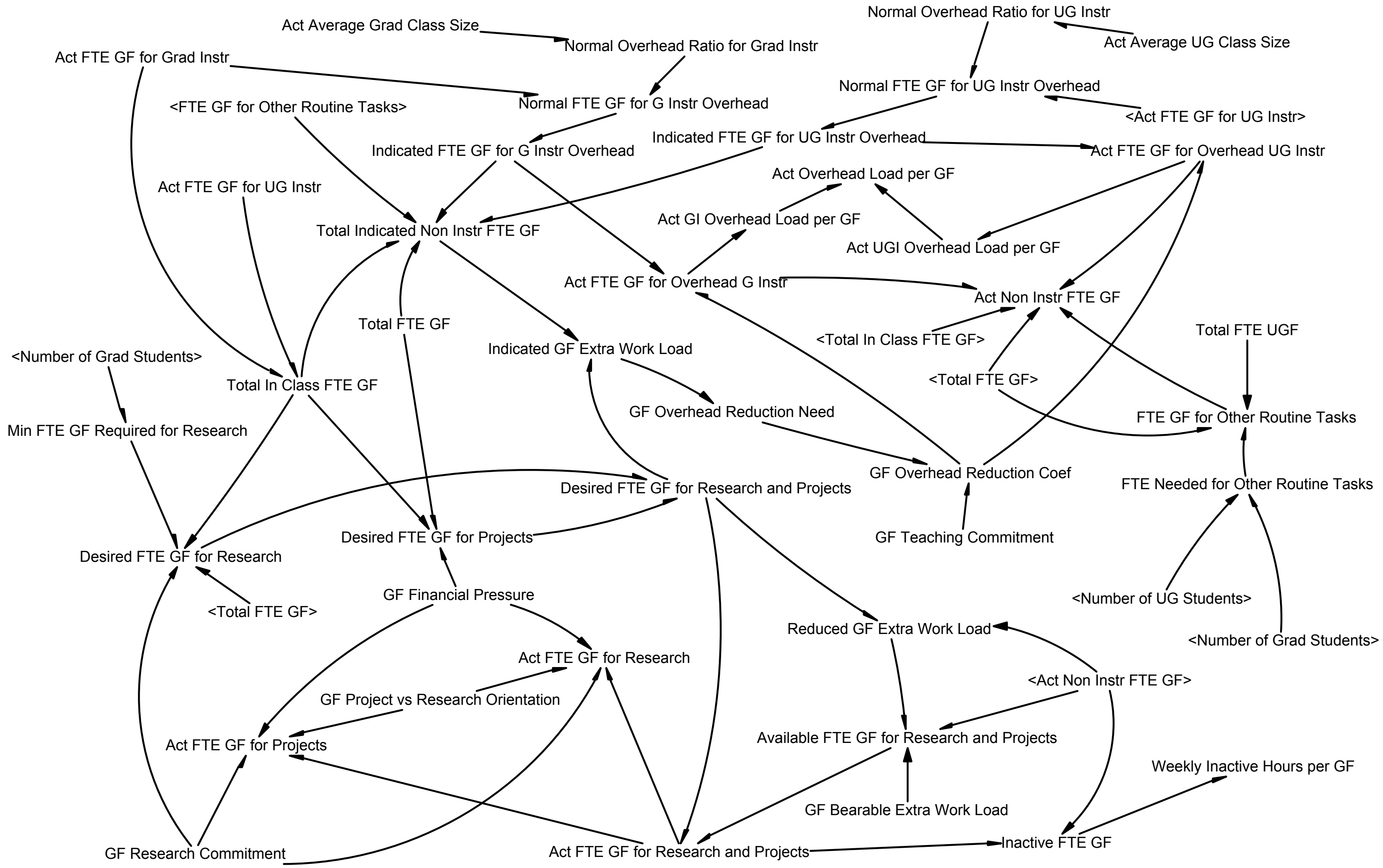

Figure 4. Graduate Faculty Overhead Sector

II. 8. Graduate Faculty Research Sector

In this sector, the graduate faculty FTE dedicated to sponsored and unsponsored research activities are determined, as well as the motivations behind them and the outcomes of these activities.

'Actual FTE GF for Research' is divided among 'Actual FTE GF for Unsponsored Research' and 'Actual FTE GF for Sponsored Research' according to the relative weights of 'GF Unsponsored Research Commitment' and 'GF Sponsored Research Commitment'. These two indicators of commitment are the historical averages of 'GF Unsponsored Research Commitment' and 'GF Sponsored Research Commitment' and take values between zero and one. The variables that determine the values of these commitments are 'GF Desired/Realized Research Papers Published', 'GF Research Culture' and the corresponding research recognitions. 'GF Desired/Realized Research Papers Published' is the ratio between the current historical average of research papers published each semester and the target average papers published. 'GF Research Culture' is the long term attitude of graduate faculty members towards research. It takes values between zero and one. Higher research culture causes higher research commitment. Research recognition represents the long term attitude of the administration towards the related research activities and takes values between zero and one. Administration expresses its recognition by rewards and this increases the research commitment. 'Unsponsored Research Recognition' depends on the unsponsored research papers productivity of the faculty members, namely:
'Unsponsored Research Papers Published Current Term' / 'Total FTE for Unsponsored Research'. On the other hand, 'Sponsored Research Recognition' depends on the financial productivity or projects, as well as research papers productivity.

After 'Actual FTE GF for Unsponsored Research' and 'Actual FTE GF for Sponsored Research' are determined, the outcomes of research activities are calculated. These outcomes depend on the relevant faculty FTE and productivity indices.

II. 9. Undergraduate Faculty Research Sector

This sector is similar to 'Graduate Faculty Research Sector', except that it is less important since, by definition, a small portion of research is carried out by undergraduate faculty In this sector, the undergraduate faculty FTE dedicated to sponsored and unsponsored research activities, the motivations behind them and the outcomes of these activities are determined.

II. 10. Graduate Faculty Projects Sector

This is the sector where the portions of the graduate faculty FTE dedicated to official projects and unofficial projects, the motivations behind them and the outcomes of the official projects activities are determined.

'Actual FTE GF for Projects' is divided among 'Actual FTE GF for Official Projects (OP)' and 'Actual FTE GF for Unofficial Projects(UP)', according to the relative weights of 'GF OP Motivation' and 'GF UP Motivation'. 'GF OP Motivation' depends on the ratio of incomes realized through official projects and unofficial projects and 'OP-UP mentality'. 'OP-UP mentality' is an index of the long term attitude of the faculty members toward doing projects through non-university channels, to earn extra income. "OP-UP mentalities", both for graduate and undergraduate faculty members, take values between zero and one. Higher OP-UP mentality indicates lower tendency for doing unofficial projects. "GF UP Motivation' is determined by 'OP-UP Income Ratio' and 'OP-UP Mentality GF'.

After 'Actual FTE GF for OP' is determined 'Gross Income Generated by OP' is calculated as a function of graduate and undergraduate faculty FTE and the related OP productivity levels. 'Net Funds/Grants Gotten by OP' is calculated by:

> 'Gross Income Generated by OP' - ['Income Share for GF on OP' + 'Income Share for UGF on OP']

'OP Share per FTE per Semester' is calculated by:

> 'OP Income Level' * 'Weekly Hours per Faculty' * 'Weeks per Semester'

'OP Income Level' represents the amount of money paid per man-hour of faculty workforce for OP. Number of active weeks per faculty member per semester is 23. Total OP share for faculty members for the current semester is calculated by:

‘OP Share per FTE per Semester’ * ‘Total FTE for OP’

An important sub-system of this sector consists of ‘GF Financial Pressure’ and the variables that effect it. ‘GF Financial Pressure’ is an index of the financial concern of the graduate faculty members. It depends on the ratio between the historical average of the actual salary and the “salary desired” by faculty members (which in turn is a function of the average market salary). .

II. 11. Undergraduate Faculty Projects Sector

This sector is similar to ‘Graduate Faculty Projects Sector’. In this sector, the portion of undergraduate faculty FTE dedicated to official projects and unofficial projects, the motivations behind them and the funds obtained by official projects are determined. (See the graduate projects sector above and Diker 1995).

II. 12. Laboratory and Facilities Sector

In this sector, the laboratory facilities are updated and then assigned to instruction, research and project activities. The criteria for assigning the facilities are the relative amounts of faculty FTE allocated to each activity. (In order to save space, this sector is not described further. The reader is referred to Diker 1995).

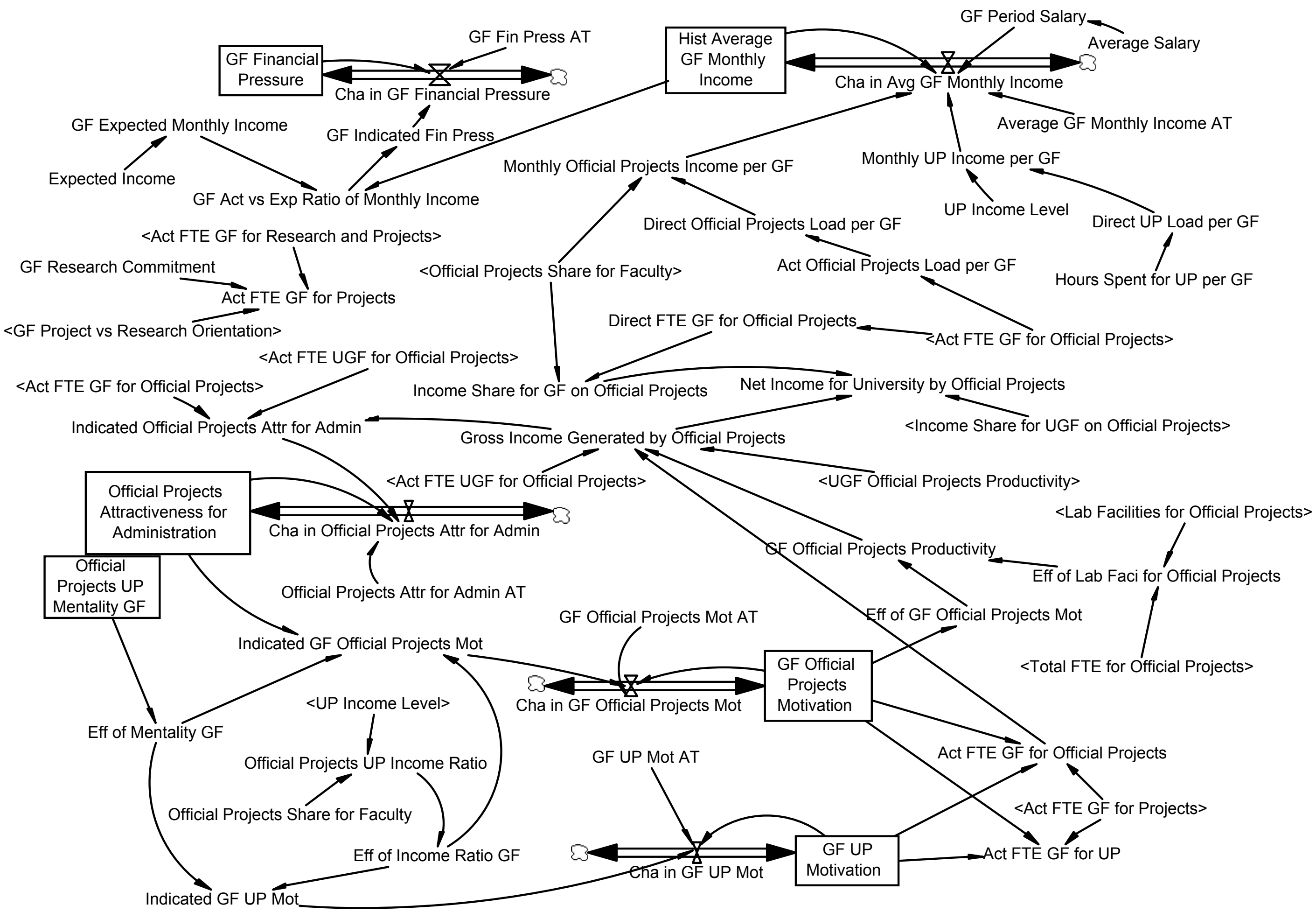

Figure 5. Graduate Faculty Projects Sector

II. 13. Assistants Sector

This sector is where the number of assistants, available assistant-hours per week and the instruction overhead assigned to these assistants are calculated. 'Number of Assistants' is a function of 'Number of Graduate Students' and 'Assistants/Graduate Students Ratio'. This value is limited by 'Assistant Positions', which is a function of the total number of faculty positions and 'Faculty/Assistant Positions Ratio'.

'FTE Assistants for Instruction Overhead' is first converted to 'faculty FTE' units by dividing the total assistant hours by weekly hours per faculty. After the "FTE assistants for instruction overhead" is computed this way, the total available assistant FTE is distributed among 'FTE Assistants for Graduate Instruction Overhead' and 'FTE Assistants for Undergraduate Instruction Overhead'. According to these values, instruction overhead loads for graduate and undergraduate faculty members are updated. These values are used as inputs to 'Graduate Faculty Overhead Sector' and 'Undergraduate Faculty Overhead Sector'.

III. BASE RUN OF THE MODEL

The 'Base Run' of the model is the simulation run made under typical expected set of parameters and input values taken from Boğaziçi University (1985-1995). In the stand-alone simulation version of the model, there are no interactive player inputs; all decisions are represented by proper behavioral formulations. The dynamics of the variables obtained in this run are used as reference in interpreting the behaviors of the same variables in validation and sensitivity runs.

Base dynamic behaviors of some important variables are shown in Figure 6.1 - 6.6. Figure 6.1 depicts the dynamic behavior of 'Number of Undergraduate Students' and 'Number of Graduate Students'. The values of both variables increase through time, but while 'Number of Undergraduate Students' increases in a steady pace, the rate of increase in 'Number of Graduate Students' decreases as time passes. In Figure 6.2, it is observed that both 'Number of Graduate Faculty' and 'Number of Undergraduate Faculty' increase in a steady pace.

Figure 6.3 is the dynamic behaviors of the instruction loads on the graduate and undergraduate faculty members. The total instruction loads on graduate and undergraduate faculty members are at their “operating maximums” (6 and 9 hrs/week respectively) until period 15. After that period, instruction loads increase gradually towards “absolute maximum” values (9 and 12 hrs/week respectively), due to high student body.

In Figure 6.4 are the weekly hours spent on research and projects by each graduate faculty member. While the weekly hours spent on research activities do not change substantially, weekly hours spent on official projects (OP) decrease and weekly hours spent on unofficial projects (UP) increase considerably. These behaviors are caused by the increase in ‘GF OP Motivation’ and the decrease in ‘GF UP Motivation’. The dynamic behaviors of ‘GF OP Motivation’ and ‘GF UP Motivation’ and ‘GF Research Commitment’ are shown in Figure 6.5. The increase in ‘GF UP Motivation’ and the decrease in ‘GF OP Motivation’ are caused by the relative values of income obtained from official projects and unofficial projects, and the “OP-UP mentality” of the faculty members.

The dynamic behaviors of ‘Research Papers Published Current Term’, ‘Unsponsored Research Papers Published Current Term’, ‘Sponsored Research Papers Published Current Term’ are shown in Figure 6.6. Here, all there variables increase steadily.

IV. VALIDITY OF THE MODEL

A crucial step in System Dynamics Methodology is model **validation**. Model validity has to do with the degree of realism and relevance of the model with respect to the real problem. Although it is a philosophically deep issue, validation practically means demonstrating that the model is an adequate and useful description of the real system, with respect to the problem(s) of concern (Barlas and Carpenter 1990).

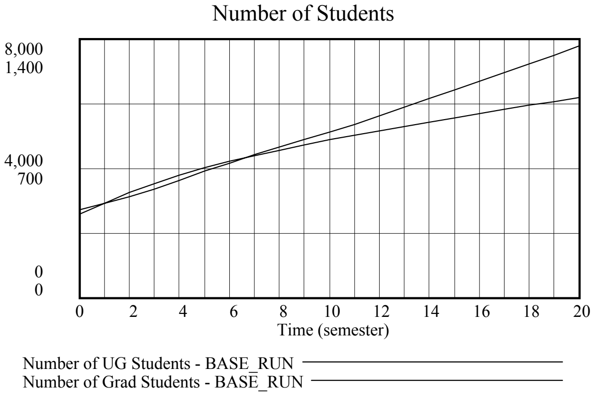

Figure 6.1 Number of Students in the Base Run

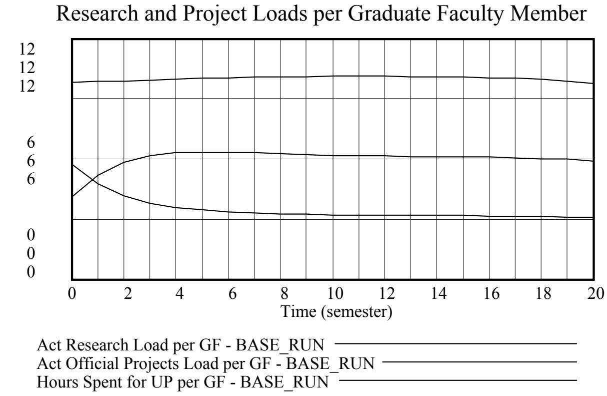

Figure 6.4 GF Research and Project Loads in the Base Run

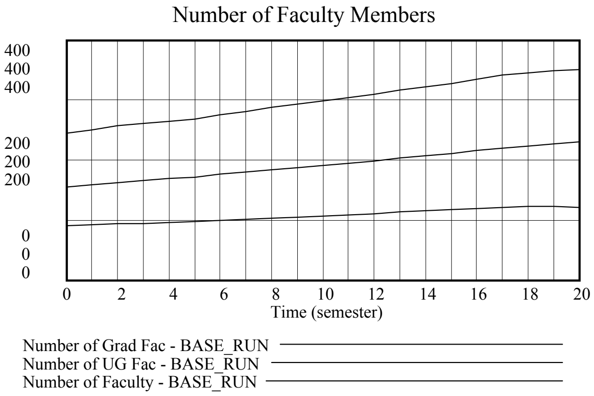

Figure 6.2 Number of Faculty Members in the Base Run

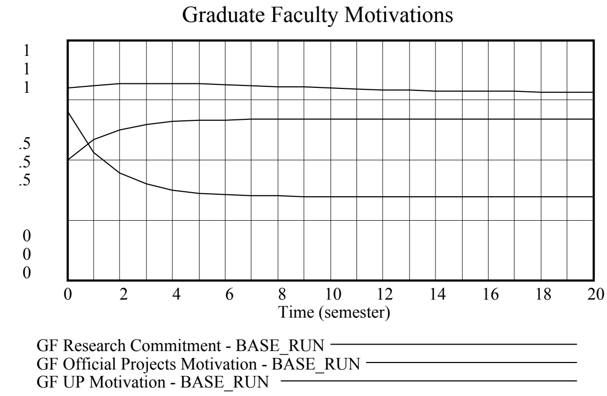

Figure 6.5 Graduate Faculty Motivations in the Base Run

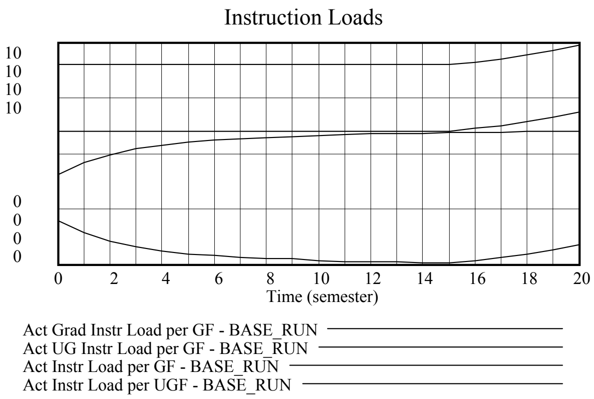

Figure 6.3 The Dynamic Behaviors of Instruction Loads in the Base Run

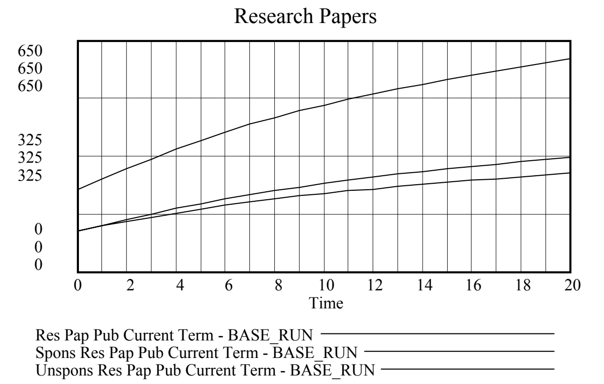

Figure 6.6 Research Papers per Semester in the Base Run

FIGURES 6.1-6.6. Dynamic Behavior of the Model in the Base Run (Reference Run)

Validation tests are grouped into two: (a) **structure** validation tests, which are done in order to determine whether the model has an adequate, meaningful structure, (b) **behavior** validation tests, which are done in order to determine whether the behavior of the model resembles the behavior exhibited by the real system that was modeled. (Barlas 1989; Barlas 1996).

IV.1. Structure Validity

To test the structural validation of the UNIGAME model, the built-in "unit consistency checking" feature of VENSIM environment, which checks the equivalence of units on both sides of the equations, was first used in order to eliminate any errors that might be in the equations. After all the sectors were individually verified, the unit equivalence check was repeated for the model as a whole.

Finally, **extreme condition** and **sensitivity** tests have been applied to complete the structural validation step. Extreme condition tests are based on the idea that the behaviors of a given model are far more predictable under extreme conditions than they are under normal conditions. Extreme condition tests are done by simulating the model after setting a certain variable to an extremely high or extremely low value and examining the behavior of key variables. The extreme value of the chosen variable implies certain predictable behaviors by other variables. If the behaviors of one or more key variables are not as they are expected to be, the validity of the model is questioned, the cause of the problematic behavior is traced to the equations which are revised accordingly. Otherwise, i.e. if the behaviors of all the key variables are as they were expected to be, the model passes the extreme condition tests. Numerous extreme condition simulation runs were done on the model, including: **No Undergraduate Admission, Extremely High Undergraduate Admission, No Undergraduate Faculty, Extremely Low Faculty Salary, Extremely High Instruction Overhead Ratio.** Results of these tests all reveal evidence of high structural validity. Due to excessive space requirement, , we are unable to show the results of these tests in this article. (Interested reader is referred to Diker 1995).

After the extreme condition tests, a series of **sensitivity** runs were made, in order to determine whether the sensitivity of the base model is within acceptable limits. Sensitivity tests were done on numerous parameters such as: different values of **'GF OP UP Mentality'**, different values of **'Average Hours per Graduate Student'**, various **Undergraduate and Graduate Class Sizes**. The results are indicate that the model has a meaningful and reasonable level of sensitivity to these parameters. These results are beyond the scope of this article. (See Diker 1995).

IV. 2. Behavior Validity

After the structural validation tests are completed, the behavior of the model is compared with the data from Boğaziçi University. (Figure 7.1.a-7.3.a and Figure 7.1.b-7.3.b). Most of the real data are taken from the 1994 edition of the yearly document 'Boğaziçi University in Numbers' (Boğaziçi University 1994.). This document includes a wide range of data on many aspects of Boğaziçi University like students, faculty members, publications and financial figures. Some other data about other aspects of the model, like official projects and available faculty and assistant positions are gathered by interviews and used for calibrating the model.

An exact matching between real data and model data points is not required for model validity, because a System Dynamics model is not designed to include the internal and external details and random factors that are needed in short term forecasting (Barlas 1989). The purpose of a system dynamics model is to generate the major dynamic behavior **patterns** of the system, in the long term. Thus, what is required is the matching of the major patterns of behavior of the model and the real system, rather than individual data points.

All the data about Boğaziçi University that could be used for behavior validation are compared with the behavior of the model and a broad resemblance between the model behavior and the behavior of the real system is obtained. (Figure 7.1a-7.3.a and Figure 7.1.b-7.3.b). Thus, it is concluded that the model is behaviorally acceptable.

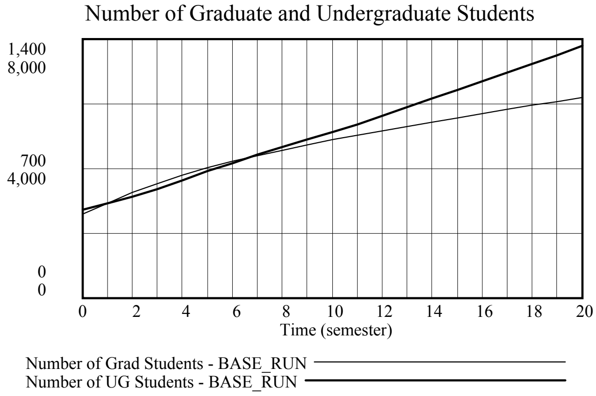

Figure 7.1.a. Dynamic Behavior of Number of Students in the Base Run

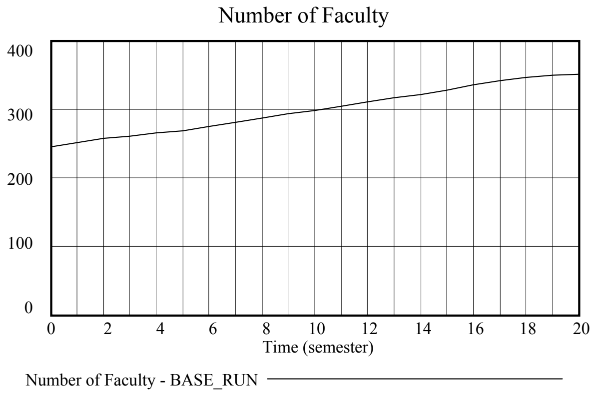

Figure 7.2.a. Dynamic Behavior of Number of Faculty Members in the Base Run

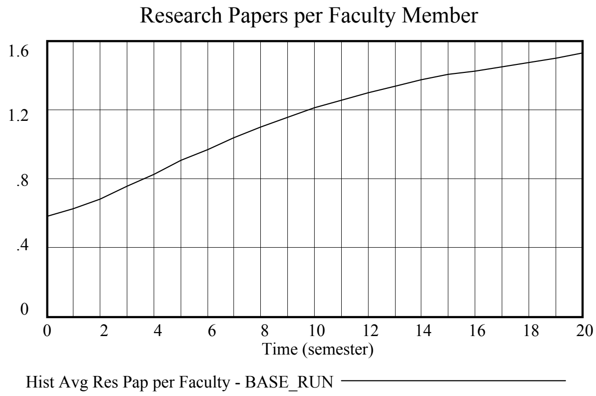

Figure 7.3.a. Dynamic Behavior of Number of Research Papers per Faculty Member in the Base Run

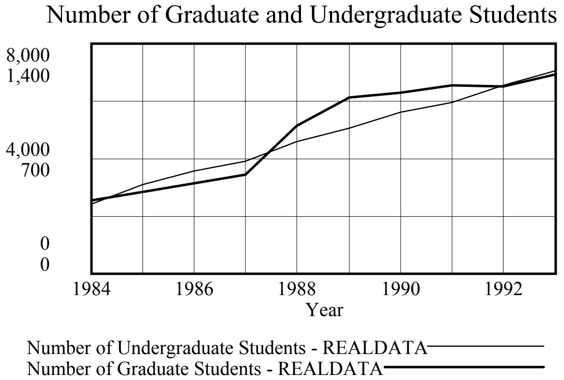

Figure 7.1.b. Dynamic Behavior of Number of Students According to Data from Boğaziçi University

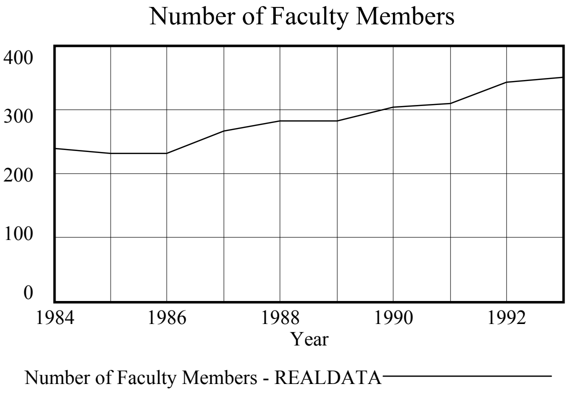

Figure 7.2.b. Dynamic Behavior of Number of Faculty Members According to Data from Boğaziçi University

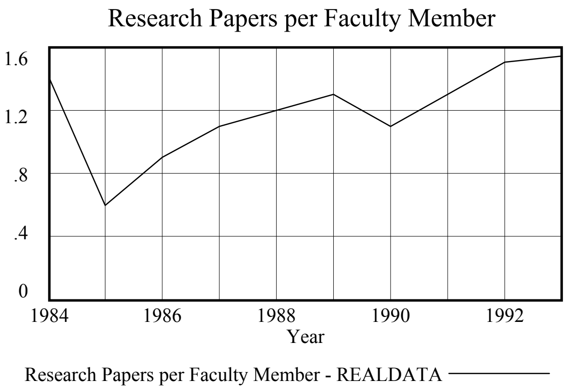

Figure 7.3.b. Dynamic Behavior of Number of Research Papers per Faculty Member According to Data from Boğaziçi University

FIGURES 7.1.a-7.3.b. Behavior Validation

VI. THE UNIVERSITY MANAGEMENT GAME (UNIGAME)

Interactive simulation gaming occupies an important place in system dynamics modeling methodology. System dynamics-based simulation gaming applications span a wide range. Sterman and Meadows (1985) present STRATEGEM-2, a macro-economic management game. Barlas and Bayraktutar (1992) develop a simulation game for software project management (SOFTSIM). Graham et al (1992) summarize several case-based games, including the well-known PeopleExpress. Mohapatra and Saha (1996) describe a simulation game for "new product growth". Anderson et al (1990) discuss the key issues in designing games based on system dynamics models.

The university management simulation model is converted into an interactive dynamic game (UNIGAME), using **Venapp** feature of **Vensim** software (Eberlein and Peterson 1994). In UNIGAME, the player assumes the role of a university policy-maker, who is trying to seek a delicate balance among the main academic functions of the university, in order to get better output from these activities, both in terms of quality and quantity. The player does not have too many decision opportunities, as most of the factors are imposed by the environment the university exists in. The objective of the player is to make **six** decisions, so as to improve the performance indicators of the university, within the limitations imposed by outside factors. These decisions are **New Graduate Students, New Undergraduate Students, Graduate Faculty Hiring Decision, Undergraduate Faculty Hiring Decision, Share from Income-generating-projects per Faculty Member and Weekly Release Time per Graduate Faculty Member** (Figure 8). Sixty different performance indicators are displayed after each decision period. There is also detailed information option that the player can use in order to carry out more detailed causal analysis of the dynamics of the model (Figure 8).

UNIGAME consists of a series of screens which are linked in-between themselves. One screen can be observed (active) at a time. Some of these screens are just query screens that ask the player what name s/he wants to give to the current game file, whether s/he wants to end the game, whether s/he wants to exit the simulation environment, etc. The main game screen is divided into **four** display boxes (Figure 8). **'Game Controls'** box includes buttons to be used in order to end the game, exit the simulation environment or see the game conditions. There are also two display objects in this box, that show final time and current time.

‘Decisions’ box includes the player decision entries and the ‘Advance’ button. The user enters her decisions on: ‘New Graduate Students’, ‘New Undergraduate Students’, ‘Graduate Faculty Hiring’ and ‘Under-graduate Faculty Hiring’ Decisions (which represent the number of new graduate and under-graduate faculty members to be hired in the current semester); ‘Share on Income-generating-projects per Faculty Member’ (which indicates the amount of money that will be paid to each person-hour of faculty workforce from income generating projects) and Weekly Release Time per Graduate Faculty Member (any load reduction from the maximum weekly instruction hours of graduate faculty members). When ‘Advance’ button is pressed the simulation proceeds one period (semester) and the new values are calculated and displayed. The ‘Help’ button calls a small frame that includes information about the decision variables.

‘Main Indicators’ box displays the values of the 60 variables in the current time period. The buttons with the names of the various decision and indicator variables display the behavior patterns of the related variables when pressed. The button ‘More Indicators’ is pressed to call another set of 30 variables.

The main button in the **‘Detailed Analysis’** box executes the link to ‘Detailed Analysis Screen’, which include certain analysis tools. The ‘Causes Tree’ tool displays the causal tree diagram of all variables that effect a certain (selected) variable. ‘Uses Tree’ gives the tree of all variables that are affected by the selected variable. ‘Loops’ is another tool which displays the causal loops that include the selected variable. ‘Graph’ plots the time graph of any selected variable and ‘Causes Graph’ plots the graphs of all the variables that affect it. Finally, ‘Causes Table’ tool yields a table that includes the time values of the selected variable and all the variables that affect it.

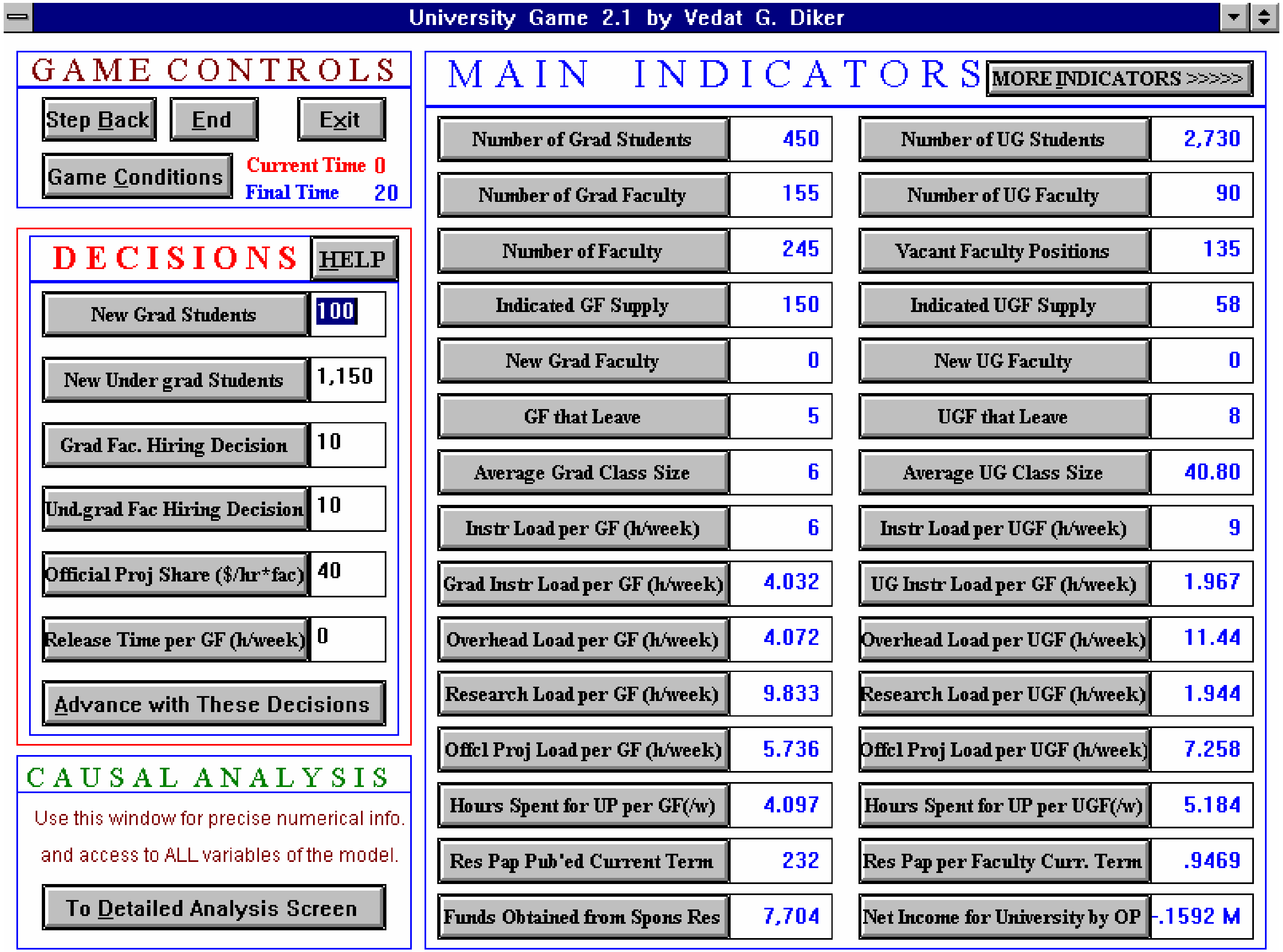

Figure 8. Main Game Screen of the University Game (UNIGAME)

A series of verification and validation tests are done on the interactive simulation game. The behavior of the variables under "extreme player decisions" are tested and several sensitivity tests are done. (These test results can not be shown due to space restrictions. See Diker 1995). The necessary improvements both in the model and the game are made according to the results of these tests. The resulting game is believed to be a valid and robust interactive simulation-gaming environment.

A group of players with different academic degrees and different orientations were invited to play UNIGAME. Among the players were graduate students, teaching and research assistants, faculty members and managers. Some selected results are presented below for illustration.

VI. 1. Game Results of a Research Oriented Faculty Member

The first player is a faculty member who has high research interests and little interest in income-generating projects, even if they were realized through official university channels. During the game, except for period 6, he consistently hires more graduate faculty than undergraduate faculty. He gives considerably release time to graduate faculty (2 h./week on the average). He decreases Official Projects share for faculty members gradually. (Figure 9.1)

As a result of his emphasis on graduate study and research, he obtains a remarkable increase in the number of research papers per semester. The average research papers per faculty member has increased, as well (Figure 9.2). On the other hand, decreasing the Official Projects share for faculty members causes Official Projects motivations of the faculty members to decrease and unofficial project (UP) motivations to increase. These, in turn, cause the weekly hours dedicated to Official Projects by faculty members to decrease and the hours dedicated to UP to increase. (A counter-intuitive result certainly not intended by the "research-oriented" player!) In Figure 9.3 the behaviors of project loads of graduate faculty members and Total FTE for Official Projects are shown; the patterns for undergraduate faculty members are similar.

VI. 2. Game Results of a Balanced Faculty Member

Another player is a faculty member who tries to strike a balance between instruction, research and project activities. He puts some emphasis on research by giving release time for graduate faculty, but also encourages “official projects” by giving a considerable official projects income share to faculty members. (Figure 10.1).

He obtains an increase in the number of research papers published per semester and average research papers per faculty member. (Figure 10.2). Although these levels are somewhat lower than those obtained by the first player, the differences are not very significant.

The important difference between the decisions of the “Research Oriented” Faculty Member and the “Balanced” Faculty Member is that the latter put the necessary emphasis on official projects activities, which the first one neglects. This factor causes significant differences in the two games, between the number of FTE faculty working on official projects, as well as differences in the distribution of the “project workloads” among official and unofficial projects. (Figure 9.3 and Figure 10.3).

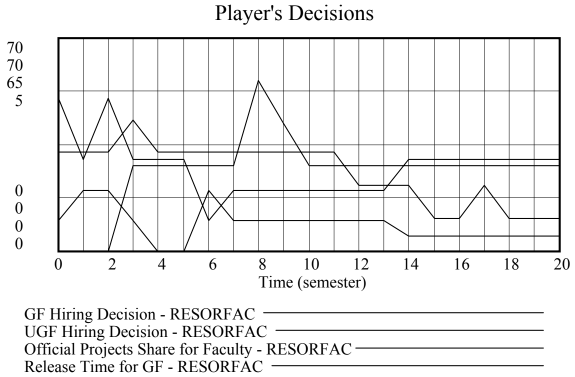

Figure 9.1. Decisions of the Research Oriented Faculty Member

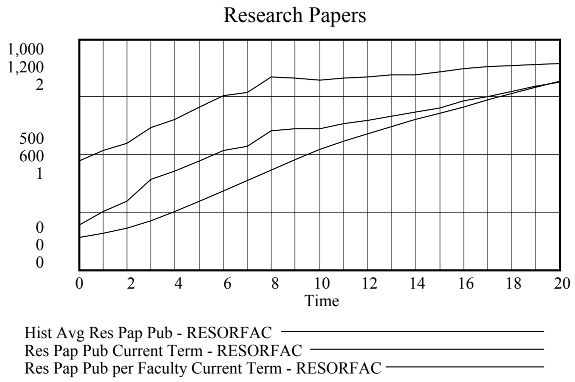

Figure 9.2. Dynamics of Research Papers in the game played by the Research Oriented Faculty Member

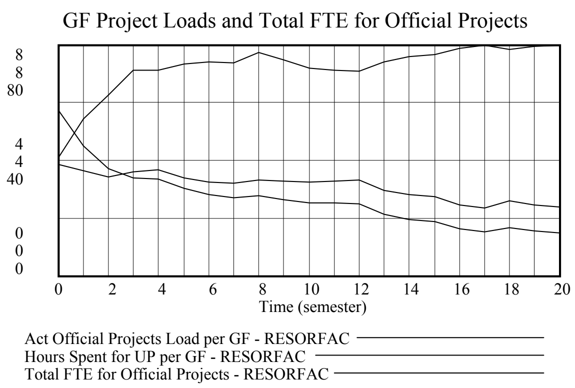

Figure 9.3. Dynamics of Project Loads of Graduate Faculty Members in the game played by the Research Oriented Faculty Member

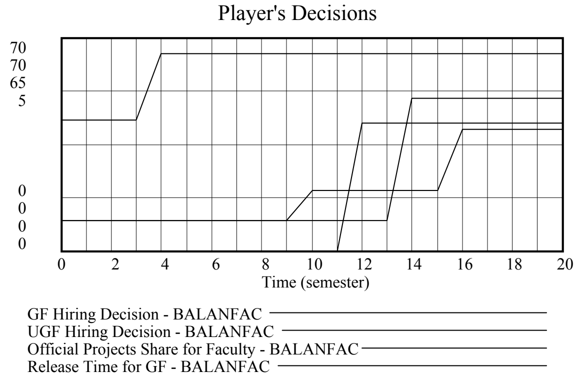

Figure 10.1. Decisions of the Balanced Faculty Member

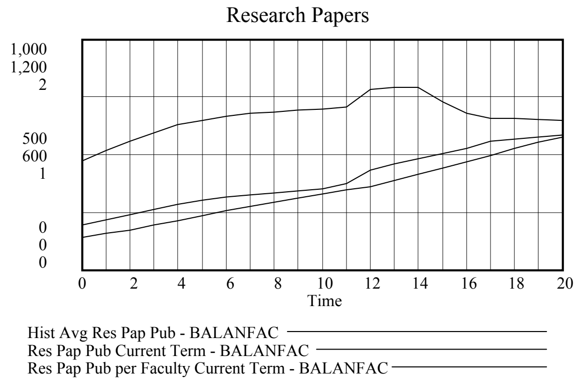

Figure 10.2. Dynamics of Research Papers in the game played by the Balanced Faculty Member

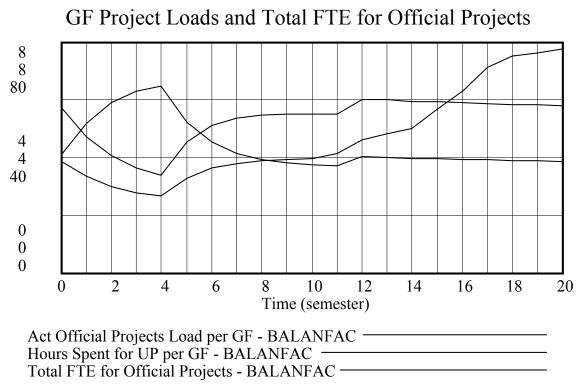

Figure 10.3. Dynamics of Project Loads of Graduate Faculty Members in the game played by the Balanced Faculty Member

VII. CONCLUSIONS

An interactive simulation model for the academic aspects of university management is presented. The model focuses specifically on the long-term, dynamic, strategic management problems, such as growing student-faculty ratios, poor teaching quality and low research productivity. The system dynamics simulation model (the “engine” behind the game) is built first. Numerous verification, validation and sensitivity tests are carried out on the model. The parameters are calibrated using data from Boğaziçi University-Istanbul and the dynamic behavior patterns generated by the model are found to be consistent with the major historical time patterns obtained from Boğaziçi University.

Next, the simulation model is converted into an interactive simulation game and the interface is built using Venapp facility of Vensim software. Players with different academic degrees, backgrounds and orientations played and tested the game. A comparative analysis of the game results of different subjects reveals that players with different orientations emphasize different performance measures of the university. Furthermore, game results show that players do not always act consistent with their stated objectives and preferences. For instance, a self-declared “research-oriented” player may indirectly cause a greater percentage of faculty members to do outside consulting. Such results demonstrate the dynamic feedback complexity and counter-intuitive nature of such systemic, dynamic games. Research results suggest that UNIGAME promises to be not only a useful technology to support strategic management, but also a laboratory for theoretical research on how to best deal with strategic university problems. We are currently carrying out further research on the existing model and the gaming interface. The model will be extended to include more aspects of the university system, such as budget considerations, support staff and in general more detailed representations of variables such as facilities, infrastructure and projects. Also, the gaming interface will be enhanced to include various additional user-friendly features.

REFERENCES

Andersen, D.F., Chung, I.J., Richardson, G.P. and Stewart, T.R. (1990). Issues in designing interactive games based on system dynamics models. In *Proceedings of the International System Dynamics Conference,* Boston, 1,31-45.

Barlas, Y. 1989. Multiple Tests for Validation of System Dynamics Type of Simulation Models, *European Journal of Operational Research,* Vol. 42, No. 1, pp. 59-87.

Barlas, Y. and S. Carpenter. 1990. "Philosophical Roots of Model Validation: Two Paradigms, *System Dynamics Review*, Vol. 6, No. 2, pp. 148-166.

Barlas, Y. and with I. Bayraktutar. 1992. "An Interactive Simulation Game for Software Project Management", *Proceedings of the International System Dynamics Conference,* Utrecht, The Netherlands, pp.59-68.

Barlas, Y. 1996. Formal Aspects of Model Validity and Validation in System Dynamics, *System Dynamics Review,* Vol. 12, No. 3, pp. 183-210.

Barlas, Y. and V.G. Diker. 1996. An Interactive Dynamic Simulation Model of a University Management System, *Proceedings of Symposium on Applied Computing '96*, pp. 120-128, Philadelphia, Pennsylvania.

Benjamin, E. 1995. A Faculty Response to the Fiscal Crisis: From Defense to Offense, *Higher Education Under Fire*, (Ed: Bérubé, M. and Nelson, C.), Routledge, NY.

Boğaziçi University. 1994. *Boğaziçi University in Numbers* (in Turkish), Boğaziçi University Publications, Istanbul.

Diker, V.G. 1995. *An Interactive Dynamic Simulation Model of a University Management System*, M.S. Thesis, Institute for Graduate Studies in Science and Engineering, Boğaziçi University.

Eberlein, R.L. and D.W. Peterson. 1994. Understanding Models with Vensim, *Modeling for Learning Organizations*, (Ed: J.D.W. Morecroft and J.D. Sterman), Productivity Press, Portland, OR.

Galbraith, P.L. (1998). System Dynamics and University Management. *System Dynamics Review,* 14(1),69-84.

Graham, A.K., Morecroft, J.D.W., Senge, P.M. and Sterman J.D. (1992). Model-supported case studies for management education. *European Journal of Operational Research,* 59, 151-1666.

Gürüz, K. et al. 1994. *Higher Education, Science and Technology in Turkey and Abroad* (in Turkish), TÜSİAD Publications, Istanbul.

Mahmoud, M. and P.Genta. 1993. Microworld of an Open University: A Strategic Management Learning Laboratory, *Proceedings of the 1993 International System Dynamics Conference,* Cancun-Mexico, pp. 318-327.

Mohapatra, P.K.J and Saha B.K. (1996). A system dynamics-based game for new product growth. *Simulation and Gaming*, 27(2), 238-260.

OECD. 1990. *Financing Higher Education*, OECD, Paris.

Saeed, K. 1993. The Dynamics of Collegial Systems in the Developing Countries, *Proceedings of the 1993 International System Dynamics Conference,* Cancun-Mexico, pp. 444-453.

Sinuany-Stern, Z. 1984. A Financial Planning Model for a Multi-campus College, *Socio Economic Planning Sciences*, Vol. 18, No. 2, pp. 135-142.

Sterman, J.D. and Meadows, D.L. (1985). STRATEGEM-2: A micro-computer simulation game of the Kondratiev cycle. *Simulation and Games*, 16, 174-202.

Vemuri, S.R. 1982. A Simulation Based Methodology for Modeling a University Research Support Service System, *Socio Economic Planning Sciences*, Vol. 16, No. 3, pp. 107-120.

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