DOCUMENT RESUME

ED 405 770 HE 030 008

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TITLE	A System Dynamics Model of the Departmental Deployment of Instructional Resources.
PUB DATE	May 96
NOTE	41p.; Paper presented at the Annual Forum of the Association for Institutional Research (Albuquerque, NM, May 1996).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	College Faculty; College Instruction; *Departments; Educational Demand; Enrollment; *Enrollment Trends; Higher Education; Institutional Research; Models; Resource Allocation; *State Universities; *Systems Approach; Trend Analysis
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ABSTRACT

This paper reports on the development and testing of a system dynamics model of the departmental deployment of instructional resources at the University of Wisconsin-Madison. A model was developed using the Stella II computer software package. The model describes describes how departments keep student enrollments, number of course sections, and number of instructional staff in balance with one another. The model was tested on data from academic departments at the University of Wisconsin-Madison for the academic years 1983-84 through 1995-96. Identified were a number of departments which appeared to fall within the explanatory range of the model, including those with major shifts in student demand (agronomy, botany, communication arts, French and Italian, geography, mathematics, and political science), and those with constraints on available instructional staff (mechanical engineering, Slavic languages, and Spanish and Portuguese). (MDM)

A SYSTEM DYNAMICS MODEL OF THE DEPARTMENTAL DEPLOYMENT OF INSTRUCTIONAL RESOURCES

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Paper presented at the
1996 Forum of the
Association for Institutional Research
Albuquerque, New Mexico
May, 1996

A SYSTEM DYNAMICS MODEL OF THE DEPARTMENTAL DEPLOYMENT OF INSTRUCTIONAL RESOURCES

I. SUMMARY

To better understand how academic departments respond to changes in enrollments, a system dynamics model was developed, in consultation with administrators and faculty. When enrollment levels change, the model describes how departments adjust class sizes, the number of classes, average course loads of instructors, or the number of instructors. The model was tested against key trend data for a twelve year period for 90 departments. A significant number of the departments appeared to engage in goal-seeking consistent with the hypothesized dynamics model. The model developed could, together with trends on key departmental indicators, provide decision support to departments and deans.

II. INTRODUCTION

During a period of budget reductions, the chief officers of the institution are exploring options for reallocating resources in order to address perceived resource inequities between the internal units of the university. Supply and demand for faculty time is a key factor. Enrollment trends, in turn, can affect demand for faculty time in the classroom.

The Provost, an engineer, is interested in the application of system dynamics modeling to some of the operational aspects of the university. A recent visit by a national consulting firm revealed the availability of powerful computer-based tools for developing system dynamic models, but the consultants were having difficulty testing and validating their models.

System dynamics modeling methods were first introduced by Jay Forrester at MIT during the 1950's. Trained as an engineer, he sought to apply the techniques of engineers to a broader array of problems in public health, environment management, business operations, and the social sciences.

There is a considerable body of work in system dynamics, including work on many aspects of educational systems. However, limited analysis has been completed on how instructional resources in institutions of higher education are deployed in response to enrollment fluctuations. A search of existing literature failed to identify any system dynamics modeling on this particular topic

The purpose of this investigation is to—

1. Apply system dynamics techniques to model a key process within university operations: departmental adjustments to enrollment trends
2. To identify, if possible, a model capable of forecasting consequences of resource allocations and policy changes at the departmental level
3. Begin testing the validity of the model by comparing the results of model simulations against trend data for actual academic departments.

III. METHOD

A. MODEL DEVELOPMENT

1. Simulation Software: STELLA II

A model, displayed on page 3, was developed using STELLA II, a computer software package specifically designed for use in system dynamics modeling. STELLA II is a product of High Performance Systems, Inc. A graphical display of a model components, and relationships between those components, makes the model easier to comprehend and modify. The software also provides rapid access to a complete list of all of the formulas for model variables. Input parameters can be defined graphically. Simulations of models can be performed through the software, based on differential equations.

2. Departmental resources or "stocks":

The current "state" or condition of the department is represented by three resources, or "stocks":

a. Number of Students enrolled in the department's courses.

b. Number of course sections (classes) being taught by the department

c. Number of Instructional staff (including faculty, temporary lecturers, and graduate teaching assistants) on the departmental payroll

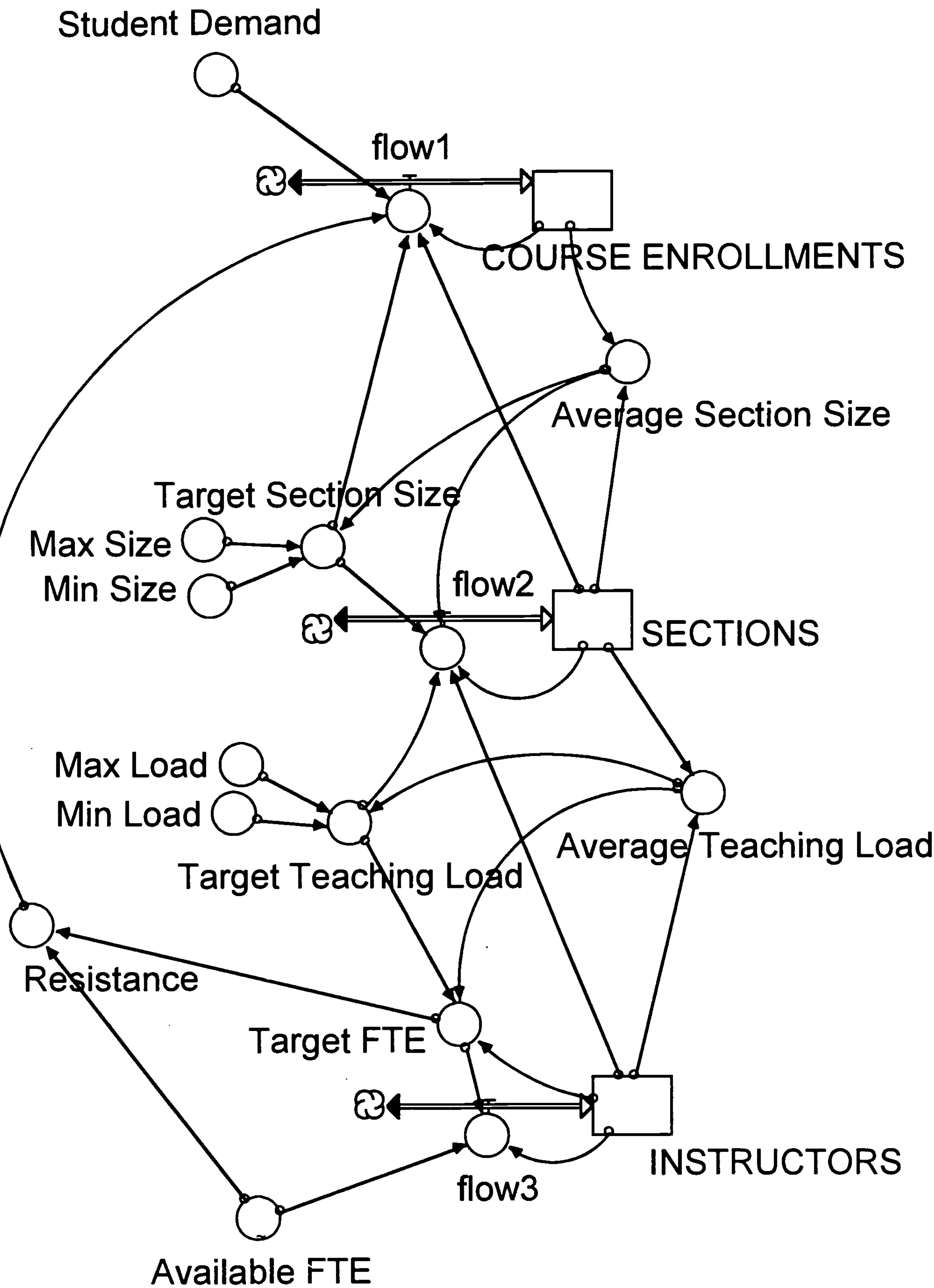
The model attempts to describe how the department keeps these three resources in a satisfactory balance with each other. To maintain satisfactory balances (or ratios), the department adjusts the levels of each of the three resource stocks.

3. Stock adjustments, or "flows"

To adjust a stock, the current stock level is compared to a target level. The difference between the target and current levels determines the magnitude of the flow into, or out of, the stock. For example, if the department is ready to teach 1,000 students, and the current enrollment level is 900, a total of 100 students will "flow" into the enrollment stock, thereby bring the level of the enrollment stock up to the "target" level of 1,000 students. Flows are rates, based on time. In a stock-adjustment model, the general form of the formula for a flow is—

flow = (target – stock) / time_unit

In the model simulations and validation tests presented below, time is measured in years. In this context, it seems reasonable to assume departments are able to complete any adjustments of stock levels without delay (i.e. in less than one year). In this preliminary model of academic departments, the possibility of time delays has been set aside. However, further development of the model would likely require that this question be revisited, especially with regard to adjustments in the numbers of instructional staff. For example, reductions in tenured faculty can likely be accomplished only through normal


Student Demand
flow1
COURSE ENROLLMENTS
Average Section Size
Target Section Size
Max Size
Min Size
flow2
SECTIONS
Max Load
Min Load
Average Teaching Load
Target Teaching Load
Resistance
Target FTE
INSTRUCTORS
flow3
Available FTE

STELLA II SIMULATION FOR A HYPOTHETICAL DEPARTMENT

Fall	Student Demand	Course Enroll-ments	Flow 1	Average Section Size	Sections	Flow 2	Average Teaching Load	Instruc-tors	Flow 3	Target FTE	Resis-tance
1	1010	1000	151	20.0	50	-5	2.0	25	-4	25.0	1.0
2	1160	1151	450	25.4	45	15	2.1	21	3	21.2	1.0
3	1630	1601	271	26.4	61	10	2.6	24	3	24.2	1.0
4	2000	1871	3	26.4	71	0	2.6	27	0	28.4	2.1
5	1990	1874	-0	26.3	71	-0	2.6	27	0	28.5	2.3
6	1990	1874	-250	26.3	71	-5	2.6	27	0	28.5	2.2
7	1600	1624	-268	24.4	67	-11	2.5	27	0	27.0	1.0
8	1340	1356	-176	24.4	56	-7	2.1	27	-3	27.0	1.0
9	1170	1181	-95	24.3	49	-4	2.0	24	-2	24.3	1.0
10	1080	1086	-62	24.6	44	-3	2.0	22	-1	22.1	1.0
11	1020	1024	-4	24.7	41	-1	2.0	21	-0	20.7	1.0
12	1020	1020	9	25.0	41	0	2.0	20	0	20.4	1.0
13	1030	1029		25.0	41		2.0	20		20.4	1.0

NOTES: This hypothetical department is seeking to keep the average section size at 25 students, and average teaching loads between 2 to 2.5 sections per FTE. The FTE available to the department is limited to 27. Some numbers are rounded off as displayed above.

workforce attrition. Additions to the instructional staff may be delayed by budget negotiations.

For each flow, there are multiple candidate calculations which are compared to determine which of them will receive designation as "the target". For example, the target for enrollment levels will reflect 1) departmental capacity, *or* 2) student demand, whichever is less. A department ready to teach 1,000 students will end up with half that number if only 500 students are seeking access to the department's courses. In that case, if current enrollments stand at 900, a total of 400 students will be *removed* from the enrollment stock, despite the department's capacity to *add* 100 students.

4. The budget plan

The concept of a department's enrollment "budget" served as the starting point for developing the model. For example, department X has, say, 25 instructors who can each teach 4 sections, yielding a total of 100 course sections. Each section can accommodate, say, 20 students. Therefore, the department has a "budgeted" capacity to provide instruction to 2,000 students.

To implement this budget logic, the model contains the following formulas:

Flow1 = (Target_Section_Size * SECTIONS) – ENROLLMENTS

Flow2 = (Target_Teaching_Load * INSTRUCTORS) – SECTIONS

The budget plan includes specific assumptions regarding *sections sizes* and *teaching loads*. These assumptions are the department's section size and teaching load *targets*. *Actual* average section sizes and teaching loads will often differ from these targets, but the presence of the departmental targets is a key feature of the model.

5. External Forces

Actual events often depart from the department's budget plan, due to forces external to the department. Two of these external factors are represented in the model:

a. *Maximum Student Demand*

The first affect of student demand is that it acts as a limit or cap on course enrollments. As noted above, the target for enrollment levels will be 1) department capacity, *or* 2) student demand, whichever is less. To build this into the model, the formula for Flow1 is modified as follows:

**Flow1 = minimum(Student_Demand,
(Target_Section_Size * SECTIONS)) – ENROLLMENTS**

Student demand is also recognized as a source of growth. When the department's budgeted enrollment capacity falls below student demand, the magnitude of this difference is allowed to increase enrollment levels beyond the department's budgeted capacity. However, the model also provides for the possibility the department may *resist* this enrollment pressure. "Resistance" will be further defined below, but the final formula for Flow1 is—

Flow1 = minimum(Student_Demand, (Target_Section_Size * SECTIONS) + (if Student_Demand > (SECTIONS*Target_Section_Size) then Student_Demand – (SECTIONS*Target_Section_Size) else 0)/Resistance) – ENROLLMENTS

b. *Maximum Available FTE*

Budgetary resources for instructional positions are allocated to the department by the dean of the school/college with which the department is affiliated. This constraint upon the department is named "Available FTE" to indicate a ceiling or limit on the ability of the department to obtain and/or retain the resources necessary to employ instructors. The department does not necessarily use all available FTE, since this is intended only to represent an upper limit on the resources the department is able to obtain, perhaps only after protracted discussions with the dean. "Available FTE" will be one component of the formula for flow3.

6. Feedback Loops

The model contains three feedback loops, which arise from 1) average section size, 2) average teaching load, 3) and departmental resistance to enrollment increases.

a. *Average Section Size is defined as follows—*

average_section_size = ENROLLMENTS / SECTIONS

Because of the impact of student demand, enrollment levels are usually *not* exactly at the level of the department's "budgeted" capacity. As a result, the actual average section size is usually at least slightly different from the department's target section size. The addition of the actual average section size completes the model's first feedback loop. Assuming, for the moment, that student enrollments remain constant, the department can bring average section sizes back to target by adjusting the number of sections. If section sizes are too high, the department can add more sections to bring the average section size back down to the level desired. If section sizes are too low, sections can be subtracted to increase the average section size.

Now there are *two* possible target levels for sections. The first level is given by budget logic based on the number of instructors and their expected teaching loads. The second level would bring section sizes back to target. *In many instances, these objectives will conflict with each other.* For this model, a decision was made to give equal weight to each of these objectives, and to set the weight for each target at 50 percent.

The final formula for flow2 becomes the following—

Flow2 = ((50% of (Target_Teaching_Load * INSTRUCTORS)) + (50% of (SECTIONS * Average_Section_Size / Target_Section_Size))) – SECTIONS

b. *Average Teaching Load is defined as follows—*

Average_Teaching_Load = SECTIONS / INSTRUCTORS

Because of external factors, the number of sections the department is teaching often is *not* exactly at the level of the department's "budgeted" capacity. As a result, the actual average teaching load is usually at least slightly different from the department's target teaching load. The addition of the actual average teaching load completes the model's second feedback loop. Assuming, for the moment, that sections remain constant, the department can bring average teaching loads back to target by adjusting the number of instructors. If teaching loads are too high, the department can hire more instructors (provided sufficient FTE are available) to bring the average teaching load back down to the level desired. If teaching loads are too low, the instructional staff can be reduced to increase the average teaching load.

The formula for flow3 is—

Flow3 = minimum(Available_FTE, Target_FTE) – INSTRUCTORS

where Target_FTE =
INSTRUCTORS * Average_Teaching_Load / Target_Teaching_Load

c. *Resistance to Student Demand*

If student demand is driving enrollments up, average section size will also increase. As section sizes increase, the department will seek to increase the number of sections in order to slow or reverse the growth in section sizes. As the number of sections increase, average teaching loads will increase. The department will respond by trying to obtain additional instructors, in order to keep teaching loads within a desired range.

However, when all available FTE are being utilized, the department will begin to resist further enrollment growth. The model includes an assumption that as the discrepancy between the FTE needed and the FTE available grows larger, department's resistance will intensify exponentially.

Resistance to enrollment pressure introduces a third feedback loop into the model. The formula for Resistance is—

Resistance = if Target_FTE > Available_FTE
then (Target_FTE / Available_FTE)^15, else 1

7. Target Intervals

Departmental standards for section sizes and teaching loads may be best described as the interval between a minimum acceptable value and a maximum acceptable value. For some departments, these acceptable ranges may be very narrow, while in other departments, there may be more latitude or flexibility regarding sections sizes and teaching loads.

To incorporate this concept of ranges into the model, the formula for Target_Section_Size is defined to take the current value of Average_Section_Size into account. Target_Teaching_Load is defined in a similar fashion:

if average > maximum then target = maximum
else [if average < minimum then target = minimum
else target = average]

B. A TEST OF MODEL IMPLEMENTATION

STELLA II was used to run a simulation of the model for a hypothetical department, as a test of whether the model has been implemented as intended. The hypothetical department is seeking to keep the average section size at 25 students, and average teaching loads between 2 to 2.5 sections per FTE. Instructional positions available to the department are limited to no more than 27 FTE. In the simulation representing a 13-year period, student demand for the department's courses suddenly doubles within four years, remains high for 2 additional years, and then declines fairly rapidly, stabilizing at approximately its original level beginning in year 11.

The table on page 4 displays the result of the test simulation. Despite significant enrollment fluctuations, the hypothetical department is able to keep average section sizes near 25 students, and keep average teaching loads within or near the target range of 2.0 to 2.5 sections per FTE. When these limits are stretched by rising student demand, the hypothetical department exhibits resistance to further enrollment increases, stabilizing enrollments below student demand when further increases in instructional staff are no longer possible. Instructional staff never exceeds 27 FTE, as intended. As student demand declines, the department reduces its instructional staff as teaching loads approach the minimum of 2.0 sections per FTE.

There is one minor flaw in the implementation of the model. When student demand is declining, course enrollments slightly outstrip student demand. This a contradiction of the intended model, since student demand is a maximum limit on enrollments. This defect appears to be due to an artifactual delay arising from how the model is represented in the computer. These errors have been reduced to approximately 1% or less by reducing the delta time (dt) used in the differential equations which represent the resource stocks. In STELLA II, dt can be modified by the user. Aside from this very minor discrepancy, the model appears to function as intended.

C. TESTING THE VALIDITY OF THE MODEL

While the model simulations may function as intended, the question remains whether the model accurately represents the behavior of actual academic departments. Data on academic departments at the University of Wisconsin-Madison were used to begin testing the validity of the model. A key requirement in system dynamics analysis is the ability to observe events over *time*. Trend data were assembled for several indicators tracked over a thirteen-year period for each of approximately 90 academic units. The operational definitions of the model variables are as follows—

1. Department:

The unit of analysis was the department. At the departmental level, there were a large number of dramatic enrollment trends, making it possible to observe a variety of departmental responses to those fluctuations.

To facilitate bringing instructional FTE into the analysis, all the departments are *budget* departments, rather than *timetable* departments. For example, the two timetable departments of 1) French and 2) Italian are both linked to, and funded from a single budget department, named "French & Italian." In this and similar instances, all of the enrollments, sections, and instructors have been aggregated into the single *budget* department associated with one or more timetable departments.

Business, Nursing, Pharmacy, Family Resources & Consumer Science, Law, and Veterinary Medicine are budget "departments" which are actually schools or colleges of the university, some of which offer multiple timetable departments. The largest schools and colleges of the university (Letters & Science, Education, Engineering, and Agriculture) were all analyzed at the departmental level rather than at the school/college level.

Under these definitions of departments, trend data were developed for approximately 90 academic units. The Medical School departments were excluded due to differences in academic calendar and curricular structures. Some additional departments were excluded, primarily because those units were either discontinued, or first created, during the thirteen-year period covered by this analysis.

2. Course Enrollments:

This is the number of students enrolled in all of the organized group instruction courses offered by the department. Students who enrolled in multiple courses in the department are counted multiple times—once for each course. Individual instruction courses are excluded. Enrollments in cross-listed courses are aggregated and assigned only to the department designated as the primary department for the course that semester. *Course* enrollments are to be distinguished from *section* enrollments, since students often enroll in multiple sections in the same course.

3. Number of Sections Offered:

This includes only organized, group instruction sections. Individual instruction sections are excluded. In many group instruction courses, students enroll in multiple sections in the same course: a primary section (often a lecture section with 3 to 4 weekly contact hours) and a supporting, secondary section (often a "discussion" or "quiz" section with one weekly contact hour). Primary-range sections include all lecture sections and seminar sections, and approximately one-half of all laboratory sections. Except as noted, section counts include only the department's *primary* sections, excluding secondary sections. Secondary-range sections include all discussion (recitation or quiz) sections, and approximately one-half of all laboratory sections. Secondary-range sections were examined separately in a few departments, including Political Science.

4. Instructional Staff FTE:

Instructional FTE include staff who are graduate teaching assistants and graders, non-faculty academic staff (e.g. lecturers, visiting faculty, emeritus faculty), in addition to tenure/tenure-track faculty members. Classified civil service employees (primarily clerical, building maintenance, and skilled trades) are excluded. The FTE count of instructional staff is based on payroll records for the month of October of each year during the period of time covered by this analysis. The FTE count includes all eligible (as further defined below) FTE regardless of how many course sections any individuals found on the payroll may have actually taught. For some departments, tenure/ tenure-track faculty FTE were examined separately from other instructional FTE.

Instructional FTE are funded from the unrestricted state appropriation. Instructional faculty have responsibility for departmental research, public service, and university governance activities, in addition to their teaching assignments. However, the FTE reported here always *excludes* positions funded under federal or private contracts for specific research or public service projects.

Instructional FTE were tabulated differently for the College of Agricultural & Life Sciences, due to historical budget definitions used in that particular college. In addition to instructional FTE as defined above, FTE funded from the unrestricted state appropriation for *research* were also included. The Department of Agronomy, examined in further detail below, is one of the departments of the College of Agricultural & Life Sciences.

5. Years:

The analysis covers a thirteen-year period. The actual time points included in the analysis are *fall semesters* only. Spring and summer terms are not included or reported. Course enrollments and section counts are as of the end of the second week of instruction in each of thirteen fall semesters. The instructional FTE are based on the October payroll in each of those years. The specific time period for this analysis is from Fall Semester of 1983-84 through the Fall Semester of 1995-96.

6. Trends:

The magnitudes of the absolute values of the model variables vary considerably. In the Mathematics department, for example, fall semester course enrollments ranged between 10,000 to 8,000, while the number of primary sections taught ranged around 200, and the average section size fell in a range between 40 to 50. To facilitate comparisons of trends in these and other model variables, all of the variables were normalized by converting them to a percentage of their respective levels in Fall 1983. The use of 1983 as a base year is totally arbitrary, except for the fact 1983 was the earliest year for which complete data were available. Any other year during the thirteen-year span could have been selected as the base year instead.

7. Necessary Assumptions

Use of the model to replicate the behavior of a department requires some assumptions regarding the unique situation of the each department. These assumptions are entered as model parameters prior to running a model simulation.

a. *Initial stock levels:*
A model simulation cannot be run in the absence of some assumptions regarding initial levels of the enrollment, section, and instructor resource stocks. In the present analysis, stock levels were initialized at the department's actual levels in the fall semester of 1983.

b. *External Factors: Maximum Student Demand and Maximum Available FTE*
Because these are external factors which impinge upon each department in unique ways, it is necessary to make assumptions about levels of, and changes in, student demand and available FTE. These maximum levels are frequently unknown, or can only be estimated as being above or below a specific level. For example, while the limits of student demand are occasionally revealed by changes in enrollment levels, most changes in enrollment levels may have a variety of possible explanations, often unrelated to student demand However, a projection model which permits the user to insert a range of alternate assumptions regarding external factors for *future* time periods may be key to developing truly useful projections. The price of this flexibility, of course, is that assumptions regarding external factors are *required.*

c. *Section Size and Teaching Load Targets*
Within a large research university, departments differ in their normative standards for sections sizes and teaching loads. The requirements for effective pedagogy differ between disciplines, depending on such factors as the level of student recitation needed, utilization of laboratory classrooms, and enrollment mix by student level (e.g. undergraduate vs. graduate). In adapting the model to a variety of departments, it is helpful to recognize and estimate these differences. Each department's targets for section size and teaching load were assumed to remained fixed for the duration of the thirteen-year period. However, *changes* in departmental standards for section sizes and teaching loads could easily be inserted into the model as an additional assumption.

IV. RESULTS

This investigation was exploratory. The primary focus of the data analysis was on locating examples from the data which provide plausible confirmations of the validity of the hypothesized dynamics model. Successful replication of thirteen-year trends in *all* of approximately 90 departments will be a continuing effort, and will likely require further refinement and expansion of the model. However, several departments have been identified which appear to fall within the explanatory range of the model:

1. Departments Subjected to Major Shifts in Student Demand:

   a. *Agronomy*
   This department underwent relentless enrollment losses during the entire 13-year period. For this simulation, it was assumed that student demand was responsible for the enrollment decline, particularly since there were no reductions in instructional FTE during this period. When it is also assumed that the department's target for average section size is a range from 21 to 35 students, and that teaching loads are allowed to fall to low levels, the model yields a useful approximation of actual trends in Agronomy. These results are presented on page 18.

   b. *Botany*
   This department experienced sharp enrollment losses in 1987 and 1988. Reduced student demand was assumed to be responsible for the enrollment decline, particularly since instructional FTE remained relatively constant during this period. In contrast to Agronomy, Botany appears to maintain tighter controls on average section size, in part to better manage student access to laboratory facilities. When the department's target for average section size is set at 40 students, and teaching loads are allowed to vary within a range, the model yields a reasonable replication of actual trends in Botany. See page 19.

   c. *Communication Arts*
   Enrollments levels have declined throughout the period by a total of over 30 percent. Reduced student demand is assumed to be the cause. The model yields an approximate replication if the department's target for average section size is estimated to be 35 students, and the teaching load target is estimated to range between 2.25 to 2.75 sections per FTE. See page 20.

   d. *French & Italian*
   Course enrollments in French & Italian increased from 1983 through 1985, remained stable through 1990, and have continued to decline significantly since then. Changes in student demand are assumed to be responsible for these trends. This department appears to maintain very tight control over average section size, keeping it at approximately 19 students. Average teaching load is more variable, but nevertheless controlled more tightly than in either Botany or Agronomy. See page 21.

   e. *Geography*
   This department also experienced significant enrollment increases followed significant declines. Again, changes in student demand are assumed to be responsible for these trends. In this department, average section size is allowed to vary between 40 to 80 students. Average teaching loads were held within relatively narrow range. See page 22.

f. Mathematics

Enrollments have declined steadily during the period from 1985 through 1994. Changes in student demand are assumed to be the cause. The Mathematics department appears to maintain extremely tight control over average teaching load. Average section size was allowed to vary between 40 to 48. Page 23.

g. Political Science

Political Science experienced large enrollment increases which peaked in 1989 and 1990. Since then, enrollment levels have steadily declined. Changes in student demand are assumed to correspond to these enrollment trends. For purposes of modeling trends in Political Science, the department was disaggregated into two sectors: a) primary-range sections (see page 25) and b) secondary-range sections taught by graduate teaching assistants (see page 26).

In the case of the secondary sections, the department appears to keep average section size between 20 to 21, and average teaching load between 10 to 11 sections per FTE. An additional assumption is that graduate assistant FTE available to the department were limited significantly during the first few years of the enrollment growth.

For primary-range sections, average teaching load is kept stable at approximately 2 sections per FTE, while average section size is allowed to vary considerably, ranging between 40 to 100 students. Given this degree of flexibility with section size, changes in instructor levels did not need to keep pace with the relatively dramatic trends in enrollment levels.

2. Departments With Constraints on Available FTE

a. Mechanical Engineering

Enrollment levels declined, then recovered partially and have been relatively stable since 1990. For this department, these changes in enrollment levels are assumed to be due to changes in available FTE. During the mid- to late-1980's, the department faced considerable salary competition from other universities, increasing the difficulty of hiring and retaining faculty. Internal reorganization within the College of Engineering also caused available FTE to fluctuate. Student demand is assumed to have been unchanged during the entire period. The model is able to approximate departmental trends during this period, if it is assumed the department was seeking to keep the average section size at 25 students, and the average teaching load at of 1.5 sections per FTE. See page 24.

b. Slavic Languages

Slavic Languages experienced steady enrollment increases which peaked in 1989, the year the Berlin Wall came down. Student interest in the Russian language was particularly great. Since then, enrollment levels have steadily declined, sinking well below original 1983 enrollment levels. Student demand was assumed to be high until 1991, when it began to decline. An additional assumption is that the FTE available to the department was limited significantly during the first few years of the enrollment growth. The department appears to maintain tight control of average teaching load. The departmental target for average section size is assumed to be a range of 13 to 18 students. See page 27.

c. *Spanish & Portuguese*
There is very high student demand for access to courses in this department. The department and the College of Letter & Science have decided hold enrollments to a level currently below student demand, in order to limit distortion of the long range curricular priorities of the College. Given this situation, it is assumed that any fluctuation in enrollment levels is due solely to changes in available FTE. The department is assumed to target average section size very tightly at 19 students, and average teaching load at 2.55 sections per FTE. Under these assumptions, the model yields a useful approximation of departmental trends. See page 28.

V. CONCLUSIONS

This analysis identified several departments in which the model appeared to be operative. Each department included in the analysis was in a unique situation during the twelve-year period. Each department faced different enrollment trends, different resource constraints, and unique pedagogical requirements. Nevertheless, when these units are observed over time, a significant number appear to function within the general framework of the hypothesized dynamics model.

Based on these results, system dynamics modeling appears to have potential for increasing our understanding of, and our ability to shape, systems for delivering instruction in higher education. The model is of potential value to departments and deans for purposes of program review, planning and resource allocation.

The model described above is still at an early stage of development. Several features of the model may benefit from further evaluation and modification. These include—

1. Modeling time delays, particularly during adjustments in the number of instructional staff.
2. Further evaluation of the relative priority of section size vs. teaching load when section levels are being adjusted
3. Disaggregation of sectors within departments, by type of instructor or by student level, may improve the accuracy of the model for some departments.
4. Expansion of the model into factors currently "external" to the model: student demand and available FTE.

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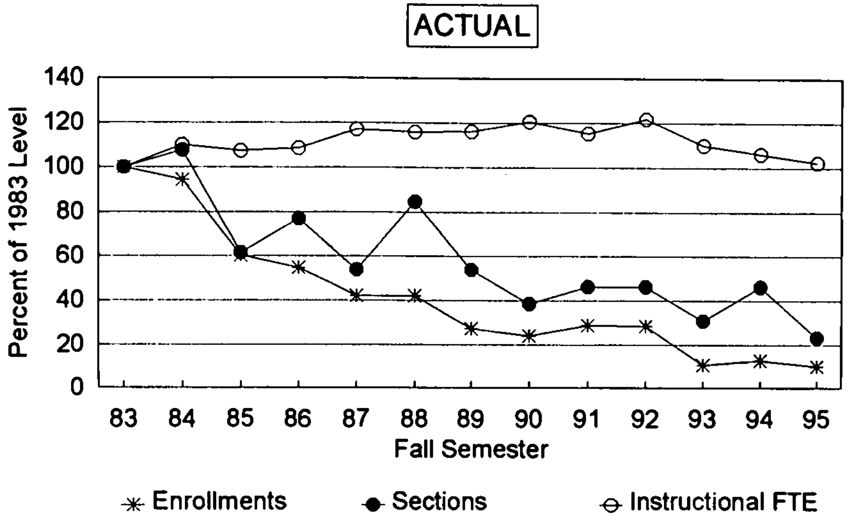
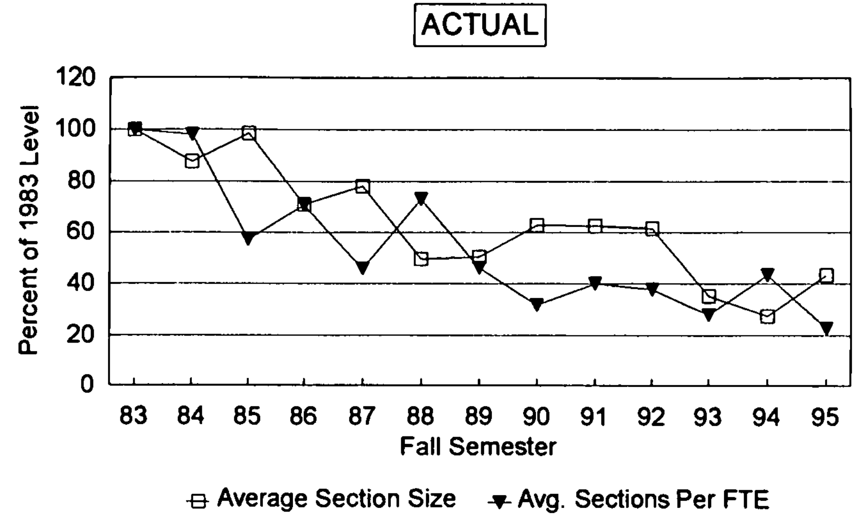
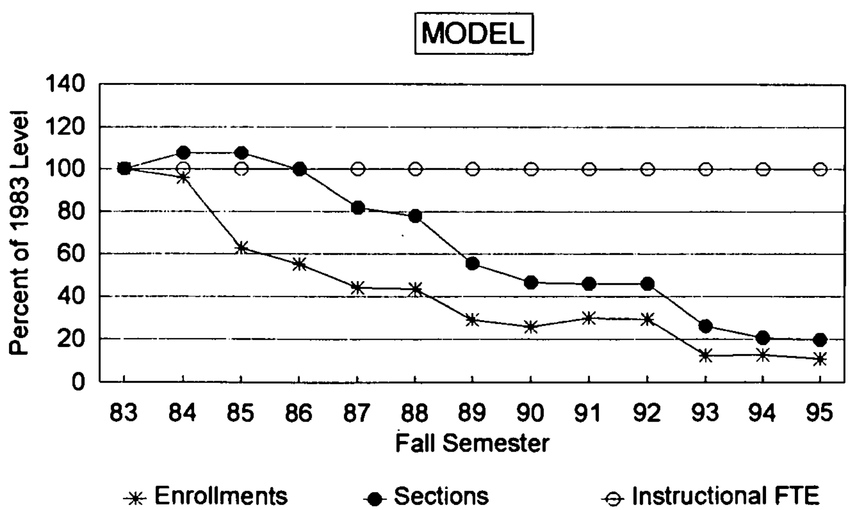
APPENDIX

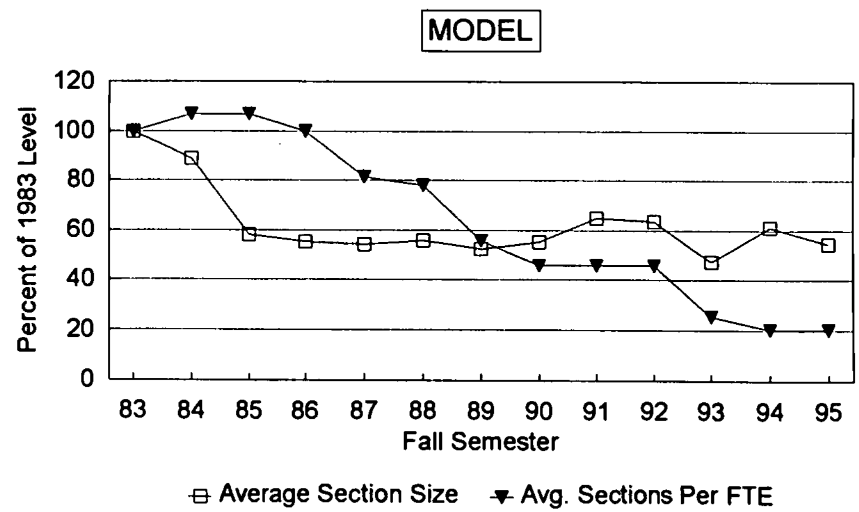
CHARTS
FOR SELECTED
DEPARTMENTS

DEPARTMENT OF AGRONOMY



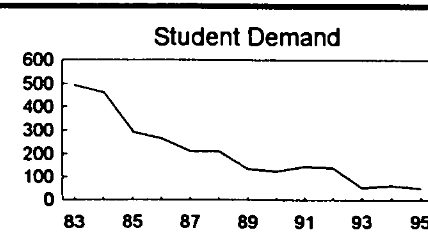


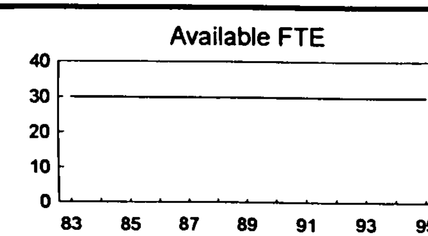




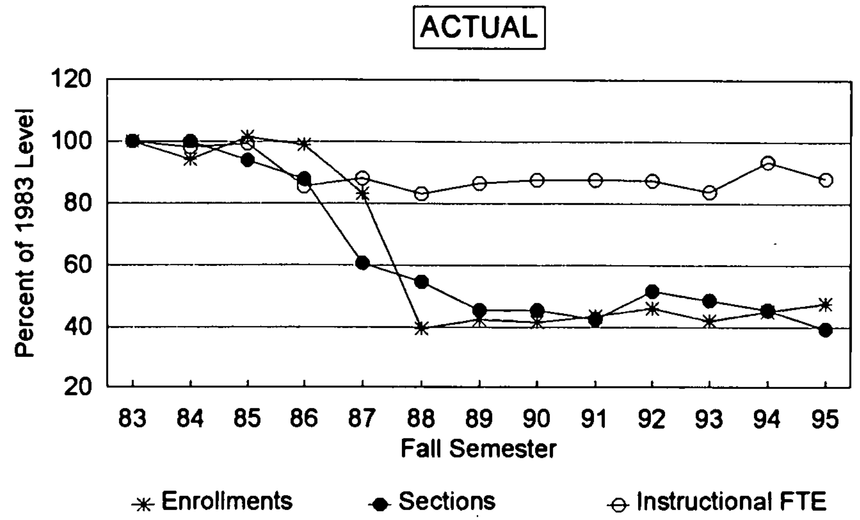
MODEL PARAMETERS:

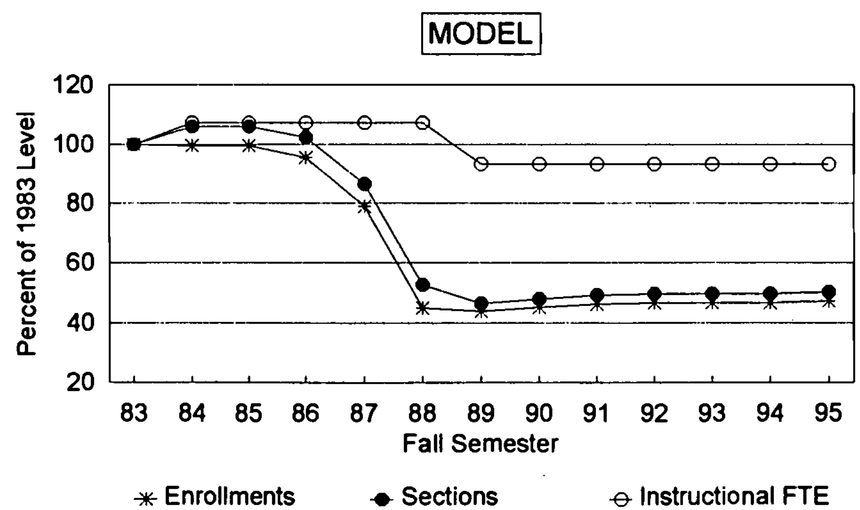
Initial Enrollments:	488	Section Size--		
		Maximum	35	
Initial Sections:	13	Minimum	21	
Initial Instructors:	22.1	Teaching Load--		
		Maximum		1.00
		Minimum		0.10

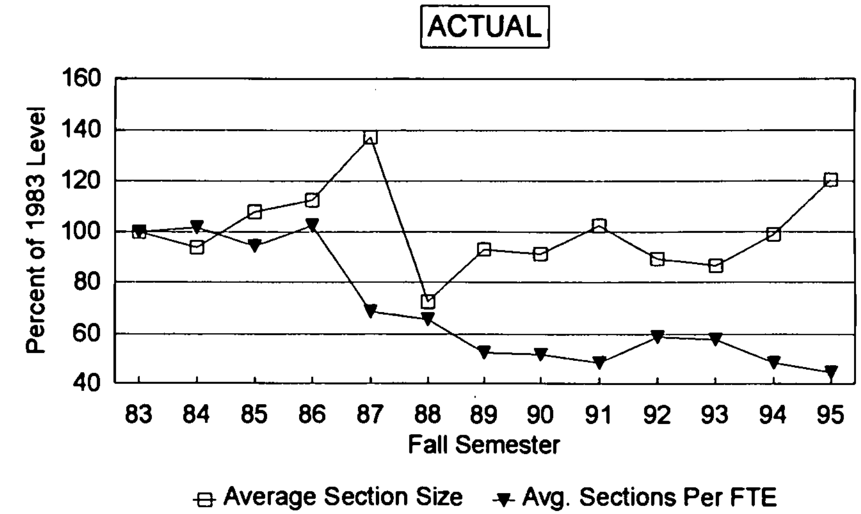


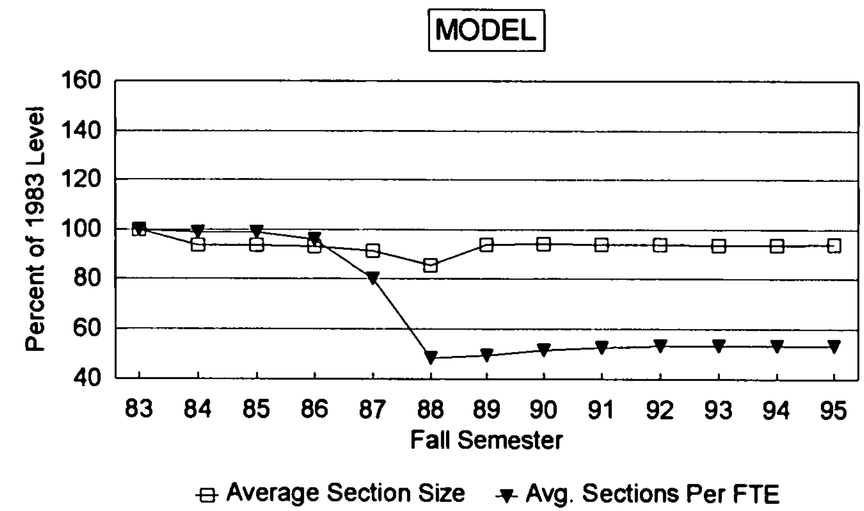


DEPARTMENT OF BOTANY





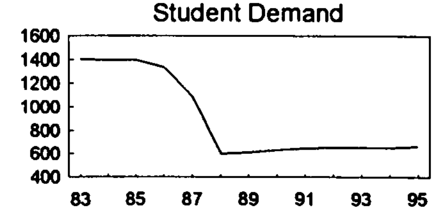




MODEL PARAMETERS:

Initial Enrollments:	1406	Section Size--		
			Maximum	40
Initial Sections:	33		Minimum	40
Initial Instructors:	32.6	Teaching Load--		
			Maximum	1.00
			Minimum	0.50

Student Demand



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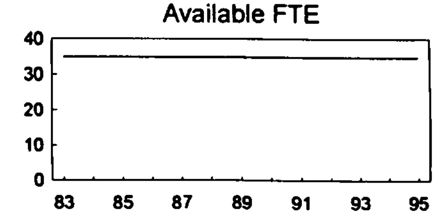
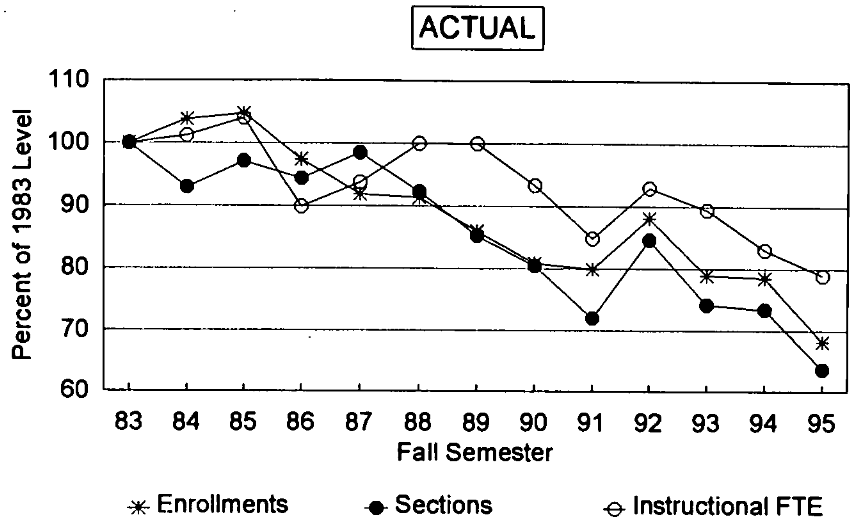
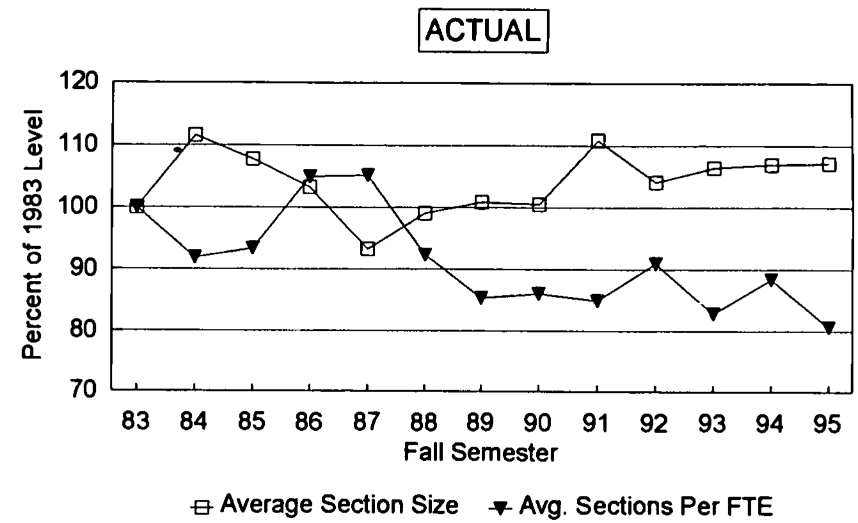
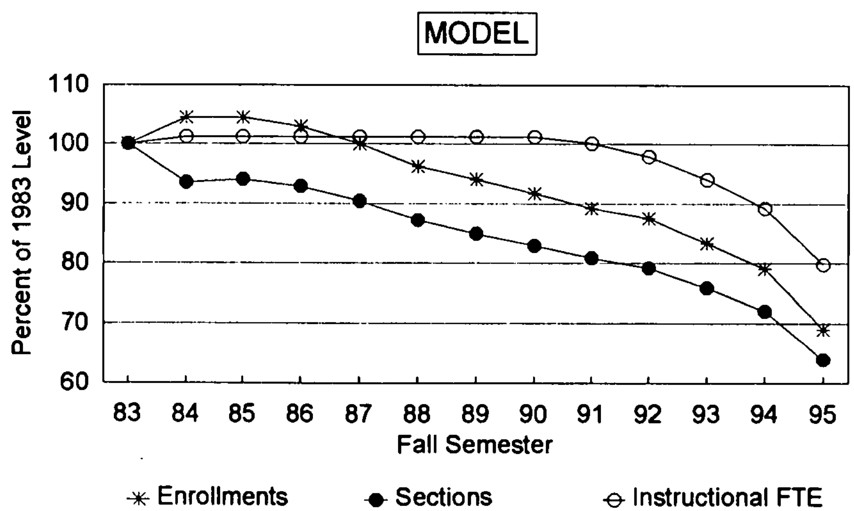


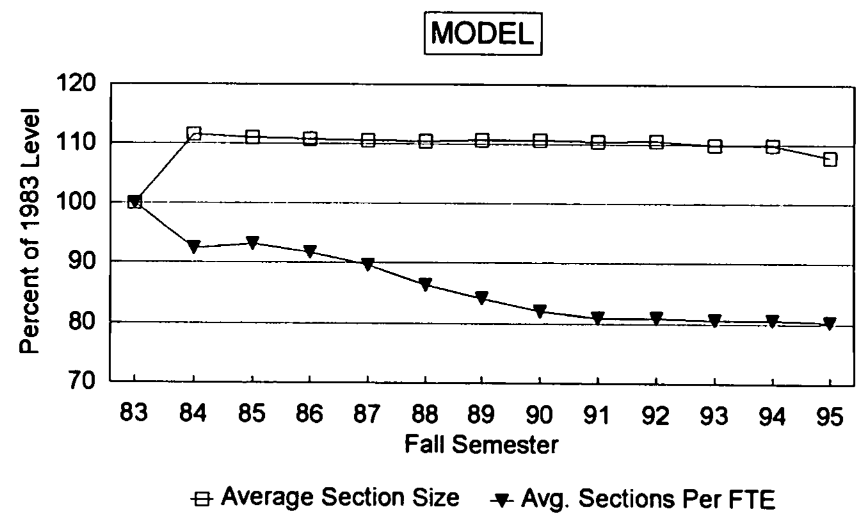
22 23

DEPARTMENT OF COMMUNICATION ARTS



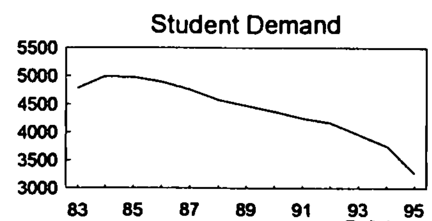


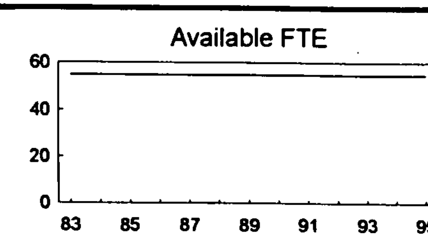




MODEL PARAMETERS:

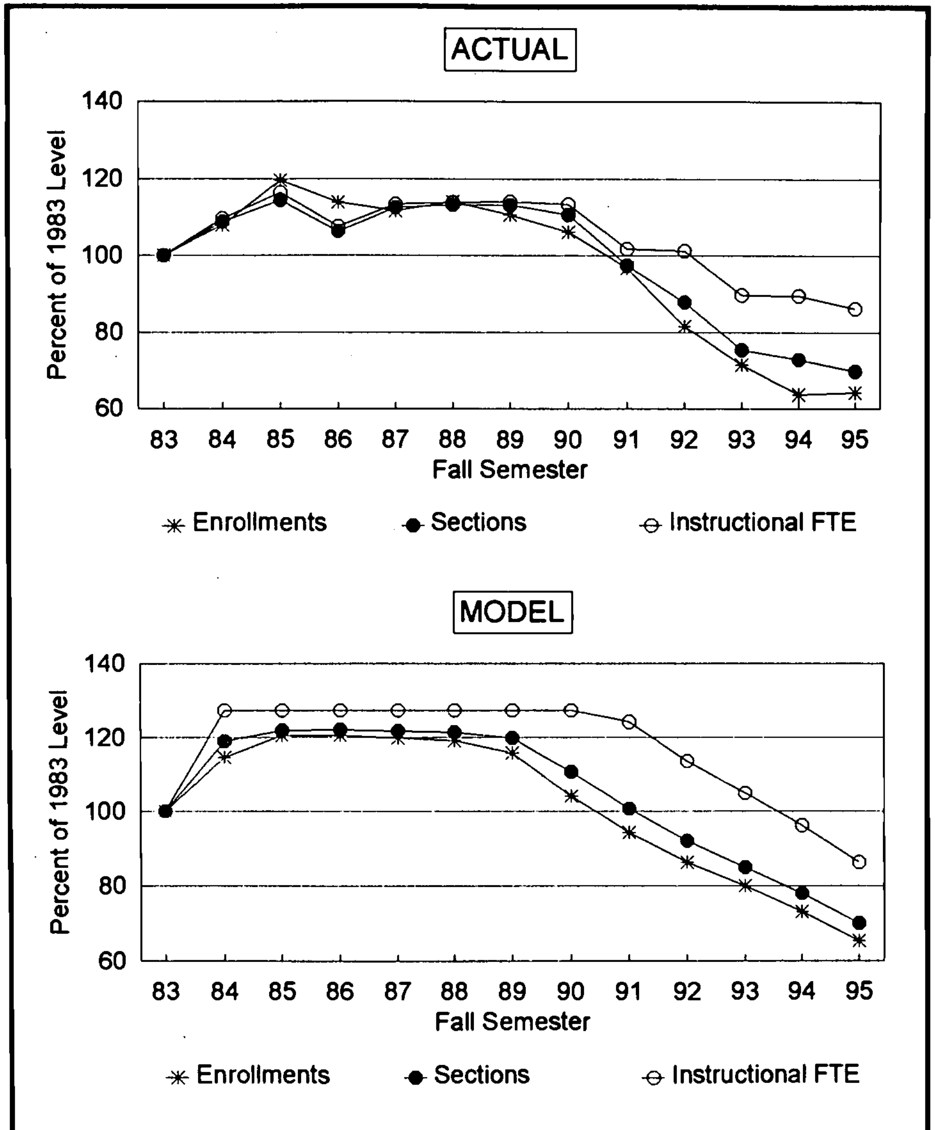
Initial Enrollments:	4768	Section Size--	
Initial Sections:	143	Maximum	37
Initial Instructors:	51.4	Minimum	37
		Teaching Load--	
		Maximum	2.75
		Minimum	2.25

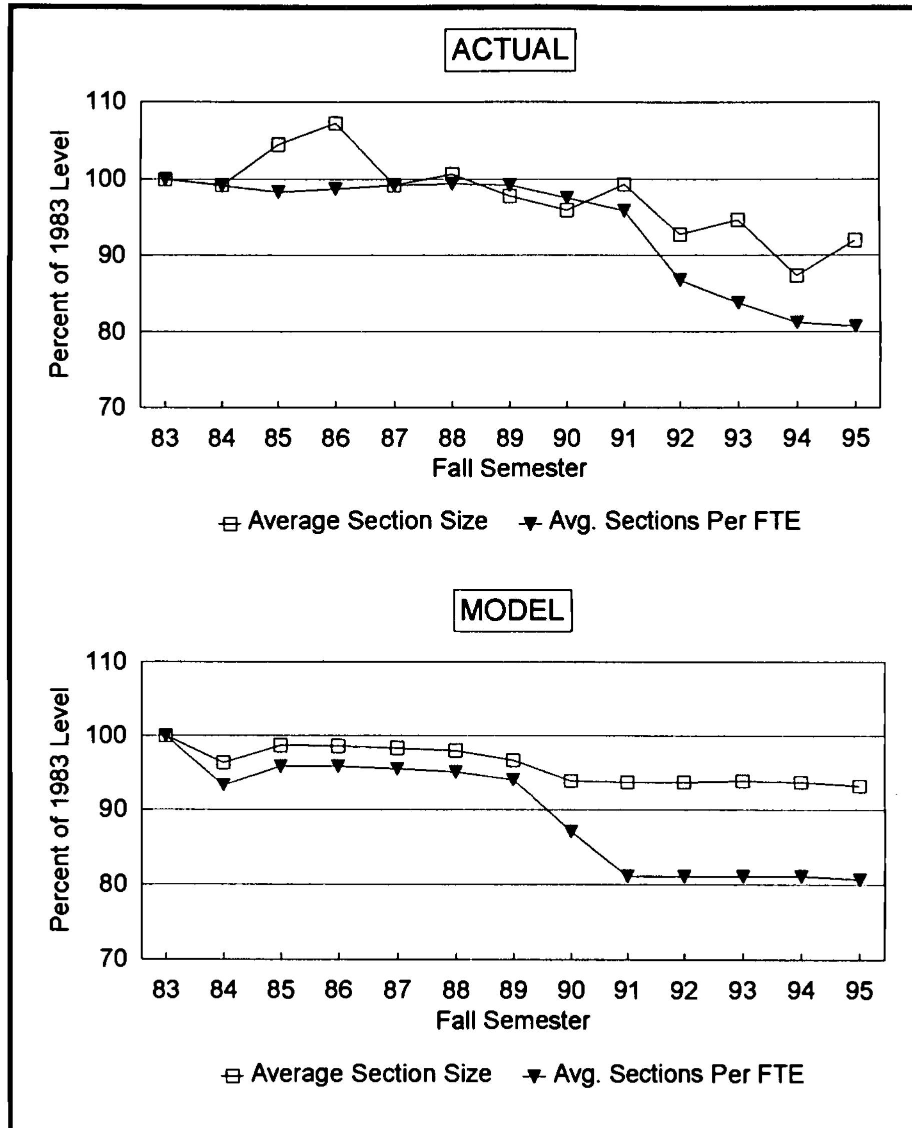




24 25

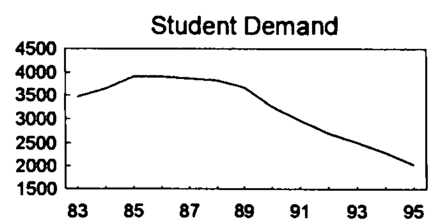
DEPARTMENT OF FRENCH & ITALIAN

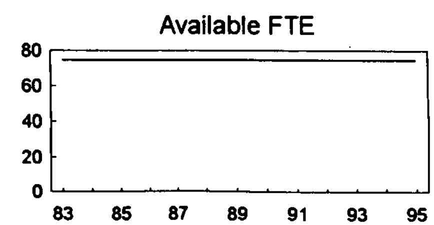




MODEL PARAMETERS:

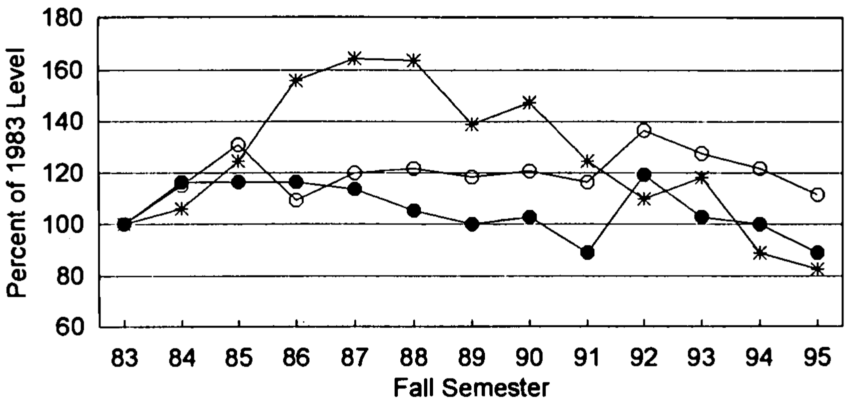
Initial Enrollments:	3167	Section Size– Maximum	19
Initial Sections:	159	Minimum	19
Initial Instructors:	58.9	Teaching Load– Maximum	2.50
		Minimum	2.20



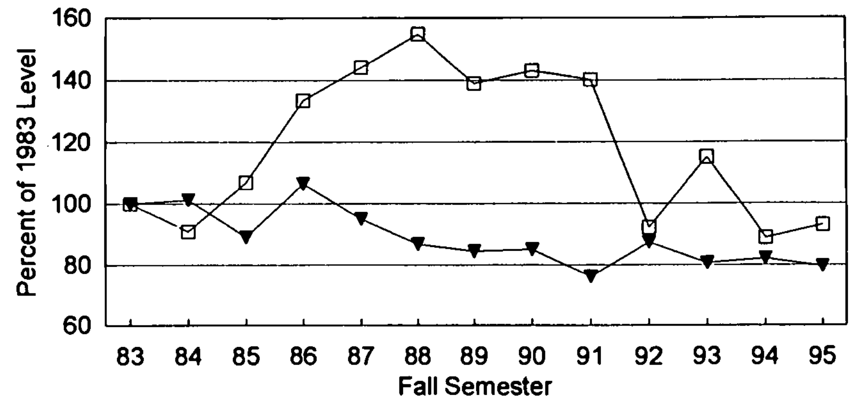


DEPARTMENT OF GEOGRAPHY

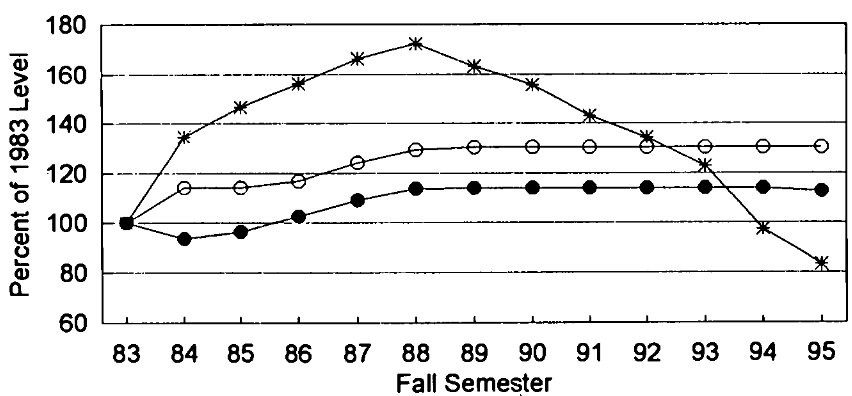
ACTUAL



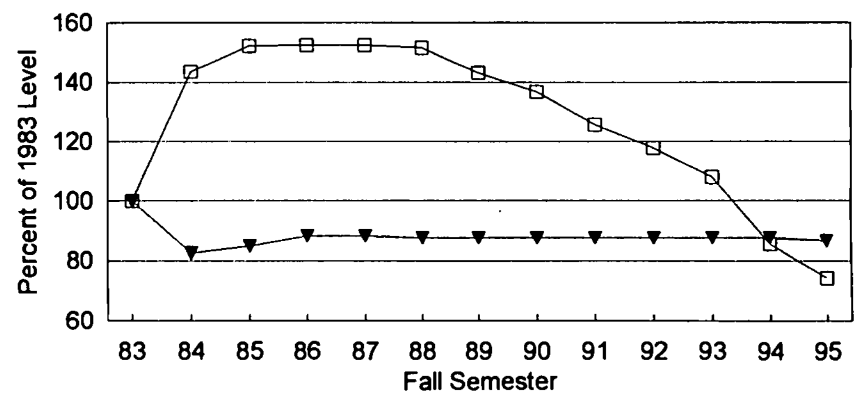
ACTUAL



MODEL



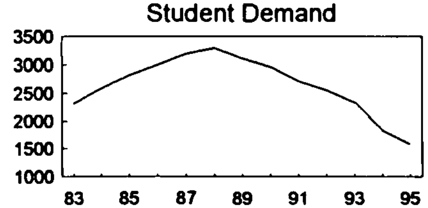
MODEL



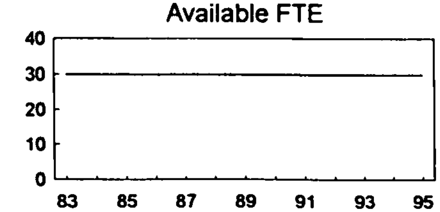
MODEL PARAMETERS:

Initial Enrollments:	1911	Section Size–	
		Maximum	80
Initial Sections:	36	Minimum	40
Initial Instructors:	21	Teaching Load–	
		Maximum	1.50
		Minimum	1.25

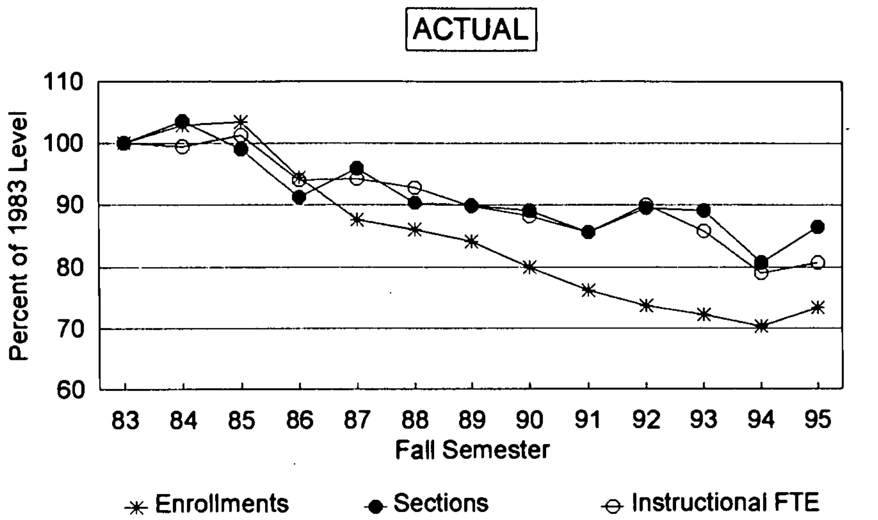
Student Demand

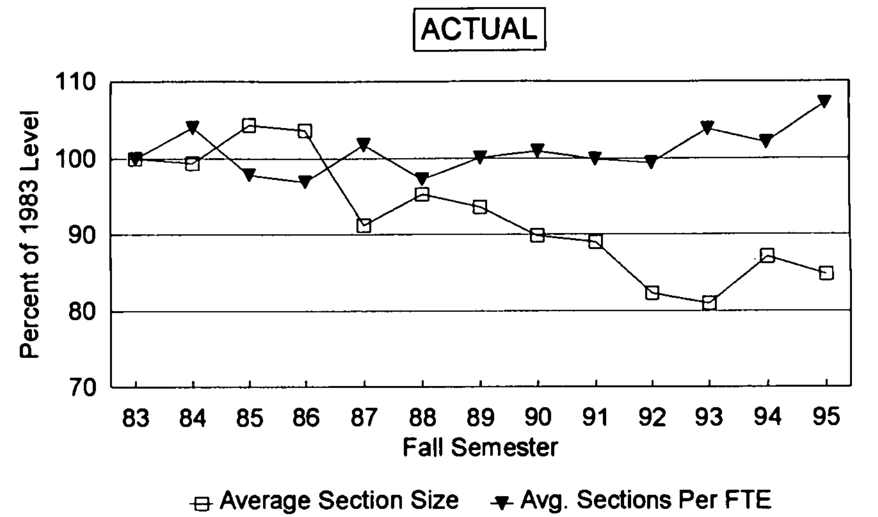


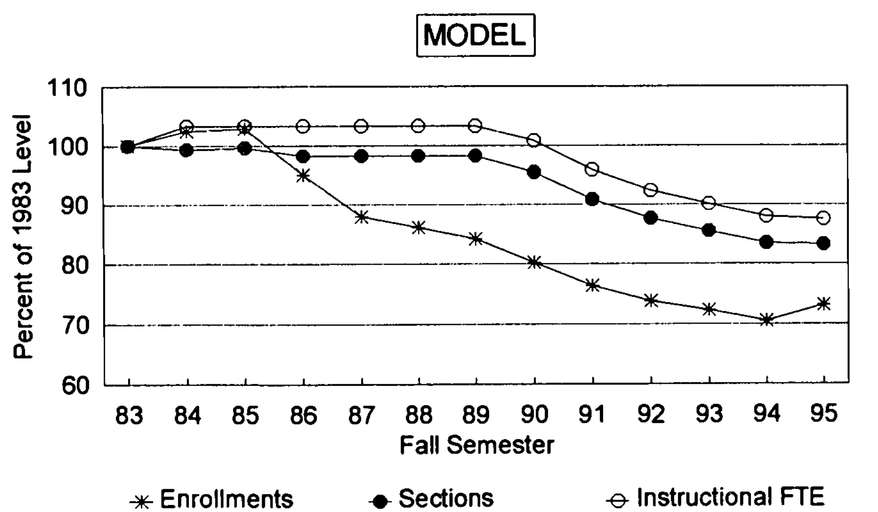
Available FTE

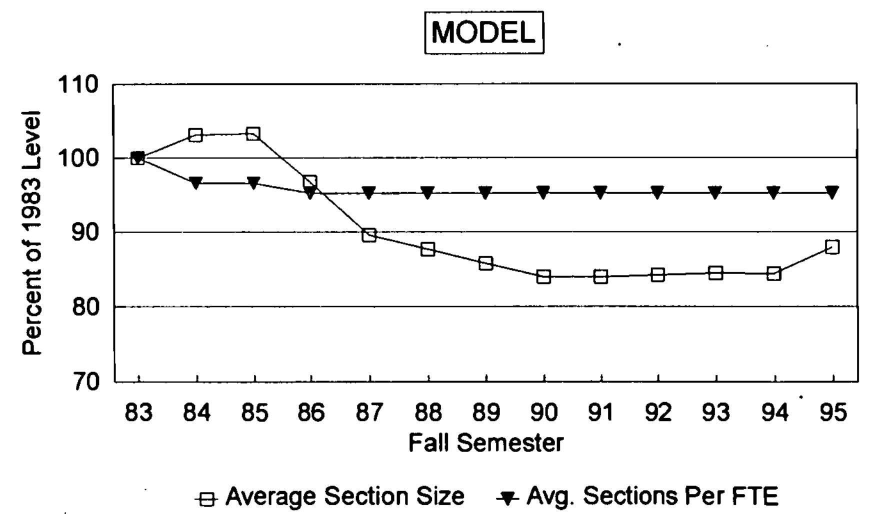


DEPARTMENT OF MATHEMATICS



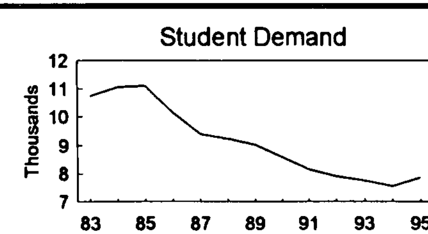


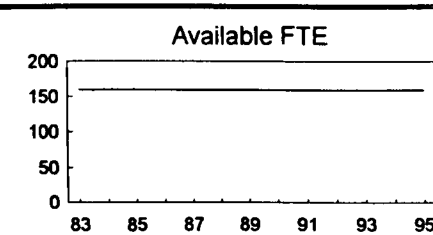




MODEL PARAMETERS:

Initial Enrollments:	10755	Section Size--	
Initial Sections:	228	Maximum	48
Initial Instructors:	154.8	Minimum	40
		Teaching Load--	
		Maximum	1.40
		Minimum	1.40

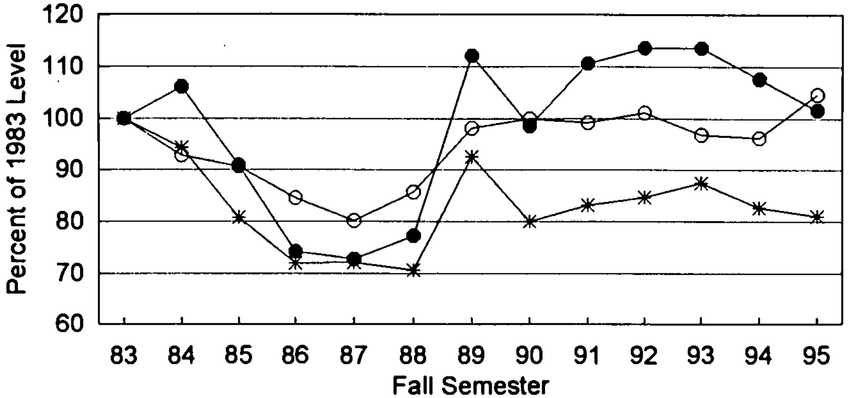




30

DEPARTMENT OF MECHANICAL ENGINEERING

ACTUAL



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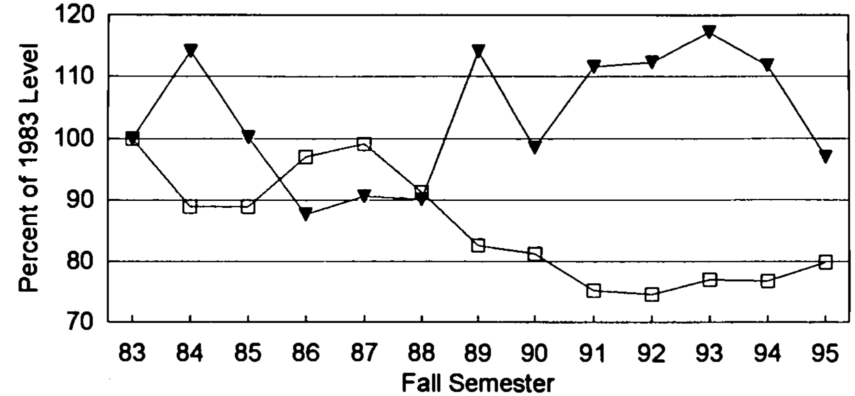
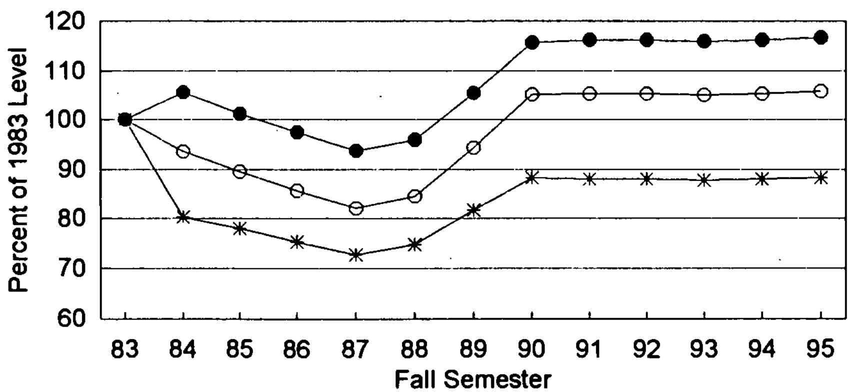


MODEL



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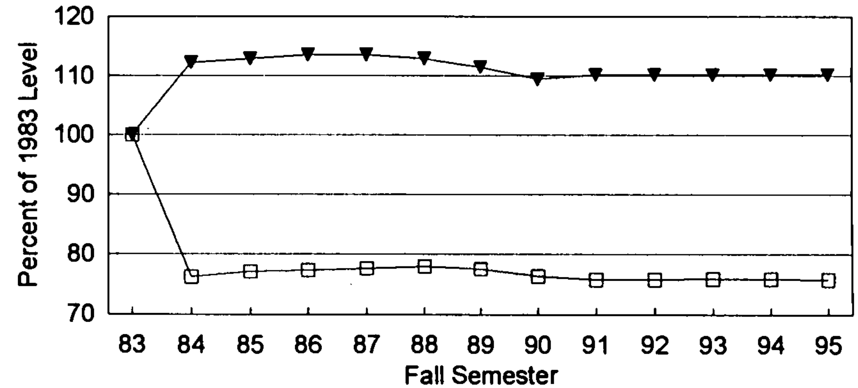
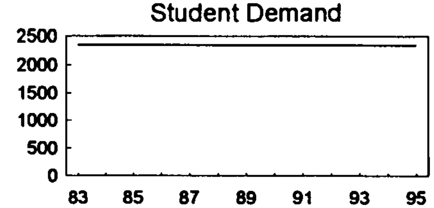


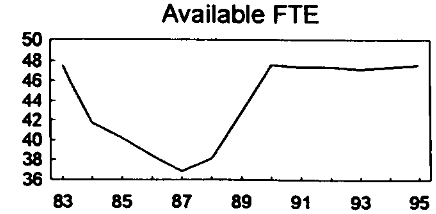
MODEL PARAMETERS:

Initial Enrollments:	2336	Section Size-- Maximum	25
Initial Sections:	66	Minimum	25
Initial Instructors:	45	Teaching Load-- Maximum	1.50
		Minimum	1.50

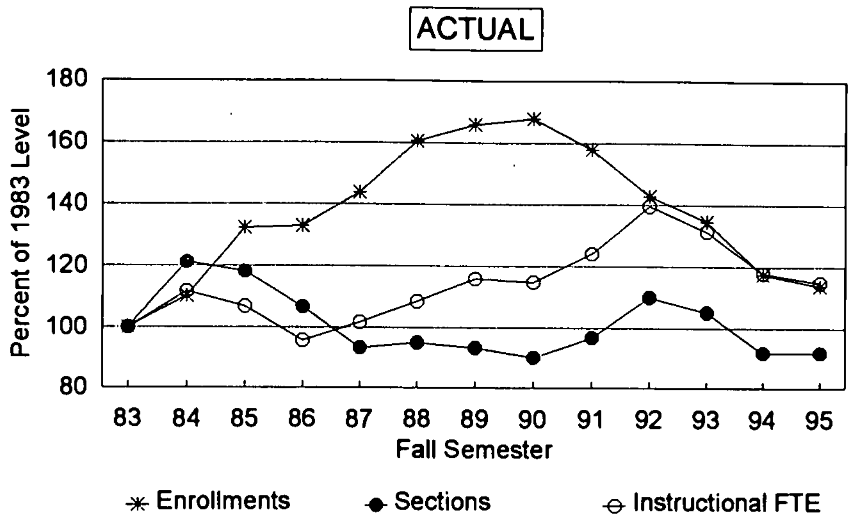
Student Demand

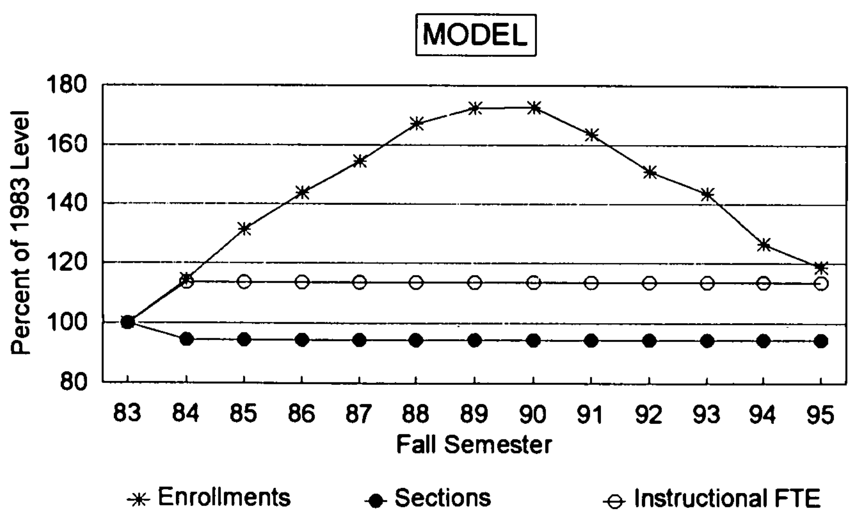


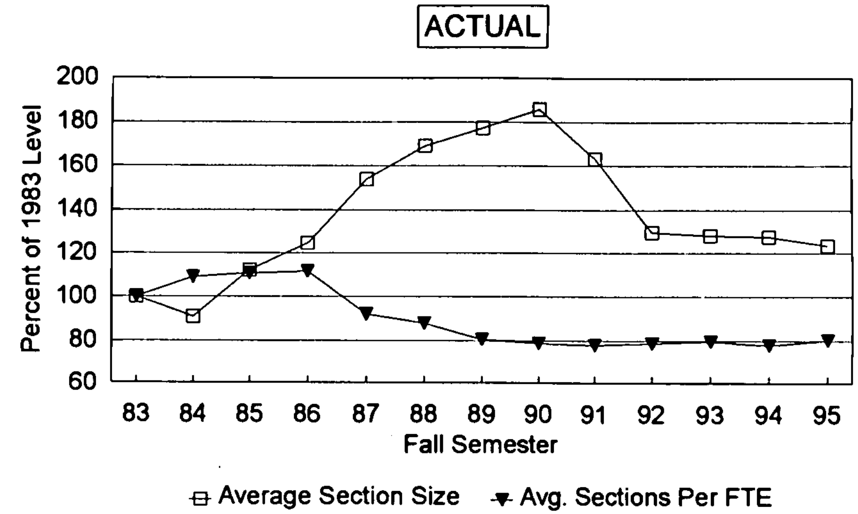
Available FTE

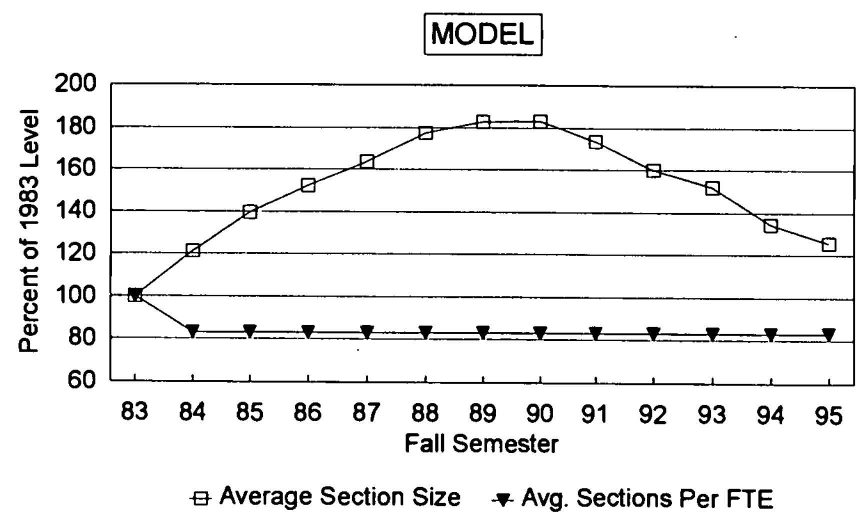


DEPARTMENT OF POLITICAL SCIENCE -- PRIMARY SECTIONS ONLY



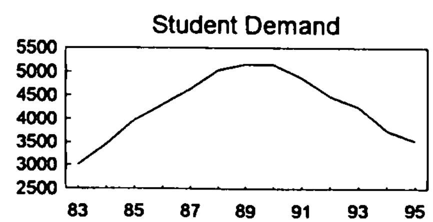


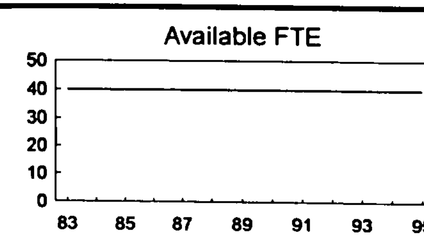




MODEL PARAMETERS:

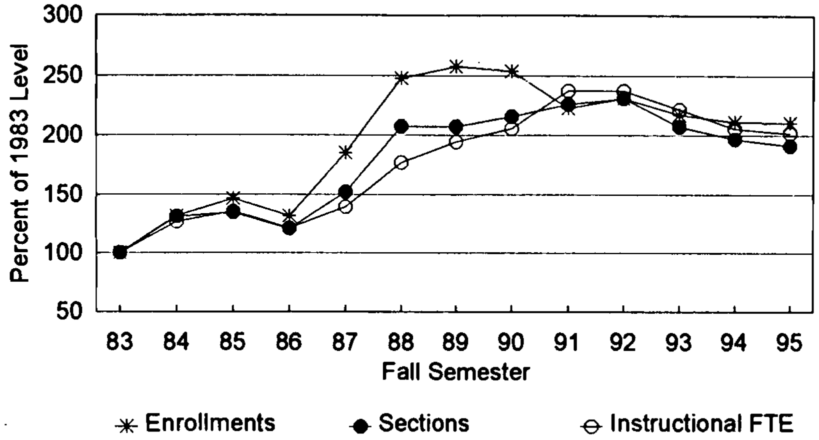
Initial Enrollments:	2992	Section Size--		
			Maximum	100
Initial Sections:	61		Minimum	40
Initial Instructors:	25.3	Teaching Load--		
			Maximum	2.00
			Minimum	2.00



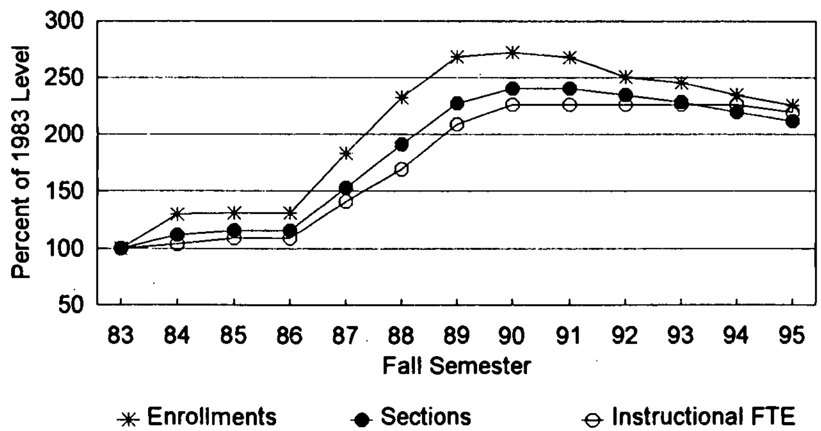


DEPARTMENT OF POLITICAL SCIENCE -- SECONDARY SECTIONS TAUGHT BY GRADUATE ASSISTANTS

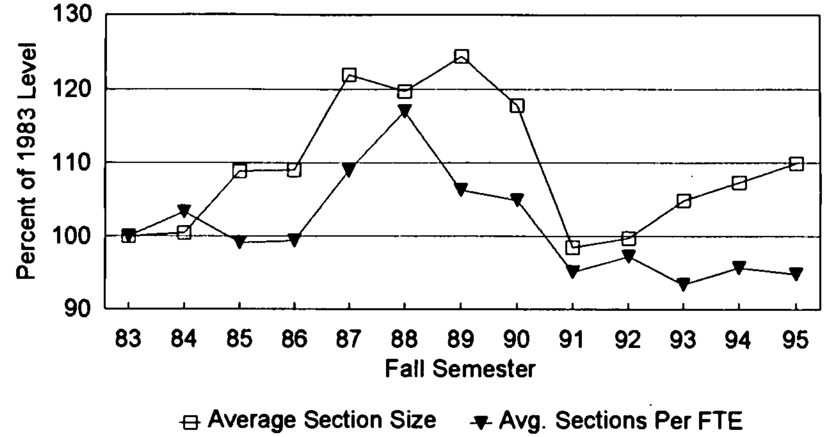
ACTUAL



MODEL



ACTUAL



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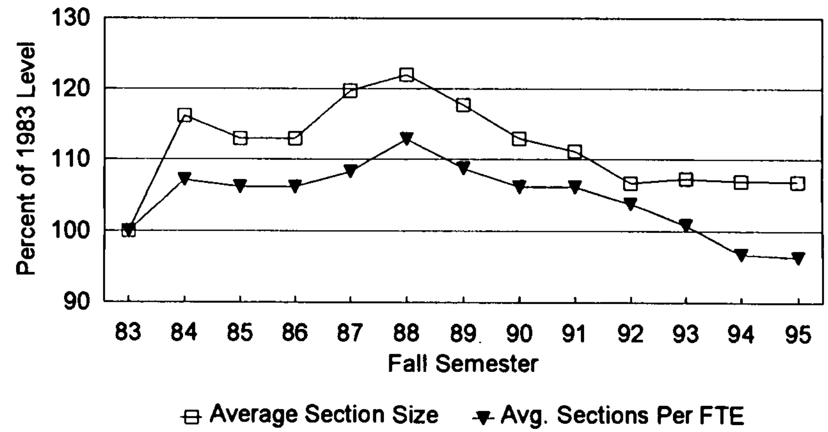
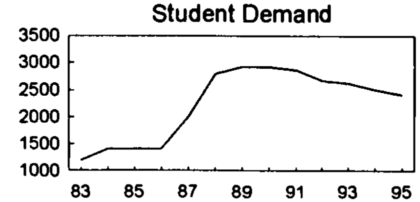


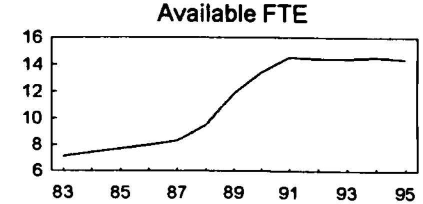
MODEL PARAMETERS:

Initial Enrollments:	1078	Section Size--		
			Maximum	21
Initial Sections:	58		Minimum	20
Initial Instructors:	5.6	Teaching Load--		
			Maximum	11.00
			Minimum	10.00

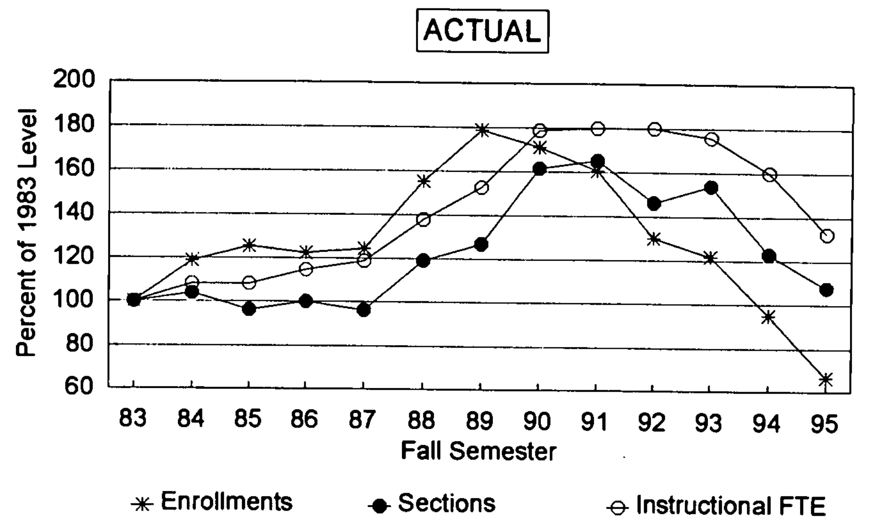
Student Demand

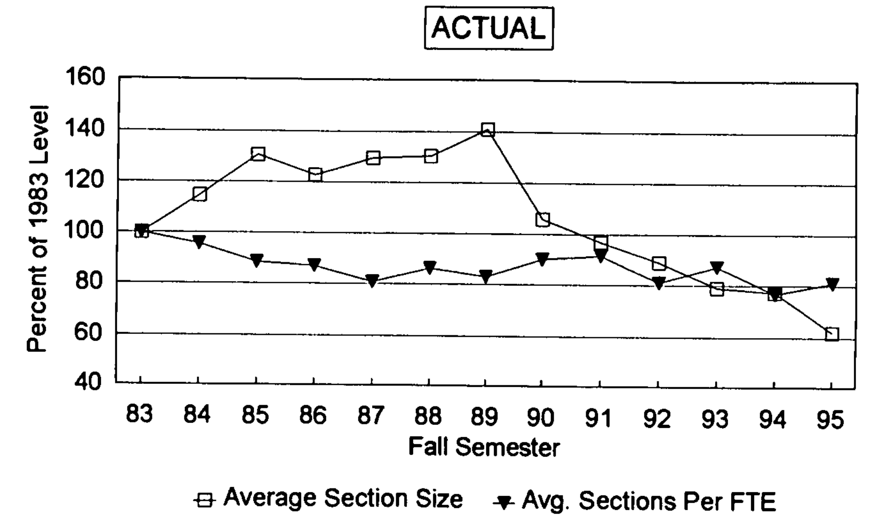


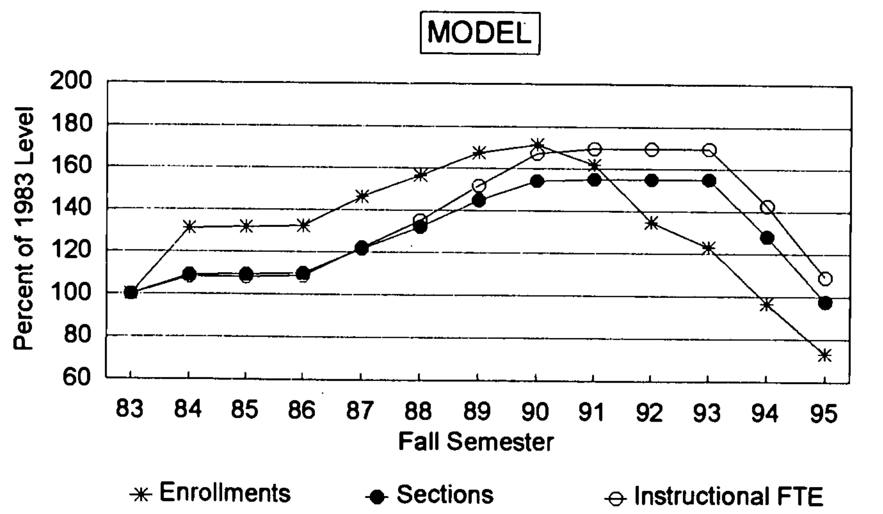
Available FTE

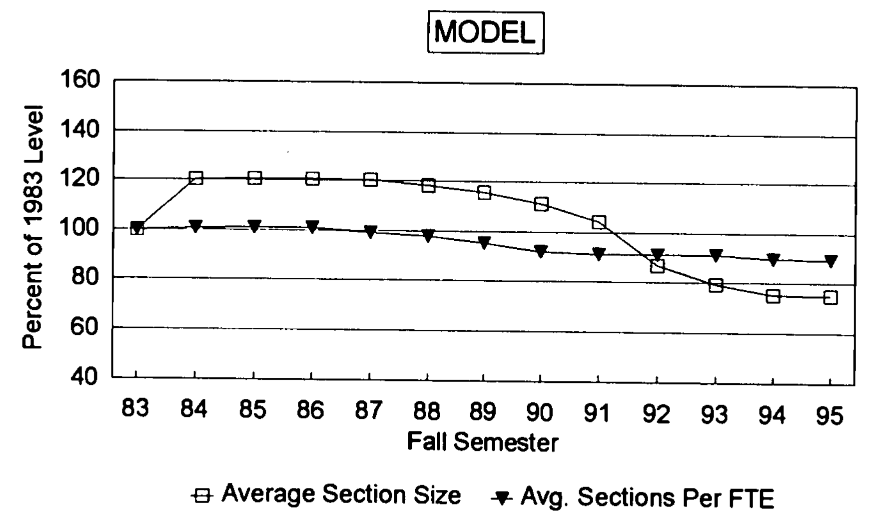


DEPARTMENT OF SLAVIC LANGUAGES



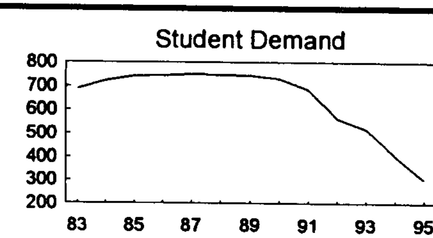


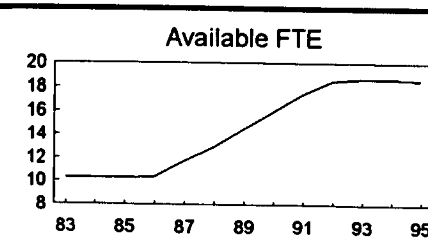




MODEL PARAMETERS:

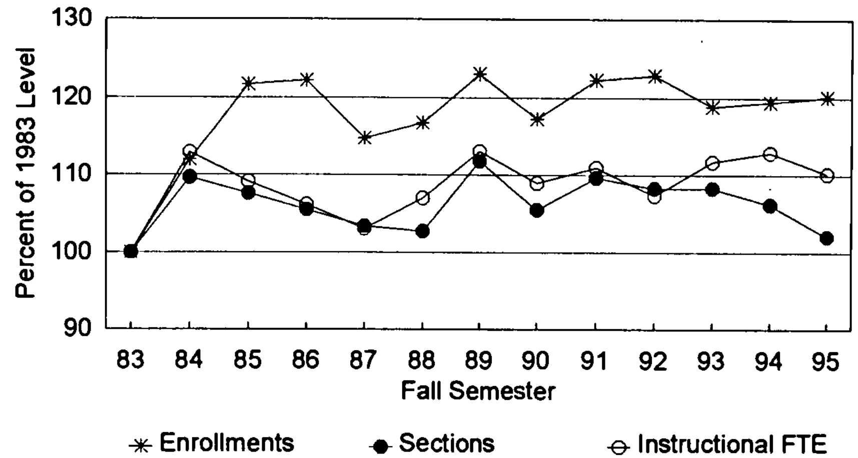
Initial Enrollments:	426	Section Size--		
Initial Sections:	26		Maximum	18
Initial Instructors:	9.5		Minimum	13
		Teaching Load--		
			Maximum	2.50
			Minimum	2.50



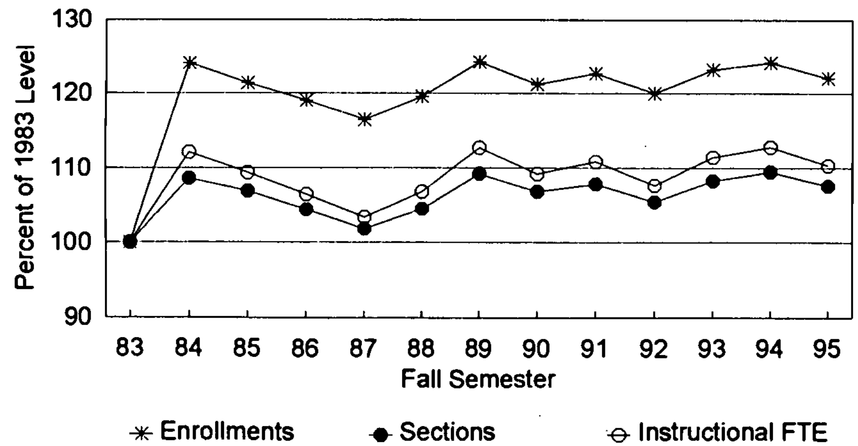


DEPARTMENT OF SPANISH & PORTUGUESE

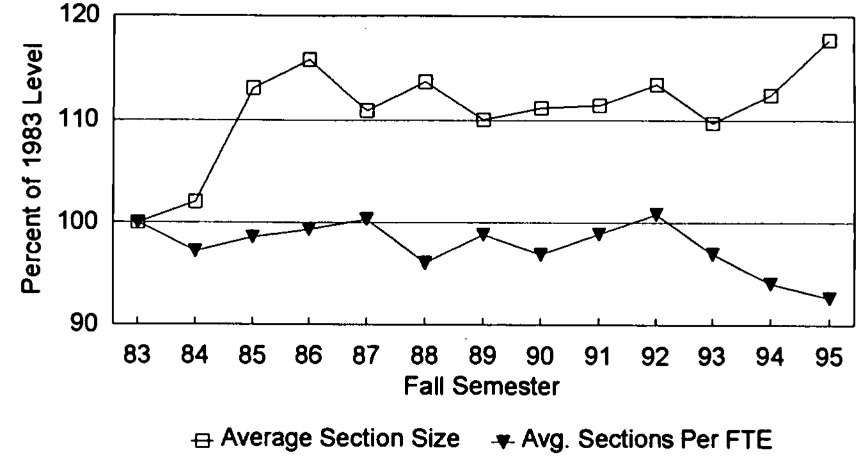
ACTUAL



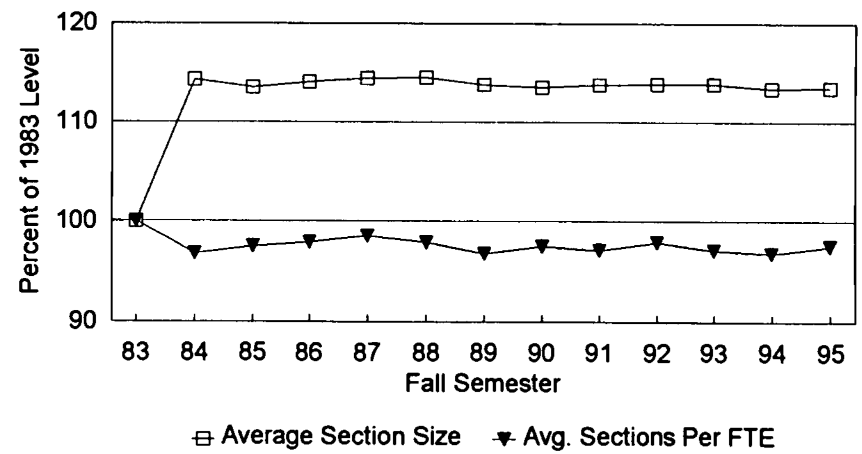
MODEL



ACTUAL



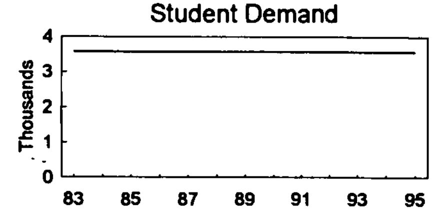
MODEL



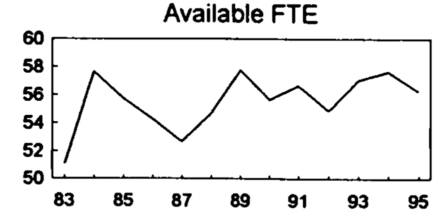
MODEL PARAMETERS:

Initial Enrollments:	2579	Section Size--		
Initial Sections:	144		Maximum	19
Initial Instructors:	51.1		Minimum	19
		Teaching Load--		
			Maximum	2.55
			Minimum	2.55

Student Demand



Available FTE



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Title: A System Dynamics Model of the Departmental Deployment of Instruct. Resources

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Date: May, 1996

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