APPLICATION OF LITTLE'S LAW TO ENROLLMENT MANAGEMENT PRACTICES IN HIGHER EDUCATION

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ABSTRACT

Little's Law is applied to university enrollment management in degree programs with capacity constraints. Using empirical data on graduation rates, number of credits taken per semester, and number of active students by program, calculated flow times from admission to graduation are compared to flow times predicted by Little's Law. Despite significant variability between students in part-time degree programs, due to students entering with varying transfer credits and taking varying credits per semester, the Little's Law model reasonably approximates the relationship between the inventory of current students, flow rates through each degree program, and flow times to graduation. This analysis utilizes institutional enrollment data and simple decision support tools.

INTRODUCTION

"Enrollment Management" often refers to recruiting and marketing to attract plenty of the appropriate students to fill academic programs. However, the "too much or too little" problem does not stop here. Universities with capacity constraints or excess capacity in specific schools or individual degree programs have enrollment management challenges extending beyond recruitment and admissions. The problem at the dean level is to match the student demand for specific schools and majors with the supply of available faculty and seats in courses.

In traditional, full-time undergraduate and graduate programs, enrollments are predictable, so the challenge is to match capacity (number of faculty, number of course sections offered, and number of seats available) to the projected demand. In university schools of continuing and professional studies, however, students progress part-time through undergraduate and graduate degree programs at variable rates.

A school's capacity (the supply of course sections and number of seats per section) can be adjusted to match demand in a flexible manner, subject to the budget for faculty salary expenses. In some schools, demand proportionally influences tuition revenues in the school budget. So matching supply and demand in academic operations is a key to managing enrollments, and success or failure can be measured in standard budget reports.

The operations research classic Little's Law (Little, 1961) describes the relationship between work-in-process inventory in a system to the flow rate of finished product exiting the system and the flow time from entry to exit.

$$\text{Average Inventory} = \text{Average Flow Rate} * \text{Average Flow Time}$$

This relationship has been used to describe diverse operations including assembly lines and supply chains, batch processes, queuing and job shop processes in Cachon and Terwiesch (2006) and numerous other sources. In this paper, this relationship is applied to describe the enrollment process from the time students enter a variety of university degree programs to the time of graduation.

This analysis has enabled more precise management decision-making under challenging scenarios such as the elimination of redundant or struggling academic programs, and the planning of new academic programs. This analysis also has supported the development of admission policies for specific degree programs, and has facilitated the preparation of class schedules by department, matching supply to demand in a cost-effective manner.

LITERATURE REVIEW

The seminal article that proved the relationship between the average arrival rate to a system, the average time spent in the system, and average number in the system appeared in *Operations Research*, over 45 years ago, Little (1961). This result does not depend on the underlying probability distributions of the arrivals or the order in which items are serviced. Since that time, there have been many, many applications in a variety of settings including queuing systems, Bertsimas and Nakazato (1995) and stochastic networks, Kook and Serfozo (1993). Tu, Chao, Chang, and You (2005) used Little's Law in an electronic wafer foundry to determine backup capacity to overcome bottlenecks in the production process. In the residential construction industry larger homebuilders sometimes view their production system as an assembly line process. It is in this context that Bashford, Walsh, and Sawhney (2005) examine the relationship specified by Little's Law to account for characteristics of construction projects that affect project performance and the resulting financial performance of the company. An important extension of Little's Law for situations where the long term, steady state relationships between average flow time and inventory do not hold but, instead the investigation of observed results over finite time periods (such as the sequences of semesters examined in this paper) are of interest, can be found in Kanet (2004).

Much of the enrollment management research has been based on marketing techniques. Bassin and Sellner (1997) present a step by step method to forecast the enrollments of college students who are well prepared as defined by a certain criteria. Bruning (2002) looked at enrollment management in the context of retention of existing students. His work showed that the attitudes held by the students regarding the public relationships of the university were important determinants in whether a not a student returned for the next year. Imenda and Kongolo (2002) examined the factors that explained a South African university's ability to sustain and raise its student enrollment levels against declining national enrollment in its category. We found no record of the application of Little's Law to enrollment management such as we present below.

METHODOLOGY

For an undergraduate operations management class project, Little's Law was applied to analyze demand measures over a five-year period in the University of Richmond School of Continuing Studies. A decision support system extracting enrollment data from the university database into Excel was used by administrators and the students to analyze flow rates, inventory of active majors, and flow times through degree programs, by degree program in each department.

Flow Rate - The flow rate of "product exiting the process" was the number of graduates per year, by degree program in each department, for the period Spring 2003 – Spring 2006.

Inventory - The number of active students in each degree program was determined for the period Fall 2002 – Spring 2007.

Flow Time - For each individual student, the flow time was calculated as the number of years between the term of admission and the term of graduation. The variability in students' flow times was calculated with a histogram and cumulative distribution table showing what percentage of these part-time students graduate within two, three, four or more years of entering a degree program. Student flow times vary widely, depending on transfer credits and number of credits taken per semester.

Excel Analysis – For graduation flow rates and flow times, a database administrator retrieved the relevant fields of source data, from the university database into Excel, including degree program, major department, admit term and graduation term for each graduating student in this time period. For inventory of active students, source data about students who took courses each semester were retrieved, such as degree program, major department, term code, and courses taken. The undergraduate operations management students then encoded and converted the data into a form usable for the analysis. (This was an opportunity to analyze a large amount of realistic data, and to experience Excel functions like filters, lookup tables, sorts, subtotals, IF statements, and histograms).

The calculation of flow time to graduation was determined to be more error-prone due to the way admit terms have historically been manually entered in the university database. Thus flow time was chosen to be the variable predicted by the other two variables, inventory and flow rate.

RESULTS

The bachelors and graduate degree programs in the University of Richmond School of Continuing Studies are part-time programs for working adults. Students take an average of two undergraduate courses per semester, or one graduate course per semester. Fewer students are active in the summer semester.

The Department of Information Systems has had non-stationary enrollments in the past five years, due to a national downward/flat trend in computer science and information systems in most universities during this period. Graduates exiting the system reflect enrollments starting about five years previously. Sample results for the bachelors degree program in the Information Systems department are summarized below.

TABLE 1

Flow Rate - Number of Graduates per Year

Bachelors Degree – Information Systems Major

2002	11
2003	13
2004	16
2005	15
2006	18

Average Flow Rate = 14.6 ISYS Graduates per Year

TABLE 2

Inventory of Active Students by Term

Bachelors Degree – Information Systems Major

Fall 2002	88
Spring 2003	80
Summer 2003	34
Fall 2003	72
Spring 2004	81
Summer 2004	38
Fall 2004	71
Spring 2005	76
Summer 2005	32
Fall 2005	62
Spring 2006	57
Summer 2006	20
Fall 2006	53
Spring 2007	57

Average Inventory = 69.7 Active ISYS Majors
(Over the fall and spring terms only)

FIGURE 1: # ACTIVE STUDENTS BY TERM
BACHELORS DEGREE - INFORMATION SYSTEMS

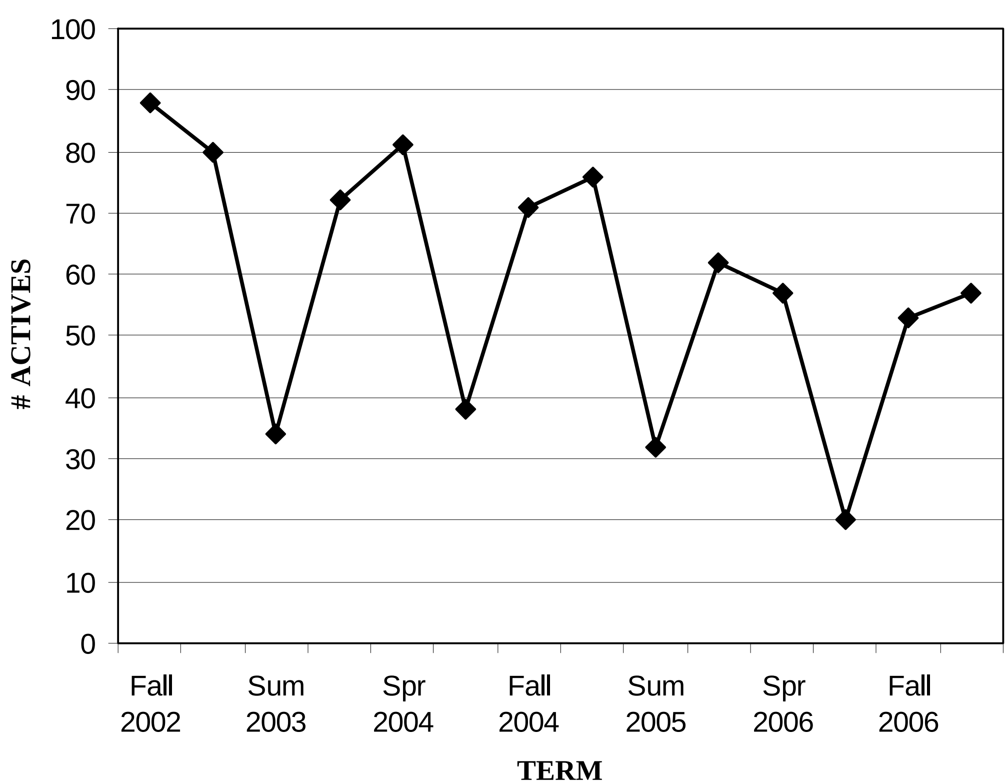


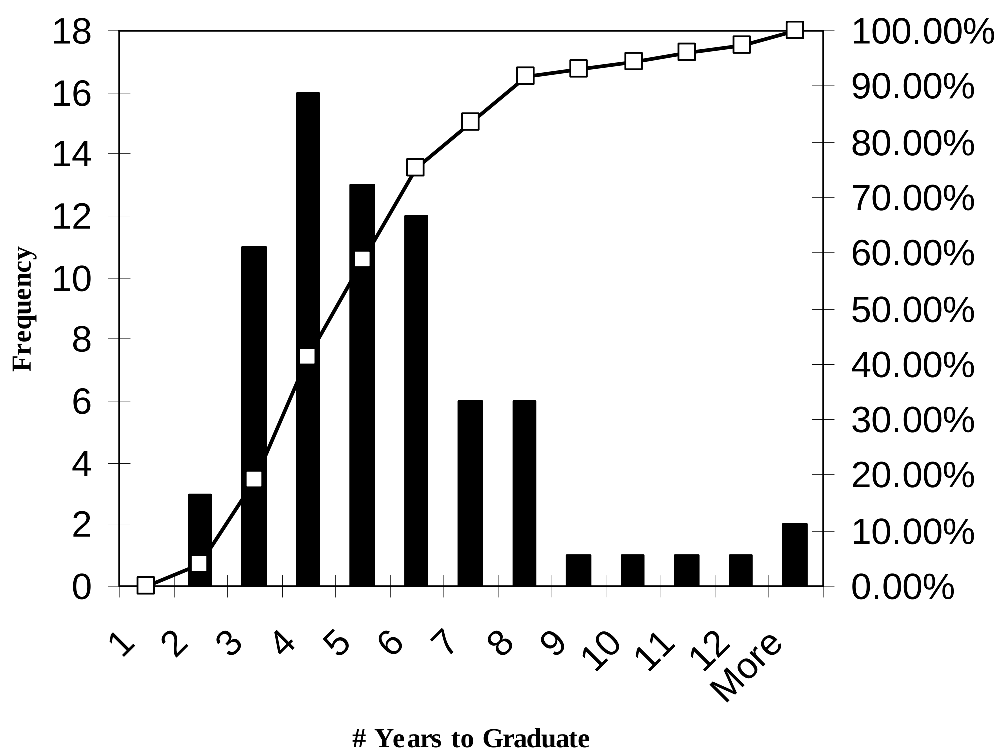
TABLE 3

Student Flow Times to Graduation

Bachelors Degree - Information Systems Major

# Years to Graduate	Frequency	Cumulative %
1	0	0.0%
2	3	4.1%
3	11	19.2%
4	16	41.1%
5	13	58.9%
6	12	75.3%
7	6	83.6%
8	6	91.8%
9	1	93.2%
10	1	94.5%
11	1	95.9%
12	1	97.3%
13	0	97.3%
14	0	97.3%
15	2	100.0%

FIGURE 2: Student Flow Times to Graduation
Bachelors Degree - Information Systems



Applying Little's Law to predict the average flow time to graduation, we find the predicted value to be somewhat lower than the actual, but closer to the median flow time to graduation for this degree program:

TABLE 4

ACTUAL VERSUS PREDICTED
AVERAGE INVENTORY, FLOW RATE, AND FLOW TIME
BACHELORS DEGREE - INFORMATION SYSTEMS MAJOR

	ACTUAL	PREDICTED (LITTLE'S LAW)
AVG INVENTORY OF ACTIVE STUDENTS *	69.7	
AVG FLOW RATE GRADS PER YEAR	14.6	
AVG FLOW TIME TO GRADUATION, YEARS	**5.2**	**4.8**

* Used fall and spring numbers to calculate this average; in the summer term, students are still active but not all of them take courses.

DISCUSSION

This analysis can be replicated by administrators utilizing institutional enrollment data and simple decision support tools. When deans and department chairs become knowledgeable about the number of active students, number of graduates per year, and the flow time to graduation, improved decisions can be made.

Whether or not a higher education institution is up for reaccreditation, the metrics in this paper are vital for continuous program assessment:

(1) To maintain enrollment levels, the number of annual admits must replace the number of annual graduates—understanding this flow rate metric allows concrete recruiting and admission goals to be set if increased (or decreased) enrollment is desired.
(2) In some degree programs, when there is a capacity constraint on enrollment, the number of active students in the program as well as the number of graduates per year must be tracked.
(3) Graduation rates and flow times to graduation are needed for routine institutional reporting.
(4) In part-time degree programs, these flow rates are directly tied to tuition revenues, and these metrics can support effective budget management.

Additional, reinforcing measures of flow rate in this application are illustrated in Figure 3 and Table 5:

Total Number of Credits Taken per Semester: When viewed by degree program in each department, this indicates the relative contribution and scope of each degree program in a school. Larger degree programs, or growing degree programs, can be monitored as critical success factors; struggling degree programs can be re-evaluated, and resources can be re-allocated to more effective uses.

Average Number of Credits Taken per Student per Semester: This measures student productivity and aggregate progress of these majors toward degree completion. This metric can have implications for student advising and communications.

FIGURE 3: NUMBER OF CREDITS TAKEN BY TERM
BACHELORS DEGREE - INFORMATION SYSTEMS

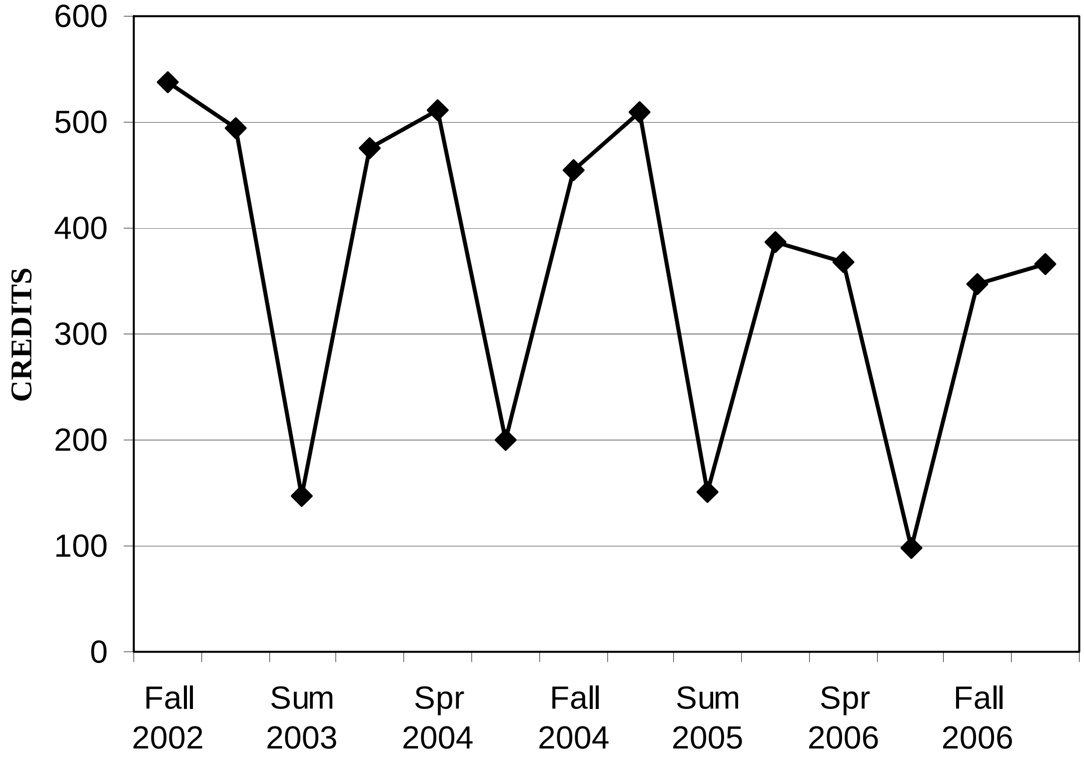


TABLE 5

Average Number of Credits Taken Per Student by Term
Bachelors Degree – Information Systems

Fall 2002	6.1
Spring 2003	6.2
Summer 2003	4.3
Fall 2003	6.6
Spring 2004	6.3
Summer 2004	5.3
Fall 2004	6.4
Spring 2005	6.7
Summer 2005	4.7
Fall 2005	6.2
Spring 2006	6.5
Summer 2006	4.9
Fall 2006	6.5
Spring 2007	6.4

This analytical approach has been used for managerial decision-making in the following ways in the Department of Information Systems. The metrics in this paper, used to understand aggregate demand from part-time students, have helped to make the scheduling of course sections more effective, to match supply of seats with the demand. Capacity utilization of available seats has improved. Furthermore, to offset a potential decrease in graduation rates in the next few years (reflecting the moving 4-5 year lag between the number of active majors and the number of graduates), the flow rate may be increased by intentional administrative measures, e.g., (1) promoting summer enrollments, and (2) by improving students' ability to take more credits per semester or per year. Improved course scheduling and student course planning, as well as some curriculum revision to remove some unwitting road blocks to degree completion, have been implemented to improve flow rates and flow times to graduation. Furthermore, in this particular example, enrollments are starting to increase again as of Fall 2007, due to external industry conditions. This analysis will track the effect of these factors on student productivity in degree programs, and signal when changes to capacity and other managerial actions may be needed.

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