The AIR Professional File

Spring 2021 Volume

Supporting quality data and decisions for higher education.

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LETTER FROM THE EDITOR

If you've spent the pandemic pondering how you can improve your institution's enrollment forecasting or better assess academic program viability, help has arrived in the Spring 2021 volume of the *AIR Professional File*. In this volume, you will find carefully constructed roadmaps for reaching both of these objectives, using basic tabulations and readily available data.

In his article, *Student Trajectories for Enrollment Forecasting, Management, and Planning*, R. Alan Bowman combines student enrollment patterns with new matriculant projections to accurately forecast enrollment. Further, the trajectory models can be used for diagnostic purposes and faculty planning.

Luna, Kendrick, and Johnson present an easy-to-create, ratio-driven metric in their article, *The Use of a Viability Index as a Better Measure of Departmental and Program Strength*. The authors explain why some widely-used indicators of quality and performance might be limiting or misleading. Their viability matrix diagram provides a readily understood visual of which departments or programs are strong and strengthening and which are weak and declining.

Don't hold back on sharing your ideas for addressing challenges faced by your IR colleagues! Your contribution to the *AIR Professional File* might be just what someone else needs to resolve their own data dilemma.

Sharron Ronco
Coordinating Editor

ISSN 2155-7535

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The Use of a Viability Index as a Better Measure of Departmental and Program Strength

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Abstract

Although many institutions and government agencies count degrees as the sole measure of determining departmental or program viability, this method fails to consider other factors such as how many students who are within programs are present to replace students who graduated from those programs or how many credit hours were generated in the area. This article highlights an easy-to-create, ratio-driven metric that can help an academic department or program to determine its overall strength.

Keywords: program viability, ratios, program prioritization, academic affairs, finance

The AIR Professional File, Spring 2021

Article 152

https://doi.org/10.34315/apf1522021

INTRODUCTION

As budgets become leaner and requirements for state and federal accountability grow stronger, higher education administrators are seeking to make smarter and more-effective business decisions to maximize revenue, cut costs, and reduce increases in tuition costs amidst a skeptical and financially strapped public. To achieve these goals, administrators must rely on performance indicators that are useful, effective, and easy to understand, and that can be used strategically to move the institution forward in uncertain times. Rather than relying on tried-and-true performance measures that carry little relevance, colleges and universities must explore the use of better means to measure institutional health. Therefore, higher education administrators, lawmakers, and the public should rely less on measures such as the Integrated Postsecondary Education Data System (IPEDS) graduation rates as part of the performance indicator toolkit; those rates were never intended to be a measure of institutional quality.

The purpose of this article is to briefly discuss the misconception behind traditional performance indicators as adequate measures of institutional or program strength, and to introduce ratios that are more logical and more useful in evaluating institutional health, academic strength, and program viability. Ratio analysis is one of the most powerful tools in higher education. Ratios are used as devices to analyze and interpret the health of an institution and to assist in determining the direction in which it should move. Ratio analysis can also help administrators evaluate whether the institution is doing better in a given year than it was the year before. In addition, ratio analysis can indicate if the institution is doing better or worse than other institutions within the same geographic location or with a similar role, scope, and mission.

THE FALLACY BEHIND THE IPEDS 6-YEAR GRADUATION RATE

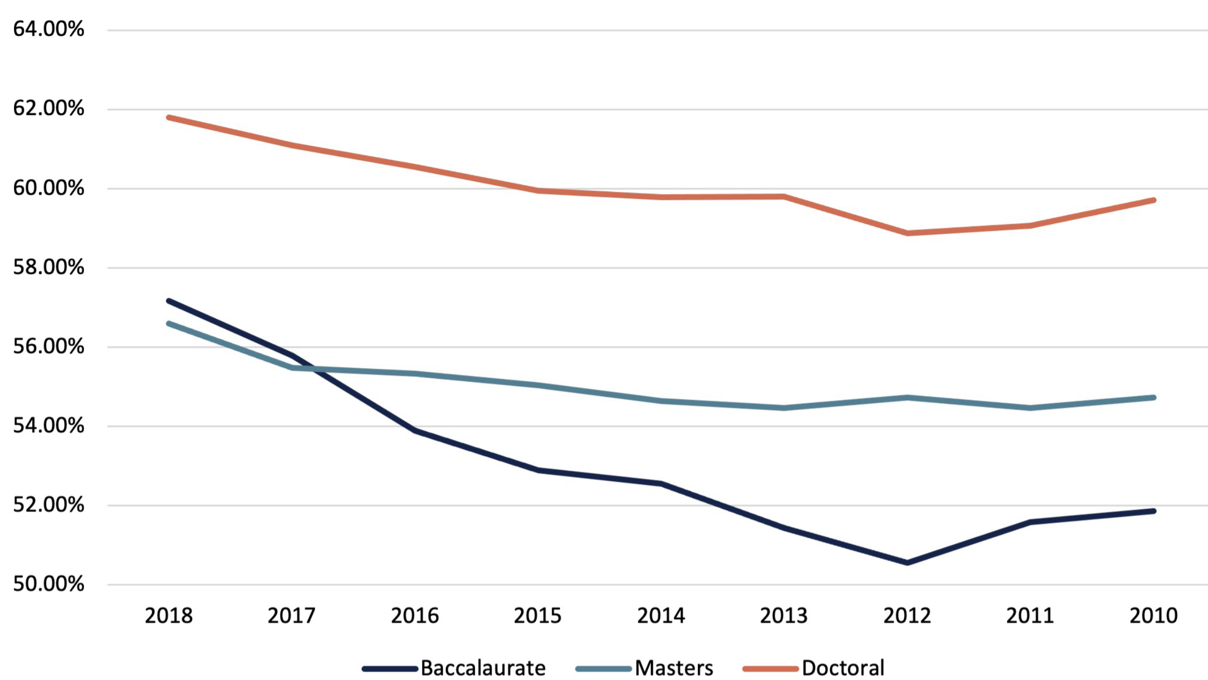
To say that the IPEDS graduation rate is heavily used by higher education as well as by those governmental and media institutions that monitor the rate's progress is an understatement. The graduation rate is used within institutional promotional materials, performance indicators for state funding, college rankings, peer reviews, and federal government oversight. This little-understood statistic is freely repeated by administrators, legislators, and news reporters with little regard as to how the number is defined and why it was initially used. Briefly, the IPEDS 6-year graduation rate begins with all first-time, full-time, degree-seeking undergraduate students. This group is placed into a cohort and tracked over a period of time to determine which of these students graduated, which are still attending, and which have left the institution. Therefore, the 6-year rate is the total number of students within the cohort who graduated within a 6-year period divided by the total number of the cohort within the first-year class. This statistic, however, was never intended for use as an overall measure of institutional health or effectiveness. Rather, it was used to help track the success of student athletes.

In 1985 the National Collegiate Athletic Association (NCAA) began to require its member schools to report graduation rate data so that the organization could compare student athletes to the non-athlete student body (Brown, 2014). Given that most NCAA student athletes are not transfer students, are required to attend school full time, and must be degree seeking, it was natural to create a comparative database with these attributes.

Seeing that these comparative data were useful, US Senators Bill Bradley and Edward Kennedy introduced the Student Right-to-Know and Campus Security Act in early 1989. While the institutional comparisons were required within NCAA, the federal bill, which was passed into law in 1990, tied Title IV funds to its new mandate (Brown, 2014). Congress was concerned that the significant revenue from college games was so great that the educational mission of the university is too easily forgotten, and their fears were supported. In 1989 a US General Accounting Office (GAO) report found that, within the NCAA's largest schools, the graduation rates of men's football and basketball athletes were significantly lower than the graduation rates for all other students (GAO 1989). It is clear that, although the law was intended to protect the educational interests of students, many administrators and lawmakers found the new comparative data to be extremely useful for other analyses as well.

According to Cook and Pullaro (2010), looking at the first-time, full-time cohort gives only partial information because this group accounts for only about 60% of the total aggregate entering class within institutions. That means that 40% of the entering class is not included in the IPEDS Graduation Rate Survey (GRS) report. Looking at trend data by highest degree offered from 2010 to 2018 through the IPEDS data retrieval system, one can observe that, among the masters- and baccalaureate-granting institutions, roughly 45% are not in the GRS cohort; and among the doctoral-granting institutions roughly 40% are not in the cohort (Figure 1).

Figure 1. IPEDS GRS Cohort as Percentage of Total Entering Class by Highest Degree Offered



With such a large number of students not being counted in the official graduation statistics due to students that either attend part time or have transferred from another institution, many have argued that the traditional GRS statistics is ineffective in determining institutional viability and strength. In fact, the National Center for Education Statistics announced in 2017 that new captured data would allow institutions to report graduation rates of part-time and transfer students (Lederman, 2017). While many, especially within the 2-year schools, applaud the decision, others believe that the move may be too little and too late.

In an effort to generate more accurate performance measures, greater attention has been given to alternative methods than to traditional graduations rates and measures of institutional viability. One such alternative method is to use a ratio of degrees to the number of students enrolled. This ratio can be observed from the institutional level down to the degree level. According to Cook and Pullaro (2010), the degree-to-enrollment ratio (DER), unlike graduation rates, provides valuable information on both enrollment trends and completions trends. Accordingly, DER is gaining popularity and has been used by the American Council on Education as well as by the Delta Cost Project, which is a combined database project between the National Center for Education Statistics and the American Institutes for Research to provide analyses and resources to aid in the understanding of what colleges do with their money

OTHER PERFORMANCE MEASURES USED

In addition to the 6-year graduation rate, other performance indicators have been used by state agencies with varying degrees of success. According to a report from the National Conference of State Legislatures (2015), 32 states have some type of performance-based funding model for their higher education institutions, with many of the outcome measures at the institutional level. Some models do include outcome measures at the department or program level.

For instance, one measure used in many models is a count of the number of degrees granted over time. Usually there is a threshold to meet: the average number of degrees during a specific period cannot fall below a certain number. Credit hour completion is another widely used measure whereby institutions track the percentage of students who complete 30, 60, and 90 credit hours. Additional performance measures include enrollment counts by major, course completion rates, and number of students who transfer in to the institution.

Simple whole or mixed data are used in most of these measures with percentage of achievement present in some. Most of these measures address only one component of viability. For instance, a state may be interested in a count of graduates by program over a period of 3 years where the average number of degrees should not fall below 10 for undergraduate students. While this measure is important, it does not take into consideration the number of credit hours that each department or program may generate to support other programs and/or the core curriculum.

One measure that is used by a few states is the number of degrees earned per 100 full-time equivalent (FTE) students. This measure clearly takes into consideration both the number of degrees and the number of FTE students within that department or program. Because degrees are being compared with credit hour production through the FTE calculation, the resulting quotient can be nebulous and difficult to understand. Moreover, since different institutions and state agencies often calculate FTE differently, the resulting measures may get lost in translation. Though this particular measure is limiting, the concept of using ratios becomes compelling.

THE USE OF RATIOS IN HIGHER EDUCATION

While the use of ratio analysis is mainly found in finance, it should not be confined to that area. Various types of managers and administrators should be interested in ratios so that they can better understand the institution as a whole and the division and/or department in which they reside, or to understand how various components within an institution relate to each other (Tahey et al., 2010). Therefore, ratios have wide applications and are of vital importance in the overall management of higher education. For instance, ratio analysis may be used for the following:

- Decision-making: Ratio analysis helps in making decisions from the information provided in financial, enrollment, and resource situations. It can be used by an individual academic department to determine if a new program should be established, or it can be used institutionally as part of its strategic initiatives regarding enrollment management, pricing, outreach, and so on.
- Forecasting and planning: Ratios calculated for a number of years can serve as a guide for the future. Meaningful conclusions can be drawn as to the overall positioning of an institution in relation to where it wants to go.
- Communication: The strengths and weaknesses of a department or program can be communicated to both internal and external constituents in an easier and more-understandable manner by the use of ratios. The information obtained through ratio analysis can also be conveyed in a meaningful manner to the individuals for whom it is meant, allowing for quicker response or action.
- Coordination: Oftentimes, higher education tends to work in silos where one department or division seems to work independently of another department or division. The use of ratio analysis can help tie these silos together by easily conveying the connections of the various components within higher education.
- Control: Ratio analysis helps to create effective controls throughout the institution. Standard ratios can be used to take a corrective action at the right time or to prevent a situation from ever happening. Furthermore, by controlling various elements within the institution, it may more effectively reach its strategic objectives (Minter et al., 1982).

The basis for the effective application of ratio analysis is a clear understanding of the institutional mission as well as those strategic steps to take the institution into the future. Every institution should have a mission that is tied to both financial and nonfinancial measurement to help it gauge its progress. These measures help guide the institution in determining what resources are available and how it will use those valuable resources.

This is all part of the strategic management model discussed by Brown (1986). This model (Figure 2) allows an institution to develop how it will move forward based on an established mission as well as on measurable indicators.

Figure 2. Strategic Management Model

Source: Brown 1986.

In order to realize its desired outcomes, the institution defines its mission, vision, and values; determines its key success factors and business fundamentals; establishes goals and objectives; and forms strategies. Clearly, ratios can serve as a major component of this process.

So, why is it important to use ratios over simple whole or mixed data? The use of only whole or mixed data may be fallacious and could have a negative impact on the institution. For instance, an institution may believe itself to be in good shape when it sees increases in new first-year enrollment from year to year. This trend could be misleading, however, if the yield rate of high school students from the traditional feeder schools is actually decreasing. In other words, although new first-year numbers might be increasing, the institution might actually see a decrease in the total number of high school graduates who could enroll. For example, say an institution enrolls 500 students from a high school graduating class of 1,000. The yield rate in this example would be 50%. The following year, the institution enrolls 550 students from a graduating class of 1,500. While there is an increase in the number of students enrolled from 500 to 550, the yield rate of students who could enroll dropped from 50% to 37%. This yield gives a better picture of enrollment than the primary data alone.

Simple whole or mixed data in themselves are a report of an event that has no economic meaning. These numbers stand alone, and are unrelated to anything else that they affect or that affects them. To make events meaningful, those numbers must be compared with data that relate to them (Tucker, 1961). For example, if a vehicle is driven 300 miles in a day, this statistic has no relationship to the vehicle's fuel economy. If it is driven 300 miles on 20 gallons of gasoline, however, the economy evaluated can be said to be 15 miles driven for every gallon of gas consumed. This is considered an elementary ratio (Tucker, 1961). Distance traveled is not the only factor in the economy of the vehicle, however. Other factors include the speed at which the vehicle traveled, the terrain on which it traveled, and the size of the vehicle itself, among others. When these factors are combined, the results create an advanced or tertiary ratio that gives a better picture of the vehicle's economy.

Simple data have absolute values, ratios have only relative values in that they have no real meaning unless they are observed longitudinally. Only when they are so observed can the true value of the ratio be appreciated. Preparing ratios can be a daunting task, however. Higher education institutions have so much simple data that it can be difficult to decide which data to use and how to relate them with other data.

The researcher begins by asking the question, "What does the institution want the ratio analysis to tell it?" Later, the researcher must ask, "What can the institution do with the information?"

A CLOSER LOOK AT THE VIABILITY INDEX

While simple or elementary ratios provide a higher quality of managerial information than primary data, they do have their limitations. Specifically, elementary ratios capture only a portion of an event or action and, therefore, may be artificially isolated from other factors that have an impact on the overall decision process. Once two primary pieces of data are used to create various elementary ratios and those ratios are tracked over a period, important information can be obtained from their relationship. This information is limited, though, because the inferences or assumption constructed on elementary ratios are based solely on the data elements used to create them and have no bearing on the external relationships that exist with other important data.

Within an academic department, the number of majors (i.e., students in programs) and graduates within those programs is very important in order for researchers to address overall health and viability. In general, the more majors there are to replace the students who graduate and leave the program, the better or more viable that department is. The primary data of majors and graduates can be useful, especially when combined into an elementary ratio where the relationships between majors and graduates can be compared with trend analysis. Again, according to Cook and Pullaro (2010), the DER, unlike graduation rates alone, provides valuable information on both enrollment trends and completion trends. While these data are important when addressing the strength of the major, other factors (e.g., credit hour production), which give a more-complete story about the department, are not contained within the ratio.

Credit hour production is another important element to measure departmental viability: the amount of credit hours produced by a department is a direct measure as to how much tuition revenue that department generates for the institution. Furthermore, credit hour production transcends the count of student majors and graduates within a department because it demonstrates to what extent a department provides academic support for other programs outside the department as well as the department's contribution to the institution's undergraduate core curriculum. Therefore, any analysis of departmental viability should contain information on the counts of majors and graduates as well as credit hour production.

In order to get broader, more-effective ratios to address program viability, higher-order ratios are required. These more-advanced ratios combine elementary ratios and/or other simple data in a way that gives more-precise information that is broader in scope within the department (Tucker, 1961). As used in this article, the Viability Index is a higher-order ratio that combines two elementary ratios:

$$\text{Viability Index} = (\text{Majors}_j / \text{Degrees Awarded}_j) * ((\text{Department CHRS}_j / \text{Institutional CHRS}_j)*100)$$

Whereas,

j = academic year

CHRS = credit hours

Majors = Number of students who declared majors within an academic department during period *j*

Degrees = Number of degrees awarded within an academic department during period *j*

Department CHRS = Total credit hours generated by an academic department during period *j*

Institutional CHRS = Total credit hours generated by institution during period *j* [/]

For purposes of this article, only undergraduate data are used from a public university in the US Southeast. While the Viability Index is equally useful for graduate degrees, students, and credit hours, it is not used in this article in order to focus on the process of gathering and analyzing the ratios rather than the difference between the undergraduate and graduate indexes. If graduate programs are used in the model, credit hours would need to be weighted based on course level and/or discipline. Accordingly, the ratio of majors to degrees awarded will be referred to as the replacement ratio, whereas the ratio of department credit hours to institutional credit hours will be referred to as the production ratio. When combined into a higher-order ratio, the seminal elements of departmental production and replacement can be assessed together with minimal effort. Since the outcome measure of the Viability Index is a score between 0 and 100, those departments with higher scores are, in effect, more viable than departments with lower scores. Furthermore, by observing trend data, it is relatively easy to track whether a department's viability is improving, staying the same, or declining.

MAJORS TO DEGREE RATIO (REPLACEMENT)

This elementary ratio determines the institution's strength to replace graduating students with other students. These other students consist of both new majors and existing majors. Therefore, a 6:1 ratio indicates that, for every student within a department who graduates, there are six students earning credit hours who are replacing that graduating student. It is understood that, throughout the United States, not every student attending a college or university will graduate from that institution. In some cases, the student will transfer to another institution, and, in other cases, the student will stop out or drop out of higher education altogether. It is important, therefore, that an academic department or program ensure there are enough students enrolled in a given year to replace those students who graduated that same year.

Historically, undergraduate ratios of between 6:1 and 10:1 are considered strong for an academic program, while ratios between 4:1 and 6:1 are considered strong for graduate programs. Numbers significantly lower than these may signal a degeneration of the department or program because, if the trend does not change, there will not be enough majors to support those students who graduate, leading to negative growth and possibly the demise of the program. To the contrary, significantly higher ratios do not necessarily signify stronger programs. A significantly higher number of majors than graduates could indicate areas where there is high attrition. In other words, while many students are entering the program, most will change to other programs within the institution or transfer to other institutions.

An example of the replacement ratio is found in Figure 3. Here, three departments are shown with total enrollment, total degrees awarded, and the replacement ratio. The ratio for Department A is a little over 7:1, signifying that there is an adequate number of majors to replace those students who graduated. Department B, however, indicates that there is just over a 1:1 ratio of majors to graduates, indicating that, even though the enrollment of majors is high, the department has barely enough majors to support the graduates it is losing. To the contrary, Department C demonstrates a very high replacement ratio, indicating possible high attrition for the department. This higher ratio could also be present when departments or programs are new and, therefore, have not yet built up the graduate base. The higher ratios could also follow a significant internal program redesign, or could be influenced by external market factors. Again, when analyzing these ratios it is important to observe them longitudinally and in context to what is happening within the department.

Figure 3. Replacement Ratio Example

Replacement Ratio Example			
Measure	Dept. A	Dept. B	Dept. C
Majors	235	325	427
Degrees Awarded	31	265	11
Replacement Ratio	7.58	1.23	38.82

While this ratio is more effectively used within an individual academic department or program, it is also useful to an institution by college or in the aggregate.

DEPARTMENTAL CREDIT HOURS TO INSTITUTIONAL CREDIT HOURS RATIO (PRODUCTION)

This elementary ratio is the percentage of total institutional credit hours generated by a particular department in relation to the total number of institutional credit hours generated. The higher the percentage, the more the academic department is contributing to institutional credit hour production. The production of credit hours within a department usually takes on at least one of three different forms. First, the department will generate credit hours to directly support the programs within the department. For example, the biology department generates credit hours in biology courses for students within the biology program. Second, departmental credit hours are generated because of support and/or fulfilment of courses within another department. An example would be nursing majors who need biology courses as part of their program requirements. A third form would be departmental credit hours that are generated as part of an overall institutional requirement. For example, students fulfilling their core curriculum requirements have the option of taking biology courses as part of their science core requirements.

Depending on the academic department, the amount of credit hours generated within each of the three forms is dependent on the role of the department. For example, the English department will generally produce many credit hours even though it may have a small to moderate number of majors. This production is mainly attributed to the general education core required courses offered within the English department. In contrast, however, the nursing program's credit hour production is focused primarily on nursing majors.

An example of the production ratio is found in Figure 4. Here, the departmental credit hour production is compared to credit hour production for the institution. As can be seen, Department A indicates a larger percentage share of credit hours as compared to both Departments B and C. This larger share could typically mean that the department might not only be generating credit hours for the major, but might also be supporting the core curriculum as well as other programs. Department B indicates an average share of credit hour production while Department C demonstrates a department with a much smaller credit hour share. Observing the ratio longitudinally will clearly indicate the position of a department or program regarding its credit hour production.

Figure 4. Production Ratio Example

Production Ratio Example			
Measure	**Dept. A**	**Dept. B**	**Dept. C**
Institutional CHRS	265,100	265,100	265,100
Department CHRS	25,400	11,050	3,250
Production Ratio	9.58	4.17	1.23

Note: CHRS = credit hours.

Similar to the replacement ratio, the production ratio is used most effectively within an individual academic department or program, but it is also useful to an institution by college or in the aggregate.

THE RELATIONSHIP BETWEEN REPLACEMENT RATIO AND PRODUCTION RATIO

While most performance indicators within higher education revolve around one or two primary measures, the Viability Index is based on two ratios and four primary sources. Observed independently, both the replacement and the production ratios can impart information that primary data alone cannot. For instance, the replacement ratio indicates how strong a department or program is by how many majors are available to replace those who graduate. Clearly, because overall enrollments are dwindling nationwide, it becomes increasingly important for a department as well as an institution to determine both high-demand and low-demand programs.

Observed over time, the replacement ratio discernibly tracks demand growth and whether a department can recruit and maintain enough majors to support it. While the replacement ratio is an important component to overall departmental or program health, its information is limited. For instance, some departments may not have had as many majors as others but they produce many credit hours in the form of general education. In order to reinforce the role, scope, and mission of the institution, administrators should also look at how the department or program supports the institution in terms of overall credit hour production. In this instance, the production ratio's market share measure ensures that all departments or programs are being assessed by how many credit hours they produce as a percentage of total institutional credit hours.

The Viability Index, therefore, becomes a fine balance between how many majors a department or program can recruit and maintain as well as how many credit hours it produces for the department and the institution. The Viability Index is seen in Figure 5 where two theoretical departments are shown with the primary data of majors, degrees, and credit hour production, along with the subsequent replacement and production ratios. Within Department X, the replacement ratio is lower than within Department Y, indicating fewer majors in Department X to replace students who graduate or leave than in Department Y. Department X is producing a significantly higher number of credit hours as a percent of total credit hours than Department Y produces, however. In each case the department could make the argument that it is equally supporting the institution, but in different ways. Because the Viability Index takes both the replacement and production ratios into consideration, the overall index value will determine which of the two is stronger.

Figure 5. Relationship between the Replacement and Production Ratios

Relationship between the Replacement and Production Ratios		
Measure	**Dept. X**	**Dept. Y**
Majors	185	265
Degrees Awarded	65	61
Replacement Ratio	**2.85**	**4.34**
Institutional CHRS	265,100	265,100
Department CHRS	12,751	7,105
Production Ratio	**4.81**	**2.68**

Note: CHRS = credit hours.

Once the replacement and production ratios have been computed, the Viability Index is calculated by simply taking the product of the two ratios. As shown in Figure 6, Department Y has a higher replacement ratio while Department X has a higher production ratio. When the product of the two are calculated, the difference in the Viability Index between the two departments is negligible. Therefore, departments with higher replacement ratio but lower production ratio, or vice versa, in this case can use the Viability Index equally to demonstrate overall health.

Figure 6. Viability Index

Viability Index			
Unit	**Replacement**	**Production**	**Viability**
Dept. X	2.85	4.81	13.69
Dept. Y	4.34	2.68	11.63

APPLICATION OF THE VIABILITY INDEX

Now that the Viability Index has been defined and demonstrated, the three panels in Figure 7 will indicate how the index is used with an actual institution. Here, the Viability Index was computed for all academic departments within a public masters-comprehensive university in the Southeast. The three panels of Figure 7 demonstrate the Viability Index over a 3-year period. The individual bars indicate the departments while the horizontal lines denote the average annual Viability Index for all departments. The Y-axis indicates the Viability Index. At first glance, all three panels clearly show those departments that are performing close to or above the mean, while other departments indicate performance well above or below the mean.

Departments 5, 14, 15, and 18 show strong viability while Departments 2, 3, 16, and 24 indicate significantly weaker viability. Department 1 has decreased viability during the 3-year period while Department 17 has steadily increased viability. According to all three panels, Department 26 is very low in viability. This lower index score is, in part, attributed to lower market demand for this particular major. Conversely, Department 27 indicates an increase from the first year to the second and a significant increase from Year 2 to Year 3. This increase is due, in part, to a redesign of the program during the second year and was mainly driven by the increased number of majors.

Figure 7a. Viability Index by Department, 2018–2019

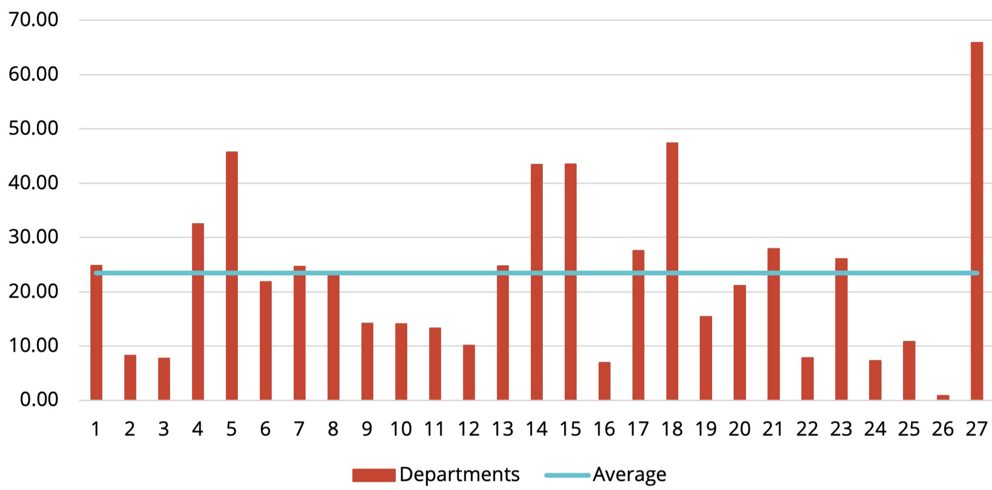


Figure 7b. Viability Index by Department, 2017–2018

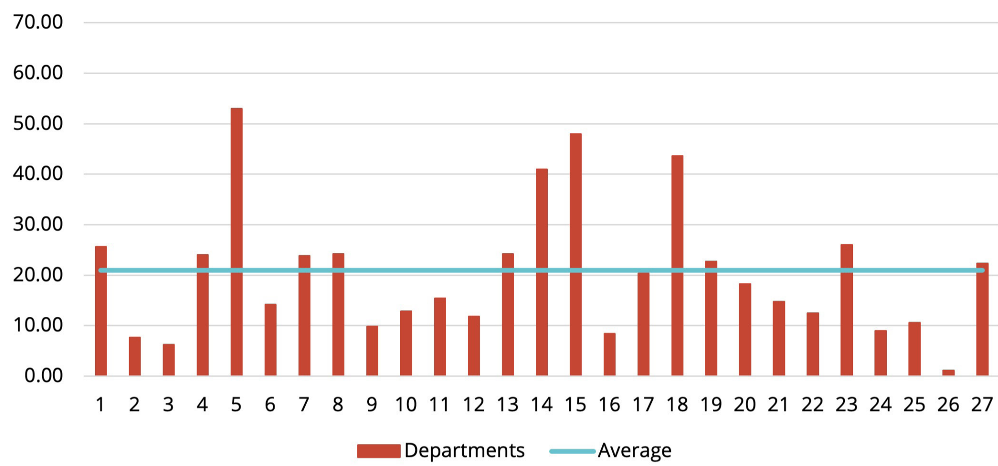
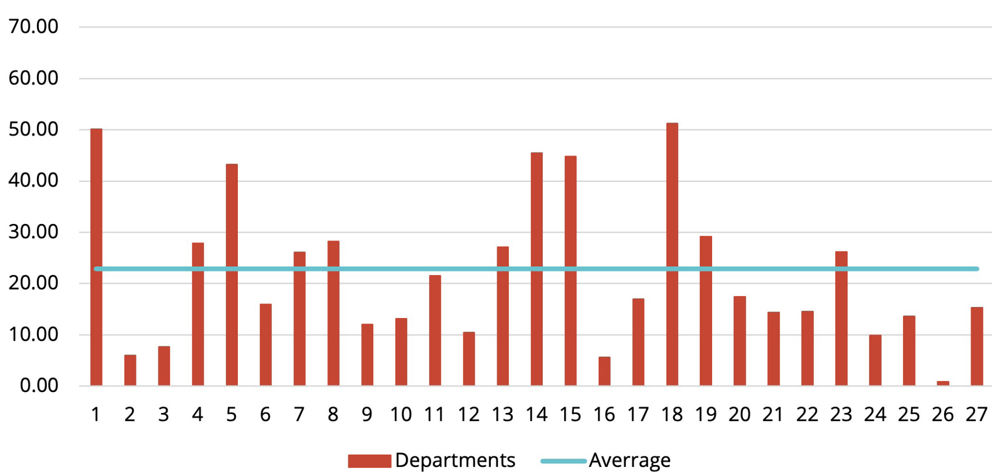


Figure 7c. Viability Index by Department, 2016–2017

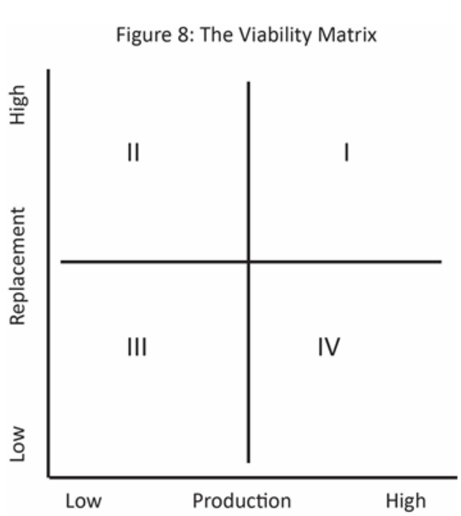


THE MATRIX: ANOTHER WAY OF DETERMINING OVERALL VIABILITY

When used together, the replacement ratio and the production ratio give a multidimensional view of a department's/program's viability. While the replacement ratio is a good measure of recruiting and retention strength, the production ratio indicates how much revenue is generated in relation to the institution as a whole. Combining the two ratios into a single measure or Viability Index reveals how the balance of the two ratios serves as a practical measure of overall departmental/program health. This balance between the replacement ratio and the production ratio can be also demonstrated in a matrix form. As shown in Figure 8, the 2x2 matrix reveals four possible quadrants or states into which each department or program may fall.

The Y-axis represents the replacement ratio while the X-axis represents the production ratio. The vertical line indicates the mean value of the production ratio for all the departments/programs while the horizontal line indicates the mean value of the replacement ratio for all the departments/ programs.

Figure 8. The Viability Matrix



Quadrant I indicates those departments or programs that have a higher replacement ratio and a higher production ratio. Unless the replacement ratio is very high (indicating possible attrition), departments or programs within this state would be considered strong. Quadrant II depicts a higher replacement ratio with a lower production ratio. Departments or programs falling within this state, while healthy, experience lower credit hour production and, generally, may not be either high-demand programs or programs that offer significant general education credit hours.

Quadrant III indicates a state where the department or program experiences a lower replacement ratio and a lower production ratio. Contrary to Quadrant I, those departments or programs falling into this state are considered weaker. Quadrant IV indicates a lower replacement ratio and a higher production ratio. Departments or programs falling within this state, while healthy, experience fewer students to replace those who are graduating. If significant, this decrease in students could be attributable to changing market conditions for the major.

As with ratios, the matrix is best observed longitudinally where year-to-year changes can be detected. From this vantage point, it is easy to see if a department/program stays in the same quadrant, shows gradual movement from its current quadrant to another, or experiences a significant shift from one quadrant to another.

Furthermore, when reading the matrix, it is important to notice the department's or program's position within the quadrant. For example, departments or programs that fall close to where the horizontal and vertical lines connect (equilibrium), or those that are close to another quadrant are in a marginal state and, through time, could move from one quadrant to another. Those departments or programs that are deep within a quadrant, however, are assumed to be in a stable position.

APPLICATION OF THE VIABILITY MATRIX

Examining the same departments within a public southeastern masters-comprehensive university as was used earlier, Figure 9a indicates that the replacement ratio mean is almost 7:1 while the production ratio mean is almost 4:1 for Year 1. Departments 1 and 11 have significantly higher replacement ratios than most of the other departments, skewing the mean and causing the other departments to cluster close to the horizontal and vertical lines. Department 18 is slightly within stronger Quadrant I along with 8, 19, and 4. The majority of the departments, however, fall within Quadrant III, indicating possible weakness. Many of these departments are close to either Quadrant II or Quadrant IV, however, indicating that further observation during subsequent years is needed to determine if the observed values are stable or shifting.

Plotting the matrix for Year 2, Figure 9b clearly reveals change and indicates that Department 1's higher replacement ratio the year before did affect other departments as well. In this panel, Department 1's higher replacement ratio was not a factor and, subsequently, many of the departments in Quadrant III during Year 1 moved to Quadrant II. This indicates that Department 1's replacement ratio did tend to skew the other departments. Department 10 moved horizontally from Quadrant IV to Quadrant III, however, and Department 17 moved diagonally from Quadrant IV to Quadrant II, indicating that departmental change was not caused solely by the skewness of Department 1's replacement ratio during Year 1.

Figure 9a. Production Ratio in Relation to Replacement Ratio by Department, Year 1

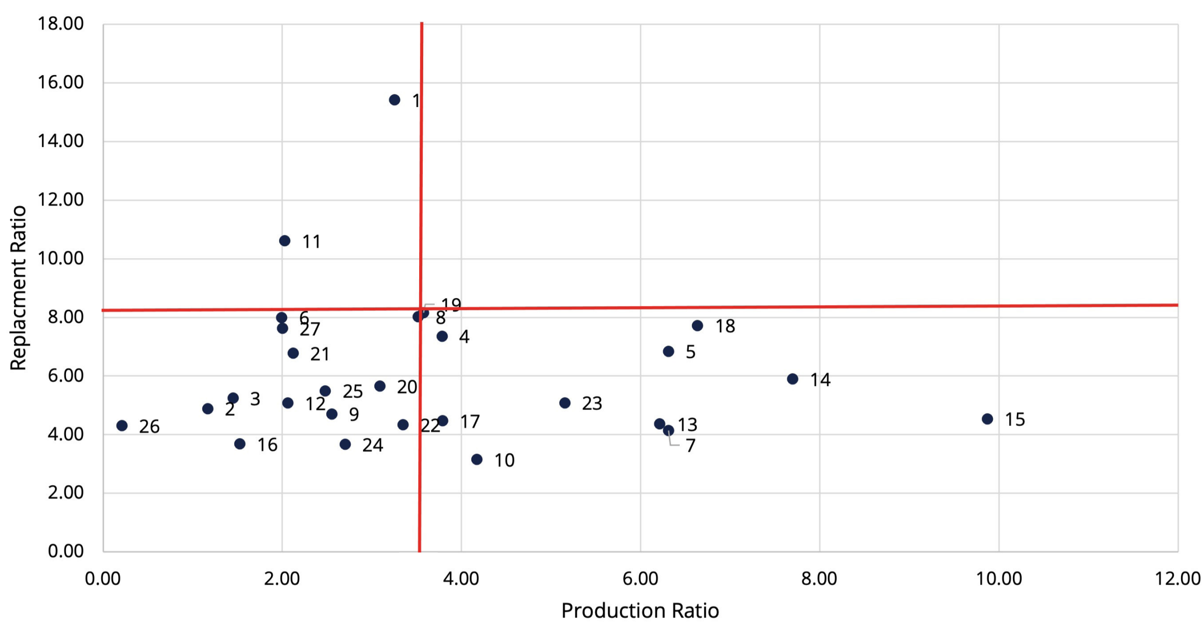
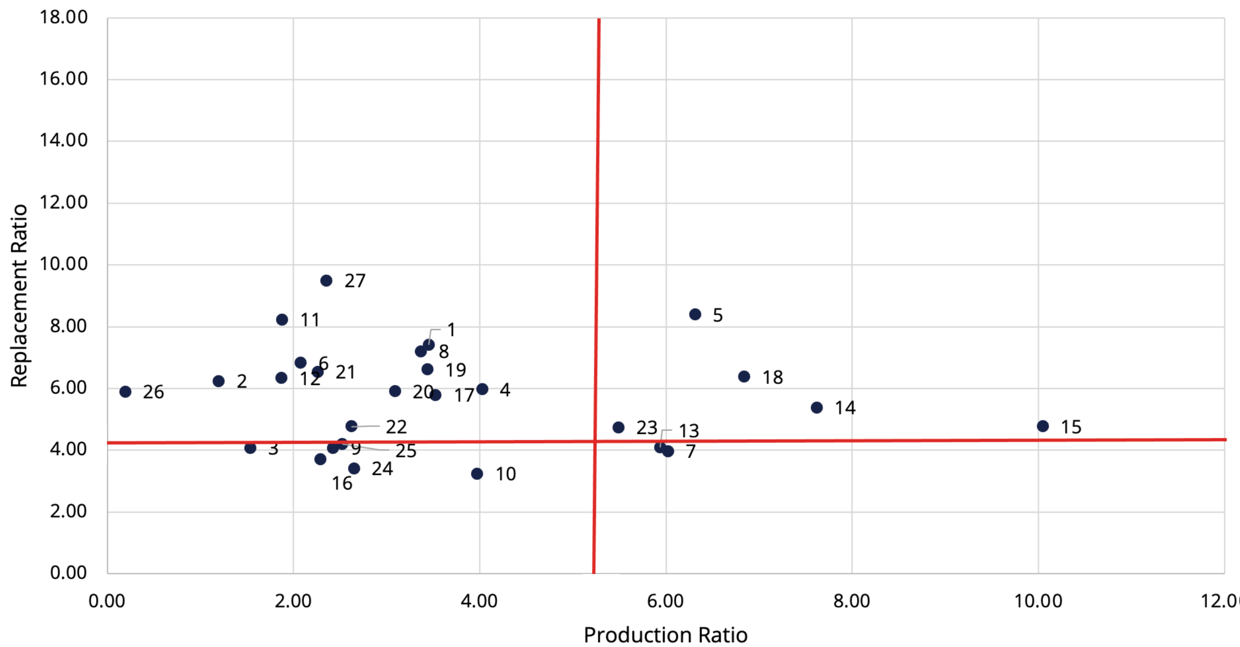


Figure 9b. Production Ratio in Relation to Replacement Ratio by Department, Year 2



By observing the matrix diagram each year, it is possible to determine which departments or programs are strong and strengthening or which ones are weak and declining. Using the strategic measurement model discussed by Brown (1986) above, one can determine how a department or program's placement on the matrix adheres to the institution's success fundamentals as well as its long-term goals and objectives. Employing strategic planning, the administration may decide to maintain current support for the department or program, allocate resources to increase promotion and recruitment, consolidate the department or program within another department or program, or defund the program and use the saved revenue to enhance stronger programs.

One drawback from using the matrix is that the variation of the replacement and production means could be caused by a significant upward or downward shift of only a few departments (skewness), so program strengthening/weakening may be masked by the fact that the mean from one year to the next shifted. To address this issue, the ratios should be evaluated on their own as well as in the relative context of the mean.

Because both the Viability Index and the Viability Matrix are easy to create, read, and understand, these tools can be shared with deans and department chairs for use in strategic planning, program reviews, and resource allocation.

USING THE VIABILITY INDEX WITH DEPARTMENTAL BUDGETS

Although the Viability Index by itself produces a lot of information about the strength of an academic program or department, an examination of expenditures is also important to understanding completely how well a program or department is doing. Clearly, some programs like science, engineering, and music cost significantly more to operate than do others like English, history, or sociology. Therefore, departments with the same Viability Index may be considerably different regarding its expenditures, and this factor should be taken into consideration when looking at the overall health of a department or program.

The focus of this article was to introduce the concept of the Viability Index in its purest form. Budget numbers were intentionally left out of the calculation of the index for the following reasons:

- The strength of the Viability Index should stand alone from the budget because it is concerned only with the recruitment of majors, replacement of graduates, and the production of credit hours. These are all key components to program or departmental viability.
- While the Viability Index is designed to be computed at multiple levels of the institution, adding a budget component to the index would be problematic, especially at the program level. Within the academic area, most budgets are distributed at the department level and are not readily divided or accounted for within the program level.

However, now that a single Viability Index can be created that considers majors, graduates, and credit hours, the index could be easily used as a divisor with the departmental budgets to create a cost per unit of viability (CPUV).

For example, say Department A has a Viability Index of 20.02 and a departmental budget of $1,102,054. The budget divided by the index would be a $54,557 CPUV. Department B has the same index of 20.2 but a budget of $524,142. The CPUV for this department would be $25,948, which is considerably less than Department A. Therefore, the viability of budget numbers as compared to the Viability Index can give a dynamic and comprehensive overview of how a department is actually doing.

The institution will need to decide what expenditures are used. In most cases, nonpersonnel or academic support (equipment, supplies, software, etc.) could be parsed out of total expenditures to determine the CPUV.

CONCLUSION

As this article has demonstrated, ratio analysis can be a powerful tool in higher education. Ratios can be used as devices to analyze and interpret the health of an institution and to assist in determining the direction in which it should move. Ratio analysis can also help administrators evaluate whether the institution is doing better in a given year compared to the previous year; in addition, it can indicate if the institution is doing better or worse than other institutions within the same geographic location or with a similar role, scope, and mission.

Academic departmental or program viability is, in large part, a function of the ability of a department or program to attract and retain students as well as to generate vital revenue through credit hour production, to support the department as well as the institution. While the success of a department or program can also depend on factors outside the institution such as the economy, availability of high school students, and the marketability of the program, other components can be controlled by the department. Past methods of determining viability have typically used only one of these important components. The Viability Index, however, clearly measures the strength of a department in relation to the degree to which it is able to replace its graduates while also determining how many credit hours it generates in relation to the overall institution.

The Viability Index is the product of the replacement ratio and the production ratio. These two ratios are relatively easy for administrators or an institutional research office to obtain and analyze, and both the index and matrices are easily understood and can be used in strategic planning, program review, and resource allocation.

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Student Trajectories for Enrollment Forecasting, Management, and Planning

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Abstract

The School of Management (SOM) at Union Graduate College (UGC) used student trajectories to forecast both individual course and total enrollments within and across various student categories. (The term "trajectory" refers to the enrollment pattern of the average student in a particular category.) The trajectories and the resultant projections formed an integral part of diagnostic tools for enrollment management decision-making, short- and long-term course section planning, and faculty capacity analyses in a variety of scenarios to inform program development, program promotion, and faculty hiring, and to make sure they were consistent with each other. This article describes the concepts behind trajectories, various types of trajectories and their respective uses, details for constructing trajectories, and how trajectories can be incorporated in reports and tools for maximum utility.

Keywords: enrollment forecasting, enrollment management, course section planning, faculty capacity planning

The AIR Professional File, Spring 2021

Article 153

https://doi.org/10.34315/apf1532021

INTRODUCTION

Enrollment forecasting and planning in higher education has received considerable attention both in isolation and as an integrated component of institutional planning; for example, see the early and comprehensive treatment by Hopkins and Massy (1981). A wide variety of approaches to enrollment forecasting and planning have been described over the years. Most methodological descriptions have been accompanied by specific applications with various differentiating factors both in terms of the setting and of the desired practical uses. Although each institution is unique, the hope of each article is that there is enough commonality that each approach will be useful to multiple institutions albeit with appropriate modifications as needed. It is with this hope that I describe an approach that was developed in the School of Management (SOM) at Union Graduate College (UGC) prior to its merger with Clarkson University in 2016. This approach has some similarities both in structure and in goals with prior approaches, as I will describe when I review relevant literature and describe UGC's approach in detail, but is fundamentally different. At this point, I summarize the most important characteristics of UGC's setting and planning needs.

The SOM offered several master's degrees, including both a master of business administration (MBA) and a health-care MBA; it also offered certificates. The number of courses, as well as the specific courses, required varied between degrees and between students within a degree due to course waivers and/or courses transferred in. There were both part-time and full-time students. Student objectives in terms of how quickly they wanted to complete their degrees also varied greatly not only between degrees and between full-time and part-time students, but also between full-time students within the same degree and between part-time students within the same degree. The academic calendar included three trimesters during the regular year plus a summer term. Admissions were on a rolling basis so that students could begin their studies in any term.

All of the classes were in the evenings or online so they could be attended by full-time and part-time students. Most of the courses were part of multiple degree or certificate programs. The total volume of enrollments from all programs allowed the SOM to offer 80 to 90 course sections per year with average enrollments of 16–18 per section.

The desired capabilities of a model were extensive and varied. Students were charged tuition on a per course basis so, although projecting the number of students was important, it was more important to project the number of course enrollments. It was also desired to project the number of enrollments in specific courses, but doing so was for the purpose of deciding the number of sections of each course that would need to be offered rather than predicting any specific course section's enrollment. Diagnostic capabilities for forecast errors were needed to help focus remedial actions such as retention strategies. The relationship between student mix (both by program and by full time vs. part time) and course enrollments (both total and by specific course) needed to be a part of the model to allow marketing and other program promotions to focus on student categories that were compatible with resource capabilities in both the short and long terms. This meant that the model needed to at least provide the necessary inputs for successful planning of faculty size and configuration.

The SOM at UGC devoted very limited resources to institutional research and planning. There was a head of enrollment planning for the entirety of

UGC and a recruiter/enrollment manager devoted to the SOM. Those two worked together to track indicators of new student recruitment as well as student retention. I developed the models described here in part while working as a full-time professor of operations management/operations research at the SOM and more fully while working as a half-time professor and half-time associate dean of the SOM. The data available were limited to what the head of enrollment planning and the recruiter/enrollment manager could provide, plus historical student records from the student information system. In summary, the model needed to satisfy a variety of needs but had to be relatively simple, easy to use, and easy to update and maintain.

LITERATURE

Chen (2008) provides a thorough review of the main approaches to enrollment forecasting that have been used in the past: subjective judgment, ratio method, cohort survival, Markov chains, neural networks, simulation, time series, fuzzy time series, and regression. His paper provides examples of and compares time series and regression and ends with very similar models to predict the number of students enrolled. Another good example of time series analysis is provided by Lavilles and Arcilla (2012). Those authors also predict the number of students enrolled; that indicator seems to be the main focus of the literature with the assumption that the number of enrollees is more important than the total number of course enrollments or that the latter follows naturally from the former. Neither of these assumptions was true at UGC. It should be noted, however, that the nature of both time series and regression is such that they could be used equally well for total course enrollments. Neither approach, however, lends itself very well to the diagnostic and prescriptive capabilities desired by UGC.

Markov chain models, on the other hand, more naturally provide the capability for both diagnosis and prescription via the transition probabilities that are at the heart of their structure. In a sense, they are the extension of ratio and cohort models to allow the modeling of more-complex, but common, behaviors, such as reentry. Although the typical transitions refer to students moving from first year to second year, for example, and eventually to either program completion or dropping out, the state definitions can be extended to help meet needs specific to particular applications. Gandy et al. (2019) add cumulative credit hour ranges and Rahim et al. (2013) add age group ranges to their state definitions to gain additional insights as well as predictive power. Nicholls (2007) specifically focuses on the use of the Markov chain model for improving the program completion results for master's and PhD students, and also identifies the usefulness of the models for longer-term analyses. The model developed at UGC has similarities with Markov chain models but is structured around course enrollments, which are related to student enrollments but have additional complexities that need to be taken into account. Shapiro and Bray (2011) discuss what they call a de-cohortized approach developed specifically for part-time programs at Northwestern University that uses transition matrices and is primarily based on the length of time an individual has been in the program. As I do in this article, those authors emphasize the prescriptive capabilities of their model beyond its forecasting use.

There are also a number of extremely useful reports and slide presentations from conferences that describe the settings as well as the approaches taken at various colleges and universities. Several also provide good reviews of the field before describing their own approach. Reiss (2012) provides a particularly good review before describing the specific approach at the University of Central Florida. Examples of other good reports and presentations include Redlinger et al. (2013, presentation based on University of Texas, Dallas), Link and Whitford (2018, presentation based on University of Buffalo), Rylee and Trusheim (2004, presentation based on University of Delaware), and the Maryland Higher Education Commission (2016, report on Maryland public colleges and universities).

UGC also needed to forecast enrollments in specific courses; this topic has received attention in the literature as well. These forecasting efforts have typically been separate from overall enrollment projections and have been shorter term in nature. These efforts take into account characteristics of specific students in the programs and, in some cases, consider information about the course offerings as well. For example, Balachandran and Gerwin (1973) offered three approaches based on including just the first, the first two, or all three of the following variables to divide the students into categories: (1) if the student has taken the course, (2) if the student has taken the prerequisites for the course, and (3) if the course is required in the student's major. Kraft and Jarvis (2005) included GPA in prerequisite courses and other groupings relevant to specific courses. Ognjanovic et al. (2016) included many demographics as well as course-specific information such as the scheduled time the course was held, who the professor was, and even teaching evaluation scores. UGC's needs in this area were longer term in nature, and were used for section planning rather than for room or term schedule planning.

The SOM at UGC needed features of all these models and wanted the model(s) to be as simple as possible and to take into account the specific characteristics of the setting that I previously described. I will discuss ways that the model developed at UGC could be extended or complemented by other models, but for now I turn to describing the UGC model itself and how it was developed and used.

STUDENT TRAJECTORIES

At the heart of UGC's enrollment forecasting approach is what I refer to as student trajectories. The main objective of this article is to introduce trajectories to the literature, including the wide variety of tools trajectories enable. The trajectory for each student category can then be applied to the number of students in each category, both actual matriculated students and forecasted incoming students, to generate enrollment projections. This concept requires more explanation but it is important to note up front that the data requirements for each student are their transcript, student category, and date of matriculation.

The building block of all the student trajectories, from which all enrollment projections are generated via various multiplications and summations, is a matrix $C_{ij}(ry,t)$. There are seven rows with ry referring to the year relative to student i's year of matriculation running from ry = 1 (the actual year of matriculation) up through ry = 7 (the 7th year of being a matriculated student). There are four columns with t referring to the term (t = 1,2,3, and 4 for Winter, Spring, Summer, and Fall, respectively). Each element of the matrix for student i and course j is given by

$C_{ij}(ry,t)$ = 1 if student i took course j in term t of their relative year ry, or
= 0 if they did not, or
= (missing value) if term t of their relative year ry has not yet occurred in the database.

Essentially, this matrix is 0's except for a 1 placed in the row (relative year) and column (term) corresponding to when student i took course j, although it could be all 0's if student i has not taken course j. The matrix could also have more than a single 1 if student i took course j more than once. It is crucial to the trajectory calculations to recognize that ry is an index relative to each student's year of matriculation and that the vector element is a missing value rather than 0 if the term has not yet occurred.

These C_{ij} matrices are then summed across all courses j for each student i to yield the total number of courses student i took in term t of their relative year ry (again, a missing value if that term has not yet occurred),

$$E_i\,(ry,\, t)=\Sigma_j C_{ij}(ry,t),$$

so that student i's total course enrollment E_i matrix also has seven rows and four columns. The C_{ij} and E_i matrices for each student are then averaged across all students in a student category x to derive the student course trajectory matrix ($SCT_x(ry,t)$) and the student enrollment trajectory matrix ($SET_x(ry,t)$), respectively, for that category x. Note that older student records in the database will have full matrices (i.e., all elements will be 0 or 1), whereas more-recent student records will have only partial matrices (i.e., missing values for some elements since those terms will not yet have occurred). The missing values should be omitted from the averages. The default for most averaging functions provided in software packages is to average in 0's but not missing values; it is crucial to make sure this convention is followed.

Although the student course trajectories are very helpful and I will describe how UGC used them later in this article, it is the student enrollment trajectories that are likely of primary interest to most readers so I start with them. The $SET_x(ry,t)$ trajectory coefficients should be somewhat intuitive although their magnitudes may be surprising in the sense that one tends to think of enrollments based on a student who completes the entire program with no course waivers or transfers and who takes a steady number of courses each term until done. To get a feel for the student trajectory coefficients, I display them for the full-time MBA category (x = 9) in Table 1.

Table 1: Trajectory Coefficients for Full-Time MBA Students

Coefficient	Year	Term	Average Number of Courses Per Student
$SET_9(1,1)$	Matriculation Year	Winter	0.198
$SET_9(1,2)$	Matriculation Year	Spring	0.335
$SET_9(1,3)$	Matriculation Year	Summer	0.457
$SET_9(1,4)$	Matriculation Year	Fall	2.551
$SET_9(2,1)$	Matriculation Year + 1	Winter	2.566
$SET_9(2,2)$	Matriculation Year + 1	Spring	2.411
$SET_9(2,3)$	Matriculation Year + 1	Summer	0.916
$SET_9(2,4)$	Matriculation Year + 1	Fall	1.832
$SET_9(3,1)$	Matriculation Year + 2	Winter	1.244
$SET_9(3,2)$	Matriculation Year + 2	Spring	0.900
$SET_9(3,3)$	Matriculation Year + 2	Summer	0.225
$SET_9(3,4)$	Matriculation Year + 2	Fall	0.334
$SET_9(4,1)$	Matriculation Year + 3	Winter	0.214
$SET_9(4,2)$	Matriculation Year + 3	Spring	0.089
$SET_9(4,3)$	Matriculation Year + 3	Summer	0.009
$SET_9(4,4)$	Matriculation Year + 3	Fall	0.027
$SET_9(5,1)$	Matriculation Year + 4	Winter	0.034
$SET_9(5,2)$	Matriculation Year + 4	Spring	0.023
$SET_9(5,3)$	Matriculation Year + 4	Summer	0.011

As noted, the coefficients were actually computed for 7 years for all categories but are insignificant for this category beyond what is shown. Some reflection on the trajectory coefficients should make it clear that they take into account not only student retention (similar to ratio/cohort/Markov chain models, including withdrawal and reentry) but also the speed with which students take courses and how many courses they take in total. The latter indicator depended not only on which program students were in but also any course waivers and transfers they were granted plus the occasional extra courses they took beyond degree requirements. Note that the total of the right column is 14.178 whereas the program required 17 courses. The difference reflects all of the previously described factors in their proper proportions. This is why the trajectory coefficients can be quite different from what one might at first expect. A key aspect of the trajectories is that they accomplish all of this with fairly simple tabulations and summations. Building separate models to adequately address each factor would be quite cumbersome.

UGC's most important objective was to forecast total course enrollments across all students and categories. To convert the trajectory coefficients into total course enrollment projections is a matter of fairly intuitive multiplications of the coefficients by new matriculant numbers across student categories and years. Since UGC computed the trajectories for 7 years, we multiplied them by 7 years of new matriculants. To project the course enrollments for any category x for year y, UGC used the matriculant vector M_{xy}, where $M_{xy}(1)$ is the number of matriculants in category x in year y, $M_{xy}(2)$ is the number of matriculants in category x in year y – 1, ..., and $M_{xy}(7)$ is the number of matriculants in category x in year y – 6. The elements of this vector were known values for years that had already occurred but forecasted values for those that had not. Again, letting t = 1, 2, 3, or 4 for the Winter, Spring, Summer, and Fall, respectively, UGC computed the total projected enrollments from all students in category x in term t of year y as

$$TE_{xy}(t) = \Sigma_{k=1}^{7} \mathrm{M}_{xy}(k) SET_x(k,t).$$

The total enrollments projection from students in category x for the entire year y was then obtained by summing across the four terms. Summing the individual term projections across all categories yielded the total enrollment projection for each term and summing the total enrollment projections for each term yielded the grand total enrollment projection for year y.

To exemplify the calculations, suppose one is trying to project the enrollments from MBA management full-time students in year 2022; the projected or known new matriculants in this category are given in Table 2.

Table 2: New Matriculants for Full-Time MBA Students

Coefficient	Year	New Matriculants
$M_{9,2022}(1)$	2022	45 (projected)
$M_{9,2022}(2)$	2021	47 (projected)
$M_{9,2022}(3)$	2020	26
$M_{9,2022}(4)$	2019	32
$M_{9,2022}(5)$	2018	48
$M_{9,2022}(6)$	2017	51
$M_{9,2022}(7)$	2016	35

The projected enrollments from this student category in the Fall term of year 2022 would be

$$TE_{9,2022}(4) = M_{9,2022}(1)\ SET_9(1,4) + M_{9,2022}(2)\ SET_9(2,4) - M_{9,2022}(3)\ SET_9(3,4)$$
$$+ M_{9,2022}(4)\ SET_9(4,4) + M_{9,2022}(5)\ SET_9(5,4) + M_{9,2022}(6)\ SET_9(6,4) + M_{9,2022}(7)\ SET_9(7,4)$$
$$= 45*2.551 + 47*1.832 + 26*.334 + 32*.027 + 48*0 + 51*0 +35*0 = 115 + 86 + 8 + 1 = 210.$$

Similar computations would be done for all student categories and for each term. The interested reader can verify that the projected enrollments for the other three terms in this year would be

$$TE_{9,2022}(1) = 170,\ TE_{9,2022}(2) = 156, \text{ and } TE_{9,2022}(3) = 70.$$

Thus, the total projected enrollments from this student category in the year 2022 would be 606. Similar calculations would be done for each student category and the total projected enrollments summed across all categories to yield the grand total enrollment projection.

The student enrollment trajectories are easily modified to reflect active student trajectories by first substituting 1 (indicating the student was active) for any positive number of courses taken into each student's total course taken matrix. In other words, let

$$A_i(ry,t) = 1 \text{ if } E_i(ry,t)>1, \text{ or}$$
$$= E_i(ry,t), \text{ otherwise,}$$

so that $A_i(ry,t)$ = 1 if student i was active in term t of their relative year ry, 0 if not, and a missing value if their term t had not yet occurred.

These active student vectors are then averaged across all students in a category x (again omitting missing values) to yield the active student trajectory AST_x, where $AST_x(ry,t)$ is the average proportion of students in category x active in term t of their relative year ry. Then one simply repeats the calculations I have just described using the active student AST_x matrix in place of the student enrollment trajectory SET_x matrix to get the projected number of active students in each category each term in the year y being projected.

Student categories should be selected to divide students into groups with similar trajectories in terms of total courses, specific courses, and time in program. Obvious ways to do this are based on the degree sought and part-time versus full-time status. Other categorizations may be useful for students who have matriculated (such as term started or number of courses already taken) but would likely not be feasible for use with projected matriculants. It should also be kept in mind that the number of students in a category needs to be large enough for the trajectory coefficients to be reliable. I will say a bit more on this later. UGC used the matriculant categories in Table 3.

Table 3: Matriculant Categories

1. Certificates
2. Juris Doctor/MBA Management
3. Leadership in Medicine/MBA Full Time
4. Leadership in Medicine/MBA Part Time
5. 5 Year Undergraduate/MBA
6. MBA Health Care Full Time
7. MBA Health Care Part Time
8. 5 Year Undergraduate/Health-Care MBA
9. MBA Management Full Time
10. MBA Management Part Time
11. 5 Year Undergraduate/MBA Part Time
12. Pharmacy Doctor/MS Health Care
13. Pharmacy Doctor/MBA Health Care
14. Accounting MBA
15. MS Health-Care Data Analytics Full Time
16. MS Health-Care Data Analytics Part Time

Note: MS is master of science.

The master of science (MS) health-care data analytics program was a new program introduced after the enrollment projection and planning approach had been implemented so that there were no data directly from the program initially to use to form a trajectory for the final two categories. UGC found, however, that using knowledge of the program structure and trajectories for other student categories as a guide, and developing a trajectory for initial use for Categories 15 and 16 was more intuitive and accurate than relying on a purely subjective estimate based on hypothesized average student behavior or, even worse, the trajectory of a hypothesized typical student in that category.

NEW MATRICULANT PROJECTIONS AND THE FUNNEL MODEL

The calculations described in the preceding section are the same whether the number of matriculants in a year is a known number (an already completed year) or a forecast (the current or future year). If it is a forecast, it might be for the purpose of making enrollment forecasts that are as accurate as possible. It might also be used to set goals or to be part of a sensitivity analysis for strategic planning. I will discuss the latter uses more below, but note now that the trajectories are well suited for all these purposes.

Although the main objective of this article is to introduce the use of student trajectories that can be combined with matriculant projections no matter how the latter are obtained, I will briefly describe UGC's approach to new matriculant forecasting. UGC used a fairly standard approach that combined ratios with subjective judgment in a funnel model. The funnel model tracked students from inquiries all the way to actual matriculation and measured the percentage that advanced to each step (which declines as the steps advance, hence the term "funnel"). The steps that UGC tracked were as follows:

1| Student inquires about the program.

2| Student applies to the program.

3| Student receives admission acceptance letter.

4| Student submits deposit.

5| Student enrolls in first course as a matriculated student.

The funnel model was tracked separately for full-time and part-time students and for foreign and US students since the percentage of students that moved from step to step varied significantly across these categories. The funnel percentages for US students just prior to the merger were as shown in Table 4.

Table 4: Percent of Inquiries Advancing

Step	% of Inquiries
Applied	31.9
Admitted	25.0
Submitted deposit	21.1
Matriculated	20.6

Not only were numbers of students that advanced through each step recorded for entire years, but the counts were also recorded on a biweekly basis throughout each year. This database enabled projections to be made at any time from several different bases. For example, suppose one wanted to project the number of full-time US matriculated students for 2020 based on the number of applications received for 2020 as of the end of March 2020, and suppose this number was 50. This base would first be used to project the total number of 2020 applications as follows:

Projected total number of US full-time applications for 2020 =
(Number of US full-time applications at the end of March, 2020) /
(Historical proportion of total annual US full-time applications received by the end of March) =
50 / .80 = 63.

The projected number of matriculated students would then be made as follows:

Projected matriculated students for 2020 =
(Projected total number of applications for 2020) *
(Historical proportion of applications that result in matriculated students) =
63 * 20.6 / 31.9 = 41.

The counts at any point in time for any of the five steps could be used in a similar manner to project the number of matriculated students. If the percent yields (i.e., the percent advancing from one step to the next) were consistent with historical data, the projections from each base would be consistent as well. Of course, another objective of the funnel model was to actually increase the yield percentages through improvements in the process of managing the students from inquiry to matriculation. For the purposes of projection accuracy, the possibility of funnel improvements favored using later steps rather than earlier steps as bases.

The head of enrollment planning and the recruiter/enrollment manager worked together to subjectively modify the numbers (either the input percentages or the output projections directly) so that they were always some combination of a historical ratio and a subjective model. Especially for longer-term enrollment projections, either very early in the year being projected or for future years as part of a long-term outlook, the matriculant projections were used in sensitivity analyses that were useful for setting student category-mix adjusted-growth goals consistent with both market forecasts and resource planning.

DIAGNOSTICS AND CONTROL MEASURES

One of the significant advantages of the trajectories compared to many other projection approaches is the ability to use the trajectory model for diagnostic and prescriptive rather than just predictive purposes. Once the enrollment numbers were known for a term, UGC produced a report for each category comparing the actual and predicted. An example report (once again for the full-time MBA management student category) is shown in Table 5.

Table 5: Example Diagnostic Report for Full-Time MBA Students Fall Term

	Year of Matriculation			
	20xx	20xx–1	20xx–2	20xx–3
Number of Students	45	47	26	32
Model:				
Percent of Students Active	86	73	20	3
Enrollments per Active Student	2.96	2.51	1.67	1
Enrollments per Student	2.55	1.83	0.33	0.03
Number of Enrollments	115	86	9	1
Actual:				
Percent of Students Active	92	58	16	0
Enrollments per Active Student	3.09	2.46	1.50	0
Enrollments per Student	2.84	1.44	0.24	0
Number of Enrollments	128	68	6	0
Enrollments (Actual-Model)	13	–18	–3	–1

In this case, the report showed that full-time students were slightly increasing the speed at which they took courses, resulting in more enrollments in the first year and fewer in subsequent years. This behavior was viewed as a positive and the main discussion centered on whether this was going to be an ongoing pattern such that the trajectories should be modified. There was some concern that the percent of active students that matriculated the previous year was down. Investigations revealed this downturn was mostly due to a variety of individual circumstances and did not warrant system changes.

For the same term, the diagnostic report for part-time MBA students showed that the enrollments per active student had dropped, resulting in a total of 14 fewer enrollments than predicted. Students were contacted and the main factor in the slowdown was determined to be employer reimbursement policies becoming more restrictive. Program administrators worried that this would eventually lead to losses in retention and discussed possible remedies such as loans or increased scholarship opportunities.

COURSE PLANNING

The literature on projecting enrollments in specific courses is essentially separate from that of projecting total enrollments but the trajectories allowed UGC to accomplish both in essentially the same manner. I have described in detail the calculations for projecting total enrollments; to project the enrollments in an individual course was simply a matter of doing the same calculations using the student course trajectory coefficients ($SCT_x(ry,t)$) in place of the student enrollment trajectory coefficients ($SET_x(ry,t)$). The resulting totals for a particular term for a particular course very much depended on whether that course was offered in that term, perhaps with more than one section; the results had to be interpreted with that in mind. The results for an entire academic year were more meaningful, which is how UGC primarily used them to make decisions about how many sections of each course to offer. The specific course trajectories reflected all the factors for the enrollment trajectories but also naturally captured the waiver/transfer likelihood for the specific course as well as the probability a student would leave before taking the course; that likelihood was higher for courses taken late in a program.

UGC's approach for determining the number of course sections of each course started with selecting a capacity for each course. This was 30 for most courses, although there was some variety based on the nature of each course. UGC used 30 for all electives (courses not required in any student category) and lumped the enrollments in these electives together to determine the total number required; specific elective choices were based on knowledge of both student preferences (demand) and faculty expertise (supply). The maximum average enrollments per section for each course (maximum average) was then set at a consistent percentage of the capacity. The precise calculation was then done by dividing the total projected enrollments for each course by the maximum average and rounding up. For example, suppose the percent of capacity was 81 so that the maximum average was 81% x 30 = 24.8 for the MBA500 course, and suppose that the enrollment projection for this course for the entire year was 93. This means that UGC desired to have the average number of enrollments per section of MBA500 be 24.8 or less so the number of sections of MBA500 would then be (93 / 24.8) rounded up, which is 4.

It is the average number of enrollments per section (i.e., the average class size), however, that is typically of more interest and that is more easily understood than either the maximum average or the percent of capacity. Average class size is often decided on as a matter of program policy that involves many factors and may change over time. To help in making this decision, UGC produced a trade-off table (see example in Table 6) that showed the percent of capacity the maximum average would have to be to achieve a range of average class sizes and the corresponding number of sections. The full table would show the results for every course and the total at the bottom. This table was created by starting the maximum average at full capacity (100%) and reducing the percent in 0.1 increments. For each increment, the resultant total number of sections across all courses was divided into the total enrollments to get the average class size that would result from that percent. The percent that corresponded to various average class sizes was then placed in a table such as Table 6. The table helped UGC make a final decision by selecting a desired column. For example, suppose UGC's desired average was 18 students per section. The maximum average for MBA500 would be 71.7% x 30 = 21.5, and there would be 93 / 21.5 = 4.3 rounded up to five sections of MBA500 with an average enrollment of 93 / 5 = 18.6.

Table 6: Trade-Off Table for Number of Sections

	Average Class Size					
	15	16	17	18	19	20
Maximum Average % of Capacity	58.3	62.0	67.0	71.7	76.0	81.0
Sections of MBA500	6	6	5	5	5	4

FACULTY PLANNING

It is intuitive that determining the number of sections of each course is very useful for conducting faculty planning. In UGC's case, the number of sections was linked to faculty planning via the Association to Advance Collegiate Schools of Business (AACSB) requirements for faculty coverage since the SOM of UGC was AACSB accredited. AACSB mandated that certain percentages be covered by participating faculty (i.e., faculty involved with the program for more than teaching, who were essentially nonadjunct faculty) both by disciplinary areas and in total. Table 7 shows the computations done by UGC for the upcoming year prior to the merger. The adequacy of coverage both by area and in total was easily seen and helped inform hiring decisions.

Table 7: Faculty Coverage

Area	Projected Sections	Participating Faculty Coverage	
		Sections	Percent
Finance/Accounting/Economics			
Required	13	9	69
Elective	9	7	78
Total	22	16	73
Marketing/Operations/Management Science			
Required	14	11	79
Elective	10	7	70
Total	24	18	75
Management/Human Resources			
Required	13	11	85
Elective	15	12	80
Total	28	23	82
Health-Care Management			
Required	7	6	86
Elective	11	6	55
Total	18	12	67
Totals			
Required	47	37	79
Elective	45	32	71
Total	92	69	75

INTERMEDIATE AND LONG-TERM PLANNING

I mentioned earlier that the matriculant projections were sometimes intended to be the most accurate estimates available and were sometimes viewed more as goal numbers. For intermediate and long-term planning, the process that was developed using the trajectory model to convert matriculant numbers into course section and faculty planning reports as shown in Tables 6 and 7 was ideal. The operational ramifications of various growth strategies (for some categories) and contraction strategies (for others) could be easily seen. New programs (categories) could be included in this type of analysis by developing hypothetical trajectories as UGC did when the MS health-care data analytics program was introduced. The result was that sensitivity analysis on faculty resource requirements was easy to conduct and easy to properly consider in planning exercises. Note that the trajectories varied by category both in terms of specific courses taken and in the timing patterns, so that the planning reports of Tables 6 and 7 needed to be done for multiple years to reflect the transient as well as steady state effects. The trajectories enabled these planning exercises to be done in a very natural manner.

ACCURACY AND USEFULNESS

There were two main insights from UGC's use of trajectories (and the funnel model) in terms of accuracy. The first was that projecting new matriculants (e.g., using the funnel model) was by far the most difficult part and prone to error. The trajectories were more accurate, which meant that enrollment projections from continuing students were more accurate than projections from new students. In the first 2 years of implementation, the new matriculant projections prior to the start of the academic year were accurate enough that the grand total enrollment projections across all student categories for the entire year were within 1% of actual. It became apparent in subsequent years, however, that the funnel percentages could change dramatically; this was both possible and problematic in UGC's case in particular, with rolling admissions and no predetermined cohort size. The trajectories were less prone to dramatic shifts but there were shifts nonetheless. Using the actual matriculants once they were known to project backwards (as in the diagnostic reports described earlier) showed that the accuracy on the total annual enrollments across all categories was within 1% in the first 3 years that the approach was implemented, but was over 3% in 2 of the remaining 4 of the 7 years the approach was used prior to the merger. This meant that the average trajectories in some categories had changed; that change leads to the second insight of thinking of forecast errors not primarily as problems with the models (although updating the coefficients may be in order), but rather as diagnostic opportunities to investigate reasons for changes in historical patterns and inform remedial and prescriptive decision-making. The diagnostics for individual student categories can often be quite helpful for prescriptive purposes even in years when the total enrollment projections are very accurate since pattern changes in different categories might be meaningful and yet cancel each other out in their enrollment effects. The trajectories (and the funnel model as well) were ideal for this purpose in that their construction was fundamentally descriptive rather than purely predictive.

CONCLUSIONS AND POSSIBLE ENHANCEMENTS

Trajectories combined with new matriculant projections to greatly enhance UGC's ability to accurately project enrollments. The approach was relatively simple (using basic tabulations, multiplications, and summations) and was easy to update using readily available data. Specific course enrollment projections, active student projections, and total course enrollment projections were all obtained using the same data and basic approach. Diagnostic reports identified changes in student behavior that informed prescriptive decision-making. Faculty planning was enhanced in both the short and long terms.

In terms of future model enhancements that would fit nicely with the trajectory approach, I had begun to look at two possible adjustments. As described, the trajectories were computed by averaging across all students in the database. First, I had looked at time series (via weighted moving averages or exponential smoothing) adjustments to computing the trajectories. Second, I had looked at conditional trajectories (similar to the conditional course probabilities of Balachandran and Gerwin [1973]) for continuing students based on the number of courses already completed. Although neither of these possible enhancements led to any useful updates during the time of use, I believe they could have done so eventually as the overall body of data aged. The conditional trajectories in particular would have benefited from more data since they essentially created more student categories, hence fewer data per category. Institutions with larger amounts of data might find these enhancements immediately effective. Although this article focused on the trajectories, the projections of new matriculants could perhaps have been enhanced using regression and/or time series approaches with explanatory variables.

An overall conclusion is that many of the approaches in the literature could possibly be used to both enhance the trajectories' accuracy and to combine effectively with them. The best way to combine approaches and the potential benefits would likely depend very much on the application. This is true as well for the broader question of whether the trajectories or any other of the methodologies previously suggested in the literature would be a useful addition to any institution's approach. If the setting has significant similarities to UGC's setting, I believe the use of trajectories could be very helpful.

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AIR expresses sincere appreciation for the members who serve as peer reviewers. Authors who submit materials to AIR Publications receive feedback from AIR members. The following individuals reviewed manuscripts submitted to this volume of *The AIR Professional File*.

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ISSN 2155-7535