The Relative Contribution of Department Ranking to College Ranking in Engineering Graduate Program Rankings Conducted by *U.S. News and World Report*

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Abstract

College rankings conducted by various popular magazines have generated both considerable interest and controversy, with concerns focused both on the formulas used by the magazines and the data supplied by the ranked schools. The present work seeks to circumvent the confounding nature of these issues by (1) considering only "reputation" rankings by academics and (2) using the discrepancy between college rankings and departmental rankings to provide insight into how the rankings of various departments contribute to the rank of the college they comprise. In this work, we present an analysis of 12 years of *U.S. News and World Report* graduate school "reputation" rankings for engineering colleges and departments, using it to reveal the relative perceived contributions of various disciplines to college rank.

Background

College rankings conducted by various popular magazines have generated both considerable interest and controversy over the past decade. However, while certain groups of prospective students increasingly rely on such rankings[1], a number of academics openly question their validity. Many express concern with the magazines' choices of measures and quantitative formulas used to obtain the "overall" rank for a college[2-7], as well as with their peer's choices of data supplied to the magazine conducting the ranking[8-11].

In the specific case of the *U.S. News and World Report* rankings of engineering colleges, the "overall" rank for a college currently is calculated by using a weighted quantitative formula[12-14] that incorporates the following measures[12]:

- Reputation (40%) – measured by separate surveys of both academics and corporate recruiters
- Student selectivity (10%) – measured by GRE quantitative and analytic scores, as well as by the proportion of applicants accepted

- Faculty resources (25%) – measured by student-to-faculty ratios, proportion of faculty in the National Academy of Engineering and with doctorates, and the number of Ph.D. degrees granted in the prior year
- Research activity (25%) – measured by total research expenditures and research dollars per faculty member

U.S. News and World Report assesses 185 engineering colleges in its annual survey.[13]

Note that this “overall” rank differs from the “reputation” rank by academics. The “reputation” rank by academics is based on a survey of deans, program directors, and senior faculty who are asked to judge the overall academic quality of engineering colleges on a scale of 1 (“marginal”) to 5 (“distinguished”).[14]

Further, individual departments within several disciplines are also ranked. These discipline-specific rankings are conducted in a manner similar to the reputation survey conducted at the college level. Deans, program directors, and senior faculty are asked to nominate up to ten top schools in each discipline, with the magazine publishing the list of schools with the highest number of nominations in each discipline.[13]

While not explicitly employing a formula, one can speculate that these leaders do, in fact, use their own personal “heuristic formulas” to select top-ranked programs in the “reputation” rank surveys. These “heuristic formulas” are based on such factors as the historical ranking of a department, the perceived quality of graduate students entering their own graduate program from a department, and the perceived quality of published research generated by a department.

As an interesting observation regarding the challenges of defining an explicit, quantitative formula that meaningfully describes the “overall” rank of a college, it has been noted that either the linear or weighted sum of departmental “reputation” rankings may not necessarily be consistent with the “overall”, formula-driven ranking of the college they comprise[15], i.e., that some colleges with a smaller number of top-5 reputation departments rank higher in the “overall” ranking formula than other colleges with a larger number of top-5 reputation departments. This is shown graphically in Figure 1 for the number of appearances in the top-5 department lists for each of the top ten colleges of engineering (based on “overall” rank). Rankings for 11 disciplines were provided in the published data, shown here for 2001. This data would indicate that there are inconsistencies between the number of departments a college has appearing in the top-5 lists and the college’s “overall” rank, since a monotonically decreasing number of top-5 department appearances is not observed as “overall” rank degrades.

The present work seeks to circumvent the confounding nature of these issues in two ways. First, by comparing departmental “reputation” rankings by academics with college “reputation” rankings by academics, rather than comparing them with “overall”, formula-driven rankings, we can eliminate data value and formula bias.[16] By doing so, we reflect back to academics their perceptions regarding the quality of various programs, not those of the formulas chosen by a non-academic journalist. Second, by accepting that the number of top-5 reputation departments (or some weighted value of this number with the weight based on department rank) may, indeed, not be an indicator of college rank, we seek to use the resulting discrepancy to provide insight into how the “reputation” rankings of various departments contribute to the “reputation” rank of the college they comprise. In this work, we present an analysis of 12 years of *U.S. News and World Report* graduate school “reputation” rankings for engineering colleges and departments, using it to reveal the relative perceived contributions of various departmental rankings to college rank.

Approach #1: Covariance

A potential means of identifying the perceived contributions of departmental rankings to college rank is to define random variables for each and then calculate the covariance between them.

Thus, for each discipline, a departmental ranking random variable, D_i, can be defined with five terms (the departmental rank for the i^{th} discipline for each of the top-5 schools). Similarly, a college ranking random variable, C_i, can be defined with five terms (the corresponding college rank for each top-5 school in the i^{th} discipline). As an example, assume the situation where the #1, #2, #3, #4, and #5 ranked departments in electrical engineering come from the #2, #4, #3, #8, and #6 ranked engineering colleges. In this case, D_{EE} = (1, 2, 3, 4, 5) and C_{EE} = (2, 4, 3, 8, 6), and the covariance for electrical engineering is 2.40.

One problem with such an approach is that the covariance of these random variables is often misleading due to the ordinal nature of the random variables. For example, consider the case of D_{EE} = (1, 2, 3, 4, 5) and C_{EE} = (1, 2, 3, 4, 5) vs. the case of D_{EE} = (1, 2, 3, 4, 5) and C_{EE} = (6, 7, 8, 9, 10). Both cases result in a covariance of 2.00, although they clearly represent significantly different relationships between the departmental rankings and the college rankings.

Another problem is that increasingly poor college rankings are rewarded with this approach. For example, consider the case of D_{EE} = (1, 2, 3, 4, 5) and C_{EE} = (1, 2, 3, 4, 5) vs. the case of D_{EE} = (1, 2, 3, 4, 5) and C_{EE} = (1, 4, 9, 16, 25). The first case results in a covariance of 2.00 while the second case results in a covariance of 12.00, although they clearly represent significantly different relationships between the departmental rankings and the college rankings, and the first case is more representative of a strong relationship between the departmental and college rankings. Thus, another approach must be found.

Approach #2: Regression analysis

One of the most intuitively desirable approaches to this analysis would be to conduct a regression analysis with the departmental rankings by discipline serving as independent variables and the college rankings serving as the dependent variable. Such an analysis would yield a series of coefficients associated with each discipline, these coefficients serving as indicators as to the extent that the department rank contributes to the college rank.

Unfortunately, available department ranking data for most years is limited to the top 5 departments for each discipline. As such, there is insufficient data to perform a meaningful regression analysis. Thus, another approach must be found.

Approach #3: Distance

An intuitively appealing approach to describing the difference between the departmental ranking and the college ranking for each discipline is to define a value that represents the difference of – or distance between – the two ranking sets. This distance value can be simply defined as the magnitude of the difference vector between the two 5-dimensional vectors for the departmental ranking and the college ranking of the top-5 departments, respectively.

Distance is, thus, defined as,

(1) $$\text{Distance for discipline i} = \left| \vec{C}_i - \vec{D}_i \right|$$

where for each discipline, a departmental ranking vector, $\vec{D}_i$, can be defined with five terms (the departmental rank for the i^{th} discipline for each of the top-5 schools) and a college ranking vector, $\vec{C}_i$, can be defined with five terms (the corresponding college rank for each top-5 school in the i^{th} discipline). The closer the relationship between department rankings and college rankings for a given discipline, the smaller the distance is.

Along the same lines as the earlier example, consider the situation where the #1, #2, #3, #4, and #5 ranked departments in electrical engineering come from the #2, #4, #3, #8, and #6 ranked engineering colleges. In this case, $\vec{D}_{EE}$ = (1, 2, 3, 4, 5) and $\vec{C}_{EE}$ = (2, 4, 3, 8, 6), so that the distance for the electrical engineering discipline in this case is $\sqrt{(2-1)^2+(4-2)^2+(3-3)^2+(8-4)^2+(6-5)^2} = 4.69$.

The problems with the covariance approach are now resolved with the distance approach. First, ordinal ranking does not confound the calculation. For example, consider the case of $\vec{D}_{EE}$ = (1, 2, 3, 4, 5) and $\vec{C}_{EE}$ = (1, 2, 3, 4, 5) vs. the case of $\vec{D}_{EE}$ = (1, 2, 3, 4, 5) and $\vec{C}_{EE}$ = (6, 7, 8, 9, 10). The distance of the first case is zero, while it is 11.18 for the second case. Also, increasingly poor college rankings are penalized in the distance approach. For example, consider the case of $\vec{D}_{EE}$ = (1, 2, 3, 4, 5) and $\vec{C}_{EE}$ = (1, 2, 3, 4, 5) vs. the case of $\vec{D}_{EE}$ = (1, 2, 3, 4, 5) and $\vec{C}_{EE}$ = (1, 4, 9, 16, 25). The first case results in a distance of zero while the second case results in a distance of 24.17.

By calculating the distance for each discipline for each year between 1990 and 2001 and taking the average, we generate the data of Figure 2. Note that for each year in which an unranked college appears in the top-5 department list for a discipline, that year's discipline data has been removed from consideration in this analysis, since no meaningful distance vector can be constructed for that discipline for that year.

While the distance approach has appeal on the basis of the insight it reveals on the question of departmental contribution to college ranking, some issues remain. Most importantly, the distance metric may have very limited interpretation since the underlying ranking variables are guaranteed to be ordinal only. Statistical interpretation of the magnitude of differences between the distance metric for different disciplines would be difficult, at best. Thus, another approach must be found.

Approach #4: Transition probability

One way to incorporate both physical meaning and statistical significance into the analysis is to observe "transitions" from department rankings in a given discipline to their respective college rankings. Shown schematically in Figure 3, the department "reputation" rankings for a given discipline and the college academic "reputation" rankings can be depicted by a series of buckets labeled according to the relative rank they represent. The relationship between these two sets of rankings can be represented as a series of transitions from one set of buckets to the other.

Along the same lines as the earlier examples, consider the situation where the #1, #2, #3, #4, and #5 ranked departments in the electrical engineering discipline come from the #2, #4, #3, #8, and #6 ranked engineering colleges. The various buckets and transitions for this example are shown schematically in Figure 4.

Further, a discrepancy value, Δ, can be identified for each transition. Δ is simply the difference between the college rank and the department rank for a given school in a given discipline. Thus, for the previous example where the #1, #2, #3, #4, and #5 ranked departments in the electrical engineering discipline come from the #2, #4, #3, #8, and #6 ranked engineering colleges, Δ values of +1, +2, 0, +4, and +1 are observed for the electrical engineering department in a given year. Note that Δ can range in value from –4 (the 5th-ranked department in a discipline corresponding to a the 1st-ranked college) to something greater than +25 (the 1st-ranked department in a discipline corresponding to an extremely low-ranked college; since in some early years *U.S. News and World Report* identified roughly the top 25 ranked colleges by "reputation", any school not on this list can be viewed as transitioning to the 25-and-over ranked college bucket).

We can use this approach to observe all transitions from all top-5 departments in a given discipline to the ranking of their respective college. For example, this is shown graphically in Figures 5 and 6 for the electrical engineering and civil engineering disciplines, respectively. In each figure, the frequency of each top-5 department-to-college transition is plotted as a function of transition (Δ) for all 12 years of data (n = 60 since there are 5 top-5 departments listed for each discipline for each of 12 years).

It is interesting to note the general differences in distribution for these two disciplines. The electrical engineering discipline distribution is relatively narrow, unimodal, and symmetric in nature, nearly centered on the $\Delta = 0$ transition. Conversely, the civil engineering discipline distribution is relatively wide and somewhat irregular, as well as centered around a $\Delta>0$ transition, which is consistent with a general loss of position between the department ranking and the college ranking for that discipline. It is reasonable to conclude then, that departmental rankings from the electrical engineering discipline are more closely indicative of the college rankings than those of the civil engineering discipline.

We can now explore the statistical evidence to determine to what extent there is a difference in how departmental rankings of various disciplines contribute to the college rankings. We can define an outcome A such that A = {some event or set of events} and the probability of A occurring by p. If we can model the number of occurrences of A as a binomial random variable, we can calculate confidence intervals for p by using the following equation,[17]

(2) $$\text{Probability}\left[p \in \hat{p} \pm Z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \right] = 1-\alpha$$

where $\hat{p}$ is the point estimate for p (in this case the observed relative frequency of A occurring or the proportion of the trials or samples where A occurred) , n is the number of trials or samples, and 1-α represents the probability range of the confidence interval, denoted by,

(3) $$\hat{p} \pm Z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} .$$

Note that this is an approximation, which holds when $np > 5$ and $n(1-p) > 5$.

To apply this analysis, we focus our attention on the set of transitions, A, in which Δ = -1, 0, +1. As an example, this is shown schematically for the 3rd-ranked department of a given discipline in Figure 7. These transitions represent the set of transitions for which department and college rankings are the most alike. Thus, to the extent that Δ = -1, 0, +1 transitions occur frequently, the departmental ranking is a reasonably good indicator of the college ranking.

The 95% confidence intervals for the probability of these transitions (Δ = -1, 0, +1) for each of the eleven disciplines that appear in *U.S. News and World Reports'* published data between 1990 and 2001 are shown graphically in Figure 8. These disciplines can be broadly categorized into five discipline clusters with successively decreasing relationship between departmental ranking and college ranking,

- Cluster A – mechanical and electrical
- Cluster B – aeronautical and computer
- Cluster C – materials, chemical, nuclear, and environmental
- Cluster D – civil
- Cluster E – industrial and bioengineering

The departmental rankings of Cluster A disciplines are statistically more closely related to college rankings than any of the other departments. Further, the departmental rankings of Cluster E are statistically least closely related to college rankings than any of the other departments. The difference between the departmental rankings and college rankings of Cluster B and Cluster C disciplines are indistinguishable, as are the difference between the departmental rankings and college rankings of Cluster C and Cluster D disciplines. However, the difference between the departmental rankings and college rankings of Cluster B and Cluster D disciplines can be distinguished statistically.

Observations and conclusions

Clearly there are some very strong relationships observed between department rankings and college rankings, with the mechanical and electrical engineering disciplines having the strongest relationships to college ranking.

It is interesting to note that these two disciplines often have the largest numbers of students and faculty and have correspondingly large research budgets, both currently and integrated over time. The only other discipline that rivals these two for current size and dollars would be computer engineering, which is often operated jointly with electrical engineering or computer science. Computer science resides within some colleges of engineering but certainly not all of them.

Thus, it is possible that the disciplines that generate the most alumni and research funding will likely also be those that produce the largest number of engineering academic leaders who participate in these surveys. While we have not studied this quantitatively, one could argue that some of the observed results could be accounted for in this manner.

Further, it could also be argued that, given their size, these two disciplines represent the largest number of technical contributions to society in recent history. As such, the visibility of departments in these disciplines might easily draw attention to the engineering colleges that they comprise.

Inversely, disciplines representing typically two of the smallest departments in an engineering college, industrial engineering and bioengineering, exhibit the weakest relationships between departmental ranking and college ranking. This adds further credibility to the argument that discipline size, both current and integrated over time, is a key factor in determining which disciplines have the greatest impact on college ranking.

Note, however, that there are exceptions to this trend. Aeronautical engineering departments, for example, typically are relatively small. However, it is a discipline for which department rank is relatively closely related to college rank. Also, civil engineering, a discipline typically represented by larger departments, exhibits department rankings that are relatively less related to college rankings.

It is compelling to begin to conjecture about the ways in which engineering academic leaders might employ this information about the relationship between departmental and college rankings. The most obvious application of these results is in the area of resource allocation.

If the goal of a college is to attain the highest ranking possible, then perhaps the most likely decision, based on the results of this work, would be to invest incremental resources primarily in the mechanical and electrical engineering disciplines. The problem with this option is that the investment required to change significantly the ranking of these departments would be very large due to the number of faculty and the research dollars necessary. In addition, few would argue that a college with only two strong departments would provide the necessary technical breadth that would constitute a top-rated college of engineering.

Another decision is when to launch new departments and when to phase out existing departments. The ranking data suggest disciplines that are in transition. Bioengineering is clearly a new discipline that has yet to establish itself as a key ingredient in the college rankings. Likewise, industrial engineering is a discipline that is observed in this study to be less able to impact the rankings of a college. The interesting point here is that while the concepts of industrial engineering continue to play a critical role in industry profitability, the perceptions exhibited by academics through this study do not correlate well with this contribution to the vitality of our economy. Thus, this study leads one to question the proportion of incremental investment that departments in these disciplines might receive.

As the relatively new discipline of bioengineering suggests, much of the current interesting and groundbreaking research takes place within interdisciplinary research centers, institutes, or departments. Many of the highly ranked colleges have such interdisciplinary units. Additionally, they have uncommon or intermingled boutique departments that do not compare well across institutions. A shortfall of the *U.S. News and World Report* rankings, as well as the current study, is that such units are not accounted for.

Obviously other factors contribute to the perceived reputation of an engineering college. One of the factors not explored in this research is the impact of the reputation of the overall university on the reputation of the college. Just as there is a relationship between college and department rankings, one would suspect that there is a relationship between college and university rankings. This question was not explored in the current paper but would be an interesting future study.

This study provides, for the first time, quantitative insight into the collective view of the engineering academic community nationally regarding the relationships between college and departmental rankings. Moving beyond the findings, the important issue to understand is the manner in which policy decisions are made based on these perceptions. Hopefully, this analysis and the corresponding questions raised will encourage us to continue asking what makes a great engineering college and to continually reconsider how to encourage our institutions to contribute to the social and economic well-being of our country.

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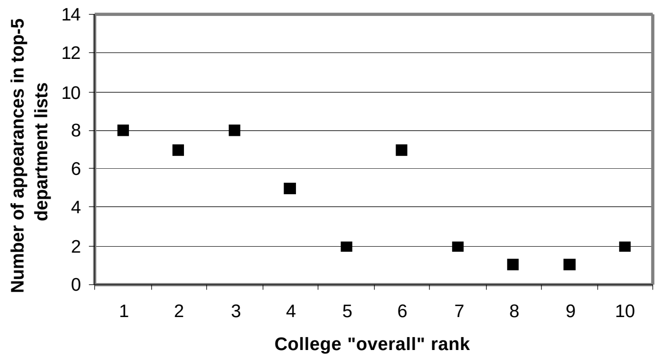

Figure 1.

Number of appearances in the *U.S. News and World Report* top-5 department lists for each of the top ten colleges of engineering (based on "overall" rank). Rankings for 11 disciplines were provided in the published data, shown here for 2001.

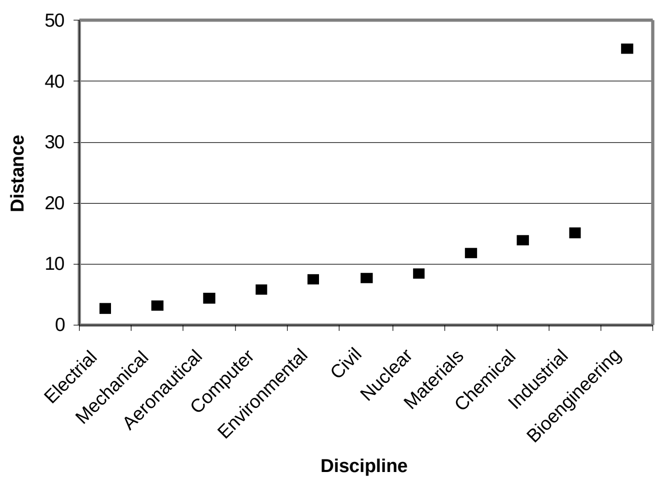

Figure 2.

Plot of distance vs. discipline for engineering college data appearing in *U.S. News and World Report* (1990 to 2001).

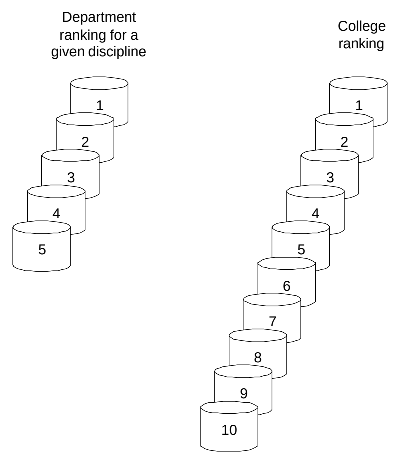

Figure 3.

Schematic demonstrating the relationship between department rankings and college rankings for a given discipline in a given year. Each ranking position is represented by a bucket. The correspondence between the department ranking in a discipline to college ranking is represented by transitioning the school from the departmental buckets toward the college buckets. To the extent a department with an i^{th} ranking transitions into the corresponding i^{th} college bucket, or whether it does not is an indication of how much correspondence there is between department rankings in a discipline and the college rankings.

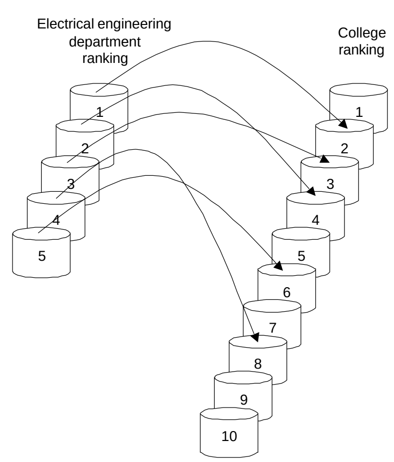

Figure 4.

Schematic demonstrating an example of the relationship between department rankings and college rankings for a given discipline in a given year. In this example the #1, 2, 3, 4, and 5 ranked departments in electrical engineering come from the #2, 4, 3, 8, and 6 ranked colleges, respectively. Such an analysis is then conducted for all of the other years and all of the other disciplines.

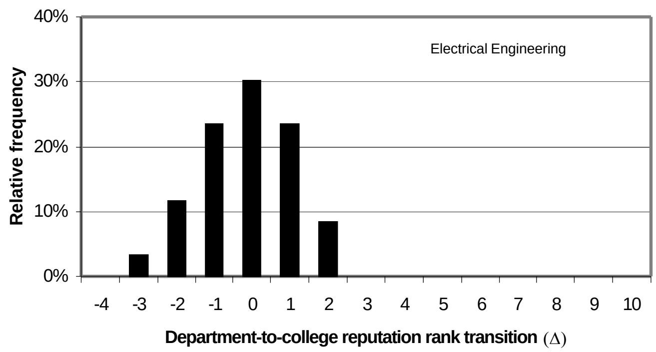

Figure 5.

Relative frequency of each department-to-college reputation rank transition (Δ) for the electrical engineering discipline based on data presented in *U.S. News and World Report* (1990 to 2001).

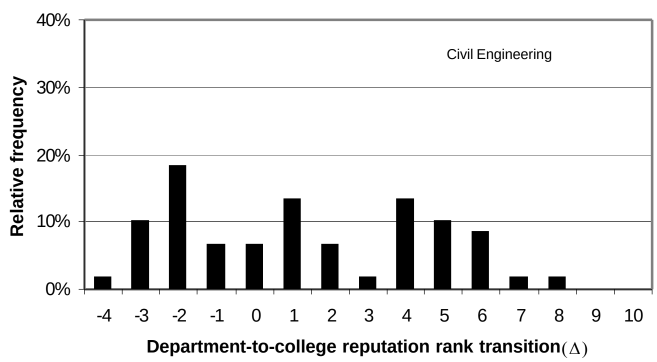

Figure 6.

Relative frequency of each department-to-college reputation rank transition (Δ) for the civil engineering discipline based on data presented in *U.S. News and World Report* (1990 to 2001).

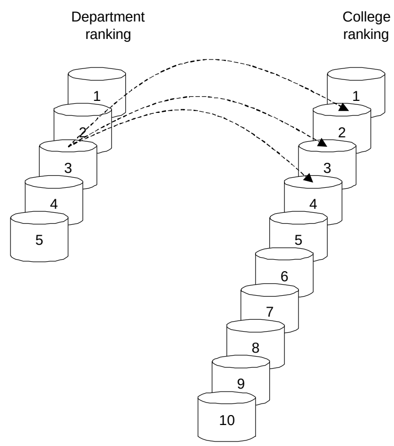

Figure 7.

Schematic demonstrating the relationship between department rankings and college rankings. In this example the #3 ranked department in a given discipline comes from either the #2, 3, or 4 ranked colleges (Δ = -1, 0, +1).

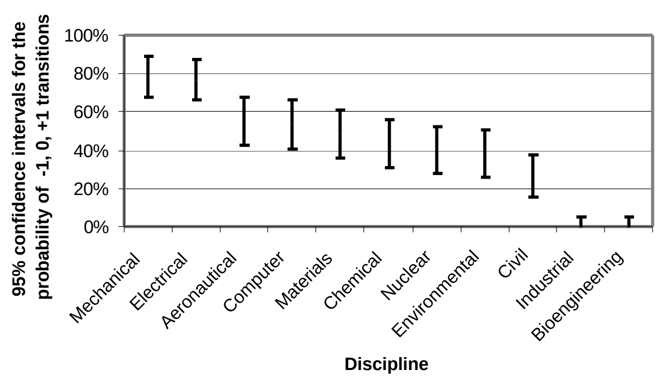

Figure 8.

95% confidence intervals for the probability that Δ = -1, 0, +1, sorted by discipline, based on data presented in *U.S. News and World Report* (1990 to 2001). This measure is an indication of how close the departmental rankings are to the college rankings for each discipline.