Transfer Paths into and out of Industrial Engineering

Ms. Sara C. Vick, Mississippi State University

Sara Vick is an Industrial and Systems Engineering Ph.D. candidate at Mississippi State University where her research focuses on human expression through virtual mediums like video games and on what it means to be an industrial engineering student. She received her MS in Industrial Engineering from Mississippi State in 2017 and her BS in the same in 2015. She was inspired to become an engineer by the HGTV show Mission: Organization and her life goal is the frustratingly vague ”to help people by making the world better”.

Dr. Lesley Strawderman P.E., Mississippi State University

Lesley Strawderman received her Ph.D. in Industrial Engineering from Pennsylvania State University in 2005. She has also received a M.S.I.E. from Pennsylvania State University and a B.S.I.E. from Kansas State University. She joined the Industrial and Systems Engineering faculty at Mississippi State University in August 2006, where she currently serves as Associate Professor and Undergraduate Coordinator. Dr. Strawderman’s research interests center around human factors and ergonomics. She is registered Professional Engineer (PE) in Mississippi and an active member of IIE, HFES, and ASEE.

Dr. Brian K. Smith, Mississippi State University

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Abstract

Engineering student recruitment and retention are crucial elements to encouraging the growth of the field of engineering. To this end, much research has been done on why engineering students attrite from engineering disciplines. A question oft left unanswered, however, is where these students go when they leave engineering. A similarly limited amount of research has been done on where students come from when transferring into engineering or on the behavior of students transferring between different engineering disciplines. In this study, a historical data set of student unit records (MIDFIELD) is used to identify common transfer paths students follow when entering or leaving Industrial Engineering (IE) degree programs. This includes when students are transferring from non-engineering programs into IE, transferring from IE to non-engineering programs, or changing degree programs to or from IE while remaining within engineering. It was found that IE was far more commonly the destination for degree program transfers, rather than the origin, both within engineering and in general. Fields that often led to IE included Electrical Engineering and Chemical Engineering as well as Business and Computer Science. However, when students did transfer out of IE, they were much more likely to be leaving engineering entirely than changing to a different engineering discipline. Further, it was found that when students transferred out of IE into a non-engineering field, Business was the field of choice for nearly 50% of students. Knowing where incoming students come from allows engineering educators to target recruitment efforts towards where those efforts will be most effective while knowing where students transfer to when they attrite from industrial engineering enables tailored retention efforts. Alternatively, this information can be used to encourage conversation about how student needs are met by different departments and supports inter-departmental communication about student achievement.

Introduction

Many students, including many STEM (Science, Technology, Engineering, and Math) students, change their major at least once while in university [1]. However, much of the research on this topic focuses on the ‘why’ of major changes rather than the ‘where’ [2]–[5]. Such studies employ frameworks like expectancy-value theory or social cognitive career theory to explain student rational for changing majors, often highlighting the role elements like grade point average [6], salary expectations [7], or engineering identity [8] play in the decision-making process.

Just as important as knowing why students change majors, however, is knowing what majors students are leaving and entering. To this end, a historic dataset was used to examine undergraduate engineering student degree program changes. The following questions were used to guide investigation:

1. What are common within-engineering transfer paths into and out of industrial engineering?
2. What are common non-engineering origins and destinations for transfer paths entering or leaving industrial engineering?

The term ‘transfer path’ used here refers to a unique pairing of an origin degree program and a destination degree program that a student traverses while changing majors. Because directionality matters, the path Aerospace Engineering > Industrial Engineering is distinct from the path Industrial Engineering > Aerospace Engineering.

Methods

Dataset

The Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) contains student unit records for more than one million undergraduate students from seventeen universities in the US from 1986 to 2018 [9, 10]. Only a small portion of the information included for each student was analyzed in this study: a unique anonymized student identifier (*mcid*), a list of each term a student was enrolled (*term*), and the degree program they were enrolled in for each such term (*cip4* or *cip2*).

R was used to parse this selection of variables as follows:

- Any *mcid* which never presented a term enrolled in *cip4* 1435 Industrial Engineering were excluded as not relevant to this study.
- Any *mcid* which *only* presented terms enrolled in *cip4* 1435 Industrial Engineering were excluded as having never changed degree program.
- For each remaining *mcid*, if for subsequent terms, the *cip4* changed, the before and after *cip4* were noted as a transfer path.

Further, paths which originated in 1401 Engineering, General or in Series 24 General Studies were excluded from analysis. Engineering, General was excluded as an origin because it primarily represents pre-engineering, undeclared engineering, or first-year engineering programs. Similarly, Series 24 General Studies primarily represents undeclared majors. Changing from either of these into industrial engineering does not indicate a change of major so much as a selection of initial major.

After this preparation, 8,501 paths representing individual student transfers into or out of industrial engineering remained for analysis.

Limitations

Before presenting findings related to common origin and destination degree programs for students entering or leaving industrial engineering, some limitations and inherent biases in the dataset should be mentioned.

While multiple institutions contribute data to MIDFIELD, not all universities contributed for the same lengths of time [12]. These universities, though distributed geographically across the US, are primarily large, public, research institutions. Contributing institutions also have varying requirements or policies on first-year engineering programs or enrollment caps [13]. Most importantly, they offer different programs. This is important because the desire to transfer between degree programs is not recorded in cases where the desire is not manifested. Students

who want to change majors but cannot because their preferred discipline isn't offered at their university are not captured in this analysis. Additionally, students who leave the reporting institution are not tracked further.

Timely completion and data sufficiency are related concepts that refer to how many terms of a student's education are included in the analysis and whether the applicable time frame is sufficient to present an accurate portrait of that student's behavior. No student records were excluded based on timely completion or data sufficiency because this study sought to understand student transfers regardless of degree completion status. Additionally, records were not excluded based on time scale: while older years had fewer datapoints than newer years, timing of record was not considered. If analysis was repeated with respect to that, results would likely differ for certain disciplines; for example, transfer paths involving Computer Engineering are presumably skewed towards more recent years.

Finally, the terminology used to describe educational fields varies. Because of this, how an institution connects its departments, programs, and majors to CIP codes is unpredictable. Some universities report 1435 Industrial Engineering while others report 1427 Systems Engineering. In this analysis, only 1435 Industrial Engineering is considered because it is much more prevalent than 1427 Systems Engineering.

Results

The transfer paths examined here fall into four groups, shown in Table 1, depending on whether Industrial Engineering served as the origin or destination degree program and whether the other end of the path was within engineering or not. The most common interaction with Industrial Engineering identified was students transferring into IE from other engineering disciplines.

Table 1. Number of transfer paths per category

	Within Engineering	Into or Out of Engineering	Total
IE as Origin	1,140 paths	1,656 paths	2,796 paths
IE as Destination	4,101 paths	1,604 paths	5,705 paths

While this analysis did not capture the number of students in the dataset who never changed between disciplines, some students encountered IE after having already changed major one or more times. Of the 8,501 total paths involving IE, 4,793 paths (56.4%) were the first recorded change for that student. Students whose second program change involved IE accounted for 3,038 paths (35.7%) while only 670 (7.9%) students transferred into or out of IE after having already changed majors two or more times.

Transfers Within Engineering

Most of the transfer paths involving Industrial Engineering involved other engineering disciplines. As expected, due to the sheer number of enrolled students, Mechanical Engineering was the most common destination for students leaving industrial engineering but remaining in an engineering discipline, accounting for 27.9% of the 1,140 paths leaving IE (Table 2). General

Engineering (22.5%), Civil Engineering (16.8%), and Electrical Engineering (12.6%) were the next most common destinations. Beyond that, a sharp decrease in frequency was noted.

Far more students transferred into Industrial Engineering from other engineering disciplines than out of IE. Mechanical Engineering was again the most common source of incoming IE internal transfers, serving as the origin degree program for 28.9% of within-engineering transfer paths destined for IE (Table 3). The rest of the most prominent fields of engineering [16] were also represented: Electrical Engineering (22.1%), Chemical Engineering (15.1%), Computer Engineering (9.1%), and Civil Engineering (8.8%).

Table 2. Engineering Destinations for IE Origin (n=1,140)

Destination	Percent
Mechanical	27.9
General	22.5
Civil	16.8
Electrical	12.6
Chemical	5.8
Computer	3.4
Aerospace	1.7
Other	9.3

Table 3. Engineering Origins for IE Destination (n=4,101)

Origin	Percent
Mechanical	28.9
Electrical	22.1
Chemical	15.1
Computer	9.1
Civil	8.8
Aerospace	7.1
Other	7.2

These values gain more context when viewed from the other direction. For example, out of the 5,521 paths entering Mechanical Engineering from other engineering disciplines, only 5.8% originated in Industrial. Conversely, 22.6% of the 5,244 paths leaving Mechanical for other engineering disciplines were destined for Industrial. Thus, from IE's perspective, Mechanical Engineering represented similar proportions of origin and destination disciplines for transfer paths into or out of IE. But from ME's perspective, IE accounted for a much higher proportion of destinations for ME origin than of origin for ME destination. Specifically, IE was the most common destination for students leaving ME but only the fifth most common origin for students entering the field. Electrical Engineering presented a similar dichotomy: Industrial was represented as a destination for a far greater proportion of the paths leaving Electrical than it was as origin for paths entering Electrical.

Transfers Into Engineering

Of the 14,198 transfer paths originating outside engineering (as defined by CIP codes), 11.3% or 1,604 ended in Industrial Engineering. The most common origin discipline was Series 52 Business, Management, Marketing, and Related Support Services (Business) at 21.8% of paths (Table 4). Contrariwise to the relationship between Mechanical Engineering and Industrial Engineering described above, IE's relationship with Business was reciprocal: 22.8% of paths leaving Business were destined for IE.

Table 4. Non-engineering Origins for IE Destination (n=1,604)

CIP Series	Origin	Percent
52	Business	21.8
11	Computer Science	19.8
26	Biological / Biomedical	9.3
40	Physical Sciences	7.9
27	Mathematics / Statistics	7.1
30	Multi / Interdisciplinary Studies	6.4
04	Architecture	5.9
45	Social Sciences	4.5
15	Engineering Technologies	4.1
42	Psychology	2.9
	Other	10.3

This list of the most common non-engineering origins for transfer paths into Industrial Engineering does not match the list for transfer paths into engineering as a whole. When considering all engineering disciplines, the most common non-engineering origins were Series 11 Computer Science (17.1% of 14,198 total paths), Series 40 Physical Sciences (16.7%), Series 26 Biological / Biomedical (11.7%), and then Series 52 Business (10.8%). Industrial Engineering subverted this by being the destination for a much higher proportion of transfer paths originating in Business and a much lower proportion of paths originating in Physical Sciences. In other words, the non-engineering disciplines that students transferring into IE come from do not reflect the general origin trends of students who transfer into non-IE engineering fields.

Transfers Out of Engineering

Industrial Engineering was the origin for 4.5% of the 37,032 paths transferring out of engineering. For comparison, Aerospace Engineering, which had a similar number of occurrences in the dataset as IE, represented the origin for 11.3% of the paths leaving engineering. Of the 1,656 paths leaving engineering via Industrial, 45.7% of them terminated in Series 52 Business (Table 5). While Business was also the overall most common non-engineering destination for transfer paths which started within engineering (19.6% of such paths), the list of the next highest frequency destinations (Computer Science, 12.7%; Physical Sciences 7.4%; General Studies, 6.9%; Biomedical / Biological, 6.6%; Social Sciences 6.2%; Engineering Technologies, 6.2%) is not reflected when considering only Industrial.

Table 5. Non-engineering Destinations for IE Origin (n=1,656)

CIP Series	Origin	Percent
52	Business	45.7

15	Engineering Technologies	7.8
45	Social Sciences	5.9
11	Computer Science	5.6
30	Multi / Interdisciplinary Studies	4.5
42	Psychology	3.7
	Other	26.8

Comparison of Prevalence as Origin or Destination

A series of ratios (Table 6) were developed to facilitate comparisons between disciplines while also partially accommodating for discrepancies in discipline size. The first ratio identified, R_{ODOO}, describes a discipline's overall destination to overall origin occurrence rate. In MIDFIELD, Industrial Engineering had a R_{ODOO} of 2.28 which indicates a net gain of students when considering both transfers in and transfers out. Of note is the related discipline, Systems Engineering, which had a R_{ODOO} of 1.88. For comparison, Civil Engineering had a R_{ODOO} of 0.90, Mechanical of 0.70, and Electrical of 0.69. These fields presented net losses in students while Industrial (and Systems) presented net gains.

Then, R_{WDND}, the ratio describing a discipline's prevalence as origin for transfer paths with within-engineering destinations to prevalence as origin for paths with non-engineering destinations was determined. Industrial Engineering had a R_{WDND} of 0.55, the second lowest of all engineering disciplines. This suggests that students who transfer out of Industrial Engineering are more likely to be leaving engineering entirely rather than transferring to another discipline within engineering. Civil had a similar R_{WDND} of 0.64 while Mechanical had 0.71. Electrical, reflecting its close relationship with Computer Engineering, had a R_{WDND} of 1.07. That students often transfer out of engineering is not unusual, but these ratios suggest that IE students leave at a higher rate than students of other disciplines.

Finally, R_{WONO}, or the ratio comparing how often a discipline was the destination for transfer paths with within-engineering origins versus for transfer paths with non-engineering origins, was calculated. Here, a higher value indicates that students transferring into the discipline are more likely to be coming from other engineering programs than from non-engineering programs. Although most engineering disciplines in MIDFIELD had R_{WONO}'s greater than one (Civil at 2.03, Mechanical at 2.59, and Electrical at 2.77, for example), Industrial's 2.56 (and System Engineering's 5.15) still serve to highlight IE's place within the engineering discipline ecosystem.

Table 6. Summary of R_{ODOO}, R_{WDND}, and R_{WONO} for selected engineering disciplines

	R_{ODOO}	R_{WDND}	R_{WONO}
Industrial	2.28	0.55	2.56
Systems	1.88	*	5.15
Civil	0.90	0.64	2.03
Mechanical	0.70	0.71	2.59
Electrical	0.69	1.07	2.77

* insufficient records available

Discussion

The most apparent conclusion that can be drawn from the data is that considerably more students transfer into Industrial Engineering than transfer out, regardless of whether the other end of the transfer path is within engineering or not. Perhaps this suggests that IE is a 'second-choice' field that students transfer to when they cannot make it elsewhere [17, 18]. Another, more positive, explanation is that Industrial Engineering is a 'forever home' field, that, once discovered students have no desire to leave [19, 20]. In terms of numbers, transfer paths with Industrial Engineering as the destination were twice as common as paths with IE as the origin. Half of the transfer paths which involved IE at all were associated with students transferring from other engineering disciplines into IE. Meanwhile, when students transfer out of IE, their destination is more likely to be outside of engineering than another engineering program.

Beyond the large-scale values, discipline-specific insights also present themselves. While Mechanical Engineering occupies similar percentages of paths transferring in and transferring out of IE, other types of engineering do not have such a balanced relationship. For example, Civil Engineering is the third most common destination for students transferring out of IE to another engineering field, but the fifth most common origin for students transferring into IE. Industrial Engineering does not appear to be an appealing option for students seeking a change from Civil in the same way that Civil is appealing to students seeking to leave Industrial. Chemical Engineering presents the opposite situation. In terms of percent of total, Chemical Engineering is the third most common engineering source for incoming students, despite being the destination for only 5.8% of students leaving IE. Industrial Engineering students are unlikely to choose to change major to Chemical Engineering. Research has shown that IE is considered an 'easy' engineering discipline [21, 22] which may explain the frequency of transfer paths from traditionally difficult fields [23] into Industrial.

When considering transfer paths which crossed the border of engineering, IE continued to subvert expectations. Incoming Industrial Engineering students were more likely to be coming from Business than would be expected for other engineering disciplines. Likewise, Physical Sciences were far less common as an origin for students transferring into IE than for other engineering programs. Interestingly, Computer Science was a common source for Industrial students though not at all a common destination for those leaving IE. Physical Sciences was an even less common destination. This suggests that Industrial Engineering is approached differently than other engineering disciplines in terms of how it topically interests potential students.

That many students transferring out of Industrial Engineering to non-engineering programs are destined for Business is unsurprising. That the percentage approaches 50% is, perhaps, more so. If subject matter preference is considered a factor in the choice of what program to transfer into, then Business makes sense because of Industrial's strong foundations in project management [24, 25]. However, does appealing to similar interests account for the high occurrence of incoming Computer Science or Chemical Engineering transfers?

Conclusion

This work is not intended to explain why students transfer between degree programs in the ways that they do. Rather, this enhances the understanding of where students are coming from and going to when the transfers occur. Without this knowledge, it can be difficult to appropriately support students who find themselves in a degree program they do not enjoy, for one reason or another. By knowing what common transfer paths are, educators can guide their students to make informed decisions in their educational journeys. This information could be applied to improve curricula to incorporate topics that students find lacking or to broaden awareness of engineering as a whole. Conversely, being cognizant of how student transfer behavior manifests can enable educators to facilitate such transfers, opening conversations about inter-departmental relationships to the benefit of students.

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