SUPPLY AND DEMAND OF ENGINEERS

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Abstract

A statistical survey of engineering majors is presented to understand potential disconnects between the supply and demand of engineering graduates. On the supply side, the primary metric is the annual number of engineering graduates by major from United States Universities. On the demand side, the presented data includes the government projections of current and future engineering positions, recent job postings on employment websites, and frequency of engineering terms in digitized books. The data indicates that supply and demand of engineers is currently well matched, but also suggests strong dynamics related to the emergence and decline of specific engineering majors.

Introduction

Division of labor — the tendency of individuals to specialize in specific occupations — is an important feature of the modern labor market [1]. The education and training of specific classes of engineers not only shapes the employability of engineering graduates at the micro scale, but also affects the future quality of life for society on the macro scale. Unfortunately, choices related to the division of labor take years to implement and have even longer term consequences; while the half-life of engineering knowledge is on the order of five years [2], the development and persistence of engineering curricula are likely closer to twenty years.

The origination of the first American engineering majors and societies was based in medieval and renaissance roots [3]. In 1920, the first Organizing Conference of the Federated American Engineering Societies was held, a transcript of which provides a historical basis regarding the development of modern engineering majors [4]:

> In 1852 the American Society of Civil Engineers was founded. Subsequently came the national society for each of the main engineering fields, Mining, Mechanical, Electrical, Chemical, Ceramic and a host of subdivisions and state and local organizations. All of these were technical in their activities, and function independently. Prior to the [first world] war, the matter of federation of these bodies was considered, so as to adequately represent the profession as a whole. The war emphasized the need still more and appears to have stirred the engineer to change his point of view from developing the technology of his branch of the profession merely, to the broad one of greater devotion to the common cause and greater service to the public.

Looking forward, there can be little doubt that technological evolution necessitates renewal of engineering curricula as well as initiation of new engineering majors. In this paper, I consider the dynamics of supply and demand of engineers. The goals are to assess the adequacy of the supply of engineers from the academy relative to national needs, evaluate the characteristic response time of engineering lifecycles, and identify any major gaps between supply and demand.

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Statistics

Supply of Engineering Graduates

The American Society of Engineering Education annually publishes leading data on engineering colleges in the United States including both individual college statistics and national trends. This data is published annually in the Profiles of Engineering Colleges book sent to all ASEE deans and is available online. Figure 1 provides the supply of engineers graduating from four-year undergraduate programs during the 2008-09 academic school year [5]. The data indicates that a predominance of students graduate from the four classic engineering majors (mechanical, electrical, civil, and chemical) along with computer science and hardware. Highly specialized majors (such as mining, nuclear, agricultural, and petroleum) represent a very small fraction of the graduating engineers.

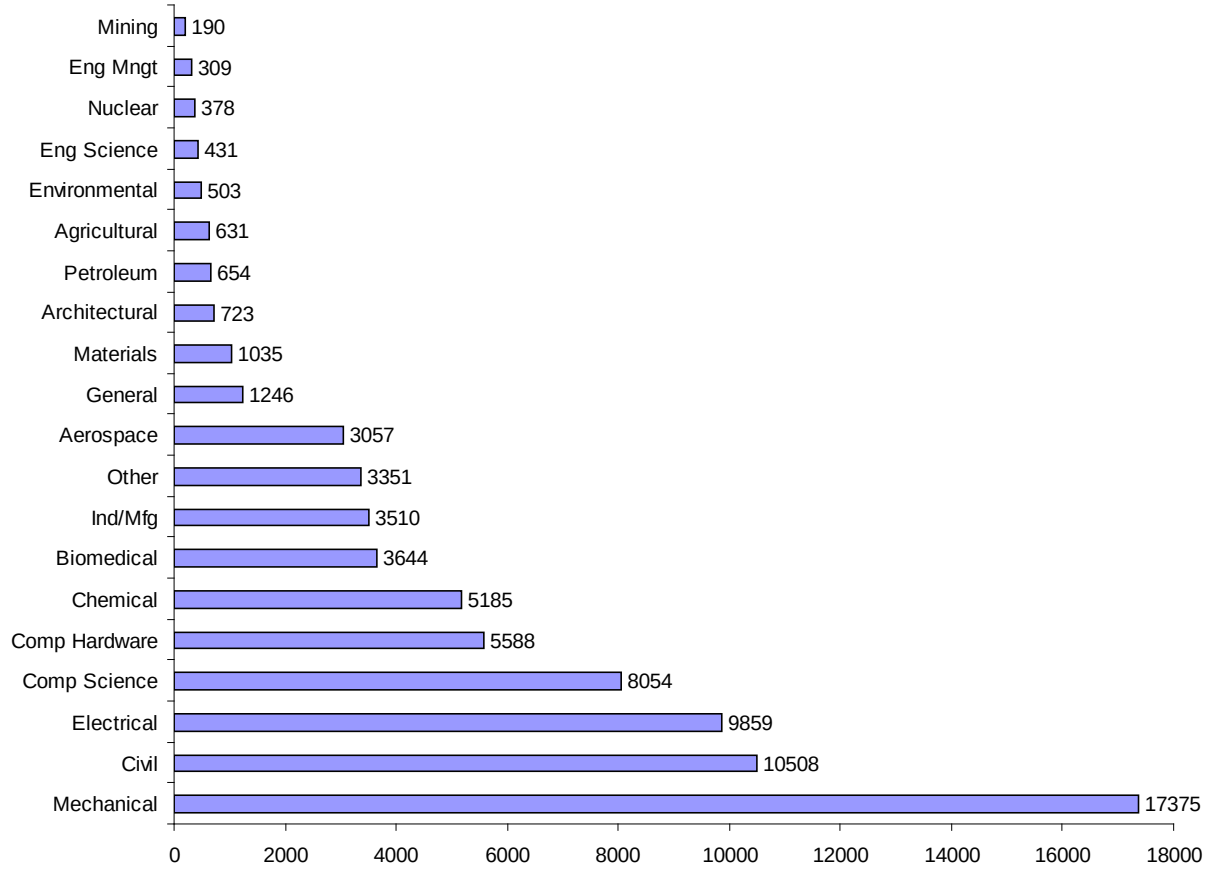

Figure 1: Supply of engineering undergraduates during the 2008-09 academic year

Government Projections of Engineering Demand

The Bureau of Labor Statistics at the United States Department of Labor annually provides occupational employment data and ten year projections. Table 1 provides the breakdown of different engineering specialties relative to all occupations [6]. The data indicates that relative to all occupations, engineers are in the uppermost wage quartile. The data also indicate an increase in engineering position of 11.35%, which is greater than the 10.12% increase across all occupations. This demand data is also classified by engineering major, and will be later compared to the supply data presented in Figure 1 within the discussion section.

Table 1: Engineering occupational employment data and projections

2008 National Employment Matrix title and code		Employment		Change, 2008-18	Percent self-employed, 2008 (1)	Job openings due to growth and replacement needs (in thousands)	Median annual wages, 2008 (2)	Median annual wage quartile (3)	Most significant source of education and training category
		2008	2018	Percent					
Total, all occupations	00-0000	150,931.7	166,205.6	10.12	7.7	50,928.5	$32,390	M	-
Engineers, all	17-2000	1,571.9	1,750.3	11.35	2.7	531.3	$84,879	VH	-
Engineering managers	11-9041	184.0	195.4	6.16	0.6	48.7	$115,270	VH	Bachelor's or higher, plus experience
Aerospace engineers	17-2011	71.6	79.1	10.39	3.3	22.3	$92,520	VH	Bachelor's degree
Agricultural engineers	17-2021	2.7	3.0	12.13	0	0.9	$68,730	VH	Bachelor's degree
Biomedical engineers	17-2031	16.0	27.6	72.02	3.3	14.9	$77,400	VH	Bachelor's degree
Chemical engineers	17-2041	31.7	31.0	-2.05	1.3	7.8	$84,680	VH	Bachelor's degree
Civil engineers	17-2051	278.4	345.9	24.27	4.3	114.6	$74,600	VH	Bachelor's degree
Computer hardware engineers	17-2061	74.7	77.5	3.77	1.3	23.5	$97,400	VH	Bachelor's degree
Electrical and electronics engineers	17-2070	301.5	304.6	1.04	1.6	72.3	$84,167	VH	Bachelor's degree
Electrical engineers	17-2071	157.8	160.5	1.71	1.6	38.9	$82,160	VH	Bachelor's degree
Electronics engineers, except computer	17-2072	143.7	144.1	0.31	1.6	33.4	$86,370	VH	Bachelor's degree
Environmental engineers	17-2081	54.3	70.9	30.62	0.6	27.9	$74,020	VH	Bachelor's degree
Industrial engineers, including health and safety	17-2110	240.4	273.7	13.81	0.7	94.6	$88,570	VH	Bachelor's degree
Health and safety engineers, except mining safety engineers and inspectors	17-2111	25.7	28.3	10.29	0.7	9.2	$72,490	VH	Bachelor's degree
Industrial engineers	17-2112	214.8	245.3	14.23	0.7	85.4	$73,820	VH	Bachelor's degree
Marine engineers and naval architects	17-2121	8.5	9.0	5.77	14.9	2.3	$74,140	VH	Bachelor's degree
Materials engineers	17-2131	24.4	26.6	9.33	0	8.1	$81,820	VH	Bachelor's degree
Mechanical engineers	17-2141	238.7	253.1	6.03	2.3	75.7	$74,920	VH	Bachelor's degree
Mining and geological engineers, including mining safety engineers	17-2151	7.1	8.2	15.3	0	2.6	$75,960	VH	Bachelor's degree
Nuclear engineers	17-2161	16.9	18.8	10.95	0	5.4	$97,080	VH	Bachelor's degree
Petroleum engineers	17-2171	21.9	25.9	18.39	0.4	8.6	$108,020	VH	Bachelor's degree
All other engineers	17-2199	183.2	195.4	6.66	6.4	50.2	$88,570	VH	Bachelor's degree

Footnotes:
(1) Based on data from the Current Population Survey, U.S. Department of Labor, Bureau of Labor Statistics.
(2) Data are from the Occupational Employment Statistics program, U.S. Department of Labor, Bureau of Labor Statistics.
(3) Based on data from the Occupational Employment Statistics program, U.S. Department of Labor, Bureau of Labor Statistics.
Quartiles are defined as follows: VH (very high) = $51,540 or greater; H (high) = $32,391 to $51,530; L (low) = $21,590 to $32,389; VL (very low) = less than $21,590.

Survey of Engineering Job Postings

The current demand of engineers was also assessed by conducting an assessment of current engineering job postings. Specifically, a web spider was written to query the largest employment website in the world (http://www.monster.com, Maynard, MA) for all engineering positions posted between March 14th and 17th of 2011 for each of the 50 United States. The titles of the queried 7,471 positions were then categorized and sorted in descending order of their frequency, which resulted in a classification of 955 unique types of positions. The 32 most prevalent job titles are provided in Figure 2 with their observed frequency.

Figure 2 provides some expected results inasmuch as the most prevalent job postings are those with which engineering faculty and students are experienced. There are, however, at least two items worth consideration. First, **most** of the positions are titled according to their organizational role (e.g. design, project, and test engineered) as opposed to their discipline (e.g. mechanical, electrical, and civil engineers). Second, many of the positions (e.g. systems, embedded, and packaging engineers) are interdisciplinary and do not reside within any single traditional engineering major. Taken together, this data indicates that hiring organizations seek engineers according to job function regardless of the strict classification of their knowledge by engineering major.

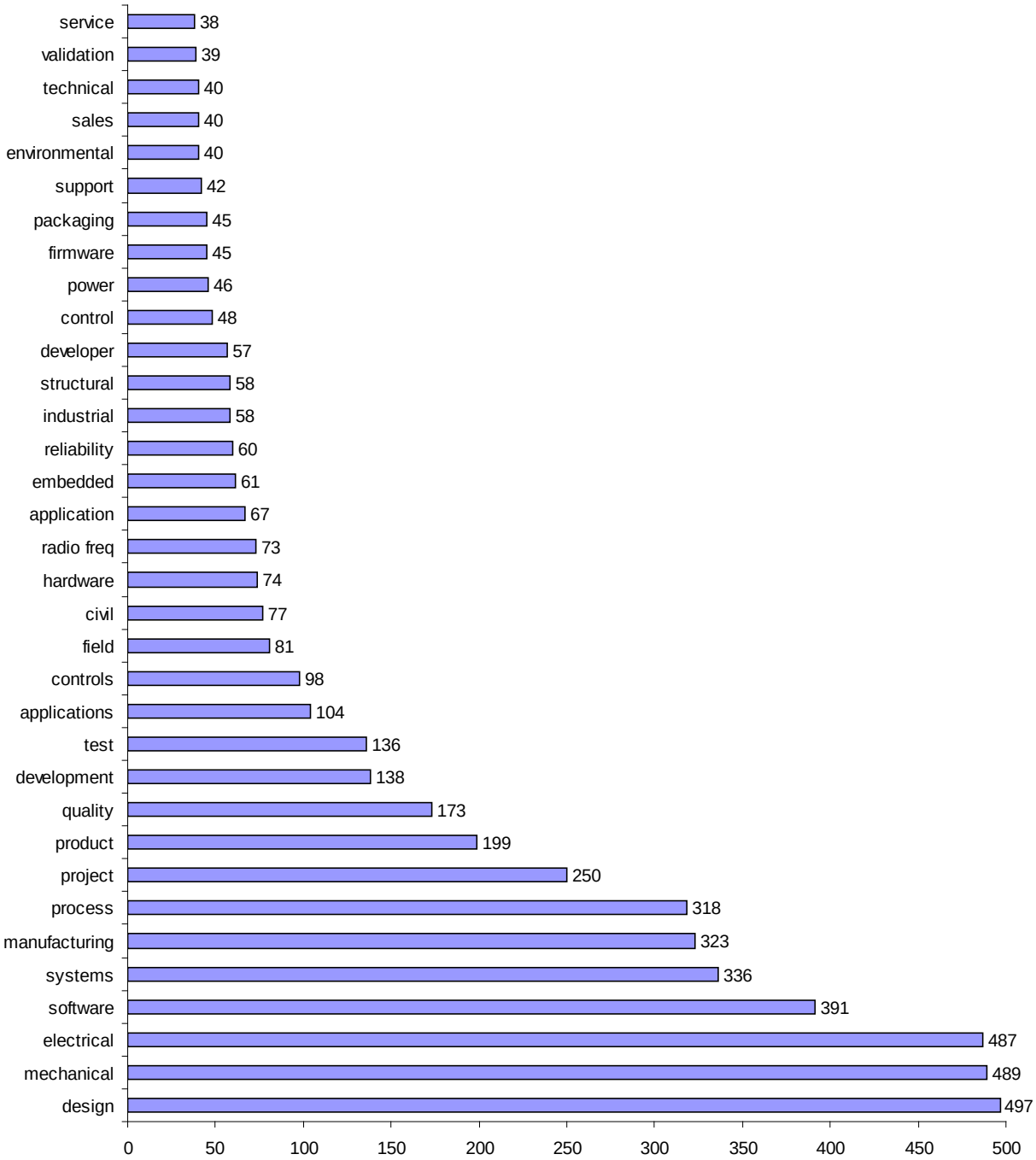

Figure 2: Number of postings across the United States by engineering job title

Engineering Term Frequency

An enormous database has emerged from Google's effort to digitize books, which were mostly drawn from over 40 university libraries around the world as well as those directly contributed by publishers. Each page was scanned with custom equipment, and the text was digitized by means of optical character recognition (OCR). Metadata describing the date and place of publication were provided by the libraries and publishers and supplemented with bibliographic databases. Already, over 15 million books have been digitized representing about 12% of all books ever

published [7]. Using this database, Figure 3 provides the frequency of usage various engineering terms (e.g. “civil engineering”, etc.) relative to their peak usage as a percentage of the entirety of all words in digitized English works.

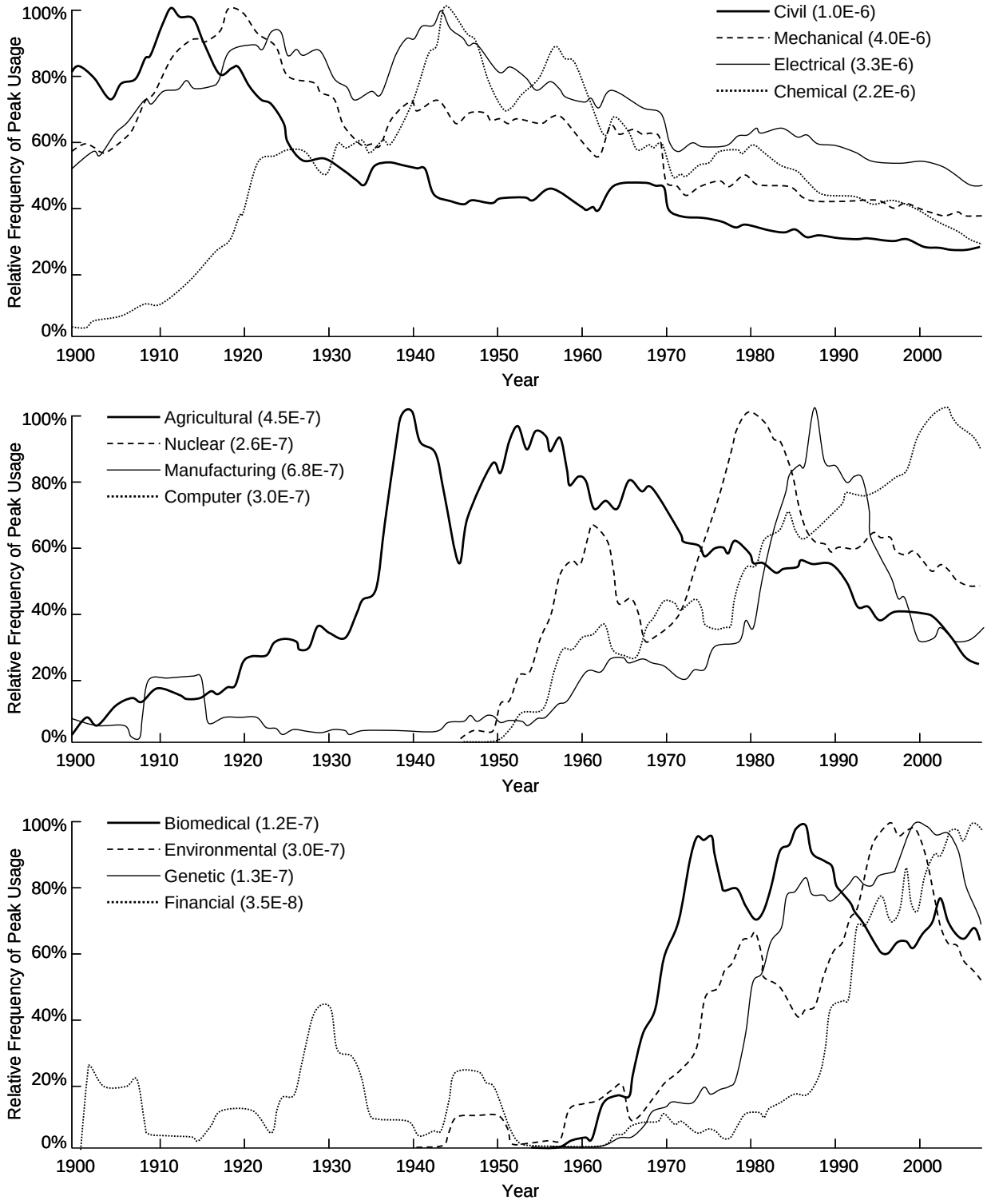

Figure 3: Relative frequency of (top) classic, (middle) peaked, and (bottom) emerging majors

It is interesting to contemplate the dynamics of the engineering frequency data plotted in Figure 3. The top graph seems to suggest that all of the "classic" engineering majors are in decline. However, the decrease in frequency is largely due to the explosion of publications being generated of which a fewer percentage pertain to engineering. The employment data of Table 1 indicates that engineering will remain a significant percentage of all occupations.

The "peaked" majors plotted at middle of Figure 3 are of interest for two reasons. First, the peak for each of these majors correspond to specific events: the depression and post-WWII boom for agricultural engineering, the cold war and three mile island for nuclear engineering, the Japan threat for manufacturing engineering, and the dot.com bubble for computer engineering. Second, the rise time of this frequency data can be estimated and used to assess and predict future engineering demand.

The "emerging" majors have been selected for their relatively recent emergence. The frequency of their usage in the literature is plotted at bottom of Figure 3. Somewhat surprisingly, most of these disciplines have actually peaked: biomedical and genetic engineering are maintaining a high level of activity while environmental engineering appears to be in decline. Only financial engineering is continuing to increase, and this behavior may be due to the 2008 recession (as also forecast by the previous peak around the Great Depression). Regardless, all of this frequency data seems to have similar dynamics. While a later paper will quantify these dynamics using system identification techniques, the characteristic response time is on the order of ten years.

Discussion

Current Supply and Demand

While the current state of the economy is uncertain, it is worthwhile to consider the match between the current supply and demand of engineers. As such, the supply of engineers (reported by ASEE and presented in Figure 1) was compared to the demand for engineers as assessed by the national job postings presented in Figure 2 in concert with the employment data of Table 1. Some job postings, such as for a mechanical engineer, will have a 1:1 mapping to their engineering major. However, other job postings (e.g. controls engineer) will not have such a clear mapping. As such, a cross correlation matrix, **C**, was defined that related the title of the job posting, **j**, to the type of engineering major, **e**. In cases where no clear mapping could be estimated, the weightings were established from the national employment data of Table 1. An example of the mapping from number of job postings to number of engineering positions is:

$$\begin{bmatrix} \textit{Mechanical engineer} \\ \textit{Civil engineer} \\ \textit{Electrical engineer} \\ \vdots \\ \textit{Mining engineer} \end{bmatrix} = \begin{bmatrix} 0.228 & 1 & 0.3 & \cdots & 0.228 \\ 0.138 & 0 & 0 & & 0.138 \\ 0.129 & 0 & 0.4 & & 0.129 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0.002 & 0 & 0 & \cdots & 0.002 \end{bmatrix} \begin{bmatrix} \textit{Design engineer} \\ \textit{Mechanical engineer} \\ \textit{Control engineer} \\ \vdots \\ \textit{Marketing engineer} \end{bmatrix}$$

Figure 4 provides the resulting comparison between the current demand for engineers with recent supply; a loglog scale is used to allow clear plotting across different magnitudes and was found to not distort the qualitative nature of the results. Assuming a Markov process for labor dynamics [8], the top left corner of the figure represents high engineering demand with low engineering supply.

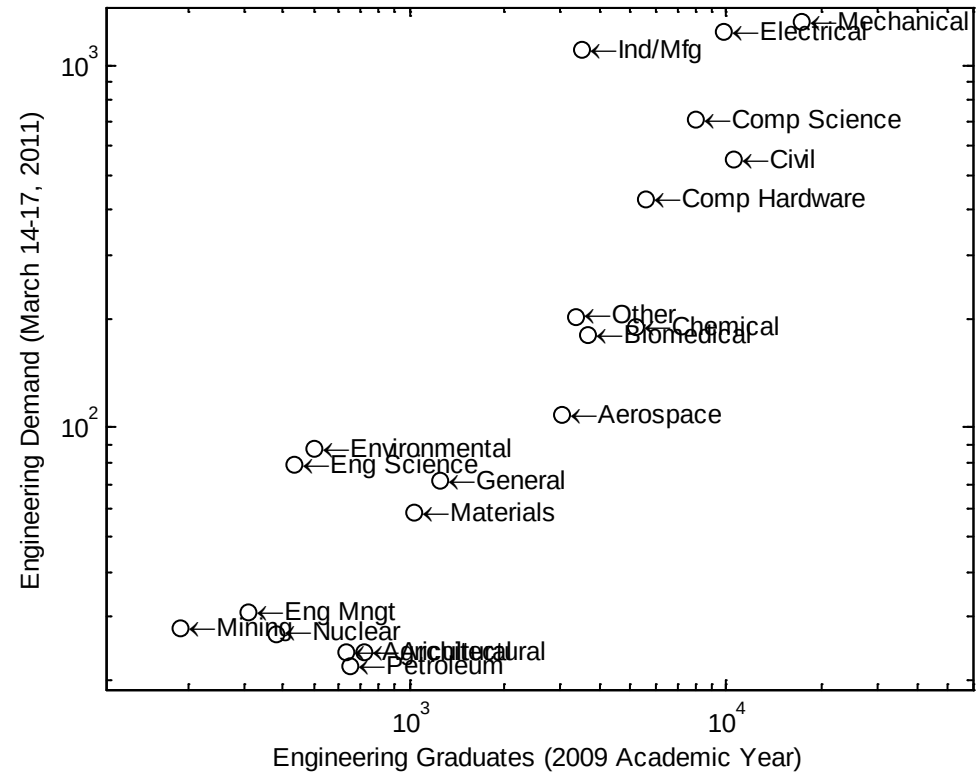

Figure 4: Comparison of current engineering demand with supply

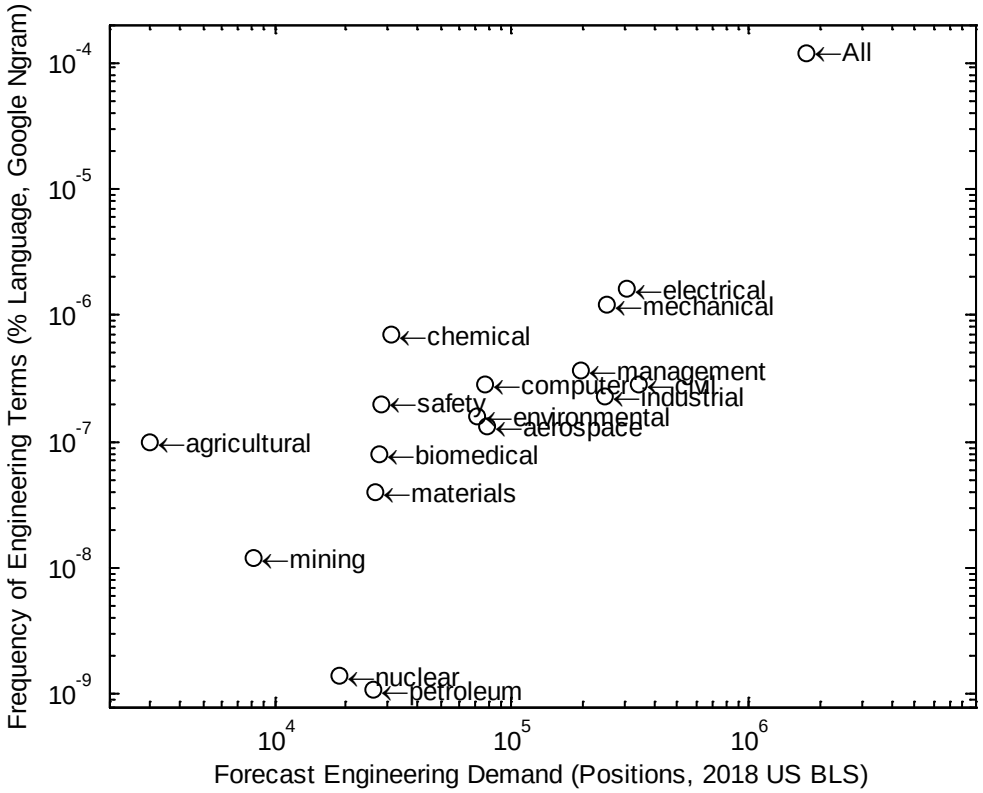

Figure 5: Forecast engineering demand compared to frequency of engineering terms

Somewhat surprisingly, the results indicate that most majors very well match the supply and demand, with no majors very far off the diagonal. Again, assuming a Markov process for labor dynamics, the major currently most in demand relative to supply are industrial/ manufacturing engineers. This result is likely due to the long term reduction in graduating industrial engineers due to continued offshoring of manufacturing [9] in concert with a potential on-shoring trend due to the weakening of the U.S. dollar and increased fuel costs. Conversely, the current demand for agricultural, architectural, and petroleum engineers is relatively low.

Future Engineering Demand

Considering future engineering demand, Figure 5 plots the current frequency of engineering majors in the literature (for 2008 of the data in Figure 3) as a function of the engineering demand forecast by the Bureau of Labor Statistics (for 2018 of the data in Table 1). The upper left corner of the figure corresponds to those majors that have a high prevalence in the literature coupled with fewer forecast positions. In general, it is observed that most majors fall upon the diagonal. Agricultural and chemical engineering are currently generating more content relative to the number of positions while nuclear and petroleum engineering are generating less content.

Conclusions

This paper was motivated by the presupposition that there are large disconnects between the supply and demand of engineering majors, with the expected conclusion that new and more interdisciplinary majors are required to meet future society needs. However, the data indicates that the contrary is true and the market is being well supplied; this can be confirmed with unemployment data segregated by engineering major. Still, the dynamics of engineering frequency in the literature suggest that there are significant swings in specific engineering disciplines albeit with short characteristic response times that jeopardize strategic realignments.

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