2018
SURVEY
REPORT

BY THE NCSEA SE3 COMMITTEE

NCSEA
National Council of Structural Engineers Associations

SE3

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Excerpt from Data Analyst Consultant's Report

SE3 MISSION AND HISTORY

The Structural Engineering Engagement and Equity (SE3) Project began in 2015 in San Francisco, California under the Structural Engineers Association of Northern California (SEAONC), with the mission of understanding the underlying reasons why people leave the profession. SE3 conducted its first survey in 2016 and collected 2,100 responses from currently practicing and former structural engineers. The study surrounding the 2016 survey revealed valuable insights into the state of our profession, and allowed SE3 to dig deeper into the root causes of satisfaction, or dissatisfaction with everyday structural engineering practice, including specific areas such as career development, pay and compensation, and work flexibility.

Publication of the 2016 SE3 Report (SEAONC SE3 2016) and presentations of the associated findings generated broad nationwide interest and discussion and led to the 2017 adoption of SE3 at a national level under the National Council of Structural Engineers Associations (NCSEA). Together with engineers from around the United States, the committee works to improve engagement, retention, diversity, and inclusion in the profession by collecting data, starting conversations, and encouraging all to do the same.

Our mission statement: **to attract and retain the best talent into our profession, and to ensure all structural engineers have a pathway to success in their careers.**

NCSEA
National Council of Structural Engineers Associations

For more information, visit
www.ncsea.com/committees/se3/
www.se3committee.com

*For the original SEAONC
SE3 webpage, visit
www.se3project.org*

EXECUTIVE SUMMARY

In 2018, the SE3 Committee expanded the study to address new research questions in several different areas. The survey included new questions about interactions with firm management, career development as it relates to performance feedback, and intentions to stay at a firm or in the profession. It also examined negotiations for pay and other benefits, options for work flexibility and childcare. The committee broadened the survey's demographic questions to better inform our understanding of equity, diversity and inclusion within the profession. In addition to age, gender, position level, and geographic location, the survey included new questions about race identity, sexual orientation, and English as a native language.

See below a summary of key findings from the 2018 SE3 study.

Overall Career Satisfaction and Retention

- 78% of respondents are satisfied or very satisfied with their choice of career in structural engineering. 59% of respondents indicated they have considered leaving the profession at some point in their careers.

- Respondents with 2-4 years, 10 years, and 18 years experience are least likely to plan on staying in the profession until retirement.

- High predictors of employee retention within a firm include emotional and financial investment in a firm, the perception that staff are treated fairly by management, having at least one dependent, and high satisfaction with work environment, and compensation.

- Positive factors related to career satisfaction include high firm morale, respect for firm leadership, and positive experiences with dependent care/work integration.

- Negative factors related to career satisfaction include being at the associate/ shareholder position level, and being Asian or Black.

Career Development

- 52% of all respondents aspire to become Principal during their careers.

- Male and female respondents define success in their careers differently. For example, women tend to define success more with the effective management of others, respect from staff, and job title and men tend to define success with high compensation.

- At every level, female respondents advanced to their current position more quickly than their male counterparts.

- Respondents without children advanced to their current position more quickly than their counterparts with children.

- A slightly higher percentage of non-white respondents reported experiencing workplace discrimination than did white respondents. Female respondents reported having experienced discrimination much more frequently than male respondents.

Pay

- Factors that predict lower pay include being a sole practitioner, identified daily tasks including Design or CAD, and having no dependents.

- Factors that predict higher pay include position level, more experience (both hours worked and years of experience), and geographic location (certain major cities).

- Men reported higher total compensation on average than women.

- Men and women respondents report negotiating pay at roughly equal rates (53% men vs. 49% women). Of those who negotiated pay, men were more successful than women (85% men vs. 75% women).

Work Life Balance

- There are perceived differences between those who work full-time in the office, and those who work remotely or work reduced hours. Respondents indicate they think coworkers who work remotely or reduced hours are more of an inconvenience, less productive, less accountable to clients and colleagues, and deserve less rewarding assignments than those who work in the office full-time.

- 21% of respondents have taken a leave of absence at some point in their careers. 39% of women respondents have taken a leave of absence compared to only 14% of men respondents. Of the respondents who have taken a leave of absence, men are more likely to report a positive perceived impact on their careers than women, and women are more likely to report a negative perceived impact than men.

- About 50% of respondents with children report that they share caregiving responsibilities equally with their partners. This is more true of younger parents than older parents in our survey response pool. 57% of parents under age 40 reported equal caregiving compared to 43% of parents over age 40.

- Of the respondents with children, the majority of men and women reported their productivity after having children stayed the same. However, 29% of women with children reported a decreased motivation to advance after having children compared to only 8% of men. Inversely, 19% of women with children reported an increased motivation to advance after having children compared to 32% of men with children.

STUDY METHODOLOGY

In fall 2017, the NCSEA SE3 committee began work on the 2018 SE3 study. The 2018 survey team included male and female engineers from different parts of the United States, representing multiple state SEA member organizations, individuals with and without partners or children, and people with varying levels of professional experience and position, ranging from graduate engineer to principal. Most of the team included engineers who worked at structural engineering consulting firms, though a small number worked for AEC industry organizations, or in academic research positions.

The team began by reviewing the questions in the original 2016 SE3 survey. With input from externally-hired data analysts, they revised or eliminated old questions and added new questions aligned with new areas of study. The 2018 survey included new questions about interactions with firm management, career development as it relates to performance feedback, and intentions to stay at a firm or in the profession. It also examined negotiations for pay and other benefits, options for work flexibility and childcare. The 2018 survey also included new and different demographic questions; in addition to age, gender, position level, and geographic location, the survey asked about race identity, sexual orientation, and English as a native language.

The 2018 survey team programmed the survey questions onto the SurveyGizmo platform, with multiple paths of questioning controlled by survey logic based on a respondent's employment status and position, and whether the respondent had dependents.

The survey underwent beta-testing by a team of about 28 engineers in January 2018. The beta-testing team sought to confirm all relevant questions were posed to a certain respondent based on his or her demographics, and also to identify non-applicable questions.

The committee administered the 2018 survey from March through May 2018 online via the SurveyGizmo platform. The survey was distributed primarily through direct emails from NCSEA to individual members of SEAs.

As with the 2016 survey, the committee retained an external professional data analyst to process and analyze the data. The analyst filtered the core survey sample by eliminating incomplete or non-applicable responses, and performed a rigorous analysis, producing statistical models of seven key outcomes identified by the committee:

- Total Compensation

- Respondent's Position

- Overall Satisfaction

- Considering Leaving the Profession

- Expected Length of Stay in Profession or Firm

- Professional Engagement

- Satisfaction with Work-Life Balance

For each outcome, the analyst followed a procedure to narrow the pool of predictors, to select variables and check their robustness, to test for variable significance, and to test high-interest variables identified by the committee (including age, gender identity, ethnicity, native language, current or past receipt of mentoring, status as caregiver for children or adult dependents, and both gender and ethnicity for respondents identified as Principals. Through these predictive models, the analyst identified the significance of several variables on each studied outcome. For more detailed information on the SE3 analyst's statistical methodology, see Appendix A.

Members of the SE3 committee wrote this report, and have presented the 2018 study findings throughout the United States and abroad, beginning with the first presentation at the 2018 NCSEA Summit in Chicago, IL. The study results presented in this report include the direct results of responses to survey questions (as calculated by committee members) as well as the predictive variable relationships identified as statistically significant according to the analyst.

DEMOGRAPHICS

The 2018 SE3 survey received 2,925 completed responses from current and formerly practicing structural engineers, with participation from almost all 50 states. Overall, California had the largest number of respondents, with 20% of those surveyed based in the four metro areas of San Francisco, San Diego, Los Angeles, and Oakland. New York City had the largest number of respondents for a single metropolitan city with 261 participants. By state, California, Washington, Colorado, Texas, Illinois and New York all had more than 150 respondents each.

RESPONSES BY STATE

Legend	
0	
1-10	
11-50	
51-150	
150+	

State responses:
- Washington: 188
- Oregon: 75
- Montana: 27
- North Dakota: 2
- Minnesota: 88
- Wisconsin: 49
- Michigan: 66
- New Hampshire: 9
- Vermont: 7
- Maine: 28
- New York: 294
- Massachusetts: 78
- Idaho: 25
- South Dakota: 0
- Wyoming: 0
- Iowa: 21
- Nebraska: 12
- Pennsylvania: 94
- Rhode Island: 4
- Connecticut: 23
- Nevada: 10
- Utah: 35
- Colorado: 159
- Kansas: 32
- Missouri: 49
- Illinois: 172
- Indiana: 20
- Ohio: 41
- Kentucky: 11
- West Virginia: 0
- Virginia: 54
- New Jersey: 15
- Delaware: 2
- Maryland: 22
- California: 728
- Arizona: 42
- New Mexico: 17
- Oklahoma: 92
- Arkansas: 13
- Tennessee: 46
- North Carolina: 37
- South Carolina: 15
- Texas: 168
- Mississippi: 1
- Louisiana: 10
- Alabama: 27
- Georgia: 53
- Florida: 57
- Alaska: 17
- Hawaii: 11

AGE

NUMBER OF RESPONDENTS

AGE OF RESPONDENTS (YEARS)

The average age of respondents was 39, and the median age was 36. Approximately 20% of those surveyed fell in the 26-30 year age range. 68.4% of respondents identified as male, 29.6% identified as female, 0.1% identified as non-binary, and 1.9% of respondents did not indicate their gender identify. The male age distribution skewed older than women, as only 13% of women were over 45 compared to 30% of men. 91% of respondents identified as heterosexual, 3% identified as gay/lesbian or bisexual, and the remainder chose not to respond.

GENDER

68.4%
2120 men

29.6%
916 women

0.1%
3 non-binary

1.9%
59 prefer
not to answer

Each figure represents 100 respondents.

By position, over half of the respondents identified at the project engineer and senior engineer levels; 758 (26%) and 796 (28%), respectively. 352 (12%) of respondents identified at the entry level/staff position level, while 467 (16%) and 517 (18%) identified at the associate and principal levels, respectively. At every level of advancing position, the percentage of women respondents decreased; women represented 43% of entry level respondents and 16% of principal level respondents.

POSITION BY GENDER

	ALL RESPONDENTS	WOMEN	MEN
Principal/CEO		16%	84%
Associate/Shareholder		25%	74%
Project Manager		28%	72%
Project Engineer		38%	68%
Staff		43%	57%

Staff 12%
Principal/CEO 18%
Associate/Shareholder 16%
Project Manager 28%
Project Engineer 26%

CHILDREN

NO | YES
48% | 52%

| 43% | MEN | 57% |
| 61% | WOMEN | 39% |
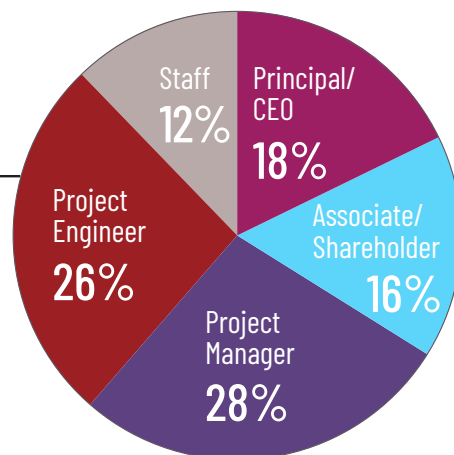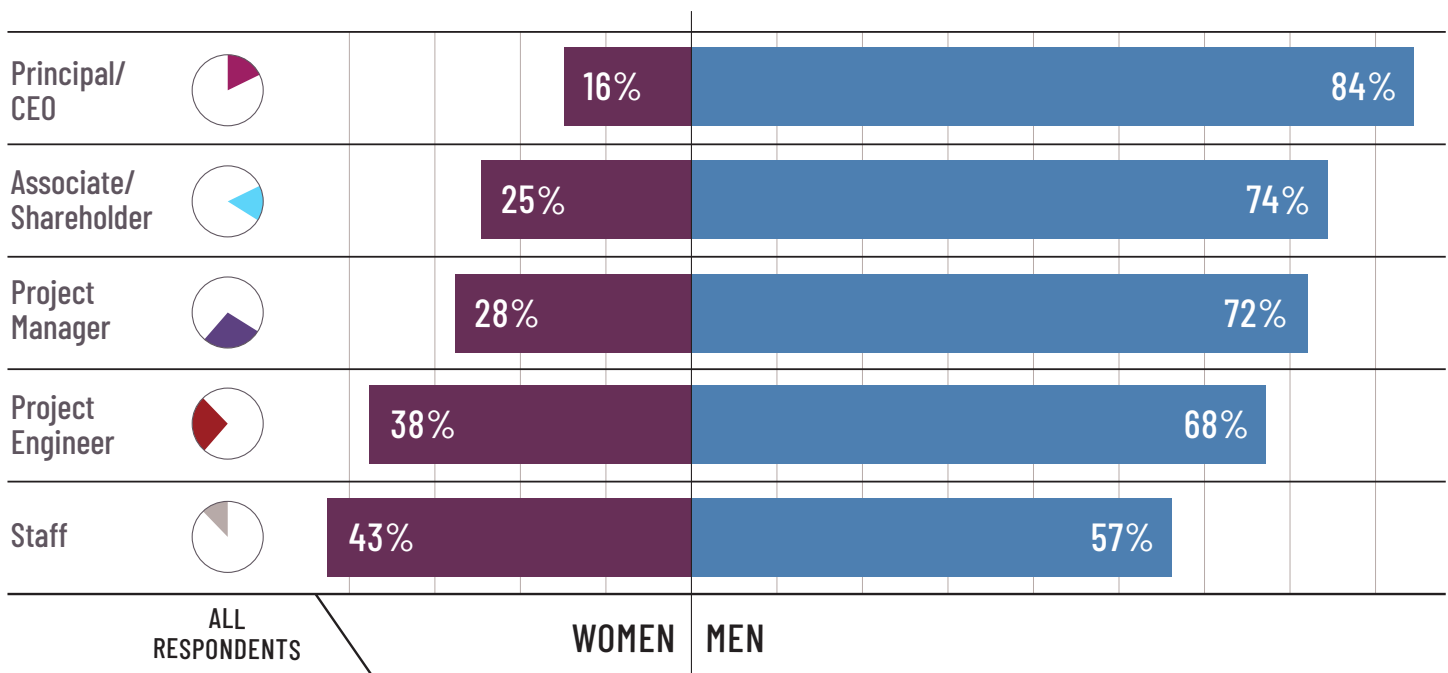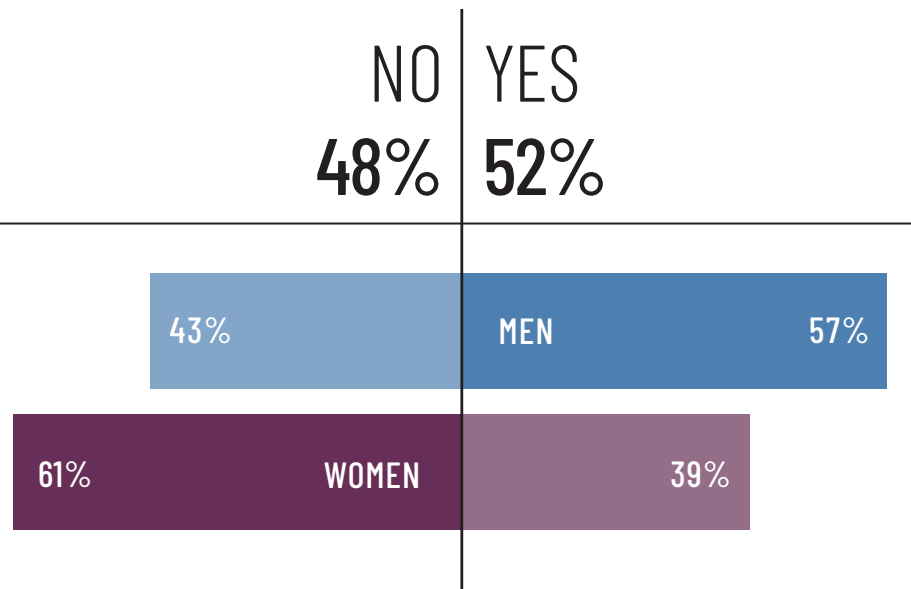
50% of all respondents had children, and this number also skewed more towards male respondents. 39% of female respondents had children compared to 57% of male respondents.

The 2018 SE3 survey included new questions on racial identity. 80.4% of respondents identified as white. Of the remaining non-white respondents, 8.9% identified as Asian, 4.9% as multiracial, 3.2% as Hispanic, Latino or Latina, 0.9% Black or African American, 0.8% Middle Eastern or North African, 0.2% American Indian or Alaskan Native, and 0.1% Native Hawaiian or Pacific Islander. At every level of advancing position, the percentage of non-white respondents decreased; non-white respondents represented 38% of entry level respondents and 14% of principal level respondents.

RACE

80.4% White

0.2% American Indian, Alaska Native

8.9% Asian

0.9% African American, Black

3.2% Hispanic, Latino, Latina

0.8% Middle Eastern, North African

0.1% Native Hawaiian, Pacific Islander

4.9% Mixed race

0.6% None of the above
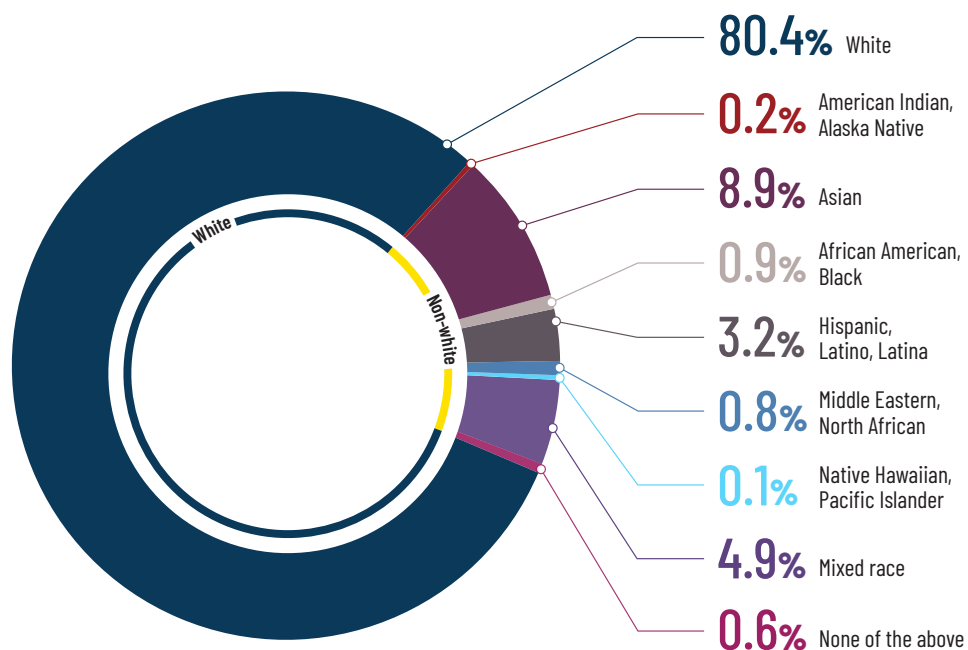
90% of respondents indicated English was their first language. The remaining 10% indicated their first language was Spanish (2%), Chinese (1.7%) or from the following larger geographic regions: Middle East/African (1.5%), Western European (1.1%), Eastern European (1%), South Asian (1%), and Southeast Asian (1%).

POSITION BY RACE

| Position	All Respondents	Non-White	White
Principal/CEO	18%	14%	86%
Associate/Shareholder	16%	17%	83%
Project Manager	28%	23%	77%
Project Engineer	26%	27%	73%
Staff	12%	38%	62%

ALL RESPONDENTS

NON-WHITE | WHITE
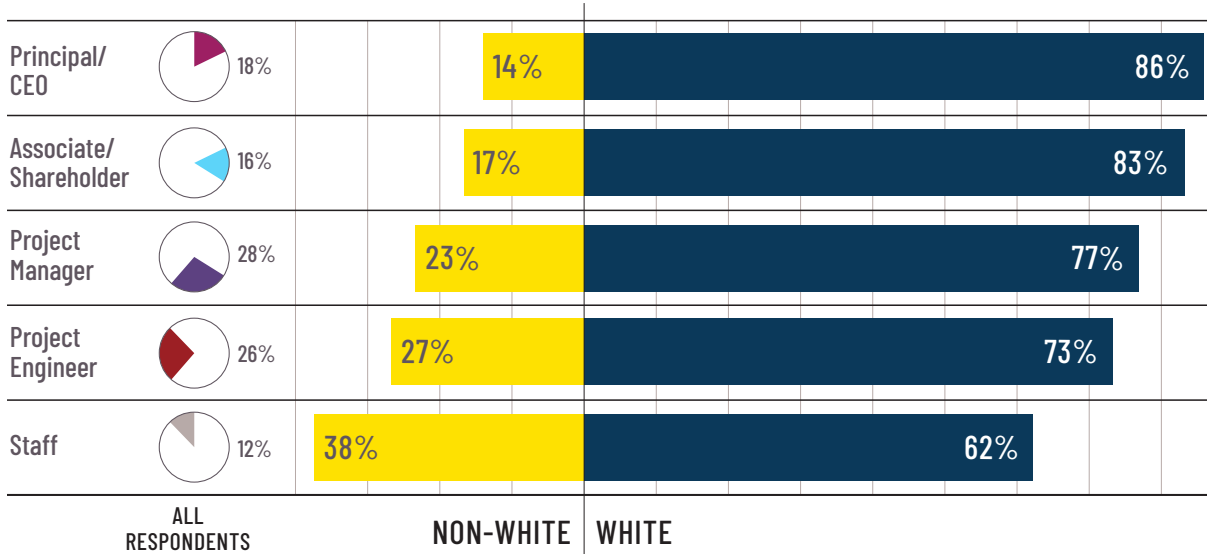
SURVEY FINDINGS

OVERALL SATISFACTION, ENGAGEMENT AND RETENTION

Overall Career Satisfaction

78% of respondents reported being very satisfied or satisfied with their career choice, while 9% reported being very dissatisfied or dissatisfied.

SATISFACTION WITH CAREER CHOICE

SATISFIED
78%

NEUTRAL

DISSATISFIED
9%

24% 54% 13% 8% 1%
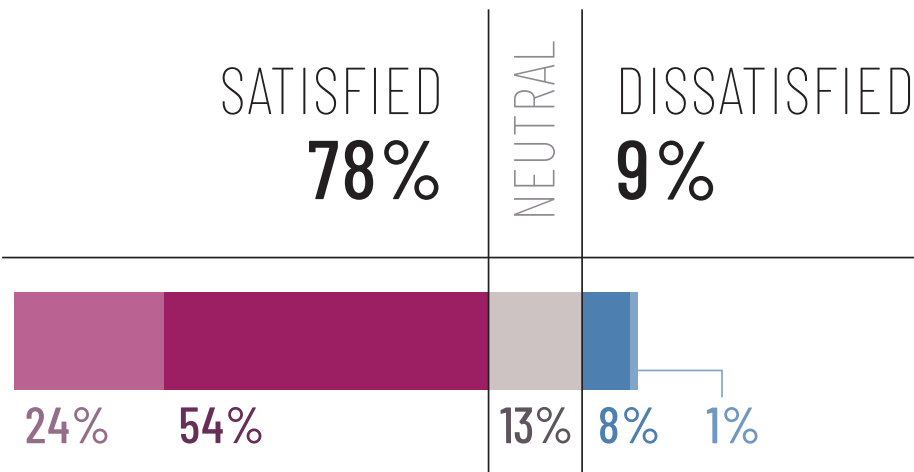
The 2018 survey analysis found the following top predictors of high reported career satisfaction: company morale, a strong desire to propel one's company forward, a positive experience with having dependents, and a positive relationship with and respect for company leadership. Feeling that daily tasks are aligned with interests and career goals, feeling that management is fair to staff, and feeling that the employer offers appropriate technical training also correlate positively with satisfaction.

When it came to negative influences on satisfaction, the 2018 survey analysis found that African-American and Asian respondents were 20% and 9% more likely to be dissatisfied with their career in structural engineering, respectively. Respondents whose position was identified as Associate/Shareholder were also more likely to be dissatisfied. Not feeling emotionally invested in one's company, not feeling that management supports staff advancement, and feeling that mentoring opportunities are not equally available to all employees also negatively impact reported satisfaction.

Pay and compensation had a relatively small, yet positive, impact on overall satisfaction. It is notable that overall satisfaction did not appear to correlate with gender identity, sexual orientation, company size, employer type, gender makeup of company leadership or racial/ethnic makeup of company leadership.

Retention

59% of respondents have considered leaving the structural engineering profession. Among other factors still being evaluated by SE3, having a positive experience with a leave of absence was correlated with a greater likelihood of staying.

It is notable that overall satisfaction did not appear to correlate with gender identity, sexual orientation, company size, employer type or gender or racial makeup of company leadership.

PLANS TO STAY UNTIL RETIREMENT
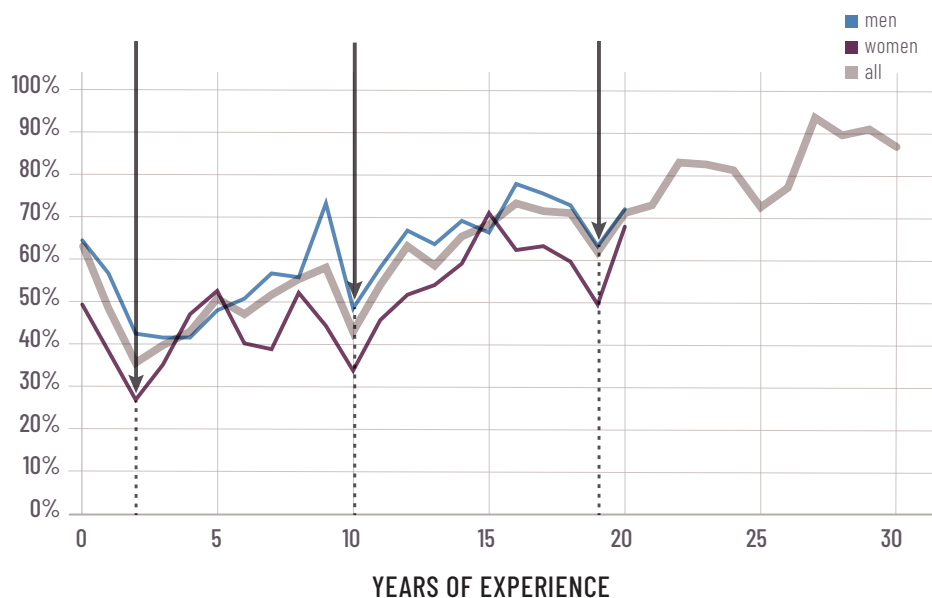
Despite the fact that most respondents have considered leaving the profession at some point in their career, 60% of respondents reported that they plan to stay until retirement.

The survey data reveals three pinch points at experience levels where respondents, on average, report being less likely to stay in the profession until retirement. The first of these pinch points occurs in the first two to four years. The second pinch point occurs around 10 years, and the third around 18 years. Notably, women and non-binary respondents at nearly all levels of experience are less likely to plan to stay in the profession until retirement than their male peers.

Controlling for variables such as position, caregiving, and years of experience revealed additional factors that affect respondents' plans to stay in the profession until retirement. Increased satisfaction with daily tasks and having dependents were both found to positively influence a respondent's intentions to stay in the profession through retirement. Female respondents and respondents who identified as non-male were 8.2% less likely to plan to stay until retirement while race/ethnicity, sexuality, and native language were not found to be significant contributors.

60% of respondents plan to stay at their current company for at least 5 years, with 36% planning to stay at their companies until retirement.

Among other factors, respondents who reported being satisfied with their daily tasks and responsibilities were roughly 19% more likely to stay at their company and nearly 50% more likely to stay in the profession than respondents who reported being dissatisfied with their daily tasks and responsibilities. Respondents who were emotionally invested in their company's future reported being 22% more likely to stay at that company until retirement than those who were not. Additional factors, including fair treatment of staff by management, increased pay, retirement benefits provided by the employer, having dependents, greater age, and advanced position were also found to correlate positively with intentions to stay at a company, to varying degrees.

Workplace Discrimination and Harassment

The 2018 SE3 survey included questions related to workplace harassment and discrimination, asking respondents to share their experiences, to the extent they were comfortable doing so.

The incidence of discrimination correlated strongly with both race and gender: 29% of non-white respondents reported ever having experienced workplace discrimination compared to 20% of white respondents and 50% of female respondents compared to 11% of male respondents.

Respondents who were emotionally invested in their company's future reported being 22% more likely to stay at that company until retirement.

HAVE YOU EXPERIENCED WORKPLACE DISCRIMINATION?

■ white   ■ non-white   ■ men   ■ women

20% White

29% Non-white

11% Men

50% Women

once   a few times   many times
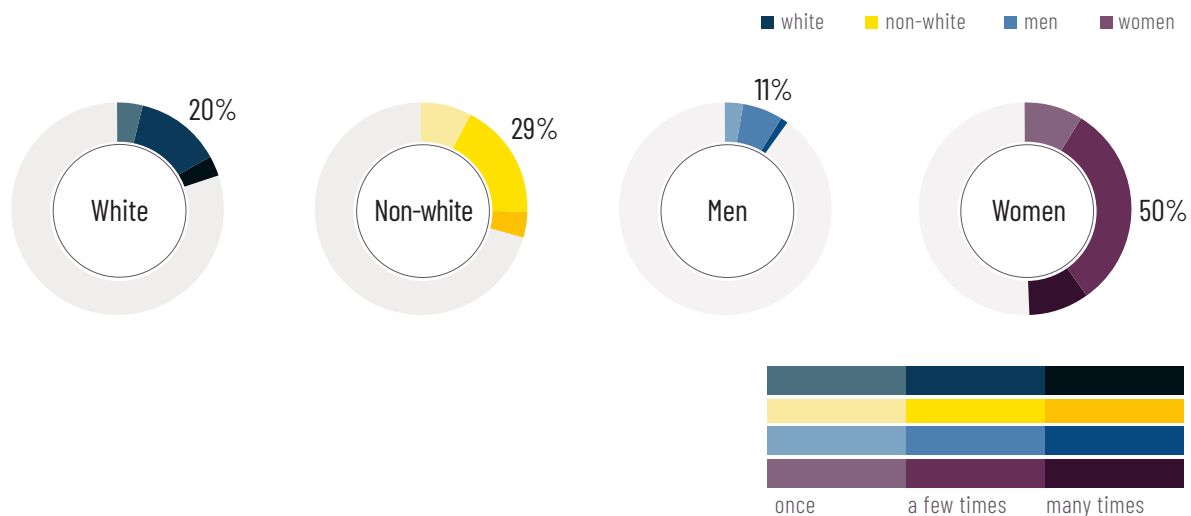
When asked about harassment, 32% of female respondents reported having experienced workplace sexual harassment compared to 5% of male respondents. Importantly, harassment was reported both at construction sites and within office settings.

HAVE YOU EXPERIENCED WORKPLACE HARASSMENT?

■ white   ■ non-white   ■ men   ■ women

15% White

11% Non-white

5% Men

32% Women

once   a few times   many times
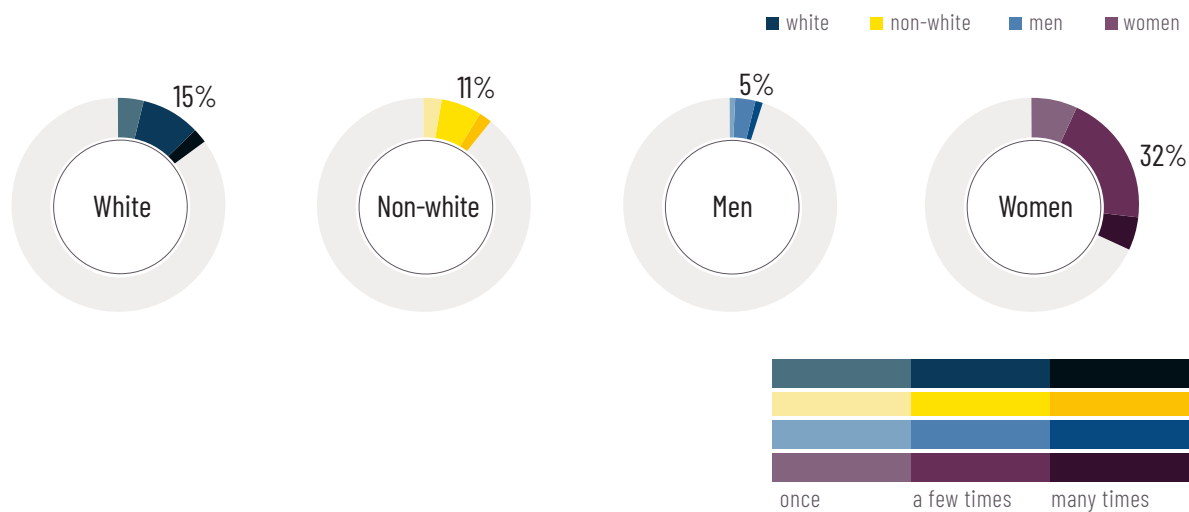
CAREER DEVELOPMENT

The 2018 survey sought to more closely examine career development from the perspective of respondents' career aspirations, job expectations, and daily responsibilities. The committee also studied the effects of firm leadership and mentorship to understand their impact on a structural engineer's career path.
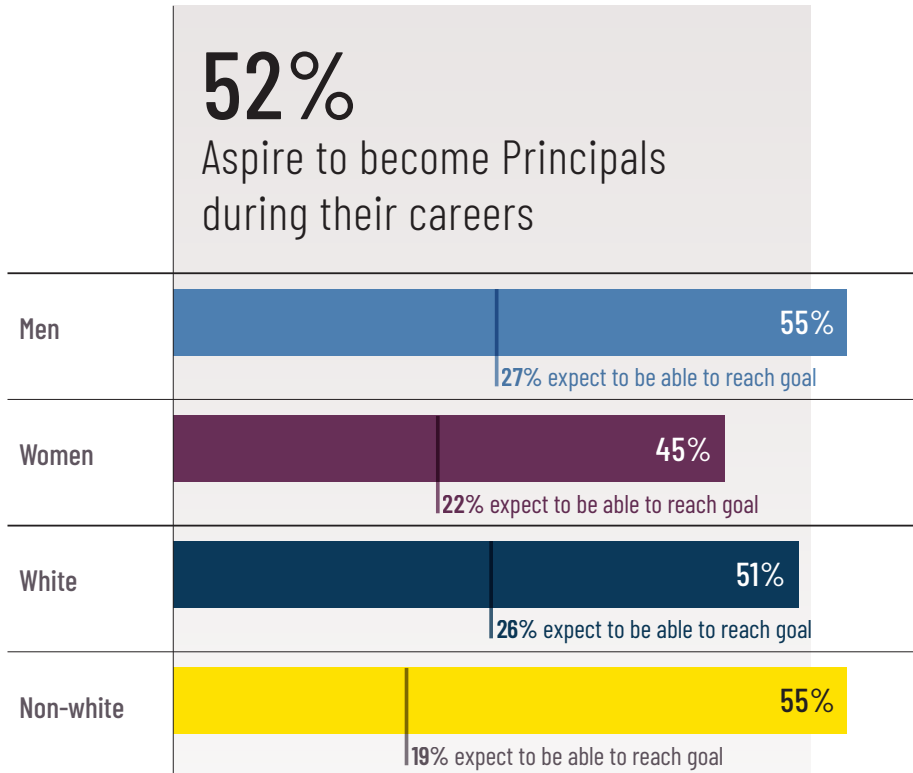
Career Aspirations

52% of respondents aspire to become a Principal during their career. Respondents who identified as non-white (55%) are slightly more likely than respondents who identified as white (51%) to aspire to the Principal level. Female respondents (45%) are less likely to aspire to reach Principal level than their male counterparts (55%).

CAREER ASPIRATIONS

52%
Aspire to become Principals
during their careers

Men	55%
	27% expect to be able to reach goal
Women	45%
	22% expect to be able to reach goal
White	51%
	26% expect to be able to reach goal
Non-white	55%
	19% expect to be able to reach goal

Only 25% of respondents expect to reach the Principal level at their current firm. Among respondents who aspire to reach the Principal level, 29% reason that there are too many people in line ahead of them to achieve a more senior position. Of those who aspire to a higher level position but do not expect they can achieve it at their current firm, 9% believe it's too significant of a time commitment and 19% of those who aspire to Principal hold caring for children or dependents and other parts of their lives as a higher priority. Interestingly, 15% of women perceive that their demographic would not fit in or be welcome among the leadership team compared to 3% of men who shared that sentiment. Also important, if only half of the respondents aspire to the Principal level, the committee would like to further investigate how many structural engineering firms are prepared to accommodate alternative career paths for those who do not aspire to the Principal leadership level.

Career Advancement

In the 2018 survey, more than 75% of respondents reported being very satisfied or satisfied with the progress of their career advancement.

On average, respondents reported high levels of satisfaction with their daily responsibilities, opportunities for professional development, and work environment. Respondents reported lower levels of satisfaction with career advancement, pay and compensation, and work-life balance. Effective management, mentorship, and professional development were found to be among the leading indicators of overall career satisfaction.
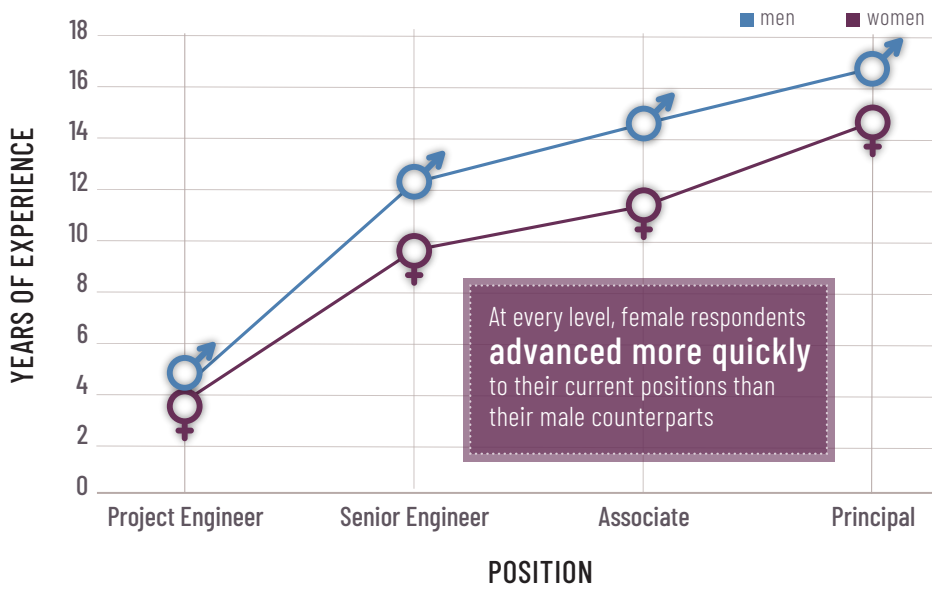
Female respondents advanced in their careers at a faster pace compared to their male counterparts, and respondents with children (both male and female) advanced at a slower pace compared to those without.

Definition of Career Success

In general, respondents had very similar definitions of career success. Achievements that ranked the highest included successful project outcomes, positive client relationships, respect from staff and effective management of others.

Female respondents believe position title is more important in their definition of success than male respondents. Male respondents believe compensation is more important than female respondents. Respondents who identified as non-white define success with high position title and compensation more than respondents who identified as white.

ADVANCEMENT BY GENDER

At every level, female respondents **advanced more quickly** to their current positions than their male counterparts

ADVANCEMENT WITH CHILDREN

Respondents without children **advanced more quickly** to their current positions than their counterparts with children
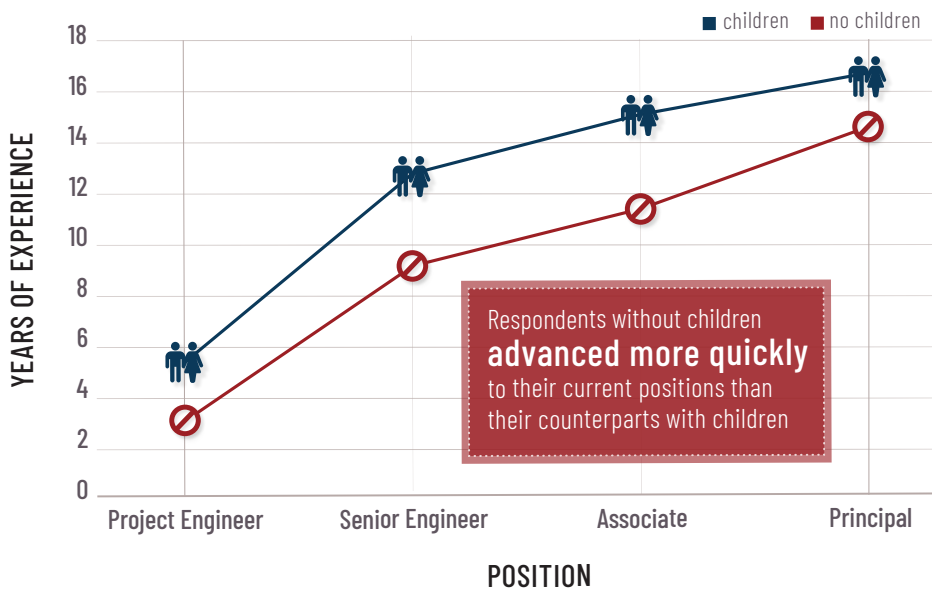
Firm Leadership and Managerial Expectations

The 2018 SE3 study found good management to be a top predictor of overall career satisfaction. Having a good relationship with and respect for firm leadership correlate positively with career satisfaction.

Approximately 75% of Principal level respondents believed that management clearly communicates expectations for advancement. Only half of respondents at all other position levels agree. Though 69% of non-principal respondents feel comfortable approaching their leadership to discuss career advancement, only 54% are satisfied with the content of feedback provided by their supervisors. Similarly, 46% of respondents are not satisfied with the frequency of check-ins and/or reviews with their supervisors. Moving forward from the 2018 study, the SE3 committee continues to provide resources and recommendations to structural engineering firms for how to improve both managerial communications and their performance feedback processes.

46% of respondents are not satisfied with the frequency of check-ins and/or reviews with their supervisors.

MANAGERIAL EXPECTATIONS FOR ADVANCEMENT

52%
Agree that management communicates expectations

Men	55%
Women	44%
White	53%
Non-white	47%
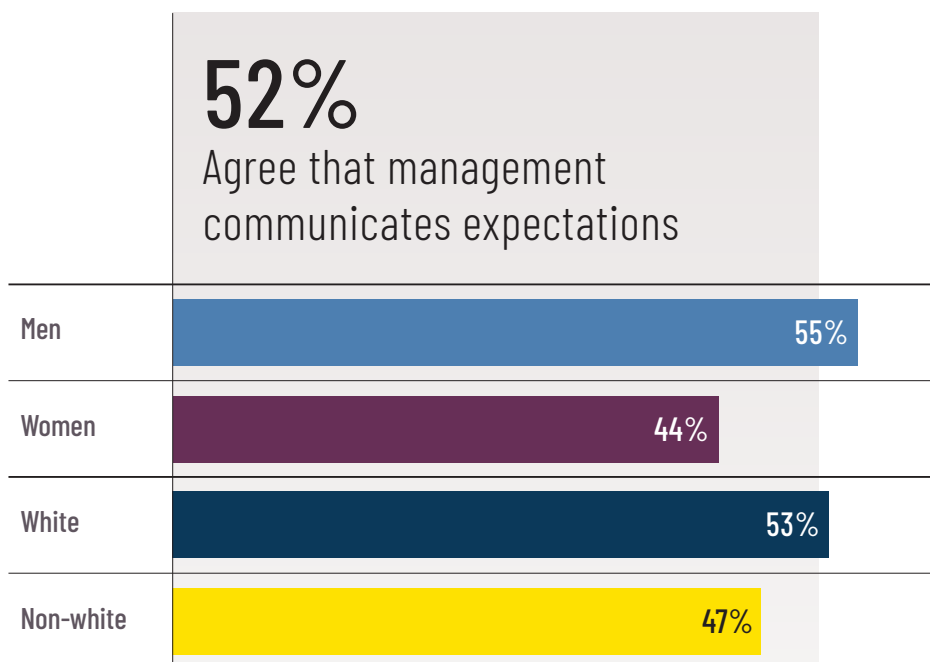
Mentorship

Approximately 75% of respondents report having a mentor at some point in their professional lives. The statistic varies by only a few percentage points between white vs non-white and male vs female respondents. Having a mentor affects a respondents satisfaction with career advancement. 84% of respondents with a mentor reported being 'satisfied' or 'very satisfied' with their career advancement compared to 69% of respondents without a mentor.

The presence of a mentor also improves retention within the profession. Respondents without a mentor are 19% more likely to have considered leaving the profession, and are twice as likely as their mentored counterparts to plan to leave the profession within 5 years. Professional and industry related organizations also provide opportunities for mentorship and camaraderie; however, 60% of respondents report having little or no involvement in professional organizations.

The 2016 SE3 study revealed similar findings about mentorship. The positive effects of mentorship on career satisfaction and retention were re-affirmed in the 2018 SE3 study.

MENTORSHIP

75%
have had a mentor at some point in their careers

WOMEN	74%	75%	MEN

| NON-WHITE	72%	75%	WHITE
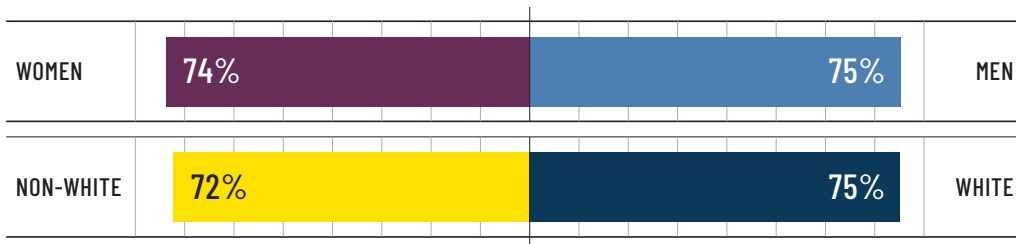
PAY & COMPENSATION

The 2018 SE3 survey asked respondents about pay and compensation. Examining the relationship between total compensation and other survey responses provides very useful and instructive data. With this data, we are able to quantify the market value of various traits, experiences, and attitudes throughout the structural engineering community, which represent a key component of the issues whose exploration is core to the SE3 mission.

For the purposes of this report, total compensation is defined as the sum of annual base pay, overtime pay, and bonuses. Pay data from respondents who indicated a non-binary gender or who preferred not to report their gender were omitted from the findings involving gender and pay due to the small number of respondents. Total annual compensation for all respondents was capped at $400,000 to avoid skewing average compensation values.

The figure below shows the average and median pay by position level for respondents who work a minimum of 32 hours per week. Median pay is $71,000 for staff/entry level respondents and $164,000 for principal level respondents.

PAY BY POSITION
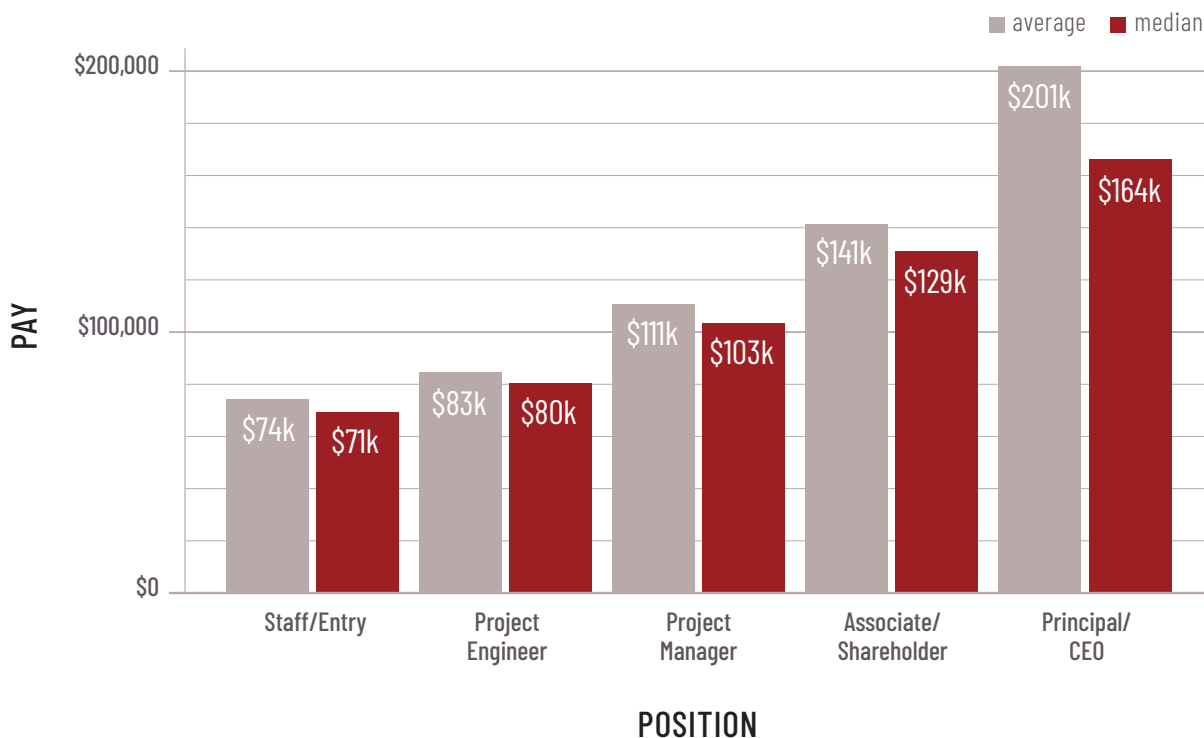
The figure below plots average pay by years of experience. Average pay is $73,000 for respondents with 0-3 years experience and $159,000 for respondents with 25 or more years experience. When comparing these figures against the data collected in the 2016 survey, the average pay is larger for all experience levels.

PAY BY YEARS OF EXPERIENCE
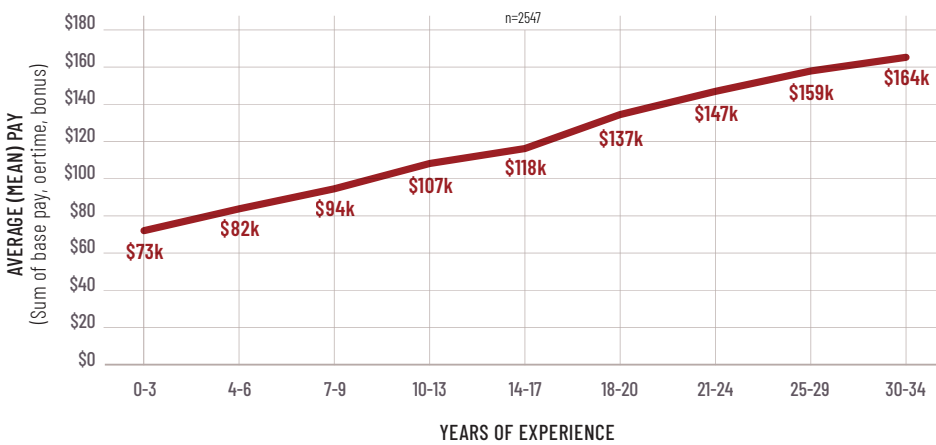
Similar to results from the 2016 SE3 study, 42% of respondents in 2018 indicate that they receive compensation for overtime, either with overtime pay, compensatory time, or an option to choose between the two. However, unlike the 2016 study, the 2018 analysis did not find a correlation between overtime pay and overall career satisfaction.

A professional data analyst performed a multivariate analysis of the 2018 pay data to determine the top predictors of increased or decreased pay. Examining the model in more detail, the figure below shows the top 20 factors most predictive of increased or decreased pay, relative to a median baseline pay.

FACTORS AFFECTING PAY
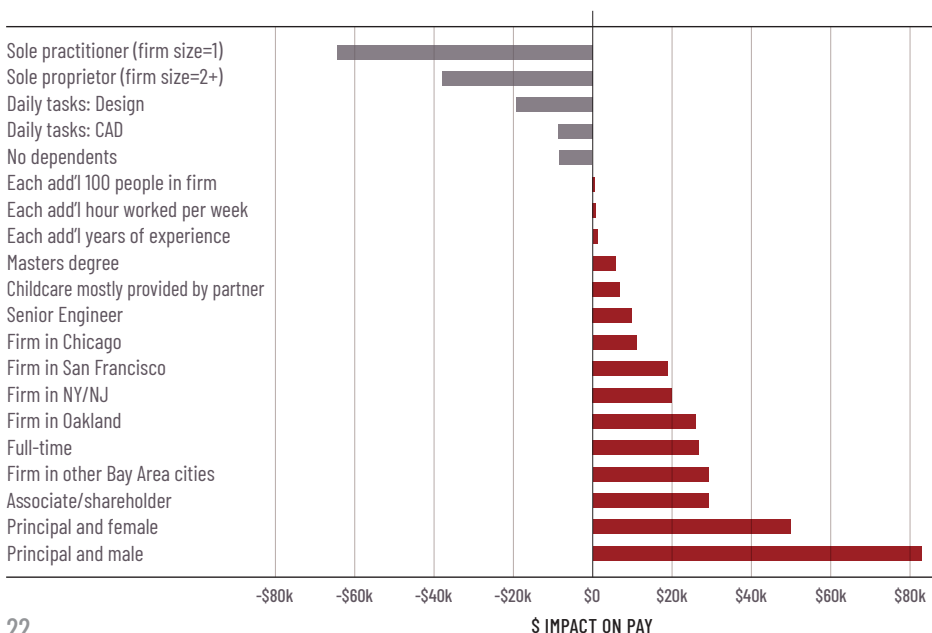
Factors which correlate with decreased pay include having no dependents, daily tasks including CAD or design, and being a sole proprietor with firm size of 1-5 employees. Factors which correlate with increased pay include higher position level working in certain geographical areas including Chicago, the San Francisco Bay Area, and New York/New Jersey; having a Master's degree; working full time, more hours each week, or at larger firms; and having a partner who provides childcare.

Note the R-squared value of this model with this data set is 51 compared to 60 for the 2016 pay study. Although this is considered to be statistically significant, the model only explains roughly half of the observed variations in pay. Other factors, including talent, performance, and attitude contribute to pay discrepancies but are not present in the survey data. This model provides useful information and reveals general trends and their magnitudes, but it does not predict exact values of pay and is not intended to do so.
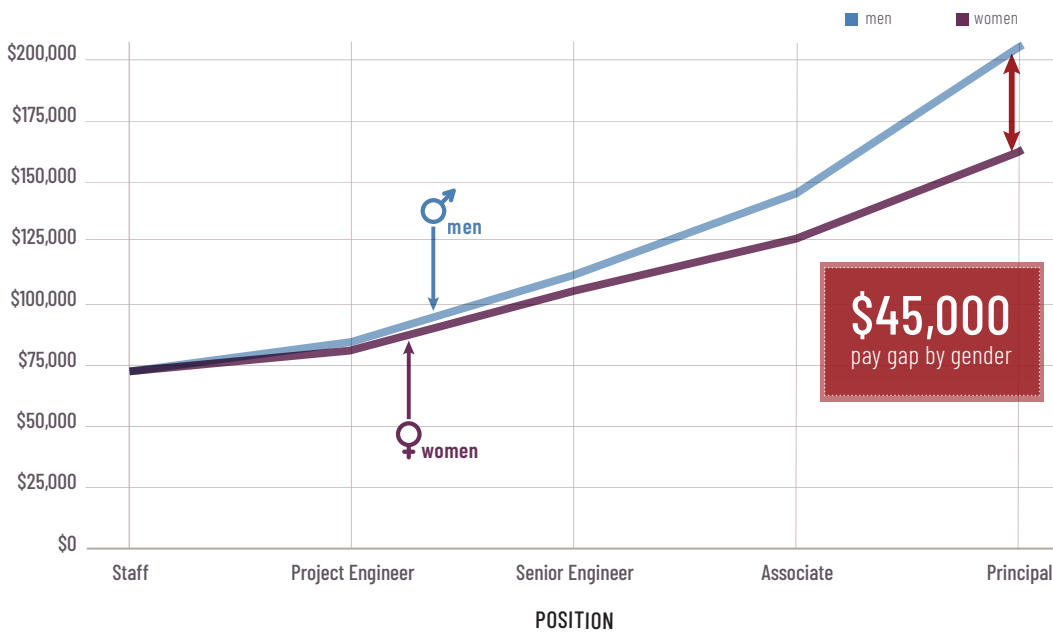
Gender Pay Gap

On average, male respondents reported higher total annual compensation than female respondents. This difference increased from near zero at 0-5 years experience (staff/entry level and project engineer positions) to approximately $43,000 at 30+ years experience (Principal level).

PAY BY YEARS OF EXPERIENCE AND GENDER
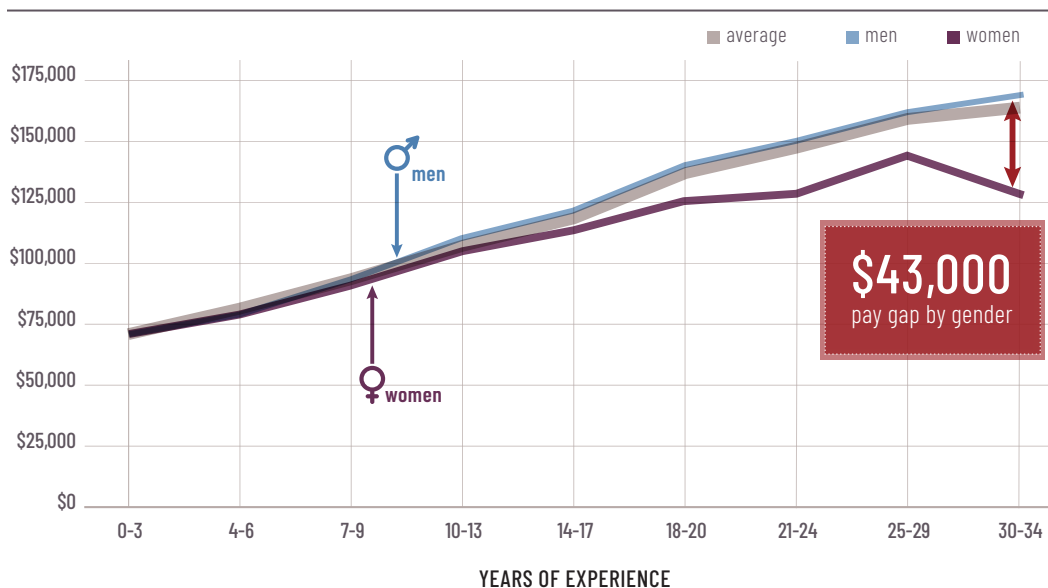
PAY BY POSITION AND GENDER

When holding all other variables constant in the multivariate analysis, the pay gap at the Principal level is the only one found to be statistically significant. In other words, the pay gap at all other position levels is explained by other factors included in the model. While being at the principal level is the only factor that affects the pay of men and women differently, it is important to note that many of the variables reported have different secondary effects on men than they have on women and thus tend to drive average pay lower for women.

For example, having dependents and having a partner who provides childcare both have a net positive effect on pay, regardless of gender. This makes sense intuitively, as alleviation of the need to be present and care for children generally allows employees to dedicate more time and energy to work performance. However, the male respondents in this data set were, on average, more likely to both have dependents and have childcare provided by their partners. This results in higher reported average pay for men, who are more likely to see a net positive effect from each of these factors on their pay.

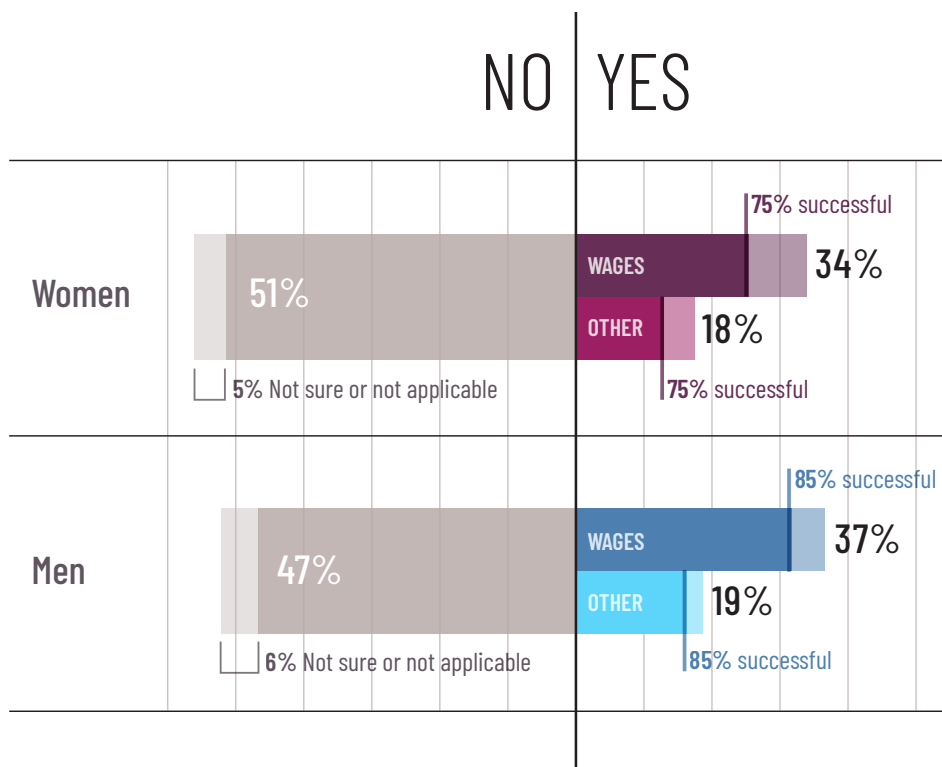This study leads us to believe that the gender pay gap is more influenced by societal gender expectations than by unequal pay for unequal work. Although the 2018 SE3 study did not explicitly consider how bias or societal norms affect pay, SE3 will continue to investigate how and why certain factors affect total compensation and what individuals and companies can do to address observed imbalances.

Negotiation

The SE3 committee included a new question in the 2018 survey regarding negotiation, specifically asking if respondents negotiated any part of their compensation package. The results reveal that women are only marginally less likely to negotiate than men (32% vs. 33%). However, despite similar negotiation prevalence between men and women, a higher percentage of men report negotiation success. Of those who indicated they had negotiated, 37% of women and 42% of men reported being successful.

Across the board, those who attempted to negotiate their compensation reported higher average compensation than those who did not attempt to negotiate. This is seen at every position level, with the largest difference of almost $30,000 at the Principal level.

DID YOU NEGOTIATE FOR HIGHER WAGES OR OTHER TYPES OF COMPENSATION?

NO | YES

Women

51%

5% Not sure or not applicable

WAGES — 75% successful — 34%

OTHER — 18% — 75% successful

Men

47%

6% Not sure or not applicable

WAGES — 85% successful — 37%

OTHER — 19% — 85% successful

WORK-LIFE BALANCE

Commonly discussed in modern studies on employment, engagement and productivity, SE3 defines work-life balance as the balance between an employee's time devoted to work and their time devoted to family, friends, social or leisure activities. In a changing economy of rising client expectations and 24/7 connectivity, achieving satisfaction with work-life balance can feel like a challenge. It is also highly personal, and thus potentially difficult to measure. In the 2018 SE3 study, the committee found satisfaction with work-life balance to be highly indicative of an employee's overall job satisfaction. Respondents also cited dissatisfaction with work-life balance as one of the top reasons for leaving the structural engineering profession.

Overall, 56% of survey respondents reported satisfaction with their work-life balance. This is the lowest scoring category of the survey's primary satisfaction metrics. Satisfaction with work-life balance did not vary based on position level, age, years of experience, gender identity or ethnicity. Factors that did predict satisfaction with work-life balance included hours worked, firm type, pay satisfaction, flexibility benefits, children and family considerations.

The number of hours worked impacts an employee's satisfaction with work-life balance.

SATISFACTION WITH WORK-LIFE BALANCE

| 20% | 36% | 23% | 17% | 5% |
| very satisfied | satisfied | neutral | dissatisfied | very dissatisfied |
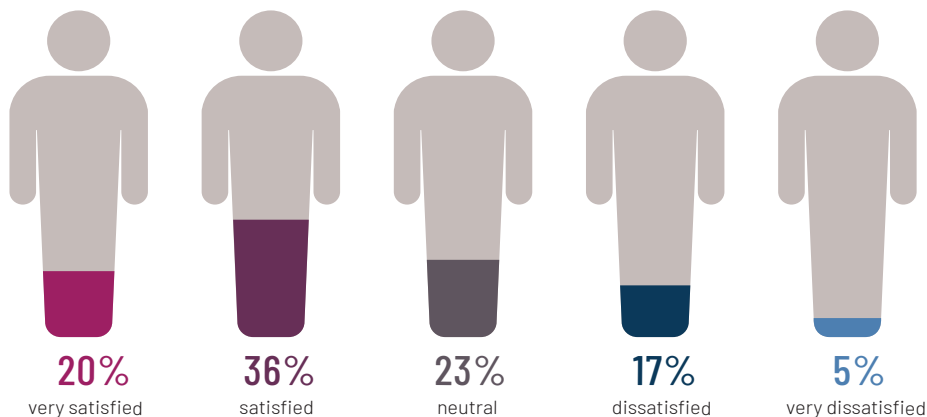
Respondents who indicated they are never expected to work more than 60 hours per week were 19% more likely to be satisfied with their work-life balance than respondents who are. In addition, respondents whose average weekly hours exceed 40 hours were 7% more likely to be dissatisfied with their work-life balance than respondents whose hours do not. This effect was not linear. Respondents who reported working between 45 and

50 hours a week have the highest level of dissatisfaction, closely followed by those who reported working between 40-44 hours per week. Those who reported working more than 50 hours per week were only 3% more likely to be dissatisfied than average. This suggests that respondents who work more than 50 hours per week are different than those working 41-50 hours, likely because there is a greater element of choice in their level of work. This is supported by the finding that respondents whose managers expect extra hours to meet project deadlines report lower satisfaction with work-life balance, regardless of the number of hours actually worked.

Satisfaction with pay also relates closely to satisfaction with work-life balance. Interestingly, there is no meaningful correlation between satisfaction with work-life balance and actual pay. In other words, higher pay does not necessarily make up for poor work-life balance. Rather, the perception that one is well-paid is the true indicator of increased satisfaction.

The type of employer affects a respondent's satisfaction with work-life balance. Respondents who reported working for a private consulting firm with multiple owners reported significantly lower satisfaction than those in any other type of firm or ownership model. Respondents who work for this type of firm also reported working above-average weekly hours, and receiving average or below-average pay. It is worth noting that 70% of survey respondents work for this type of firm.

Satisfaction with work environment and daily tasks also relates to satisfaction with work-life balance. Employees who are satisfied with their work environment are up to 30% more likely to be satisfied with their work-life balance; employees who are satisfied with their daily tasks are 21% more likely to be satisfied.

In the modern economy, employees are increasingly drawn to a company's flexibility benefits as they consider employment opportunities. Flexibility benefits may include parental leave, daily or weekly schedule flexibility, location flexibility and the options for a leave of absence.

In general the largest firms (more than 500 employees) and the smallest firms (fewer than 10 employees) offer the most flexibility benefits; however, the types of benefits offered are different. Large firms are more likely to offer paid parental leave; 40% of respondents working for firms with more than 1,000 employees and 28% of respondents working for firms between 500 and 1,000 employees are offered parental leave with full pay and benefits. Note at least 28% of firms larger than 100 employees report some form of parental leave, whether with full or partial pay. Firms with fewer than 10 employees, however, are more likely to offer schedule flexibility over pay. 75% of respondents from these firms report being offered daily schedule flexibility, and 46-58% of small firms offer weekly schedule flexibility, such as the opportunity to work four, 10-hour days. In general, flexibility benefits do not contribute significantly to respondents' reported satisfaction with their work-life balance.

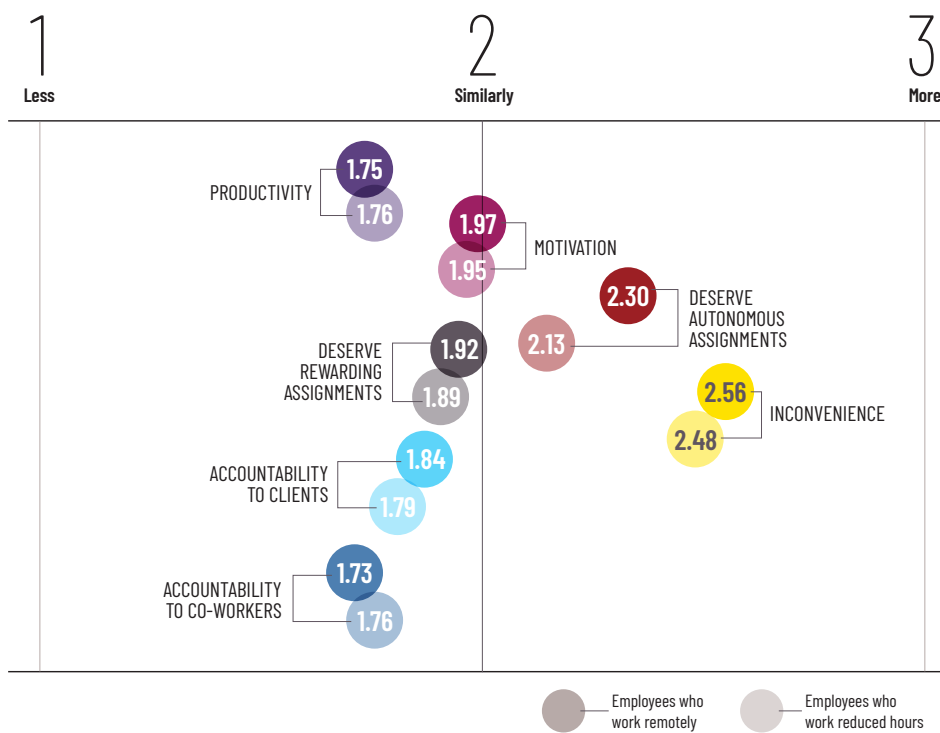*Employees who are satisfied with their work environment are up to 30% more likely to be satisfied with their work-life balance.*

The 2016 SE3 study found that principals work more hours on average than other respondents, but are also more satisfied with work-life balance. This suggests the element of choice, and control over number of hours worked is more indicative of satisfaction than the actual number of hours worked.

Small firms are equally likely to offer location flexibility (the ability to work remotely) as large firms. 50% of respondents from these sized firms report having the option to work remotely. Overall, respondents from mid-sized firms (10-250 employees) report the lowest percentages of schedule flexibility and remote work opportunities.

Interestingly, while 70% of respondents report they would use the ability to work remotely, there is a pervasive stigma against employees who do. Respondents reported believing that people who work remotely at least one day a week are similarly productive, but are an inconvenience, are less accountable to their clients and coworkers, and should receive assignments that are easier to complete autonomously, and are less rewarding. This perception was true across all respondents, regardless of gender, race, or position level. Interestingly, the negative stigma observed was not as significant for employees who work reduced schedules.

PERCEPTIONS OF WORK FLEXIBILITY

1 — Less
2 — Similarly
3 — More

PRODUCTIVITY 1.75 / 1.76

MOTIVATION 1.97 / 1.95

DESERVE AUTONOMOUS ASSIGNMENTS 2.30 / 2.13

DESERVE REWARDING ASSIGNMENTS 1.92 / 1.89

INCONVENIENCE 2.56 / 2.48

ACCOUNTABILITY TO CLIENTS 1.84 / 1.79

ACCOUNTABILITY TO CO-WORKERS 1.73 / 1.76

Employees who work remotely   Employees who work reduced hours

While 70% of respondents report they would work remotely, there is a pervasive stigma against employees who do.

The SE3 survey examined leaves of absence - who takes them, for what reasons, and with what impact. For the purposes of this study, a leave of absence is defined as a period greater than a month away from one's primary job, while maintaining employee status. Overall, 21% of respondents have taken a leave of absence. Female respondents are more likely to have taken a leave of absence than male respondents; 39% of female respondents compared to only 14% of male respondents. The most common reasons for reported leaves of absence were parental leave for a newborn (40%), Travel/Vacation (16%) and "Wanted or Needed a Break" (9%). No matter the reasons cited, the respondents who took a leave were equally satisfied with their career and equally desirous to remain in the profession as those who did not take a leave. This suggests that leaves of absence do not significantly impact retention.

SE3 also studied the perceived impact of a leave of absence on one's career. For both men and women, the majority of respondents reported that a leave of absence had no perceived effect on their career progression. However, while 32% of men who took a leave of absence reported that it positively impacted their career, 30% of women reported that it had negatively impacted their career. Because women were more likely to take a leave of absence than men, and because the most common reason for leave of absence was parental leave, this may suggest a correlation between having a family and career progression as well.

PERCEIVED IMPACT OF LEAVE ON CAREER BY GENDER

MEN

| 10% | | 32% |

NEGATIVE ⟵————— NEUTRAL —————⟶ POSITIVE

WOMEN

| 30% | | 16% |
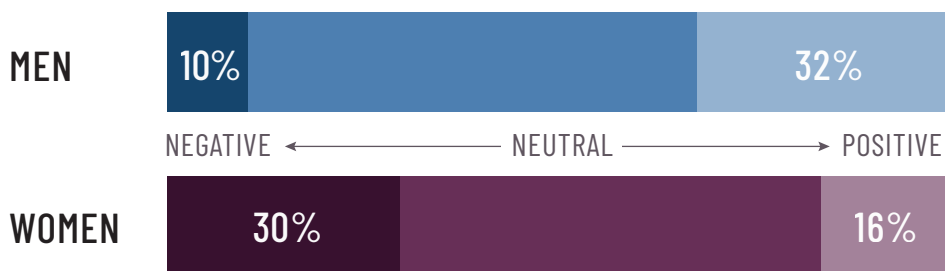
The committee examined the impact of children on one's career, and the differences by gender. The majority of both men and women (68% and 62%, respectively) reported that their productivity stayed consistent after having children. Men and women also reported that their motivation to advance remained the same. However, the difference was larger (60% of men vs. 52% of women). 32% of men reporting their motivation to advance increased after having children, while 29% of women reported a decrease in motivation to advance.

This may be related to the percentage of men and women providing childcare. 45% of men and 50% of women report equally sharing of after-work childcare. This is more true of younger parents than older parents in our survey response pool. 57% of parents under age 40 reported equal caregiving compared to 43% of parents over age 40. Women were more than five times more likely than men to report providing more caregiving outside of work hours. 33% of men with children reported that their partner provides more of the after-work caregiving. Women were also more likely than men to be a single parent.

PRODUCTIVITY AND MOTIVATION TO ADVANCE AFTER HAVING CHILDREN

	PRODUCTIVITY		MOTIVATION TO ADVANCE	
	MEN	WOMEN	MEN	WOMEN
INCREASED	20%	21%	32%	19%
DECREASED	12%	17%	8%	29%
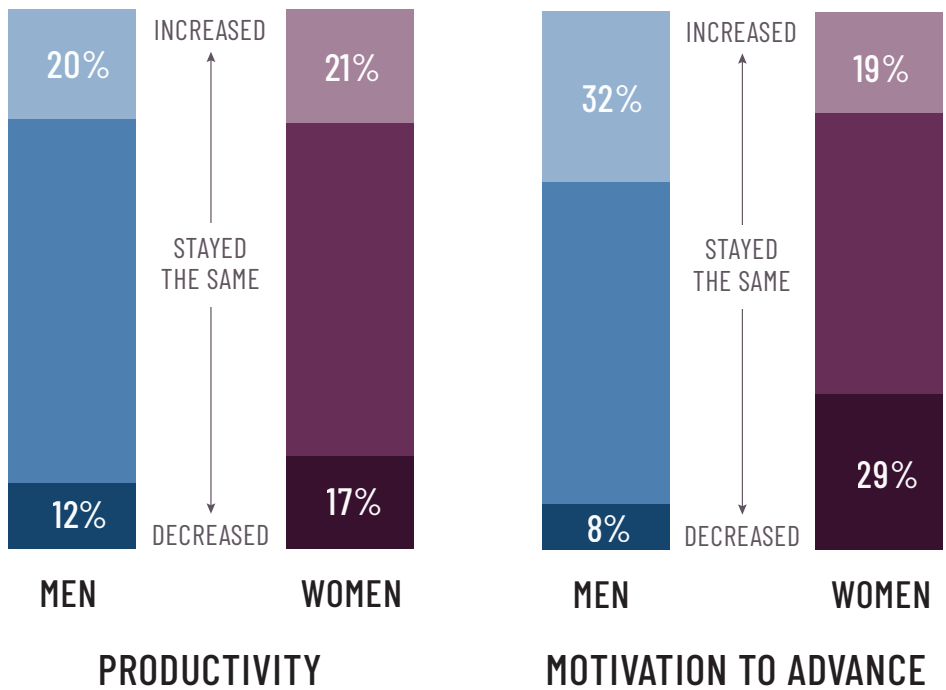
Overall, there was no difference in satisfaction with work-life balance between the parents and non-parents, or even between those who reported providing a significant amount of child care versus those who reported having a partner who provided the majority of caregiving.

CHAPTER 6
THE FUTURE OF SE3

Following the release of the 2016 and 2018 surveys, the SE3 Committee has continued work to improve engagement and equity within the structural engineering profession. Collectively, we have participated in over 70 speaking engagements to audiences across the United States and abroad. We have hosted two symposia in Northern California and are scheduled to present the first national symposium at the NCSEA Summit in November 2019. We have connected with and shared resources amongst individuals across several state SEA member organizations, and created new SE3 chapters in many state SEAs. We have organized mentorship programs, networking events, and panel discussions.

The SE3 survey findings present a unique opportunity to promote open dialogue and discussion on common issues which affect the practice of structural engineering professionals. By leading with the data, we have always created a safer way for people to enter into conversations, which might otherwise be too sensitive or difficult to have. Though we are committed to collecting data and tracking progress, many in the larger SE3 community also feel it is time to move beyond the data. More than ever, we are committed to the future of our profession. And if we believe that future is threatened by factors which contribute to reduced attrition or retention, we must rise to the challenge of adapting our businesses and work environments to address those concerns.

In 2020, we will be launching a new "Call to Action" and we will be recruiting individuals and organizations to the cause. If you are interested in hearing more about this effort, please subscribe to our mailing list at https://www.se3committee.com/connect.

CONSULTANTS' REPORT

Analysis of the SE3 2018 survey data

Prepared by Eirik Evenhouse and Ruohnan Hu
For the Structural Engineering Engagement and Equity (SE3) Project
January 10, 2019

SE3

Executive summary

This report summarizes statistical analyses of response data from a survey conducted by the Structural Engineering Engagement and Equity (SE3) Project during the summer of 2018. The SE3 Project Committee identified seven outcomes for in-depth statistical analysis. For each of the seven selected outcomes, the consultants developed a full-fledged multi-factor regression model. This report summarizes the general findings from the 2018 survey along with the more detailed findings from each of the seven statistical models.

Section 1 provides an overview of the key demographic characteristics of the 2,925 respondents who answered enough of the survey's questions for their responses to be designated as "complete." The consultants have also provide, in an accompanying file, a graphical summary of responses for every survey item (Appendix C), and the working dataset in CSV format.

Section 2 provides a detailed explanation of the analytical methods used by the consultants in developing the final statistical model for each of the topics designated by the SE3 Committee for in-depth scrutiny. The first stage of analysis involved the use of standard machine-learning tools to narrow the initial pool of candidate predictors. The second stage involved the use of three competing methods of variable selection to develop parsimonious model specifications. The third stage consisted of a check for excessive collinearity among predictors as well as tests for overfitting. In the fourth stage, a limited number of variables of high interest to the designers of the 2018 SE3 survey (such as gender identity or ethnicity) were re-tested for inclusion in the final models, even if they had been rejected in the previous stages of analysis. The final model for each outcome, a multivariate linear regression model, is thus the product of a development process designed to identify the most relevant factors from a large pool of possible predictors and arrive at a robust model specification. The same process was followed for each of the separate statistical models presented in this report.

Sections 3-9 presents the final regression model for each of the outcomes examined in depth. The seven outcomes are:
1. A respondent's total compensation
2. A respondent's position
3. A respondent's level of career satisfaction
4. Whether a respondent has ever considered leaving the profession
5. How long a respondent expects to stay at current firm, and to stay in the profession
6. A respondent's level of professional engagement
7. A respondent's rating of work-life balance

Section 10 provides a summary of the main findings from the 2018 survey. Key findings include:
- ##Finding 1 Very little in the way of unexplained differences by gender
- ##Finding 2 Very little in the way of unexplained differences by race/ethnicity
- ##Finding 3 What questions are raised by the findings, i.e. what findings merit further investigation in future surveys?
- ##Finding 4

Section 1. Overview of key respondent characteristics

This section provides an overview of the characteristics of the subset of respondents who completed enough of the survey for their responses to be designated as complete.

1.1 Core sample

A total of 5,163 surveys were begun (possibly more than once by some individuals), and 3,117 were completed by respondents currently or previously employed in the structural engineering profession.

Among those 3,117 respondents:

- 620 had taken the 2016 SE3 survey, 1887 had not, and 703 were unsure whether they had
- 13 were interns
- 74 were in academia
- 82 were employed in another profession
- 53 were unemployed
- 10 were employed in countries other than the United States

Excluding respondents who are interns, academics, unemployed, working in another profession, working as a structural engineer but outside the United States, or who responded with profanity leaves a total of 2,925 survey responses.

All tabulations, charts, and statistical analyses in this report are based on that core sample of 2,925 respondents.

1.2 Social demographics of core sample

The core sample of 2,925 respondents represents approximately 30 percent of U.S.-based structural engineers. While that is a large fraction of the survey's target population, the reader is reminded that the patterns reported here represent that core sample and may not be representative of the profession as a whole.

Gender identity

Respondents were limited to one answer to the question about gender identity, but were offered an open-ended response box if they chose the "Non-binary or another gender identity" response. The breakdown of responses to the gender identity question is shown in Table 1.1 below. For modeling purposes, the two respondents in the "Non-binary" category were grouped with the "Prefer not to answer" (PNTA) responses, and depending on the specific outcome being modeled, gender identity was handled in one of three ways: male vs non-male, or female vs non-female, or male vs female vs other/unknonwn.

Table 1.1

Gender identity	Count
Male	2,006
Female	857
Non-binary or another gender identity	2
Prefer not to answer	56

The survey also asked, as a separate question, "Do you consider yourself transgender?" The response breakdown is shown in Table 1.2 below.

Table 1.2

Transgender?	Count
No	2,830
Yes	6
Prefer not to answer	85

Sexual orientation

Respondents were limited to one of five possible responses for the question about sexual orientation. Their responses break down as shown in Table 1.3 below.

Table 1.3

Orientation	Count
Straight/heterosexual	2,669
Gay or lesbian	59
Bisexual	28
None of the above	6
Prefer not to answer	159

Racial/ethnic identity

Respondents could choose more than one response to the question about their racial or ethnic identity. Table 1.4 shows the breakdown of responses for all respondents and, in percentage terms, as a function of gender identity.

Table 1.4

Ethnicity	Count	Percentage among Gender= Female	Gender= Male	Gender=Other or Unknown
American Indian/Alaska Native	19	0%	1%	2%
Asian	301	15%	9%	0%
Black or African American	29	2%	1%	2%
Hispanic, Latino, or Latina	144	5%	5%	2%
Middle Eastern or North African	38	1%	2%	0%
Native Hawaiian or other Pacific Islander	18	1%	0%	0%
White	2,366	81%	83%	14%
None of the above	17	1%	0%	2%
Prefer not to answer	135	2%	3%	79%

Languages

2,630 respondents (or 90.0 percent) indicated that English is their first language. Among those who said that it was not and also opted to name their first language, the distribution of native languages across broadly defined categories was as shown below in Table 1.5.

Table 1.5

Language group	Count
Spanish	67
Chinese	52
Arabic/African	44
Western European	34
Eastern European	32
South Asian	30
Southeast Asian	28
Unknown/prefer not to answer	4

Age

The histogram (frequency chart) below shows the distribution of respondent age across age categories five years in width. The average age is 39, the median age is 36, the youngest respondents are 22 (5 cases), 21 respondents are over 75, and the oldest respondent is 88 years old. Respondents aged 26-30 constitute the largest age group (620 cases).

Figure 1.1
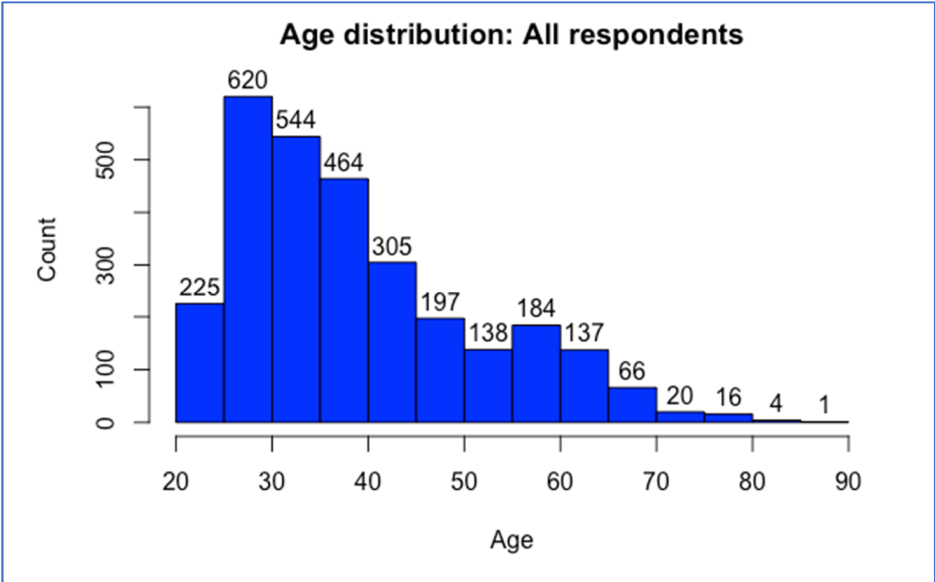
The age distribution for men looks quite different from that for women, as seen from the two frequency charts of Figure 1.2 below. The male respondents, on average, are older. Only 13 percent of female respondents are over 45, compared to 30 percent of male respondents. The extent to which this reflects increased female entrance into the profession versus higher attrition from the profession among female engineers cannot be determined from the survey data.
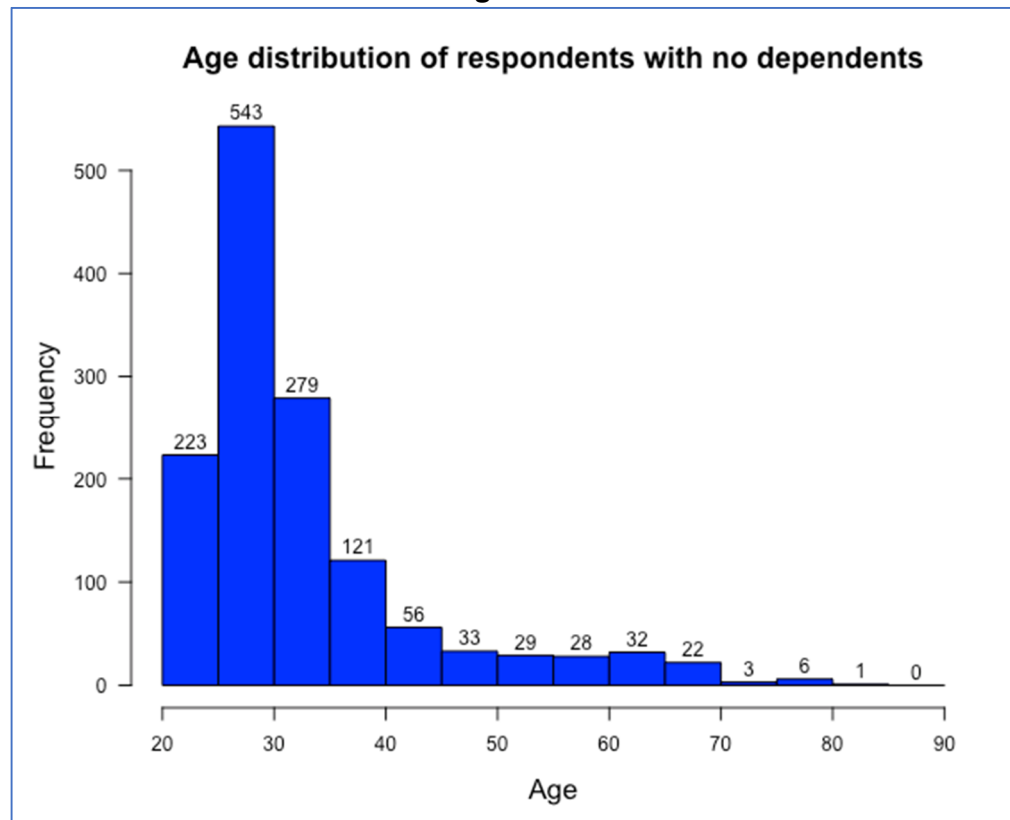
Figure 1.2
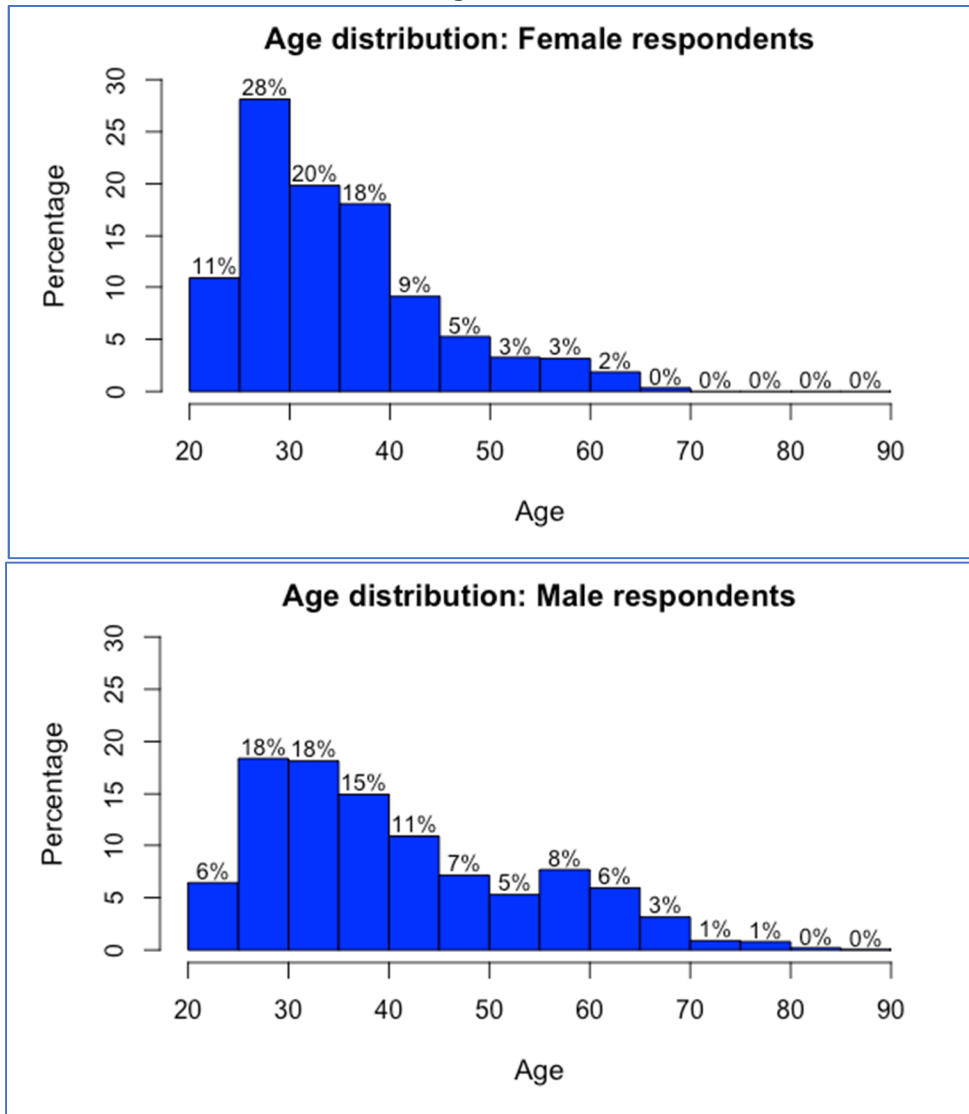
Dependents

Respondents were asked about their dependents. Table 1.6 below shows the distribution across the response categories, for the whole core sample and also broken down by gender identity. Percentages add to more than 100 percent, as respondents could choose multiple categories.

Table 1.6

Ethnicity	Overall count	Percentage among		
		Gender= Female	Gender= Male	Gender=Other or Unknown
No children or other dependents	1,376	61%	42%	33%
Pre-school children	624	20%	22%	24%
Children in kindergarten-12th grade	726	19%	27%	31%
Adult children	476	7%	20%	19%
Elderly relatives	109	2%	4%	3%
Other dependents	9	0%	0%	3%

The large number of respondents reporting no dependents reflects, in part, the relatively large numbers of young people in the core sample. This can be seen from Figure 1.3 below, which shows the age distribution for respondents with no dependents.

Figure 1.3

Geographic distribution of respondents

Respondents' geographic locations (based on their zip codes) are listed in Figure 1.4 below for all metro areas with four or more respondents. The five metro areas most heavily represented in the core sample are the New York/NJ metro area (*n=261* respondents), San Francisco (*n=215*), Seattle (*n=162*), Chicago (*n=148*), and Los Angeles (*n=145*).

Figure 1.4

Respondent's Metro Area

| Metro Area	n
New York	n=261
San Francisco	n=215
Seattle	n=164
Chicago	n=148
Los Angeles	n=145
Denver/Boulder	n=140
SF_BayArea_Other	n=101
DC Metro	n=91
Minneapolis-StPaul	n=87
Oklahoma City	n=86
Houston-Austin	n=85
Portland	n=70
DallasFtWorth	n=69
Philadelphia	n=68
Oakland	n=64
Boston	n=60
Sacramento	n=57
San Diego	n=53
Atlanta	n=52
Detroit	n=47
Nashville	n=41
Orlando	n=39
Phoenix	n=31
Madison/Milwaukee	n=30
Topeka	n=27
Salt Lake City	n=25
Kansas City MO	n=25
Birmingham	n=25
St Louis	n=20
Indianapolis	n=19
Boise	n=19
Baltimore	n=19
Hartford/New Haven	n=18
Columbus	n=16
Pittsburgh	n=15
Raleigh-Durham	n=14
Jacksonville FL	n=14
Helena MT	n=14
Grand Rapids	n=14
Anchorage	n=14
Omaha	n=8
Fresno	n=8
Cleveland-Akron	n=8
Las Vegas	n=7
Little Rock	n=6
Billings MT	n=4

1.3 Professional demographics of core sample

Section 1.3 provides an overview of the professional demographics of the 2,925 respondents that comprise the core sample, in terms of their level of experience, job mobility, position attained, firm size, firm type, and weekly hours worked.

Years of experience

Figure 1.5 below shows the distribution of respondents' years of experience in the structural engineering profession. The "0-5 years" category is the largest by a wide margin, with 809 respondents, nearly a third of the core sample. This is consistent with the relative youth of the overall sample, and may indicate that younger members of the profession were more likely to take the survey. Nevertheless, the core sample includes 447 respondents – roughly 1 respondent in 7 – who have who have 30 or more years of professional experience.
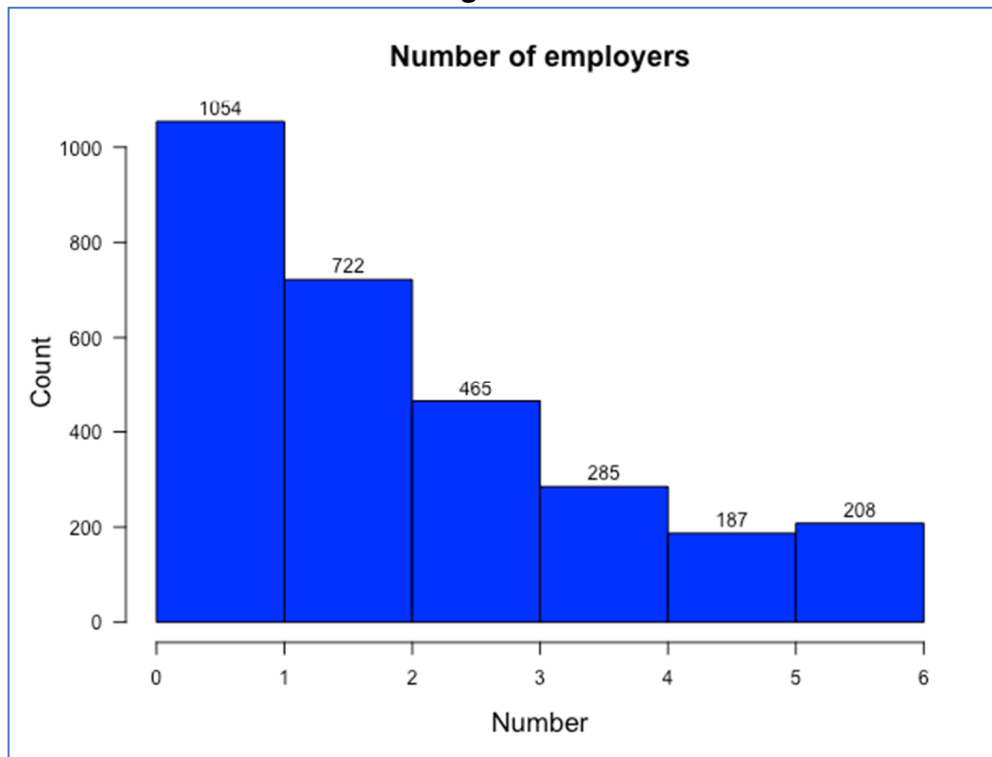
Figure 1.5
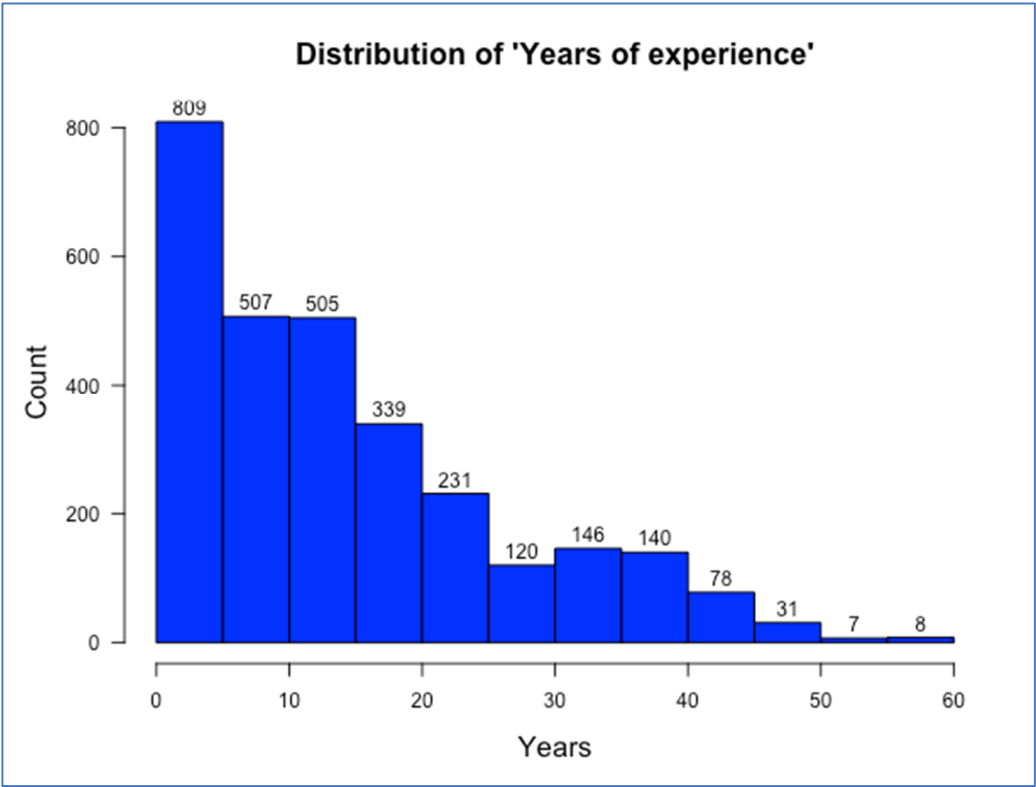
Job mobility

Figure 1.6 shows the distribution of the number of different employers respondents have had in their structural engineering careers to date. Note that the last category actually corresponds to "six or more" employers rather than exactly six.

Figure 1.6

Number of employers

Job position currently held

Respondents were asked which of five broad job descriptions best matched their current position. Figure 1.7 below summarizes the core sample's breakdown by position, with an added category of 'Sole practitioner' (a respondent who is a sole proprietor and reports a firm size of one).

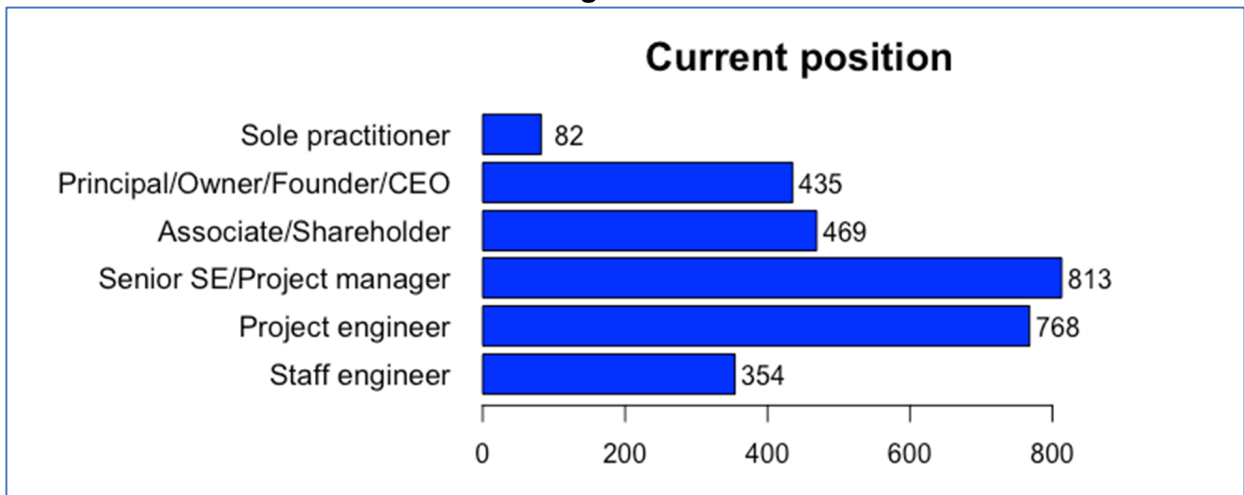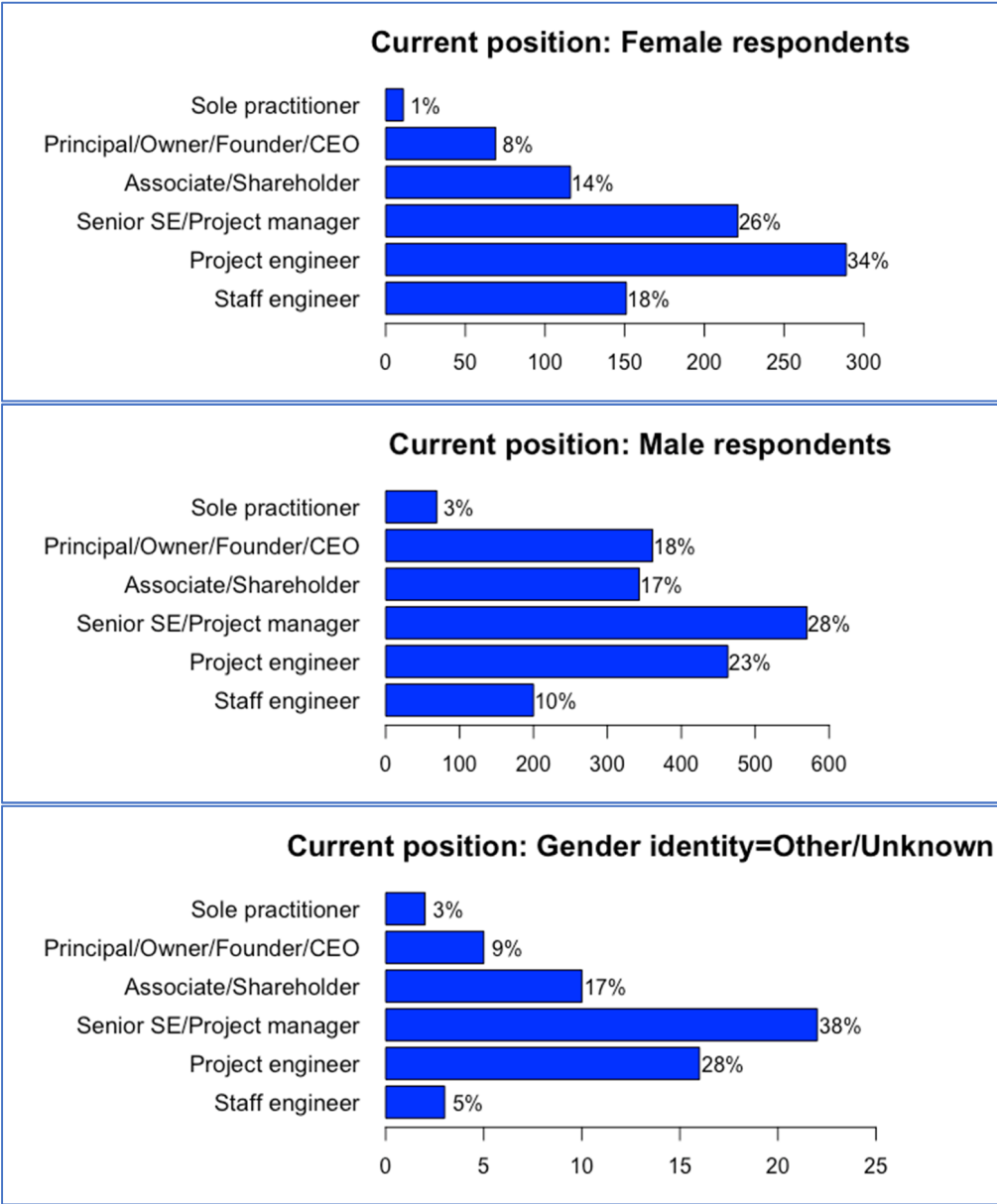**Figure 1.7**

Current position

Figure 1.8 below shows the distribution across positions as a function of gender identity. The major difference observed among these distributions is that male respondents are substantially more likely to be in the two most senior positions – Associate/Shareholder or Principal/Owner – than other respondents. As noted above, though, female respondents are younger, on average. More detailed analysis of the link between gender identity and position is deferred to Section ###, which presents an in-depth statistical model that predicts a respondent's position.

Figure 1.8

Employer size and type

Figure 1.9 below shows the respondent distribution with respect to employer size, measured in terms of the total number of employees (as estimated by the respondent). Figure 1.10 tabulates the different types of employers. While there is considerable variation among respondents in terms of employer size, the overwhelming majority of respondents (90%) work for engineering consulting firms.
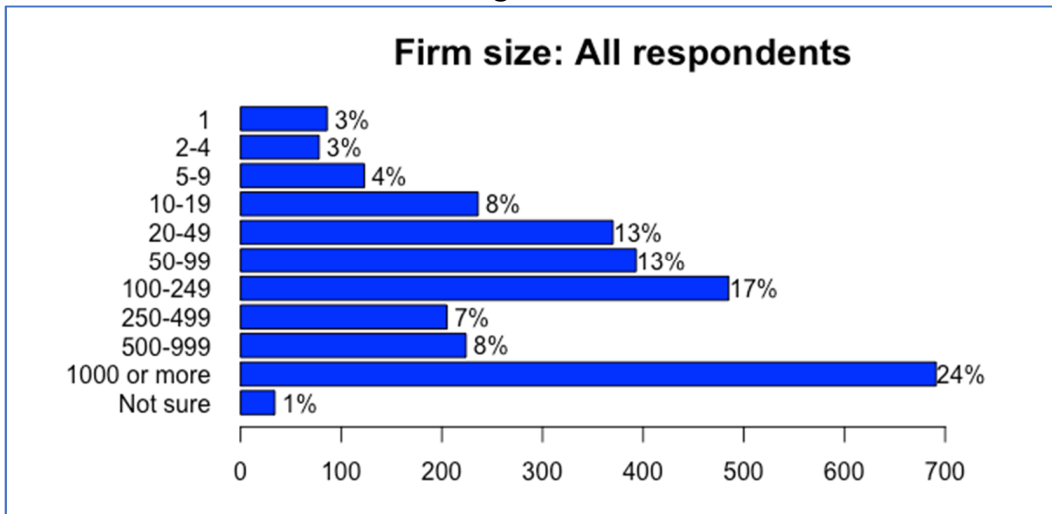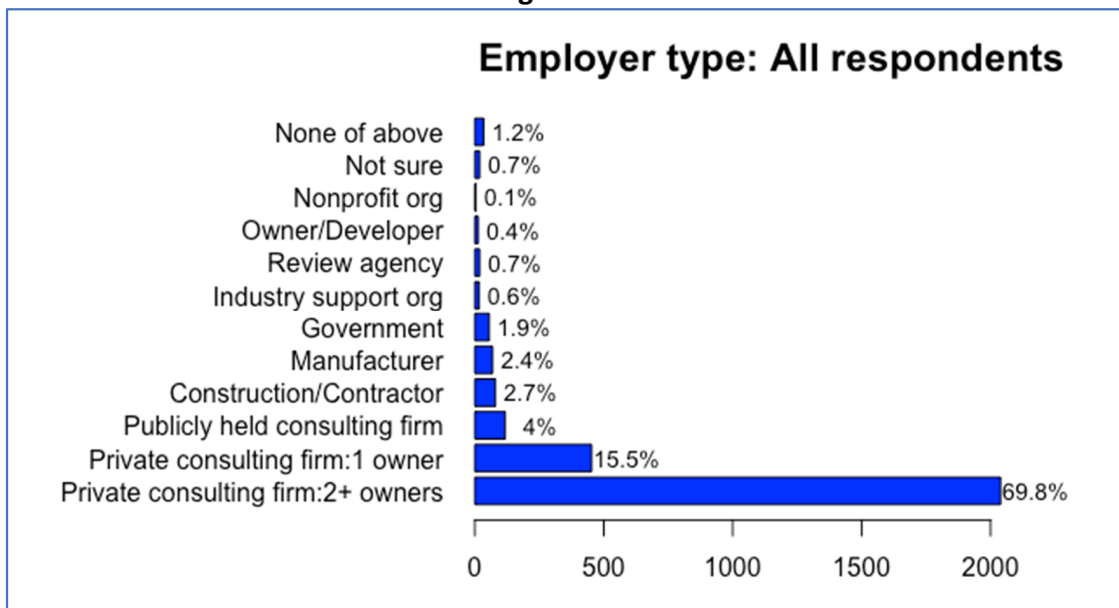
Figure 1.9

Firm size: All respondents

Firm size	Percentage
1	3%
2-4	3%
5-9	4%
10-19	8%
20-49	13%
50-99	13%
100-249	17%
250-499	7%
500-999	8%
1000 or more	24%
Not sure	1%

Figure 1.10

Employer type: All respondents

Employer type	Percentage
None of above	1.2%
Not sure	0.7%
Nonprofit org	0.1%
Owner/Developer	0.4%
Review agency	0.7%
Industry support org	0.6%
Government	1.9%
Manufacturer	2.4%
Construction/Contractor	2.7%
Publicly held consulting firm	4%
Private consulting firm:1 owner	15.5%
Private consulting firm:2+ owners	69.8%

Firm leadership, by gender and race

Figure 1.11 reports the gender and racial composition of the leadership in respondents' firms. Overall, leadership is less diverse in terms of race than in terms of gender. Roughly 28 percent of respondents report the leadership of their firm to be exclusively male, while 36 percent report it to be exclusively white. 58 percent of respondents report their firm's leadership to be mostly male, and 47 percent report it to be mostly white. The fraction who believe their firm's leadership is roughly balanced in terms of gender – about 7 percent – is the same fraction who believe it is roughly balanced in terms of race.

**Figure 1.11 Gender and racial diversity in firm leadership**
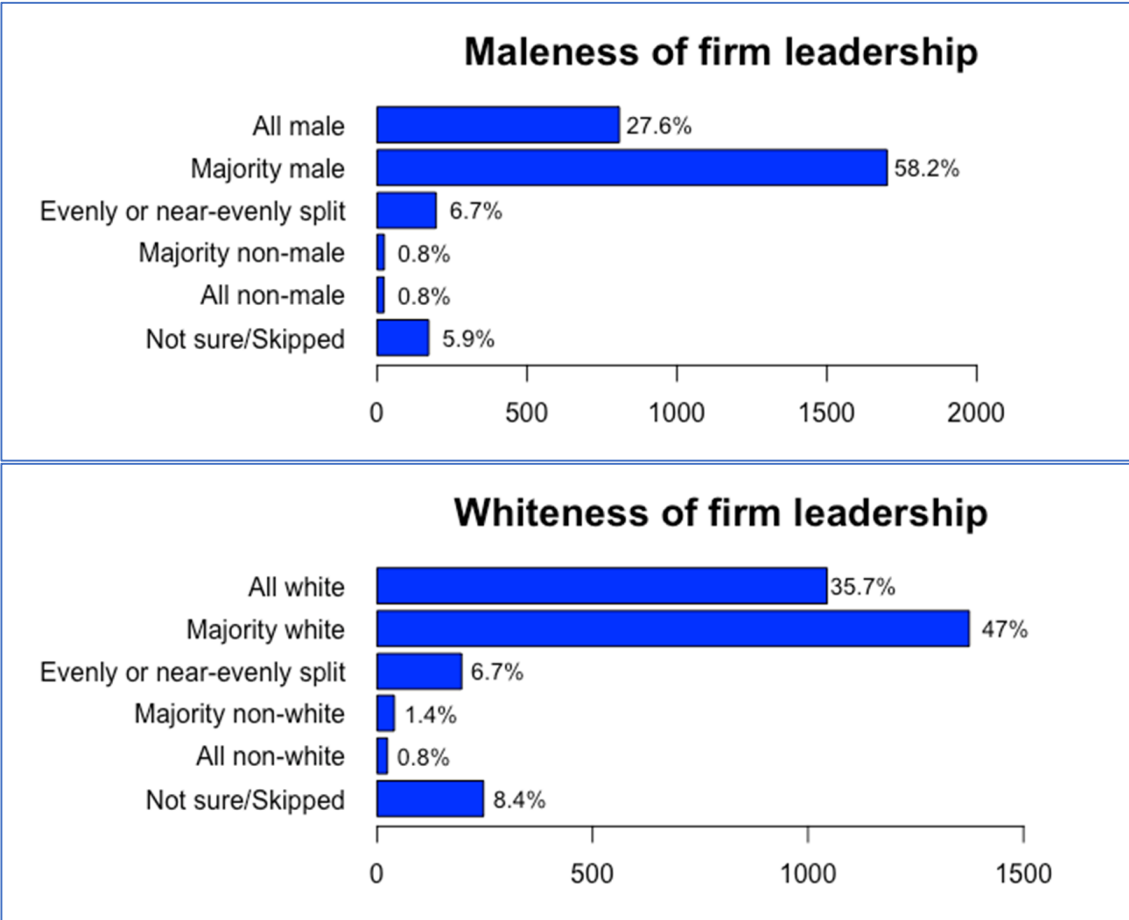
Weekly hours of work

Respondents were asked how many hours they work per week, on average, and were also asked whether they are considered full-time employees. Among female respondents, 7% were part-time employees; among all other employees, 4% worked part-time.

Figure 1.12 below summarizes the average weekly hours worked by respondents who indicated that they are considered to be full-time employees. Note that the 10 respondents who reported working more than 65 hours per week on average are grouped with the respondents working 60-65 hours per week. Similarly, the 43 who reported that they are considered full-time employees but work fewer than 35 hours per week are grouped with respondents working 35-40 hours per week.

It is striking that 24 percent of respondents who report that they are considered full-time work fewer than 40 hours per week on average.

Figure 1.12

Average hours worked (full-time employees)
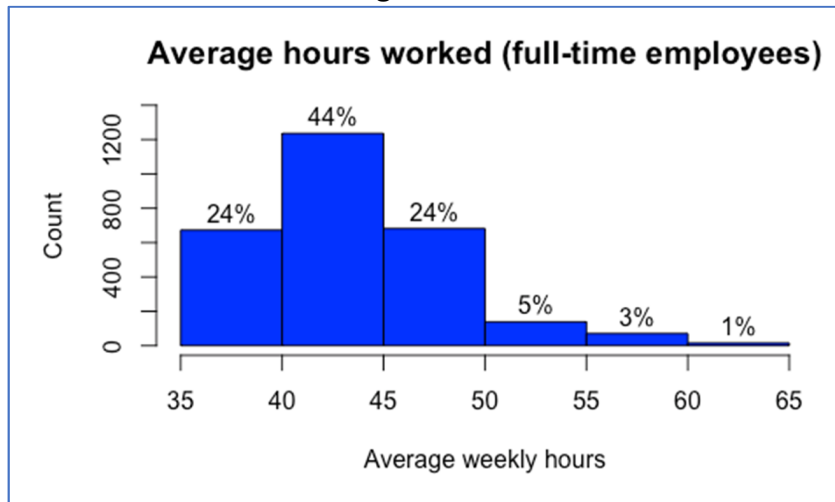
The distribution of weekly hours worked differs across gender categories. Figure 1.13 below shows the distribution for female and male respondents (the distribution for respondents whose gender identify is 'Other' or unknown is similar to that for men), all of whom are considered full-time employees. As the figure shows, , female respondents are substantially more likely than male respondents to work fewer than 40 hours per week (33 percent vs 20 percent). Male respondents are more likely to report working more than 50 hours per week (10% among men vs 4% among women).

Figure 1.13

Avg full-time hours (Female respondents)

Avg full-time hours (Male respondents)
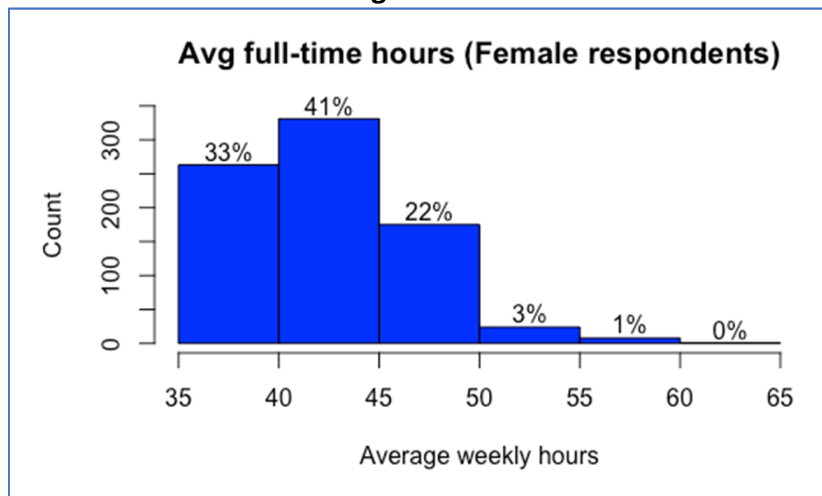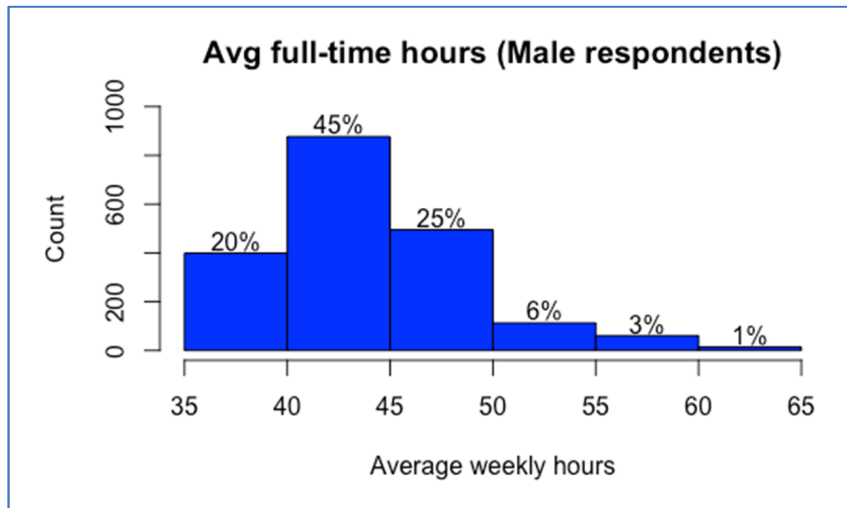
For breakdowns of responses to other survey questions, see Appendix A, an embedded PDF file containing a frequency chart of responses for every single survey item.

Section 2. Statistical methodology

The SE3 Committee identified seven specific topics for in-depth investigation with the data from its 2018 survey. For each outcome of interest, the consultants carried out a rigorous statistical analysis that began wide and then drilled down to identify, for each outcome, the factors most predictive of that outcome. For each outcome, the consultants used a machine-learning (ML) approach as the first step, to identify the 50 most relevant factors for that outcome. Focusing on that set of 50 factors, and adding some variables of particular interest (such as ethnicity or gender identity) even if they were not in the top 50 factors, the consultants then developed a detailed statistical model of the outcome that balanced predictive power against ease of interpretation.

Each of the seven topics is covered in detail in Sections 3-9. This section gives an overview of the four steps that were involved in developing each of the final statistical models.

Step One: Narrowing the pool of candidate predictors

For each outcome of interest, the first analysis phase was to implement a standard ML method known as a gradient boosting machine (GBM). An 'ensemble learning' method, GBM is one of data science's workhorses for constructing robust predictive models. The details of GBM models are beyond the scope of this report, but a brief description is provided here to explain their utility in analyzing the 2018 SE3 survey data.

An 'ensemble learning' model is a collection of many sub-models. Because little structure is imposed on these sub-models, and because the raw input variables can be interacted to create new predictors, the total number of possible variables (and, therefore, models) is enormous. A fast and iterative method is needed to evaluate correlations between the outcome variable and the many possible predictors. The GBM method estimates a succession of what are known as weak and shallow regression trees, with each new tree learning from and improving on previous trees ('boosting' refers to the general process of turning weak learners into stronger ones). The individual trees are only weakly predictive, but the final set of trees may be highly predictive.

As with most ML tools, GBM's drawback is limited interpretability. A standard regression model can answer a basic question like "What is the average salary difference between respondents in San Francisco and other respondents, after adjusting for other factors?" A GBM model cannot. ML tools are not yet the best way to summarize the relationship between a predictor of particular interest and the outcome variable.

However, one element of a GBM model's output—its 'variable importance' ranking—can be valuable for developing an interpretable model. A low-importance variable, in the context of survey data, has predictive value for only a handful of respondents, while a high-importance variable is predictive for many respondents. A quick way to identify the five, ten, or 100 variables most consistently correlated with an outcome eliminates a great deal of guesswork for the analyst confronted by an overwhelmingly large number of predictors. Note that 'variable importance' is reported for only the raw input variables, and not for the derived variables generated through interactions of those raw variables; this is actually helpful when the goal is to develop a model amenable to interpretation.

With the 2018 SE3 survey, the 110 questions answered by respondents currently employed as structural engineers in the United States generate a modeling dataset with over 1,000 distinct predictors.[1] By fitting a GBM model to that full dataset, the analysts were able to quickly surface the top 50 predictors for a given outcome.

Figure 2.1 below illustrates a variable importance ranking, showing the relative importance of the top 50 variables in a GBM model of "Satisfaction with work-life balance." Relative importance is measured on a scale of 0-100. A striking feature of the chart is the rapid falloff in importance, a pattern that will differ from one outcome to another. For this particular outcome, only six variables have an importance score larger than 3, suggesting that relatively few variables would be needed to construct a satisfactory model of that outcome.

Figure 2.1
Variable importance ranking from GBM model of "Satisfaction with work-life balance"

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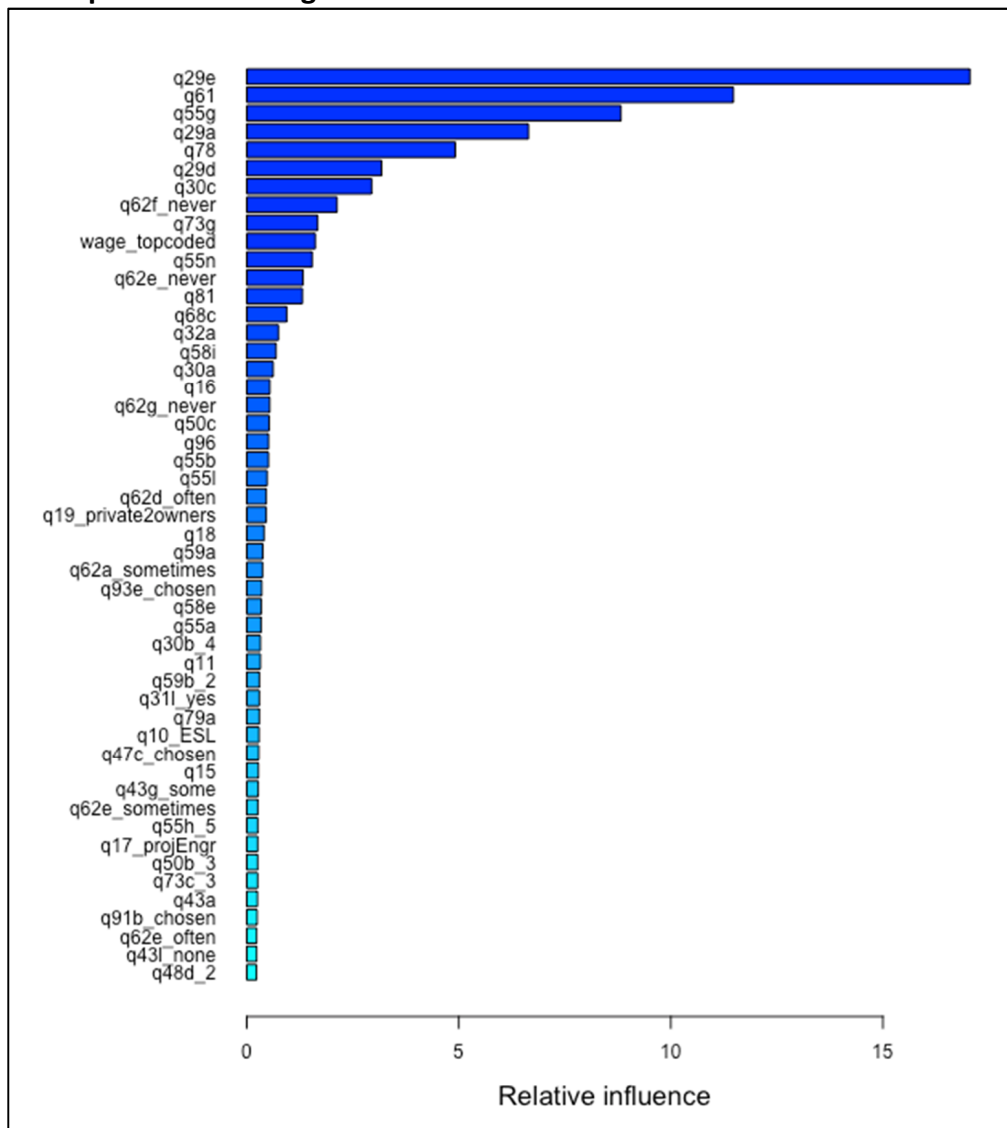
[1] Some survey questions had multiple sub-questions. In addition, a question with, say, five categorical (non-numerical) responses must be converted into five separate indicators, one for each possible response, so that the responses to that question have a numerical representation.

Appendix B contains charts that summarize, for each of the outcomes studied in detail, the ranking of the top 50 predictors derived from a GBM model of that outcome.

Thus the first step in modeling each outcome was to use a GBM mode's importance ranking to narrow the large pool of candidate predictors to a more manageable number. For each outcome, the analysts retained the top 25-40 variables identified by the GBM tool as the starting point for developing a more interpretable model of that outcome. The analysts also retained some select variables – henceforth referred to as "high-interest" variables – regardless of whether they ranked among the top 50 GBM predictors. Those variables pertain to the SE3 Project's stated goals of identifying social dimensions of equity or engagement in the structural engineering profession. They variables include a respondent's gender identity, sexual orientation, ethnicity, native language, age, current or past receipt of mentoring, status as caregiver (for children or adult dependents), current position, average hours worked, and the maleness or whiteness of upper management.

Step Two: Variable selection and robustness checks

The dataset resulting from Step One was the starting point for development of a more conventional regression model. For this second phase of the variable selection process, the analysts wanted to avoid the common approach of undertaking an idiosyncratic search process and then offering the resulting specification as their best model. Instead, the analysts applied three distinct methods of selection, to see whether different selection techniques resulted in the same set of variables being chosen. A variable selected by at least two of the three methods was retained as eligible for inclusion in the final model. The aim in using competing methods of variable selection was to guard against overfitting and obtain as robust a model specification as possible.[2]

The reader should note that, in contrast with machine-learning techniques like GBM, a shared feature of these three variable selection methods is that they operate on only the raw input variables; they do not involve creation of a potentially huge number of additional predictors derived from the initial set of variables.

The first method was stepwise selection, in which variables are added one at a time to the model as a function of their correlation with the outcome variable. After each addition, every variable is re-evaluated to check that it remains statistically significant. The significance threshold for a variable to enter the model initially was a p-value of 0.001, and it was retained for the final stepwise model only if its p-value was smaller than 0.001 (a relatively stringent criterion given a sample size of 2,925 observations).

The second method was that of "best subset regression" (BSR). In contrast with stepwise selection, BSR is an exhaustive search approach. For a given subset size, all possible subsets of the input variables are evaluated, to identify the one giving the best prediction performance for a model of that size[3]. In practice, BSR's exhaustive nature made the computational requirements for models with more than 14 variables too burdensome to be practical. The analysts therefore used this method to identify the best model for model sizes ranging from 8 to 14 variables. If a variable identified by the BSR method had not also been selected in the stepwise procedure, it would have been added to the stepwise model; in practice, each variable selected using BSR had also been selected by the stepwise selection procedure, in each of the separate modeling exercises.

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[2] An overfitted model is one that has been overly tailored to the data sample used to develop it, and that generalizes poorly to new data. A more robust model is one that will give comparable prediction in the development sample and in a new sample.
[3] The "size" of a model is the number of variables in it.

The third approach was Bayesian Model Averaging (BMA). The premise behind BMA is that a model obtained by averaging over all possible models will generally give better prediction performance than any one individual model. The practical obstacle to such model averaging is that, with enough variables and respondents, computational constraints limit the number of models that can be estimated. BMA methods, to oversimplify them, strongly favor simple models over complex models and use algorithmic ways to sample judiciously the enormous space of possible models. Averaging over the selected models produces a ranking of variables that reflects the number of models in which the variables appear and the explanatory power of those models.

Using these three approaches in parallel is helpful in building a parsimonious model.[4] If the BSR method or BMA method identifies as important a variable that is absent from the stepwise model, it can be added to the stepwise model to see its impact on explanatory power and on the other variables already in the model. Conversely, if the stepwise model includes a variable not identified as important by either the BMA or BSR method, it can be dropped to see how much that impacts model performance. In general, however, relatively little of this back-and-forth testing of specific variables was needed, as there was a fairly high degree of consistency in the variables selected by each method. The intermediate models resulting from this triangulation process can be thought of as consensus models.

Step Three: Additional tests of variable significance

The analysts' third step in developing a statistical model for each outcome was to subject the consensus model to three additional checks: one for excessive collinearity and two for evidence of overfitting.

Collinearity among predictors does not impair a model's predictive ability, but it reduces the confidence one can have in the estimated effect sizes for the collinear predictors. The analysts therefore checked the Variance Inflation Factor (VIF) value for every predictor, and removed predictors with VIF values above 10. In practice, only a handful of predictors were removed for this reason, and in no case did a variable's removal have a significant impact on the model's explanatory power.

Two methods were used to check for overfitting. The first check was k-fold cross-validation, in which a model is re-estimated using a subset of the modeling data (the 'training' data), and its predictive performance is then evaluated in the remainder ($1/k^{th}$) of the data (the 'validation' data). This is done k times in a random yet systematic way such that every observation ends up being included only once in the validation data. The analysts performed five-fold cross-validation, for each of the seven outcomes.

The second check for overfitting was to re-estimate the consensus model using data in which the true values of the outcome variable have been replaced with the predicted values from Step One's GBM model. These predicted values can be thought of as a 'smoothed' version of the response surface. If the consensus model were been overfit, re-estimating it in this way could produce sizeable changes in the size or significance of some coefficients.

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[4] A parsimonious model is simple yet has high explanatory power. A preference for parsimony in modeling reflects the principle of Occam's razor: For a given level of explanatory power, the simplest model is the one most likely to be the true model.

In practice, for each of the seven outcomes examined in depth, the overfitting tests indicated a low degree of overfitting in the consensus model. For the cross-validation exercises, the consensus model's mean squared error (MSE) in the validation data was not markedly higher than its MSE based on the entire dataset. When the model was refit to GBM-predicted values in place of the true outcome values, there were no striking changes in coefficients, and all remained significant. Some did have somewhat reduced statistical significance (i.e., slightly larger *p*-values), but all were still statistically significant at the *p<0.01* threshold or better. This consistently low degree of overfitting is not surprising, given the consensus model was itself obtained through a process of triangulation with three different variable selection methods.

Step Four: Final test of high-interest variables

The last step in finalizing the model of each outcome was to try once again to add each of the high-interest variables to the consensus model. As noted above, and as many of the survey questions suggest, the SE3 Project is interested in the social dimensions of respondents' feelings of professional engagement and of their perceptions of workplace equity. This fourth step in model building was intended as a conservative measure. The consultants did not want to exclude any of the high-interest factors from the final model without a third confirmation that, after adjustment for their correlation with other factors already in the model, they were not significantly and independently correlated with the outcome variable.

As noted above, these high-interest variables include a respondent's gender identity, sexual orientation, ethnicity, native language, age, current or past receipt of mentoring, status as caregiver (for children or adult dependents), current position, average hours worked, who provided most of the childcare (for respondents with minor dependents), and the maleness or whiteness of upper management. Numerous re-specifications were estimated and evaluated, with these high-interest variables added singly, or in groups, or as interactions with variables already in the model.

The consultants' repeated efforts to include these high-interest factors in the final models are emphasized in order to reassure the reader that, if a final model does not include any race or ethnicity effects (for example), it is not because such factors were not adequately evaluated. On the contrary, the inclusion of those factors was tested at multiple steps in the development of the final model.