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Insights to research and practice from developing and deploying an early career engineers' trajectory survey

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ABSTRACT

CONTEXT

Online surveying is a commonly used research method to explore and validate theoretical constructs. The ease with which online questionnaires can be developed and deployed has led to their adoption by many academics. This survey method has many positive effects and negative effects that must be considered by the researcher before and during deployment.

PURPOSE

We created the Career Trajectory Survey (the Survey) to facilitate a better understanding of the career trajectory of early career civil engineers. This paper draws upon our experiences, intending to serve as both a theoretical and practical resource for other researchers planning to conduct an online survey. In particular, we assess the considerations about deploying online questionnaires to individuals outside the academic context.

METHOD

The Survey questionnaire was deployed to persons with an Engineering Bachelors degree who were located within Australia over an eight week period from May to July 2021. This deployment was undertaken after questionnaire validity checks were performed during a pilot survey. The 10-15 minute online questionnaire utilised the Qualtrics platform, with over 340 valid responses received. Invitations to participate were sent to engineering associations, engineering organisations and individuals through a social media campaign. Valid respondents were offered the opportunity to enter a major prize draw.

OBJECTIVES

This paper presents the Survey deployment plan, its ongoing amendments and insights gained. The basis for deploying a questionnaire to individuals working in industry differs significantly from deployment inside of the academic setting. The issues of participant recruitment, incentives, contacting industry organisations and engineering associations, and the possible pitfalls of a social media campaign are presented. This paper intends to serve as a practical resource for other researchers, particularly those working individually or in small groups, without official sponsorship.

RECOMMENDATIONS

We recommend that the deployment plan of any online questionnaire remains flexible. During this phase the data should be regularly interrogated, allowing for potential deployment changes as required. We advocate for the implementation of strong survey security protocols. Moreover, we advise of the typical low response rates of online surveys, the need for adaptability and the benefits of an advocate.

KEYWORDS Australia, Civil Engineer Career Trajectory, Survey Deployment, Response rate, Insights

Introduction

This paper presents both academic survey development literature and practical recommendations to researchers regarding the deployment of an online questionnaire, particularly targeting respondents working in industry outside of the academic setting. Accurate data collection is an important phase of the research process, highlighting the importance of designing a survey deployment campaign.

We first introduce the Early Career Civil Engineers Career Trajectory study (the Study), research context and a summary of the work completed to date. We then discuss the development and deployment of the Career Trajectory Survey (the Survey) as well as the deployment campaign and anticipated response rates. Finally, we provide insights gained and practical strategies for survey development and questionnaire deployment. While many existing publications provide information regarding the design of a concise questionnaire (Boateng, Neilands, Frongillo, Melgar-Quiñonez, & Young, 2018; Creswell, 2014; Neuman, 2014), not many provide support regarding an effective deployment campaign to achieve high target group response rates.

Context

Internationally, there is a complex and not fully understood disconnect between one's obtaining an engineering qualification and working as an engineer. Consider Australia in 2018, with fewer than 35% of 25-29 year-old qualified Australian engineers working as a professional engineer (Palmer & Campbell, 2018). While a record number of engineers are graduating from Australian universities, the number of domestic undergraduate enrolments has been decreasing since 2015, leaving Australia highly reliant upon migrant engineers (Department of Education and Training, 2020; Engineers Australia, 2019). This necessitates the need to understand early career engineers' trajectories. Our Study uses a social constructivist worldview to undertake an exploratory sequential mixed methods study of early career civil engineers (our subject cohort). The Survey has included the deployment of an online questionnaire of individuals who have earned an engineering Bachelors degree and are currently residing in Australia, including those who work outside of the engineering field. Although our research particularly intends to investigate our subject cohort, the participation of individuals from a wider sample group, including those with other qualifications and experience levels will add to the research veracity. We identify our subject cohort as having graduated from a Civil Engineering Bachelors approximately five years previously.

Our Concept Model

The Early Career Civil Engineer's Trajectory Concept Model (the Model) theoretical underpinnings are observed through the Person-Environ fit theoretical lens of the Theory of Work Adjustment (TWA) (Dawis, 2004). Our Concept Model proposes that critical influential factors impacting the trajectory of an early career civil engineer are constructed upon the *Person*, their *Adjustment* and the *Environment* (Reis, Bunker, & Dawes, 2020). More detail is provided in our upcoming journal paper. Our Survey will support the validation of the Model.

Survey Development

Development of the Survey has been guided by the relevant literature on engineering practice and persistence (Palmer & Campbell, 2018; Sheppard, Antonio, Brunhaver, & Gilmartin, 2015), our concept model (Reis et al., 2020), survey theory (Neuman, 2014) and scale development and validation theories (Boateng et al., 2018). Construct and content validity have been checked through recognised methods including various levels of peer, expert and practising engineers' reviews for language, clarity and appropriateness (Creswell, 2014; Neuman, 2014). To further test and validate the Survey questionnaire a pilot of 26 Higher Degree Research (HDR) students was undertaken. The participants had a median of 7 years of experience after

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Bachelors completion, identifying the applicability of this sub-cohort to our larger study. The results of this pilot survey are discussed in our upcoming journal manuscript.

Benefits and Limitations of Surveys

Utilising surveys for research has grown in popularity. With the increasing application of online survey methods, the tools used to create questionnaires have become increasingly available to novice users. However, with society's increasing survey fatigue, researchers must be increasingly aware of the challenges of designing a concise and effective questionnaire. Surveys are created for many and varied reasons; thus, the developer must be clear about one's purpose and outcomes. A survey provides a sample, rather than a census, of the target population. If developed and undertaken correctly, a survey can correlate and generalise information, resulting in efficient learning about that population (Dillman, Smyth, & Christian, 2014). With those benefits in mind, the developer must also be aware of the potential difficulties with surveys and especially with the deployment of questionnaires.

Online questionnaires can reduce data entry errors, allow larger sample collection and allow backups for increased data security. This wider reach can be achieved with minimal costs, leading to increased response rates and the ability to collect confidential data (Boateng et al., 2018). However, potential survey errors must also be understood. These include coverage error (when the sample does not represent the population), sampling error (difference between a sample and general population), nonresponse error (difference between those that complete the survey and those that do not), and measurement error (respondents may be unwilling or unable to provide accurate answers) (Dillman et al., 2014). Before the deployment of a survey questionnaire, the developers must have a range of planned analysis methods. The implementation of these options may change dependent upon the number, demographics and quality of responses. Many well resourced online surveys have low response rates (de Leeuw, 2008), and research plans must adapt and adjust as the research progresses (Creswell, 2014).

Survey Deployment Strategy

Incentives

For some individuals, responding to another's request upon their time is an altruistic consideration. This often occurs in situations where the topic is of personal interest, or as a personal favour to the individual making the request. For others, it is a reciprocation to the offer of a token benefit (Dillman et al., 2014). People are more likely to respond to any request if there is potential for them to receive something in return. Many studies of engineering students and practising engineers, particularly those based in the United States (US), offer financial compensation to respondents. Small rewards are shown to be effective for increasing responses in some groups, including students (Conn, Mo, & Sellers, 2019). Between 2003-2007, the *Academic Pathways Study* paid each participant US$175 to complete the Persistence in Engineering Survey, and US$4 each to complete the *Academic Pathways of People Learning Engineering Survey* (Chen, Donaldson, & Toye, 2008). Other studies, including the *Situational Judgement Test* and the *Global Engineering Competency Scale* both utilised Qualtrics to identify respondents and pay them 'appropriately' (Jesiek, Woo, Parrigon, & Porter, 2020) (Mazzurco, Jesiek, & Godwin, 2020). In 2015, a study regarding job turnover intentions reported utilising an online recruitment website to recruit and pay each respondent US$0.75 (Dahling & Librizzi, 2015).

Quality signalling may be enhanced by offering a charity donation for each response received. For *pro-social* individuals, this may be as effective as offering a monetary incentive (Conn et al., 2019). For example, *Mental Health in Construction Research* (Nwaogu, Chan, Hon, & Darko, 2020) offers to donate $1 for each completed questionnaire response to a nominated charity, with a donation of up to $500 per charity. Although the incentives offered by these

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previous surveys correspond with the research into boosting survey response rates (Conn et al., 2019), we cannot determine their effectiveness, not many surveys report response rates.

Conn's study of Survey Response Rates concluded that a small number of large prizes is the most cost effective lottery structure (2019). In a survey, it is vital that to achieve the validity of responses, the developers must aim for a non-biased deployment campaign. Due to the wide demographic of our target groups, we decided to create a random prize draw of two $250 e-gift cards for respondents to the Survey. This value was deemed to be in line with current prize draws across our institution. Additionally, the values were chosen to be high enough to encourage the target groups to participate but low enough to discourage invalid participants from responding.

Data collection strategy

The Survey questionnaire was deployed for eight weeks from May to July 2021 (after receipt of ethics approval number 2000000256) from our Institution. The target population for the sampling in this study were individuals having completed an Engineering Bachelors and being present in Australia. Although our study investigates the occupational outcomes of early career civil engineers, the responses from participants from differing fields and experience levels will build upon the research validity. Both qualitative and quantitative data were collected using an online questionnaire hosted by Qualtrics (Qualtrics, 2021) via a secured cloud server. The Survey questionnaire design was optimised for mobile devices, aiming to increase completion rates. Additionally, the platform allowed users to return to the questionnaire for up to seven days, allowing time-poor respondents the opportunity to complete the questionnaire over a longer period.

To ensure this research contributes to a national perspective, nationwide organisations and associations were contacted and asked to distribute the invitation to participate in the survey to their engineering personnel or members respectively. Participants were recruited through adaptive sampling techniques, including both convenience and snowball sampling (Neuman, 2014). The Survey questionnaire was deployed to colleagues, contacts, peers, previous classmates, engineering organisations, engineering associations, *LinkedIn*, *Facebook*, and an Australian state department of transport. This strategy was similar to that undertaken by the ASCE Young Professionals Committee's Survey of Structural Engineering Professionals (Leong et al., 2013). To maximise participant engagement with the Survey, we utilised several methods of contacting target groups. This included telephone, email and social media campaigns, and attending engineering seminars. The time consumed by the research team to locate and contact potential respondents during this deployment provided strong insight into this form of commitment.

In deploying the Survey questionnaire, we contacted 40 engineering and construction firms, 23 engineering associations and posted it to two social networking sites. Although no private firms accepted our invitation to share the Survey questionnaire with their staff, the Queensland Department of Transport and Main Roads (QTMR) did. The invitation and flyer were shared in their daily e-news for a week and added to their *Yammer* site. Additionally, our Institution's School of Civil and Environmental Engineering permitted all Higher Degree Research Students to be contacted. Many of our research students attained industry experience before entering a research program, as identified by our pilot study.

Following receipt of our email, several engineering associations incorporated the Survey link in their periodic e-newsletters, which was similar to methods utilised by other researchers (Bairaktarova & Pilotte, 2020; Buse, 2011). Organisations that accepted our invitation to share with their members included: Engineers Australia (QLD), Professionals Australia (PA), the Australian Institute of Transport Planning and Management (AITPM), the Queensland Major Contractors Association (QMCA), and several chapters of the Institute of Public Works Engineering Australasia (IPWEA). Of the invitations issued, this resulted in response rates of 5% for organisations and 35% for engineering associations. The social media site *LinkedIn*

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was used heavily for the deployment of the Survey questionnaire, through several open posts and over 80 individual personalised messages. Additionally, we sent over 85 personalised emails to previous colleagues and classmates as well as current contacts and peers. Our institution's alumni Facebook site was used to contact Alumni from our institution; however, the single permitted post did not elicit any 'likes'.

In a confidential survey deployed through convenience sampling, the exact response rate cannot be calculated, as it is not possible to know how many people were invited or further shared the invite with colleagues (Chance, Lawlor, Direito, & Mitchell, 2021).

Emails to individuals were issued with a header of *"Would you like to win a gift card in the XXX Engineering Career Trajectory Study?".* Emails to organisations had a different header, "*XXX Engineering Career Trajectory Study – Invitation to participate".* The subject line of an email message is important to motivate the receiver to open it. The sender must also increase and emphasise the benefits of taking part, and enhance the research legitimacy (de Leeuw, 2008). The researcher needs to show potential respondents that their involvement serves a purpose. Moreover, a personalised message, showing the receiver or potential respondent the applicability of the research to their context can increase response rates (Chen et al., 2012). Throughout these amendments to the deployment strategy, the research team must display a consistent research intent, ensuring potential respondents understand the research purpose. To assist other researchers with the creation and deployment of questionnaires we have included the Survey flyer in Figure 1. To increase the trustworthiness of the flyer, we included our institution's logo as well as details of our ethics approval and contact details.

Figure 1 The Survey Flyer

Anticipated Response rates

Nonresponse is a potential issue for any survey, and it is anticipated that a large survey has a low response rate. "Even the most well resourced surveys carried out by experienced survey organizations suffer from nonresponse" (de Leeuw, 2008). Many surveys do not report response rates. Although there are no guidelines for anticipated response rates, an email based survey has a maximum anticipated response rate of 25% (Vanette & Krosnick, 2018). This value is confirmed by the response rate from a US Institution's graduate leadership survey, in which only 23% of professionals at their recruitment day completed their questionnaire (Hartmann, Stephens, & Jahren, 2017). Our Survey is comparable in scale to the Australian Competencies of Engineering Graduates study. This questionnaire was deployed through the University of Western Australia Alumni and engineering associations, receiving 300 responses with approximately a 12% Alumni response rate (Male, Bush, & Chapman, 2010). This correlates with the 12% Alumni response rate of the Graduate

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Pathways Survey (Coates & Edwards, 2011). The modest response rates reported by these Alumni surveys of Australian engineers guided us to anticipate modest response rates.

Research studies that deploy a questionnaire to an exact number of respondents are more likely than others to report response rates. Examples of response rates include those of employees (41%) (Harden, Boakye, & Ryan, 2018), alumni (52%) (Hotle & Katz, 2018), and association members (42%) (Reese, 2003). Due to the convenience and snowball sampling method of our Survey, an overall response rate cannot be determined, this conforms with other research (Morello, Issa, & Franz, 2018).

Survey Responses

We received over 340 valid responses to the Survey. By examining the deployment response graph, presented in Figure 2, for two days after each distribution method, we gained feedback on the relative effectiveness of each. Typically, individuals decide to respond to online self-administered questionnaires within the first two days of invitation (Dillman et al., 2014). Our response rates are higher from invitations sent to alumni or contacts than from other engineers identified through social media. The significant response rate from the QMCA could be due to the accompanying message from their CEO. His email advised members of the industry's incoming workload and the importance of retaining engineers in their industry, encouraging members to participate.

Much of the original deployment plan relied upon the agreed involvement of Engineers Australia, ultimately the survey link was shared by EA Queensland (EA Qld). The planned response from the 21,000 EA Qld members who we targeted is believed to be small, as shown in Figure 2. The responses received in the 48 hours following this e-newsletter were mainly from civil engineers, with an industry and position title matching those from the QTMR deployment on the same day. If the takeup had been from the wider EA Qld demographic we would have received responses from engineers from wider disciplines, industries, and position titles. This low response has been attributed to the survey link being placed at the end of a long e-newsletter, with no mention of the prize draw, under a heading of 'call for comment'. Through the deployment phase we attended three EA Qld events, many attendees at these sessions were interested in the research and retrieved a flyer. However, in the subsequent 48 hours, only one response was received utilising the QR code issued at all three events. We cannot prove why this was so; perhaps people only took the flyer to be agreeable in the social situation, or used the reminder to access the survey through our other access means.

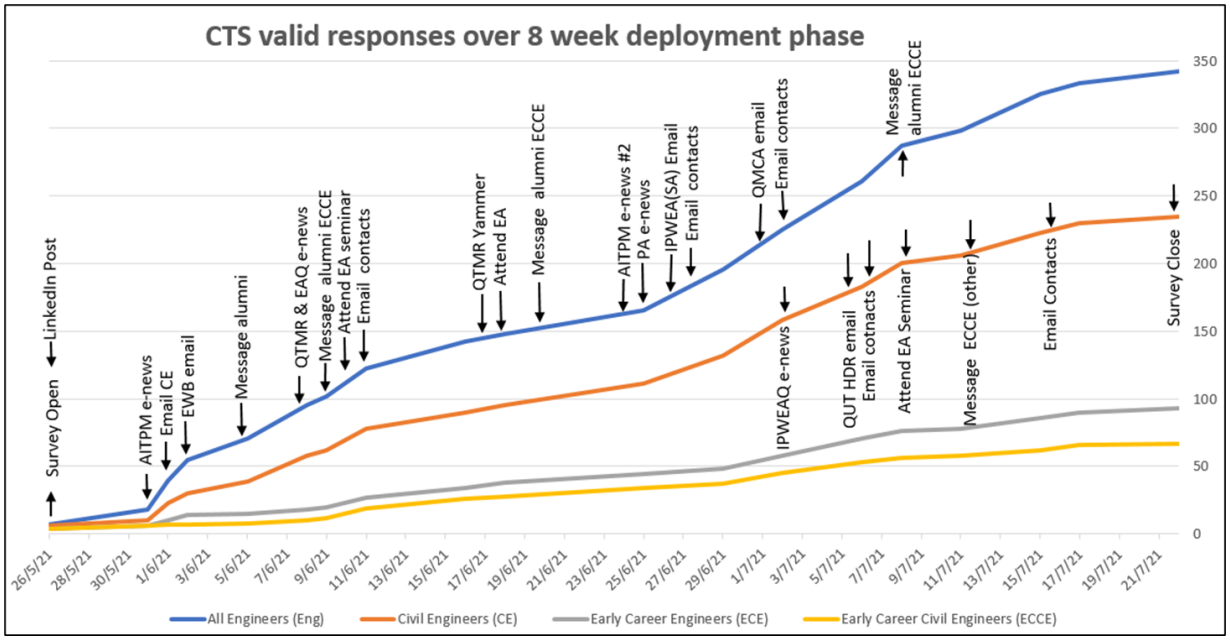

Figure 2 Cumulative Valid Responses

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We found *LinkedIn Premium* to be the distribution method with the highest response rate. We contacted alumni from our institution and asked them to share with colleagues and contacts. Whether or not these individuals personally completed the survey cannot be identified due to the confidential nature of the data collection. However, the graph shows that within 24 hours of bulk emails to alumni there was an increase in responses. This may also be due to the intended snowballing effect. Two individuals, including one not known to the research team, personally contacted us to voice their opinion about the importance of this research to the wider industry, highlighting many of the issues they view as important within the wider engineering industry. This emphasises the importance of incorporating short answer responses in any online questionnaire, as we have, allowing participants to provide information and context to their closed question responses. In future, we may incorporate a different link for each method of distribution, including organisations, associations, individuals, and social media platforms. This would permit the identification of the deployment methods gaining the most responses, either valid or invalid, allowing us to identify successful deployment methods. Additionally, it would allow responses obtained from the source of the highest percentage of invalid responses to be more tightly scrutinised.

The need for sponsorship

Research in engineering professional studies are typically conducted through well resourced Alumni offices or across large numbers of institutions. Several US studies utilised the resources of up to 30 (Sheppard et al., 2015) (Singh, Zhang, Wan, & Fouad, 2018) and 51 institutions (Okahana, 2019). These large US based surveys have received up to 7000 responses, the scale of which is significantly different from our research study. Several research studies have used firms that recruit through their institution (Morello et al., 2018) (Hartmann et al., 2017) or include additional questions in the university wide graduate survey (Naukkarinen & Bairoh, 2021). (Dillman et al., 2014) reported that deployment will receive higher response rates if there is a sponsorship provided by a senior member of a legitimate organisation. We achieved low response rates from the questionnaires deployed to individuals arbitrarily, as shown in Figure 2. However, requests made to individuals with a prior working relationship with the research team or the university were more likely to be received favourably. This included our contacts with the AITPM and EA Qld (both sponsored by a present or past board or committee member) and QTMR (sponsored by the QTMR Chair at our institution). Coincidentally, senior members of IPWEAQ and QMCA were alumni of our institution, increasing their engagement with our research. This highlights the need for a small research team to obtain advocacy or sponsorship from an individual who can provide strategic or influential direction.

Coverage and Sampling Checks

Halfway through the eight week deployment period, we reviewed our data for coverage and sampling errors. Reviews of the incoming data impacted the deployment strategy, allowing us to target demographics that had responded at rates lower than anticipated. We compared responses with previous analyses of the 2016 Australian census (Crosthwaite, 2019; Palmer & Campbell, 2018). This data was used to determine an applicable range of response percentages from each response group, including gender, experience, and industry sector of respondents. From this review, we identified the low number of responses from those working in the construction industry and contacted the QMCA. Additionally, we identified the low number of responses from females in the tertiary sector and contacted our HDR students. After the questionnaire close, a preliminary cross-tabulation analysis comparing industry and experience level against gender confirmed our ability to engage with a wide demographic. Respondents that identify as female or nonbinary are represented in all but one of these cross-tabulations. Moreover, the number of respondents per industry category are comparable with anticipated percentages (Crosthwaite, 2019). Approximate participation percentages include Construction and Operations (19%); Professional, Technical and Management Consulting (46%); and Education, Training and Research (14%). The high participation rate of 19% for

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those working in the Government and Public Sector is likely due to the systematic distribution by the QTMR and IPWEA.

Response Validity Checks

During deployment, we continuously reviewed the incoming responses to check validity. We needed to ensure that the security protocols of the survey platform were correctly initialised and functioning. Qualtrics security protocols warn of potential duplicate responses through fraud detection, including duplicate IP addresses. However, those responses identified as potential duplicates should be probed before deletion. An organisation's external IP address may not show an individual computer's internal network address (WhatIsMyIP.com, 2021). By example, many potential duplicates were received on the day of distribution through QTMR. A review of these potential duplicate responses included a comparison of the participant's role description, position title, and potential non-response of closed questions. Interrogation of short-answer questions is another method of identifying potential invalid responses. After review, many of these potential duplicates were considered to be valid. Thus, removal of potential duplicates should be undertaken with care, utilising more than one method of identifying invalidity. For example, responses including position titles of 'the engineer' and 'I'm an employee' were then investigated for validity and removed.

In the first week, the LinkedIn post that launched the Survey received over 1000 views and 20 shares; however, this did not lead to a large number of responses. During the first 36 hours after the LinkedIn launch, there were 60 invalid responses and only 25 valid responses. The security settings, including geolocation, bot detection and duplicate IP addresses, identified potential invalid responses but did not remove them from the survey flow. After enhancement, the security protocols were relatively effective throughout the deployment. Approximately 34% of responses were deemed invalid or incomplete, with 63% of these identified as being outside Australia's geolocation and an additional 24% with a response time of fewer than two minutes. In future, we will ensure that two levels of expert review of security protocols are undertaken before deployment. We recommend that other researchers be mindful of the global nature of social media, particularly with respect to uncontrolled sharing of access to a prize draw. The analysis protocol to identify valid responses is presented in Table 1.

Table 1 Analysis protocol to identify valid or incomplete responses

Step	Protocol	Notes
1	Note number of responses received	This will identify percentage invalid or incomplete
2	Identify geolocation outside Australia	This Qualtrics security protocol was not fully enabled for the first 36 hours
3a	Identify responses of 0 seconds or those identified by Qualtrics as Bots	Properly activated Qualtrics security protocols do not allow invalid respondents to enter
3b	Identify responses of less than 2 minutes	These are mainly straight-lined responses or bots
4	Identify: *Qualtrics Relevant ID Fraud Score* >30 *Qualtrics ReCaptcha Score* <0.5 *Qualtrics Relevant ID Duplicate* - True	Refer Note 1
5	Identify the required percentage complete of each response. This cutoff value may differ for each analysis method.	Responses over 75% complete had finished the Likert questions required for the Factor Analysis.
6	Identify responses with significant numbers of missing answers to closed questions.	Respondents are not forced to answer questions, thus requiring review of closed answer questions.
7	Review remaining responses for the authenticity of short answer responses and position title.	Several invalid responses have nonsensical text, refer discussion.
Note 1: Review these responses for validity before removal, large organisations often utilise one external IP address, individual internal network users are not identified by Qualtrics. Refer discussion.		

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The potential for survey fatigue was reviewed during the deployment phase. The average completion time was 13 minutes (removing extreme outliers), this is considered acceptable compared to the 10-15 minutes advertised. To reduce respondent fatigue and drop out an internet survey should be limited to 10-15 minutes (de Leeuw, 2008). Of the respondents who commenced but did not complete the Survey online questionnaire, the average time commitment was 6 minutes (after removing outliers), thus we considered that survey fatigue was not an issue. To examine the national reach of this research survey, the geolocation of a respondents IP address was recorded by Qualtrics. However, we consider that many large organisations communicate an IP address geolocation that identifies the organisation's head office rather than satellite offices. A small number of responses show regional geolocations. This contrasts with the advice provided by many of our regional contacts upon completion.

Positive Aspects of our Deployment Campaign

From the first author's perspective, there have been many positive aspects of deploying the questionnaire ourselves, rather than engaging (paying) a third party to collect data. The knowledge of the database gained during this period has directed the flow of the deployment. Moreover, contacting previous colleagues, as well as rekindling and making new industry contacts has provided both personal and professional growth.

Practical Advice for Researchers

This paper intends to provide practical advice to researchers intending to deploy outside the tertiary context. In this vein, we present some of our insights gained from this survey:

1. Display a consistent research intent.
2. Plan your questionnaire deployment schedule. Be aware of the significant time taken to contact large numbers of individuals, associations and organisations.
3. Be wary of the global and uncontrolled nature of social media. Be careful if offering a prize draw on an open-access social media platform.
4. Note the perils of only one distribution method. Stay flexible in your deployment methods, but ensure any changes remain in line with your ethics approvals.
5. Don't expect too much from contacts and colleagues. The survey may not be as important to your contacts as it is to you.
6. Anticipate a low response rate, and plan distribution and analysis options to manage accordingly.
7. Ensure that layers of expert review are provided for the security protocols.
8. Provide separate URL links to enter the online questionnaire for each distribution method.
9. Review your incoming data regularly for consistency, demographics and validity. Multiple responses received through one large organisation may be communicated from a common IP address.
10. Obtain an advocate or sponsor, either corporate, alumni, or university based.

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Conclusions

This paper is part of the larger Early Career Civil Engineers Career Trajectory Study, which uses a social constructivist worldview to implement an exploratory sequential, mixed methods research approach. Our Study intends to provide a better understanding of the career trajectories of early career civil engineers.

The recommendations in this paper are intended to serve as a practical resource for other researchers, particularly those working individually or in small groups, without official sponsorship. We recommend that the deployment plan remain flexible and that during this phase the data be regularly interrogated, allowing for potential distribution changes. We advocate for researchers to implement strong security protocols for online questionnaires, particularly those deployed through social media. Most importantly, we remind researchers that many surveys receive low response rates and that the distribution and analysis protocols should be prepared for these potential outcomes.

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