ARCHITECT-BPS CONSULTANT COLLABORATIONS
Harmony or hardship?

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ABSTRACT

Multi-disciplinary collaboration is considered necessary for solving complex designs, and belief in its merits is unequivocal in Architecture, Engineering and Construction (AEC) literature. However, this paper argues that collaboration is a challenging endeavour that entails creating a unified platform for professionals to converge. Challenges are compounded when the collaboration is for building performance assessments, as architects' and BPS consultants' worldviews are divergent. This paper presents part of a mixed-methods study investigating collaborative relationships between architects and BPS-consultants. Questionnaires are designed to re-test non-technical barriers in collaboration, described during preceding interviews. Six salient factors, representing barriers impeding fruitful collaborations are extracted, and inter-relationships are explored using inferential statistics. Barriers include perceptions about architects' attitudes toward BPS, using BPS for compliance, trust and communication between architects and consultants. Finally, this research illustrates how recourse to methodologies from outside the traditional BPS realm may open new research avenues in this field.

KEYWORDS

Collaboration; architects; BPS consultants; questionnaires; inferential statistics.

1. INTRODUCTION

The aim of this paper is to serve as a starting point, to explore and unravel the complex nature of collaborative relationships between architects and Building Performance Simulation (BPS) consultants. This paper also aims to determine barriers that may be reducing the effectiveness of collaborative relationships between architects and consultants; based on the opinions of a relatively large sample of both professional groups in England and Wales.

'Collaboration' is a much-used buzzword in the Architecture, Engineering and Construction (AEC) industry, frequently appearing in much of its literature (for examples, see van Marrewijk et al., 2014; Summerfield & Lowe, 2012; Bresnen, 2013; Hill et al., 2013; Rosenman et al., 2007; Eppler, 2007; Heerwagen et al., 2004; Moses et al., 2008). Demolishing beliefs that works of architecture are born out of the architect's autonomy and mystical *"lone design genius,"* (Domeshek, Kolodner, Billington, & Zimring, 1994), collaboration is frequently described as a key mechanism undertaken to complete tasks in the design and construction process that would remain unforeseeable if undertaken individually (Kalay, 2001; Chiu, 2002; Kvan, 2000). The sheer size and complexity of most construction projects predicates that most collaborative efforts are multi-disciplinary, driven by interactions and negotiations of AEC professionals from a multitude of backgrounds.

Consulting with the divergent knowledge bases of professionals from varying backgrounds may seem like an obvious solution to overcome limitations in knowledge and resources, and streamline project design, delivery and procurement processes. Belief in the opportunity promised by multi-disciplinary collaboration is unequivocal in much AEC literature. Barrow (2004) states that the architect's historical status as master-builder, whose core value lies in *"aesthetic-based intuitive subjective design";* is being replaced by *"a dynamically-networked team of design and construction knowledge specialists."* Duffy and Rabeneck (2013) believe that the most sustainable means of protecting architects' professionalism, while ensuring superior design quality proven using measurable results as indicators of design performance, is through collaboration. This is echoed by Bordass and Leaman (2013) in their BRI editorial '*A new professionalism: remedy or fantasy?*' who ceremoniously declare inter-disciplinary collaboration as the most promising avenue for future evolution and survival of the professional architect in the dynamic and ever-evolving building industry.

However, multi-disciplinary collaboration is a multi-faceted endeavor that comprises much more than simply bringing together individuals to work on the same project. Cuff (1991) contends that bringing professionals into the same physical setting does not automatically translate into equal participation, or even mean that they are working together at all. Nor is collaboration a simple division of tasks, such as in the case of Building Integrated Modelling

(BIM) technologies, which is often claimed to facilitate and streamline collaboration (for examples, see Barbosa et al. (2016); Singh et al. (2011); Sebastian, 2011; Zhao et al. (2015)). Kvan (2000) argues that simulating co-location through software platforms alone is not an effective predecessor to collaboration. Rather, relying on such platforms propagates an 'out-sourcing' archetype of collaboration; which assumes that collaboration only entails fragmenting the design into a series of 'parts,' which are distributed to different professionals. Each professional works on 'their' part of the design in comfortable isolation; possibly meeting from time-to-time to adjust the design, and re-assemble the respective parts at the end of the process.

Kvan (2000) argues that instead of creating data-exchange mechanisms between professionals who are physically-isolated and ideologically-disparate, multi-disciplinary collaborations need to be regarded as creating an integrative and unified platform for professionals to work together in harmonious synergy. Arriving at such an orchestrated synthesis is a time-intensive undertaking; entailing building relationships and arriving at mutual understanding between project participants. Full commitment to project goals is essential, and these should be favoured above individual goals; predicating a high level of trust, understanding and compromise between collaborating partners (Kvan, 2000).

While collaborative endeavors exist in an array of professions (e.g. medicine, engineering and law), AEC collaborations are thornier than in the afore-named subjects. For example, medical professionals follow an interdisciplinary structure of education and training (Bordass & Leaman, 2013), meaning that they share a common professional identity, mutual foundations and are likely to at least understand others' worldviews within the medical milieu (Hartenberger et al. 2013). However, in the AEC industry design team members (architects, civil engineers, mechanical engineers, project managers) seldom have a common educational foundation (Kalay, 2000; Hartenberger et al., 2013). Collaborative design studios and experiences seldom feature as a characteristic of built environment professionals' training. Hartenberger et al. (2013) assert, *"a unifying corpus of knowledge (or self-understanding) that ties together the different groups of professionals"* in the AEC industry *"appears to be missing."*

2. COLLABORATION FOR BUILDING ENERGY PERFORMANCE

The challenges of multi-disciplinary collaboration are inextricably compounded when its purpose is to quantify and assess the impacts of design decisions from an energy and performance perspective (Hill et al., 2013). Nowadays there are stringent requirements to meet minimum standards for energy-consumption, often in concurrence with building regulations (e.g. Approved Document Part L; Conservation of Fuel and Power in the UK) (Planning Portal, 2016)[1], which cannot be achieved without accurate quantification. However, quantifiably assessing a building's performance is a *"non-trivial task"* due to the *"myriad of physical interactions"* in the building's thermodynamic and performative domains; including air-movement, daylighting and radiation exchanges, amongst others (Clarke, 2001). Traditional design methods are visibly limited in this respect. Rough guidelines, abstract rules of thumb or design intuition cannot be used to predict the impacts of such simultaneous and dynamic interactions on energy consumption.

Instead, a broad category of software known as building performance simulation (BPS) is often used for this purpose. BPS software relies on the construction of complex mathematical models that simulate energy flows within the building, as well as internal interactions between each of these energy flows (Clarke, 2001). A wide variety of software is available on the market falling under the BPS umbrella. At the time of writing, over 120 packages are listed on the Building Energy Software Tools (BEST) directory (BEST, 2016), covering a range of performative domains including thermal, solar-thermal, lighting and acoustic analyses.

[1] Approved Document Part L; Conservation of Fuel and Power addresses energy-efficiency standards that need to be met to comply with building regulations in the UK (Planning Portal 2016). This document is referred to as 'Part L' throughout the remainder of this manuscript.

It has been recognized by the scientific community that BPS has the potential to assist architects' design decision-making to realize more energy-efficient design-solutions (Augenbroe, 2001; Attia et al., 2009; Clarke, 2001). In recognition of this potential, there are multiplying efforts to integrate BPS in the design decision-making process, to quantifiably assess the impact of architectural design decisions and forecast the performance (Attia et al., 2009; Attia et al., 2012; Pedrini & Szokolay, 2005; Venancio et al., 2011a). A number of commercial BPS packages and third-party interfaces, tailored for architects' use, are available on the market (e.g. Autodesk Ecotect Analysis, 2014; Autodesk Green Building Studio, 2016; OpenStudio, 2016). This is additionally supported by efforts within the academic community, to develop 'architect-friendly' tools and interfaces (Attia et al., 2009; Attia et al., 2012; Pedrini & Szokolay, 2005; Venancio et al., 2011b). Nevertheless, a seamless and fluid integration between these two professions has yet to be realized, as a host of barriers continue to this integration have yet to be resolved (Attia et al., 2009; Attia et al., 2012; Pedrini & Szokolay, 2005; Venancio et al., 2011b; Bleil De Souza, 2009). These include technical barriers within software design such as complexities in data-input, difficulties interpreting alpha-numeric outputs (Attia et al., 2009) and lack of graphical user interfaces, which is considered the most effective means of communicating with visually-oriented architects (Punjabi & Miranda, 2005). It is arguable that non-technical barriers cited in the literature, such as practicing architects' inadequate knowledge of building physics and heat transfer processes (Soebarto, 2005; MacDonald et al., 2005; Bleil De Souza, 2009; Palme, 2011), are more difficult to overcome. Since this material is not always covered in architectural curricula in support of BPS, it becomes difficult for architects to observe the building from the thermodynamic lens necessary for them to understand heat and mass transfer processes occurring between the outside and building interior.

Architects needing to assess the performance of their designs seldom undertake BPS themselves, instead relying on collaborations with specialists in the BPS field (hereon described as BPS consultants[2]) to conduct BPS for them (MacDonald et al., 2005; Prazeres & Clarke, 2003; Prazeres et al., 2007; Prazeres et al., 2009; Bleiberg & Shaviv, 2007; Bombardekar & Poerschke, 2009). These collaborations are inherently multi-disciplinary, merging between practitioners from disparate social and professional groups to work together in a single environment. However, architects-BPS consultant collaborations mean that perceived responsibilities of BPS consultants occasionally overlap with architects' responsibilities. Decisions of building orientation, form, spatial layout and fabric composition, previously relying on architects' qualitative judgment and intuition, must now be assessed quantifiably according to performance; particularly to comply with stringent building regulations. Correspondingly, the architect of today no longer resides in an undisputable leadership position in the design team. Knowledge and technological prowess are progressively shifting positions of power as the BPS consultants' underlying knowledge of thermodynamics, experiences in using BPS software and abilities to interpret outputs of thermodynamic models often places them in the position of the prime decision-maker on the design team, based on quantification (Alsaadani & Bleil De Souza, 2016). Reversal and overlap of professional roles on the design team, as well as the eroding status of today's modern architect, is an active topic of discussion explored in several publications (e.g. Hamza & Greenwood, 2009; Barrow, 2004; Sebastian, 2011 to name a few).

An additional complication to the premise of multi-disciplinary collaborations between architects and BPS consultants is that members of these two groups *"subscribe to different worldviews and paradigms when undertaking their everyday activities"* (Bleil De Souza, 2012). Bleil De Souza (2012) asserts that mechanisms of knowledge retention and acquisition differ; for architects knowledge is constructivist and generated from experience, while knowledge for BPS consultants departs from Systems Theory, who learn to observe the building from a thermodynamic lens. Praxis used by members of the two groups, as derived from knowledge, is also in contrast as a result. As a consequence of paradigmatic differences, Bleil De Souza (2012) concludes that architects' and consultants' worldviews are

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[2] The term 'BPS consultant' is used throughout this paper to describe building practitioners who use BPS software throughout their day-to-day working process and, in the case of this research, collaborate with architects to assist them in design decision-making. These professionals may originate from a variety of different professional backgrounds e.g. mechanical engineering, building services engineering, building science, etc.

incommensurable, arguably making the question of arriving at common grounds for both these professions to reach mutual understandings challenging.

This paper describes part of a mixed-methods PhD study, aiming to understand collaborative relationships between architects and BPS consultants, and some of the non-technical barriers that may arise between these two professional groups as a consequence of difference in worldviews. Since there is little or no underlying theory confirming the existence and impact of non-technical barriers in collaboration, a qualitative study consisting of semi-structured interviews with a small sample of architects and BPS consultants in England and Wales was initially conducted to extract potential barriers[3]. A questionnaire-based study was performed in the second research stage to retest qualitatively derived theories. This paper focuses on the results of this questionnaire-based study.

In this instance, the use of quantitative methods in the form of multivariate inferential statistics facilitates the exploration of inter-relationships between variables and the extraction of meaningful results from raw statistical data, which could not be deduced using descriptive statistics alone.

3. Methodology

3.1. Questionnaire design

Two self-completion questionnaires were designed. Questionnaire 1 was designed to re-test barriers voiced by architects interviewed in the preceding qualitative stage, and to ascertain whether these barriers are recognizable beyond the initial sample of architects interviewed. Similarly, questionnaire 2 were designed to re-test barriers voiced by BPS consultants interviewed. Seeing as there was some overlap in barriers described by architects and consultants interviewed, these featured in both questionnaires 1 and 2. All questions were designed in the form of five-point Likert-scale[4] statements, and each statement was derived from an interview quote worded based on original interview quotes or inspired from the preceding interview stage (Appendix A).

3.2 Populations and samples of architects and BPS consultants.

To construct a potentially representative sample of architects in England and Wales, and another potentially representative sample of BPS consultants, it was first necessary to determine the population sizes, from which the potential representative samples could be derived.

3.2.1 Determining the populations of architects and BPS consultants

The RIBA Chartered Members Directory (RIBA, 2016) was assumed to be a comprehensive compilation of UK architects. The predicted population of practicing architects, on the RIBA Chartered Members Directory, at the time this research was conducted, was found to be 2304 architects (N_A = 2304).

The population of BPS consultants within the UK building industry was less identifiable than that of architects. While associations such as the RIBA and the ARB have firm criteria of who an architect is based on *"education, experience and practice"* (ARB, 2016), a parallel set of criteria determining who a 'BPS consultant' is could not be found. The Register of Low Carbon Consultants, provided by the Chartered Institute of Building Services Engineers (CIBSE) was used as a delineation of the population of BPS consultants (CIBSE, 2016), as no comprehensive list of BPS consultants practicing in England and Wales could be found on

[3] A detailed discussion of non-technical barriers, based primarily on qualitatively derived insights, is presented and discussed in detail in Alsaadani & Bleil De Souza (2016).

[4] The Likert-scale is a psychometric itemized rating scale, commonly employed in questionnaires for the measurement of attitudes, personality traits or opinions (Himmelfarb, 1993; Fink, 1995; Albaum, 1997). The Likert-scale allows measurement of an individual's support or opposition toward the statement being tested, as well as the strength of support or opposition.

IBPSA websites (IBPSA, 2016). This register was used to define the population of BPS consultants in England and Wales; which was found to be 1029 BPS consultants (N_{BPS} = 1029), from which BPS consultants were sampled.

3.2.2 Constructing the two samples

Equal probability systematic sampling was used to generate the two samples. Attempted sample sizes were calculated using equation 1, with the correction factor for large populations (equation 2) (Czaja & Blair, 1996). According to these equations, and for a confidence level of 95%, the sample of architects required 329 architects (n_A = 329), and 280 BPS consultants (n_{BPS} = 280).

$$\boldsymbol{Sample\ size} = \frac{\boldsymbol{Z^2 \times p \times (1-p)}}{\boldsymbol{m^2}}$$

Such that:

Z = the confidence level. 95% confidence level means Z = 1.96.

p = worst case percentage, expressed as a decimal. Conservative value = 0.5.

m = margin of error, expressed as a decimal, m = .05.

Equation 1. Used to calculate the sample sizes of architects and BPS consultants from their respective populations.

$$\boldsymbol{New\ sample\ size} = \frac{\boldsymbol{sample\ size}}{\left[\frac{\boldsymbol{(sample\ size - 1)}}{\boldsymbol{population}}\right] + \boldsymbol{1}}$$

Equation 2. Correction factor.

A sampling interval was needed to systematically select members of the sample from the population. Equation 3 (Czaja & Blair, 1996) was used to determine the interval size. Based on equation 3, a sampling interval of 7 was used to derive the sample of 329 architects from the population. A random starting point was chosen at the third architect. Architects selected were numbered 3, 10, 17, etc. For the BPS consultants, the sampling interval was at every 4 consultants. The second consultant on the list was used as the starting point, and every 4 consultants (6, 10, 14, etc.) were subsequently sampled.

$$\boldsymbol{Interval\ size} = \frac{\boldsymbol{N}}{\boldsymbol{n}}$$

Such that:

N = Total population
n = Sample size (calculated from equation 6.1).

Equation 3. Used to calculate interval sizes, to determine members of the population of architects and BPS consultants to be included within the samples.

3.3 Data-collection

Both questionnaires were launched online using the tool SurveyMonkey (www.surveymonkey.com) on 17th October 2011; and both were available for 166 days. Emails were sent to each of the sampled architects and consultants requesting their participation, including a link to the questionnaire. Despite advantages of online distribution such as ease of distribution across a wide geographical area (Wright 2006), and time and cost efficiency, one of the known limitations of online questionnaires is low-response rate (Kaplowitz et al., 2004; Wright, 2006). The threat of low response rate was heightened in the case of this research as both samples consisted of busy professionals with heavy workloads. To overcome this, reminder emails were sent out to sampled participants. Another measure taken was to refrain from collecting personal information from the respondents; including name, age or years of experience, as recommended by Fowler (2002). While refraining from collecting personal information was initially considered an opportune trade-off to increase participation, it was later recognized that this meant that basic sample demographics were unavailable and sample characteristics were unknown. This means that there was no way of ascertaining whether the samples were fully representative of the two populations, and any elements of sampling bias could not be traced. The analysis was also limited considerably as a consequence. Comparisons could only be conducted based on profession; whereas collecting knowledge of sample demographics may have allowed further trends to be uncovered, based on years of experience or gender, for example. This has been recognized as a research-limitation.

3.4 Response rates

218 responses were returned from sampled architects, 175 of which were suitable for analysis (table 1). 148 responses were returned from sampled BPS consultants, all of which were suitable for analysis (table 1). Therefore the sample size for architects is 175 and the sample size for consultants is 148.

Table 1. Architects' and BPS consultants' response rates.

		ARCHITECTS		BPS CONSULTANTS	
SAMPLE APPROACHED		329		280	
TOTAL RESPONSES RETURNED		218		148	
	Unanswered	*43*		*0*	
	Partially answered	***38***	*Analysed*	***22***	*Analysed*
	Fully answered	***137***		***126***	
RESPONSE RATE		53.2%		52.8%	

3.4.1 Implications of non-response on results' generalization

While 323 responses were collected for both questionnaires, this response only slightly exceeds 50% for both and architects' and BPS consultants' samples. Evidence from the literature from sociology and behavioural science suggests that a 56% response rate for questionnaires could even lead to generalizations (Baruch, 1999) as non-responses are inevitable, and response rates of 100% are unlikely to be attained. In the simulation / energy research literature it is also possible to find studies which claim generalizations with questionnaire response rates of 56% (e.g. Raslan and Davies, 2010).

Despite having seen results claimed as representative in previous studies with similar response rates, this work does not claim findings are generalizable to the populations of architects and BPS consultants. However, the high response rate attained provides good indication of the nature of the phenomena being studied, enabling the work to still contribute to the body of knowledge in this area. This is because a response rate of 50% is still a significantly high rate to achieve in practice especially among busy professionals (Baruch, 1999). Moreover, in the fields of sociology and behavioural science, several examples of significant contribution to the body of knowledge have been found with response rates far smaller than this one (e.g. 24% in Lam (2010), 26.4% in Honeycutt and Freberg (2017) and 37% in Tichenor et al. (2017)).

3.5 Statistical analysis

Data sets collected consist of a large number of categorical variables. Hence a procedure known as exploratory factor analysis was used to summarise the data. This was followed by a series of inferential statistics (independent samples t-tests, correlations and one-way ANOVAs) to examine variables inter-relationships. Exploratory factor analysis performed on data gathered from architects' and BPS consultants' questionnaires (N=323) are detailed in section 3.5.1. Analyses performed on data from BPS consultants' questionnaires (nBPS = 148) are presented in section 3.5.2. Statistical analyses described throughout this paper were conducted using IBM SPSS.

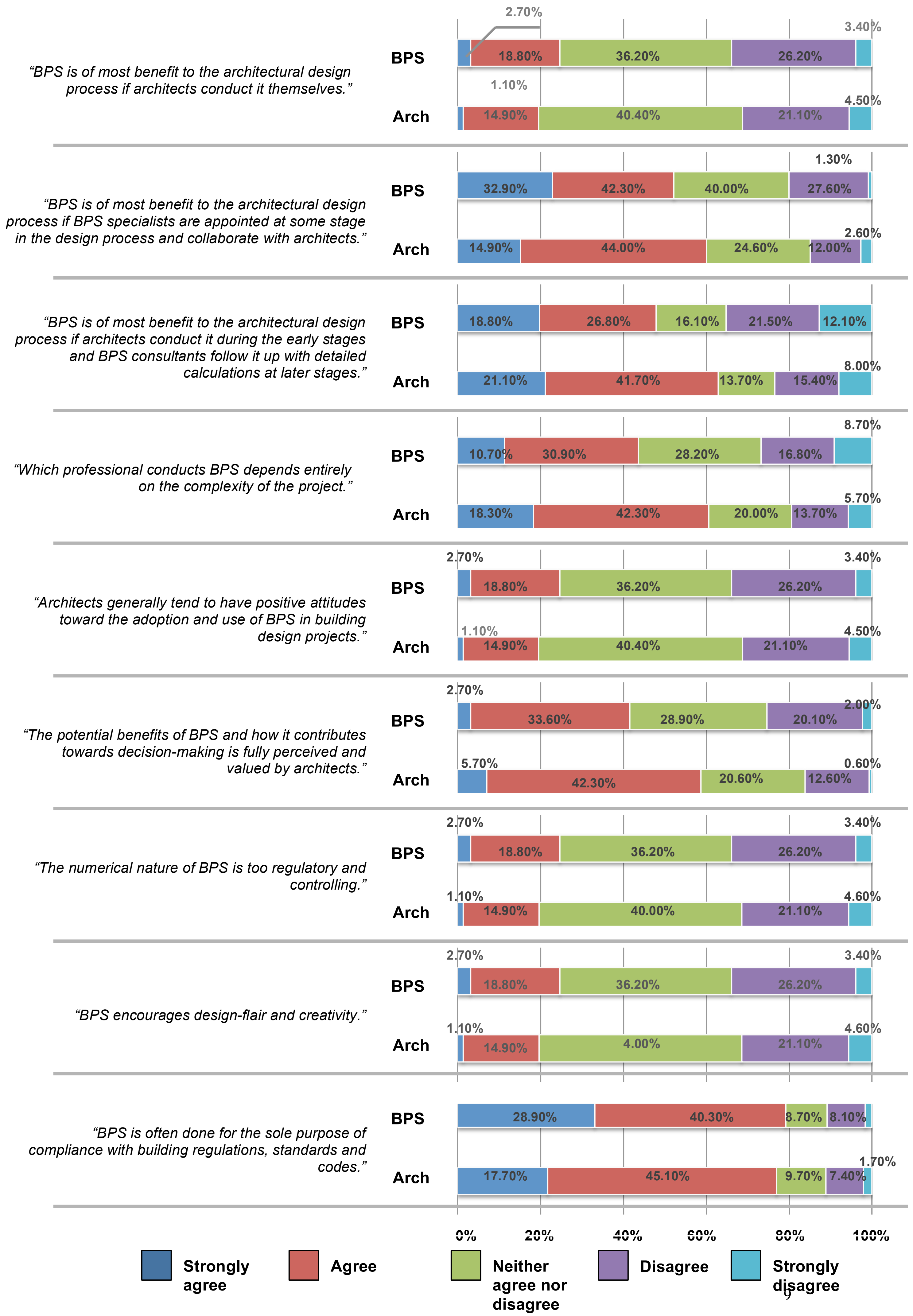
3.5.1 Exploratory factor analysis performed on data from both questionnaires 1 and 2 (architects and BPS consultants).

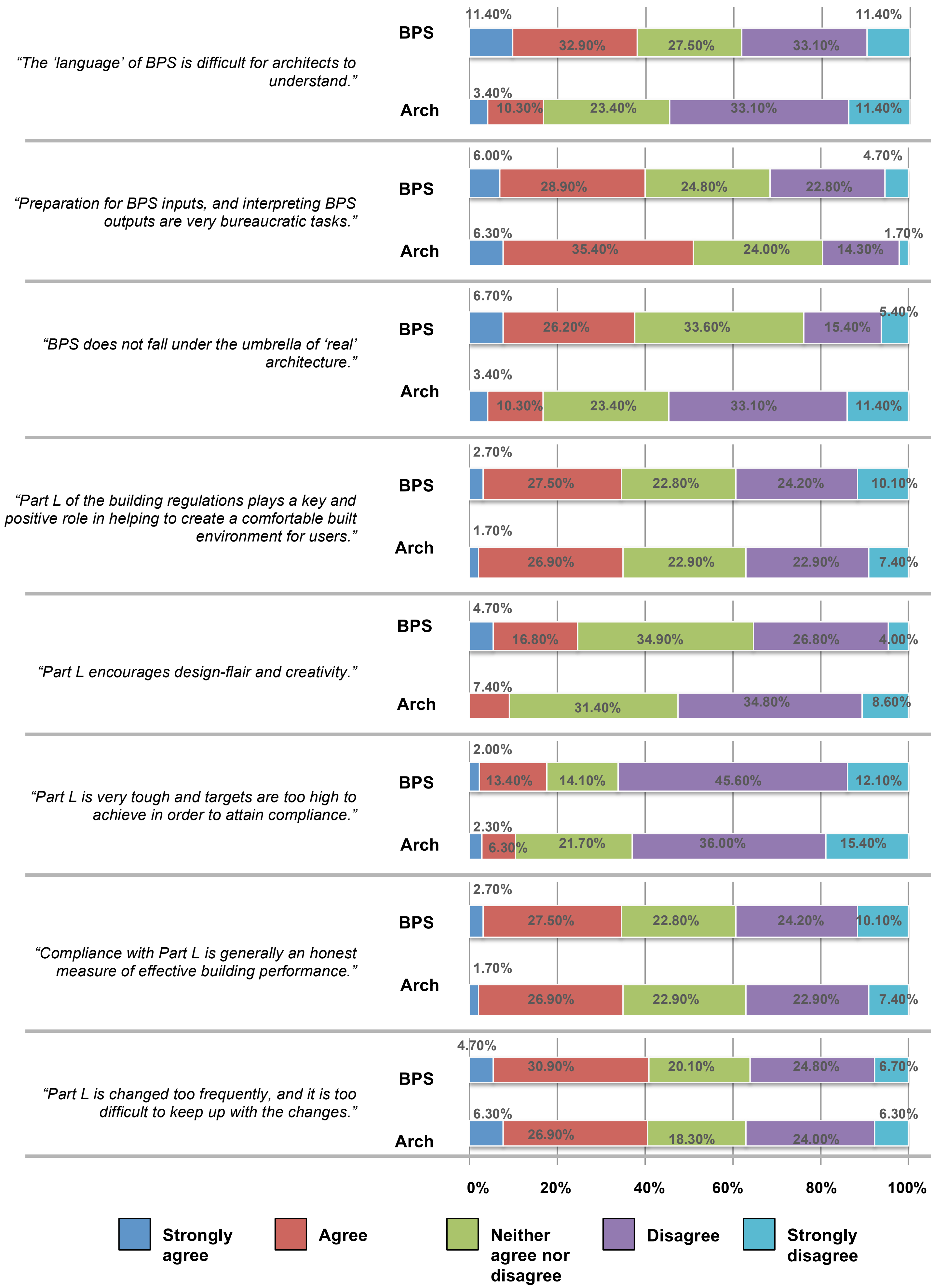
Variables shown in figure 1, from the combined sample (N=323) were reduced to a set of underlying factors using exploratory factor analysis. This process, and subsequent inferential tests performed on this reduced data, is summarized in figure 2. Preliminary analyses were undertaken to assess suitability of the sample size for factor analysis (Field, 2005). Based on a correlation matrix, nine variables were eliminated for having a majority of non-significant correlations (Appendix B), and thirteen variables were retained for the subsequent analyses. The total combined sample size (N = 323) was also found suitable for factor analysis based on the KMO statistic (0.700, which is a 'good' result according to Hutcheson and Sofroniou's (1999)) and a highly significant result for Bartlett's test of spherecity (p=.000).

Five factors returned eigenvalues greater than 1; meaning that these best summarise the original variables (table 2)[5]. This was also confirmed using a Scree Plot. By examining the variables that loaded highly onto the extracted factors, the meaning or recurrent underlying theme of that factor was interpreted, and abstract labels assigned to each based on thematic interpretation, to facilitate further analysis. Variables that loaded highly onto factor 1 were indicative of *'negative attitudes toward BPS.'* Variables loading highly onto factor 2 were encircled around *'positive trust'* between architects and consultants. Factor 3 was renamed *'compliance modeling encourages design flair and creativity.'* Factor 4 was re-named *'architects should conduct BPS themselves,'* as the variables that loaded highly onto this factor were encouraging of architects' self-employment of BPS. The final factor, factor 5 was named *'BPS as a bureaucratic employment exercise.'*

Finally, composite scores were generated for each factor in the solution, based on the means of each variable that had loaded highly onto that factor. These composite scores determine the sample's central tendencies, and extents of agreement or disagreement to each factor. Generating factor scores meant that further statistical tests (e.g. correlations, t-tests and one-way ANOVAs) could be conducted to investigate each factor further (figure 2).

[5] In table 2, the first five columns following the list of original variables show the factor loadings. The final column is entitled 'communalities,' which shows the amount of common variance of each variable (i.e. the amount of variance that is shared with other variables).


"BPS is of most benefit to the architectural design process if architects conduct it themselves."
BPS
2.70%
18.80%
36.20%
26.20%
3.40%
Arch
1.10%
14.90%
40.40%
21.10%
4.50%
"BPS is of most benefit to the architectural design process if BPS specialists are appointed at some stage in the design process and collaborate with architects."
BPS
32.90%
42.30%
40.00%
27.60%
1.30%
Arch
14.90%
44.00%
24.60%
12.00%
2.60%
"BPS is of most benefit to the architectural design process if architects conduct it during the early stages and BPS consultants follow it up with detailed calculations at later stages."
BPS
18.80%
26.80%
16.10%
21.50%
12.10%
Arch
21.10%
41.70%
13.70%
15.40%
8.00%
"Which professional conducts BPS depends entirely on the complexity of the project."
BPS
10.70%
30.90%
28.20%
16.80%
8.70%
Arch
18.30%
42.30%
20.00%
13.70%
5.70%
"Architects generally tend to have positive attitudes toward the adoption and use of BPS in building design projects."
BPS
2.70%
18.80%
36.20%
26.20%
3.40%
Arch
1.10%
14.90%
40.40%
21.10%
4.50%
"The potential benefits of BPS and how it contributes towards decision-making is fully perceived and valued by architects."
BPS
2.70%
33.60%
28.90%
20.10%
2.00%
Arch
5.70%
42.30%
20.60%
12.60%
0.60%
"The numerical nature of BPS is too regulatory and controlling."
BPS
2.70%
18.80%
36.20%
26.20%
3.40%
Arch
1.10%
14.90%
40.00%
21.10%
4.60%
"BPS encourages design-flair and creativity."
BPS
2.70%
18.80%
36.20%
26.20%
3.40%
Arch
1.10%
14.90%
4.00%
21.10%
4.60%
"BPS is often done for the sole purpose of compliance with building regulations, standards and codes."
BPS
28.90%
40.30%
8.70%
8.10%
Arch
17.70%
45.10%
9.70%
7.40%
1.70%
0%
20%
40%
60%
80%
100%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree


"The 'language' of BPS is difficult for architects to understand."
BPS
11.40%
32.90%
27.50%
33.10%
11.40%
Arch
3.40%
10.30%
23.40%
33.10%
11.40%
"Preparation for BPS inputs, and interpreting BPS outputs are very bureaucratic tasks."
BPS
6.00%
28.90%
24.80%
22.80%
4.70%
Arch
6.30%
35.40%
24.00%
14.30%
1.70%
"BPS does not fall under the umbrella of 'real' architecture."
BPS
6.70%
26.20%
33.60%
15.40%
5.40%
Arch
3.40%
10.30%
23.40%
33.10%
11.40%
"Part L of the building regulations plays a key and positive role in helping to create a comfortable built environment for users."
BPS
2.70%
27.50%
22.80%
24.20%
10.10%
Arch
1.70%
26.90%
22.90%
22.90%
7.40%
"Part L encourages design-flair and creativity."
BPS
4.70%
16.80%
34.90%
26.80%
4.00%
Arch
7.40%
31.40%
34.80%
8.60%
"Part L is very tough and targets are too high to achieve in order to attain compliance."
BPS
2.00%
13.40%
14.10%
45.60%
12.10%
Arch
2.30%
6.30%
21.70%
36.00%
15.40%
"Compliance with Part L is generally an honest measure of effective building performance."
BPS
2.70%
27.50%
22.80%
24.20%
10.10%
Arch
1.70%
26.90%
22.90%
22.90%
7.40%
"Part L is changed too frequently, and it is too difficult to keep up with the changes."
BPS
4.70%
30.90%
20.10%
24.80%
6.70%
Arch
6.30%
26.90%
18.30%
24.00%
6.30%
0%
20%
40%
60%
80%
100%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree

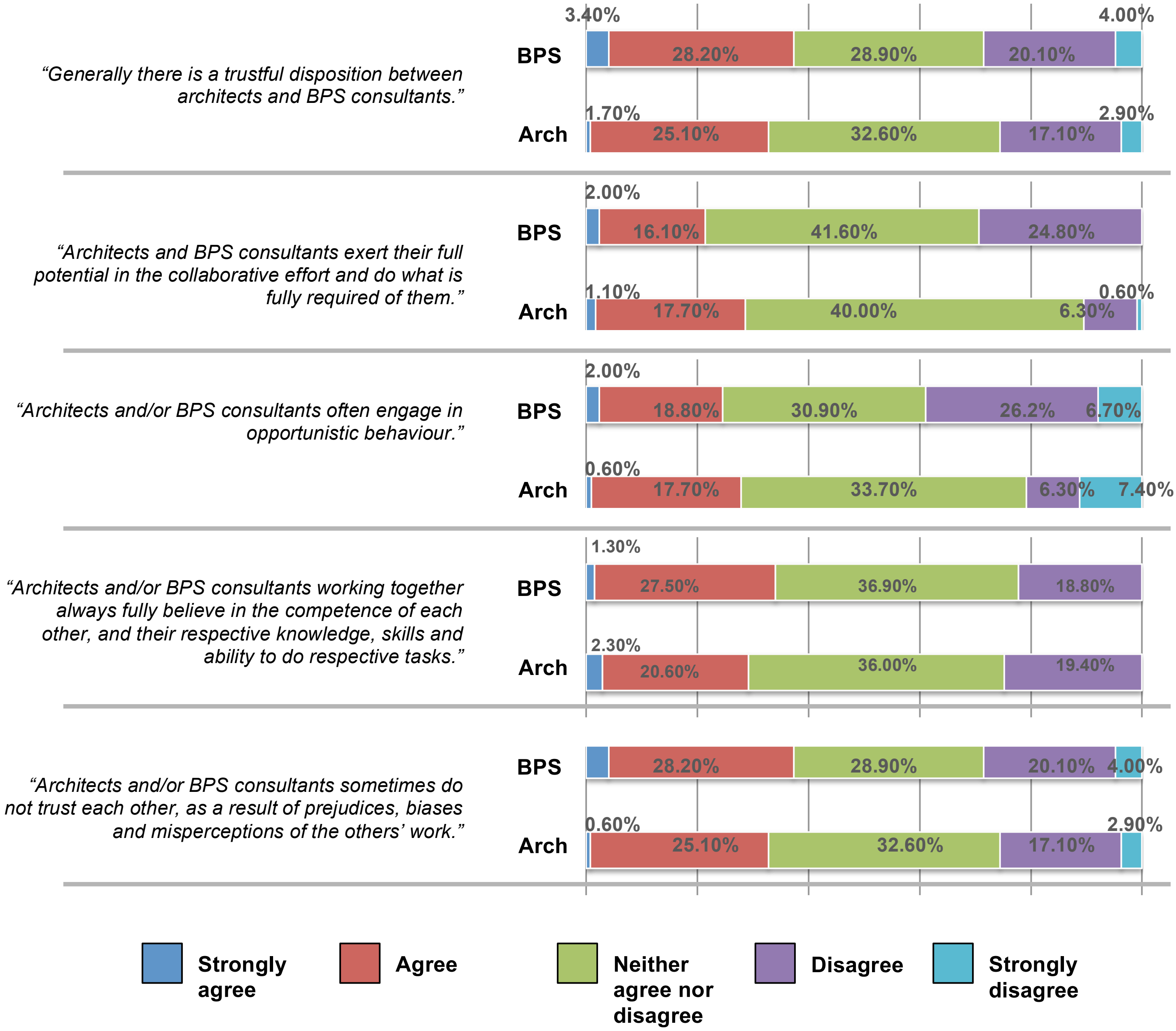


Figure 1: Descriptive statistics showing architects' and BPS consultants' responses to the 22 Likert-scale variables analysed in this section.

Table 2. Factor loadings and communalities for the remaining thirteen variables included in this factor analysis (N = 323).

VARIABLES	FACTORS 1	2	3	4	5	COMMUN-ALITIES
BPS does not come under the umbrella of 'real' architecture.	**.789**					**.682**
The numerical nature of BPS is too regulatory and controlling.	**.760**					**.608**
The 'language' of BPS is too difficult to understand.	**.670**					**.598**
Preparation for BPS inputs, and interpreting BPS outputs, are very bureaucratic tasks.	**.551**				**.474**	**.625**
The potential benefits of BPS, and how it contributes towards decision-making, are fully perceived and valued by architects.				**.784**		**.683**
Architects generally tend to have positive attitudes towards BPS.	**-.704**					**.585**
Generally, there is a trustful disposition between architects and BPS specialists.		**.574**				**.416**
Architects and BPS specialists sometimes do not trust each other; as a result of prejudices, biases and misperceptions of the others' work.		**-.503**	**.429**			**.578**
BPS encourages design-flair and creativity.			**.754**			**.673**
Part L of the building regulations encourages design-flair and creativity.			**.748**			**.630**
BPS is of most benefit to the architectural design process if BPS specialists are appointed at some stage in the design process and collaborate with architects.				**-.756**		**.710**
BPS is of most benefit to the architectural design process if architects conduct it themselves.				**.738**		**.666**
BPS is often done for the sole purpose of compliance with building regulations, standards and codes.					**.835**	**.741**

Rotation method: Varimax rotation.

Factor loadings < .4 are suppressed.

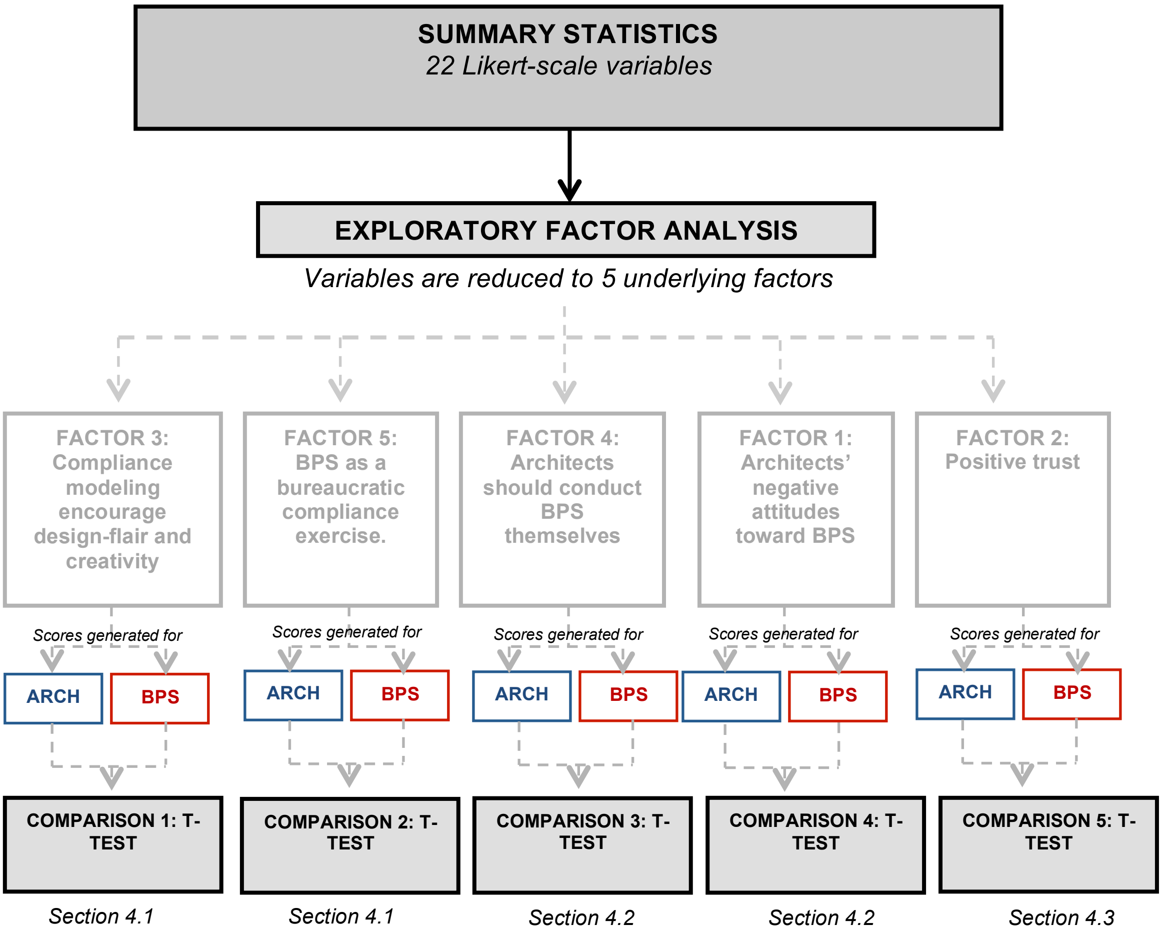


Figure 2: Procedural framework of exploratory factor analysis and statistical tests on the 22 variables examined in this section.

3.5.2 Exploratory factor analysis performed on data from questionnaires 2 only (BPS consultants).

The same methodology described in section 3.5.1 was used to reduce the twenty-one variables shown in figure 3 into underlying factors. Variables were initially screened using a correlation matrix. Two were eliminated for having non-significant correlations, and nine variables were removed for yielding a majority of correlation co-efficients outside the acceptable range of .3-.9 (Appendix C). Ten were retained to be included in the analysis (table 7).

The sample size (nBPS = 148) was also found suitable for factor analysis based on the KMO statistic (0.874, a great result according to Hutcheson & Sofroniou (1999) and a significant result for Bartlett's test of spherecity (p = .000). Principal Components Analysis was used for factor extraction; according to the associated eigenvalues of the factors. Only one factor had an eigenvalue greater than 1; albeit a very high one of 4.788; therefore this factor was considered a summary of all the original variables. All the variables loaded highly onto this factor; their factor loadings are shown in table 3. Nine out of these ten variables highlight positive features of the architect-BPS consultant relationship. The only variable signifying a negative sentiment in the collaborative relationship yielded a negative factor loading. By reverse-coding this variable, the negative sign was converted into a positive one. As all ten variables now indicate positive features of this professional relationship, this factor (factor 6) was labeled *'BPS consultants perceive that they have positive relationships with architects they work with.'*

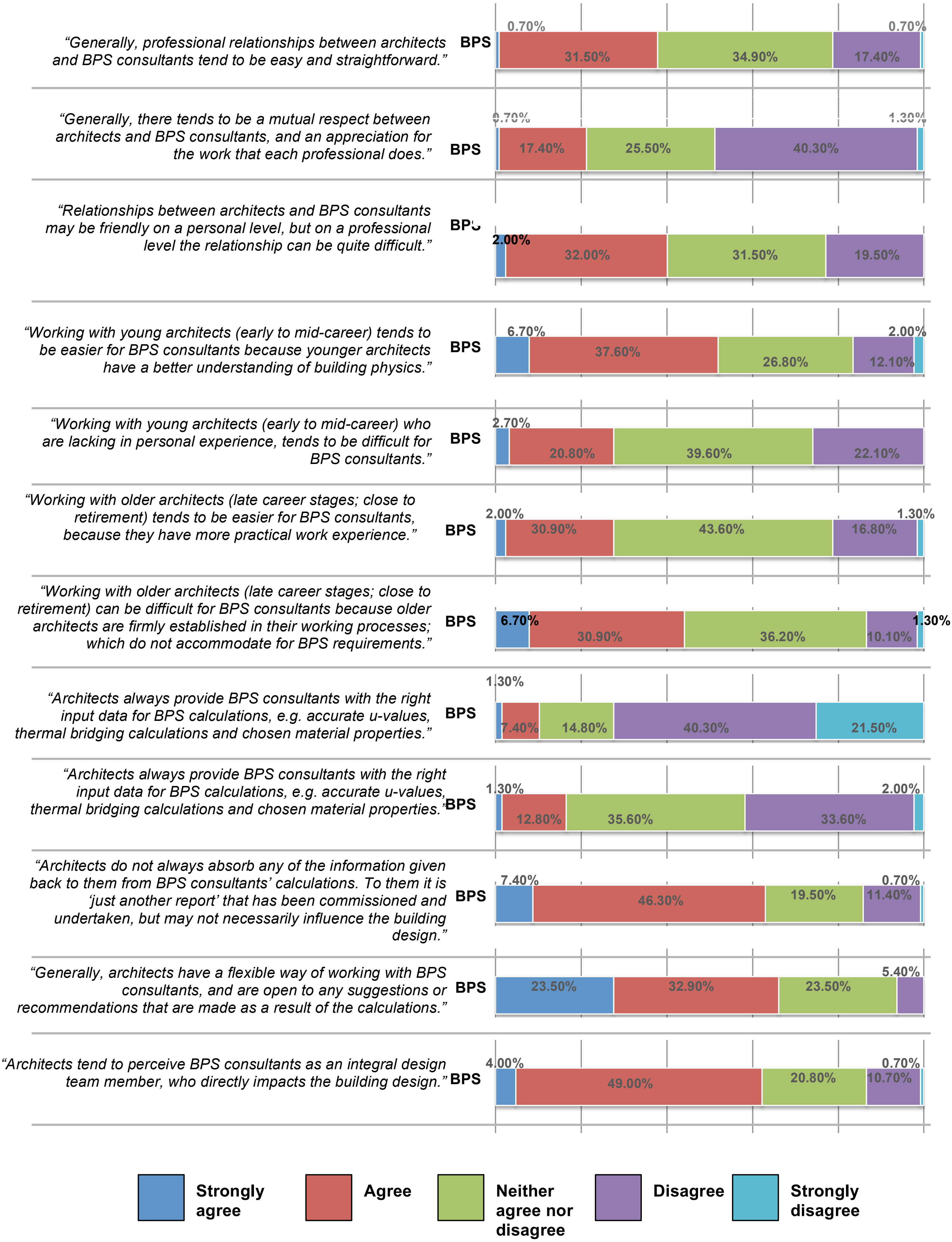

"Generally, professional relationships between architects and BPS consultants tend to be easy and straightforward."
BPS
0.70%
31.50%
34.90%
17.40%
0.70%
"Generally, there tends to be a mutual respect between architects and BPS consultants, and an appreciation for the work that each professional does."
BPS
17.40%
25.50%
40.30%
"Relationships between architects and BPS consultants may be friendly on a personal level, but on a professional level the relationship can be quite difficult."
2.00%
32.00%
31.50%
19.50%
"Working with young architects (early to mid-career) tends to be easier for BPS consultants because younger architects have a better understanding of building physics."
BPS
6.70%
37.60%
26.80%
12.10%
2.00%
"Working with young architects (early to mid-career) who are lacking in personal experience, tends to be difficult for BPS consultants."
BPS
2.70%
20.80%
39.60%
22.10%
"Working with older architects (late career stages; close to retirement) tends to be easier for BPS consultants, because they have more practical work experience."
BPS
2.00%
30.90%
43.60%
16.80%
1.30%
"Working with older architects (late career stages; close to retirement) can be difficult for BPS consultants because older architects are firmly established in their working processes; which do not accommodate for BPS requirements."
BPS
6.70%
30.90%
36.20%
10.10%
1.30%
"Architects always provide BPS consultants with the right input data for BPS calculations, e.g. accurate u-values, thermal bridging calculations and chosen material properties."
BPS
1.30%
7.40%
14.80%
40.30%
21.50%
"Architects always provide BPS consultants with the right input data for BPS calculations, e.g. accurate u-values, thermal bridging calculations and chosen material properties."
BPS
1.30%
12.80%
35.60%
33.60%
2.00%
"Architects do not always absorb any of the information given back to them from BPS consultants' calculations. To them it is 'just another report' that has been commissioned and undertaken, but may not necessarily influence the building design."
BPS
7.40%
46.30%
19.50%
11.40%
0.70%
"Generally, architects have a flexible way of working with BPS consultants, and are open to any suggestions or recommendations that are made as a result of the calculations."
BPS
23.50%
32.90%
23.50%
5.40%
"Architects tend to perceive BPS consultants as an integral design team member, who directly impacts the building design."
BPS
4.00%
49.00%
20.80%
10.70%
0.70%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree

Figure 3: Descriptive statistics showing responses to 21 Likert-scale variables featured in BPS consultants' questionnaires.

Table 3: Factor loadings and communalities for the remaining ten variables included in this factor analysis (nBPS = 148).

VARIABLES	COMMUN-ALITIES	FACTOR 6
Generally, architects have a flexible way of working with BPS specialists, and are open to any suggestions or recommendations that are made as a result of the calculations.	.579	.761
Architects tend to perceive BPS specialists as an integral design team member, who directly impacts the building design.	.564	.751
Generally, there tends to be a mutual respect between architects and BPS specialists, and an appreciation for the work that each professional does.	.539	.734
Channels of communication between architects and BPS specialists tend to be open.	.526	.725
Architects are fully able to understand and interpret the information that BPS specialists communicate to them.	.524	.724
Generally, professional relationships between architects and BPS specialists tend to be easy and straightforward.	.511	.715
Architects are always fully able to engage in conversation with BPS specialists.	.441	.664
Architects fully understand the aims of BPS specialists work; making the relationship a fruitful one.	.478	.691
Relationships between architects and BPS specialists may be quite friendly on a personal level, but on a professional level the relationship can be quite difficult.	.456	-.597
Working with older architects (late career stages; close to retirement) tends to be easier for BPS specialists, because they have more practical work experience.	.471	.521

4. Results' interpretation and discussion

4.1. Use of BPS for compliance

Two factors extracted concerned with compliance modeling are presented and discussed here. These are:

- Factor 3: Compliance modeling encourages design-flair and creativity.
- Factor 5: BPS as a bureaucratic compliance exercise.

Independent samples t-tests were performed to compare architects' and BPS consultants' composite scores. For factor 3, the t-test returned a non-significant difference in the means of architects' ($M = 3.182$, $SD = .572$) and consultants' ($M = 3.040$, $SD = .606$) composite scores; $t(261) = -1.966$, $p = .051$. Both architects' and consultants' means for this factor were centralized between the third and fourth points on the Likert-scale; suggesting neutrality but skewed slightly toward the fourth point on the Likert-scale denoting disagreement. *Therefore, on average, neither group necessarily considers compliance modeling to encourage design-flair and creativity.*

Based on this result, we may infer that architects in this sample in particular perceive BPS uptake, particularly for the purpose of achieving compliance with stringent building regulations, as an additional constraint to their designs. This is notable considering that architects often prefer to *"challenge constraints,"* as a route towards arriving at novel design solutions; *"because that is what allows them to be creative,"* as opposed to working within constraint boundaries (Alsaadani & Bleil De Souza, 2016). Cross (2001), asserts that rigorous placement of constraints and extensive early problem-formulation does not lead to creative solutions. Imrie and Street (2009) highlight that architects feel building design is often bounded by highly prescriptive standards that *"strangle"* the creative process. Carmona et al. (2006) fear that *"formulaic building designs"* ensue as a consequence of the *"prescriptive"* nature of building regulations. Architects may therefore perceive the need to use BPS tools to ensure compliance as an additional constraint, which may further limit the designer's creativity and curtail the likelihood of creative design solutions transpiring.

The result of the t-test for factor 3 returned a non-significant result for both architects and BPS consultants; meaning that BPS consultants sampled agree with architects that compliance modeling does not necessarily encourage design-flair and creativity. However, while this may be considered an undesirable feature of compliance modeling for architects, this may conversely be regarded as a positive feature for BPS consultants. Results of the preceding qualitative stage indicated that BPS consultants often perceive their role on the design team to *"be there at the outset to constrain the parameters of design"* (Alsaadani & Bleil De Souza, 2016), essentially opposing the architects' need for free space to explore multiple design options. In a collaborative scenario, it is therefore likely that conflicts may arise as a consequence of such ideological differences between architects and BPS consultants surrounding constraints and creativity.

The independent samples t-test conducted on factor 5 also retained a similar result. A non-significant difference in architects' (M = 2.591, SD = .798) and BPS consultants' (M = 2.247, SD = .718) means was found; t(271) = -3.442, p = .231. The means for both groups were also roughly located between the second and the third point on the Likert-scale for this factor. *It can therefore be inferred from this result that on average both architects and consultants similarly agree that BPS is often viewed in practice as a compliance exercise, rather than a potential design-aid.*

This result may initially indicate that both architects and consultants sampled similarly perceive the main purpose of BPS to be for compliance with Part L; rather than to guide design decision-making, as both groups yielded a similar result. Results from the previous, qualitative research stage, indicate that many UK-based architects do not necessarily differentiate between BPS for compliance purposes and BPS that is used to aid design decision-making. Architects are often unaware that software used to grant compliance with Part L (compliance software); quasi-steady state calculators in which building parameters are fixed and variables are averaged out over long periods of time, does not fall within the same category as dynamic simulation modeling (DSM) software (Alsaadani & Bleil De Souza, 2016). DSM software accounts for complex interactions and heat transfer phenomena occurring over short-time steps, and can therefore be used to aid design decision-making[6]. This inability to differentiate between different software capabilities and uses may arise from architects' lack of awareness that building performance simulations exist outside of a regulatory framework.

Architects may therefore be restricting the use of BPS for compliance checks, incorporating it only during later stages of the design process, as a consequence of this lack of awareness. This would explain part of the result of the t-test conducted on factor 5; that architects view BPS as a compliance exercise rather than a potential design-aid. On the other hand, it is unlikely that BPS consultants' agreement that BPS is often viewed in practice as a compliance exercise, rather than a potential design-aid, arises from lack of awareness of the differences between compliance modeling software and DSM. It is unlikely that BPS consultants therefore believe that BPS **should** be used only to grant compliance. Rather, the result for BPS consultants may illustrate **how** BPS is actually used in practice; as a consequence of architects' lack of awareness, and delaying the use of BPS until all design decisions are 'set.'

Moreover, the notion that project clients tend to serve as the primary financial driver behind a project, as explored in Alsaadani and Bleil De Souza (2016) may also partially explain this result. Cost tends to factor higher on the client's list of priorities than the building's energy efficiency. This means that consultants are only brought onto the design team to perform compliance calculations once all design decisions are 'set,' and are correspondingly only paid a minimal fee for this particular service. The client's financial limitations may therefore partially explain architects' agreement that BPS is often used to check for compliance, rather

[6] For an expanded description and discussion of software that is used to grant compliance with Part L of the UK building regulations, and dynamic simulation modeling (DSM) software, including software platforms that fall within each category, please read Raslan and Davies (2010).

than a potential design aid. In all cases, the result can be interpreted to reflect that BPS is nowadays often restricted to later design stages to check that designs meet minimum standards required to ensure compliance with regulations. This interpretation of the result aligns strongly with findings in de Wilde et al. (1999), de Wilde, Augenbroe and van der Voorden (2002) and Bleil De Souza and Knight (2007), all of which suggest that BPS is often restricted for compliance purposes rather than aiding design decision-making.

Building regulations are highly influential in the undertaking and procurement of building design projects (Bakens et al., 2005). Using BPS only to check that the design complies with regulations means that collaborations with BPS consultants only occur at later, more detailed stages of the design process, after most design decisions are 'set,' rather than from the onset. We can therefore infer that the way the regulatory framework is imposed, coupled with the divide between compliance software and DSM software as well as architects lack of awareness of this divide may have an impact on collaborative relationships between architects and consultants, and the fruitfulness of these collaborations. Moreover, it is questionable whether architects appointing BPS consultants to check for compliance; *"a tick in the box that does not influence the design in any way* [but]*…just provides benchmark requirements"* (Alsaadani & Bleil De Souza, 2016) can be labeled as 'collaboration' at all. As asserted at the beginning of this paper, collaboration is a much more complicated endeavor than a simple division of tasks; incurring a sense of equal participation and even involvement in the decision-making process which; based on inferences made from the results for factor 5, does not appear to be occurring.

4.2 Perceptions about architects' attitudes toward BPS

An attitude is *"a relatively enduring organization of beliefs around an object or situation pre-disposing one to respond in some preferential manner"* (Rokeach, 1972). By imposing an evaluative structure on a particular object, this allows us to either favourably include this object within our realms of acceptance; or to decide not to accept it. For architectural designers, this involves adopting *"a distinct mindset for problem-solving and decision-making"* (Michlewski, 2008). It is therefore important that architects adopt positive attitudes toward the tools that are used to assess the impact of design decisions made, as *"unsupportive attitudes … represent significant stumbling blocks to construct*[ing] *buildings with better energy efficiency standards"* (Ryghaug & Sorensen, 2009).

Two factors extracted addressing architects' attitudes toward BPS are presented and discussed here. These are:

- Factor 4; Architects should conduct BPS themselves.
- Factor 1; Architects' negative attitudes toward BPS.

Architects' and BPS consultants' composite scores for these two factors were compared using independent samples t-tests.

A statistically significant difference between the mean composite scores for architects (M=2.541, SD = .650) and BPS consultants (M=2.872, SD = .640) was found for factor 4; t(303) = 4.057, p=.000. This result indicates that architects demonstrate greater agreement that they should undertake BPS calculations themselves than BPS consultants. Therefore, architects in this sample are more likely to agree that they should conduct BPS calculations themselves, instead of relying on collaborations with BPS consultants. This aligns with the literature (e.g. MacDonald et al., 2005; Prazeres & Clarke, 2003; Prazeres et al., 2007; and Prazeres et al., 2009).

Nevertheless, there was also a statistically significant difference between the mean composite scores for architects (M=2.743, SD = .6741) and BPS consultants (M=3.051, SD=.7382) for factor 1; t(271) = -3.575, p=.000. This result indicates that on average, sampled architects are likely to demonstrate negative attitudes toward BPS, whereas on average, BPS consultants sampled perceive architects' attitudes to be more positive. However, this result does not expose underlying causes of architects' negative attitudes toward BPS, or what may lead to the construction of negative attitudes toward BPS. In addition, this result does not allow us to draw any conclusions about practitioners' attitudes toward particular BPS software packages, unlike He & Passe's (2015) contribution; which constitutes a thorough exploration of attitudes toward BPS with respect to both underlying causes as well as subjects' opinions of different software packages. Respondents to He & Passe's (2015) questionnaire feel that BPS software generally lacks means of informative and effective communication with the user; in terms of user interfaces, difficulties with input parameters; complexity of interpreting outputs and troubleshooting software bugs. The authors assert that the greater the capabilities and complexity of the software package used, the more confusing it becomes for users to apply simulation results to validate design decisions. He & Passe (2015) questioned respondents' opinions of six BPS packages; and received both positive and negative feedback about each packages questioned. Positive attitudes were encircled around usability (e.g. Climate Consultant), software power (e.g. IES VE) and how easy it is to learn the package (e.g. Coolvent). On the other hand, negative attitudes arose from concerns about user interface flexibility (e.g. Climate Consultant), duration of computing time (e.g. Rhino DIVA) and were even related to users' background knowledge of building science (e.g. to use Ecotect).

Reasons for negative attitudes voiced by respondents of He & Passe's (2015) questionnaire may be equally relevant to the construction of negative attitudes toward BPS found in this paper. However, it is important to note that He & Passe (2015) investigate attitude-construction in an educational setting, as the subjects of their research are undergraduate and graduate students. On the other hand, respondents to the questionnaires described in this paper are professionals and practitioners. Therefore, the authors speculate that there may be more reasons contributing to the construction of underlying reasons for architects' negative attitudes toward BPS than the causes revealed in He and Passe's (2015) research; related to professional practice, collaboration and/or even use of BPS for compliance. Ultimately, He & Passe (2015) state that architecture students often limit their use of BPS to *"when it is required by a course,"* as opposed to volunteering to use BPS from the onset of the design process to inform their design decisions. It is therefore worth investigating in future research whether architecture students' view of BPS as a *"requirement"* during their professional education is equally interpreted as a regulatory *"requirement"* during their professional route, as the results seem to imply. Regarding BPS simply as a *"requirement"* that needs to be fulfilled to ensure compliance may explain why architects' attitudes toward BPS are more likely to be negative, as discussed in the previous section, and by association reducing the positive impact of collaboration with BPS consultants.

It is important to further study attitudes in relation to BPS uptake, because attitude theorists recognize a direct relationship between one's attitude toward an attitude-object, and their corresponding behavior towards that object. Individuals who uphold positive attitudes toward an attitude-object are generally likely to initiate similar positive behaviors toward the same object in consistence with their attitudes, and vice versa (Haddock & Maio, 2012). According to this theory, architects with positive attitudes toward BPS are more likely to encourage BPS uptake and collaborations with BPS consultants; whereas architects with negative attitudes toward BPS may disregard the potential opportunities promised by BPS software in informing design decision-making and correspondingly, may prefer to delay or even overlook the use of BPS altogether; and by association collaboration with BPS consultants; unless needed to satisfy regulatory *"requirements".*

However, when the results for factor 4 and factor 1 are observed in conjunction, they appear to be in conflict with the theory that architects who have negative attitudes toward BPS are less likely to encourage BPS uptake. The result of the t-test for factor 4, indicating that architects in this sample are more likely to agree that they should conduct BPS calculations themselves is inconsistent with the result for factor 1, indicating that the same sample of architects are likely to demonstrate negative attitudes toward BPS. One would expect architects who have negative attitudes toward BPS to be less inclined toward BPS uptake and vice versa; based on Haddock & Maio (2012)'s theory. Nevertheless, this contradiction between the theory and results highlights the need to examine the relationship between architects' attitudes and behaviours in the BPS context further, potentially by administering a two-part attitude and behaviour survey. The first part of the survey would consist of Likert-scale statements questioning architects' attitudes toward BPS and the second would consist of Likert-scale statements to gauge information about architects' self-reported behaviours related to using the tools. Conjoint examination of responses from both these sections using inferential statistics may shed more light upon the complex relationship between attitudes and behaviours within this context.

4.3 Do architects and BPS consultants trust each other?

In the academic literature, trust is defined as *"a psychological state comprising the intention to accept vulnerability, based upon positive expectations of the intention or behaviour of the other"* (Rousseau et al., 1998). Having trustworthy intentions in collaboration entails assuming that other project team-members are trustworthy, and withholding from the expectation that they may engage in opportunistic actions (Nooteboom, 2006). By association, trusting another member in a collaborative team is a way of admitting to one's own vulnerabilities, be those knowledge limitations, lesser capabilities or fewer resources. In a collaborative scenario, it is important to ensure that trust dynamics are positive, as negative trust dynamics may have a potentially destructive impact on the collaborative effort. In this case, no matter how advanced BPS technologies are, poor interpersonal trust dynamics threaten to impede delivery of energy-efficient buildings. Therefore, although the concept of trust may appear distantly related to BPS, trustworthy relationships are crucial to a harmonious and fluid collaboration between architects and consultants.

An independent samples t-test was conducted to compare architects' and consultants' means for composite scores for factor 2 addressing trust dynamics between the two groups. A non-significant difference was found between architects' ($M = 2.748$, $SD = .529$) and BPS consultants' ($M = 2.759$, $SD = .476$) results; $t(261) = .157$, $p = .876$. This indicates that both groups have a similar opinion about trust dynamics between architects and BPS consultants. *The means for both groups indicate that on average both architects and BPS consultants have similar levels of trust toward each other; both are positive but skewed slightly toward the third point on the Likert-scale denoting neutrality.*

This result also indicates that, on average, architects and BPS consultants in this sample trust each other to a comparable degree (i.e. architects trust BPS consultants as much as consultants trust architects). This aligns with existing literature on trust in multi-disciplinary collaborations in building projects. Laan et al. (2011) describe trust as a two-sided virtue. Rousseau et al. (1998) highlight that an assumption of trustworthiness from one party is likely to induce reciprocated patterns of benevolence from the other party. On the other hand, opportunistic behaviours[7] are alternatively likely to stimulate pre-emptive distrust; and attitudes of close monitoring and control.

The reciprocal degree of trust that architects and consultants exhibit toward each other is greater than what is expected in the literature. The result for factor 2 for both architects and consultants is located between the second and third point on the Likert-scale; a positive result. However, it is important to note that interpersonal trust relationships in collaborative building project environments conducted in previous research have been studied in the specific context of owner-contractor relationships (e.g. in the work of Wong et al. (2008); Kadefors (2004); Wong & Cheung (2004); Pinto et al. (2009) and Cheung et al. (2011) to cite a few). Research studies concerned with trustworthy interpersonal architect-BPS consultant relationships could not be found[8].

The finding that both architects and BPS consultants share sentiments of positive trust toward each other is a promising result, considering that architect-BPS collaborations tend to be temporary alliances, often representing competing organisations. Aside from project goals, which may be shared amongst both groups of professionals, it is unlikely that personal and professional goals will overlap. Collaborating team-members may set out to achieve their own long-term organizational and professional goals; beyond the short-term goals of the project. On the other hand, the existence of positive trust dynamics, confirmed from the t-test

[7] Opportunistic behaviour is that which involves consciously taking advantage of circumstances for self-interest; with little or no regard for principles (Kadefors, 2004).
[8] Williamson (2010) investigated in the BPS context but his investigation was more concerned with trustworthiness of the models.

performed on factor 2 addressing trust, are crucial to a harmonious and fluid collaboration between architects and consultants. Cheung et al. (2011) describe trust as *"the lubricant of social interaction"* for the positive impacts it promises project design and delivery. Conversely, neutral or negative trust may contribute toward a breakdown in the collaborative effort, regardless of how advanced BPS technologies being used.

Despite the fact that a positive result was yielded, the results' skew toward the third point on the Likert-scale, denoting neutrality, suggest that there is still room for improvement of trust dynamics between architects and BPS consultants. When the result for factor 2 is interpreted in light of results of the four previously discussed factors, concerned with the use of BPS for compliance, and architects' attitudes toward BPS, it is laudable to speculate that architects' lack of understanding about the purpose and potential of BPS, and their misperceptions that the primary purpose of BPS is to guarantee compliance, coupled with pre-existing negative attitudes toward the software, may be affecting trust dynamics to a lessening degree. This interpretation highlights the importance of investigating the construction of trust and/or distrust between architects and BPS consultants in collaborative scenarios in more detail. Understanding reasons that contribute to positive and/or negative trust dynamics may allow researchers to adopt a tailored approach, targeting misinformed perceptions and raising awareness about the potential of BPS software, and the role of BPS consultants on the design team beyond compliance checking. Removing such barriers and misperceptions would ultimately strengthen trust dynamics by association and contribute toward improved collaborative relationships between the two parties.

Ultimately, the issue of trust cannot be regarded as a 'stand-alone' concept. Trust dynamics are affixed within the context in which they are bred and nurtured; either growing or deteriorating based on these contextual surroundings. Furthermore, trusting another member in the collaborative initiative is, in a way, admitting one's own vulnerabilities, be these knowledge limitations, lesser capabilities or fewer resources. However, given architects' negative attitudes toward BPS and misperceptions about the importance of BPS consultants on the design team, it seems unlikely that either of these parties would fully admit to such vulnerabilities.

4.4 BPS consultants' perceptions about communication with architects

Communication is *"human behaviour that facilitates the sharing of meaning and which takes place in a particular social context"* (Llevrouw & Finn, 1990). In a building project scenario, communication is encircled around the open and timely exchange of knowledge, skills and information among project actors. Transparent and timely communication is likely to lead to improvements in co-ordination and decision-making. Simply put, *"the better the communication, the better the design process"* (Mesa et al., 2016).

Consultants' perceptions about their communication with architects, and the impacts of communication on trust dynamics were further explored in this quantitative study. Eight 'communication' variables were featured in questionnaire 2, and are shown in figure 3, included in the factor analysis described in section 3.5.2. A composite variable was generated combining the results of all 'communication' variables (M = 3.184, SD = .533). This mean lies at the third point on the Likert-scale, denoting neutrality. Even though neutrality does not imply negativity, it does not imply effectiveness either, meaning communication between architects and consultants is probably not idea. Subtleties and different dimensions on communication are further explored in the sister paper of this one (Alsaadani and Bleil De Souza, 2016).

While the issue of communication was not explored in the architects' questionnaire (questionnaire 1), it is unlikely that architects would feel that their communication with BPS consultants is effective, when BPS consultants have neutral opinions about their communication with architects.

Moreover, it is likely that architect-BPS consultant communication may be affected by additional factors beyond those investigated in depth in this paper. For example, in previous qualitative research stages, discussed in detail in Alsaadani & Bleil De Souza (2016), it was asserted that one reason for ineffective communication between architects and consultants is that architects generally lack knowledge about the work of BPS consultants; as a consequence of paradigms of architectural education that do not place enough focus on building science to allow streamlined communication.

As stated in the beginning of this paper, architects and BPS consultants' worldviews are divergent. It is therefore plausible that each is likely to understand information from disparate points of reference; each point of reference related to each professional's background education and experience, which seldom intersect. In addition, referring to different worldviews often means that different professional languages are spoken in the building industry. Linguistic diversities between building industry professionals further complicates the construction of mutually-understood meanings (Ryghaug & Sorensen, 2009). If sender and recipient employ the same professional language in collaboration and communication, intended meanings will accordingly be shared and understood. In contrast, collaborations in which each professional speaks a different professional language may lead to misunderstandings and conflict.

Finally, an inherent cause-and-effect relationship between communication and trust is underlined in the literature, as open interpersonal communication is assistive to nurturing interpersonal trust relationships (Ryghaug & Sorensen, 2009). Reciprocally, those who trust each other are more likely to open up in communication and share information (Ryghaug & Sorensen, 2009; Ruppel & Harrington, 2000). A Pearson's correlation was performed to explore the relationship between trust and communication variables in this research, as perceived by BPS consultants. A strong positive correlation was found between the two, with trustworthy interpersonal relationships associated with perceptions of effective interpersonal communication ($r = .535$, $p = .000$, $n_{BPS} = 148$). The questionnaire data therefore confirms the link between positive trust dynamics and effective interpersonal communication underlined in the literature, and indicates that trustworthy relationships between architects and BPS consultants are affected by open and efficient communication, and vice versa. As BPS modeling is often considered a nebulous *"black box"* (Donn, 2001) to architects, the result therefore emphasizes the necessity of ensuring BPS consultants' communication with architects about BPS, including the process, inputs and outputs is as understandable as possible. This means that BPS outputs and results should be translated into the language that is comprehensible to architects, and the impact of these results on design decision in question must also be clearly communicated, as prerequisites to increasing trust dynamics and leading to the construction of positive relationships between the two parties.

4.5 Do BPS consultants feel that they have positive relationships with architects?

To conclude whether BPS consultants in this sample feel that their relationships with architects are positive, a composite factor score for factor 6 was generated by averaging the scores of the variables that had loaded onto this factor ($M = 3.001$; $SD = .5604$). The mean of the composite score falls at the central point on the Likert-scale; indicating neutrality. *This means that BPS consultants neither feel that their relationships with architects can wholly be described as 'positive' or 'negative.'* This result is similar to the results of statistical tests performed on trust and communication variables (sections 4.3 and 4.4 respectively) both of which yielded results that indicated neutrality. A cause-and-effect relationship between trust and/or communication and BPS consultants' perceptions of positive relationships with architects cannot be ascertained based on similarity in the results alone. For this reason, a one-way ANOVA was performed to statistically determine whether consultants' perceptions of trust affect their perceptions of relationships with architects. In this case the dependent, numerical variable is the set of composite factor scores for factor 6, exploring BPS consultants' perceptions of their relationships with architects. The independent, categorical variable is the variable entitled 'trustful dispositions between architects and BPS consultants.' The categorical variable consists of three categories:

- Category 1: BPS consultants who agree that their relationships with architects are trustworthy.
- Category 2: Who are neutral.

- Category 3: BPS consultants who disagree that their relationships with architects are trustworthy.

A highly significant difference was found in the means of the three groups; F(2, 123)=4.076, p = .000. Post-Hoc comparisons using a Tukey HSD test revealed that differences lie between category 1, who agree that their relationships with architects are trustworthy (M = 2.719, SD = .505) and category 2, who have a neutral opinion (M = 3.200, SD = .453). Post-Hoc comparisons also showed that differences lie between category 1, who agree that their relationships with architects are trustworthy, and category 3, who disagree that their relationships with architects are trustworthy (M=3.490, SD = .672). Based on this result, it can therefore be concluded that levels of trust do have an impact on BPS consultants' perceptions of their professional relationships with architects. Consultants who find that their relationships with architects are trustworthy are most likely to experience analogous positive relationships with architects. Once again, this result underlines the necessity of forming trustworthy relationships between architects and consultants, as a precondition needed to enhance the quality of professional collaborative relationships between architects and BPS consultants.

5. Conclusions and recommendations for further research

Multi-disciplinary collaboration is widely commemorated as a significant route toward enabling complex tasks in the design and construction process. Prof. Anne Grete Hestnes (2003) states that the benefits of such collaborative initiatives are *"not limited to the improvement of environmental performance."* Rather, multi-disciplinary collaboration allows participants to engage in *"open inter-disciplinary discussion*" in which *"the client takes a more active role than usual, the architects becomes a team leader rather than a sole form giver and … engineers take on active roles at early design stages"* leading to improved design quality as well as reductions in capital and operational costs (Hestnes, 2003).

However, collaboration is often, rather simplistically, propagated through an 'outsourcing' archetype. This entails fragmenting design tasks, distributing them to relevant professionals to work on 'their part' of the design in comfortable isolation from other members of the design team; possibly meeting from time-to-time to adjust the design accordingly. At the end of the process, all professionals come together once again to, attempt to piece their 'parts' back together into a cohesive whole.

The results presented in this article reinforce the argument that multi-disciplinary AEC collaboration is a much more intricate endeavor than a simple distribution of tasks. Instead of relying on data-exchange mechanisms between professionals who are physically-isolated and ideologically-disparate, collaboration needs to be regarded as creating an integrative and unified environment for architects and BPS consultants to work together as a single team; from the start of the design and throughout the process. This unified environment emphasizes the need to regard the collaborative design process from social lens rather than a technical one. Correspondingly, this work highlights the importance of looking beyond the technical dimension of collaboration, which is currently being resolved through BIM technologies. Instead, investigating the human side of collaborative interactions for BPS integration, which *"has not been thoroughly addressed in the past … may divulge promising opportunities for progress in the building performance simulation domain"* (Mahdavi, 2011).

This paper serves as a starting point, attempting to disentangle the complex nature of collaborative relationships between architects and consultants, understanding non-technical barriers in collaboration which may be affecting relationships between members of the two groups, yet which may be difficult to unfold. Complications arising during architect-BPS consultant collaborations were unfolded in this paper through the use of exploratory factor analyses and inferential statistics, as these permit a deeper processing of raw data beyond what is permissible through descriptive statistics. A series of six salient factors were extracted from the questionnaire data, primarily pertaining to:

- **Attitudes:** Architects sampled are likely to demonstrate negative attitudes toward BPS, whereas consultants perceive architects' attitudes to be more positive than the latter proclaim. However, the result does not expose underlying causes for the construction of architects' negative attitudes toward BPS. Based on inference, and conjoined interpretation of the results, the authors speculate that the construction of architects' negative attitudes may be related to their misperceptions about the purpose of BPS to be primarily for compliance, which is perceived by architects as hindering creativity.

- **Trust:** Both architects and BPS consultants in this sample demonstrate comparable degrees of trust toward each other. While this result points to slightly positive; almost neutral trust dynamics between members of the two groups, there is still great room for improvement of trust dynamics. Again, interpretation of this result in light of the previous ones implies that misperceptions about the purpose of BPS, coupled with negative attitudes may be having a lessening effect on trust dynamics between the two groups.

  It was also ascertained that levels of trust do have an impact on BPS consultants' perceptions about their professional relationships with architects. As trust dynamics between the two groups improve, healthier professional relationships between the two groups are likely to be experienced.

- **Communication:** BPS consultants in the sample expressed that communication with architects is neutral; neither effective nor ineffective. Again, it is speculated that perhaps findings related to misperceptions, as well as dissimilar worldviews, different professional languages spoken and paradigms of architectural pedagogy that do not support building science education may be reasons to why communication is simply neutral rather than effective. Moreover, an inherent relationship between trust and communication was underlined based on a correlation analysis that revealed a strong, positive relationship between the two variables. This points toward the necessity of investing improvements in communication as a prerequisite to improving trust dynamics between the two groups. Neutral levels of communication do not promise successful collaborative relationships; effective communication is a prerequisite for collaborative relationships to be fruitful.

One noteworthy observation is that only trust and communication factors are related to the human interactions that occur between architects and consultants when they meet. On the other hand, attitude construction is related to worldview and the enculturation of the professional. Multi-disciplinary professionals entering the collaboration cannot embark on this initiative as a blank canvas; rather each enters the collaborative initiative with a set of pre-constructed perceptions based on worldview, education and experience. This further reinforces the notion that, in order to arrive at a harmonious synergy between collaborating design professionals, multi-disciplinary collaboration should not be regarded as a fast and easy solution to realize design aspirations, and solve complex problems but a time-intensive process that requires relationship building, and where ensuring mutual understandings are in effect is fundamental.

Many more questions, pertaining to **why** the identified barriers exist, are raised. These questions, listed below, are recommended as research questions to be answered in future investigation about architect-BPS consultant collaboration. Answering these questions may allow researchers to propose tailored solutions to improve collaborative relationships between architects and BPS consultants, and transform collaborative initiatives from complex, intricate endeavours to the harmonious synthesis widely sought-for in the literature.

- Practicing architects seldom undertake BPS themselves, instead relying on collaboration with consultants. Results from this research contradict this, as it was found that architects sampled are more likely to believe that they should perform BPS themselves. What are the reasons of this discrepancy?
- Results indicate that architects do not feel that BPS adds to their design-flair and creativity. If this is the case, why do architects believe that they should be conducting BPS themselves, when they perceive the primary purpose of BPS being to attain compliance?

- Is there a relationship between architects' misperceptions about the purpose of BPS and the construction of negative attitudes toward BPS? What other underlying reasons exist, leading to the construction of negative attitudes toward BPS amongst architects?
- What are the underlying reasons affecting the construction of trustworthy relationships between architects and BPS consultants? Correspondingly, how can current trust dynamics be improved?
- Why do BPS consultants perceive their communication with architects to be neutral; as opposed to efficient? Are these reasons that may be addressed through short-term solutions (e.g. BPS consultants do not explain the results of simulation outputs effectively?) Alternatively, could these reasons be related to underlying worldviews, education and differences in professional languages spoken?

In conclusion, this work only serves as a preliminary investigation toward deciphering the multi-faceted, thorny and inherently complex social order underlying multi-disciplinary collaborations. Correspondingly, few factors; determinants of collaborative relationships, are revealed. While this is just a starting point, ***one of the main contributions of this work is providing direction for future research; channeling further investigation in the human dimension of collaboration, which we contend is equally important to the technical and computational vantages***. Furthermore, this research underlines the need to further examine architect-BPS consultant collaborations from a project management and procurement standpoint. Observing collaborations that occur during real-world project design and delivery processes, possibly using ethnographic approaches, may help us to foster a richer, deeper and more accurate illustration of the project dynamics that ensue between architects and consultants. Observational research may allow additional factors, beyond those unraveled in this research to transpire, which may be increasing the complexity of collaboration and reducing tangible impacts of integrating BPS in the architectural design process.

REFERENCES

Albaum, G. (1997). The Likert Scale revisited: An alternate version. *Journal of the Market Research Society 39,* 331-348. Retrieved from http://repository.ust.hk/ir/Record/1783.1-17657

Alsaadani, S. & Bleil De Souza, C. (2016). Of collaboration or condemnation? Exploring the promise and pitfalls of architect-consultant collaborations for building performance simulations. *Energy Research and Social Science*, 19, 21-36. doi: 10.1016/j.erss.2016.04.016

Augenbroe, G. (2001). Building simulation trends going into the new millennium. *Proceedings of Building Simulation '01, 7th International IBPSA Conference,* Rio De Janeiro, Brazil, August 13-15, 2001, 15-28.

Autodesk, Autodesk Ecotect Analysis, Sustainable Building Design Software. (2014). Retrieved from http://www.autodesk.co.uk/adsk/serlet/pc/index?id-15055760&siteID-452932

Autodesk, Green Building Studio. (2016). Retrieved from http://www.autodesk.com/products/green-building-studio/overview.

Architects Registration Board (ARB). (2016). Retrieved from http://architects-register.org.uk/list/regions,

Attia, S., Beltran, L., De Herde, A. & Hensen, J. (2009). Architect friendly: A comparison of ten different building performance simulation tools. *Proceedings of Building Simulation '09, 11th International IBPSA Conference,* Glasgow, Scotland, July 27-30, 2009, 204-212.

Attia, S., Hensen, J. L., & De Herde, A. (2012). Selection criteria for building performance simulation tools: Contrasting architects' and engineers' needs. *Journal of Building Performance Simulation, 5,* 155-169. doi: 10.1080/19401493.2010.549573

Bakens, W., Foliente, G. & Jasuja, M. (2005). Engaging stakeholders in performance-based building: Lessons from the Performance-Based Building (PeBBu) Network, *Building Research and Information,* 33 (2), pp. 149-158.

Barbosa, M. J., Pauwels, P., Ferreira, V. & Mateus, L. (2016). Towards increased BIM usage for existing building interventions. *Structural Survey, 34,* 168-190. doi: 10.1108/SS-01-2015-0002

Barrow, L. (2004). Elitism, IT and the modern architect opportunity or dilemma. *Automation in Construction, 13,*131-145. doi: 10.1016/j.autcon.2003.09.001

Baruch, Y. (1999). Response rate in academic studies – A comparative analysis. *Human Relations* 52 (4), pp. 421-438.

Bleiberg, T. & Shaviv, E. (2007). Optimisation for enhancing collaborative design. *Proceedings of Building Simulation '07, 10th International IBPSA Conference,* Beijing, China, September 3-6, 2007, 1698-1705.

Bleil De Souza, C. & Knight, I. (2007). Thermal performance from an architectural design viewpoint. *Proceedings of Building Simulation '07, 10th International IBPSA Conference,* Beijing, China, September 3-6, 2007, 87-94.

Bleil De Souza, C. (2009). A critical and theoretical analysis of current proposals for integrating building thermal simulation tools in the design process. *Journal of Building Performance Simulation 2,* 283-297. doi: 10.1080/19401490903349601

Bleil De Souza, C. (2012). Contrasting paradigms of design thinking: The building thermal simulation tool user vs. the building designer. *Automation in Construction 22,* 112-122. doi: 10.1016/j.autcon.2011.09.008

Bombardekar, S. & Poerschke, U. (2009). The architect as performer of energy simulation in the early design stage. *Proceedings of Building Simulation '09, 11th International IBPSA Conference,* Glasgow, Scotland, July 27-30, 2009, 1306-1313.

Bordass, B. & Leaman, A. (2013). A new professionalism: remedy or fantasy? *Building Research and Information, 41,* (1), 1-7. doi: 10.1080/09613218.2012.750572

Building Energy Software Tools (BEST) Directory, 2016. www.buildingenergysoftwaretools.com

Bresnen, M. (2013). Advancing a 'new professionalism': professionalization, practice and institutionalization. *Building Research and Information 41,* pp. 735-741. doi: 10.1080/09613218.2013.843269

Carmona, M., Marshall, S. & Stevens, Q. (2006). Design codes: Their use and potential. *Progress in Planning* 65 (4), pp. 209-289.

Chartered Institute of Building Services Engineers (CIBSE) 2016. *Low Carbon Consultants and Energy Assessors* [Online register of CIBSE certified low carbon consultants]. Retrieved from http://www.cibseenergycentre.co.uk/online-registers/search-for-a-low-carbon-consultant.html

Cheung, S. O. Wong, W. K., Yiu, T. W. & Pang, H. Y. (2011). Developing a trust inventory for construction contracting. *International Journal of Project Management 29,* 184-196. doi: 10.1016/j.iiproman.2010.02.007

Chiu, M. (2002). An organizational view of design communication in design collaboration. *Design Studies 23,* 187-210. doi: 10.1016/S0142-694X(01)00019-9

Clarke, J. (2001). *Energy simulation in building design, 2nd edition.* Oxford: Butterworth Heinemann.

Cross, N. (2001). Design cognition: Results from protocol and other empirical studies of design activity. *In:* Eastman, C., MCracken, M. and Newstetter, W. eds. *Design Knowing and Learning: Cognition in Design Education.* Oxford: Elsevier, pp. 79-103.

Cuff, D. (1991). *Architecture: The story of practice.* Cambridge, Massachusetts: The MIT Press.

Czaja, R. & Blair, J. (1996). *Designing surveys; A guide to decisions and procedures.* London: Sage.

Domeshek, E. A., Kolodner, J. L., Billington, R. & Zimring, C. M. (1994). Using theories to overcome social obstacles in design collaboration. In: S. J. Gero,, L.M. Maher & F. Sudweeks, (Eds). *Papers from the AAAI Workshop: AI and Collaborative Design* (pp.143-148). Seattle, Washington: AAAI Press.

Donn, M. (2001). Tools for quality control in simulation. *Building and Environment,* 36, 673-680. doi: 10.1016/S0360-1323(00)00059-7

Duffy, F. & Rabeneck, A. (2013). Professionalism and architects in the 21st century. *Building Research and Information* 41, 115-122. doi: 10.1080/09613218.2013.724541

Eppler, M. J. (2007). Toward a visual turn in collaboration analysis. *Building Research and Information 35,* 584-587. doi: 10.1080/09613210701355724

Field, A. 2005. *Discovering statistics using SPSS for Windows (and sex and drugs and rock'n'roll), 3rd edition.* London: Sage.

Fink, A. 1995. *How to ask survey questions.* London: Sage Publications.

Fowler, F. J. 2002. *Survey research methods, 3rd edition.* London: Sage Publications.

Guglielmetti, R., Macumber, D. & Long, N. (2011). OpenStudio: An open source integrated analysis platform. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, 442-449.

Haddock, G. & Maio, G. R. (2012). Attitudes, attitude properties and behaviour: Introduction and overview. In: G. Haddock & G. R. Maio (Eds.) *Contemporary perspectives on the psychology of attitudes (pp. 1-15).* Hove, East Sussex: Psychology Press Taylor and Francis Group.

Hamza, N. & Greenwood, D. (2009). Energy conservation regulations: Impacts on design and procurement of low energy buildings. *Building and environment, 44,* 929-936. doi: 10.1016/j.buildenv.2008.06.010

Hartenberger, U., Lorenz, D. & Lutzkendorf, T. (2013). A shared built environment professional identity through education and training. *Building research and information, 41*, 60-76. doi: 10.1080/09613218.2013.736202

He, S. and Passe, U. (2015). Architectural student's attitude toward building energy modeling: A pilot study to improve integrated design education. *Proceedings of Building Simulation 2015, 14th International IBPSA Conference,* Hyderabad, India, December 7-9, 2015, 231-238.

Heerwagen, J. H., Kampschroer, K., Powell, K. M. & Loftness, V. (2004). Collaborative knowledge work environments. *Building Research and Information, 32,* 510-528. doi: 10.1080/09613210412331313025

Hestnes, A. G. (2003). Solar low energy buildings and the integrated design process. In: Murphy, P. (ed). *IEA Solar Heating and Cooling Programme 2002 Annual Report.* Washington, USA.

Hill, S., Lorenz, D., Dent, P. & Lutzendorf, T. (2013). Professionalism and ethics in a changing economy. *Building Research and Information, 41,* 8-27. doi: 10.1080/09613218.2013.736201

Himmelfarb, S. (1993). The Measurement of Attitudes. In: Eagly, A. H. and Chaiken, S. eds. *The Psychology of Attitudes* (pp.23-87). California: Thomson Wandsworth.

Honeycutt, N. and Freberg, L. (2017). The liberal and conservative experience across academic disciplines; An extension of Inbar and Lammers. *Social Psychological and Personality Science* 8 (2), pp. 115-123.

Hutcheson, G. & Sofroniou, N. (1999). *The multivariate social scientist: Introductory statistics using generalized linear models.* London: Sage Publications.

International Building Performance Simulation Association (IBPSA) 2016. http://www.ibpsa.org/

Imrie, R. and Street, E. (2009). Regulating design: The practices of architecture, governance and control. *Urban Studies* 46 (12), pp. 2507-2518.

Kadefors, A. (2004). Trust in project relationships: Inside the black box. *International Journal of Project Management* 22 (3), pp. 175-182.

Kaplowitz, M. D., Hadlock, T. D. & Levine, R. (2004). A comparison of web and mail survey response rates. *Public Opinion Quarterly, 68,* 741-755. doi: 10.1093/poq/nfh006

Kvan, T. (2000). Collaborative design: what is it? *Automation in Construction, 9*, 409-415. doi: 10.1016/S0926-5805(99)00025-4

Kalay, Y. (2001). Enhancing multi-disciplinary collaboration through semantically rich representation. *Automation in Construction, 10,* 741-755. doi: 10.1016/S0926-5805(00)00091-1

Laan, A., Noorderhaven, N., Voordijk, H. & Dewulf, G. (2011). Building trust in construction partnering projects: An exploratory case-study. *Journal of Purchasing and Supply Management, 17,* 98-108. doi: 10.1016/j.pursup.2010.11.001

Lam, A. (2010). From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'? Academic scientists in fuzzy university-industry boundaries. *Social Studies of Science* 40 (2), pp. 307-340.

Llevrouw,L. & Finn, T. (1990). Identifying the common dimensions of communication: The communication systems model. In: B. D. Ruben and L. A. Llevrouw (eds). *Mediation, information and communication: Information and behaviour Vol 3.* New Jersey: Transaction Publishers.

MacDonald, I. A., McElroy, L. B, Hand, J. W. & Clarke, J. A (2005). Transferring simulation from specialists into design practice. *Proceedings of Building Simulation '05, 8th International IBPSA Conference,* Montreal, Canada, August 15-18, 2005, 657-662.

Mahdavi, A. (2011). The human dimension of building performance simulation. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, K16-K33.

Mesa, H. A., Molenaar, K. R. & Alarcón, L. F. (2016). Exploring performance of the integrated project delivery process on complex building projects. *International Journal of Project* Management, 34, 1089-1101. doi: 10.1016/j.iiproman.2016.05.007

Michlewski, K. (2008). Uncovering design attitude: Inside the culture of designers. *Organization Studies,* 29, 373-392. doi: 10.1177/017840607088019

Moses, S., El-Hamalawi, & A., Hassan, T. M. (2008). The practicalities of transferring data between project collaboration systems used by the construction industry. *Automation in Construction, 17,* 824-830. doi: 10.1016/j.autcon.2008.02.007

Nooteboom, B. (2006). Forms, sources and processes of trust. In: R. Bachmann & A. Zaheer, (Eds). *Handbook of Trust Research.* Cheltenham: Edward Elgar, pp. 247-264.

Palme, M. (2011). What architects want? Between BIM and simulation tools: an experience teaching Ecotect. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, 2164-2169.

Planning Portal (2016). Conservation of fuel and power: Approved Document L. Retrieved from: https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l

Pinto, J. K., Slevin, D. P. & English, B. (2009). Trust in projects: An empirical assessment of owner/contractor relationships. *International Journal of Project Management* 27 (6), pp. 638-648.

Pedrini, A. & Szokolay, S. (2005). The architects approach to the project of energy efficient office building in warm climates and the importance of design methods. *Proceedings of Building Simulation '05, 9th International IBPSA Conference*, Montreal, Canada, August 15-18, 2005, 937-944.

Punjabi, S. & Miranda, V. (2005). Development of an integrated building design information interface. *Proceedings of Building Simulation '05, 9th International IBPSA Conference,* Montreal, Canada, August 15-18, 2005, 969-976.

Prazeres, L. & Clarke, J. A. (2003). Communicating building simulation outputs to users. *Proceedings of Building Simulation '03, 8th International IBPSA Conference,* Eindhoven, Netherlands, September 18-21, 2003, 1053-1060.

Prazeres, L., Clarke, J. A., Hand, J. & Kim, J., (2007). Delivering building simulation information via new communication media. *Proceedings of Building Simulation '07, 10th International IBPSA Conference,* Beijing, China, September 3-6, 2007, 1499-1505.

Prazeres, L., Kim, J. & Hand, J. (2009). Improving communication in building simulation supported projects. *Proceedings of Building Simulation '09, 11th International IBPSA Conference,* Glasgow, Scotland, July 27-30, 2009, 1244-1251.

Raslan, R. & Davies, M. (2010). An analysis of industry capability for the implementation of a software-based compliance approach for the UK Building Regulations 2006. *Building Services Engineering Research and Technology, 31,* 141-162. doi:10.1177/0143624410362009

Rockeach, M. (1972). *Beliefs, attitudes and values.* San Francisco: Jossey-Bass.

Rosenman, M. A., Smith, G., Maher, M. L., Ding, L. & Marchant, D. (2007). Multidisciplinary collaborative design in virtual environments. *Automation in Construction, 16,* 37-44. doi: 10.1016/j.autcon.2005.10.007

Royal Institute of British Architects (RIBA), 2016. RIBA Directory of Chartered Members. Retrieved from https://members.architecture.com/directory/default.asp?dir=3

Reichard, G. & Papamichael, K. (2005). Decision-making through performance simulation and code-compliance from the early schematic phases of building design. *Automation in Construction, 14,* 173-190. doi: 10.1016/j.autcon.2004.07.012

Rousseau, D. M., Sitkin, S. B., Burt, R. S. & Camerer, C. (1998). Not so different after all: A cross discipline view of trust. *Academy of Management Review, 23,* 393-404. doi: 10.5465/AMR.1998.926617

Ruppel, C. & Harrington, S. J. (2000). The relationship of communication, ethical work climate and trust to commitment and innovation. *Journal of Business Ethics, 25,* 313-328. doi: 10.1023/A:1006290432594

Ryghaug, M. & Sorensen, K. H. (2009). How energy efficiency fails in the building industry. *Energy Policy, 37,* 984-991. doi: 10.1016/j.enpol.2008.11.001

Sebastian, R. (2011). Changing roles of the clients, architects and contractors through BIM. *Engineering, Construction and Architectural Management 18,* 176-187. doi: 10.1108/09699981111111148

See, R., Haves, P., Sreehanthan, P., O'Donnell, J., Basarkar, M. & Settlemyre, K. (2011). Development of a user interface for the EnergyPlus whole building energy simulation program. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, 2919-2926.

Sherman, S. J. (1982). Smoking intention in adolescents: Direct experience and predictability. *Personality and Social Psychology Bulletin,* 8, 376-383. doi: 10.1177/0146167282082030

Singh, V., Gu, N. & Xiangyu, W. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. *Automation in Construction, 20,* 134-144. doi: 10.1016/j.autcon.2010.09.011

Soebarto, V. I. (2005). Teaching an energy simulation program in an architectural school: lessons learned. *Proceedings of Building Simulation '05, 9th International IBPSA Conference,* Montreal, Canada, August 15-18, 2005, 1147-1154.

Summerfield, A. J. & Lowe, R. (2012). Challenges and future directions for energy and buildings research. *Building Research and Information, 40,* 391-400. doi: 10.1080/09613218.2012.6993839

Tichenor, V., McQuillan, J., Greil, A. K., Bedrous, A. V., Clark, A. and Shreffler, K. M. (2017). Variation in attitudes toward being a mother by race/ethnicity and education among women in the United States. *Sociological Perspectives* 60 (3), pp. 600-619.

van, A., Veenswijk, M. & Clegg, S. (2014). Changing collaborative practices through cultural interventions. *Building Research and Information, 42,* 330-342. doi: 10.1080/09613218.2014.867619

Venancio, R., Pedrini, A., van der Linden, A., van den Ham, E. & Stouffs, E. (2011a) Think designerly! Using multiple simulation tools to resolve architectural dilemmas. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, 522-529.

Venancio, R., Pedrini, A., van der Linden, A., van der Ham, E., & Stouffs, E. (2011b) Understanding envelope design: Survey about architectural practice and building performance. *Proceedings of Building Simulation '11, 12th International IBPSA Conference,* Sydney, Australia, November 14-16, 2011, 514-521.

de Wilde, P., Augenbroe, G. & van der Voorden, M. (1999). Invocation of building simulation tools in building design practice. *Proceedings of Building Simulation '99, 6th International IBPSA Conference,* Kyoto, Japan, September 13-15, 1999, 1211-1218.

de Wilde, P., Augenbroe, G. & van der Voorden, M. (2002). Design analysis integration: Supporting the selection of energy saving building components. *Building and Environment, 37,* 807-816. doi: 10.1016/S0360-1323(02)00053-7

Williamson, T. J. (2010). Predicting building performance: the ethics of computer simulation. *Building Research and Information 38,* 401-410. doi: 10.1080/09613218.2010.481204

Wong, W. K. and Cheung, S. O. (2004). Trust in construction partnering: Views from parties of the partnering dance. *International Journal of Project Management* 22 (6), pp. 437-446.

Wong, W. K., Cheung, S. O., Yiu, T. W. & Pang, H. Y. (2008). A framework for trust in construction contracting. *International Journal of Project Management* 26 (2), pp. 821-829.

Wright, K. B. (2006). Researching internet-based populations: Advantages and disadvantages of online survey research, Online questionnaire authoring software packages and web services. *Journal of Computer-Mediated Communication*, *10,* Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1083-6101.2005.tb00259.x/full.

Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C. & Nikkhoo, P. (2015). Building collaborative construction skills through BIM-integrated learning environments. *International Journal of Construction Education and Research, 11,* 97-120. doi: 10.1080/15578771.2014.986251

APPENDIX A:

Showing how Likert-scale statements were designed from statements voiced during the preceding interview stage.

CONSTRUCT TESTED	INTERVIEW QUOTE	LIKERT-SCALE STATEMENT DESIGNED
Perceptions of architects' attitudes toward BPS.	*"It [BPS]* ***helps designers make the right kind of early decisions like where to place their buildings, how to orientate them, what the depth of plan should be, percentage of glazing, what the mix of renewables might be."***	Architects should conduct BPS themselves because it better improves **EARLY STAGE ARCHITECTURAL DECISION-MAKING.**
	"Architects probably find it [BPS software] ***too complicated to use."***	Architects are **EASILY ABLE TO UNDERSTAND HOW BPS SOFTWARE WORKS.**
Attitudes toward Part L of the building regulations.	***"I'm 80% negative about Part L,*** *but I'm sure every architect has the same opinion."*	Part L of the building regulations plays **A KEY AND POSITIVE ROLE** in helping to create a comfortable built environment for users.
	"Part L ***keeps changing."***	Part L is **CHANGED TOO FREQUENTLY,** and it is difficult to keep up with the changes.'
Trust dynamics between architects and BPS consultants.	*"I expect* [the BPS consultant] *to work with me. But there's got to be a trust there. I've got to have an expectation that* ***he will do his best."***	Architects always believe that BPS consultants **EXERT THEIR FULL POTENTIAL** in the collaborative effort, and do what is fully required of them. (Questionnaire 1 – architects). OR BPS consultants always believe that architects **EXERT THEIR FULL POTENTIAL** in the collaborative effort, and do what is fully required of them. (Questionnaire 2 – BPS consultants).
	"I don't think an engineer would trust results from an architect! Because unless I believe in the ***technical competence*** *of the person who's modeling, why would they? The person has to carry the same credentials and experience so, 'are you as good as our modeler?' Or 'are you as good as me?'*	Architects and BPS consultants working together always fully believe in the **COMPETENCE OF EACH OTHER,** and their respective **KNOWLEDGE, SKILLS AND ABILITY** to do their respective tasks.
BPS consultants' perceptions about their communication with architects.	*"The problem with architects on occasion is that* ***they lack the technical ability to engage with engineers.*** *So perhaps engineers feel like they shouldn't engage with architects."*	Architects' **LACK OF TECHNICAL KNOWLEDGE HINDERS EFFECTIVE COMMUNICATION** with BPS consultants.
	"I don't think maybe we communicate the results and the impact of results [to architects]. *And certainly we don't go into* ***the details of cause and consequence*** *either."*	BPS consultants always communicate the results of their calculations in ways that are **FULLY COMPREHENSIBLE** to architects.
BPS consultants' perceptions about their relationships with architects.	*"Generally we have a good relationship* [with architects], *but that's more our company ethos and how we want to work, because we want to build relationships."*	Generally, professional relationships between architects and BPS consultants tend to be **EASY AND STRAIGHTFORWARD.**
	"Sometimes, they [architects] *don't want to change the outlook of their building. And you are struggling, depending on that particular decision, because they want the building to look very fancy and very good from the outside.* ***I know that sometimes architects give us trouble."***	Generally, architects have a **FLEXIBLE WAY OF WORKING WITH BPS CONSULTANTS**, and are **OPEN TO ANY SUGGESTIONS OR RECOMMENDATIONS** that are made as a result of the calculations.

APPENDIX B

Variables excluded from the exploratory factor analysis based on the correlation matrix.

VARIABLES EXCLUDED FOR HAVING A MAJORITY OF NON-SIGNIFICANT CORRELATIONS
'Architects and BPS specialists working together always fully believe in the competence of each other, and their respective knowledge, skills and ability to do respective tasks.'
'BPS is of most benefit to the architectural design process if architects conduct it during the early stages and BPS specialists follow it up with detailed calculations at later stages.'
'Which professional conducts BPS depends entirely on the complexity of the project.'
'Part L of the building regulations plays a key and positive role in helping to create a comfortable built environment for users.'
Part L is very tough and targets are too high to achieve in order to attain compliance.'
'Part L is changed too frequently, and it is too difficult to keep up with the changes.'
'Compliance with Part L is generally an honest measure of effective building performance.'
'Architects and BPS specialists exert their full potential in the collaborative effort and do what is fully required of them.'
'Architects and/ or BPS specialists often engage in opportunistic behavior.'

APPENDIX C

Variables excluded from the exploratory factor analysis based on the correlation matrix.

VARIABLES EXCLUDED FROM THE EXPLORATORY FACTOR ANALYSIS CONDUCTED IN THIS SECTION BASED ON THE CORRELATION MATRIX.	
VARIABLES REMOVED FOR HAVING NON-SIGNIFICANT CORRELATIONS	'Working with younger architects (early to mid-career) who are lacking in personal experience, tends to be difficult for BPS specialists.'
	'Architects tend to perceive BPS specialists' role in the design team as a necessity required to prove that the building works.'
VARIABLES REMOVED FOR HAVING CORRELATION COEFFICIENTS OUTSIDE THE RANGE OF .3-.9.	'Working with young architects (early to mid-career) tends to be easier for BPS specialists because younger architects have a better understanding of building physics.'
	'Working with older architects (late career stages; close to retirement) tends to be easier for BPS specialists, because they have more practical work experience.'
	'Architects always provide BPS specialists with the right input data for BPS calculations, e.g. accurate u-values, thermal bridging calculations and chosen material properties.'
	'Architects do not always absorb any of the information given back to them from BPS specialists' calculations. To them it is 'just another report' that has been commissioned and undertaken, but may not necessarily influence the building design.'
	'Information communicated through face-to-face meetings tends to be more effective than telephone communication or email.'
	'Architects' lack of technical knowledge hinders effective communication with BPS specialists.'
	'Differences in architects' and BPS specialists' natures may inhibit mutual understandings between the two in collaborative settings.'
	'BPS specialists always communicate the results of their calculations in ways that are fully comprehensible to architects.'
	'BPS results communicated to architects do not always seem to have the desired impact on building design.'