

1                   **POST-OCCUPANCY EVALUATION: A REVIEW OF LITERATURE**

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18  
19                  **ABSTRACT**

20                  **Purpose:** This paper seeks to: analyse extant literature on POE of a building's operations and  
21                  performance as a means of holistically mapping the existing body of knowledge (BoK); identify  
22                  impediments preventing its wide scale adoption throughout practice; and develop new theory that  
23                  seeks to integrate digital technologies (such as building information modelling (BIM)) within  
24                  facilities management (FM) via a POE feedback mechanism.

25                  **Approach:** An inductive and interpretivist methodological approach is adopted that utilises a  
26                  mixed methods systematic review to map bibliometric data on the POE, associated underpinning  
27                  processes and benchmarking facilities. Publication and citation metrics are produced via the  
28                  software VOSviewer to determine the extent to which POE interrelates with other fields of study  
29                  (namely, digital technologies and facilities management (FM)).

30                  **Findings:** The body of knowledge (BOK) accrued illustrates that whilst POE has received  
31                  comparatively scant academic attention in comparison to other fields of study, interest in the area  
32                  is growing. The work also identifies that a stronger community of practice (CoP) is needed (that  
33                  comprises of academics and practitioners) to ensure that a consistent approach to POE  
34                  implementation is developed and that the barriers to POE implementation are addressed.

1 **Originality/ value:** Findings presented accentuate the need for design practitioners to reverse  
2 engineer POE implementation to inform future design vis-a-vis simply reporting upon an existing  
3 building's performance post construction. Other new theories are also introduced as a means of  
4 engendering wider academic discourse in this field of science.

## 6 **KEYWORDS**

7 Post-Occupancy Evaluation, VOSviewer, Interpretivist Methodological Approach, Bibliographic  
8 Data, Body of Knowledge.

## 10 **INTRODUCTION**

11 The Architecture, Engineering, Construction and Operations (AECO) sector is responsible for  
12 creating and managing the built environment (both buildings and infrastructure) to facilitate human  
13 activities (i.e., work, leisure and housing) over time. Creating this man-made environment directly  
14 impacts upon the people who inhabit or use buildings and infrastructure but also the surrounding  
15 environment. For example, buildings: are major consumers of environmentally polluting natural  
16 resources (Milutienė *et al.*, 2012); are essential to socio-economic development (Acharya and  
17 Sadath, 2019); and can impact upon occupants' health and well-being (Al horr *et al.*, 2016). Within  
18 the whole life cycle of a built asset's life, conspicuous academic attention is paid to the design and  
19 construction phases (Kessem *et al.*, 2014; Roberts *et al.*, 2018). However, it is the operational  
20 phase of building occupancy and use that is the chief contributor to pollution, whole life cycle  
21 costs and performance metrics (c.f. Bosch *et al.*, 2014; Liu and Issa, 2014; Lindkvist, 2015; Nical  
22 and Wodynski, 2016). For this reason, far greater attention is needed to review and evaluate  
23 building performance in-use.

24  
25 To measure a building's operations and performance, a post-occupancy evaluation (POE) is  
26 typically utilised to determine whether decisions made by the design, construction and facilities  
27 management professionals have met the envisaged requirements of end-users and the  
28 development's commissioners (Adeyeye *et al.*, 2013; Skills Funding Agency, 2014). Such work  
29 has significant implications in the area of soft landings (within a building delivery process) by  
30 ensuring that future decisions made about similar buildings designs are based upon lessons learnt  
31 from an existing building's operational performance and the fulfilment of client and user  
32 requirements (Gana *et al.*, 2018). POE considers a broad range of diverse performance metrics  
33 including: building use, energy consumption, maintenance costs and user satisfaction (c.f. RIBA,  
34 2016; RIBA, 2017a; RIBA, 2017b). A building's operational performance is measured using: i)

1 project team feedback that recounts the commissioning and construction phases; ii) end-user  
2 feedback on finishes and functional performance; iii) technical performance feedback from a  
3 building's systems; and iv) a strategic overview incorporating the data from each of the  
4 aforementioned evaluation stages (c.f. HEFCE, 2006; RIBA, 2016; RIBA, 2017a; RIBA, 2017b).

5  
6 The widely espoused beneficial implications of POE implementation include: i) transference of  
7 operations knowledge accrued in order to inform future building designs (Cooper, 2001); ii)  
8 iterative improvement of an existing facility's performance (Göçer *et al.* 2015); and iii) the ability  
9 to benchmark building performance between facilities, particularly within the same estate (Preiser  
10 and Vischer, 2005; Olivia and Christopher, 2014). However, practitioners have hitherto either  
11 failed to adopt a POE or lacked consistency in approach to its implementation (Alborz and Berardi,  
12 2015). Part of the lack of consistency issue can be attributed to the various POE implementation  
13 strategies found within literature and practice (cf. Riley *et al.*, 2010). Consequently, the  
14 opportunity to reduce excessive energy usage, reliance on resources and material wastage is  
15 squandered, whilst financial returns on investment and occupant satisfaction are simultaneously  
16 reduced (Ahuja *et al.*, 2016). Research suggests that the accrual of value and passive attitudes  
17 toward sustainable solutions represent major stumbling blocks that discourage sector stakeholders  
18 (i.e. designers, contractors and clients) from completing a POE (Wong and Kuan, 2014). Increased  
19 societal and political demands for 'greener buildings' may aid in dispelling these unduly negative  
20 attitudes (Miller *et al.*, 2012).

21  
22 Against this contextual backdrop, this research seeks to: analyse extant literature on POE of a  
23 building's operations and performance as a means of mapping the existing body of knowledge  
24 (BoK); identify impediments preventing its wide scale adoption throughout practice; and develop  
25 new theory that would seek to integrate digital technologies within facilities management (FM)  
26 via a POE feedback mechanism. Both industry guidance and academic literature are reviewed to:  
27 construct an overview of the differing POE strategies available to building commissioners and  
28 developers; and identify the interconnectedness of key authors undertaking contemporary POE  
29 research. Cumulatively, this accrued BOK is then utilised to determine the extent to which POE  
30 interrelates with other fields of study. These other fields include: digital technologies such as sensor  
31 based networks and building information modelling (BIM) which are increasingly being used to  
32 tailor a building's performance to individual occupant needs; and facilities management (FM)  
33 where FM teams are the custodians of buildings and utilise POE findings to modify buildings in-  
34 use (cf. Parn *et al.*, 2017). Concomitant research objectives are to: provide insightful guidance on

1 POE implementation throughout a building's whole life cycle; generate new theories on POE  
2 usage within practice; and propose future avenues of investigative research that will augment  
3 current and future building design, construction and performance.

#### 4 5 **RESEARCH APPROACH**

6 From an overarching epistemological perspective, an inductive and interpretivist methodological  
7 approach was adopted utilising a mixed methods systematic review of pertinent literature to  
8 generate new theories on POE. This research approach was adopted because an interpretation of  
9 academic and professional practice literature enabled the development of new theories using  
10 inductive reasoning; where the latter represents the first step towards developing a much clearer  
11 ontological perspective of the POE phenomena under investigation (Suddaby *et al.*, 2015).  
12 Petticrew and Roberts (2008) and Oraee *et al.* (2017) assert that a 'mixed methods systematic  
13 review' is the most effective method for identifying gaps in a BOK. In contrast to a 'mono-method  
14 manual systematic review', it is resistant to biases realised through subjective interpretation and  
15 judgement (He *et al.*, 2017). Within this overarching methodological framework, a two stage  
16 operational process was adopted. In stage one, a detailed review of building performance  
17 measurement using POE was undertaken to contextualise the research and further delineate the  
18 specific areas of POE evaluation, process and benchmarking.

19  
20 In stage two, bibliometric data was mapped to provide a systematic review of relevant extant  
21 literature. Hayvaert *et al.* (2016) state that the amalgamation of quantitative and qualitative  
22 methods requires the development of a protocol stating methods, processes and sampling strategies  
23 for both data collection and study objectives. With this in mind, an iterative search protocol was  
24 developed which utilised three bibliometric data searches incorporating the following pertinent  
25 terminologies: i) 'POE'; ii) 'POE' and 'process'; and iii) 'POE', 'process' and 'benchmark'. Data  
26 utilised to produce the bibliometric map could be sourced from a number of electronic repositories,  
27 for example: Web of Science, ProQuest and Scopus. However, Web of Science was utilised  
28 because it claims to be the most accurate citation database available for bibliometric analysis  
29 (Clarivate Analytics, 2017). Each search sought to capture literature that contained the selected  
30 terms in the abstract, title or keywords of published work. To avoid conflation with unrelated  
31 studies pertaining to alternative disciplines, the term 'Poe' was excluded to ensure the results  
32 related to the built environment and not to other disciplines.

1 The Web of Science repository allows for the tailoring of searches to meet specific needs, such as  
2 the date of citation. No limit on the date of citation was implemented (1970-2018) to secure a more  
3 complete perspective on the entire POE BOK. The first two searches were conducted using the  
4 VOSviewer bibliometric analysis software in order to construct bibliographic visualisations and  
5 map the interconnections between authors researching the three topic areas. The bibliometric data  
6 sourced from the Web of Science was organised using the repository's 'analyse' function to  
7 indicate the top 25 academic journals publishing POE research. A third stage of analysis was  
8 conducted manually and was not restricted to the top 25 academic journals as the search generated  
9 only seven results. The Web of Science search functions were also utilised to discern key statistics  
10 (date of first citation and total number of research items) with which to critically compare similarly  
11 aligned disciplines pertaining to the design, construction and operational phases of a  
12 development's life cycle (i.e. BIM and FM).

13

#### 14 **BUILDING PERFORMANCE AND MEASUREMENT**

15 Each year, buildings produced and operated by the AECO sector consume 40 per cent of global  
16 anthropogenic material and energy flows, 25 per cent of total timber harvested and 16 per cent of  
17 freshwater (Milutienè *et al.*, 2012). These unsustainable rates of consumption mean that the sector  
18 consequently engenders monumental environmental impact, for example, per annum the sector  
19 contributes: 24 per cent of India's CO<sub>2</sub> emissions; 33 per cent of Canada's energy production; and  
20 42 per cent of Australia's normalised solid waste (El shenawy and Zmeureanu, 2013). Globally,  
21 buildings' life cycles account for 40 per cent of energy requirements and carbon dioxide emissions  
22 and 70 per cent of total greenhouse gas emissions (Motawa and Carter, 2013; Lui *et al.*, 2015).  
23 Against this statistical backdrop, Cooper (2001) and Riley *et al.* (2010) assert that buildings  
24 constructed using contemporary design and construction innovations, without process feedback on  
25 performance, effectively remain an unproven prototype. Yet the majority of a building's  
26 environmental impact occurs during the operational phase, which may last several decades (Guo  
27 and Wei, 2016). To further exacerbate matters, occupants spend more time indoors - within the  
28 United States for example, people spend up to 90 per cent of their time within buildings that  
29 constitute a 120 million real estate stock and account for 40 per cent of the nation's total annual  
30 energy requirements (Shoubi *et al.*, 2014). Consequently, the AECO sector's unsustainable record  
31 of poor environmental performance during a building's construction and operation phases renders  
32 a *laissez-faire* 'business as usual' attitude untenable (Ahuja *et al.*, 2016). During these phases  
33 buildings require expert management of budgets, schedules and environmental impact to enhance  
34 returns on investment, mitigate wastage/environmental impact and augment occupancy

1 satisfaction (Ahuja *et al.*, 2016). Herein resides the inherent importance of a POE and its innate  
2 ability to provide invaluable reflection upon a building's performance.

3

#### 4 **Post-occupancy Evaluation (POE) Implementation**

5 POE encompasses an expansive range of processes and activities that systematically evaluate a  
6 building's performance subsequent to its handover (Ilesanmi, 2010; Tookaloo and Smith, 2015).  
7 Traditionally, building performance knowledge was passed down through generations of  
8 construction specialists who possessed exhaustive tacit knowledge of a client's cultural, social,  
9 operational, technical and economic parameters (McGrath and Horton, 2011). The Royal Institute  
10 of British Architect (RIBA) report "Plan of Work for Design Team" (1965) first introduced the  
11 concept of an architect returning to a completed development to assess its success and/or identify  
12 areas for improvement (RIBA, 1965). However, despite fifty years of subsequent development,  
13 the vast majority of discourse on POE planning and implementation is generated via real estate  
14 departments of higher education institutions and is not routinely applied throughout the wider  
15 AECO sector (Leaman, 2004; Hadjri and Crozier, 2008; Zhang and Barrett, 2010).

16 When implemented for a newly developed facility, POE can accrue various benefits in terms of:  
17 maximising space utilisation, reducing operational costs and optimising maintenance costs (c.f.  
18 Shohet *et al.*, 2003; RIBA, 2016; RIBA, 2017a; RIBA, 2017b). However, the roles,  
19 responsibilities, perspectives and expectations of both industry practitioners and built asset end-  
20 users differ significantly (Rebaño-Edwards, 2007). For instance, whilst developers are primarily  
21 concerned with efficiency and cost (Gervásio *et al.*, 2013), end-users focus more upon the quality  
22 of the building's finishes, its environmental performance and services (Turpin-Brooks and Viccars,  
23 2006; Hassanain and Mudhei, 2006; Riley *et al.*, 2010; Choi *et al.*, 2012; Hussanain and Iftikar,  
24 2015). Regardless of perspective, prudent business decision making for buildings requires the  
25 efficient management of data and information (García-Peñalvo and Conde, 2013; Gong *et al.*,  
26 2018). Undertaking a POE presents a significant opportunity to garner insightful feedback on the  
27 design, construction and management decisions taken during the building's whole life cycle  
28 (O'Neil and Duvall, 2005; Skills Funding Agency, 2014). POE reports can contain invaluable data  
29 regarding: i) end-user feedback of facility performance; ii) project team feedback regarding the  
30 design and construction phases; iii) technical data from the facility's building management system;  
31 and iv) strategic data from an organisation's estates management perspective (HEFCE, 2006;  
32 RIBA, 2016; RIBA, 2017a; RIBA, 2017b). Garbowski and Mathiassen (2013) assert that sound  
33 real estate decision-making is crucial to ensuring an organisation's financial and strategic success.  
34 Additionally, García-Peñalvo and Conde (2013) proffer that the more useful the available

1 information, the more efficient and considered the decision-making process will be. However,  
2 despite voluminous ‘big data’ available, significant gaps are apparent between a building’s  
3 predicted and actual performance (de Wilde, 2014; Brown, 2015).

#### 4 *Barriers to POE Implementation*

6 Curiously, the implementation of POE is inconsistent internationally and prevailing practice within  
7 the United States is far more advanced than international counterparts (Adewunmi *et al.*, 2010).  
8 Within the UK, two prominent guidance documents offer insight into the financial importance of  
9 a POE. The Higher Education Funding Council England (HEFCE) Guidance to Post-occupancy  
10 Evaluation (2006) refers to a “*PFI [Private Finance Initiatives] /PPP[Public Private*  
11 *Partnerships] review to allow a length of experience of operating the building*” (HEFCE, 2006,  
12 p13). PFI and PPP are funding mechanisms combining public finances with private capital and  
13 have been used widely throughout UK construction industry (Bing *et al.*, 2005). The Skills  
14 Funding Agency (SFA) Post-occupancy Evaluation Guide (2014) offers a link to the  
15 Government’s “*SFA capital funding: evaluation documents*” online utility, similarly indicating  
16 financial diligence influenced governmental thinking (c.f. Skills Funding Agency, 2014). Despite  
17 UK Governmental interest in, and academic endorsement of, POE its implementation within  
18 practice remains elusive partial due to this lack of a singular guidance source (Alborz and Berardi,  
19 2015). Other reasons for this are varied but centre upon three key inhibiting sets of factors (refer  
20 to Table 1):

21  
22 [Insert Table 1 about here]

- 23
- 24 i) *ownership* – a prevailing culture of litigation and blame present major stumbling blocks to  
25 POE implementation – an issue further exacerbated by blurred lines of responsibility for  
26 such (Riley *et al.*, 2010; Jiao *et al.*, 2013);
  - 27 ii) *cost, procurement and incentives* – the cost of, and value perceived from conducting a POE  
28 create significant barriers to POE adoption (c.f. Zimmerman and Martin, 2001; Vischer,  
29 2001). Contractual clauses within a chosen procurement path could alleviate this issue but  
30 at the conception stage, anecdotal evidence (sourced from the authors’ own industrial  
31 experiences as a practitioner and informal conversations held practitioner colleagues)  
32 suggests that a POE is hardly considered. Financial and non-financial incentives could also  
33 be employed but at present these are not well defined or utilised; and





1 POE findings provide benchmark criteria for comparing one facility's quality of finish, services  
2 and performance against another's (Wauters, 2005; Hassanain *et al.*, 2016) and offer guidance to  
3 improve future developments (Tookaloo and Smith, 2015). However, benchmarking facility  
4 performance via POE is problematic due to industry reservations that any value accrued is largely  
5 beneficial to industry competitors vis-à-vis the developer commissioning the evaluation (Olivia  
6 and Christopher, 2014). Zeisel (1981) states that the built environment design process should be  
7 cyclical, rather than being initiated and concluded in accord with the specific building's design  
8 and construction phases. This is further reinforced by Zimmerman and Martin (2001) who propose  
9 that POE forms a 'logical final step' to the cyclical process, providing a basis of 'lessons learned'  
10 which are fed forward into future developments. Similarly, Leaman and Bordass (2001) introduce  
11 the concept of 'virtuous circles of improvement' where POE is implemented as a benchmarking  
12 strategy throughout the design phase. This approach fosters a dynamic, continually evolving BOK  
13 to engender continuous improvement throughout the design and construction phases as opposed  
14 to final feedback at the handover (c.f. Leaman and Bordass, 2001, p.151). However, despite a  
15 variety of POE benchmarking strategies, Green and Moss (1998) suggest that organisations must  
16 implement knowledge cycles based upon their facility's bespoke management requirements  
17 (Hadjri and Crozier, 2008).

18

## 19 **BIBLIOMETRIC ANALYSIS**

20 Bibliometric analysis has been developed and utilised across multiple disciplines due to its ability  
21 to visually represent a large body of literature (van Eck and Waltman, 2010). In contrast to manual  
22 analysis, bibliometric analytical software such as Gephi (Bastian *et al.*, 2009) or VOSviewer (van  
23 Eck and Waltman, 2010) avoids introducing researcher bias and removes time and resource  
24 limitations relating to the practical number of studies selected (He *et al.*, 2017). Visual  
25 representation of bibliometric data also allows an academic topic to be expediently and  
26 comprehensively investigated (Cobo *et al.*, 2011). VOSviewer constructs distance-orientated  
27 network maps where each node/cluster represents the occurrence of a term or author, dependent  
28 upon the map generated. Nodes/clusters can also be assigned different colours within a  
29 visualisation, differentiating them from other nodes/clusters. VOSviewer's clustering function  
30 represents an advancement on previous mapping techniques, allowing deeper observations of  
31 connectedness than were previously possible using alternative software such as Statistical Package  
32 for the Social Sciences (SPSS) and Pajek (c.f. van Eck and Waltman, 2010). The distance between  
33 nodes/clusters gives a better indication of the strength of relationship between these items when

1 compared to graph-based maps (Waltman *et al.*, 2010). The analysis of direct citations can also  
2 pinpoint the most influential studies within a specific field under investigation.

3  
4 To produce citation visualisations for POE, the minimum number of papers published by an  
5 academic was arbitrarily set at two and the minimum number of citations was also set at two. These  
6 minimum values were selected to reflect the POE BOK which in comparison to alternative areas  
7 of built environment research, returns a relatively small sample size of applicable published  
8 research. For example, a Web of Science search on the term ‘Building Information Modelling’  
9 returns 51,937 results (May, 2018) compared with 516 results for the term ‘Post-occupancy  
10 Evaluation’ (May, 2018) – hence, POE represents a mere 0.98% of the available BIM BOK. Three  
11 varieties of visualisation were produced: i) co-authorship visualisation; ii) term density  
12 visualisation; and iii) a term date visualisation for the whole POE BOK. To maintain a systematic  
13 approach, the same specifications and settings were applied throughout the analysis to ensure  
14 consistency and for each visualisation fractional counting was utilised. van Eck and Waltman  
15 (2014) recommend using fractional counting when producing visualisations. Both full counting  
16 and fractional counting utilise the number of documents co-authored by two authors when  
17 formulating connections, however fractional counting also takes into account the total number of  
18 authors of each of the co-authored documents (*ibid*).

19  
20 When producing the term density visualisations, a number of specifications and filtering methods  
21 were applied. First, the minimum number of occurrences of a term for it to be considered  
22 significant was set at 12 following trial and error experimentation – too low a number and less  
23 significant terms could complicate the final visualisation but too high a number and significant  
24 terms would be omitted. Second, VOSviewer provides options to manually remove irrelevant  
25 terminology not pertaining to the visualisation; in this instance common research terms such as  
26 ‘introduction’ and ‘conclusion’ were removed because whilst important to research *per se*, they do  
27 not contribute to the theoretical lens of POE. The term date visualisation generated for this study  
28 utilised the same data and specifications used to analyse term density, but the ‘date overlay’  
29 function within VOSviewer was applied as opposed to the ‘density overlay’. This was done to  
30 ascertain the chronological development of various components of a POE emanating from  
31 academic literature pertaining to the POE BOK. The final stage of analysis examined the  
32 interconnectedness of publications discussing ‘Post-occupancy Evaluation’, ‘Process’ and  
33 ‘Benchmarking’. This focused search returned only seven research papers. Each paper was  
34 manually examined to ascertain: i) date of publication; ii) publishing journal; iii) total number of

1 citations per research item; iv) average number of citations; and v) the total number citations  
2 combined. These metrics offered insight into the interconnections between research into this  
3 specific topic within the larger POE BOK and the chronological development of POE, process and  
4 benchmarking research.

## 6 **FINDINGS**

7 The research findings for the bibliometric analysis are reported upon within the three iterative and  
8 thematic groups analysed in the visualisations, namely: POE literature; POE literature with a focus  
9 upon process; and qualitative analysis of literature pertaining to POE, POE process and facility  
10 benchmarking.

### 14 **POE Literature**

15 Figure 1 depicts a citation visualisation for the POE BOK indicating the strength of connections  
16 between authors who have published POE research. Of the 1122 individual authors who have  
17 cumulatively published 516 papers, only 119 authors remained once the filtering specifications  
18 were applied (i.e. two papers and two citations). Although VOSviewer's program functionality  
19 permits selection of authors who are linked through co-authorship (thus removing the nodes which  
20 share no direct link), for this visualisation unconnected nodes were included to expose the 39  
21 authors working in isolation, with no co-authorship links with any other researchers within the  
22 POE BOK. The unconnected authors displayed can be observed as being equidistant from the  
23 central linked cluster, or as having a weak relationship with the centrally located connected  
24 academic material. Figure 1 reveals eight distinct clusters where co-authorship between authors is  
25 indicated by representation of the same colour. The notably small distances separating independent  
26 clusters indicates strong connectedness in terms of citations between each cluster and its  
27 corresponding author(s). This indicates that the community of researchers working on POE  
28 represented in the central cluster are closely linked. Prominent authors noted include: Bordass and  
29 Leaman (2005) who reviewed a portfolio of POE feedback techniques; Baird (2010) who  
30 examined the relationship between POE and post occupancy review of buildings and their  
31 engineering (PROBE); and Husin *et al.* (2012) who attempted to link POE to safety for low cost  
32 housing in Malaysia.

34 [Insert Figure 1 about here]

1  
2 Figure 2 presents a density visualisation of key terms and phrases emanating from the POE BOK.  
3 The overlay colour(s) presented on the visualisation are predicated by the number of items which  
4 appear within *the neighbourhood* – where the latter refers to the items populating a point/area  
5 within a visualisation which share common properties. The higher the density of items within the  
6 neighbourhood, the warmer the colour produced, where blue represents no connection and red  
7 represents the strongest connection (van Eck and Waltman, 2014). Two distinct density clusters  
8 can immediately be observed, with a further seven sub-clusters present within each. The first  
9 density cluster, located to the left hand side of the visualisation, has the term ‘process’ at its centre.  
10 Moving out from this centre point are the terms: framework; design process; interview; occupancy;  
11 nature; effectiveness; architecture; staff; facility; student; school; and university. The visualisation  
12 suggests that all of these terms share a strong relationship which centres upon the fulcrum of the  
13 process of conducting a POE - hence, this cluster can be conveniently assigned the nomenclature  
14 ‘*POE process implementation*’. This cluster supports the earlier work of Göçer *et al.* (2015) who  
15 sought to develop a collaborative effort of continuous building performance improvement by using  
16 the results of POE implementation embedded into BIM. The second density cluster has no defined  
17 centre but rather consists of four sub-clusters: system; occupant; comfort; and satisfaction. The  
18 fulcrum of these sub-clusters orientates around occupant/ building user feedback and consequently  
19 the cluster is assigned the nomenclature ‘*POE building user feedback*’. This cluster supports  
20 Preiser’s (1995) ground breaking work that sought highlight the importance of POE to facility  
21 managers in terms providing a tool with which to systematically identify and evaluate critical  
22 aspects of building performance.

23  
24 [Insert Figure 2 about here]

25  
26 Figure 3 represents the previous density visualisation with the citation date overlay applied to  
27 illustrate when specific topics under the larger POE umbrella received specific academic attention  
28 (c.f. van Eck and Waltman, 2010). The figure illustrates that ‘occupancy’ (particularly regarding  
29 hospitals, schools, universities and residential property) was at the forefront of academic attention  
30 from 2010 to 2012, whilst between 2011 and 2012 the focus was upon: ‘processes’,  
31 ‘measurement’, ‘feedback’ and ‘climate’. Between 2012 and 2013, ‘systems’, ‘energy’, and  
32 ‘satisfaction’ (comfort, lighting and temperature) received prominent academic attention. During  
33 2014 ‘indoor environmental quality’, ‘health’ and ‘occupant behaviour’ received the most  
34 academic attention whilst ‘simulation’ appears from 2014 onwards. The body of research on POE

1 for passive buildings revealed problems with indoor air quality and comfort due to ‘building  
2 tightness’; where the latter refers to virtually hermetically sealed buildings and environmental  
3 efficient building - this research could explain the higher number of citations concerning health  
4 and indoor air quality as reported in Figure 3.

5  
6 [Insert Figure 3 about here]  
7

8 A breakdown of the POE BOK organised by journal publication was also analysed. The journals  
9 most frequently publishing POE were: Building Research and Information (frequency ( $f$ ) = 42);  
10 Building and Environment ( $f$  = 35); and Energy and Buildings ( $f$  = 23). Within the remaining  
11 journals publishing POE, publication frequency fell from Journal of Architecture and Planning  
12 Research ( $f$  = 19) down to multiple journals publishing four items or less.

#### 13 14 **Process Focus within POE Literature**

15 Figure 4 depicts a co-authorship visualisation of ‘POE’ and ‘process’ literature. Of the 292 authors  
16 who published 111 research items, only 12 remain after applying filtering specifications. Nodes  
17 which share no connections with any other items within the visualisation are again included to  
18 offer an insight into the overall connectedness of literature. Of the 12 authors who met the  
19 threshold, only five are connected through co-authorship. The observable significant spacing  
20 between each node and differing cluster colour indicates that said authors listed in this visualisation  
21 are not linked by co-authorship and work in relative isolation. Of the 292 authors who have  
22 published research on the topic of ‘POE’ and ‘process’, only five (1.71%) were linked through  
23 co-authorship. This lack of interconnections could possibly explain why standardised POE  
24 implementation strategies in practice remain elusive. Interestingly, the total number of citations  
25 pertaining to POE and process have grown exponentially since 2010 - indeed, as of May 2018, the  
26 number of citations has already surpassed the total annual citations recorded in 2013. Hence,  
27 although interest in the area remains relatively small, research undertaken is rapidly increasing in  
28 volume.

29  
30 [Insert Figure 4 about here]  
31

32 A term density map of ‘POE’ and ‘process’ bibliometric data is presented in figure 5. There is a  
33 notably significantly smaller set of terms arising from this visualisation with four distinct clusters  
34 being identified, namely: analysis; user; performance; and quality. These clusters offer an insight

1 into the research currently being undertaken regarding POE and processes and represent the four  
2 key areas of research within this niche. The Web of Science bibliometric data regarding 'POE'  
3 and 'process' was also organised to indicate the top 25 academic journals under which the research  
4 has been published. Journals with the highest frequency of publication were: Building Research  
5 and Information ( $f = 16$ ); and Herd Health Environments Research Design Journal ( $f = 10$ ). Within  
6 the remaining journals, publication frequency fell from that of Energy and Buildings ( $f = 4$ ) to  
7 multiple conferences with one publication each.

8  
9 [Insert Figure 5 about here]

### 11 **Analysis of Literature Pertaining to POE, POE Process and Facility Benchmarking**

12 A synthesis of literature pertaining to the search terms 'POE', 'process' and 'benchmark' identified  
13 only seven research items, of which six have been cited since publication (c.f. Zagreus *et al.*, 2002  
14 [88 citations]; Zimmerman and Martin, 2001 [77 citations]; Bordass and Leaman, 2005 [33  
15 citations]; Curwell *et al.*, 1999 [14 citations]; Elijah-Barnwell and Friedow, 2014 [2 citations];  
16 Gorgolewski *et al.*, 2016 [1 citation]; and Kujawski, 2013 [0 citations]). Of these six items, four  
17 papers published between 1999 and 2005 dominate the citation ranking, making up 98.60% of the  
18 total citations emanating from this group. The two later items (published 2014 and 2016)  
19 contributed three citations between them.

20  
21 Figure 6 shows a density visualisation map of key term occurrences using the search results for  
22 'POE', 'process' and 'benchmark' terms. As before, the number of occurrences required for a term  
23 to be considered significant was set at 12. Five distinct clusters can be observed: i) construction  
24 and comparison; ii) benchmarking, maintenance and feedback; iii) client, survey and case study;  
25 iv) engineering, occupant satisfaction and occupant; and v) owner and benefit. Of these five  
26 clusters, three exhibit a stronger concentration, namely cluster i, cluster iii and cluster v. A sixth  
27 cluster regarding 'best practice' can be observed within the visualisation located equidistant from  
28 the other five clusters, which suggests that the concept of best practice is crucial as it arises in all  
29 of the other clusters. Bibliographic search results for this stage of the analysis were broken down  
30 to examine pertinent journals publishing on this topic. These journals were: i) Building Research  
31 and Information ( $f = 3$ ); ii) Herd Health and Environment Research Design Journal ( $f = 1$ ); iii)  
32 Indoor Air ( $f = 1$ ); iv) Journal of Green Building ( $f = 1$ ); and v) Sustainable Building and  
33 Refurbishment for Next Generations ( $f = 1$ ).

1 [Insert Figure 6 about here]

2

### 3 **DISCUSSION**

4 The analysis presented highlights that a small number of POE researchers are working in relative  
5 isolation; this finding generates new theory that suggests that a prevailing lack of a cohesive  
6 ‘community of practice’ (CoP) in this important area should be resolved by the creation of a cross  
7 industry-academic body to promote, regulate and govern POE implementation. Interestingly,  
8 ‘POE process implementation’ and ‘POE building user feedback’ were identified as significant  
9 clusters of academic enquiry to underscore their importance in terms of ensuring a consistent POE  
10 approach adopted and securing subjective feedback from building users. These conclusions have  
11 largely stemmed from studies conducted on higher education institutions vis-à-vis the wider built  
12 environment (c.f. Garbowski and Mathiassen 2013; García-Peñalvo and Conde 2013) – this is most  
13 likely because researchers have readily available access to buildings within their own host  
14 institution that support POE implementation. However, researchers have hitherto failed to  
15 influence built environment practitioners’ adoption of POE in practice (c.f. Bordass and Leaman,  
16 2005; Alborz and Berardi, 2015). In addition to a CoP body being developed, a plethora of  
17 potential financial and non-financial incentives are apparent and gravitate around building  
18 benchmarking. For example, environmental based legislative instruments could be used to set a  
19 minimum level of building performance to be expected to support existing rating schemes such as  
20 Leadership in Energy and Environmental Design (LEED) (cf. Ofori-Boadu *et al.*, 2012; Martek *et*  
21 *al.*, 2019). At present, such schemes are supported by government for government buildings but  
22 are not mandatory for non-government buildings (Ofori-Boadu *et al.*, 2012). Alternatively,  
23 building performance could be used to set the level of financial revenue streams accrued from  
24 building users, i.e. higher performing buildings recover higher rental rates or purchase values.  
25 Incentives could also present an opportunity to remove overriding fears of practitioners regarding  
26 the value within POE implementation and how competitors could benefit from such (c.f. Preiser  
27 and Vischer, 2005; Olivia and Christopher, 2014).

28

29 Ultimately market forces are required to create demand for POEs and that may require further  
30 education and marketing to the general public (Martek *et al.*, 2019) – perhaps under the guises of  
31 finance savings, environmental performance and user comfort. Whatever the solution to the POE  
32 uptake problem domain, it is apparent that a notable lack of a CoP within academia and practice  
33 has hitherto failed to embed POE as an integral part of a building’s life cycle. Moreover, other  
34 initiatives (e.g. BIM, digitizing the built environment, industry 4.0 or environmental legislation)

1 are conspicuous by their absence in literature reviewed – yet, POE arguably represents the best  
2 means of measuring the success of these initiatives within the built environment.

#### 4 **Theory Development**

5 Using knowledge accrued from this research, Figure 7 was constructed depicting a theoretical 2 x  
6 2 matrix for digitalising the built environment which incorporates similarly aligned fields of built  
7 environment research. The x-axis represents the financial importance of a particular established  
8 field of study to a development’s life cycle. The y-axis indicates the frequency of academic  
9 literature produced on particular areas of built environment research. Cleaning and maintenance ( $f$   
10 = 3,062 with the first citation in 1978), whilst critical to the operation of a built asset, has largely  
11 been amalgamated into the larger Facilities Management (FM) field of research ( $f$  = 36,583 with  
12 the first citation in 1976). BIM ( $f$  = 51,937 with the first citation in 1988) has a limited impact  
13 upon the operational phase of built assets’ life cycles at present, although the emergent fields of  
14 ‘BIM in FM’ and ‘Digital Asset Management’ ( $f$  = 613 with the first citation in 1992 and  $f$  = 527  
15 research items with first citation in 2000 respectively) indicate significant research efforts to  
16 amend this. POE ( $f$  = 515 with the first citation in 1981) can be adjudged to have had a far greater  
17 impact upon the financial performance of a development’s life cycle, yet has received substantially  
18 less academic attention. Future work is however required to empirically test this emergent theory.

19  
20 [Insert Figure 7 about here]

21  
22 Disruptive technologies such as BIM drive innovation and offer digital solutions for well  
23 documented and persistent issues within the built environment (c.f. Eastman *et al.*, 2011;  
24 Motamedi *et al.*, 2011; Race, 2013; Kensek, 2014a; Kensek, 2014b; Thomson and Boehm, 2015  
25 Chan *et al.*, 2016). However, whilst increasing the application of disruptive innovations generates  
26 voluminous data/information on buildings *per se*, such does not automatically translate into  
27 knowledge or wisdom. If practitioners were to utilise POE to evaluate user feedback and learn  
28 from the building’s functionality and performance during its in-use phase, then the design feedback  
29 loop originally envisaged by Pärn *et al.* (2017) could readily be realised. At present, POE has  
30 largely utilised manual paper-based feedback mechanisms and has been perceived to create  
31 problems, including: i) inadequate funding to conduct a POE (Vischer, 2001; Zimmerman and  
32 Martin, 2001; Riley *et al.*, 2010); ii) lack of clarity on who is responsible for the evaluation  
33 (Bordass and Leaman, 2005; Riley *et al.*, 2010); and iii) the mitigation of liability of the project  
34 stakeholders regarding any issues highlighted by the POE (Zimmerman and Martin, 2001; Jauzens



1 *et al.*, 2003; Khosrowshahi and Arayici, 2012; Jiao *et al.*, 2013). Consequently, the literature  
2 (augmented by anecdotal evidence from industry) suggests that POE is either not used or that the  
3 data generated is not exploited to its fully inherent capacity. There appears to be an ominous  
4 disconnect between building users and designers and perhaps a ‘building handover’ is symbolic of  
5 designer abdication of performance liability? Building upon these theoretical ideas, Figure 8  
6 presents a triumvirate of BIM, FM and POE. The figure illustrates that the integration of BIM in  
7 FM has many palpable benefits that could be realised via a POE feedback mechanism (cf. Pärn *et*  
8 *al.*, 2017). The application of this ‘missing link’ within the digital development process could  
9 contribute to accelerating the development of smart buildings and cities. Again, future work is  
10 required to test this theory and measure the impact that POE could have upon expediting smart  
11 buildings and cities development.

12 [Insert Figure 8 about here]

13

#### 14 **Research Limitations**

15 Using an interpretivist epistemological lens as part of an inductive research approach has several  
16 significant limitations. First, interpretivist researchers assume that access to reality is only through  
17 social constructs such as the prevailing academic discourse on POE (Antwi and Hamza, 2015).  
18 Second, and as a branch of positivism, the interpretivist philosophical position also emphasises  
19 qualitative *vis-a-vis* quantitative analysis (Symon *et al.*, 2016). The subjective nature of qualitative  
20 research can: introduce researcher bias into the study; be subject to literature searching practices  
21 that may omit significant research; and introduce translation errors (cf. Mallett *et al.*, 2012). Third,  
22 the interpretivist approach cannot be generalised because the data and findings elucidated upon are  
23 heavily influenced by the researcher’s personal views and values (Kiernan and Hill, 2018). These  
24 limitations apart, all research has a beginning and one significant benefit of an interpretivist  
25 approach is the generation of new theories that can signpost future research direction.

26

#### 27 **CONCLUSIONS**

28 Whilst related research published has focused on specific aspects of conducting a POE (i.e. human  
29 comfort or energy consumption), this research presented represents the first detailed ‘holistic  
30 examination’ of extant literature of POE. Findings highlight that a significant dearth of relevant  
31 research is apparent and moreover, that a CoP in this field of study is needed to widen practitioner  
32 participation and their consistent implementation of POE. This finding is somewhat enigmatic  
33 given that POE is fundamental to measuring the technical and functional performance of current  
34 buildings and improving the designs of future buildings developed. Moreover, consistency of POE

1 implementation is essential particularly when comparing between buildings. Without reliable data  
2 and information, this research posits that important knowledge and wisdom required to enable  
3 smart building and smart city developments will be significantly hampered. Specifically,  
4 architects, designers and contractors should work with facilities management teams post building  
5 occupation to undertake POEs (that measure building performance across all pertinent  
6 benchmarking criteria (energy consumption, lighting and heating control etc.)) to ensure that future  
7 designs perform as they were envisaged at conception. At present, prominent members of the  
8 design and construction team rarely contribute to the POE process and so the opportunity to learn  
9 from mistakes or develop improvements is largely lost. Such a recommendation may require  
10 changes in procurement processes to ensure that all project stakeholders involved throughout the  
11 building's whole life cycle are involved in POE.

12  
13 A number of practitioner barriers to POE implementation were also observed and reported upon  
14 but prominent issues related to: scarce POE funding; unclear lines of responsibility for conducting  
15 POE; and liability mitigation for any issues highlighted by the POE. These barriers perhaps explain  
16 why the subject area fails to attract research funding and wider research activity – as evidenced by  
17 the small pool of fragmented research being conducted in the field. To overcome these barriers,  
18 future work is required to expand the current research study and engender wider practitioner and  
19 academic debate. Such work may include: i) reporting upon case studies of POE implementation  
20 within wider industry (vis-à-vis higher education institutions) to report upon examples of practice  
21 and provide tangible evidence of benefits to be accrued. Such work could be used as the basis for  
22 changing attitudes towards POE and educate future generations of practitioners; ii) working with  
23 professional bodies and higher education institutions to ensure that pertinent under- and  
24 postgraduate awards (or continual professional development programmes) give sufficient  
25 coverage on how to conduct a POE and the benefits that such yields for business and society. To  
26 change the prevailing culture within the AECO sector will require a cohesive effort to bridge the  
27 divide between academia and practice using factual evidence accrued from case studies; iii)  
28 developing a standardised approach to conducting a POE that would facilitate direct comparison  
29 between POEs conducted for various building developments - such work would enable the creation  
30 of a wider community of practice and knowledge bank that would feed into taught curricular and  
31 industry practice. Present variations between competing POE processes further exacerbate barriers  
32 reported upon and thus prevent wider POE implementation; and iv) empirically testing or refining  
33 the theories and interpretations emanating from this inductive research (for example, the  
34 theoretical matrix for digitalising the built environment). Deductive research is now required to

- 1 either prove or disprove the work presented as a means of advancing research knowledge and
- 2 practitioner attitudes.
- 3

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1 **Table 1 - Factors Preventing POE Implementation**

<b>Inhibitor of POE</b>	<b>Description</b>
Ownership.	Ownership of the POE process within a collaborative team of developers is often a stumbling block to its execution (Riley <i>et al.</i> , 2010). Mitigation of liability is a significant driving factor for individual built environment professionals within the team (Khosrowshahi and Arayici, 2012; Jiao <i>et al.</i> , 2013). This is further exacerbated by a culture of fear, blame and conflict which is synonymous with the building sector (Jauzens <i>et al.</i> , 2003).
Cost, procurement and incentives.	Riley <i>et al.</i> (2010) assert two prominent questions when considering the POE process: i) which party is responsible for commissioning and funding the evaluation? and ii) which party is professionally responsible for carrying it out? When examining this dilemma from a client perspective, the client often believes the ‘testing’ phase of the building life cycle has already been paid for (Riley <i>et al.</i> , 2010). Consequently, the factors of cost, failure to agree on POE measures and disjointed incentives to implement POE, represent significant barriers (c.f. Zimmerman and Martin, 2001; Vischer, 2001).
Education and culture.	Within the AECO sector, many designers, builders and project managers believe that they are in possession of in-depth knowledge of building performance, when often such knowledge extends only to the experience required to create and adjust buildings (Bordass and Leaman, 2005). Furthermore, there remains a notable absence of any obligation or payment to undertake a POE and POE implementation does not feature in contemporary architectural courses (Cooper, 2001).

2

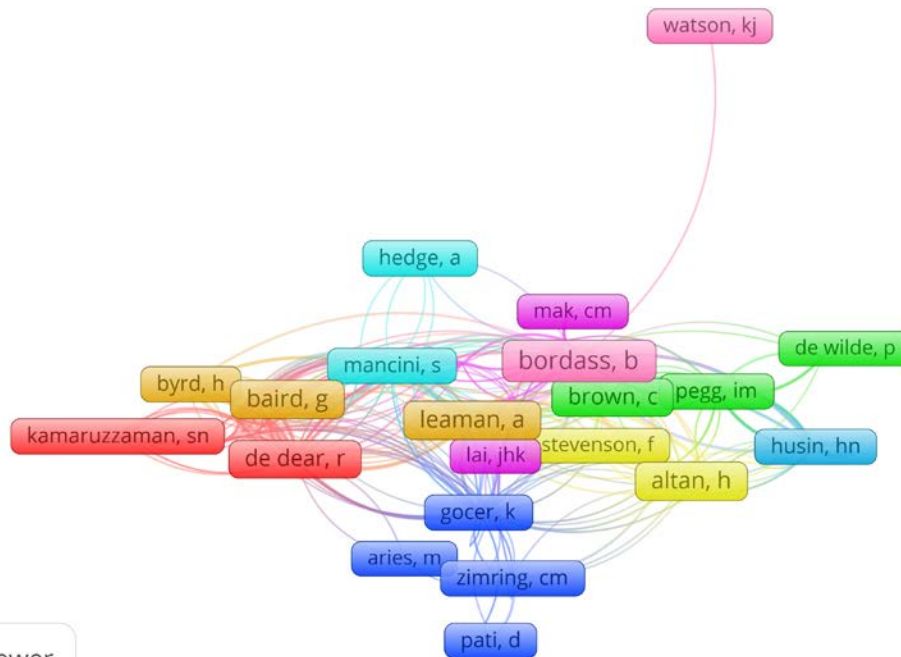
1 **Table 2 - POE Strategies**

<b>POE Strategy</b>	<b>Description</b>
PROBE	PROBE is designed to utilise both quantitative and qualitative data regarding: energy consumption; occupant surveys and interviews; observational walkthroughs; and technical reviews (Riley <i>et al.</i> , 2010)
BUS Occupant Survey	The Building Use Studies (BUS) occupant survey utilises questionnaires to gather end-user feedback on considerations such as: thermal comfort; ventilation; lighting and noise; personal control; space; design; and image (BUS Methodology, 2017). The BUS occupant survey uses key performance indicators to benchmark against other facilities held on the company's databases (Riley <i>et al.</i> , 2010).
CIC DQI	Construction Industry Council (CIC) Design Quality Indicators (DQI) utilises a questionnaire specifically designed to capture feedback from any individual (from the project team to neighbours) over the course of the building's life cycle (CIC, 2003).
OLS	Overall Liking Score (OLS) analyses three aspects of sustainability, namely: i) economic; ii) social; and iii) environmental (c.f. WCED, 1987). The OLS is predicated on an end-user questionnaire designed to capture opinions on successes and potential improvements (Riley <i>et al.</i> , 2010).
HEDQF POE Forum Methodology	The Higher Education Design Quality Forum (HEDQF) Post-occupancy Evaluation Forum Methodology utilises facilitated seminars organised approximately a year after the handover of the facility (RIBA, 2010). Unlike the other strategies, this method can be executed as part of the HEFCE Guidance to Post-occupancy Evaluation, as opposed to simply being a stand-alone strategy (HEFCE, 2006; RIBA, 2010).
Soft Landings	Soft Landings considers the whole life cycle of the building, committing resources into consideration of: i) briefing; ii) pre-handover; and iii) the long term operation of the facility (Sustainable Cities, 2009). Soft Landings creates an environment and ethos suitable for the undertaking of a POE (Riley <i>et al.</i> , 2010).
HEFCE Guidance	The HEFCE Guide to POE is the preeminent document used in the higher education sector (Riley <i>et al.</i> , 2010). It was developed with the intention of increasing the preciseness of: benchmarking; management; and operation of educational buildings. The HEFCE Guidance advises collection of data at specific intervals after handover of a facility to maximise its usefulness: i) practitioner team feedback data collected between 3 to 6 months after handover before the project team move on to future projects; ii) end-user feedback data collected 9 to 18 months after handover when building users have settled in; and iii) technical data from an asset Building Management System, for instance after the initial snagging period (c.f. HEFCE, 2006).

2

3

1 **Figure 1** - Bibliometric Citation Visualisation of Researchers Contributing to the POE BOK



2

**Clusters: from left to right**

<b>Red</b>	Watson, K.J	Loftness, V.	<b>Green</b>
Salleh, N.M.	<b>Cyan</b>	Aziz, A.	Brown, C.
Kamaruzzaman, S.N	Vietch, J.A.	Lai, J.H.K	Gorgolewski, M.
Zawawi, E.M.A.	Mancini, S.	Sanni-Anibire, M.O	Wheeler, A.
Zagreus, L.	Soebarto, V.	Hassanain, M.A.	Pegg, I.M.
Arens, E.	Dorsey, J.A.	Hwang, T.	Allan, N.
Zhang, H.	Hedge, A.	Kim, J.T.	Sodegar, B.
Candido, C.	Birt, B.J.	Mak, C.M.	Goodhew, S.
Schiavon, S.	<b>Blue</b>	Xue, P.	de Wilde, P.
Thomas, L.E	Aries, M.	<b>Yellow</b>	Jones, R.V.
Williams, M.	Shepley, M.M.	Stevenson, F.	<b>Turquoise</b>
Kim, J.	Göçer, K.	Raslan, R.	Nawawi, A.H
de Dear, R.	Preiser, W.F.E.	Altamirano-Medina, H.	Ismail, F.
<b>Beige</b>	Newton, C.	Guptar, R.	Husin, H.N.
Lenoir, A.	Pati, D.	Chandiwala, S.	Khalil, N.
Garde, F.	Kantrowitz, M.	Nicol, F.	Labaki, L.C.
Rasheed, E.O.	Hua, Y.	Altan, H.	Kowaltowski, D.C.C.K.
Byrd, H.	Zimring, C.M.	Patlakis, P.	Pina, S.A.M.G.
Baird, G.	Yaldiz, E.	Santacruz, H.B.	Ruschel, R.C.
Leaman, A.	<b>Purple</b>	Oreszczyn, T.	
Bordass, B.	Choi, J.H.	Mumovic, D	

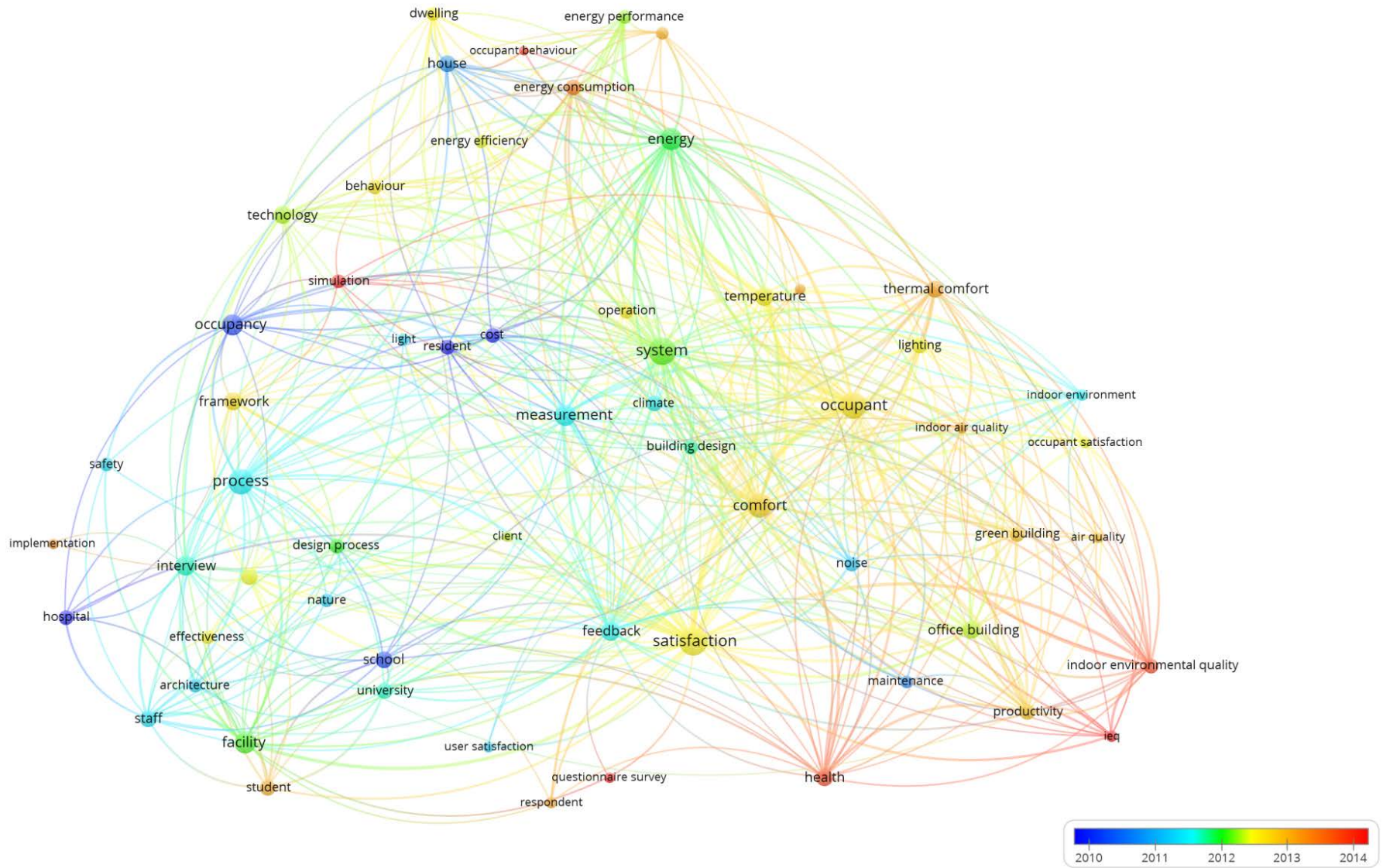
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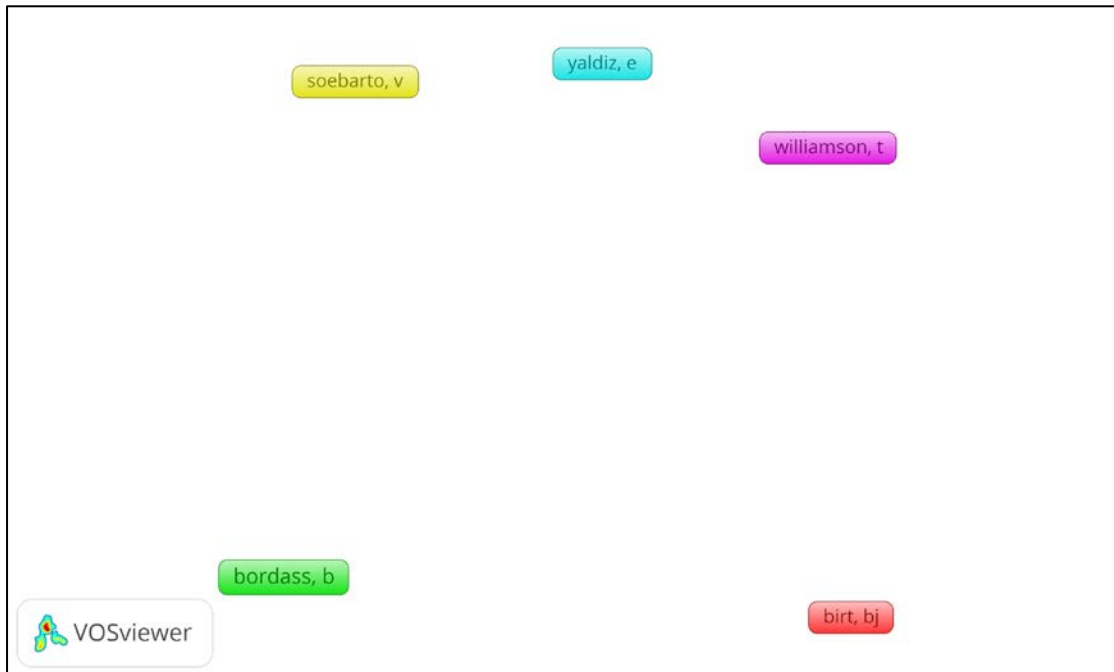


1 **Figure 3** - Density Visualisation of the POE BOK with the Citation Date Overlay

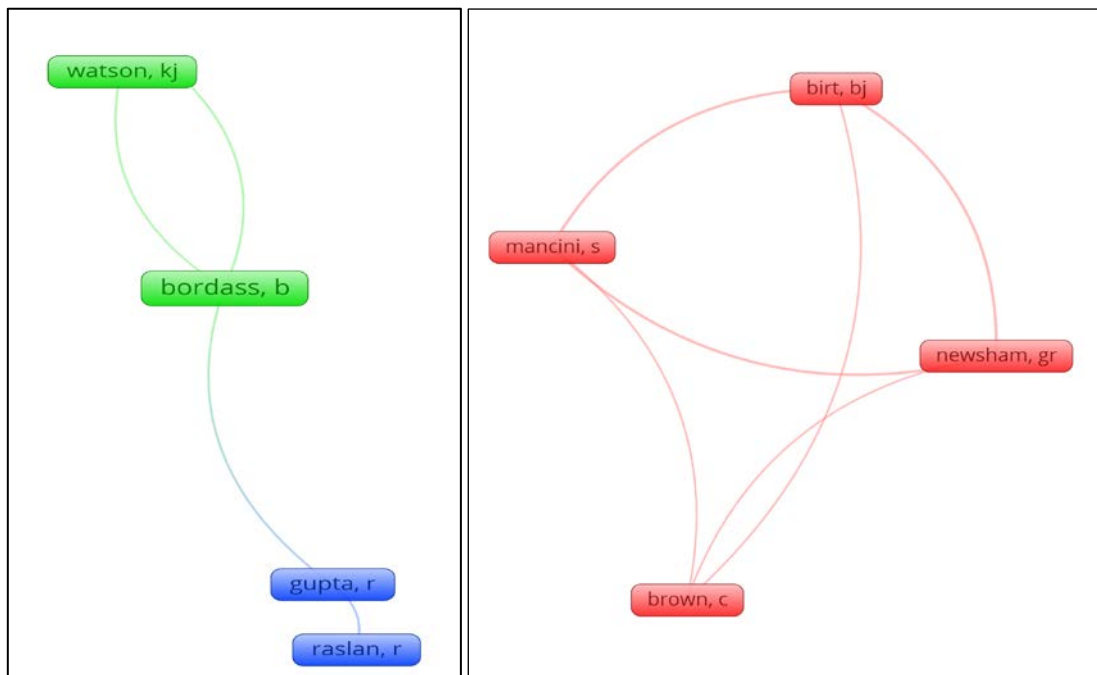


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1 **Figure 4** – Bibliographic Visualisation of Researchers Contributing to POE and Process Literature



2

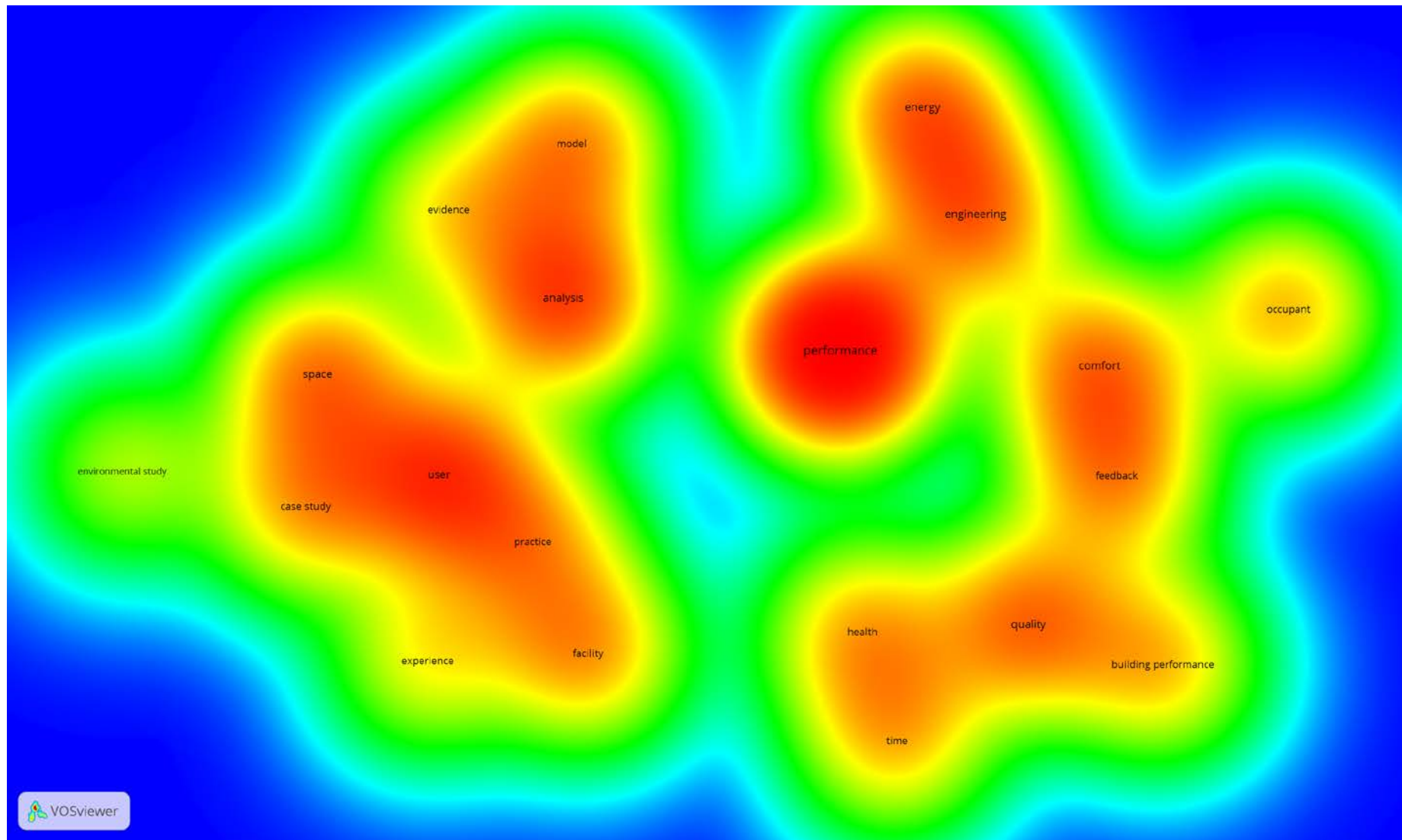


3

Authors (Co-authorship overview)	Authors (Bordass Cluster)	Authors (Birt Cluster)
<b>Yellow</b> Soebarto, V. <b>Cyan</b> Yaldiz, E. <b>Purple</b> Williamson, T.	<b>Green</b> Watson, K.J. Bordass, B. <b>Blue</b> Gupter, R. Raslan, R.	Mancini, S. Brown, C. Newsham, G.R. Birt, B.J.

4

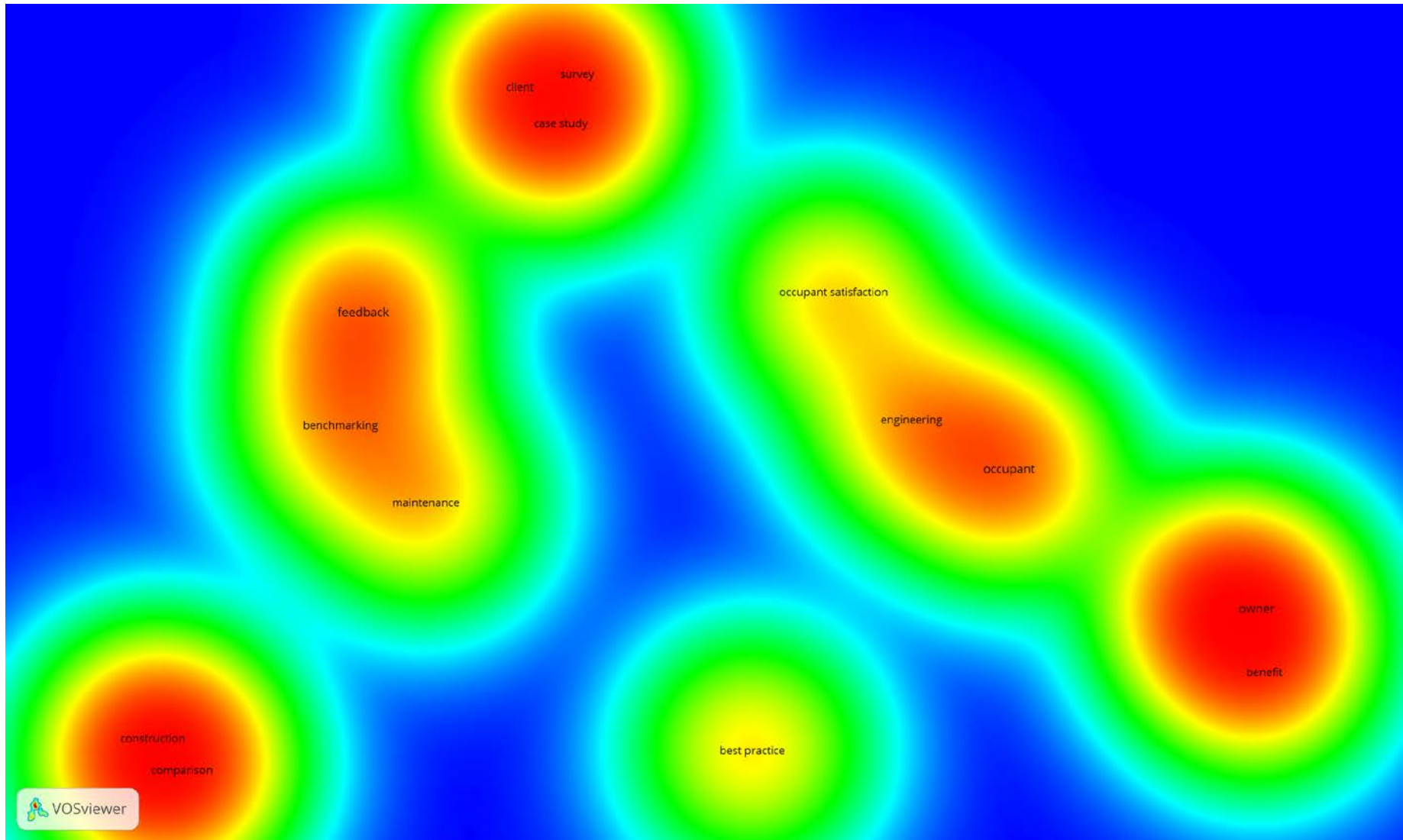
1 **Figure 5** - Term Density Map of POE and Process Bibliometric Data



2

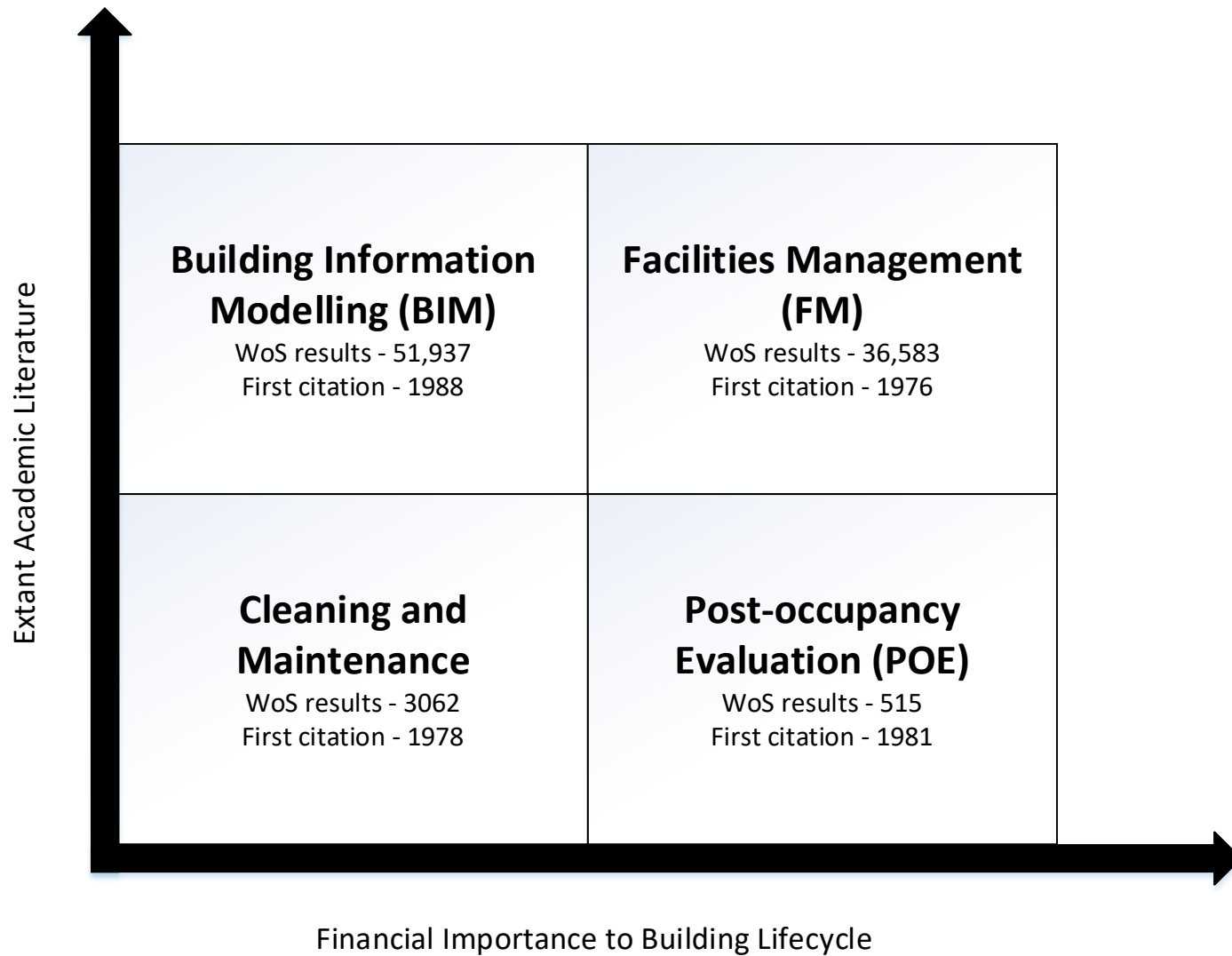


1 **Figure 6** – Term Density Map for POE, Process and Benchmark



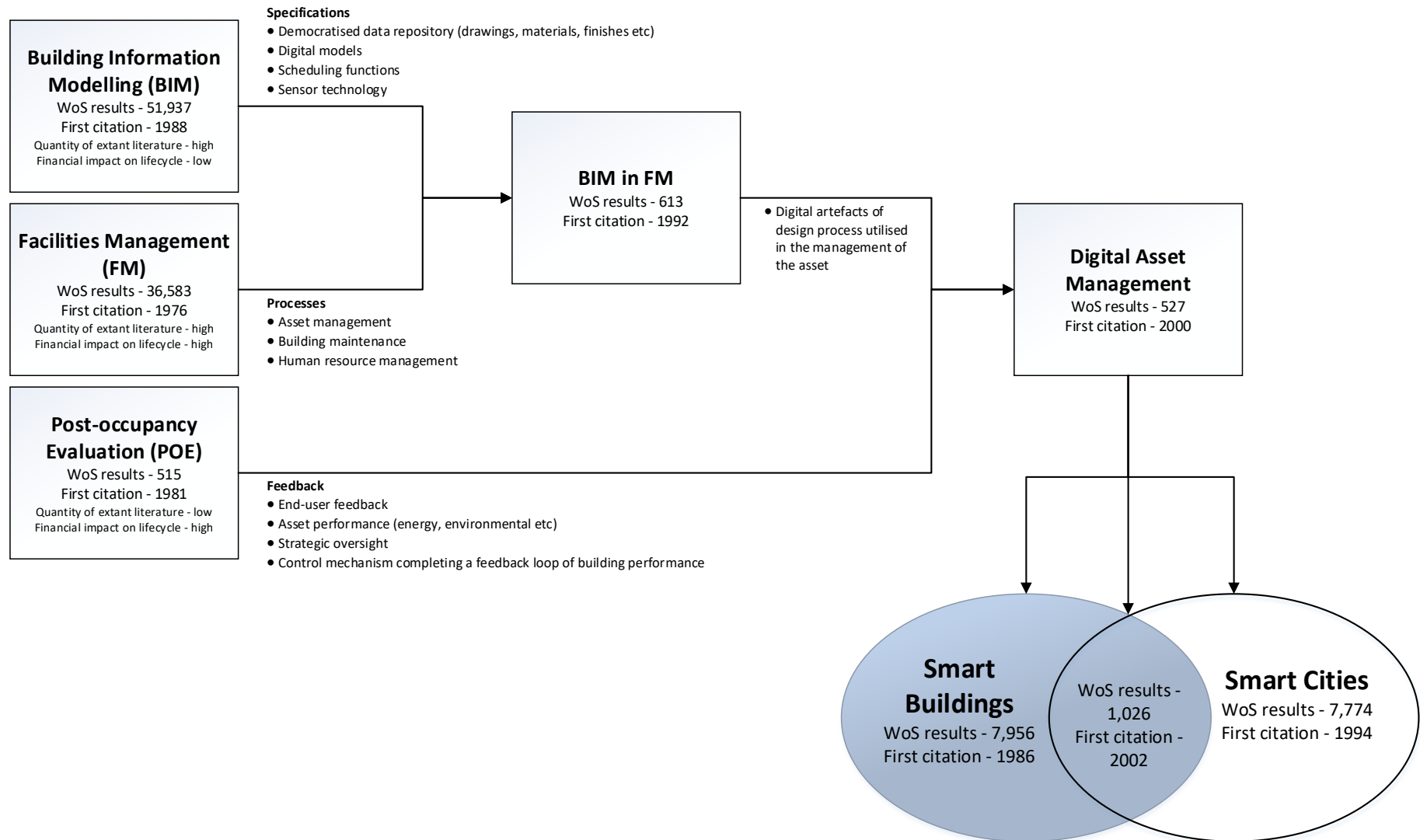
2

1 **Figure 7** - Theoretical Matrix for Digitalising the Built Environment



2

1 **Figure 8 - Future Trends in Smart Building/Smart City Development**



2