An artefact for improving the delivery of building energy retrofit project in South Africa

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Abstract

Purpose – The built environment is well known for carbon emission and its impact especially as it pertains to existing buildings. This has culminated in an increasing need for a retrofit of such buildings. This study details the development of an artefact for improving the delivery of energy retrofit projects therein to curb these impacts.
Design/methodology/approach – The study utilized a mixed method research design for data collection. In achieving this, data was collected in three different phases; (1) a pilot study; (2) a juxtaposition of desktop case studies, live case studies, focus group discussion forum and an expert survey; and (3) a questionnaire survey for the validation of the emergent artefact. Accordingly, the quantitative data was analysed using descriptive statistics, whereas qualitative content analysis was deployed for qualitative data.
Findings – The findings enabled an identification of the elements of a building energy retrofit project (BERP) such as project initiation, building assessment, detailed energy survey, technical analysis and implementation plans of energy measures, monitoring and verification. Also, it provided the challenges and enablers associated with successful BERP. This information was subsequently utilized in the development and validation of an artefact for delivering successful BERP. Summarily, a set of guidelines comprising of seven stages for managing successful BERPs were elucidated.
Practical implications – The validated artefact provides an adaptive and innovative route for achieving sustainability in retrofit trade.
Originality/value – The study conceptualizes an artefact for improving the delivery of BERPs.

Keywords Artefact, Building, Energy, Retrofit, South Africa
Paper type Research paper

Introduction

The attainment of optimal energy efficiency levels in existing building holds a plethora of benefits for the individual, organization and society in the bid for sustainable built environment futures. However, retrofitting existing buildings remains a daunting

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challenging, when compared to the design of a new sustainable building (Miller and Buys, 2011). Also retrofitting existing buildings is often considered an expensive disruptive process particularly in the face of the resistance faced by building occupants (Miller and Buys, 2011). Building energy retrofit processes include addition of existing walls, opening walling elements, removal and installation of Heating, Ventilation and Air Conditioning (HVAC) elements and strengthening of frames and entail demolishing, lengthy construction time and occupant relocation (Wilkinson, 2011). Disruptions associated with these processes usually deter building owners from retrofitting their buildings (Cheung *et al.*, 2000; Wilkinson, 2011).

Although retrofitting appears to have gained traction in most developed countries, it is yet at its infancy levels in South Africa. In the South African built environment context, five indicators manifest this status quo, namely: absence of a delivery system for retrofitting, non-consideration of energy retrofit in the official schedule of rates of government agencies, scarcity of contractors and skilled artisans knowledgeable in retrofitting, limited knowledge among professionals concerning retrofitting options and limited information on retrofitting (Milford, 2009). As a result, the use of retrofitting as a tool for managing carbon emission remains fraught with obstacles in South Africa. South Africa is one of the highest ranked CO_2 emitters in the world (Sustainable Energy Africa (SEA), 2015). As such, South Africa has set ambitious targets of reducing CO_2 by 34% by 2020 and 42% by 2025 through the "intended nationally determined contribution" plan. This plan has triggered a flurry of studies within this research domain.

It is necessary to note that this research direction has been demonstrated to be an important topic in the subject area. For example, various researchers have proposed different methodologies for energy retrofit project. Some of the studies focussed on energy savings, whereas others looked at overall retrofitting for the whole building. Junghans (2013) proposed a facilities energy efficiency (FEE) model for a strategic approach for energy efficiency for a municipality's entire building stock. In the "analysis of building" stage, a wide range of parameters, including location, procedures for operation and usage, and the building conditions and its current technical standard are covered. Ray (2004) also develop a structured multi-criteria assessment methodology for renovating office buildings that takes into account environmental (energy consumption), socio-cultural (thermal and visual comfort) and economic (cost) criteria. In their study, Xu *et al.* (2012) analysed key performance indicators (KPIs) for the sustainability assessment of building energy retrofitting in hotel buildings in China. The KPIs can help decision-makers to identify an optimal solution between alternatives, which presents the maximum sustainability performance. Jones and Bogus (2010) propose a decision-making process for energy-efficient retrofit project. In this study, a qualitative analytical approach is considered using patterns and relationships of energy use data. In specific terms, these studies highlighted the issues surrounding building energy retrofit to propose artefacts that resonate from socio-technical dimensions in building energy retrofit with precise steps for improving the delivery of the projects.

To this end, this paper contributes towards resolving this challenge through the development of an artefact for improving building energy retrofits in South Africa. The rest of the paper is structured as follows: research method, presentation and discussion of findings/results, artefact development and validation and conclusion.

Research method

A mixed method research design was utilized in this study. The choice of this research design was predicated on its utility in resolving complex research problems leveraging on the extant complementarities between qualitative and quantitative data collection and analysis techniques (Creswell, 2009; Gray, 2014). The study set out to develop and validate an artefact and an associated set of guidelines for engendering successful building energy retrofit projects (BERPs) for existing buildings in South Africa. To achieve this objective, data collection and analysis were carried out in three phases, namely:

(1) Phase 1: A pilot study;

(2) Phase 2: Live and desktop-based case studies, a focus group discussion forum and an expert survey and;

(3) Phase 3: Expert survey for the validation of the artefact.

Phase 1: The pilot study comprised of the conduct of unstructured interviews with a purposively selected sample of knowledge experts located across the globe. The interviewee demographics are presented in Table 1.

The use of the platform availed by Skype enabled face-to-face interview sessions with these interviewees, thereby eliminating proximity challenges. The interview sessions lasted for an average of 30 mins each and were conducted between September and November 2017. Besides enabling an assessment of the current best practices associated with the successful delivery of BERPs, the pilot interviews were used to further elicit key elements of BERP. Also, it allowed for an in-depth understanding of the challenges and enablers affecting successful BERPs. The data collected from this phase was analysed using a variant of the qualitative content analysis – the thematic analysis. The information gained from this pilot study further enriched the authors' knowledge of the BERP practice and research domain, especially in the face of the scant literature on BERP focussing on the South African context. In furtherance to this, it contributed to the development of the research instruments for subsequent data collection.

Phase 2: In the second phase, a mix of different methods was deployed to collect context and non-context data concerning the phenomenon being understudied from globally and locally renowned best practice case studies, semi-structured interviews, a focus group discussion and an expert survey. Following the development of a set of case study selection criteria, the authors adopted a juxtaposition of convenience and purposive sampling in the selection of relevant case studies for data collection. The main criterion was the evidence of successful retrofitting reportage associated with the selected cases in the corpus of existing literature. These selection criteria led to the identification of six case studies. Whereas four (4)

Interviewee	Organization type	Position	Experience in years	Country
PS 1	Research institute	Director	22	United Kingdom
PS 2	Research institute	Director	17	United Kingdom
PS 3	Consultant	Senior manager	14	South Africa
PS 4	Municipal government	Energy manager	26	South Africa
PS 5	Municipal government	Energy manager	17	Singapore
PS 6	Consultancy services	Energy manager	19	United States
PS 7	Consultancy services	Energy manager	12	United States
PS 8	Consultancy services	Energy manager	16	United Kingdom
PS 9	Research institute	Senior research fellow	7	South Africa
PS 10	N/A	Research fellow	14	Nigeria
PS 11	Consultancy services	Building energy use Expert/Analyst	17	Australia
PS 12	Consultancy services	Manager	15	Singapore
PS 13	Research institute	Research fellow	7	South Africa

Source(s): Authors' fieldwork (2017)

Table 1. Interviewee demographics for pilot study

of these case studies were situated beyond South Africa, two of such cases were situated within the country. A description of the case studies is provided in Table 2.

The authors relied on a content analysis of the literature concerning case studies 1–4. In cases 5 and 6, data was elicited from a review of project-related documents and six semi-structured interviews, evenly spread across both cases. Table 3 highlights the demographics of the interviewees within the live cases.

The central objective of the case study reviews and within-case interview sessions was to gather information pertaining to the practical experiences of relevant stakeholders who have been involved with BERPs within the South African context whilst also reviewing the utility of most of the operational facets identified during the pilot study interviews in engendering successful BERPs. Data relating to the latter was obtained from the analysis of the best practice desktop-based case studies (cases 1–4). These interviews were held at the offices of both organizations who had delivered cases 5 and 6 in Cape Town and Bloemfontein, both in South Africa between March and April 2018. The interview sessions lasted for an average of 20 mins each. The sessions were tape recorded with permission from the interviewees and transcribed verbatim for analysis. The data was subsequently analysed using thematic analysis according to the themes which had been used for the qualitative content analysis of the desktop-based case study materials and the other project-related documents obtained from cases 5 and 6.

In the aftermath of the interviews and document reviews and analysis of the case study data, a focus group discussion forum was convened by the authors to seek consensus on the various facets relating to the elements, the challenges and enablers affecting successful BERPs within the South African context. Achieving such consensus was deemed imperative as a wide-ranging data set had culminated from the various data collection techniques

Table 2.
Description of case studies

Number	Country
1	Australia
2	Singapore
3	United States
4	China
5	South Africa
6	South Africa

Source(s): Authors' fieldwork (2018)

Table 3.
Case study interviewee demographics

Category	Classification	Frequency	Percentage (%)
Gender	Female	1	16
	Male	5	84
Years of experience	5–10 years		
	10–15 years	1	16
	15–20 years	4	68
	20 years +	1	16
Profession	Architect	1	16
	Electrical engineer	1	16
	Facility manager	1	16
	Mechanical engineer	2	36
	Client	1	16

Source(s): Authors' fieldwork (2018) deployed for data elicitation. To this end, the lead author facilitated this focus group discussion forum. Although invitations were extended to the six interviewees drawn from cases 5 and 6, only five interviewees participated in the focus group proper. The focus group discussion was held in Bloemfontein with two discussants from the organization responsible for case 6 in the Cape Town, joining in through Skype. During the focus group discussion, discussants were presented with a recap of the variables which they had identified during the interview sessions which influenced successful delivery of BERPs by their organizations. The session which was also recorded with the permission of the discussants lasted for 45 mins.

Upon the attainment of a consensus concerning the elements of the successful delivery of a BERP as well as challenges negating such processes and enablers by practitioners during the focus group discussion session, the authors engaged in an expert survey with the intent of achieving a ranking of the various components (elements) of a successful BERP delivery exercise. Such ranking was expected to facilitate effective decision-making as it relates to the prioritization of these components in the development of the artefact for successful delivery of optimal BERPs in South Africa. As such, the questionnaires were developed from the data emanating from the previously described data collection platforms which was validated through the focus group discussion session.

Respondents who have been practically involved in the delivery of BERPs across the globe whose contact details were publicly available alongside the initial participants of the pilot study and interviewees/focus group discussion sessions were targeted. A total of 58 questionnaire surveys were electronically administered, and 38 responses were received, representing a 66% response rate. See Table 4 for the distribution of respondents. This response rate was considered sufficient for the intended purpose, as Moser and Kalton (1971) argue that the results of a survey can be regarded as acceptable even if the return rate is as low as 30–40%.

Phase 3: This phase marks the final phase of the data collection process for the study. This phase comprised of the validation of the developed artefact through the use of an expert survey. Of the 32 purposive survey questionnaires administered for this purpose, a total of 17 were returned and deemed useful for the intended purpose. This represents a response rate of approximately 53%. The validation questionnaire consisted of structured and semi-structured questions, which covered various aspects including practical relevance, coherence, applicability, logical structure, meaningfulness, clarity, areas of concern and

Category	Classification	Frequency	Percentage (%)
Gender	Female	9	24%
	Male	29	76%
Years of experience	5–10 years	8	21%
	10–15 years	15	39%
	15–20 years	12	32%
	20 years or more	3	8%
Profession	Architect	4	11%
	Electrical engineer	13	34%
	Facility manager	7	18%
	Mechanical engineer	8	21%
	Project manager	4	11%
	Construction manager	2	5%

Source(s): Authors' Fieldwork (2018)

Table 4. Distribution of expert survey respondent

suggested improvements. Table 5 highlights the distribution of respondents who participated in the validation of the artefact.

Quantitative data from the both surveys were analysed using descriptive statistics particularly the Mean Item Scores.

It is expected that the deployment of mixed methods for data collection and analysis as highlighted in the preceding sections serves as an indication of the degree of rigour and robustness ascribed to this study.

Presentation and discussion of findings

This section comprises of the findings emanating from the three phases of data collection and analysis described in the preceding section. However, the presentation of the data and subsequent discussion will be aligned to main categories namely: (1) determination of components of a successful BERP delivery process and (2) the development and validation of the emergent artefact. This presentation format is expected to enable coherence and streamlining of the data emerging from diverse data sources.

Components of successful BERP delivery in existing buildings: This section of the data presentation provides details concerning the elements (components) of the BERP delivery process, the challenges and enablers influencing successful BERP delivery as well as the ranking of various components of the BERP delivery process. This section is further delineated according to the themes relied upon in analysing the data from the pilot study interviews, the live and desktop case studies as well as the focus groups respectively in an integrated manner. In the aftermath of these, presentation of the ranking of the identified components will ensue.

Identification of components (elements) of successful BERP delivery

The identification of the components (elements) of successful BERP delivery is imperative for proper planning and management of the BERP delivery process. Most interviewees during the pilot study referred to the flexible, adaptable, complex socio-technical nature of the BERP delivery project. The complexities associated with BERP delivery were due to the prevalence of various stakeholders with conflicting interests and various factors and components needing to be considered (Awuzie and McDermott, 2013). According, interviewees called for

Category	Classification	Affiliation	Frequency
Gender	Female		6
	Male		11
Years of experience	5–10 years		1
	10–15 years		4
	15–20 years		10
	20 years or more		2
Level of qualification	Diploma		2
	Bachelor’s degree		4
	Master’s degree		5
	Doctoral degree		6
Profession	Architect	Consultant	1
	Electrical engineer	Energy service company	3
	Facility manager	Client (municipal government)	4
	Mechanical engineer	Energy service company	3
	Building energy analyst	Consultant	6

Source(s): Authors’ fieldwork (2019)

Table 5. Background information on experts that participated in the artefact validation

BERP delivery to be viewed through a multi-objective optimization model to cater to such complexities (PS3/4/5) taking cognizance of the building analysis, development of energy efficiency measures, implementation measures and monitoring and verification (interviewees PS1/2/6/7/8/12). By implication, the various components of a BERP delivery process can be categorized as belonging to either social or technical facets. Whereas aspects such as retrofit technology, building fabric, technology fit, client resources and payback periods were identified by interviewees as technical aspects of the BERP delivery process, the social aspects pertain to the behaviour of users of a facility regarding how they accept and use the retrofit technology. The uniqueness of different BERPs is influenced by the nature or availability of these components. This much was buttressed by the findings from the desktop-based and live case studies where building orientation, the building assessment, the detailed energy survey, the technical analysis, the retrofit technologies used, the cost–benefit analysis, the nature of the building, the implementation plan and the geographical location were highlighted as influencing the approach adopted during BERP delivery. Also, similar studies have highlighted this lack of a widely accepted approach to delivering substantial reductions in energy usage through BERPs, thereby indicating the reliance on a series of measures is uniquely required as per each project (Hewitt, 2012). The interviewees within case 5 and 6 affirmed this notion stating that to develop a context-specific solution to energy retrofitting of their building, they had conducted a thorough building assessment to determine the buildings' current energy consumption and performance level. The interviewees claimed that a detailed energy survey was conducted in order to identify needs, current operating and maintenance procedures and to estimate occupant behaviour and energy use density. According to these interviewees, these steps are carried out systematically in order to carry out a technical analysis, which assists in formulating an action plan for improving building energy performance, thereby benchmarking assessment to work out the best option for energy efficiency retrofit.

Challenges and enablers of successful BERP delivery

The BERP delivery process has continued to be beleaguered by certain factors which influence the delivery performance as well as the performance levels of the retrofitted building. Based on the interviews conducted and the case studies examined, these challenges identified from the various data sources include insufficient communication and insufficient consultation among relevant stakeholders. Interviewees admitted to lack of platforms for engendering stakeholder interaction and contribution towards successful BERP delivery. A lack of stakeholder agreement, the piecemeal fashion of doing things and the lack of social data incorporated in the project were also highlighted by the interviewees These were closely followed by a lack of collaboration and cooperation, which revolves around a lack of stakeholder activities to obtain buy-in into the project and experts operating randomly, which makes work move haphazardly. Lack of flexibility/adaptability was identified as another serious challenge in BERPs. This ability in times of unpredictability and complexity requires a trade-off between adherence to a process and adaptability/flexibility. They advocated that experts dealing in BER projects should obtain substantial benefits from being flexible, by applying learning through continuous improvement and administrative innovation, because no two BER projects are the same. Also, end users' awareness, attitudes and behaviours in relation to energy use and clients' requirements and experience (in most cases they have limited knowledge) were identified by the interviewees and the case study data. Any solutions proffered for overcoming these challenges serve as enablers for successful BERP delivery. Accordingly, the enablers for successful BERPs identified by the interviewees and buttressed by the case study analysis consist of establishment of robust communication channels, effective consultation among stakeholders to secure buy-in, identification of local/

contextual peculiarities associated with the existing building, deployment of the right technology, proper understanding of the socio-technical aspects of successful BERP delivery and their incorporation into the various stages of the BERP delivery process in an integrated manner.

Summarily, the discussants to focus group discussion forum corroborated the views elicited from the previously mentioned data sources.

Ranking of components of BERP delivery

This section of the analysis measures the key components worthy of inclusion in the design of an energy retrofit project for existing buildings. The experts were asked to assess the components of a building energy retrofit project according to a set of predetermined criteria. Possible scores for each of the criteria were 1 (not important), 2 (somehow important), 3 (fairly important), 4 (definitely important) and 5 (very important). The five-point scale was converted to mean percentages and mean scores (MSs) for each of the aspects as rated by the respondents. The scores made it possible to recognize the level of significance of the different aspects as rated by the respondents. This technique was then used to decipher the data gathered from the questionnaires.

The numerical results of the relative MSs were deduced from the data. This depended on the rule that respondents' scores on all the chosen aspects, considered together, are the observationally decided findings of relative importance. The record of MS of a specific aspect is the sum of the respondents' genuine ratings given by every single respondent as a small amount of the aggregate of all the most extreme conceivable ratings on the five-point scale that every one of the respondents could provide for that particular criterion. A scale was allocated to every response, ranging from 1 to 5. It is expressed mathematically further. The MS was calculated for each aspect as follows:

$$*\text{mean score} = (5*ns + 4*n4 + 3*n3 + 2*n2 + 1*n1)/(5+4+3+2+1),$$

where ns, n4. . . are corresponding responses relating to 5, 4. . .

Table 6 shows the results for these measurements and their ranking.

Table 6 indicates the extent of importance of seven components of building energy retrofit in terms of percentage responses on a scale of 1 (not important) to 5 (very important) and an MS between 1.00 and 5.00. It is notable that 71% of the components have MSs of >4.00 ≤ 4.30, which indicates that in general the components are very important factors, worthy of inclusion. It is also notable that the remaining components have MSs of> 3.80 ≤ 4.0, which indicates that they are important in any BERP.

From Table 6, it can be deduced that the aspect of a building assessment has an MS of 4.23, which suggests that it is worthy of inclusion in a given BERP. The MSs for detailed energy

Aspect	Scale (%) 5	4	3	2	1	MS	Rank
Building assessment	26.00	71.00	3.00	0	0	4.23	1
Detailed energy survey	24.00	71.00	5.00	0	0	4.18	2
Monitoring and verification of energy efficiency initiatives	18.00	82.00	0.00	0	0	4.18	3
Technical analysis	18.00	79.00	3.00	0	0	4.15	4
Cost–benefit analysis	15.00	82.00	3.00	0	0	4.13	5
Measurement of implementation	11.00	76.00	13.00	0	0	3.97	6
Project initiation	21.00	61.00	18.00	0	0	3.92	7

Source(s): Authors' Fieldwork (2019)

Table 6. Ranking of components of a building energy retrofit project

survey, monitoring and verification of energy efficiency initiatives, technical analysis and cost–benefit analysis are 4.18, 4.18, 4.15 and 4.13, respectively, which suggests that the respondents agreed that these aspects are relevant to delivery of any BERP. Measurement of implementation has an MS of 3.97, which shows the importance of this aspect in any BERP, while project initiation has an MS of 3.92, which indicates its importance. The scores of each of the components are >3.80, which suggests that these components are important in delivery of any BERP. Therefore, from the analysis it can be deduced that the various aspects highlighted are important in delivery of any BERP. This finding confirms findings from similar literature as it relates to key components of a successful BERP delivery process (see Bayat, 2014; Davies and Osmani, 2011; Hermelink, 2005; Koshman and Ulyanova, 2014; Ma *et al.*, 2012; Swan and Brown, 2013; Swan *et al.*, 2013, p. 181).

Artefact development

The artefact (Figure 1) was developed through the data elicited from the coterie of data sources mentioned in phases 1 and 2 of this research study. Herbert Simon's (1996), "*the* sciences of the artificial", first published in 1969 (Gregor and Jones, 2007; Iivari, 2013), provides the knowledge on how to evolve artefacts. According to these authors, Simon believed that design theory was concerned with how things ought to be to attain goals. To Simon, an objective of design activity was the description of an artefact in terms of its organization and functioning. The design process could be informed by knowledge of the laws of natural science, engineering, socio-technical factors, psychology and sociology for an artefact's internal operations and its interactions with the external environment (Gregor and Jones, 2007; Iivari, 2013).

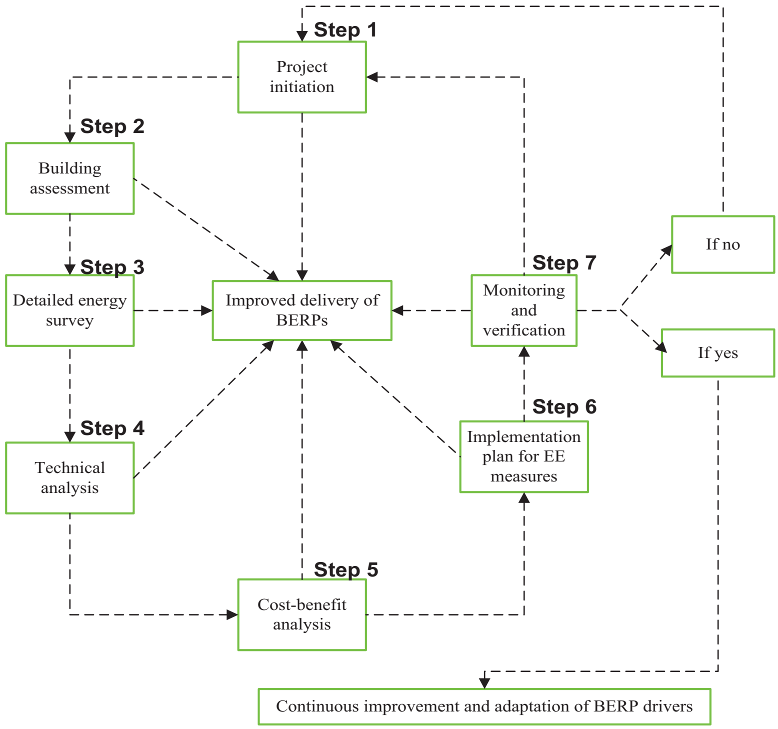

Figure 1.
Proposed artefact for BERP delivery in South Africa (Authors' fieldwork, 2019)

However, the literature on artefact development in building retrofit studies is limited. As such, this research relied on prior work on artefact development and validation in other fields to arrive at the basic principles for artefact development, testing and validation. The artefact development stages revolve around identifying the component parts, the relationship between principal components and the logical flow. This process of artefact development was underpinned by the theory of the CAS. The operationalization of the artefact consists of all the perceived components of Building Energy Retrofit practices and the expected outcomes. The expected artefact platform for BERP delivery is influenced by socio-technical aspects of energy retrofit. The proposed construct comprises of distinct but complementary parts, which include human factors (social viewpoints and attitudes towards energy), material culture (retrofit technologies and the building fabric), the retrofitting programme, end-user energy management and energy retrofit best practices.The artefact is developed through a logical linking of multiple sequential areas of inquiry, which include:

(1) Evaluating the current best practice of energy retrofit within the industry;

(2) Evaluating the key elements involved in energy retrofit of an existing building;

(3) Critical evaluation of the challenges and the solutions associated with BERPs;

(4) The correlation between these variables and the impact on the project's whole life cycle; and

(5) Examining opportunities for this broader vision of the artefact to serve as a point of reference for continuous improvement of the industry, as the artefact is not an end, but the means to an end.

Artefact evaluation

According to Venable *et al.* (2012), artefact evaluation is a scientific process of demonstrating the quality of work towards achieving the research objectives as demonstrated by the researcher and peers in the industry. Table 7 presents the results of the artefact evaluation. Overall, the general feedback on the artefact is positive. The experts surveyed made positive comments on the artefact and its components. The systematic approach followed in its development was applauded, as well as its applicability. The artefact was classified as being a product of pioneering research with clear and comprehensive underlying relations, within its context. Moreover, the developed artefact was seen to be compatible with global contemporary thinking in attempts to find a new approach to BERP delivery.

Table 7 shows the artefact validation results.

For the scoring method, the interviewees were asked to assess the artefact according to a set of predetermined criteria based on the artefact reviewed by them. Chew and Sullivan (2000) argue that the objective of any artefact validation is to ensure that it adequately reflects

Table 7. Artefact validation based on the scoring method

	Excellent……………….Poor						
Criterion	5	4	3	2	1	MS	Ranking
Practical relevance	41.00	53.00	6.00	0	0	4.35	1
Coherence	41.00	41.00	18.00	0	0	4.23	2
Applicability	35.00	53.00	12.00	0	0	4.23	3
Logical structure	29.00	59.00	12.00	0	0	4.17	4
Meaningfulness	23.00	71.00	6.00	0	0	4.17	5
Clarity	23.00	65.00	12.00	0	0	4.11	6

Source(s): Authors' fieldwork (2019) the artefact objectives. Further to this, Martis (2006) stated that the artefact developed should adequately meet the following criteria: logical structure, clarity, comprehensiveness, practical relevance, applicability and meaningfulness. These criteria were the ones included in the questions asked. Possible scores for each of the criteria were 5 (excellent), 4 (above average), 3 (average), 2 (below average) and 1 (poor). Table 6 shows the results for this method of validation in terms of percentage responses on a scale of 1 (poor) to 5 (excellent) and an MS between 1.00 and 5.00.

*mean score $= (5*ns + 4*n4 + 3*n3 + 2*n2 + 1*n1)/(5+4+3+2+1)$, where ns, n4... are corresponding responses relating to 5, 4...

Practical relevance has an MS of 4.35, which indicates that the idea is capable of being done or put into effect. The MSs for coherence and applicability are both 4.23, suggesting that the respondents agree that the artefact is clear and relevant and that all the parts fit together. Logical structure has an MS of 4.17, which indicates that this score is by far above average. Logical structure in this case assesses the consistency of the artefact, where the properties of the real system are mimicked. The results indicate that no logical disjoint exists. Artefact clarity has an MS of 4.11, which shows that the artefact captures important variables that can aid in improving BERP delivery.

These scores are, once again, above average, which suggests the utility of the artefact. They also support the comments that the artefact is robust enough and covers important issues necessary for implementation of BERP delivery. Generally, the participants confirmed the uniqueness of the artefact in demonstrating the innovative features that can transform the current industry practices and avail the industry of some useful tools needed for raising awareness and understanding of implementation issues in BERPs. Its implementation should engender improved new leadership attitudes, knowledge and skills and a new industry culture. In addition, the feedback on the artefact appropriateness to the industry was positive. Some of the respondents described the artefact as very comprehensive and expressed their willingness to adopt its principles for their future building works. However, some participants suggested some ideas and areas for improvement for the artefact operationalization. Some such suggestions are: "The project initiation should read 'BER project initiation', and the stages in the artefact should be clearly stated. Subsequently provide clarity in the flow of events". These suggested areas for improvement were analysed in the light of consistency with other comments, the available literature and data, to justify their worthiness for incorporation in the BERP artefact.

Artefact improvement

The improved artefact is presented in Figure 2. It links the enabling drivers that would necessitate effective implementation of BERPs in the South African construction industry. The goal of this artefact is to define various levels of effort needed for energy efficiency in existing buildings and thus provide reference steps for building owners, managers, government entities and other stakeholders sharing different levels of energy assessment and different procedures.

Energy retrofitted building has proven to provide conservation of energy and to offer one of the quickest, most cost-effective and most environmentally friendly ways to reduce CO_2 emissions. In achieving this, a detailed process was deduced from the study as depicted in the improved artefact. See Table 8:

The validated artefact therefore accomplished the main aim of the study. Since industry stakeholders have expressed the need for a shift from a piecemeal fashion to a more holistic approach in delivery of BERPs (Swan *et al.*, 2013), this new paradigm will emerge when stakeholders are equipped to critically assess the impact of the interaction between the social and the technical components of building. For this interaction to be meaningful, stakeholders

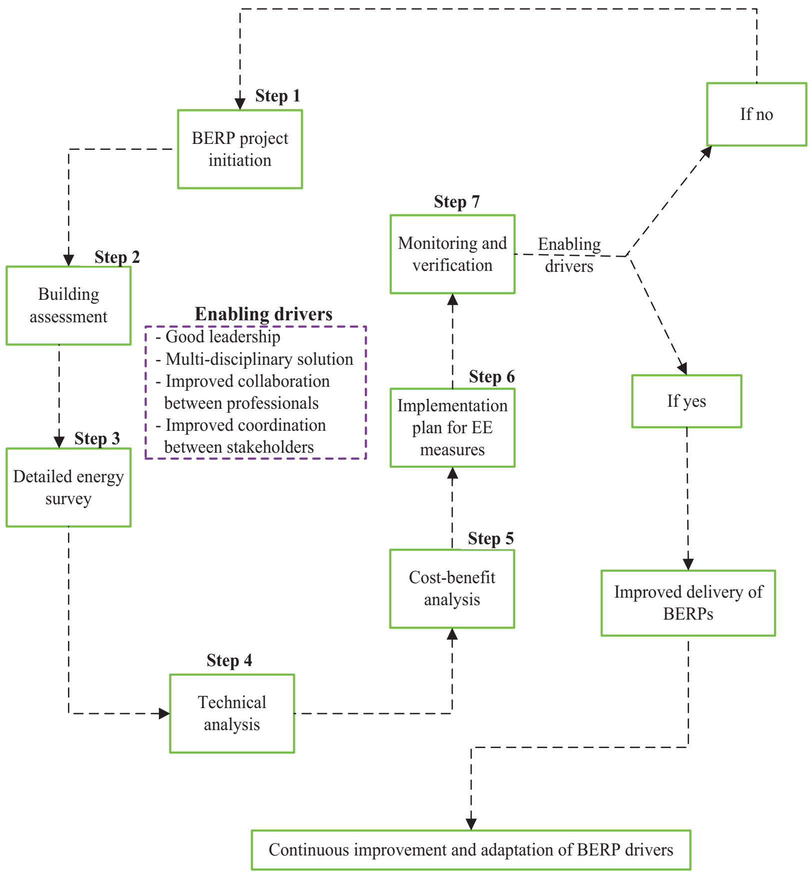

Figure 2.
Validated artefact for BERPs delivery in South Africa (Authors' fieldwork, 2019)

need to understand the socio-technical dimensions in building energy use. Industry stakeholders should be able to evaluate their current practices in terms of integrating this concept.

Concluding remarks

The study conceptualizes an artefact for improving the delivery of BERPs from complex adaptive system perspective and provides an adaptive form of governance needed for socio-technical systems such as BERP delivery systems. The article has outlined an adaptive route for sustainable BERP delivery by explaining ways in which an integration of socio-technical principles can drive transformation in the retrofit space. The use of data from mixed methods design to develop and validate the artefact by experts show a possible way forward regarding the promotion of sustainability in the built environment in South Africa. The proposed artefact was validated for its robustness in transforming BERP delivery. Such a shift will engender efficient and effective deployment of resources and techniques.

The following recommendations for policy and industry practice are made based on the findings and the conclusions. The artefact requires better leaders to engender its principles. Integrated forms of BERP delivery are required to deliver the type of value chain needed for

Table 8. Description of BERP stages according to artefact

BERP stages	Description
Stage 1 (BER project initiation)	Key to successful delivery of a BER project is preparation, planning and leadership. This can be achieved through the following steps: consulting with the stakeholders in the early stages of the project, collaboration and cooperation with the stakeholders in the early stages of the project, a complete plan of action, stating what is to be done and how best to achieve it, clear, correct and concise modes of operation, user engagement and education in the early stages of the project, thorough planning on how to meet user needs without stopping building operations, provide an overview of building energy used, provide a forward-looking view to guide investment for decision-makers and provide an evidence-based estimate of expected energy savings and associated benefits. The goal of this stage is to define various levels of effort needed for energy efficiency in existing buildings, to provide a point of departure for building owners, facility managers, contractors, government entities and other stakeholders that are embarking on energy efficiency drives in existing buildings
Stage 2 (Building assessment)	A building assessment can assist the stakeholders in establishing long-term strategies. Providing information on measures to stimulate cost-effective deep retrofit of buildings can unfold as follows: determining energy consumption of the building, determining performance level of the building, determining user behaviour and collecting utility bills for at least one year, with the aim of lowering energy consumption. The goal of this stage is to review the collected data, so as to incorporate it in the final energy efficiency measures that are to be installed
Stage 3 (Detailed energy survey)	In this phase, an energy survey is carried out with the help of an energy auditing team, so as to understand the energy system for the building. An energy audit needs to include all possible energy details in the energy system. The following should be observed in a detailed energy survey: The retrofit strategy must be tailored according to the needs of the facility; the team should include professionals including architects, HVAC engineers and electrical engineers. Team selection helps ensure that energy audit results can be implemented at the site, by involving experts from various disciplines. Importantly, while selecting team members, it is important for the owner to define shared goals. The team is responsible for a systematic approach in identifying, selecting and formulating recommended measures. Energy mapping is done to determine how much energy is consumed by the building, by collecting all information related to the energy system and equipment details, energy segregation can be estimated. A walk-through survey will aid in providing adequate information, where familiarity with all the energy systems helps in generating recommendations for retrofit measures. In determining the baseline, an energy survey is performed to collect the operating condition details of the building. After the data collection process is complete, a sheet could be formulated to analyse the building's energy consumption. Based on the operating characteristics, the minimum energy requirements of the building can be determined. This basic data collection helps to identify either a low-cost or a no-cost measure for improving energy efficiency. Historical building energy data needs to be collected for at least three years. This data is required to provide historical energy use profiles. The collected data needs to be put in graphical form to examine the patterns and identify the anomalies (pattern matching). By comparing the graphs and the values, unexpected patterns in energy use can be seen. More cost-saving measures can be identified. The baseline assessment after the energy survey will determine the minimum energy requirements of the building. It provides a critical reference point for assessing changes and impact, as it establishes a basis for comparing the situation before and after the intervention, and for making inferences as to how effective the installed system is

(*continued*)

BERP stages	Description
Stage 4 (A technical analysis)	A technical analysis studies the data from the energy survey, including energy consumption and peak demand analysis. It identifies and provides technical parameters, by selecting electrical product options through energy simulations. With more extensive data collection and engineering analysis, this plan provides most of the information, which can be acted upon. Based on the retrofit options available for energy efficiency, detailed analysis is carried out by formulating an action plan, conducting a benchmarking assessment and doing an analysis through software. Some features of a technical analysis are as follows: Formulating an action plan helps to improve building performance through maximum energy savings. To determine the energy plan, the following steps are to be followed: analysing the energy system of the building from on-site observation, measurement and engineering calculations of the building envelope, lighting, HVAC and so on, reviewing existing operations and maintenance, and then change plans, improvements and estimations of costs, measuring important parameters and compare them to the design levels, determining the rate structure for energy usage. A benchmarking assessment helps to work out the best option for energy efficiency retrofitting in existing buildings. Electrical measurement carried out through instruments helps in generating secondary data. Furthermore, it is required to work on the observations and then benchmark the received data, which can be compared to the design level as per codes and standards. Based on the comparison of information of existing levels, if there is a need to improve the energy levels, an organization can opt for a more detailed energy audit. The most important factor for success is to identify where energy is exceeding and, based on the plan of action, to select the retrofit option that has maximum saving potential. After determining the gaps, it is advised to perform energy simulations, to determine the retrofit potential based on the best available technology and its respective payback period. After all the measurements and data collection, the team needs to identify the software (DIALux, Ecotect, Revit, etc.) on which the simulation is to be performed, to analyse the operating conditions and to determine the areas where most cost-benefiting retrofit plans can be executed. After energy simulations of various electrical loads, a suggested plan of action should be carried out. Modelling (simulation) of annual energy performance needs to be done. It provides detailed project cost and savings calculations, with a high level of confidence. As for major capital investment decisions, a comprehensive life cycle cost analysis is the best decision-making tool. In addition, the following options can also be considered: selecting of (best available technology BAT): After performing the energy simulation, the team is required to provide the owner with retrofit plan. The team should then look for best available technology present in the market and then decide on BAT they will adopt, by working on the various parameters, such as efficiency, payback period, first initial cost and so on. After selecting the BAT present in the market, the team needs to perform the energy simulation again, in order to determine the difference in efficiency, comfort level and so on, between the suggested retrofit option and the installed equipment
Stage 5 (A cost–benefit analysis)	In appraising the cost potential, with respect to the findings from the technical analysis, capital payback calculations should be performed. This helps to choose the best retrofit option in line with user requirements and budgetary constraints. For all the practical measures and recommendations, a cost–benefit analysis needs to be carried out. This is done to identify efficiency-modification opportunities. The energy auditor requires a building envelope expert, a mechanical engineer and an electrical engineer (lighting and control system expert). The best outcome of retrofits depends on a combination of skills and procedures. Complex building and varied energy systems require a more experienced team. Importantly, the facility manager needs to develop synergy between site staff, contractors and building occupants, to support and provide building information

(*continued*)

Table 8.

BERP stages	Description
Stage 6 (An implementation plan of energy efficiency measures)	Once the retrofit plan is finalized after conducting a thorough cost–benefit analysis, the team should then work on implementing the retrofit. Proper project planning should be done, in terms of assigning appropriate timelines and understanding the commitment and involvement mechanisms, as well as project finance, so that implementation is seamless
Stage 7 (Monitoring and verification)	This serves to track implementation and outputs systematically and to measure the effectiveness of energy efficiency (EE) drives. In addition, it helps to improve performance and achieve results. It helps to determine exactly when an EE drive is on track and when changes may be needed. Its goal is to improve current and future management of outputs, outcomes and impact. Monitoring and verification provides information that will be useful in analysing the situation in the BERP, determining whether the inputs in the projects are well utilized, identifying problems facing the EE drivers and finding solutions, ensuring that all activities are carried out properly, by the right people and in time and using lessons learnt for continuous improvement

Source(s): Authors' fieldwork (2019)

Table 8.

BERPs, which can only be actualized through having better industry leaders. Industry stakeholders who are in the business of building energy retrofit should be developed with the skills required to engender such complex BERP delivery practices, in such a way that they will become standard practice. The study has assisted stakeholders to have a comprehensive view of the validated artefact and its impact on BERP performance. So it offers a knowledge base for industry stakeholders and organizations that intend to implement BERPs. It will also assist contracting organizations to be better equipped with a critical understanding of the strategies to be adopted, in order to enhance the overall sustainability of the trade.

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