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A HOLISTIC MULTI-METHODOLOGY FOR SUSTAINABLE RENOVATION

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Abstract. A review of the barriers for building renovation has revealed a lack of methodologies, which can promote sustainability objectives and assist various stakeholders during the design stage of building renovation/retrofitting projects. The purpose of this paper is to develop a Holistic Multi-methodology for Sustainable Renovation, which aims to deal with complexity of renovation projects. It provides a framework through which to involve the different stakeholders in the design process to improve group learning and group decision-making, and hence make the building renovation design process more robust and efficient. Therefore, the paper discusses the essence of multifaceted barriers in building renovation regarding cultural changes and technological/physical changes. The outcome is a proposal for a multi-methodology framework, which is developed by introducing, evaluating and mixing methods from Soft Systems Methodologies (SSM) with Multiple Criteria Decision Making (MCDM). The potential of applying the proposed methodology in renovation projects is demonstrated through a case study.

Keywords: sustainable building renovation, problem structuring, multi-methodology, Soft Systems Methodologies (SSM), Multiple Criteria Decision Making (MCDM).

Introduction

Recent investigations into the field of building renovation[1]/retrofitting[2] reveals an increasing attention in many European countries. The main reason for this is due to the fact that existing buildings consume a considerable amount of energy – more than 40% of the total European energy consumption is used in buildings for heating and operating equipment (Buildings Performance Institute Europe [BPIE], 2011). It is important to initiate retrofitting projects in which the energy efficiency is improved and hence the cost of cooling, heating and lighting is decreased. But enhancing energy efficiency is not the only goal for renovation of existing buildings. At present, the extent of the potential for energy improvements can be described and made up in several ways. This can happen with focus on climatic interests, security of supplies, environmental impacts, life-cycle cost, indoor climate, building functionality, spatial quality issues and other relevant arguments. There is a wide array of advantages that can be obtained as an outcome of retrofitting to higher energy performance standards from a sustainability point of view. Many are tangible and possible to quantify, while others are less so and may be difficult to allocate a monetary value. These renovation goals must be identified and targeted precisely, and presupposes that the different stakeholders are involved and stay involved throughout the process (for the reasons that are investigated in the following section).

[1] This paper concerns renovation of ordinary and contemporary built buildings. The outcome is particularly useful for renovation of residential buildings (social housings / dwellings) with no specific historical background and values, which cause to exclude them to go under a deep renovation. In other words, the term building renovation in this paper should be distinguished with preservation or conservation fields that are related to the buildings with historical values or monuments.

[2] In this paper, the term "building renovation" is used as the equivalent of "building retrofitting" in accordance with the "sustainable development paradigm". The authors' intent is to fill the gap, which exists between these two terms in existing literature.

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1. Current barriers in the building renovation field

Experience from projects and research carried out over recent decades has identified numerous barriers that hinder the uptake of a comprehensive building renovation. BPIE (2011) reported existing barriers in this field, including headlines such as '*financial*', '*institutional* & *administrative*', '*awareness, advice* & *skills*' and '*separation of expenditure and benefit*'. Further, a list of five main constraints that building renovation projects face, from pre-retrofit to post-retrofit stages, were explored by Cattano, Valdes-Vasquez, Plumblee, and Klotz (2013), including:

- Pre-existing hidden conditions are identified late in the design process,
- Typical renovations do not account for interactions between building systems,
- Energy retrofits are not coordinated with other building system renovations,
- Many industry professionals lack experience with the methods and materials required to deliver successful sustainable renovations,
- Poor measurements of the benefits achieved in sustainable renovations.

Galiotto, Heiselberg, and Knudstrup (2015) discussed retrofitting barriers that occur due to *politico-economic* barriers (which need to be addressed by policy makers and market developers), *technical* barriers (which need to be addressed by architects and engineers), and *behavioural* barriers (which are the direct impact of building owners and occupants). In relation to the last-mentioned barrier, the authors (Galiotto et al., 2015) emphasized the role of occupants' behaviour in building energy consumption, and reasons for *behavioural* barriers reported as for instance limited knowledge about the building renovation process (Boeri, Antonin, Gaspari, & Longo, 2014) and its benefits among stakeholders, or lack of guidance from the government and responsible institutions etc.

The building occupants indirectly influence the pattern of energy demands due to the changes over time in occupancy schedules and usage patterns (Masoso & Grobler, 2010). In connection to this, Booth and Choudhary (2013) categorized the most common barriers in a building renovation as the *pre-bound effect* which is known as the divergence between modelled and actual energy consumption for the pre-retrofit, and *rebound effect* in which the post-retrofit energy consumption is higher than predicted, due to either technical issues such as incorrect design options, failures and mistakes during construction works, pre-existing conditions (solar exposure conditions and orientation, historical and cultural heritage interest, local, many others) or more importantly changes in occupant behaviour. The essence of the pre-bound and rebound effects lead to a substantial disparity between the predicted and actual energy savings. The authors (Booth & Choudhary, 2013) considered that the removal of these barriers may reduce renovation costs and yield buildings that consume less energy and resources. Nevertheless, Yu, Fung, Haghighat, Yoshino, and Morofsky (2011) stated that understanding of building occupants' behaviour in a renovation field is not addressed adequately through the renovation process since the general focus in this field is still on technical goals i.e., energy efficiency. It seems essential that the design approach should integrate the effects of a building's technical aspects together with the users' behaviour representation, giving them the same importance (Degan, Rode, Vettorato, & Castagna, 2015; Tweed, 2013). From another perspective, Acre and Wyckmans (2015) discussed that post-occupancy evaluation of renovated buildings, which is often used to assess the impact of energy renovation, fails to examine the social context correctly due to the fact that many of the energy efficiency measures and technical issues in energy renovation remain abstract to the occupants. The authors (Acre & Wyckmans, 2015) indicated that due to the abstract nature of technical issues, and to improve the interface between technical dimensions and occupants, the non-technical issues which are more intuitive to human perception, need to be unfolded to the key stakeholders involved in the renovation process.

1.1. The concept of holism in building renovation

In order to find a common pattern for the identified barriers, we begin by posing the question "what is the reason for renovating existing buildings"? Buildings are renovated to make changes. The motivation for making these changes can be different from project to project. From one perspective we can discuss how objectives/criteria are met by applying technical/physical or technological renovation solutions through changes to the building itself (Kamari, Schultz, & Kirkegaard, 2018d). As an example, we see how re-insulation of the external wall can be a possible renovation solution when the objective is to improve the energy efficiency of a building. From another perspective (as discussed in the previous section), many of the barriers in contemporary building renovations are related to use of the building. As such, another way of improving the objectives/criteria can be to update the building occupant's knowledge about renovation and sustainability objectives. Such objectives are usually demanded by governments, or bodies of the governments such as municipalities, to meet some specific goals i.e., promotion of consumption patterns for reduction of the energy. Regarding the full scope of this discussion, Kamari, Corrao, and Kirkegaard (2017c) addressed a new "Holistic sustainability decision-making support framework for building renovation" by applying Checkland's Soft Systems Methodologies – SSM (2000) beside Keeney's Value Focused Thinking – VFT (1992). As such, sustainability was defined and represented in its full sense from three categories including Functionality, Accountability and Feasibility (18 sustainable value-oriented criteria have been identified) for holistic/deep building renovation purposes (see Appendix 1).

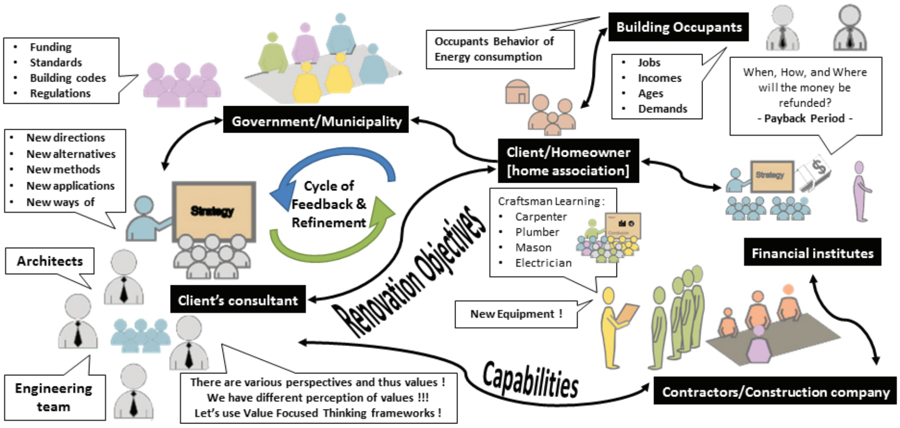

Figure 1. The key stakeholders involved in the process of a typical renovation project[3]

Based on the above, the authors suggest that the origin of changes in the renovation field can be divided into two categories including 1) the changes which need to be applied to the building itself (physical changes and potential application of renovation technologies) and 2) the changes which relate to the building's occupants (to respond to the behavioural barriers). For this discussion we borrow the concept of *Transformational* and *Incremental* changes from the "organizational change management" domain (McNamara, 2006). The term *Incremental* change might include continuous operational improvement or implementation of a new technical system to increase efficiencies while *Transformational* (or radical, fundamental) change targets changing an organization's *culture* (the people or society). Similarly for the building renovation field, we can refer to option 1 above as the *Incremental* changes and option 2 as the *Transformational* changes.

However in the renovation field, *Transformational* changes targets a bigger community than only the occupant of the building. In other words, there are various stakeholders who are involved in this field and act as decision makers in the renovation design process. They all have influence in the process and therefore need to be included and considered as *culture* for this field. For more clarification, Figure 1 illustrates the different stakeholders who are involved in a building renovation process, as well as key factors which they each deal with.

Accordingly, in order to achieve a successful building renovation, the requirements are:

Cultural (or Transformational) changes, [which targets society and here refers to enhancement of the awareness, education and inspiration among the 'society' or the community of different stakeholders who are involved in a retrofitting process (see Figure 1)],

and

Technological/Physical (or Incremental) changes, [which targets the physical changes of the building and potential application of new technologies, i.e. insulation of the external walls which will be applied as part of a renovation strategy for the enhancement of the various objectives (i.e. energy efficiency, aesthetic, water efficiency, safety etc.). A comprehensive list of renovation approaches based on analysis of a real case study and existing literature was developed by Kamari, Corrao, and Kirkegaard (2018a) in 26 categories (see Appendix 2) including 139 renovation technologies/actions].

Hereafter, the concept of "*Holism*" is assigned to initiatives which combine *Transformational (cultural)* and *Incremental (technological/physical)* changes for building renovation. A renovation problem, hence, is considered as a complex system because it cannot be fully addressed, evaluated and enhanced without comprehension of the relationships between its *culture* and *technological/physical* changes. For further clarification about the problem, we lean on the notion of *messy/wicked* problems from the field of social planning. The phrase *wicked problems* (Churchman, 1967) was originally used to demonstrate problems that are difficult to solve, because they address complex social interdependencies (Midgley, 2000). There are at least two attributes of a wicked problem; firstly, it is difficult to formulate solutions, because of the complexity of socio-cultural interactions and interdependencies; this leads to the inability to foretell long-term effects of decisions since the recognition of the source of the problem is highly complicated. Secondly, the definition of objectives due to various circumstances is provisional, and it entails different features, ideas and interests (Estkowski, 2013). Similarly, the characteristics of the problem within the renovation field involves various types of stakeholders, sustainability criteria (qualitative and quantitative) and selection of potential alternative renovation solutions that vary from case to case. In addition, renovation solutions that work well in one project may be inapplicable in another due to changes in environmental circumstances or in the constellation of stakeholders.

[3] The Figure has been developed by Aliakbar Kamari as a part of development of a Rich Picture (a common SSM method) for building renovation during conducting a workshop regarding to the RE-VALUE project in November 2016.

The description above reflects that building renovations make up highly complex problems. As such, there is an identified need to investigate and develop an appropriate holistic methodology, which can deal with both *cultural* and *technological/physical* aspects simultaneously. The methodology should be able to address the wicked nature of renovation problems and improve the awareness and learning about sustainability, sustainable retrofitting and sustainable living among the stakeholders. In addition, it should be able to identify, manage and evaluate the building objectives concentrating on selection of the multiple criteria, which form the basis for generation of alternative renovation scenarios[4]/packages. But a logical question arises: what type of design methodology is most suitable and how can it be developed to deal with the complexity of such problems (?).

1.2. Three levels of decision-making for building renovation

As part of previous research, Kamari, Jensen, Corrao, and Kirkegaard (2017a) investigated current design methodologies and processes of building renovation. Furthermore, the same authors (Kamari, Corrao, Petersen, & Kirkegaard, 2017b) explored the decision-making processes for the building renovation field, and here through identified a need for introducing three different decision-making levels (see Figure 2) to help stakeholders in the renovation process discuss their project "on the same level" and make transparent decisions in a rational order. As such, the researchers (Kamari et al., 2017b) introduced two Sustainable Retrofitting Framework and each one including three levels of decision-making. The frameworks were developed based on application of Multiple Criteria Decision Making (MCDM) including either Multiple Attribute Decision Making – MADM methods (option "A") or Multiple Objective Decision Making - MODM (option "B") for building renovation. The authors concluded that the decision-making at the third level of option "B" (based on application of MODM) can be considered as a scientific design approach and was introduced as an integrated design process implementation and evaluation for the use of both quantitative and qualitative objectives/criteria. Further, the frameworks helps to facilitate understanding of the design process implementation through identification of the different activities, which need to be carried out.

The aim of the present paper is to develop a Holistic Multi-methodology for Sustainable building Renovation (hereafter referred to as HMSR), which can help stakeholders overcome the problem formulated in the previous

Decision making at level 1

It has been designed to respond to variety of stakeholders who are involved in the renovation process as well as problem structuring of the renovation case regarding to the building conditions.

Decision making at level 2

It has been formulated to address the trade-offs or correlations between the sustainability criteria and related renovation strategies.

Decision making at level 3

It has been addressed to make the decision on selection of the most efficient renovation scenarios, and entitled *Scientific Decision-making.*

Figure 2. Three levels of decision-making for building renovation (adapted from Kamari et al., 2017b)

section. To this end, the HMSR is structured following the option "B" from (Kamari et al., 2017b) to make decision at the third level, which has been entitled "scientific decision-making" within an integrated design schema. This is elaborated further in section 3.4.

1.3. Research methods and strategy

The research strategy employed in the present study calls for an inductive research approach (Groat & Wang, 2013). It involves an interpretive approach and comparative analysis to its subject matter (Denzin & Lincoln, 1998). A case study has been investigated as well. Nevertheless, the primary challenge in this study was to recognize areas of knowledge and disciplines that affect the discovered renovation barriers. They were identified as *sustainability, complexity, wicked/messy problems*, *stakeholders, change management, decision-making,* and ultimately configuring the concept of *Holism* for the building renovation field. Considering these identified areas, and in order to develop an equipped design methodology, the research has found a starting point in Systems Theory and Thinking (Bertalanffy, 1968; Checkland, 1999; Weinberg, 2001; Midgley, 2003), Operation Research (Churchman, Ackoff, & Arnoff, 1957; Hillier & Lieberman, 1967), Critical Systems Thinking (Flood & Romm, 1996) which *aims to combine systems thinking and participatory methods to address the challenges of problems characterized by large scale, complexity, uncertainty, impermanence, and imperfection* (Bammer, 2003, p. 1), and Critical Realism (Bhaskar & Hartwig, 2008; Mingers, 2014) which combines a general philosophy of science (transcendental realism) with a philosophy of social science (critical naturalism) to describe an interface between the natural and social worlds.

2. Understanding of 'methodology' and 'design methodology'

The word 'methodology' was originally used to describe 'the science of method', which technically makes the concept of 'a methodology' meaningless. However, Checkland (2000) distinguishes this traditional meaning of 'a methodology' towards a new one including different sets of principles. He addresses 'methodology' as *a body of methods used in a particular activity* (Checkland, 2000, p. 26).

[4] The term "renovation scenario" used in this study refers to the selection and combination of different renovation technologies/actions (i.e. insulation of the external walls or replacement of the windows are each a renovation action) that together build alternative renovation scenarios/packages and subsequently is applied to a renovating project.

Moreover he claims that this latter definition makes the crucial distinction between 'methodology' and 'method'. As the structure of the word indicates, 'methodology' in this situation leads to selection of some certain 'methods', in the form of the specific approach adopted for the specific situation. According to Checkland (2000), most recently developed methodologies follow this latter definition.

There is now a huge diversity of methodologies within the broad field of Decision-making and Management Science, and Engineering Design, all having differing characteristics and stemming from various paradigms based on different philosophical assumptions. Depending on the type of the problem that they are dealing with, including "objective" or "subjective", "soft" or "hard", and "quantitative" or "qualitative", the methodologies can be categorized in two types including Soft Systems Methodologies and Hard Systems Methodologies (Checkland, 2000). "*Soft value management skills are used more in the early project stages when the project is not fully defined. This usually involves reaching consensus with many different stakeholders. As the design develops towards resolved design solutions, so hard value management skills and methods increase in importance*" (Dallas, 2006, p. 122). The two mentioned terms have been explored more in detail in sections 3.1 and 3.2.

Researchers such as Cross (2001) strived to investigate and address the methodologies and their differences between *design* and *science* contexts. In this consideration, he identified "Operation Research" as a Scientific Design concept and "Systems theory and thinking" as a Design Science concept (Cross, 2006). Simon's (1969) positivist concept leads to a view of design as 'rational problem solving', and Schön's and Wiggin's (1992) constructivist concept leads to a view of design as 'reflective practice'. Cross (2006, p. 102) argues that these two concepts might appear to be in conflict, but Dorst's (1997) use of the two paradigms in analysing design activity, leads him to the appreciation that the different paradigms have complementary strengths for gaining an overview of the whole range of activities within the design domain (Schön, 1988). Whilst this plenitude can enhance practice, it also poses problems for practitioners who often tend to restrict themselves to one paradigm or even one methodology (Mingers, 2014). Similar to Dorst's concept mentioned above, Jackson (2003) states that different methodologies are making different assumptions about the problem at hand and are hence complementary to one another; it is therefore necessary to make a choice as to which methodologies are appropriate for a particular intervention. Mingers and Brocklesby (1997, p. 2) contribute to the discussion by stating that to deal with the richness of the real world, it is desirable to go beyond using a single (or, on occasions, more than one) methodology. They argue that it is possible to combine several methodologies – in whole or in part – which stem from different paradigms.

The multifaceted problem for building renovation (which was elaborated in section 1.1) is diverse and complex in character and, it therefore seems obvious that it cannot be served by a single methodology. Consequently, it is the authors' intention to develop a multi-methodology as a way to strengthen multiple perspectives on this complex problem and thereby overcome the shortcomings of traditional approaches. The following section of the paper will focus on exploring existing methodologies and methods (see sections 3.1 and 3.2); subsequently to mix them (section 3.3) and ultimately to develop the HMSR (section 3.4), which aims to deal with different aspects of the concept of *Holism* for implementation in the building renovation field.

3. Developing the Holistic Multi-methodology for Sustainable Renovation (HMSR)

3.1. Appropriateness of Soft Systems Methodology (SSM)

SSM was developed by Peter Checkland in 1970s at Department of Systems, University of Lancaster. Checkland and Scholes (1990) distinguish between "hard" and "soft" systems thinking within the attempt to use system concepts to solve problems. Simonsen (1994) describes Hard Systems Thinking within a) Systems Engineering (as the traditional research strategy or design approach for engineers and technologists) and b) Systems Analysis (as the systematic appraisal of the costs and other implications of meeting a defined requirement in various ways). In this perspective the author (Simonsen, 1994, p. 2) discusses that *Hard Systems Thinking has the starting point in 'structured' problems and the assumption that the objectives of the systems concerned are well defined and consistent*; unlike *Soft Systems Thinking* [which] *has the starting point in 'unstructured' problems within social activity systems in which there is felt to be an ill-defined problem situation*. Checkland (1981) refers to Hard Systems Thinking as the 'optimization paradigm' while Soft Systems Thinking is referred to as the 'learning paradigm'. As such, the SSM approach stems from the 'systems movement', which Checkland (1981) considers as an effort to give holistic approaches in socio-technical problems. It is a method that in a systematic way attempts to establish and frame a debate regarding actions for complex and messy situations (Simonsen, 1994). SSM is primary applied in the analysis of complex situations where there are divergent views about the definition of the problem i.e., where nonlinear relationships, feedback loops, hierarchies and emergent properties have to be taken into account. The soft system's method postulates understanding of a system, by iterative learning process. The methodology provides a well-defined action research approach to help address wicked problems. The concept of SSM has been explained in detail by Checkland (2000) in a 'seven stages model' (in 1981), which was subsequently developed through a 'two main stream' approach (in 1988) and finally concluded by a 'four main activity' method (in 1990).

The final version of the SSM (which is named 'the four main activity' method), and, according to Checkland (2000), encourages group learning and is ideal as a group decision-making approach to deal with messy problems.

It is strengthened by active participants and stakeholders, and encourages joint ownership of the problem solving process. Neves, Dias, Antunes, and Martins (2009) in their study about application of SSM in energy efficiency, discussed that it played a central role in suggesting questions for eliciting a 'cloud of objectives' that each potential evaluator of energy efficiency initiatives may pursue. Further, Rose (1997) recommended SSM where an organization is seeking to achieve changes in workplace culture and transformation into a learning organization. In this perspective, using SSM for the building renovation field could be a way to develop an integrated design process which deals with the complexity, captures it and communicates it among the key players/decision makers/stakeholders, including non-expert decision makers and occupants.

A successful example of application of SSM methods for building renovation field was done in (Kamari et al., 2017c). The authors used Rich picture, CATWOE analysis, Root Definition and development of a Conceptual Model (a brief description of the mentioned methods can be found out in Appendix 3) for the problem of knowledge management in building renovation corresponding to sustainability concept. It was done through conducting two workshops and series of academic participant's meetings. The focus group included variety of participants as illustrated in Figure 1. Using the mentioned methods enabled the authors to explore and capture the needs of different participants and also to categorize and address them as criteria for the future of renovation field. Likewise, the participants were clarified of various principles that are challenging to understand and difficult to act upon. Consequently, application of SSM in a renovation project is suggested as a way to deal with the *culture* and society, because, it promotes an appropriate way of problem structuring, group decision-making and group learning, and hence it supports the implementation of sustainability goals in groups of different stakeholders.

3.2. Appropriateness of Multiple Criteria Decision Making (MCDM)

MCDM is a sub-discipline of Operations Research. It investigates and assesses multiple criteria throughout complex decision analysis (Belton & Stewart, 2002; Figueira, Greco, & Ehrgott, 2005). These methods can address both quantitative as well as qualitative criteria to analyse conflicts in criteria presented by different decision makers (Pohekar & Ramachandran, 2004). Parnell et al. (2013) discuss it as *a philosophy and a social-technical process to create value for decision makers and stakeholders facing difficult decisions involving multiple stakeholders, multiple (possibly conflicting) objectives, complex alternatives, important uncertainties, and significant consequences*. MCDM can provide a technical-scientific decision-making support approach to justify its choices clearly and consistently, especially for addressing issues in connection with the sustainability (Cavallaro, 2009). Conflicting criteria are typical in evaluating options i.e., cost is usually one of the main criteria, and some measure of quality is typically another criterion, easily in conflict with the cost (Gal & Hanne, 1999).

MCDM have been categorized into different groups and methods. The more popular MCDM categories are Multiple Objective Decision Making – MODM and Multiple Attribute Decision Making – MADM (Climaco, 1997; Zimmermann, 1991). MODM focuses on decision problems in which the decision space is continuous while MADM concentrates on problems with discrete decision spaces (Triantaphyllou, Shu, Nieto, & Ray, 1998). Taha and Daim (2013) discuss that the decision problem in MADM is characterized by the evaluation of a set of alternatives against a set of criteria rather than, as in MODM, the existence of multiple and competitive objectives that should be optimized against a set of feasible and available constraints.

A successful example of application of MODM together with MADM methods for building renovation was done in (Kamari, Christensen, Jensen, Petersen, & Kirkegaard, 2018b, 2018c). A performance of a total of 55 renovation scenarios were simulated and evaluated in terms criteria for Energy Consumption, Investment Cost, and Thermal Indoor Comfort. The authors applied Pareto-front approach from MODM, and AHP, TOPSIS, WSM, and ELECTRE related to the MADM methods (a brief description of the mentioned methods can be found out in Appendix 3). They concluded that MCDM methods are a valuable method to rank and address conflicting criteria subject to application of several MADM methods for cross validating the ranking – which similar studies also have concluded (Wang et al., 2009). Consequently building renovation, on one side, can benefit from application of MODM methods to resolve the trade-off between criteria (typically based on the preferences of a decision maker) when a solution performs well in all conflicting criteria. On the other side, MADM methods potentially can be used to deal with evaluation of various renovation scenarios upon evaluation of multiple criteria in decision-making processes when selecting the most efficient and optimal renovation scenarios/packages.

3.3. Mixing SSM with MCDM

The potential of using methodologies such as SSM or MCDM can also be considered from their vast application in the other disciplines. Above all, the availability of the various tools and software in the making and implementation of decisions when using SSM or MCDM is another reason that increases their appeal. Neves et al. (2009, p. 11) applied SSM to structure a Multi-Criteria Decision Analysis (MCDA) model for appraising energy efficiency initiatives and concluded that: *"SSM is a viable alternative to using mapping-based problem structuring methods to help unveiling a set of objectives for structuring a multi-criteria decision analysis model"*. The most important weakness of SSM is the lack of support, when using it during the last phases where a decision is made. Similarly, the weaknesses of MCDM was identified during the problem exploration and problem structuring stages due to the lack of adequate appreciation (Jayaratna, 1994). However, Petkov and Petkova (1997) underline that these weaknesses should not be considered as a cause for rejection of these methods. On the contrary, on the basis of Critical Systems Thinking (Flood & Romm, 1996) and Critical Realism (Bhaskar & Hartwig, 2008; Mingars, 2014), one can find a common foundation for the complementarity use of MCDM techniques with SSM approaches. The authors (Petkov & Petkova, 1997) conclude that there is a considerable scope for new and fruitful combined application of MCDM methods with different strands of systems thinking, which could ultimately enrich both approaches. It can be adopted from Petkov et al. (2007, p. 13) that it is useful to explore the possibilities to combine separate techniques from SSM with MCDM in order to both reflect the conflicting nature of the criteria, when dealing with increased complexity and multiple stakeholders. It further guides decision makers in complex situations and harness their potential to support learning about the problem and more effective decision support.

In this perspective, and following the main aim of the present paper, the authors suggest to apply a mix of SSM and MCDM methods for the building renovation field in order to deal with the problem formulated in section 1.1. Issues related *culture* can be addressed through attention to regular communication, collaboration, brainstorming, group learning and group decision-making among the stakeholders to promote learning and participation in a top down procedure by using SSM. Issues related to *technological/physical* aspects, can be addressed by using MCDM. As a result of these interventions, the stakeholders can concentrate on building a common appreciation about the most essential issues corresponding to the soft and hard aspects of the issues at hand. Moreover, it propels better informed management decision related to the particular situation.

There are a range of different methods available in SSM and MCDM that are capable of dealing with either *appreciation* and/or *analysis* and/or *assessment* and/or *taking action* (Mingers & Brocklesby, 1997) while facing a problem. In addition, the framework for implementation and evaluation of factors affecting the retrofitting field serves different perspectives and stakeholders as demonstrated in Figure 1. As such, when mixing SSM with MCDM, it is essential to consider which methods are the most applicable. For this reason, the research has used Habermas' (1984) three worlds including *social*, *personal* and *technical* worlds for the evaluation of the capabilities of the methods, which are in line with the terms *Transformational* and *Incremental* changes discussed in section 1.1. Table 1 in the following represents the mapping of the various selected methods from SSM and MCDM as well as their capabilities in relation to the three worlds of *social*, *technical*, *personal* for building renovation purposes. The selected methods in this study are quite popular due to their mechanisms, understandability in theory, and the simplicity in application to their related problems. In addition they have all been used by the authors in previous works. However, it should not hinder application of other methods from SSM or MCDM. The following considerations serve to clarify the correct application of these methods, when using them in the development of the HMSR in the next step. It should be noted that a short description and required citation relevant to the indicated methods in Table 1 has been provided in Appendix 3.

3.4. The step-by-step HMSR development

In order to establish the applicability of the methodologies as part of a multi-methodology, we have studied the underlying assumptions behind each methodology with reference to Mingers and Brocklesby (1997), Vo et al. (2001), Jackson (2003) and Petkov et al. (2007). For the SSM part, the framework for the development of the HMSR, has been applied from "four main activity approach"; it can be described as a four main activities process of analysis, which uses the concept of a human activity system as a means of getting from "finding out" about a situation to "taking action" and improving the situation (Checkland, 2000).

In addition, as discussed in section 1.2, Kamari et al. (2017b) considered the application of MCDM methods for building renovation, and hence two typical decision-making frameworks based on application of the two different types of MCDM (MADM or MODM) were developed. Subsequently, the decision-making on third level of the second framework including use of MODM (i.e. the study by Juan, Gaob, & Wangc, 2010) was entitled as "scientific decision-making" and considered as the inte-

Table 1. Mapping of popular methods from SSM and MCDM discussed in relation to the three worlds of Habermas (1984) for dealing with the concept of Holism in building renovation

	Appreciation		Analysis		Assessment		Action	
Social world	A, B, C, D	–	A, E, F, G	H	F, G	I, J, K	–	J, K
Personal world	A, B, C, D	–	C, D, E	H	C, D, E	I, J, K	D, E	J, K
Technical world	A, B, C, D	–	C, F, G	H	F, G	I, J, K	–	J, K
	SSM	*MCDM*	*SSM*	*MCDM*	*SSM*	*MCDM*	*SSM*	*MCDM*
A) Rich picture; B) CATWOE; C) Root definition; D) Conceptual models; E) PQR; F) POT; G) SAST; H) Delphi method; I) Pairwise comparison; J) AHP; K) TOPSIS								

Table 2. Mixing SSM with MCDM methods for sustainable building renovation [matching the three levels of integrated design process (from Kamari et al., 2017b) with the framework of the SSM (from Checkland, 2000)]

Decision-making at Level 1	Stage 1	Finding out about a problem situation, including culturally/politically
		Proposed methods: Root definition, Rich picture, CATWOE, Conceptual models, PQR (What, How, Why), and Delphi method
	Stage 2	Formulating relevant purposeful activity models
		Proposed methods: PQR (What, How, Why)
Decision-making at Level 2	Stage 3	Debating the situation, using the models, seeking from that debate both a) changes which would improve the situation and are regarded as both desirable and (culturally) feasible b) the accommodations between conflicting interests which will enable action to improve to be taken
		Proposed methods: POT or SAST + Pairwise comparison and/or AHP
Level 3	Stage 4	Taking action in the situation to bring about improvement
		Proposed methods: AHP and/or TOPSIS

grated design process implementation and evaluation of sustainable building renovation (Kamari et al., 2017b). In the present paper, HMSR uses the mentioned framework[5] as the main framework to apply MCDM in renovation process. Accordingly, as demonstrated in Table 2, the "four main activity approach" from (Checkland, 2000) have been matched on the "three levels of the decision-making" which were represented in Kamari et al. (2017b). Next, the methods from SSM and MCDM based on their capabilities, which were represented in Table 1, have been assigned to these stages.

By merging the "four main activity approach" from SSM with the framework for application of MCDM for building renovation by introducing use of a DSS (Decision Support System) for generation of renovation scenarios from Kamari et al. (2017b), it is possible to deal with different aspects of *Holism* (see section 1.1). In doing so, a renovation project can primarily be explored and the problem can be structured towards making the most efficient decision about which scenario to pursue at the end of the process. The results have been combined in Table 3 and configure/constitute the HMSR with a listing of activities relevant at each decision level (activities 1 to 23).

When applying the HMSR, the relevant stakeholders are first identified and their demands or their relevant concerns are explored (see Figure 1); the design objects are set up; then, there will be a separation on "soft" and "hard" (quantifiable) criteria; next, the criteria are assessed and finally the decision on which scenario to pursue is made. By following the methods which were introduced in Table 3 for performing each step and based on the mechanism of the methods, the mentioned activities can be carried out by performing two rounds of iteration in the process. For more clarification on how and where the proposed methods are applicable, a real renovation project is described in the following section, including a discussion about the potentials of applying the methods from HMSR.

[5] The framework was used from Kamari et al. (2017b, p. 6 – Figure 3).

4. Case study

In order to demonstrate how the HMSR could be applied in practice, we introduce a case study in Aarhus, Denmark. The case is included as an example of how a renovation project is carried out today, and how applying the HMSR could have supported the process. This is done with reference to the activities and methodologies put forward in Table 3 and based on the author's previous experiences with implementing the activities and methodologies in previous cases.

The included case is a social housing block from the late 1960's, which is currently undergoing renovation. The eight-storey building block has an area of approximately 9.500 m^2 and forms part of the first phase of a comprehensive plan to renovate and transform the entire neighbourhood, which consists of approximately 2400 apartments and 200.000 m^2 in total. The renovation and transformation of the housing block includes a general renovation of the apartments, renovation of the facades and the establishment of new apartment types. The project it put out to tender as a turn-key contract with an integrated architectural competition (Brabrand Boligforening, 2014; Århus Kommunes, 2007, p. 5). At the moment of writing this paper, the tender for the project has been settled, but the renovation project not yet completed.

The insights communicated in the present paper are based on information meetings and a research by design-study conducted in one of the bidding teams. As such, the insights convey the process as experienced from this specific view point. The research through design-study, together with the present paper, has been conducted as part of the Danish research project RE-VALUE (Value Creation by Energy Renovation, Refurbishment and Transformation of the Built Environment, Modelling and Validating of Utility and Architectural Value). The research project has been initiated to establish a more holistic approach to the assessment of value creation in building renovation projects.

Table 3. The step by step HMSR

Levels of decision-making		Relevant activity	Methods from SSM and MCDM	No. of Act
Decision-making at Level 1		Project start-up - using the "Characteristic Diagram" from (Kamari et al., 2017c)		1
		Identify stakeholders	Rich picture + CATWOE analysis	2
		Engage with the project team		3
		Define the project boundaries and objectives	Root definition + CATWOE analysis + Conceptual models	4
		Gather evidence regarding the building		5
		Review the best and worst practices in similar renovated cases		6
		Review criteria and indicators (division on Soft & Hard criteria) - using the "Value Map" from (Kamari et al., 2017c)	PQR + Delphi study	7
		Selecting the main design criteria and indicators		8
Level 1: It would be possible to develop and evaluate renovation scenarios using certain simulation and analytical software at the end of this decision level. This would reflect a common/traditional process. At this level, the process could be supplemented by using for instance the Danish Total Value Model (Schunck, 2011) and/or RENO-EVALUE (Jensen & Maslesa, 2015)				
Decision-making at Level 2	Hard criteria	Identification and selection of the purposeful criteria where the trade-offs need to be addressed (i.e. cost and quality)	Development of a Decision Support System (DSS) by use of MODM (Näegeli, Ostermeyer, Kharseh, Kurkowska, & Wallbaum, 2017; Yin, Stack, & Menzel, 2011; Juan et al., 2010)	9
		Developing assessment questions and relevant items (renovation actions) for the indicators.		10
		Developing a scoring system based upon purposeful criteria for the assessment items (using experts' proposals)		11
		Assessment of the questions with relevant stakeholders		12
		Development of a DSS using MODM (i.e. Evolutionary algorithms or Genetic algorithms) based upon assigned scores		13
		Create ranking of renovation scenarios based on assigned scores		14
	Soft criteria	Starts with the top ranked scenarios resulted from previous step	POT or SAST	15
		Developing measurement scales for the sub-criteria (Soft)		16
		Drawing of causal diagrams		17
		Score indicators	Pairwise comparison or AHP	18
		Justify responses		19
		Review and revise appraisal based on stakeholder feedback		20
Level 2: It is possible to make a decision at the end of this decision level using for instance brainstorming between the involved stakeholders and hence the renovation scenario is selected				
Decision-making at Level 3		Aggregating scores – Soft criteria + Hard criteria	AHP and/or TOPSIS	21
		Visualizing the results with relevant tools		22
		Analysing the results (i.e. using sensitivity analysis) and making the decision on the selection of the right renovation scenario		23
Level 3: The decision which is made at this level, is scientifically and rationally sound				

Note: A short description and required citation relevant to the introduced methods in the body of the methodology has been provided in Appendix 2; The symbol ◯ refers to the fact that the design process is not linear, but iterative in character. As such, several iterations of the activities are likely to the performed throughout the process. It results from the application of the introduced methods.

4.1. Demonstrating the application of the HMSR in the renovation case

In the initial phase of the project, the client (the housing association) engaged client consultants to perform initial investigations, *"gather evidence regarding the building"* and develop a building program as the basis for the tender. In this phase, the client consultants engaged in a user process and initiated dialogue with relevant stakeholders, hereunder the municipality and funding institutions. Due to the status of the housing block as a pilot project in the overall rehabilitation of the neighbourhood, the project has been of interest to a large number of stakeholders. This process can be described as *"identification of stakeholders"* and *"Engaging with the project team"* in accordance with Table 3. The stakeholders entered the project with different priorities, spanning *"hard"* criteria related to e.g. finance and thermal capabilities, as well of more *"soft"* criteria related to the general image and safety of the area as well cultural-heritage concerns to name but a few. Due to the socio-economic status of the area, the soft criteria have carried considerable weight throughout the process, which has added to the complexity of the renovation task at hand. Together, the project stakeholders involved at this initial stage have *"defined the project boundaries and objectives"*.

Applying *Root definition*, *CATWOE analysis* and development of a *Conceptual Model*, could have supported the task of identifying key stakeholders and investigate the renovation case from different perspectives. This would offer a framework for capturing and dealing with the complexity of the project and create a shared language for discussing this complexity in a holistic manner.

Back to the studied case; as part of the initial process, a group of representatives of the housing association, consultants, municipality and users went on study trips in Denmark and abroad with the aim to *"review best practices in similar renovated cases"*. Based on this initial process *"criteria and indicators"* were reviewed, selected and communicated in the building program, which founded the basis for the following tender and competition phases. In the specific case, the building program included actual principle scenarios for the renovation, developed by the client consultants prior to the tender and competition phases, to communicate principles to the users, who had to vote for or against the renovations before any further actions were taken. Referring back to the HMSR in Table 3, this process of formulating criteria could have been supported by using the *PQR* method from SSM, and *Delphi method* from MCDM, as these methods offer a knowledge-based approach to prioritizing and selecting criteria and sub-criteria. By applying the PQR (Do P by Q in order to contribute to achieving R, which answers the three questions: What to do "P", How to do it "Q" and Why do it "R") method, P can be referred to building components, Q can be referred to alternative renovation solutions and R can be referred to sustainability objectives. The first round iteration on previous activities in the process is performed by applying the *Delphi method*.

Returning to the studied case, the task of the bidding teams was to interpret the criteria and principles put forward in the building program and develop specific design scenarios, which were ultimately narrowed down to one proposal in each team. During start-up meetings within the team, consisting of a contractor, an architectural consultancy company and an engineering consultancy company, the *"criteria and indicators"* put forward by the client were discussed. The project group met up once a week to discuss and evaluate scenarios for realising these objectives. Within each sub-group, e.g. the architecture group, several iterations would be carried out during the course of the week, leading up to these weekly joint meetings. During the weekly meetings a dialogue-based evaluation of the scenarios was carried out. In a number of cases the contractor would calculate cost consequences of alternative scenarios after the meeting by use of spreadsheets, and continuous dialogue between architects and engineers would serve to secure integrated solutions. At two occasions, the project group had presentations/dialogue meetings with the client, where the proposed design solution was discussed relative to the originally stated criteria. Based on these activities, the scenarios were gradually narrowed down to one proposed scenario, which was delivered to the client and subsequently evaluated by an assessment committee.

If we relate the process in the case study to Table 3, we see that the process can be described with reference to decision-making level 1. In the following, we use the framework of the case study to elaborate upon how moving through the decision levels 2–3 could have further influenced and supported the process (see Figure 3).

Applying the HMSR [moving forward to decision-making at level 2], using a DSS (Näegeli et al., 2017; Yin et al., 2011) could support the process of generating renovation scenarios focusing on "hard" criteria. It improves the quality of the decision as it provides the stakeholders a detailed overview of the possible solutions and how they perform and therefore encourages stakeholders to accommodate holistic renovation solutions. The authors see a potential to optimise the current process of developing and testing scenarios and, subsequently, reduce the number of meetings needed to evaluate them. Further, by applying the *POT* method (P for Personal, O for Organizational and T for Technical) from SSM, and *AHP* from MCDM, the process of evaluating the final scenarios (i.e. the top ten scenarios generated by application of the DSS) is supported by use of weighted criteria.

Here the weighting progress using *AHP* methods benefits from the *POT* method. Performance rating of sustainable value oriented criteria are constructed as quantitative and qualitative values. The quantitative values are used for criteria that can be quantified using numbers (i.e. Energy consumption) which is addressed using a DSS. Qualitative values are used to characterize how well a building

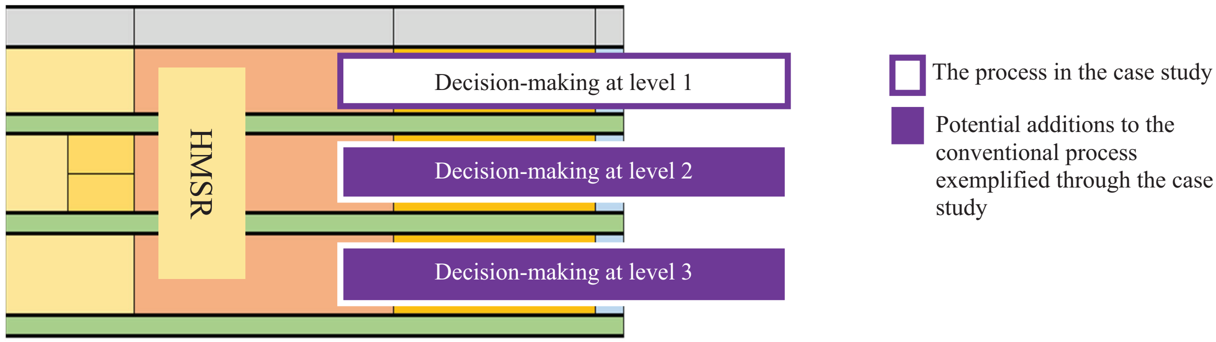

Figure 3. Principle diagram illustrating the use of the case study to exemplify how applying the HMSR could potentially influence the renovation process

scheme is rated against particular criteria in situations where the rating is based on qualitative judgment (i.e. spatial quality, sociality, aesthetic etc.), and thus not normally subject to quantification. Keeney (1992) states that the values must be identified and defined precisely; then, they can be articulated through this meaning qualitatively by stating objectives, and, if desirable, they can be embellished with quantitative value judgments. To this end, the criteria are weighted using *AHP* through setting up the *POT* methods by running a workshop. Application of i.e., *POT* ascertains the second round of iteration on previous activities as well. When the O (Organizational) and P (Personal) perspectives are "swept into" the T (Technical) perspective, gaps between the perspectives are discovered. *"The gaps occur because different perspectives use different languages to talk about the same problem and thus it is difficult for one perspective to communicate with the other perspectives"* (Vo et al., 2001, p. 3). Added to this, application of methods such as *POT or SAST* enables stakeholders to hear each other's voices and the common present challenges in the renovation field (e.g. the re-bound effect) can be highlighted and emphasized, which potentially help to increase the level of awareness, group learning, and finally group decision-making. This helps to deal with the aspect of *culture,* which was formulated in section 1.1. After this step, and by going through the level 3 of the HMSR, the selection of the most efficient renovation scenario, based on aggregation of the gained scores from selected "soft" and "hard" criteria for retrofitting, can be finalized. The authors suggest to apply two different MCDM methods (i.e. *AHP* and *TOPSIS*) including a *sensitivity analysis* to determine how different value of an independent objective/criterion impacts a particular dependent objective/criterion under a given set of assumptions.

4.2. Summary on the case study

In the above, a case study has been introduced as a means to demonstrate how the HMSR could be applied in practice. The case exemplifies the complexity of renovation processes due to, i.e. involvement of a large number of stakeholders, with different priorities spanning both "soft" and "hard" criteria. Through the case study, the authors have aimed to demonstrate how the HMSR could potentially help overcome this complexity by suggesting a mix of activities and methodologies from SSM and MCDM in a unified multi-methodology. The authors further make use of the case as a means to demonstrate how activities at design-making levels 2–3 can add value to the process by providing a systematic methodological framework for developing and evaluating design scenarios. The suggested activates and methods for exploring design scenarios through the use of i.e. generic algorithms are expected to support the current "manual", dialogue-based process of translating criteria into scenarios, through time reductions and the ability to evaluate multiple criteria simultaneously. In total, application of SSM methods from the beginning serves to structure the renovation problem and using MODM (the DSS) and MADM methods helps to generate and select the most optimal and efficient scenario for the renovation project.

As such, the case serves to demonstrate the potential of the HMSR as a systematic methodology for handling the complexity of the renovation field and there through add value for stakeholders, not least the end-users of the building, by promoting a holistic approach to building renovation.

Conclusions and further studies

A review of the barriers for building renovation has revealed a lack of methodologies, which can promote sustainability objectives and assist various stakeholders during the design stage of building renovation/retrofitting projects. To this end, this paper explored the notion of complexity in building renovation. It identified retrofitting as a complex field given its multifaceted value profile and involvement of many different stakeholders. Ultimately, it produced a multi-methodology, based on a mix of SSM and MCDM methods, which can serve as a means to structure retrofitting problems in accordance with the sustainability to support the decision making and help to develop and select the most optimal and efficient renovation scenarios.

It is the main aim of the paper that the proposed HMSR, through a 'proactive' approach, can help consultancy companies and housing associations, or even municipalities, to deal with the increased complexity and wicked nature of building renovation. Further, it is the aim that the proposed HMSR can address issues related to both *cultural* changes (subjects to essence of various stakeholders, and above all, behavioural barriers to improve the building occupants' learning about the sustainability and the sustainable living) and *technological/physical* changes (subjects to physical and/or technological changes to the building) simultaneously, in order to promote sustainability in a holistic sense. In other words, it deals with the full complexity of a building renovation given its multifaceted value profile and multiple stakeholders.

While this work remains theoretical in scope, we hope it can contribute to building new approaches to building design, and the methods and tools that support them. Application of the MCDM together with the SSM in building renovation as well as building design [in general] may sound too complex and confusing to be performed. But, the authors of the present paper believe that the application of such methods should become popular. Therefore, their application need to be studied and taught within relevant disciplines, particularly Architecture or Architectural Engineering disciplines. The intention to promote such methodologies is to deal with the interdisciplinarity and transdisciplinary (Woyseth & Nielsen, 2004) characteristics of the problems in these domains. The complexity of issues within the domain should be explored through broader perspectives and hence the traditional design approaches should be reconsidered and equipped to deal with its level of complexity and multifaceted nature.

Although the work presented in this paper is informed by the application of existing methods and building renovation projects we have taken part in over recent years, we accept that it is theoretical in scope, and we have yet to apply the HMSR practically to a building renovation project to test its relevance in a real-life renovation design process. Further development of the HMSR will include more explicit examination and application of recently developed SSM and MCDM methods.

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Appendix 1

Table A1. List of three different categories and their related sustainable value oriented criteria (Kamari et al., 2017c)

Functionality	Accountability	Feasibility
Indoor comfort	Aesthetic	Investment cost
Energy efficiency	Integrity	Operation & maintenance cost
Material & waste	Identity	Financial structures
Water efficiency	Security	Flexibility & management
Pollution	Sociality	Innovation
Quality of services	Spatial	Stakeholders engagement & education

Appendix 2

Table A2. The A-Z renovation categories (Kamari et al., 2018)

Insulation approaches	HVAC system	Increasing solar gain
Envelope (exterior finishes)	Renewable energy sources	Avoiding overheating
Window (replacement)	Energy storage	Re-designing of external and internal spaces
Doors (replacement)	Electrical system	Common areas (interior)
Airtightness and damp proofing approaches	Plumbing system	Individual building elements
Waste facilities	Controls	Sanitary appliances
Building security approaches	Flooring	Fixed furniture [essential]
Building site	Interior finishes – ceiling	Movable furniture [optional]
Structural system	Interior finishes – walls	

Appendix 3

Table A3. The list of proposed Methods and their purpose of usage in the developed HMSR

Method		Purpose	References
SSM	Rich picture	Understanding of the organizational context; Identification of the stakeholders and Key Players	Mingers and Brocklesby (1997), Checkland (2000), Neves et al. (2009)
	CATWOE	Customer, Actors, Transformation, Weltanschauung, Owner, Environmental constraints (CATWOE) - Mnemonic for a checklist for problem or goal definition	Checkland (2000), Neves et al. (2009)
	Root definition	Identification of key transformation	Mingers and Brocklesby (1997), Checkland (2000)
	Conceptual models	Recognition of key transformation	Mingers and Brocklesby (1997), Checkland (2000), Neves et al. (2009)
	PQR	Do P by Q in order to contribute to achieving R, which answers the three questions: What to do (P), How to do it (Q) and Why do it (R)	Checkland (2000)
	POT (Personal, Organizational, Technical)	The three most typical perspectives in addressing complex problems: T is the Technical perspective; O is the Organizational or Societal perspective; and P is the Personal or Individual perspective	Mitroff and Linstone (1993), Mingers and Brocklesby (1997), Vo, Paradice, and Courtney (2001)
	SAST (Strategic Assumptions Surfacing and Testing)	Method for approaching ill-structured problems	Mason and Mitroff (1981), Petkov, Petkova, Andrew, and Nepal (2007)
MCDM	Delphi method	Estimation of the likelihood and outcome of future events doing by a group of experts	Linstow and Turoff (2002), Wang, Jing, Zhang, and Zhao (2009), Parnell, Bresnick, Tani, and Johnson (2013)
	Pairwise comparison	Comparison of alternatives in pairs to judge which of each entity is preferred	Jaccard, Becker, and Wood (1984), Wang et al. (2009), Parnell et al. (2013)
	AHP (Analytic Hierarchy Process)	Organizing and analysing complex decisions	Saaty (1980), Wang et al. (2009), Parnell et al. (2013), Petkov et al. (2007)
	TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)	Selection of alternatives that is closest to ideal solution and farthest from negative ideal solution	Hwang and Yoon (1981), Wang et al. (2009), Parnell et al. (2013)