Understanding the change of heritage values over time and its impact on energy efficiency

Decision-making at residential historic buildings through system dynamics

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Abstract – This paper explores how cultural meanings attached by home owners to traditional listed or non-listed buildings conflict with their need for thermal comfort. The paper further examines how this tension influences residents' renovation decisions regarding cultural features of a house. System dynamics are used in the paper for the analysis of in-depth, semi-structured interviews carried out with fifteen households located at the Local Borough of Waltham Forest in London. The paper concludes with a dynamic hypothesis of how home owners' priorities change over time. It is shown that residents tend to appreciate the cultural value of original features at the time of purchasing an old building. However, as they settle into their new places, it becomes evidently more important for them to provide comfort for their everyday life, including thermal comfort and reduction in energy bills. The priority is again shifted towards cultural values and heritage preservation when the wider surrounding market puts a high economic value on cultural features of a house.

Keywords – heritage values; historic buildings; system dynamics; energy efficiency; thermal comfort

1. INTRODUCTION

The tension between thermal comfort and cultural meanings (often referred to as heritage values in the heritage literature) assigned by residents of historic dwellings has been widely recognised both in academia and policy. However, what drives this tension and how this tension manifests itself over time is less well understood [1] [2]. To address this tension and enable the preservation of original features, national heritage organizations (such as Historic England) and European endeavours (such as the European Standard [EN 16883:2015] Guidelines for Improving the Energy Performance of Historic Buildings) have provided guidance for balancing energy efficiency interventions and heritage preservation. However, such guidance is not necessarily reaching those who ultimately inhabit and manage historic dwellings and are not taking into account future change of values and technological developments.

Since, as we would like to argue, heritage is a dynamic and a complex socio-technical system that comprises of interlinked physical and cultural dimensions which change over time (such as materials, values and meanings, stakeholders and decision-makers, the wider cultural and political landscape), socio-technical, systemic methods capturing this change need to be integrated into heritage research. We argue that system dynamics can offer a suitable method for exploring the dynamic and complex interrelationship of factors that drive decision-making processes. It is therefore the aim of this paper to examine through system dynamics how cultural meanings, associated with notions of authenticity and aesthetics, change over time in the context of residential historic buildings, and what the impact of that change is on energy efficiency interventions. We do this by analysing 15 semi-structured interviews with tenants and homeowners of traditional listed or non-listed buildings in one of the most deprived boroughs of London – Waltham Forest. Given the limited uses of this method in the context of heritage, this paper attempts to provide a detailed presentation of the method alongside the results.

2. SYSTEM DYNAMICS AND CRITICAL SYSTEMS THINKING

The term ‘system’, in system dynamics, refers to a set of things and/or people interconnected in such a way that they produce their own pattern of behaviour over time [3]. The method of system dynamics is underpinned by the theory of systems thinking. Systems thinking is underscored by the idea that events and patterns, or things that we observe, are driven by systemic structures and hidden mental models [4]. Systems thinking is, in other words, about understanding the interconnection and systemic structure of elements that form a whole [5].

Systems in systems thinking have traditionally (and rather problematically we would argue) been distinguished between ‘hard’ and ‘soft’ systems [6]. ‘Hard systems’ refer to the technical operations of a system, while ‘soft systems’ signify systems in which human beings play an important part [7]. Initially, systems thinking prevailed in hard systems approaches back in the 1960s, such as operation research, system analysis, and systems engineering. In the 1970s, hard systems approaches were challenged by new developments in soft systems thinking [8] acknowledging the role of people in the operation of systems, but failed to deal with critical issues of power and social change [9].

The lack of engagement of soft system approaches with critical issues led to the emergence of critical systems thinking during the 1980s [10]. Critical Systems Thinking is committed to question the methods, practice and theory and committed to pluralism insisting that all system approaches, either hard or soft, have a contribution to make. Our analytical approach aligns with principles of Critical Systems Thinking in that we have been critically debating and questioning our analytical approach, constantly being aware of the need to improve policies and communities through our results and adopt a pluralistic methodological approach combining qualitative and quantitative tools. Indeed, due to the restrictive size of this paper, we have developed a lengthy paper that will be submitted to a peer-reviewed journal, outlining the critical and analytical approach that we debated during the process. However, in this paper we point out some of the key challenges that we faced and debated during the analytical process.

3. METHODOLOGY

The first step in system dynamic analysis is identifying the *problem* under examination. This is followed by defining the *system's boundaries* – that is the identification of those parameters that are viewed as critical for the change of the system. The next step is to create a matrix of causes and effect relationships which will graphically be presented into a *dynamic hypothesis* and represented via a suitable software (we have used Vensim in this paper) in the form of a *causal-loop diagram*. The *causal-loop diagram* provides the basis for developing the *stock-flow* diagram, which is essential for the development of the *system dynamics model* (fifth step). The *stock-flow diagram* represents the *stocks* and *flows* of the system or, in simple words, it represents *what* accumulates over time and *what* drives this accumulation. Each relationship between *stocks* and *flows* is described with simple mathematical equations [11] in order to enable the simulation of the dynamic hypothesis created (sixth step). This has indeed been one of the most challenging steps for us. How can (or should even) abstract concepts – such as that of cultural meanings – be represented via mathematical equations? After lengthy debates and discussions (and also due to the willingness and need to experiment in order to create a much needed, novel framework) it became apparent that the effort to represent the relationships of the different variables with simple mathematical equations, forced us to think even more about how these interrelationships behave (as explained below). Once the *dynamic hypothesis* or *system dynamics model* is created, the final step is to test and validate in the real-life context (seventh step).

As mentioned above, defining and articulating the problem caused by a complex and dynamic system is the first step in developing a *dynamic hypothesis* [12]. In our case, the problem that triggered the research question is the observed tension between thermal comfort and the preservation of original features in historic buildings. The problem was further refined by looking at the interview data with an 'open-eye'. In other words, interviews were coded through an *open coding* process, allowing the identification of themes and variables linked to the problem [13]. The identified variables were grouped into wider themes following an *axial coding* process. The *coding* facilitated the refinement of the problem under examination, the identification of the system boundaries and the mapping of the cause and effect relationships between the variables.

The boundaries of the system in our case studies consist of the building fabric, the home owners and the values/meanings they assign to the building. Once the interviews were coded, cause-effect relationships were identified and mapped on tables following the template developed by Kim and Anderson [14]. Identifying the cause and effect variables is the basis for creating a *causal loop diagram.* A causal loop diagram visualizes the *feedback loops* that are assumed to have caused the behaviour of key variables over time [15]. In other words, causal loop diagrams depict the causal links among variables with arrows from cause to effect [16]. Each cause-effect relationship is indicated with + or – depending on whether the relationship is positive and reinforcing (e.g. the more … the more) or balancing (e.g. the more … the less).

The system dynamic analysis of the interviews results is – what is known in system dynamics – a *dynamic hypothesis*. This is a hypothesis of how residents (mainly home owners) treat the dilemma between heritage preservation and energy efficiency over time. It is worth mentioning here that the proposed *dynamic hypothesis* presented in this paper requires validation and testing by sharing and discussing the hypothesis with the involved stakeholders (i.e. communities, policy-makers, etc.). Given that the research at this stage relies purely on qualitative, interview data, we incorporated a series of validity strategies including using analytical description of the context of the study; clarifying the biases that we both bring to the study through critical self-reflection; using peer debriefing, independent coding before discussing together, and an external auditor who is not familiar with the project but has expertise in system dynamics [17].

4. RESULTS

The *dynamic hypothesis* developed during the study can be summarised as follows: home owners tend to appreciate the cultural value of original features at the time of purchasing an old building. However, prioritization of cultural values, with which traditional buildings are originally imbued, declines over time as functional values associated with the need for thermal comfort and reasonable energy bills increase in significance. It is likely though that the decline of cultural values may be reversed when the wider surrounding market puts a high economic value on original features of a house – for instance when the market value of original features of traditional buildings increases in the area, especially when the area acquires conservation area status. This dynamic hypothesis is captured in the aggregate causal-loop diagram which demonstrates how cultural values (such as authenticity and aesthetics) associated with original features change over time (Figure 1).

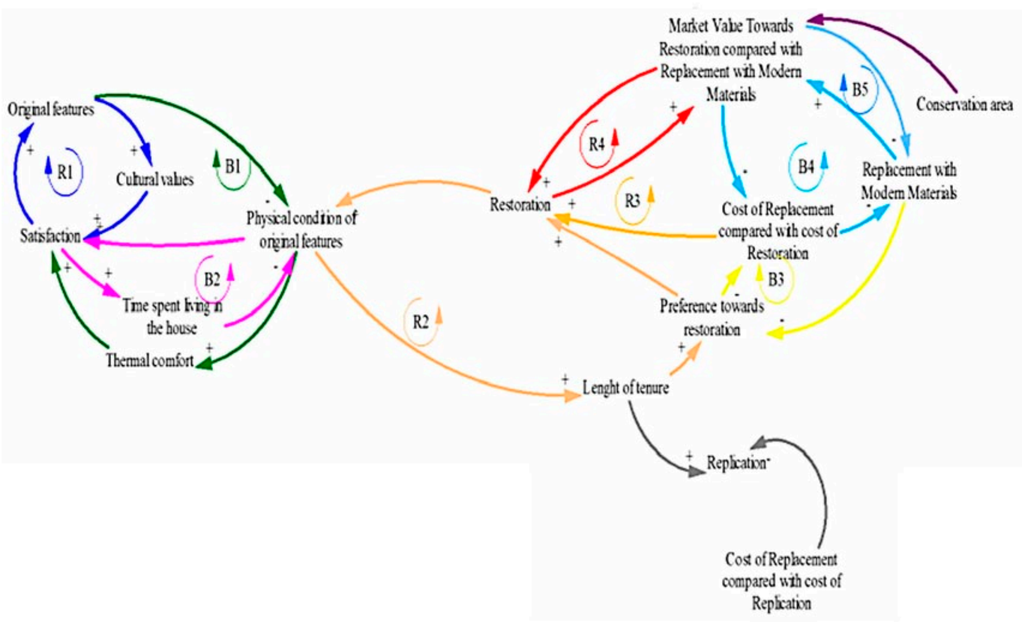

Figure 1. Aggregate causal loop diagram created on Vensim.

The first loop (R1) of the diagram is reinforcing that the *higher the number of original features,* the *stronger the cultural values* assigned to the building. Furthermore, the *stronger the cultural values*, the *more satisfied* the residents are with the overall house. As one of the interviewees stated *"They [original windows] are part of the fabric of the house and it was nice to keep the house as it was, as it was meant to work, you know it still had all the original weights and the cavities and, so yeah, you know, it was part of the soul of the house"* (Interviewee 1: Female, 40–45, housewife). However, over time, the residents experience the poor physical condition of the original features and its impact on thermal comfort, thus affecting their overall satisfaction with the house.

The balancing loop (B1) indicates that the *more the original features,* the *higher the risk of physical damage* and drafts and, thus the *lower the perceived thermal comfort* and *overall satisfaction* with the house. This loop reflects the problem in question, i.e. the dilemma between preserving the *original features* and replacing them with modern ones in order to improve the *thermal comfort.* (B2) takes into account the parameter of *time* as the more time spent living in the house, the more the residents realize the deteriorated physical condition of the house, and the lower their overall satisfaction.

The tension between *heritage preservation* and *thermal comfort* leaves the residents with three main options: a) restoration/preservation of original features; b) replacement of original features with modern features, and c) replacement of original features with replicas. Option *b)* is mainly adopted in the case of sash windows, while option *c)* occurs usually in the case of decorative features such as cornices or, sometimes, fireplaces. Final decisions will ultimately depend on the cost of restoration, the market preference in the surrounding area and the years the residents are planning to spend in the same house (length of tenure).

Indeed, there is a reinforcing interrelationship between the years that the residents are planning to stay in the house and their willingness to restore the original features (R2). According to this relationship, the *more the years they intend to stay*, the *more likely to restore*. As Interviewee 2 put it *"If I'd plan to stay here forever, but you know, if I plan to sell the house in a short to mid-term there was no point, if it's my forever house yeah, but it's, if it's not house I'm planning to stay for a longer time then I won't bother".* (Interviewee 2: Male 45–50, restaurant owner). Options will also depend on the cost of replacing the windows in comparison with the cost of restoration (R3). According to the reinforcing loop (R3), the higher the cost of replacing the more likely to restore, and vice versa. An additional correlated factor is the type of area and the degree to which the market in the surrounding area values *original features*. This is of relevance for those home owners who intend to sell their property in the near future.

In sum, the *dynamic hypothesis* represented by the aggregate cause-loop diagram, is that cultural values associated with the original features of an 'old' house prevail at the early phase of purchasing an old building, but decline over time as the need for thermal comfort becomes more imperative. However, if the market in the surrounding area values the preservation of original features, or if the house is located in a conservation area, then cultural values regain their importance. Home owners will choose to restore, replace or replicate original features depending on the type of feature, the physical condition and its impact on the perceived thermal comfort, the comparative cost of replacement, replication and restoration, the length of tenure and the market value in the wider area.

The next and possibly most challenging task was to model the interrelationships of the aforementioned factors and their change over time on Vensim software (Figure 2). As mentioned above in the methodology section, the core elements of system dynamics modelling is to model the interrelationship between *what accumulates over time* (stocks) and *what drives this accumulation* (flow). Figure 2 presents a small section of the model in order to depict the dynamic interrelationship between *what values and meaning increase over time* and *what drives this increase.* The terminology that we have used is conventional. We developed it together after consensus as one of the authors is a heritage scholar and the other a 'system dynamist'. We thus come from different epistemological backgrounds, which offered a fruitful ground for discussion and debate.

For clarity purposes, we explain the 'stocks' and the 'flows'. The section presented in Figure 2 shows an orange box. The orange refers to *the role that the original features play in enhancing the cultural value of the house.* In one word, we could define it as the **original significance** of the house. This is a 'stock' in system dynamic terms in the sense that it increases over time

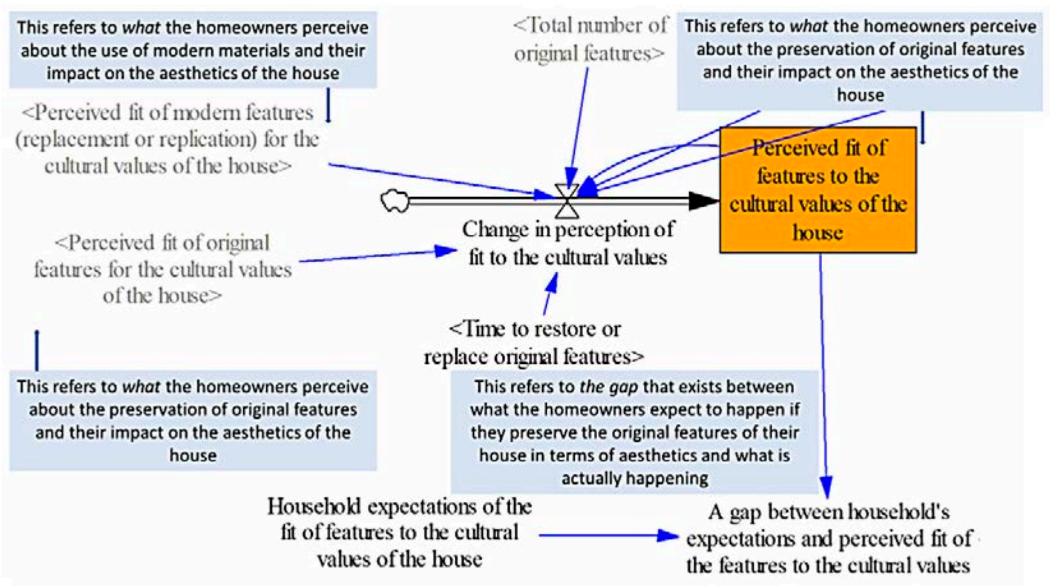

Figure 2. This figure presents a very small section of the model. The orange box is the 'stock', i.e. what accumulates, changes over time (in this case we have the example of cultural values associated with aesthetics as they are enhanced by the preservation of the original features of the house). The 'flow', i.e. what drives a change, is depicted in the middle by an arrow. The text in the blue boxes provides a short explanation for each variable.

till an event occurs (such as the physical deterioration of the original features) that leads to its decrease. Indeed, the ‘flow’ which refers to *what drives the accumulation or change over time,* is depicted with an arrow in the middle of the diagram. We have used an abbreviation phrase, i.e. *change of the perception of the residents that the original features do actually enhance the cultural significance of their building.* We have inserted an explanatory note on the diagram to make this illustration clearer. As mentioned in the methodology section, in order to enable the simulation process of how the dynamic interrelationship between two variables changes over time, mathematical equations are needed. This was the most challenging aspect, especially for the heritage scholar, as it was difficult to conceptualize on how the aesthetic value with which the original features attributed can be represented by a number or an equation. However, as we acknowledge that a historic house is a socio-technical, dynamic system, we decided to experiment and through critical discussion elaborate on what a model or a mathematical equation actually does and does not. In our selected section presented in Figure 2, the ‘perceived fit original features to the cultural values’ is an abbreviation that we used in order to connote our finding that the homeowners attach originally an aesthetic value to the house if it preserves the original features. In other words, the homeowners view the original features as aesthetically pleasant, a value that closely links to the visual aesthetics. Hence, for abbreviation purposes and to make the model workable, the equation that represents the orange box (stock) of this aesthetic value associated with the original features, was conventionally named ‘visual points’. It is important to note at this stage how conversations between an interdisciplinary team need to be recorded as the actual content of the abbreviations may be forgotten in due time. Once we decided the name of the equation, we had to assign a numerical scale in order to generate the simulation. This provoked an additional heated debate on how to assign a numerical scale. Aesthetic values cannot be measured with numbers, or could they? We concluded that the scale again is only a tool that we use in order to map numerically the change that will enable the simulation. We noted from the interviews that the home owners attached a very high value to the originality of the house as they thought it enhances the aesthetics – hence, if we could represent this on a scale between 1 and 10, for example, the value could be 10. Over time, thermal comfort across the spectrum of a scale between 1 and 10 gains priority over the original features. Hence, the initial value of aesthetics (or visual points as we have conventionally called them) declines while the thermal comfort increases. We obviously do not have data on how much it declines since we did not do carry out quantitative questionnaires with Likert scale questions. We thus acknowledge this limitation. However, we can we still represent on scale that 10 represents the highest importance, 0 the no importance, and 5 the medium importance.

Figure 3 shows an example of the simulation testing the developed hypothesis. The simulation that we run shows how the need for thermal comfort (we conventionally name it thermal points) declines or increases over time versus the aesthetic values (we conventionally named it visual points).

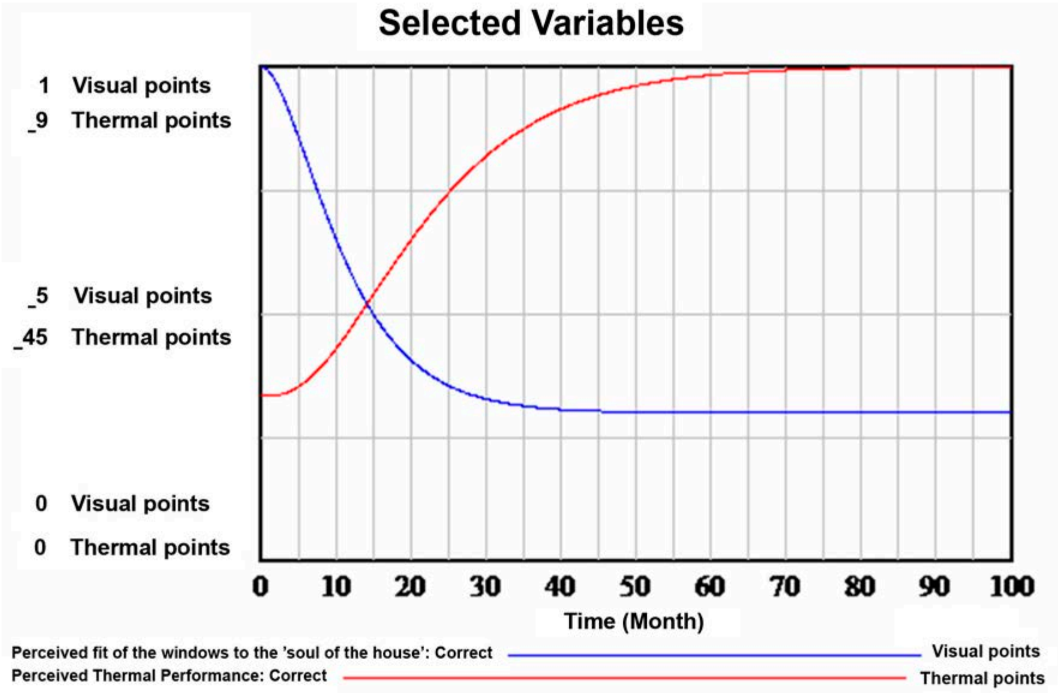

Figure 3. An example of simulation which shows how the need for thermal comfort (conventionally named as 'thermal points') increases over time while the priority over the original features that enhance the aesthetics and other cultural values of the house (conventionally named as 'visual points') declines over time.

Finally, as can be seen by the *stock and flow* diagram in Figure 3, there is a gap between what the owners perceive and how they expect the original features (with special reference to the sash windows) to perform from a thermal point of view. This gap creates a desire to change the current condition which results from the difference between the initial household's expectations and the perceived fit of windows to fit the aesthetic values. The desire to change the visual conditions of the house will emerge by the gap that exists between the residents' expectations of the contribution of the windows to the aesthetics and other cultural values with which the house is imbued (for instance, almost all interviewees made reference to how the original features were part of the 'soul of the houses'). The larger the gap, the larger the desire to change the visual conditions.

5. CONCLUSION

In this paper we introduced the application of system dynamics in heritage management studies and we developed a dynamic hypothesis regarding the change of cultural values with which residential historic buildings houses are attributed over time. We demonstrated that homeowners of traditional, listed or non-listed buildings, assign at the point of purchase high cultural values at their residence if it preserves most of its original features which then decline over time as the need for thermal comfort and affordable energy become their major priority. However, this decline may be reversed if the market value of cultural features of a house increases in the surrounding area.

More importantly, this study is an experimental, albeit challenging, effort towards socio-technical studies on complex and dynamic systems, such as that of heritage. Testing the applicability of a methodological tool that emerged from within 'hard sciences' was definitely a challenge. Despite its limitations and challenges – with the main one being to quantify abstract concepts such as that of values – the application of system dynamics forced us to think of the tension between heritage preservation and thermal comfort in a complex and dynamic way by addressing the issue of change over time. It also enabled us to better understand that the way homeowners and tenants act is determined by the gap that exists between *what they perceive* is happening or is important and *what is actually happening*. It takes time for the homeowners to realize this gap and once they do, they undertake interventions depending on other factors such as cost, practicalities and trends in the wider neighbourhood.

As change itself is a system and complex process, we would like to advocate for more research in this area that will allow development of a heritage dynamics theoretical and methodological framework that will enable heritage managers and researchers to study and manage sustainably heritage change. We also want to stress that this type of studies require very close and time-consuming collaboration between different experts, not only because a shared terminology and understanding needs to be developed but also – and more critically – because the analytical, conceptual and methodological process needs to be debated, discussed and reflected.

Our proposed *dynamic hypothesis* has significant implications for current policy and practice guidance on energy efficiency in historic buildings. Current guidance fail to encapsulate the complex and interconnected values with which historic dwellings are imbued and the dynamics of those values. For instance, the evolvement of cultural values into economic values over time can have significant impacts (positive and negative) on the type of energy efficiency interventions that homeowners adopt.

Our paper is only the starting point for opening up a wide array of questions around the widely acknowledged tension between energy efficiency and heritage preservation. It instigates a series of areas for further research, both for system dynamic and heritage management researchers. Firstly, the field of system dynamics must certainly address the relationships between qualitative mapping and quantitative modelling – in short, when to map and when to model, as well as how to model (especially qualitative data). To advance in this area, the field requires both academic research and reflective, constructively self-critical practice. More research is also needed on merging system dynamics with other approaches in order to capture decision-making behaviour of more than one individual. In addition, more heritage-related studies are needed to integrate qualitative and quantitative data into the system analysis.

The next steps of our research are to test and validate the *dynamic hypothesis* in different geographical and cultural contexts. We also intend to discuss the system dynamics model with key heritage policy-makers and heritage practitioners in order to test its relevance and applicability. Since one of the main applications of system dynamics is to inform, design and evaluate policies, our next future research stage is to also examine the impact of current heritage conservation policies and guidance on decisions made by the residents on energy efficiency. A longitudinal study that explores decision-making processes over a period of time combining measurable, quantitative data associated with the building and energy performance of historic houses with qualitative data, will be extremely enlightening in terms of how perceptions differ from what is actually happening and how this gap between the *perceived* and the *actual state* of a phenomenon drives certain decisions.

6. REFERENCES

[1] K. Fouseki and M. Cassar. (2014) “Editorial: Energy Efficiency in Heritage Buildings: Future Challenges and Research Needs”. The Historic Environment, [Online] 5 (2), pp. 95–100, https://www.tandfonline.com/doi/full/10.1179/1756750514Z.00000000058 [Jan. 21, 2017].

[2] F. Berg, A. Flyen, A. Godbolt and T. Broström (2017) “User-driven energy efficiency in historic buildings: A review”. Journal of Cultural Heritage [Online] Available: https://www.sciencedirect.com/science/article/pii/S129620741730362X [Dec.20, 2017].

[3] D.H. Meadows. Thinking in systems: A primer. Chelsea Green Publishing, 2008.

[4] P. Checkland. “Systems thinking” in Rethinking Management Information Systems: An Interdisciplinary Perspective, W. Currie and B. Galliers Eds. Oxford: Oxford University Press, 1999, pp. 45–56.

[5] J.P. Monat and T. F. Gannon (2015) “What is Systems Thinking? A review of selected literature plus recommendations” American Journal of Systems Science 4 (1), pp. 11–26.

[6] P. Checkland. “Systems thinking” in Rethinking Management Information Systems: An Interdisciplinary Perspective, W. Currie and B. Galliers Eds. Oxford: Oxford University Press, 1999, pp. 45–56.

[7] M.C. Jackson (1991). “The origins and nature of critical systems thinking”. Systems practice, 4(2), pp. 131–149.

[8] D. Schecter. Critical systems thinking in the 1980s: A connective summary in Critical Systems Thinking: Directed Readings. Wiley: Chichester, 1991, pp. 213–227.

[9] M.C. Jackson (1991). “The origins and nature of critical systems thinking”. Systems practice, 4(2), pp. 131–149.

[10] M.C. Jackson (1991). “The origins and nature of critical systems thinking”. Systems practice, 4(2), pp. 131–149.

[11] E.F. Wolstenholme. System enquiry: a system dynamics approach. John Wiley & Sons, Inc., 1990.

[12] L.F. Luna-Reyes and D.L Andersen (2003) “Collecting and analyzing qualitative data for system dynamics: methods and models”. System Dynamics Review, 19(4), pp. 271–296.

[13] A. Strauss and J.M. Corbin. *Basics of qualitative research: Grounded theory procedures and techniques*. Sage Publications, Inc. 1990.

[14] H. Kim and D.F. Andersen (2012). “Building confidence in causal maps generated from purposive text data: mapping transcripts of the Federal Reserve”. System Dynamics Review, 28(4), pp. 311–328.

[15] J. Randers. Ed. Elements of system dynamics method. Wright Allen Pr. 1980.

[16] J.D. Sterman. Business dynamics: systems thinking and modeling for a complex world (No. HD30. 2 S7835 2000). 2000.

[17] J.M. Morse, M. Barrett, M. Mayan, K. Olson and J. Spiers (2002). “Verification strategies for establishing reliability and validity in qualitative research”. International journal of qualitative methods, 1(2), pp. 13–22.