A social ontology for appraising sustainability of construction projects and developments

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Abstract

The social dimension of sustainability has been growing in importance as a criterion for evaluating the viability of projects in the construction sector. The authors present an ontology that can be employed to provide a systematic articulation to the issues that impinge on the social dimension of sustainability appraisals. The development of the social ontology was a consequence of a research project that explored the tools, metrics and models (SUE-Mot) employed in the evaluation of sustainability within the urban built environment. The development was achieved by the method of focus group interaction. The proposed ontology can be combined with the environmental and economic requirements of projects to assist developers and others stakeholders gain a more comprehensive and holistic view of the sustainable issues that attend construction and urban developments.

Keywords: Sustainability; Social issues; Construction; Project; Ontology

1. Introduction

The concept of sustainability has been growing in importance over the past two decades and currently forms a cornerstone of most developments and socio-economic activities in the built and natural environments. The current sustainable agenda takes its roots from the initiative put forward by the World Commission on Environment and Development [1], and reflects predominantly the environmental dimension of sustainability [2]. The WCED defined the concept to reflect natural resource utilisation in the quest to attain development objectives by national, regional, and individual stakeholders. Within the UK, the concept of sustainability embraces other dimensions beyond the environment-oriented definition to include the social and economic aspects of development [3]. While the issues for exploring environmental sustainability are well rehearsed and known, the issues that should form the social dimension are less appreciated and addressed by stakeholders involved in the development process. As such, while there are clear guidelines on minimising ‘carbon footprint’, and is often encouraged in the selection of materials for construction projects and urban developments, the equivalent social measures are less promoted.

The authors of this paper put forward an ontology that should provide a systematic articulation to the issues that impinge on the social dimension of sustainability appraisals. The development of the social ontology was a consequence of a research project that explored the tools, metrics and models (SUE-Mot) employed in the evaluation of sustainability within the urban built environment. The proposed ontology can be combined with the environmental and economic aspects of projects to assist developers and others stakeholders gain a more comprehensive view of the sustainable issues that attend construction and urban developments.

2. The SUE-MoT project

The SUE-MoT Project is a publicly funded research project by the UK EPSRC and forms part of a bigger
research agenda on Sustainable Urban Environment. Within this bigger research platform, the SUE-MoT Project addresses Metrics, Models and Toolkits for Whole Life Sustainable Urban Development. The primary aspiration of the SUE-MoT Project was to identify existing capabilities and gaps in the current assessment of urban sustainability. The gaps in assessment should provide an opportunity to develop an inclusive, holistic, multi-dimensional instrument that can be employed as a toolkit by key decision-makers and related stakeholders involved at various stages of the development process within the urban context. The vision of the research project is to develop this toolkit as a comprehensive and transparent framework that encourages key decision-makers to systematically assess the sustainability of the urban environment, taking account of scale, life cycle, location, context and all stakeholder values. Such an undertaking will require decision-makers to confront not only the environmental factors, but equally so, the social and economic factors that attend development projects. Fig. 1 presents the underlying concept of the multi-dimensional view of sustainability on which the SUE-MoT project is based. The rationale of the SUE-MoT concept is that for sustainable development to be effectively attained, the social, economic, as well as the environmental aspects need to be appropriately addressed. The factors that would need to be addressed will be represented by the concurrent overlap of the three dimensions of environment, economic, and social. The extent of the overlap between the various dimensions will be governed by the nature of the development and its socio-economic circumstances and context. The context can be defined by global, national, regional, local, and project factors, and is subsequently described as the spatial scale within the SUE-MoT programme [4]. The multi-dimensional view of sustainability adopted by the SUE-MoT project is rooted in the notion that consumption of natural resources is driven by the behaviour of people. Such behaviour is mainly propelled by socially constructed views in communities that make up urban built environment.

Fig. 1 also shows the different states of sustainability that could exist for any development. First order state reflects only economic, social, or environmental issues separately. Any project thus executed can only attain a single state sustainable status. Traditionally, projects in the construction sector have often explored such a single state sustainability within the economic dimension. The second order state describes a partial overlap between two dimensions, such as economic and environmental optimisation at the expense of the social dimension. Its generic form is the optimisation of any two dimensions at the expense of the third dimension. The third order of sustainability refers to an optimisation of all three dimensions, and is a state that is rarely attained in most urban development projects in isolation. The ability to establish optimisation of the third order relies on the awareness of the issues and dominant requirements that is each of the principal dimensions within a generic as well as a specific spatial context. The social dimension presents the aspect of sustainability that is most difficult to define. This is because of a greater proportion of subjective factors that is reflected as dominant requirements for consideration. As such, defining generic social factors that would require attention in the assessment of sustainability should present an opportunity for conducting a more systematic appraisal of the issues that would need to be addressed for any project or urban development.

3. Social ontology for urban development projects

The concept of social ontology reflects the social realities that exist in any community which can be formally defined [5]. It revolves around the notion that social realities do not spring from vacuum, and are created by the dynamic interaction of individual values and notions for any particular society. As such, social ontology depict the ‘state-of-affairs’ in a particular social domain at an abstract level and indicates the associations among, and the most prominent attributes of individuals within that domain [5]. By constructing such a structure, one is able to authenticate the veracity of existing social phenomena as well as to infer new ones that would arise from any proposed development.

For example, the value of a particular currency in different regions of the world does not carry the same worth. According to Searle [6] even though the paper described as money would have minimal intrinsic economic value, it is often exchanged for goods and services that have high intrinsic economic and social value. The process of creating bringing into being these social realities involves selecting agreements and peculiarities of individual engagements in any community with others based on each person’s value system. The aggregate effect of all the individual choices is what is reflected as the social ontology of the community. Coleman [7], therefore, argued that it is the interpretation...
of the aggregate effect, otherwise described as conceptualisation that lies at the heart of social science. Little [8] suggested that sociologists form conceptualisations of social phenomena by identifying extensions from the individual to events, structures, and other social systems. Such conceptualisations rely on the aggregation of large amounts of data on social actions and behaviour, occurrences, and properties into entities, structures, or processes [9–12]. The formation of the entities and structures enable causal and explanatory relationships in the changes that transpire within social urban environments [13]. Ontology for the social dimension will require a definition of the entities that exist in the urban environment that impact on sustainability and a categorisation to enable subsequent phenomena to be classified. Little [8] argues that defining such ontology would require the identification of a social concept that sufficiently draws together a range of social actors, institutions, spatial scales into a single entity. It will also call for a criterion for determining the uniqueness of the concept by defining rational and reliable boundaries for the entity [7]. An institution in the context of such a social ontology can be described as a complex socially embodied powers, limitations, and opportunities within which individuals pursue their lives and aspirations [14]. Examples of institutions would include a property system, a legal system, and an educational system. Table 1 presents representation for the individual and institution characteristics that Little [8] proposed for exploring social ontology. Table 1 provides an example of classes of social realities that exist at the two levels of individual (micro) and institutional or community (macro) and could form the basis of entity modelling for the urban social environment for sustainable development.

Within each category, the hierarchy of characteristics is obvious. For instance, it is the relationship among individuals that give rise to organised groups, where the nature of relationships is aligned to the same values for several individuals. Similarly, the behaviour of the group gives rise to social practices or norms, which practice is in turn determined and influenced by power. Once an order of such social hierarchy is established, any action, development or event that seeks to alter that social order can be construed as an intervention. Construction projects create interferences or interventions in the order of sustainability within the urban social domain. These interventions induce actions by social actors that result in the creation of new realities making up the sustainability of their communities and vice versa. In this regard, the difficulty of evaluating the contribution of cities and buildings to sustainable development in a way that is comprehensive, practical and accurate, logically sound, and acceptable to a wide range of stakeholders with differing views and priorities has been recognised [15]. Urban environments are often associated with problems of unsustainable resource use, waste production, poor environmental quality, pollution, crime, and other socially undesirable features [16,17]. These associations reflect elements of sustainability that are in a state of flux and involve many issues, scales, interrelations, feedbacks, synergies, and often, unknown consequences.

The sustainability of urban environments represents complex interaction of a multiplicity of factors. A significant proportion of the complexity is contributed to by a lack of sufficiency in the definition of the multiplicity of factors, and more specifically the social-related factors that influence urban sustainability. As such, the need for a more systematic approach that improves the contribution of the ontological factors for each dimension that contributes to sustainability over all stages and scales in urban development needs to be prefaced by an appropriate definition of the factors that determine such sustainability.

Table 1
Individual and institutional attributes for forming social ontology

<table>
<thead>
<tr>
<th>Socially constructed individual</th>
<th>Institutions and communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual agent</td>
<td>Relations among individuals</td>
</tr>
<tr>
<td>Human needs and desires</td>
<td>Organised groups</td>
</tr>
<tr>
<td>Rational agency</td>
<td>Social practices embodying and conveying norms and worldview</td>
</tr>
<tr>
<td>Individual worldview and norms</td>
<td>Power</td>
</tr>
<tr>
<td></td>
<td>Communication and transportation</td>
</tr>
<tr>
<td></td>
<td>Technology – agriculture, manufacture</td>
</tr>
<tr>
<td></td>
<td>System of production and re-production</td>
</tr>
<tr>
<td></td>
<td>Social formation</td>
</tr>
</tbody>
</table>

4. Development of social ontology for SUE-MoT

A comprehensive listing of social issues, stakeholders and related factors were compiled from the literature. The principal sources included construction and non-construction related sources such as journals, research reports, trade and the government literature was undertaken to compile an initial list of the issues, stakeholders, systems and scales relevant to the sustainability of urban developments. For example, the make up a social community was drawn from sources outside construction such as social welfare and other categories employed by the local authorities. By relying on such a wider range of sources, the direct and indirect impacts any development within the built environment became apparent.

5. Ontological boundaries

A specification for the ontological topography is reflected in Fig. 2 and shows the highest level categories adopted for developing lower level entities. Fig. 2 defines three broad categories: those which represent spatial scales, urban systems and development life cycles, and sustainability dimensions and their associated issues and sub-issues, such as
stakeholders, impact, influences and policies associated with any entity. The three broad categories are further elucidated in the sections below to provide their relevance to sustainability of urban environments.

5.1. Spatial scale

Spatial scale is an important concept in relation to sustainability assessment. The spatial scale adopted for the SUE-MoT project reflects eight (8) subsidiary levels as follows: global, supranational (e.g. EU), national, regional, city, urban development, building and element (or material). The constructed social ontology focuses on the lowest three levels of the scale, namely, the elemental (materials), building and urban development categories to enable the establishment of consistency for identified entities. The rationale is that the constructs from these three levels provide a good foundation for extending relevant entities to any further levels or details required for establishing the social issues associated with any project.

5.2. Life cycle phases

The life cycle identifies the instance of existence for each entity within a selected scale. For example, life cycle of a building would include all activities which would be deemed essential for executing the feasibility and business case, pre-design, design, build, operate, maintain and refurbish reuse and final decommission.

5.3. Sustainability dimensions

The ontology is also based on sustainability dimensions (environmental, social and economic) and their associated issues. Each dimension reflects the issues in a parent and children relationship. Each sustainability dimension can therefore, be decomposed into a list of issues and sub-issues and would display the following:

- The ability to show the sustainability issues related to each spatial scale and/or life cycle stage.
- The ability to show the inter-connections between the issues and their sub-issues of the same dimension for different spatial scales (again only the three spatial scales) and at different life cycle stage.
- The ability to show inter-connect between the issues and their sub-issues across the dimensions for each special scale and for each life cycle stage.

The sustainability issues relate both to the built products and the workforce involved in the construction, operation, maintenance, refurbishment and decommissioning. Additionally, given the importance of supply chain performance to sustainability, the ontology reflects sustainability issues associated with the production and manufacturing of construction materials. The paper addresses the social dimension of this nomenclature to provide an input into the broader SUE-MoT mapping effort of establishing the effect on sustainable development for each of the factors associated with a project in the built environment.

5.4. Stakeholders

Within the project, the term stakeholders is used to designate all individuals or groups who are directly and/or indirectly involved in the selected scales and beyond and whose lives, environment or business are affected by the three spatial scales and beyond the adopted constructs. A more comprehensive listing of the key stakeholders is provided below. The listing reflects the following classes.

1. Those stakeholders that make the decision.
2. Those stakeholders that facilitate the decisions.
3. Those stakeholders that are affected by the decision.
4. The policy makers, development team and those impacted by the sustainability issues. The development team can additionally be broken down into supply and demand. However, the memberships of these classes will change as a function of spatial scale. This is because of the hierarchical nature of the stakeholder ordering in the development of projects within the built environment.
5. Stakeholders of a building for example can be grouped into: policy makers, project (building) sponsor, client organisation team, project (building) organisation team, end user, external team members e.g. “suppliers and sub-contractors” and community and external independent concerned groups.
6.1. Modelling environment

The comprehensive listing drawn from the desk study provided the first stage of the data collection. The list was ratified through a Delphi exercise in a series of workshops that employed a small focus group of six (6). The finalised version of the list and their dependencies were subsequently subjected to a review by a larger group comprising participants from industry and academia. The participants from industry reflected key professional and stakeholder roles in the delivery of projects and developments in the built environment. They included architectural, engineering, planning, contracting, regulatory, clients, occupants, local authority, and department for environment.

6.1. Modelling environment

Given the number of entities that would have to be handled in a social ontology of this proportion, it became useful to explore an appropriate environment in which the information would be modelled [18,19]. The purpose of the modelling was to identify internal correlations between the entities that emerge, in order to provide sufficient and efficient representation of entities for the ontology on social sustainability for urban development projects. It was also aimed at establishing the dependencies between high level entities and within the sub-entities making up a particular category. Five process mapping software applications were explored for their suitability to support the modelling. These were: Visual Mind, Axon Idea Processor, MindManager, MindMapper, and MS Visio.

Axon Idea Processor was selected because of its wide functionality, its ability to create XML files allowing for efficient conversion into multimedia software, its ability to provide any map in one of 12 different visualization options allowing flexibility during the development of the ontology, and its cost-effectiveness. In addition, Axon Idea Processor served as the standard modelling environment for the main SUE-MoT project, so working in that environment enhanced the interoperability of the outputs from the different sustainability dimensions. Idea Processing is concerned with problems and solutions, questions and answers, unknowns and facts. An Idea Processor enables any modelling to be conducted at a higher conceptual level. The added benefit of the adopted modelling environment derives from its non-prescriptive format for developing solutions [20]. It does not require one to learn or follow a defined procedure, nor does it restrict the modeller to a hierarchical pattern of thoughts. The lack of restriction produces three major advantages. Firstly, it facilitates working with ideas and concepts and not simply terms and words. Secondly, it allows the modeller to bring together the Big Picture and not just the details. The level of detail and abstraction is entirely at the discretion of the modeller. The third advantage is the ability to analyse and resolve more complex problems by adopting methods appropriate to the purpose of the modelling.

6.2. Modelling the social sustainable ontology

Fig. 3 shows two illustrations of the modelling exercise. Fig. 3.1 depicts the modelling for the social dimension, and Fig. 3.2 details the integration of the social categories within the global set of entities for a more comprehensive modelling across the whole SUE-MoT project.

The links and inter-connections between the various issues, stakeholders, systems and scales identified from the initial listing were modelled to establish categories and hierarchies between and within the categories.

To validate the theoretical content and construct of the map, a workshop of relevant stakeholders and experts was organised where the issues, stakeholders systems and scales, and the links between them were presented for formal verification and comments. Feedback from this testing phase was integrated into the set of issues and dependencies. Validation of the developed categories was
undertaken through a workshop to which relevant stakeholders and experts were invited. Comments and feedback were used to guide the production of a final ontology.

The modelling exercise involved identifying all the issues, stakeholders and impacts for the three selected spatial scales. The selected scales comprise the following categories. The sustainability issues relevant to three spatial scales:

- the urban development as a whole,
- the systems which it comprised (buildings, services, urban transport, landscapes), and
- the materials from which these systems are constructed.

Fig. 3. Modelling environment for social ontology.

Fig. 4. Material level categories for assessing social sustainability.
Fig. 5. Systems level categories for assessing social sustainability.

Fig. 6. Urban level categories for assessing social sustainability.
The exercise also captured the inter-connections showing the influence between the issues within and across the three scales and the potentially different life cycles associated with each scale.

The resulting list was then subjected to normalisation in order to establish efficiency in the representation of the categories in the ontology. The normalisation exercise was to ensure the elimination of any duplicated concepts. The resulting normalised categories were subsequently fed into the overall SUE-MoT mapping exercise to establish the nature of interaction between economic, social and environmental dimensions in defining sustainability for built environment developments.

Figs. 4–6, display the resulting entities and sub-entities that emerged after the normalisation for the each of the three featured spatial scales for which the social ontology was developed. Fig. 4 presents the categories at the materials level. The material level captures the inputs that eventually get incorporated into projects within the built environment. Fig. 5 presents the categories at the building/systems level, and Fig. 6 presents the categories at the urban level. The urban level brings together all the systems to create a social community that is impacted, and impacts on global sustainability of the earth.

At each spatial level, the ontology defines principal stages that make up that level for the cycle its production activities. At the material and building/systems levels, the cycle reflects the key phases associated with the development of products for the respective spatial scale. In the particular case of the building level, this becomes the project. At the urban level, the cycle defines the urban reach that is associated with sustainable policies. The reach ranges from the individual to the wider urban area. Equally, associated with each stage of the cycle are principal social issues that form the high level entities for ordering the ontology. The high level entities form the basis for giving consideration to the different categories of stakeholders, namely, primary, secondary and external. Each of the categories of the primary, secondary and external decomposes into sub-entities that help to define the nature of social factors making up the respective entities. The primary category defines those stakeholders that directly influence or are affected by the principal issues of sustainability under examination. Examples of stakeholders in this category include key decision-makers, such as the client, designers, contractor, and financial institutions.

The secondary stakeholders define those whose influence or affectation are experienced through derived demand or consumption of the operations within the stage under consideration. External stakeholders are the ones that have no direct or derived input into or impacted upon by the activities of the stage under consideration. Examples of external stakeholders include national governments and inter-governmental organisations. Further detail for each of the spatial scales can be defined based on the specific context for any project or development. Fig. 7 illustrates how the social ontological maps were incorporated into the broader SUE-MoT map and also the connections between the spatial levels for the three levels making up the social dimension. At each spatial level, the social impacts and influences on sustainability is evaluated in its own right. The influences and impacts can be other social issues at the level under consideration, as well as influences and impacts from the economic and environmental dimensions. Fig. 7 also shows the influence of social issues across spatial scales. The accumulation of the effects of any social impacts at say the building level reflects in the urban level. The trans-spatial scale influence of the social factors...
Eqs. (1)–(3) provide varying levels of definition of the social contribution to project sustainability (SC) at each level social issue (PI). The conceptual form of the social map for establishing sustainability is presented in Fig. 8 below.

Within Fig. 8 the high level issues are defined as PI. Each high level issue decomposes into primary (X), secondary (Y) and external (Z) sources of sub-issues. The contribution of the sub-issues to each high level issue is defined by Eq. (1) as the aggregation of the contribution from the sources

\[ PI_j \approx \alpha \sum_i SF_x + \beta \sum_i SF_y + \gamma \sum_i SF_z \]  

(1)

Where \( \alpha, \beta \) and \( \gamma \) are equation factors that reflect the importance or contribution of each sub-issue to sustainability for the high level issue based on the social policy within the regional or national context. Similarly, the contribution of each high level issue to the social sustainability at the spatial scale level and that of each spatial scale to the overall sustainability at the urban level are depicted by Eqs. (2) and (3) respectively as the weighted aggregation of the contributory variables

\[ SC_k \approx \sum_j PI_j \]  

(2)

\[ OSS \approx \sum_k SC_k \]  

(3)

Eqs. (1)-(3) provide varying levels of definition of the social contribution to the sustainability that can combine with entities within the other dimensions of economic and environment to establish the global impact on the project or development.

7. Discussion

The social ontology at each level defines the nature of the interaction that could transpire for socially driven requirements from issues, contextual factors and the influence of stakeholders as inputs for establishing social sustainability. These requirements reflect the dynamic nature of the inputs, and help to identify the changes that could occur in the contribution to social sustainability from project to project. The ontological map for social sustainability provides a comprehensive framework for systematically considering the different issues and stakeholders that would feature at each spatial scale for any project in the built environment. The incorporation of social ontology into the combined SUE-MoT topography of project sustainability enabled a more comprehensive consideration of the issues that would often not feature in the adoption of solution within the built environment.

The hierarchies between the different spatial scales imply that any aggregation within a particular scale will reflect the partial contribution from lower level scales. This is because of the compensatory behaviour between the various high level social variables in the ontology. The degree to which the issues are aligned or divergent will influence the extent of the partial contribution. A crucial aspect that emerges from the ontology is the need to understand, from and empirical and fundamental principles, the nature of the internal interaction between the issues that define social sustainability at each spatial level. Addressing the dynamics of the interaction between the various issues presents opportunities for developing a better understanding of the various social issues contribute to sustainable projects, developments and communities. Such an investigation will help to provide solution on the extent to which each of the social factors should be addressed in order to create sustainable communities and places where people want to live and work, now and in the future. Proposing solutions based on such fundamental information will help to meet the diverse needs of existing and future communities, as well as address their environmental concerns, and contribute to quality of life and safety of those communities. The ontology provides an opportunity to address externalities that are increasingly required for all projects within the built environment to reflect inclusive, well planned schemes that ensures equality of opportunity and good services for all.

8. Conclusions

The importance of the social dimension to the definition of what constitutes sustainable development for projects in the built environment has grown over the last two decades. The rationale for this phenomenon is that, consumption behaviour of people is seen as what drives the utilisation of what and how much of natural resources, which in turn impacts on the environment. The ability to comprehensively address the social issues that should be given due consideration in any such sustainability appraisal will be determined by awareness of the issues and a framework for applying the issues. The authors have put forward an ontology that should provide a systematic articulation of the social issues for undertaking such a sustainability appraisal. The social ontology can be combined with the environmental and economic aspects of projects to assist developers and others stakeholders gain a more comprehensive view of the

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**Diagram:**

![Conceptual representation of interaction between social entities.](image)

**Fig. 8.** Conceptual representation of interaction between social entities.
sustainable issues that attend construction and urban developments.

References


