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The Future of Architecture: Measuring the Sustainability of Paradigm Shifting Architectural Interventions

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Abstract

Sustainable development in the built environment seems paradoxical given that the architecture, construction, and buildings sector is one of most polluting, wasteful, and inefficient industries. Despite this notion, the role of the architect is evolving and their influence on design is expanding beyond ideas for physical structures and into designing interactions between the built environment and components such as policy, material usage, sustainability, and urban regeneration. Architects that are able to implement paradigm shifting design ideas that improve the environmental, social, and economic dimensions of sustainability can be catalytic for systemic change and act as a vehicle to move away from linear systems and into circular models. This study aims to review international building sustainability assessment methods (BSAM) used by architects to assess the extent that sustainable building criteria is being fulfilled. The study will then address the limitations that these models have in measuring sustainability criteria through a process-based lens. The paper presents specific modifications to the Simplified Method for Evaluating Building Sustainability (SMEBS) which was also created to address limitations in BSAM. Modifications to the SMEBS model will be implemented through the context of Lisbon's historical and current sustainability initiatives.

Keywords

Architect; construction, building, sustainability; material cycles; building sustainability assessment methods

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1. *Introduction*

Architects are traditionally viewed as designers of the built environment, but the systemic environmental, economic, and social space that is generated through the physical manifestations of design are often not associated with architect's influence. The world's infrastructure accounts for 40% of total carbon dioxide emissions which is just one tangible symptom of the underlying disease of exploitation, extraction, unfettered economic growth and waste that is the norm of the industry (Tavengwa & Rao, 14).. There is potential for the architecture discipline to shift its paradigm of intervention in society to rectify systemic issues propagated through the built environment and facilitate environmentally, economically, and socially sustainable development.

In the book *Multiplicity*, Alden Copley discusses the nuances of architecture and contends that "The thing that gets built is just what gets squeezed out after it has been through ten different wringers that aren't controlled by architects. Political whims, financial constraints, lot sizes, what resources are available in what location, what's socially accepted… The fundamental tradition of architecture must be questioned" (Tavengwa & Rao, 14). The architectural tradition to build for permanency is incongruent with the volatility of today's world.

There is increasing urgency for the architecture, construction, and building sector to shift toward sustainability and an associated need for tools that can effectively assess, measure, and improve aspects of sustainable development which has led to the creation of multi-criteria assessment systems. The application of these systems in urban scale renovation projects is not common practice (Pedro, Reis & Silva, 2020).

The indicators of sustainable development will be different throughout various social, environmental, and economic contexts, but underlying paradigm shifts like transitioning from linear to circular models of material-use are necessary to include as criteria to measure sustainable development in the built environment. After analyzing projects in 50 cities for successful urban regeneration, the European Commission for Regional and Urban Policy concluded that best practices include "Area-based interventions such as physical renewal with accompanying soft measures (education, social welfare, and labor market)" (Santos, Ramalhete & Juliao, 290). This highlights the importance for architectural design to transcend physical renewal, and contribute to the design and integration of accompanying soft measures.

The insights provided from the Lisbon Architecture Triennale support the studies belief that the architecture, construction, and building sector are interconnected in such a way that they will essentially be used interchangeably in this paper. The aim of this study is to address deficiencies in sustainability assessment systems for the buildings industry and create an applicable framework that can measure the implementation of the paradigm shifting visions presented from the Lisbon Architecture Triennale.

This study analyzes *A Simplified Method for Evaluating Building Sustainability in the Early Design Phase for Architects* (Jernej Markelj, Manja Kuzman & Petra Groselj, 2014) which contains the SMEBS framework for sustainability in the early design and building phase. In this publication, the authors critically reviewed commonly used and accepted BSAM and found deficiencies. The authors then provide a framework for more effective, simple and accessible measuring of sustainability. Our study finds that despite the SMEBS model demonstrating improvements in indicators for measuring sustainability, there was still a lack of processes-based criteria used in the SMEBS.

2. Literature Review

The research for this study began with a search of peer-reviewed academic literature that was conducted using electronic databases (Science Direct, Portuguese Climate Plan Documents, and JSTOR) between November 2022 and December 2022 to identify literature that contains:

- Climate impacts of the construction and buildings industry
- Contextual and historical information on the economic, social, and environmental sustainability initiatives in Lisbon
- Frameworks and Analysis of Building Sustainability Assessment Measures (SMEBS Model)
- Insights on paradigm shifting architectural thought

9.1 *The Construction and Buildings Industry*

The background on the construction and buildings industry is constructed by referencing the *2022 Global Status Report for Buildings and Construction* by the Global Alliance for Buildings and Construction along with insights from publications containing interviews with architects associated with the Lisbon Architecture Triennale.

9.2 *Lisbon Sustainability and Built-Environment Context*

The following publications were selected to help provide socio-economic and environmental context to build the foundation from which this study analyses the limitations of the SMEBS Model. *Sustainable Architecture and Urban Design in Portugal* by M. Guedes, M. Pinheiro, and L. Alves identifies current examples of sustainable building structures adapted to local socio-economic, cultural and environmental contexts in Lisbon. The paper also presents needs and future trends for sustainable architecture in Lisbon. *The Lisbon European Green Capital 2020* publication provides quantifiable and qualitative data on Lisbon's sustainability initiatives and progress towards being recognized as the European Green Capital for 2020. The *Integrated National Energy and Climate Plan 2021-2030* published by the European Commission provides climate data and policy implications for the future of Portugal.

9.3 *Frameworks and Indicator References*

This study performed a literature review containing various publications that analyze common sustainability assessments for the architecture, construction, and buildings industry. The main framework assessed in this paper presents a *Simplified Method for Evaluating Building Sustainability in the Early Design Phase for Architects*. This publication presents a simplified method for evaluating building sustainability through reviewing and analyzing International BSAM inadequacies. This study aims to draw on the insight provided from several publications that looked critically at the current landscape of sustainability indicators. *How Can the Construction Industry Contribute to Sustainable Development? A Conceptual Framework* provides frameworks for measuring three sustainability principles namely resource management, life-cycle design and design for humans. *Building Sustainability Assessment Methods:*

Indicators, Applications, Limitations, and Development Trends will be leveraged to infer on best practices for creating effective indicators to measure sustainability.

9.4 *Insights from the 2022 Lisbon Architecture Triennale*

The 2022 Lisbon Architecture Triennale is a non-profit association that produces architectural research and holds a major forum every three years to debate and discuss architectural thinking. This year's theme titled *Terra* is a call to action to reassess the future of architecture through the exchange of knowledge and practice and includes four main exhibitions and publications. The Triennale proposes new paradigms of "place-making in a globalized planet to address how climate challenges, pressure on resources, and socioeconomic and environmental inequities are profoundly intertwined. Understanding these complex situations requires a paradigm shift from a linear growth model ("cities as machines") to a circular evolutionary model ("cities as organisms")" (Trienal De Arquitectura, 2022).

The insights from the Triennale's publications will be discussed and used to construct a framework for sustainable design with metrics specific to what would be most effective for Lisbon. The first publication, *Visionaries,* explores the production of visionary design through the age of the climate disaster, proposing a shift in aesthetic value and the processes and agents involved in doing so (Trienal De Arquitectura, 2022). *Retroactive* focusses on where 1/3 of humanity resides, in "broken cities" and explores the challenges and opportunities that architectural and urban design presents to provide for citizens. *Multiplicity* looks at architectural practice through environmental, social, and political challenges and seeks to reclaim and redefine the field to mirror the structural form of the issues it seeks to address. *Cycles* looks at the levels in which architecture operates. Rather than looking at the design of format and physical structure, architecture can operate at the scope of material process design (Trienal De Arquitectura, 2022). This book reflects on the art of designing cycles and argues for architecture not just in construction, but in deconstruction (Trienal De Arquitectura, 2022).

3. *Methods*

This paper will critically analyze current Building Sustainability Assessment Methods (BSAM) through assessing qualitative and quantitative data on sustainable development in general and specifically to Lisbon. The paper will offer adjustments to the qualitative aspects of the *Simplified Method for Evaluating Building Sustainability* which is offered as a simplified tool for architects in the early design. The paper believes it is suitable to provide qualitative revisions for the criteria of the model given that the quantitative equations in the model are supported by evidence to effectively account for aggregated group judgements to generate a total sustainability score.

The scope of the project begins at a world view to reveal current issues within the architecture, construction, and building industry. This study will refer to the buildings industry as a term encompassing the architecture and construction industry as well. The scope then zooms into Lisbon to assess its sustainable development initiatives and vision for the future. The paper provides context and statistics on a macro scale to gain an understanding of the overarching vision for the city and to understand how it seeks holistic impact. Operating from this scale of context, the study then explores different BSAM. The SMEBS model was identified as a model with very effective quantitative measuring for sustainability assessments, but with potential to improve more holistic qualitative criteria. The SMEBS model was also chosen for analysis because of its thorough review on existing BSAM and general rather than acute approach to sustainability. The study will then explain the SMEBS model's method and development to give context to support the reasoning for improving the model. The study aims to modify the SMEBS through the socio-political, economic, and environmental context of Lisbon, Portugal. A SWOT analysis is utilized to identify the strengths, weaknesses, opportunities and threats of the SMEBS model to help organize and illuminate the improvements that could be made. The insights provided to alter the model draw from the paradigm shifting ideas and visions developed from the Lisbon Architecture Triennale. The author of this study read the four publications and attended the *Cycles* exhibit at the Culturegest Museum and the *Visionaries* exhibit at the *Garagem Sul Museum* to generate an in-depth understanding of the ideas presented.

Sustainable development remains a priority for policymakers and citizens in Lisbon given the continuous climate change impacts and the momentum of being the recipient of the 2020 European Green Capital. Therefore, vast opportunity for paradigm shifting design for sustainability in the built environment exists. In order to shift paradigms of growth and development in Lisbon, there must tangible interventions. This study aims to provide effective indicators for measuring the sustainability of these interventions in order to properly account for and value the impact of these visions and designs manifesting in the built environment.

10. Findings: Background on the Global and Local Architecture and Building Sector

In her exhibit for *Visionaries,* architect Charlotte Malterre-Barthes proposes "A Moratorium on New Construction." In it she contends that "To build is to destroy… Every single component of the built environment is the product of extractive processes" (*Visionaries Exhibit*, 2022). She argues that sustainability campaigns driven by finance, real estate, and the corporate construction industry do little to rectify or slow the actual excavating, mining, smelting, manufacturing, transporting, assembling, etc. of materials (*Visionaries Exhibit*, 2022). The data from the *2022 Global Status, 2022 Report for Buildings and Construction* corroborates Malterre-Barthes' claim given that carbon dioxide emissions from the building sector are currently the highest ever recorded *(Global Status, 2022).* Despite increasing energy efficiency regulations, building energy demand increased 4% in the past year, the most drastic increase in the last ten years *(Global Status, 2022).* Energy efficiency measures generally take a decade to show measurable results, especially when competing against ceaseless construction that uses energy and resources at every step *(Global Status, 2022).* The geo-political implications of COVID-19 and the Russian invasion of Ukraine are driving European countries to find new ways to provide energy and material security for their citizens in the face of rising prices and material shortages *(Global Status, 2022).* Fossil-fuel based energy systems are being exposed for their fragility and limited resilience to converging pressures. There is an opportunity for the buildings sector to rapidly divest from fossil-fuels and de-escalate the pressures of climate change, energy dependency, and the cost-of-living crisis. In 2021, there was global policy progress for Nationally Determined Contributions (NDCs) toward climate targets with 23 countries revising their goals to commit to greater energy efficiency *(Global Status, 2022).* 80% of countries currently include buildings within their NDC action plans which is an 11% increase from 2020.

Energy efficiency also increased 16% from 2020 to 2021, with the highest contributions coming from European countries that have already publicly invested for efficiency nearly a decade ago *(Global Status, 2022).* 19% more buildings constructed this year were certified as sustainable or green compared to those built in 2020 *(Global Status, 2022).* While this is a catalyst for decarbonization in the building sector, it is expected that humans will consume double the amount of raw materials from current levels by 2060 (Organization for Economic Co-operation and Development [OECD], 2019).

The International Resource Panel has emphasized the opportunity for greenhouse gas emissions reduction driven by material efficiency strategies applied across the building stock (Hertwich et al. 2020, *Global Status, 2022*). G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom, and the United States) alone could reduce greenhouse gas emissions in the material cycle of residential buildings by over 80% by 2050 (*Global Status, 2022).* Whole building life-cycle and systems thinking combined with shifts in financial and legislative incentive for the structural longevity of buildings will be needed for this drastic reduction to occur (*Global Status, 2022).*

4.1 Lisbon Context and Macro-Level Sustainability

In the 2021-2030 National Climate and Energy Plan, Lisbon specifically outlines the following target areas to combat climate change and improve quality of life: Energy, Mobility, Water, Waste, Biodiversity and Sustainable Land-Use (European Commission, 2020). Significant improvements since the 1990's have been made in each of these areas given effective implementation of policy and infrastructure intervention, but there is further policy intervention needed to meet ambitious 2030 climate goals (European Commission, 2020).

In the early stages of urban development in Lisbon, construction was devoted to developing space for housing and commercial needs with car-centric infrastructure (Guedes, Pinheiro, Alves, 2009). Like other European countries, the inception of research on energy efficiency arrived in the 1970s, mostly due to economic motivations (Guedes, Pinheiro, Alves, 2009). As environmental concerns grew through the 1990s, a regulatory policy for energy performance was instituted which legally defined requirements for energy performance for new construction and large retrofits (Guedes, Pinheiro, Alves, 2009). In the early 2000s the Lisbon government sought to address the declining population throughout the 1990s because of its negative economic implications on human labor capital (Lisbon Green Capitol, European Commission, 2020). This offered an opportunity for a paradigm shift in urban development. The progress stemming from policy initiatives in the early 2000s are a major factor in Lisbon's growing recognition as a model for sustainable development (Lisbon Green Capitol, European Commission, 2020).

4.2 Sustainable Development Progress

A. Energy and Mobility

In 2008, Lisbon made a commitment to evolve past the economic crisis through sustainable investments. Lisbon is a model city for inducing economic growth through sustainable development (Lisbon Green Capitol, European Commission, 2020). The 2008 initiatives led to the formation of nine new green corridors driving an 18% increase in green areas by 2014. The initiatives also sought to renovate the 30 city squares and plazas and shift from car-centric transportation to public transport (Lisbon Green Capitol, European Commission, 2020).

In 2012, a new master plan was implemented that called for a new approach to land use. The plan emphasized higher-density housing and planning as well as re-zoning construction in sensitive ecological areas (Lisbon Green Capitol, European Commission, 2020).

In actualizing this plan, Lisbon has proven the measured benefits of investing for sustainability. Lisbon has increased quality of life (an integral component to sustainable development) in the city by investing in public transport, green infrastructure, and promoting and renovating high-quality public spaces in all neighborhoods (Lisbon Green Capitol, European Commission, 2020). As a result, people have become increasingly attracted to living and working in the city. The population growth rate average over the past 15 years is .51%. (Lisbon Green Capitol, European Commission, 2020). Between 2002 and 2014, carbon dioxide emissions fell by 42%. The building sector was responsible for these remarkable reductions in emissions given that individual car use rose to 48% during this time and only 34% of transport between 2001 and 2011 was considered public (Lisbon Green Capitol, European Commission, 2020). The 2012 masterplan also sought to revolutionize transport in the city. The national government made major leaps to achieving this vision by requiring ownership of the public bus and tram company in 2017 (Lisbon Green Capitol, European Commission, 2020). As a result, reductions in energy consumption amounted to 28% between 2012 and 2017. Since investments were made into the tram and bus network there are 10,000 fewer cars being used within the city (Lisbon Green Capitol, European Commission, 2020).

The 2013 Pedestrian Accessibility Plan developed with the insight of a plethora of stakeholders applies to all public space interventions within the Lisbon City Council area. The plan constitutes minimum widths and specifications for footpaths; leveled pedestrian crossings; and car-free zones which systematically creates standards 400 pedestrian crossings have been upgraded since this plan was implemented and the remaining 9,000 crossings will be completed in the coming years (Lisbon Green Capitol, European Commission, 2020). So far, wider footpaths, additional cycling lanes, shared bicycle, scooter and car initiatives have contributed to an increase of 43.8% in walking and cycling which accounts for 32% of all travel undertaken (Base year 2013) (Lisbon Green Capitol, European Commission, 2020).

In 2015, Lisbon was awarded the prize for European Entrepreneurship Region and continues to be regarded as a top European entrepreneurship and innovation hub (Lisbon Green Capitol, European Commission, 2020). The entrepreneurial ecosystem acts synergistically with the development of new green jobs as the innovation of startups plays to the demand for urban sustainability and the new business opportunities it presents (Lisbon Green Capitol, European Commission, 2020).

Between 2016 and 2017, Lisbon saw a 700% increase in bicycle use in response to public investment for cycling infrastructure and bike access (Lisbon Green Capitol, European Commission, 2020). 93% of people live within 300 meters of public transport and in combination with more accessible fares (€1 per day) has led to a 20% increase in public transport use since April 2019 (Lisbon Green Capitol, European Commission, 2020). The city continues to invest heavily in the existing public transport infrastructure (Lisbon Green Capitol, European Commission, 2020).

Sustainable energy infrastructure interventions have included large scale solar photovoltaic developments (Lisbon Green Capitol, European Commission, 2020). The “Solar City” project doubled the solar energy installed in buildings between 2018 and 2021 raising capacity to 8 MW (Lisbon Green Capitol, European Commission, 2020). Furthermore, all new social housing developments will have solar panels installed on their roofs. A retrofit of City

Hall led to a 50% decrease in energy consumption, saving €83,0000 and is a model for the retainment of heritage within historical buildings while increasing energy efficiency (Lisbon Green Capitol, European Commission, 2020). This was possible through a partnership with the Energy and Environment Agency of Lisboa, a non-profit association that acts as a shared platform for innovation and climate action between the municipality and the main private and public stakeholders. A target is also set for 30% reduction in energy consumption of municipal buildings by 2030 from the base year 2016 and 20% for private buildings (Lisbon Green Capitol, European Commission, 2020).

The New Covenant of Mayors for Climate and Energy targets a 60% carbon dioxide emissions reduction from the base year 2002 by 2030, and to be carbon neutral by 2050. The approach seeks to design greater efficiency and integrate energy sources and infrastructure in order to support decarbonization (Lisbon Green Capitol, European Commission, 2020).

B. Biodiversity and Sustainable Land-Use

There are a plethora of greening initiatives that have contributed towards sustainable development in Lisbon The European Union funded a program under its LIFE+ project initiatives from 2019 to 2024 that will see 100,000 trees planted throughout the streets, replace traditional lawns with rain fed meadows, and install infrastructure to increase shadowing and reduce temperatures (Lisbon Green Capitol, European Commission, 2020). Similar to the integrated nature-based solution seen with the green corridors, the rain fed meadow lawns also provide regenerative benefits like soil organic matter replenishment, drought resiliency, air pollution reduction, water retainment, biodiversity and act as carbon and nitrogen sinks (Lisbon Green Capitol, European Commission, 2020). Another example of urban ecosystem regeneration is found in the 85-year old hand-planted Monsanto Forest Park, one of Europe’s largest urban forests. In 2012, Lisbon constructed its first green corridor connecting the city center to Monsanto Forest Park and will continue to implement corridors throughout the city that will include 45 km of vegetation filled streets at an average rate of 25,000 plantings per year (Lisbon Green Capitol, European Commission, 2020). The myriad benefits derived from the corridors include, but are not limited to, combatting the heat-island effect, habitat provision and species integration, increased water retention, drought and flood mitigation, air and noise pollution reduction, and health benefits to humans (Lisbon Green Capitol, European Commission, 2020). In 2019, Praça de Espanha square was converted from a massive asphalt area to six hectares of green parkland with a rain garden design. 85% of people already live within 300 meters of green urban spaces and the city has plans to increase that to 93% with the completion of ongoing projects (Lisbon Green Capitol, European Commission, 2020).

In 2008, a strategy was formulated to develop urban agriculture. The Urban Allotment Garden program (AUG’s) was subsequently implemented with parks opening in 2011 at brown field sites (Lisbon Green Capitol, European Commission, 2020). As of 2020, the AUG’s encompass 9.1 hectares, 750 organic allotment gardens at 20 different parks utilized by over 750 families, schools and community groups. This enables citizens to grow their own food, increase social inclusion, food security, and drive self-sustainable food production (Lisbon Green Capitol, European Commission, 2020). The program trains all its plot owners, provides shared tools, sheds, and rainwater recovery systems and adopts a Mediterranean diet that values local production, seasonality and biodiversity (Lisbon Green Capitol, European Commission, 2020). The UAGs are used by almost 750 families, as well as by schools and community groups. Since the initiatives in 2008, green spaces increased 16% by 2021 and this number is projected to reach

20% by the end of 2022 (Lisbon Green Capitol, European Commission, 2020). In 2020, the mayor announced that the city center will generate long-term benefits for citizens and tourists by improving air quality, more open spaces, and greater mobility with the construction of new tram lines. Public space enhancements including wider footpaths and open-air restaurants will take the place of 2,000 street car parking spaces (Lisbon Green Capitol, European Commission, 2020). Speed limits will be lowered to 30 km/h throughout the city to increase walkability, bicycle lanes will continue to be developed along with 7,750 bicycle parking spaces. Furthermore, bicycle purchases will be subsidized by a €3 million mobility fund. New affordable housing projects are required to meet Near Zero Emissions Building (NZEB) standards (Lisbon Green Capitol, European Commission, 2020).

C. Water and Waste

The city reduced its water consumption by 50% from 2014 to 2018 through leakage control measures and a monitoring system that detects damaged pipes within fifteen minutes. A 170$ million public investments into a Drainage master plan will help to mitigate the impacts of 100-year extreme flooding events (Lisbon Green Capitol, European Commission, 2020).

Only an impressive 2.5% of waste is diverted to landfill while the rest is converted to energy through incineration. Lisbon has a 26.1% reuse and recycle rate, the best in Portugal. There is also a domestic and community composting organization that distributes free compost bins and training to citizens to produce and use compost in 2,308 homes as of 2021 (Lisbon Green Capitol, European Commission, 2020). A city-wide domestic bio-waste collection program was introduced in 2021 to bolster the existing restaurant bio waste collection routes where it goes to an anaerobic digestion facility for conversion to biogas and compost (Lisbon Green Capitol, European Commission, 2020). Lisbon’s historic neighborhoods have long posed challenges for waste collection given the close proximity of small buildings that makes door-to-door collection unhygienic. In 2018, the problem was circumnavigated by replacing the old systems to put bins in public spaces with interconnected unground recycling stations (Lisbon Green Capitol, European Commission, 2020).

D. Climate Threats and Remaining Challenges

Imported oil is the predominant energy resource in Portugal accounting for 42% of the total energy consumption (European Commission, 2018). Significant progress must be made in the six different target areas identified in the National plan to continue to improve sustainability: (1) mobility, (2) energy, (3) water, (4) waste and circular economy, (5) air quality and noise, and (6) awareness and public engagement (European Commission, 2018). The built environment plays an essential role in mitigating further climate change induced impacts and also in retaining and raising the quality of life for its citizens. The building and transport sector poses the greatest difficulty to achieving these targets given that the two sectors account for 90% of primary energy consumption in Lisbon (Lisbon Green Capitol, European Commission, 2020). Paradigm shifting ideas in architecture and transcending the disciplines notions of physical design are necessary to evolve past the already impressive progress in sustainable development.

11. Findings: Building Sustainability Assessment Methods

A case study was done in Beato, Lisbon that applied a revised sustainability assessment system that aimed to more effectively represent the economic dimension of sustainability. The publication, *Evaluating the Economic Benefits of Moving from A Single Building to A Community Approach for Sustainable Urban Redevelopment: Lisbon Neighborhood Case Study* performed an extensive literature review on existing sustainability assessment systems and found that the majority of early Building Sustainability Assessment Methods (BSAM) focused heavily on environmental impacts such as energy consumption, pollution from emissions, water-use, and biodiversity, but now seek to integrate functionality, economics, accessibility, and social dynamics (Pedro, Reis, Silva, 2020). Increasingly holistic assessments leverage life-cycle analysis of buildings through maintenance, demolition, and disposal. While many regulations and assessments focus on the building's physical life, less focus on the architectural design phase exists which is crucial to enabling 'selective' and passive design techniques such as position and orientation, structure, and material (Pedro, Reis, Silva, 2020). The paper contends that methods to assess individual design and functioning parameters of a building are "useful but deficient." Furthermore, most existing BSAM are inaccessible to architects without a licensed assessor and consultants are often needed for life-cycle analysis, life-cycle assessment, simulation of energy flows etc. There are added financial costs to evaluating and certifying buildings and there is difficulty in scaling BSAM across various local cultural, environmental, and political contexts (Pedro, Reis, Silva, 2020). These results are similar to the findings in *A Simplified Method for Evaluating Building Sustainability in the Early Design Phase for Architects* which "Found there is a need for a method that evaluates the project solution in a comprehensive manner in the early design phase and is at the same time simple enough for independent use by architects" (Markelj, Kuzman, Groselj, 8779).

The most utilized and familiar BSAM include the Building Research Establishment Environmental Assessment Method (BREEAM) UK 1990, Leadership in Energy and Environmental Design (LEED) USA 1998, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) Japan 2001, German Sustainable Building Council (DGNB) Germany 2008, and LiderA (Portugal, 2005) (Pedro, Reis, Silva, 2020). The following graphic below demonstrates the capacity and constraints of these models.

Figure 1. Overview of the urban sustainability assessment criteria (Pedro, Reis, Silva, 2020).

This study aims to address the lack of integration of certain indicators for sustainability in all models. Specifically, only one of five models uses life cycle assessment, only two of five models performed material selection cost-analysis or life-cycle cost, two of five measured passive design, two of the five measured demand-supply smart systems, and only one of five measured thermal comfort of open spaces. This study contends that the aforementioned factors must be incorporated into all models for accurate measures of sustainability.

11.1 *Case Study: The SMEBS Model*

The SMEBS model seeks to address many of these deficiencies while remaining simple and applicable to the nuances of the local environment. Our study aims to further improve the SMEBS Model.

The parameters for evaluation were generated through comparable analysis of various pre-existing, commonly used BSAM criteria and then structured through a four-layer hierarchal model: level 1–assessment of the building's sustainability, level 2-aspects, level 3–categories, and level 4-criteria (Markelj, Kuzman & Groselj, 8779). Level two identifies the burden to the natural environment, the quality of the built environment, and the economic efficiency. These aspects then diverge through thematically connected categories. The final 33 criteria at the fourth level are recognized as core indicators given the assumption that the building is considered through its life-cycle entirely (Markelj, Kuzman & Groselj, 8779).

The following Model for evaluating building sustainability was subsequently generated:

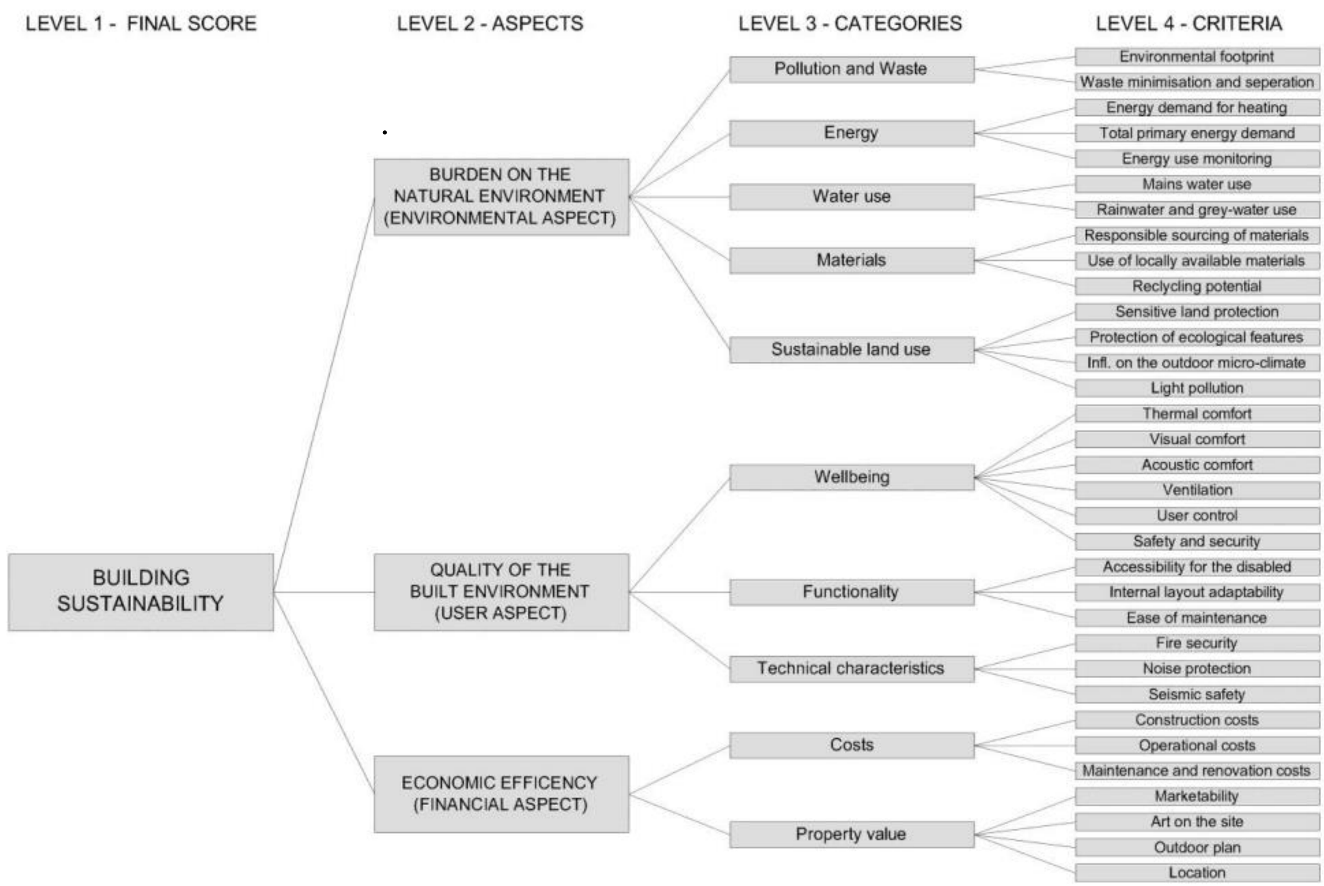

Figure 2. Model for evaluating building sustainability (Markelj, Kuzman & Groselj, 2014).

5.2 We*ighting the Criteria*

The Analytical Hierarch Process (AHP) was leveraged to assign weighted importance to each of the criteria to determine the final building sustainability score (Markelj, Kuzman, Groselj, 2014). The AHP is considered one of the most utilized and effective methods for applying weights to multiple-criteria-decision making (Markelj, Kuzman, Groselj, 2014). The AHP process beings by initially defining the problem which in this case is to address limitations of other models (Markelj, Kuzman, Groselj, 2014). A sample group of experts was selected to execute the pairwise comparisons between the criteria presented. The criteria were measured on a scale of 1-9. The individual selections for the pairwise comparisons were aggregated into group judgment through a geometric mean method that derived local weights of parameters using Saaty's eigenvector method. The global weights were calculated by using an individual parameter equation that multiplied local parameter weights with hierarchal higher sections (category and aspect) (Markelj, Kuzman, Groselj, 2014). The criteria was then judged and entered into a matrix formula, bolstered with the credibility of a consistency ratio to calculate if there is significant consistency across chosen parameters (Markelj, Kuzman, Groselj, 2014). Figure 3 shows examples of the pairwise comparisons.

Circle a Number to Show Which of the Parameters You Believe is More Important		
	Wellbeing	Functionality
1	thermal, light and acoustic comfort, quality of ventilation, user control over systems for local settings of desired comfort, security	accessibility for the disabled, internal layout adaptability, ease of maintenance
	9 8 7 6 5 4 3 2 1	2 3 4 5 6 7 8 9
	Wellbeing	Technical properties
2	thermal, light and acoustic comfort, quality of ventilation, user control over systems for local settings of desired comfort, security	fire security, noise protection and seismic safety of the building
	9 8 7 6 5 4 3 2 1	2 3 4 5 6 7 8 9
	Functionality	Technical properties
3	accessibility for the disabled, internal layout adaptability, ease of maintenance	fire security, noise protection and seismic safety of the building
	9 8 7 6 5 4 3 2 1	2 3 4 5 6 7 8 9

Figure 3. Pairwise Comparison Examples (Markelj, Kuzman, Groselj, 2014).

Figure 4 displays the subsequent implication of each numerical value selection, showing that the greater the number, the greater the proportional importance in weight.

Table 3. Explanation of numerical value in allocating judgments.

Intensity of Importance	Definition	Explanation
1	Equal importance	Parameters *i* and *j* are equally important.
2	Weak or slight difference in importance	
3	Noticeable difference in importance	Parameter *i* is moderately more important than *j*.
4	Medium difference in importance	
5	Large difference in importance	Parameter *i* is much more important than *j*.
6	Very large difference in importance	
7	Strong difference in importance	Parameter *i* is proved to be more important than *j*.
8	Very strong difference in importance	
9	Extreme difference in importance	Parameter *i* is absolutely more important than *j*.

Figure 4. Explanation of numerical values in allocating judgements (Markelj, Kuzman, Groselj, 2014).

5.3 Background of Respondents

Of the 17 respondents, 35% of the respondents were in the planning and consulting field, 29% in the educational and research institutions, 12% in production and sale of materials and building components, 12% in development agencies and interest groups, and 12% in public and state administration. The majority of the educational background (59%) was in the architectural field.

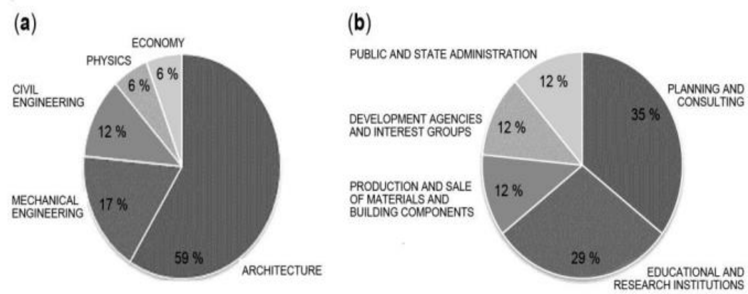

Figure 5. Demographic of Respondents (Markelj, Kuzman, Groselj, 2014).

5.4 Measuring the Results

Figure 6 focuses on the burden on the natural environment aspect. The table also ascribes global weights for the quality of the built environment and economic efficiency. The final results demonstrated that the respondents ascribed the most weight in determine a sustainable building through the high quality of the built environment with a high level of well-being for users and appropriate functionality and technical characteristics. User aspects that promote well-being include thermal comfort, ventilation, accessibility for the disabled, internal layout adaptability, fire security and seismic safety.

Aspect	Local Weight	Category	Local weight	Criteria	Global Weight	Global Weight	Global Weight
Burden on natural environment–Environmental aspect	0.1708	Pollution and waste	0.7473	Environmental footprint	0.0439	0.0588	0.3441
			0.2527	Waste minimization and separation	0.0149		
	0.2302	Energy	0.3501	Energy demand for heating	0.0278	0.0792	
			0.5220	Total primary energy demand	0.0412		
			0.1278	Energy use monitoring	0.0101		
	0.2189	Water use	0.5310	Mains water consumption	0.0400	0.0753	
			0.4690	Rainwater and grey-water use	0.0353		
	0.2199	Materials	0.3874	Responsible sourcing of materials	0.0293	0.0757	
			0.2657	Use of locally available materials	0.0201		
			0.3469	Recycling potential of components and materials	0.0262		
	0.1602	Sustainable land use	0.2776	Sensitive land protection	0.0153	0.0551	
			0.2490	Protection of ecological features	0.0137		
			0.2935	Influence on the outdoor micro-climate	0.0162		
			0.1800	Light pollution	0.0099		

Figure 6. Weighting of the Criteria (Markelj, Kuzman & Groselj, 2014)

12. Discussion

SWOT Analysis of Criteria

The measurement of a building's sustainability is only as effective and accurate as the indicators that measure it. If the circularity of a material is not measured, there is a whole component of potential sustainability that becomes excluded. While the AHP model and the mathematical equations of the SBEMS model produce effective ways to aggregate individual judgements into weighted significance, this study seeks to revise some qualitative aspects of the SMEBS model that would alter the coefficients of the quantitative equations. From the research collected through the Lisbon Architecture Triennale, three main areas of revision are proposed: The demographic of the respondents selected to perform the pairwise comparisons, the narrow scope of measuring material-based impact, and the impact that various design principles could have on each of the aspects.

Strengths

- The AHP Method is an effective way to allocate parameter weights
- Pairwise comparisons can help balance the different components of sustainability
- The quantitative methods are effective in ascribing weights to the different criterias
- Level 1 (Final Score) and Level 2 (Aspects) provide the potential to measure sustainability holistically

Weaknesses

- The group of experts selected do not include many citizens, therefore lacking a participatory component
- The qualitative descriptions for certain aspects of the pairwise comparisons lack specificity which alters the quantitative measurements that factor into the equations determining end weights
- The Material criteria is inadequate for determining environmental and social sustainability
- There is a lack of life-cycle analysis
- The Well-being Category accounts for the User Aspect considerations, but it does not incorporate the Environmental Aspects, therefore failing to create a holistic comparison

Opportunities

- Further participatory Involvement
- Offering new qualitative descriptions
- Creating a way to account for more of a process-based architecture pardigm
- Revision of the Material and Well-being criteria
- Overall, the fragmented and isolated nature of the model could benefit from an interconnected structure along with measurements for the pre-building, building, and post-building phase

Threats

- Architechtural tradtions of aesthetics can impede sustainability efforts
- Determining weights for processes versus individual criteria components is difficult to derive quantitativley

Figure 7. SWOT Analysis of the SBEMS Model

6.2 Questioning the Demographic of Experts: Participatory Role in Sustainability Assessment

In *Multiplicity*, a conversation occurs between the architects Vyjayanthi Rao, Tau Tavengwa, and Alden Copley where they discuss who should be considered "experts" in the field of architecture that no longer constitutes just the design of building, but the design of systemic change (Visionaries, p. 9-16, 2022). Alden Copley articulates that projects that are readily adopted by a community involve processes where the people who will use the space are considered the experts on that space (Visionaries, p. 9-16, 2022). While architects and governments can offer resources, it is important to recognize that end users are often experts on the purpose of the space (Visionaries, p. 9-16, 2022). Governments often try to institute a standardized, bureaucratic approach to housing and introduce the most cost-effective solution. While this may not suit the communities need, the other extreme of having end-users as the experts can sometimes be problematic because the want for change does not always translate to understanding what that change should look like or how it should be undertaken (Visionaries, p. 9-16, 2022). Vyjayanthi Rao builds on this point by contending that architects should act as brokers for other people's expertise (Visionaries, p. 9-16, 2022). There are many stakeholders: politicians, investors, consultants, architects etc. with valuable knowledge. Architects can take on the role of navigating the differences between actors' values and generate collaborative expertise (Visionaries, p. 9-16, 2022).

6.3 Applications of this Solution to Lisbon

There is unprecedented citizen involvement in urban sustainability initiatives in Lisbon evidenced by the 5,400 volunteers that planted 20,000 trees and shrubs in just one day on the inception of Lisbon's European Green Capital year on January 12, 2020 (Lisbon Green Capitol, European Commission, 2020). There are also policy mechanisms that account for citizen ideation and implementation. The annual "Participatory Budget" enables citizens to both propose, campaign, and vote on urban sustainability projects presented by the municipality. This budget increased to €5 million in 2020, up from €2.5 million when it began in 2010 (Lisbon Green Capitol, European Commission, 2020). Between 2008 and 2018, 2,079 citizen project proposals were given, 303,208 citizens were involved in the voting, and 139 were considered feasible. As of 2021, 66 public space projects proposed by citizens have been implemented including renovation projects, local gardens, urban allotment gardens, cycle-paths, cycle-pedestrian bridges and fruit orchards (Lisbon Green Capitol, European Commission, 2020). The majority of the projects focused on climate, energy, and the environment, while the others focused on sustainable mobility. €25.2 million has been devoted to projects derived from bottom-up approach decisions that are being implemented or have been completed (Lisbon Green Capitol, European Commission, 2020).

The SMEBS model sample group of experts seems to inadequately factor in the end-user expertise and citizen perspective. The only possible participatory involvement in the SMEBS model appears to be the 12% of respondents from interest groups (Markelj, Kuzman, Groselj, 2014). The study could benefit from providing a separate aggregation of individual citizen pairwise comparison judgements. This is essential for the social dimension of sustainability.

6.4 Material Criteria Revision

Cork illuminates the paradox that when a "sustainable" material is implemented on a wide scale for the purpose of measurable reductions in environmental degradation, it can often loose its social and environmental sustainability (Prado, Alonso, 2022). The montado ecosystem for cork production is both regenerative and sustainable. A cultural staple for centuries, the cork oak trees are embedded within agriculture and livestock fields which increases organic soil matter, nutrient absorption, water retention, and habitat provision (Prado, Alonso, 2022). Cork oaks are first harvested between 25 and 40 years after planting and then legally debarked every nine years after (Prado, Alonso, 2022). Architects and the construction industry are enticed by the materials potential as a natural insultation material (Prado, Alonso, 2022). Cork has "Exceptional thermal performance, longevity, often with lower emissions, is impermeable, fire-retardant, rodent-resistant, and non-allergenic" (Prado, Alonso, p.13, 2022). Compared with plastic-based insulation, cork possess exceptional thermal abilities, physical longevity, non-hazardous waste, and lower emissions. Portugal is the world's largest exporter of cork, accounting for 62% of total cork production (Prado, Alonso, 2022). The economic benefits to Portugal as it accounted for $1.2 billion in revenue in 2020. Global demand has recently increased which is reflected by increasing investments in plantations (Prado, Alonso, 2022). Climate issues and property constraints threaten the inverse correlation between production and market demand. The combination of more frequent and intense fires and temperature anomalies threaten planation health (Prado, Alonso, 2022). The stalled return on planation investment to first harvest increases pressure for production and territorial competition from eucalyptus plantations, agricultural expansion, and solar farms and lithium mines prevents expansion (Prado, Alonso, 2022).

There is pressure to increase production through monocropping and genetic selection for faster maturation to complete the first debarking at 8-10 years (Prado, Alonso, 2022). Both biodiversity and the human traditions of the montado system would be drastically reduced as a result. There are consequences when transitions are made to sustainable, green, or natural materials in an economic growth paradigm that does not account for externalities (Prado, Alonso, 2022). In Indy Johar's exhibition on democratizing architecture they contend that "Governments all over are leaning into this next stage of transition and understand that unless we embrace the multiple benefits that any asset can produce and fully account for those in both our decision-making and how we respond to emerging challenges, we are going to – again – end up in an environment where everything is optimized for capital" (Johar, Multiplicity, P. 39, 2022). Product-based sustainability operating under unsustainable processes and systems can make the production of the product inherently unsustainable. If the increased demand of cork - a sustainable material - surpasses environmental or social limits, the process is not sustainable and therefore the material is neither (Prado, Alonso, 2022). Simply opting to insulate a house with cork instead of plastic is not sustainable architecture. This paper aims to demonstrate that sustainable architecture would seek to design processes where the life cycle of the cork is extended as much as possible and its applications for future re-use rather than intensifying the speed of production for wider scale implementation (Prado, Alonso, 2022). It is only when sustainable processes underlie sustainable material interventions that it should be considered sustainable (Prado, Alonso, 2022). This example acts as evidence that many sustainability indicators and metrics that quantify sustainability through material-based solutions may be missing a key component of systems and processes indicators (Prado, Alonso, 2022).

In the SMEBS model, the material criteria include three components to measure its sustainability: 1. Responsible sourcing of materials ("Reduction of burden on the environment and health risks through the use of verified materials") 2. Use of locally available materials ("Reduction of negative effects due to transport and stimulation of the local economy"), and recycling potential of components and material (Promotion of recycling of obsolete parts of the building and the return of materials in the biological or technical life cycle" (Markelj, Kuzman, Groselj, p. 8781, 2014). An example of the cork material demonstrates the inadequacy of these three criteria and their descriptions to measure their contributions to overall sustainability.

6.5 Designing for Processes
Initial Considerations: Architectural Aesthetics of Waste and Recycling

The nature of architecture is the freedom to design, but this freedom is often constrained by bureaucracy, policy, legal issues, clients, financiers, clients, contractors, engineers etc. The architect's initial vision is often altered in order to become feasible (Tevengwa, Rao, 2022). On the world scale this has resulted in the architectural field acting as a complacent orchestrater for accumulating and organizing the formless, fragmented matter extracted from natural resources into built structures (Tevengwa, Rao, 2022). The production of waste that arises from the ceaseless demand for building construction is integral to capitalism (Tevengwa, Rao, 2022). The rate at which materials render themselves obsolete is intertwined with profitability, but it could be argued that market forces are just one downstream symptom of over production and consumption (Tevengwa, Rao, 2022). Upon further examination of architectural practice, it becomes apparent that there are many fundamental processes in architecture that lead to waste production downstream in the building and construction sector (Tevengwa, Rao, 2022).

Regardless of human intervention, materials undergo cyclical processes. In *Cycles*, Pamela Prado and Pedro Ignacio Alonso exemplify the potential for architects to design cyclical material processes when they accept rather than resist the transformation, exchange, and redistribution of matter that occurs with all physical processes (Prado, Alonso, 2022). When this compromise is made between architects and Earth's processes, the notion of "waste" no longer makes sense in the lexicon of architecture (Prado & Alonso, 2022).

Unfortunately, this compromise is rarely made because for "waste" to be integrated into the building process it must be deemed reliable and certificated which means it is no longer deemed "waste" (Prado & Alonso, 2022). While this concept appears self-explanatory and conducive to circular economy principles, a paradox arises that shows a root of the "waste" problem.

Historically, a pervasive architectural tradition proposes that "Architectural form must be the faithful expression of construction, revealing a truth of materials" (Prado & Alonso, P.10, 2022). The implications of this tradition mean that architecture should enhance the expression of waste which means that if it is to be deemed sustainable, it must express itself as "environmentally friendly." In other words, the perception of architecture as circular or environmentally friendly is in the ability for the material to be constructed as a symbolic expression of "waste" (Prado & Alonso, 2022). This makes it challenging for waste to both be expressed as waste, yet also be deemed reliable. The aesthetic value placed on waste expressionism translates to market value and makes it challenging for tangible circular material flows to be valued over the symbolic expression of waste in construction (Prado & Alonso, 2022).

The paradox also extends to recycled material aesthetics. The architect designs the recycled material to represent "un-recycled" material in order to emphasize the truth of the materials used. The process of making something look "un-recycled" often means additions or modifications to a product that are energy intensive (Prado & Alonso, 2022).

The material expression of “recycled” and “waste” materials is detrimental to designing material cycles and also brings into question the validity of the recycling component for the material criteria in the SMEBS model.

The sustainable architecture argued for in *Cycles* is not one that focuses on physically designing and acting upon material objects, but rather through paradigm shifting ideas that re-organize materials into cycles to alter the human subject’s perception and value on sustainable design (Prado & Alonso, 2022). When circularity is properly integrated into architecture, costs are reduced. This notion shows the need to integrate the categories in the SMEBS model together, given that choices in material processes can have positive implications on not just the environment, but also economics which can make it more affordable thus impacting the social dimension of sustainability.

6.6 Aesthetic Value Modifications to the SBEMS Model

The SBEMS model includes *recycling potential of material* as one its criteria to measure the environmental aspect of the building’s sustainability; specifically, the return of materials in the biological or technical life cycle. The SBEMS model could become more effective at accounting for the true sustainability of a material within common aesthetic valuations of the built environment by expanding upon this specific criterion. A *Cycles* exhibition titled *Logbook: Illustrated strategies for use and reuse* devoted four days in Lisbon towards finding companies that specialize in the sale of second life materials. Lisbonwood, Warehouse Collective and NovoNovo are Lisbon-based companies that adopt the philosophy that there are no leftovers, just potential materials (Prado & Alonso, 2022). These companies are showing the potential to reduce upstream production through effective downstream exploitation of “waste”. The findings from exploring and investigating the practices of these demolition and consulting platforms are as follows: *A leftover is a material* (Limit, anticipate, classify and use the leftovers), *Design from available resources* (Lisbonwood finds and organizes structural components of houses, and an architect selects the elements he wishes to design with), *Non-standard materiality* (Take advantage of the marks of a materials past life), and *Anticipating the end of life of a work* (Constructing buildings for later dismantling of materials to contribute to local chains of material re-use) (Logbook (Cycles), Prado & Alonso, 2022). These four findings can more effectively encapsulate the *recycling potential of material* criteria by being included as components to questions in the survey of pairwise comparisons of criteria.

Furthermore, Keller Easterling, a writer and architectural critic stated that “Architects should design not only built objects, but the advent of their ideas into culture” (Visionaries, P. 103, 2022). The ability of local material re-use supply chains can enhance the functional symbolism of infrastructure. When the built structure provides the functions desired in a specific context, it fosters a place-based culture around the built structure. Infrastructure can act as a vehicle for synthesizing a sense of community, and becomes symbolic not because of its physical expression of material, but through the interactions and function enabled through the structure. Local infrastructure can incorporate re-used materials that retain the local signatures of their past and catalyze an aesthetic shift towards the new processes and functions derived from existing material rather than symbolic expressions of “waste” and “recycled” material (Tavengwa & Rao, 2022).

6.7 Criteria for Material Design Processes

Cycles contends “There is no such thing as building with waste” (Prado & Alonso, p. 9, 2022).). Cycles argues for “warehouse architecture” which is “not the shape texture, or colour of things recovered from permanent loss, so much as the new ways they can be organized” (Prado & Alonso, p. 11, 2022). Warehouse architecture steps away from looking for newly constructed forms, but rather new ways to order material processes (Prado & Alonso, 2022). Warehouse architecture seeks to transition the aesthetic appreciation away from the uniqueness of material design towards a value of designing new cyclical processes for materials (Prado & Alonso, 2022). Expanding a materials longevity, durability, and ability to be re-organized and re-used for various uses is often invisible when the material is in its built form. We must begin to value the architect’s ability to show the truth of sustainable design through the invisible design for circular processes rather than a symbolic visual expression of sustainability (Prado & Alonso, 2022).

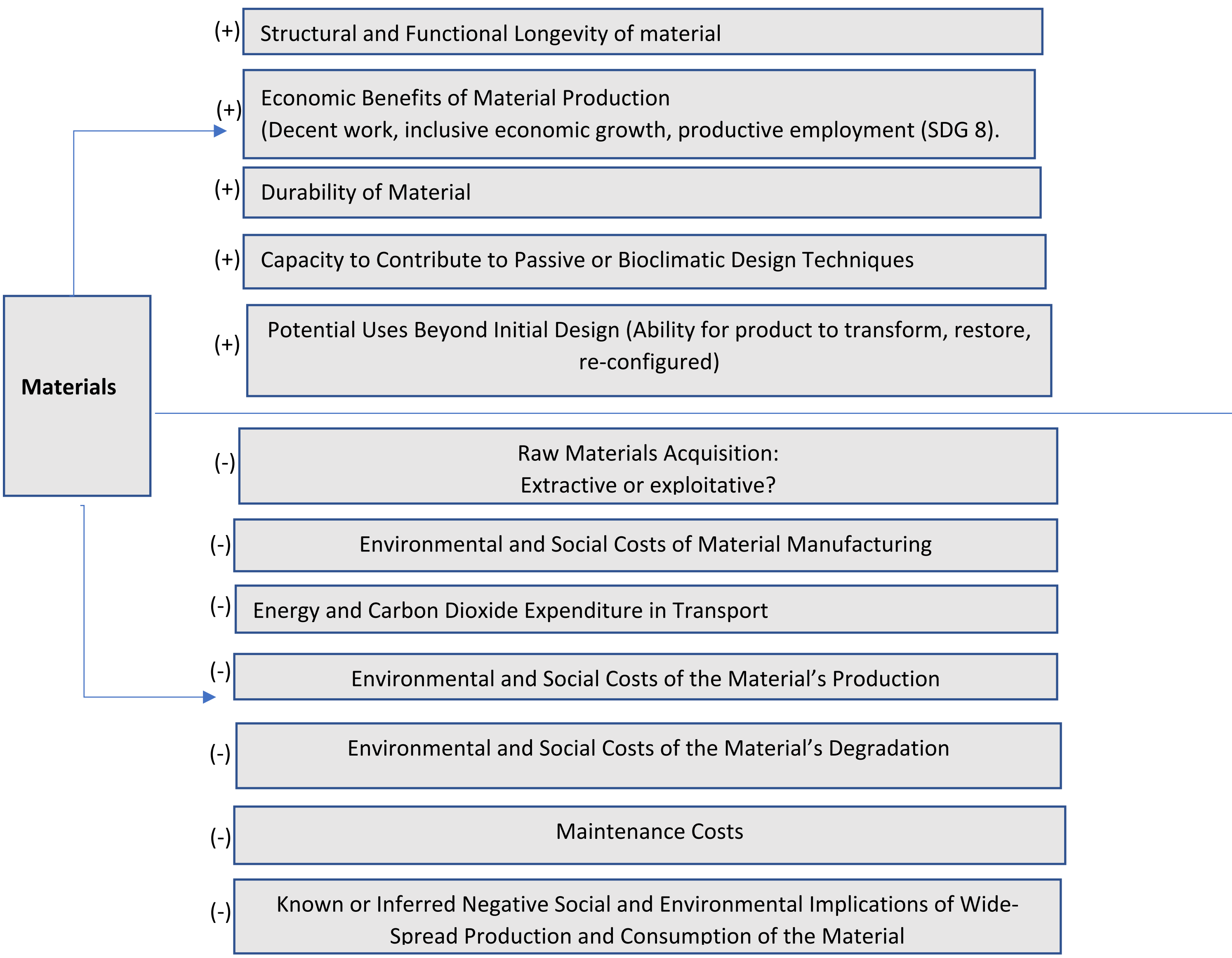

Figure 8. Proposed Improvement to Material Criteria

This study proposes the expansion of the material category to create more holistic criteria to measure sustainability. The model has five components that positively contribute to the sustainability score and seven components that negatively contribute to the sustainability score. The insights from the Lisbon Architecture Triennale inform this studies belief that the material criteria should not only have positively contributing scores given that underlying processes are often negative. This model seeks to account for the invisible extraction and environmental degradation of “recyclable” or “sustainable” materials that occurs away from the initial design and construction of the building.

For example, sand is removed in mass quantities in very close proximity to Lisbon (Prado & Alonso, 2022). 1,350,000 tons per year are extracted and production is expected to double in the coming year. The riverbed continues to be modified upstream the Tagus River to meet demand (Prado & Alonso, 2022). Furthermore, the material used to renovate inner walls in Lisbon as well as expand the metro lines in Estrela, Lisbon is known as Gypsum (Prado & Alonso, 2022). This resource is longer extracted near Lisbon, but imported from ships in Spain or North Africa (Prado & Alonso, 2022). Both of these materials physically remain the same, but the processes that underly them have changed which alters their true sustainability. In the example of the Sand, the SMEBS model would not account for the impact that doubling production would have economically or socially because the weighted score only applies to the environment aspect. Furthermore, the criteria’s scoring would not be altered given that the descriptions do not account for the impact of increased production. In the example of Gypsum, the criteria may factor in local production, but does not account for the potential impacts both positive and negative, to production shifting away from Lisbon and into Spain and North Africa.

6.8 Accounting for Construction Costs and Deconstruction Costs

The publication *Visionaries* argues that demolition should cost a lot more than construction meaning that we would hold ourselves accountable for all the energy and carbon dioxide that was used for construction, the houses performance, the material processes of extraction and manipulation, and the energy expended on deconstruction (Smirnova, 2022). While construction is based in research and design, deconstruction and demolition are rarely viewed through the same lens. The ability to separate, organize, and re-use various types of building components or the ability to retrofit pre-existing structures at the end of the buildings “life-time” should be factored into an initial sustainability assessment. As architecture transitions its ethos from the image and aesthetics of material construction to design thinking, sustainability assessment methods must be able to adequately value processes and systems-based thinking (Prado & Alonso p. 91, 2022). This study argues that in addition to the cost of construction, the cost of deconstruction should be measured across financial aspects, user aspects, and environmental aspects. If the SMEBS model could account for the cost of deconstruction it could drive society towards revising the notion of design and building from a “Process of conception consisting of finite stages leading towards a closed totality” towards a “Continuous process of repair, alteration, and modification” (Prado & Alonso, 127). This notion shows the need for building sustainability models to contain paradigm shifting criteria rather than wait for a shift in the tradition of architecture to occur and then design subsequent models.

6.9 Thermal Comfort and Passive and Active Design

A building can relate itself to the natural environment in "Exclusive" or "Selective" modes. The "Exclusive" approach secludes itself from the environment of the outside world (Giedes, Pinheiro, Alves, 2009). Artificial lighting, climatization and other signatures of the "exclusive" style would be greatly detrimental if wide-scale implementation were to occur in Lisbon given their dependency on exported oil (Giedes, Pinheiro, Alves, 2009). In the National Plan, there is an objective to reduce energy dependency to 65% by 2030 (European Commission, 2018).

	Projected reduction of GHG emissions with respect to 2005 (%)	
Sectors	**2030**	**2040**
Hydraulic	73	89
Industry	45	45
Transport	48	72
Services	64	82
Residential	27	29
Agriculture	19	19
Waste and Wastewater	57	69
Total without LULUCF	52	64

Figure 9. Potential GHG Emissions Reduction with Respect to 2005 (%) – Existing Policy Scenario (European Commission, 2018).

The residential sector is expected to reduce GHG emissions by 27% by 2030 and then plateau around 29% by 2040 under existing policy scenarios (European Commission, 2018). The overall renewable energy share of energy production is projected to increase from 31% to 47% by 2030, but only gross final energy consumption of renewables is only expected to increase 4% by 2030 for heating and cooling (European Commission, 2018). Therefore, it would be detrimental to build with active design for heating, cooling, lighting, and other aspects of comfort (European Commission, 2018). Relative to other European cities, Lisbon has very low energy consumption given its mild climate that reduces the need for heating and cooling (European Commission, 2018). At present, it is not justified to implement district heating networks for the residential sector in Lisbon (European Commission, 2018). Since 2009, residential energy consumption dropped 4% annually which was enabled through energy efficiency, equipment improvements, and higher energy prices (European Commission, 2018). This progress is threatened by rising demand for energy in new buildings catalyzed by economic growth, altered housing requirements, and accessibility and affordability of electrical appliances (European Commission, 2018). Interestingly, ventilation and thermal comfort are under the wellbeing category within the quality of the built environment aspect in the SMEBS Model. Passive techniques for the *user* aspect are not included in the *measures of sustainability* or *burden on the environment* despite have very large implications on total energy consumption and cost reductions, once again showing the need for interconnections between categories. Professionals of the building sector such as architects, engineers or builders, have a responsibility in terms of their contribution for inverting the exclusive design tendency to promote a more sustainable development (Giedes, Pinheiro, Alves & 2009). Passive design like natural ventilation, solar orientation, use of thermal inertia and other techniques used in previous centuries are often adopted for the contemporary pressures of today (Giedes, Pinheiro & Alves, 2009). Lisbon's climate enables the city to lean on "selective" and passive design interventions because the use of artificial climatization is generally unnecessary (Giedes, Pinheiro & Alves, 2009). In Portugal the vast majority of existing buildings remain naturally ventilated (Pedro & Pedro, 2021). There are general techniques and principles applicable throughout Lisbon including "Night ventilation with thermal inertia, proper solar orientation, adequate insulation, adequate shading etc." (Giedes, Pinheiro & Alves, p. 2004, 2009). Active systems and technologies such as solar thermal and photovoltaic systems may be able to drive reductions in energy consumption from non-renewable sources, but in the context of Lisbon, active systems are unnecessary, increase energy usage or are compensation for poor passive design strategies (Pedro & Pedro, 2021).

Given that 70% of homes were built prior to 1990 in Portugal, it is essential that revision of outdated and ridged comfort standards occurs (Pedro & Pedro, 2021). Indoor comfort standards are defined by the 'optimum environment' for comfort which impedes development of low-carbon buildings (Nicol & Humphreys, 2009). International standards such as ASHRAE's (U.S.) and the E.U. ISO 7730 (Portuguese standards) are contested by the results of field work carried out in the past three decades on thermal comfort standards (Guedes, 2009). The standards are considered inflexible and implicate unnecessary energy consumption, cause occupant dissatisfaction and even health problems (Guedes, 2009). Adaptive algorithms can tailor new comfort criteria to local climatic context, which would prevent bioclimatic and passive architecture from facing as many regulatory impediments (Guedes, 2009). Passive design strategies are so crucial because despite active design increasing in energy efficiency it has been shown that "Energy efficiency required in building performance has paradoxically led to high-level CO2 emissions in construction, both in regards to pallets of building materials and tectonics" (Tevengwa, Rao, p. 19, 2022). The SMEBS model accounts for total primary energy demand, but greater emphasis on passive design techniques could be beneficial to de-incentivize the momentum towards active design choices in Lisbon.

If an initial building is built for active-design, it will require renovation or large-scale refurbishment to implement passive techniques. It could be beneficial to incorporate "building technique" as a category in the SMEBS Model because passive design techniques such as position and orientation, structure, and material as well as the use of adaptive algorithms to determine local comfort standards can optimize the mutualistic interaction with the outside environment and reduce energy usage long-term.

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13. Conclusion

This study aimed to identify limitations of the SBEMS model and applied specific improvements in building sustainability measurement with specific examples from the economic, environmental, and social context of Lisbon. The methodology proposed can be replicated for future analysis of BSAM and can applied for various local contexts to tailor criteria measurements for specific environmental, economic, and social contexts. The improvements proposed in this study called for a greater participatory component, a more holistic and process-based approach to measuring the sustainability of materials, accounting for the cost of deconstruction, and factoring in the use of passive design techniques that are integral to Lisbon's low residential energy consumption. The results of this study can help to generate a building sustainability assessment method that can tangibly measure the sustainability of the implementation of process and systems-based visions of architecture and building. The ability to measure paradigm shifting ideas can lead to greater evidence for market value and subsequent wide-spread integration in society. Ultimately, if the improvements from this study are incorporated as criteria, the next step is to create a new structure for the model that is synergistic between aspects, categories and criteria. Alongside the structural change of the model, the development of equations that accurately account quantitatively for the compounding role that various criteria can have on sustainability will be needed.

14. Limitations of the Study

Given the authors lack of mathematical expertise, the limitations of this study include the inability to generate equations that can measure synergies between aspects, categories, and criteria of sustainability. Effective quantitative measurements must be generated from an improved model in order to accurately distinguish sustainability measurements and generate baselines with the ability for comparison.

15. Recommendations for Further Study

In addition to modifying the structure of the SBEMS model to incorporate synergies and creating resulting equations that can measure the compounding effects, there also is a need to scale the model beyond one singular building and embed the measuring of one buildings sustainability within its urban and regional context.

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