American Journal of Environmental Engineering 2017, 7(2): 35-46
DOI: 10.5923/j.ajee.20170702.02

A Decision Support Tool for Sustainable Land Use, Transportation, Buildings/Infrastructure, and Materials Management

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Abstract One issue for community groups, local and regional planners, and politicians, is that they require relevant information to develop programs and initiatives for incorporating sustainability principles into their physical infrastructure, operations, and decision-making processes. This research project addressed the issue through two research questions. The *first research question* that this project was designed to address, which was greatly influenced by the vast number of references in the sustainability literature, was an ontological one, "***what are the major categories that sustainability decisions can be grouped under, and how might those categories be related?***". The *second research question* that this project answered was, "***how can information contained in the sustainability literature be made accessible to users in a convenient format?***". The Multi-Sector Sustainability Browser (**MSSB)** is a decision support tool (**DST**) designed to synthesize and summarize research in four sustainability decision domains, Land Use, Buildings and Infrastructure, Transportation, and Materials Management in a manner that provides easy and rapid access to information for use in planning and decision making. Weblinks are provided to reference documents and resources from the four sustainability decision domains, allowing users to download relevant documents and extract information in support of sustainability decisions and related program initiatives.

Keywords Sustainability, Land Use, Transportation, Materials Management, Buildings/Infrastructure, Health, Environment, Decision Support

1. Introduction

The United States Environmental Protection Agency (**EPA**) Sustainable and Healthy Communities (**SHC**) Research Program develops methodologies, models, and internet-based tools to assist community planners, community members, and political decision makers in implementing sustainable policy choices for managing resources affecting the built environment, the natural environment, the economy, and human health. **EPA** researchers have created computer-based systems, including models, databases, automated guidance tools ('wizards'), and web browsers, to help communities decide on approaches that can enhance their desired sustainability outcomes. The reality for people requiring information to support planning and implementation of sustainability initiatives is that the literature on sustainability has a large number of references, incorporating a number of different dimensions and contexts, making it difficult to determine which references and information resources should be consulted when embarking on a sustainability effort.

One issue in reviewing sustainability literature is that there are a number of different categories under which sustainability literature can be placed, and there is no formal segregation of the literature into a set of logical decision-making domains. An important first step that this project took in addressing this issue was to review a large segment of the sustainability literature, categorize the reviewed literature into logical decision-making domains, and describe the relevance of the references within the context of each of those sustainability decision-making 'dimensions'. Four teams of **EPA** scientists and engineers, along with a professional librarian, took on this challenge, and divided the sustainability literature that was reviewed into four logical decision-making domains, Land Use, Buildings and Infrastructure, Transportation, and Materials Management (i.e., Municipal Solid Waste [**MSW**] Disposal/Processing). Separate reports were developed for each of these four areas, totaling over 516 pages, with more than 1500 references. The four reports focused on describing and explaining the important topics and sub-topics within each sustainability decision-making domain, placing the relevant references within the applicable topic/sub-topic

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Published online at http://journal.sapub.org/ajee
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areas, and indicating the best application or use of the references within the appropriate context. These four sustainability reports for Land Use, Buildings and Infrastructure, Transportation, and Materials Management answered the question of what are reasonable and logical decision-making categories for sustainability decisions.

The reports provide a great deal of information and resources that are useful to community groups, local and regional planners, and politicians, but the information as it exists in the reports, is not readily accessible. Users needing access to this sustainability information should not be required to read through more than 500 pages of reports, find the references applicable to their sustainability decision context(s), and search through libraries to obtain copies of the relevant documents. This second issue was addressed in the following manner. The contents and structure of the four sustainability reports for Land Use, Buildings and Infrastructure, Transportation, and Materials Management were used as the basis of the design for the Multi-Sector Sustainability Browser (**MSSB**). A systems engineering approach was used to develop the **MSSB** as described below. The inherent structure of each individual report was used to divide each sustainability decision domain (Land Use, Buildings and Infrastructure, Transportation, Materials Management) into sub-domains and sub-headings. This natural division of topic headings in the reports provided the framework of the design for the **MSSB** displays. Using the original report structures both illustrated and preserved the relationships between the different sustainability topics found in the literature review.

An important objective of the research project was to develop a tool to allow communities to evaluate decisions in a holistic manner across multiple problem domains, based on factual knowledge shared by all components of society [1]. Communities require access to high quality information under science-based decision-making [2], and resources that will allow them to achieve their sustainability goals through science-based decision-making. Communities require, new tools to support sustainable decision-making [3]. Decisions where sustainability is the primary driving issue is an intersection of social, economic, and ecological interests [4]. Robust frameworks are needed to provide information for the decision-making process in support of sustainability [5]. When developing models, databases, wizards, web browsers and other tools that provide information on sustainability for planning and decision-making, the scientific literature must be surveyed to determine the key trends, findings, and available resources on sustainability. There have been a number of tools developed to assist in implementing sustainability [6]. Decision support tools exist for managing and establishing green spaces in suburban neighborhoods [7], and municipal solid waste management [8].

Once a decision has been made to embrace sustainability, the next step is understanding how to implement it [9]. Decision support tools and their application in general are divided between community-based (participatory) and expert approaches [10]. From a practical perspective, sustainability-focused decision support tools should not require expert knowledge or special software to use. It should be designed to provide information on sustainability for both expert and non-expert users and should facilitate easy access to sustainability information. The tool should contain descriptions and explanations, which provide sustainability information in language that is understandable to a wide audience. It should also include linkages and relationships between related concepts, and incorporate both quantitative and qualitative data. Sustainability tools should provide information on indicators and indices, to allow tracking of long-term trends [11]. It should be visually appealing and intuitive.

The **MSSB** is designed to accomplish these objectives and to allow its users find and access sustainability information that can be used to inform the planning and implementation of sustainability projects and initiatives. The user is the one who shapes and provides the context for the use of the information provided by the **MSSB** (e.g., the political and resource constraints, the objective[s], etc.) and applies it in their prevailing context[s]. The user must decide how to use the information provided by the tool, since the **MSSB** is not designed for a single sustainability context and is intentionally agnostic with respect to the application of the tool in a sustainability context. The **MSSB** is designed so that the user can find and assess sustainability information in four key decision domains (Land Use, Buildings and Infrastructure, Transportation, and Materials Management) and apply in their unique decision context[s]. These were the primary design requirements [12] specified by the EPA (author) for the **MSSB**, which has the following capabilities:

a. Visually displays the *linkages* between the four major sustainability decision domains (Land Use, Buildings and Infrastructure, Transportation, and Materials Management) and their supporting concepts.
b. Provides *literature sources* and references (including weblinks where applicable) containing information about each major sustainability decision domain and its supporting concepts.
c. Provides *quantitative data* related to each major sustainability decision domain and its supporting concepts (including weblinks where applicable).

The **MSSB** serves as a 'visual database' and a topic-specific literature review resource, allowing users to: investigate one or more of the four key sustainability decision domains; explore available scientific literature references, and; assess potential impacts of sustainability initiatives. The **MSSB** reduces the amount of time and effort required to assess the state of sustainability science and engineering research relating to: 1) Land Use; 2) Buildings and Infrastructure; 3) Transportation, and; 4) Materials Management. The **MSSB** is an information resource, and is not designed to be an expert system or a full-capability decision support system. The **MSSB** is a sustainability

decision support tool that could be used in conjunction with a decision support system such as **PETUS** (Practical Evaluation Tools for Urban Sustainability: *http://www.petus.eu.com* – Last Accessed: 10 Apr 2017). **PETUS** supports management and development of programs and projects to incorporate sustainability into urban infrastructures, which are compliant with strategic environmental assessments, and includes a list of applicable tools, a glossary of terms, a checklist, case studies, a project management matrix format, and information on applicable European Union (**EU**) Legislation. The **MSSB** can be applied in the preparatory stage of a project, before **PETUS** is used, since its role would be in the *information gathering* phase, and would provide required input for the project planning and management process to develop sustainable urban infrastructures.

The **MSSB** was designed to provide both visual and conceptual linkages between the four sustainability decision domains, and quantitative information, where available, for use in planning contexts. The **MSSB** is a general-purpose tool which assists a wide range of users, including individuals, communities, local and regional planners, political decision-makers, researchers, and the general public, in understanding the impacts that sustainability, as viewed through the 'lenses' of Land Use, Buildings and Infrastructure, Transportation, and Materials Management, can have on human health, the economy, the built environment and natural environments. The **MSSB** references and resources incorporate important issues that influence and are influenced by sustainability initiatives including: individual and societal well-being, environmental justice, inequality, and poverty, public health, etc. The result of this project is that the **MSSB** is the first **DST** specifically designed to allow users to access sustainability information, with active weblinks to reference documents, which can be used to assist in project planning and development of sustainability initiatives. The purpose of this manuscript is to document the design and software development process used in creating the **MSSB**, describe the operation of the **MSSB**, how to use it, and potential scenarios where it can be applied, and explain how it can support public health decision-making through sustainability-related programs.

2. Methods: (Report Development)

2.1. Land Use Report

The **Land Use** Report was developed by 19 primary EPA authors and 18 additional EPA contributors. An interim version of the report was completed in April 2012 (6 months after starting the project). Key areas were identified and researchers were assigned to those areas to collect, read, and analyze the references. A ***common bibliography of 1400 references*** was developed in **EndNote**, and ***different groupings*** were created for the references. Those **groupings became sections of the report**. Weekly conference calls were held at a specific time with a set agenda, and the discussion was based on the topics discussed by those who participated in the conference calls. One important issue that was addressed in developing this report was learning how to effectively integrate and incorporate the social science dimension of sustainability with the physical science and engineering implications. The sustainability scientific literature reviewed by the research team was grouped under seven major headings in this report: 1) environmental protection, federal regulation and land use planning; 2) impacts of land use on the environment, economy, and human well-being; 3) relevant metrics, indicators, and indices of sustainability; 4) land use patterns show causal relations to economic, health, and environmental impacts; 5) decision science and land use practices; 6) research needs to address community land use sustainability, and; 7) linkages for land use across federal agencies. There are a number of sub-topics under each of these groupings, which provide more detail on issues influencing sustainability in land use contexts.

2.2. Materials Management Report

Two **Materials Management** Reports were developed by 2 primary EPA authors, and contributions were made by two EPA contractors. The two EPA contractors each contributed to a separate and distinct version of the report. One version of the report contains input from the contractor team of Research Triangle Institute (*RTI*) and Innovative Waste Consulting Services, LLC., and was used to design the displays for the materials management segment of the MSSB. This report was focused on the sustainability of the processes used to treat municipal solid waste, and represents more of the 'standard' (traditional) materials management approach (excluding waste collection, material recovery facilities [MRFs], materials recycling, etc.). Use of this report in the design of the materials management segment of the MSSB provides the user who may not be familiar with the materials management process an understanding of the key materials management processes affecting sustainability. Subsequent sections in this report focused on each major process for handling municipal solid waste and the important considerations for each method: 1) landfilling; 2) anaerobic digestion; 3) aerobic composting; 4) combustion; 5) gasification, and 6) pyrolysis. The last major section of the report looks at the systems-based impact assessment of municipal solid waste processing.

A second version of the report contains input from a different contractor, *Industrial Economics, Inc*. This version of the report focused on the sustainable materials management (SMM) approach. This version of the report can be accessed via a weblink inside the MSSB, and it provides information on where and how sustainability activities are included in the materials management process as an available reference for users. This report version provides information on the principles of sustainable materials management which includes the opportunities,

challenges, and analytical framework for sustainable materials management. The flow of materials in the United States is examined from raw materials extraction through post-consumer processes. Material recovery, source reduction, energy recovery, and green design influences in sustainable materials management processes is discussed. Acknowledgement of the importance of stakeholders and incorporation of cost-benefit analysis is included in the report. The use of both report versions in the MSSB provides a more complete understanding of the role of sustainability in the materials management process.

2.3. Transportation Report

The **Transportation** Report was developed by 1 primary EPA author and 18 additional EPA contributors. In developing this report, the sections describing the nature of the pertinent relationships between sustainability elements in transportation were separated from the sections containing information on tools providing information on sustainability in transportation. There are ***four impact areas*** under transportation with lists of '***cause and effect***' **and** ***tools*** for each: **i.** economy; **ii.** health; **iii.** air; **iv.** Water. One key section of the report illustrates the relationship between transportation and ***policy, practices, and infrastructure*** **and** the relationship between transportation and ***health, eco-systems, and environment***. This report provides information on the history of surface transportation in the United States and the current trends in transportation. The report reviews the strategies and categories of tools that can be used to assess community sustainability with respect to transportation. Information on factors influencing choice of transportation modes, trip frequencies, lengths, and purposes is also provided to illustrate which factors contribute to sustainable transportation. This report provides discussion on travel behaviors and how transportation affects air pollution. The effects of transportation on greenhouse gases, water, and the economic impact of transportation are discussed with respect to sustainability.

2.4. Buildings and Infrastructure Report

The **Buildings and Infrastructure** Report was developed by 2 primary EPA authors and 13 additional EPA contributors. This report views the impact of buildings and infrastructure through the 'lens' of sustainability. The influence of buildings and infrastructure on population health and various socio-economic factors is discussed. Buildings and infrastructure have an effect on the economy, especially with respect to 'green' projects designed to promote sustainability. The energy consumption and water consumption of buildings and infrastructure is an important factor to consider when assessing their inherent sustainability. The extent of and cost of research done on buildings and infrastructure is another critical issue that is presented in the report. The key subject content areas contained in the four reports are provided in Table 1.

Table 1. Major Content Areas Documented in Sustainability Reports

Sustainability Area	Key Issues Included in Report
Land Use	**1)** environmental protection, federal regulation and land use planning; **2)** impacts of land use on the environment, economy, and human well-being; **3)** relevant metrics, indicators, and indices of sustainability; **4)** land use patterns show causal relations to economic, health, and environmental impacts; **5)** decision science and land use practices; **6)** research needs to address community land use sustainability; **7)** linkages for land use across federal agencies
Buildings and Infrastructure	**1)** population health; **2)** socio-economic factors; **3)** economy, especially with respect to 'green' projects; **4)** energy consumption; **5)** water consumption; **6)** extent of and cost of research done on buildings and infrastructure
Transportation	**1)** economy; **2)** health; **3)** air; **4)** water; **5)** relationship between transportation and ***policy, practices, and infrastructure*** **and** the relationship between transportation and ***health, eco-systems, and environment***; **6)** the history of surface transportation in the United States; **7)** current trends in transportation; **8)** strategies and categories of tools that can be used to assess community sustainability with respect to transportation; **9)** factors influencing choice of transportation modes; **10)** trip frequencies; **11)** trip lengths; **12)** trip purposes; **13)** travel behaviors; **14)** transportation effects on air pollution; **15)** greenhouses gasses; **16)** water; **17)** economic impact of transportation
Materials Management **(2 Reports)**	**1)** Landfilling; **2)** anaerobic digestion; **3)** aerobic composting; **4)** combustion; **5)** gasification; **6)** pyrolysis; **7)** flow of materials in the United States; **8)** Material recovery; **9)** source reduction; **10)** energy recovery; **11)** green design influences in sustainable materials management processes; **12)** stakeholders; **13)** cost-benefit analysis

3. Methods: (Software Development)

3.1. Software Development

A detailed 20-page software design specification document was generated from the four sustainability reports (Land Use, Buildings and Infrastructure, Transportation, and Materials Management). The **MSSB** software design was developed in a slightly different way for each of the four individual sustainability decision domains based on the unique structure, content, and themes contained in each report. A standard software quality assurance procedure [13] was used to ensure that the **MSSB** code was built and tested in a manner that ensured successful completion of the tool. The **MSSB** is coded in the JavaScript language, and uses the D3 JavaScript (D3.js) library capabilities for manipulating documents based on data content (Version: 3.5.13). The JSON (JavaScript Object Notation) approach is used to provide real-time server-to-browser (full-duplex) communication, without using browser plugins such as Flash or Java Applets (which represent early 2000's technology). JSON can be used in situations where Extensible Mark-up Language (XML) is normally used, but JSON has less communication overhead in computer networks. The MSSB was developed in the Drupal Content Management System (CMS) environment, (Version: 7.34). A Microsoft SQL database was developed that includes all of the data used in the **MSSB**.

The MSSB was developed in a rapid application development (RAD)/joint application development (JAD) Agile-style format by the EPA and the contractor, Oneida Total Integrated Enterprises (OTIE) LLC, later joined by Jacobs Technology, Inc. Small portions of MSSB capability were developed and tested by the EPA (author) on a weekly basis. During the weekly status meetings, EPA (author) provided detailed notes on the capabilities that were not functioning in accordance with the software design specification, and provided suggestions on potential software fixes. Upon revision of the MSSB software, the latest (current) version of the software was tested during the subsequent week, and the results were discussed at the next scheduled weekly meeting. This process was used and repeated throughout the MSSB development cycle. Software issues were tracked by the JIRA system, and all project team members used that system to communicate the status of software fixes, internal test results, and external test results. When the MSSB capability met the minimum functional performance requirements, a 'beta' test version was posted on the internet, allowing for testing and evaluation on a near-continuous basis and speeding development of the tool. The beta-test version of the MSSB is currently available at the above-mentioned weblink. Once the MSSB is cleared by EPA for public release, expected sometime in the fourth quarter of 2017, it will be available on EPA's EnviroAtlas website (*https://www.epa.gov/enviroatlas* - Last Accessed: 10 Apr 2017).

3.2. Software Structure

The structural and logical relationship(s) between the different sustainability concepts in the MSSB is that of a graph structure (a collection of nodes [vertices] and linkages [edges]). The MSSB display architecture is composed of a series of 'one-to-one' relationships (e.g., each 'child' display [node] has one and only one parent), and 'one-to-many' relationships (e.g., each parent can have many children). This arrangement is essentially a hierarchical 'tree', structurally similar to the Table of Contents listing in a book. However, a number of the subject areas presented in the MSSB cuts across concepts (e.g., 'Sprawl' is a subject area/concept used in the Land Use, Transportation, and Buildings and Infrastructure sustainability decision domains), therefore the true nature of much of the MSSB data is a series of many-to-many relationships (e.g., 'child' displays [nodes] can have one or more parents).

Data for the MSSB is made available as a JSON object, which is a lightweight data-interchange format that is easy for humans to read and write, and it is very easy for machines to parse. The MSSB condenses the subject matter from the four primary report texts into approximately 350 display nodes, where each node contains a block of text formatted using standard HTML tags. The process to move the text that was written for the MSSB display nodes from document(s) into HTML format, and subsequently JSON is a non-trivial exercise involving: a) formatting the text blocks into HTML; b) associating text blocks to nodes in Microsoft Excel; c) transferring text into a Microsoft SQL Server, and finally; d) using Microsoft SQL to create the JSON object, load the entire application into Drupal, and reassign the URLs. The skillset required to design, build, and manage the MSSB research project included, system design expertise, program management experience (including software quality assurance, software testing, and software engineering/ coding), and knowledge of at least one aspect of sustainability science.

4. Operational Behavior

The **MSSB** displays can be selected on a desktop computer using a computer mouse, 'page up/page down' keys, and arrow keys on the keyboard as shown in the user manual [14]. The **MSSB** can be used by both Apple and Microsoft-based computers. The **MSSB** was designed to be accessible by laptop computers, tablets, and smartphones using any operating system and platform. No special software is required to use the **MSSB**, and any standard browser can be used with the **MSSB**. When using a desktop computer, displays can be selected either by using the drop-down list menu or by direct selection of the displays using a mouse (see Figure 1). Figure 1 illustrates the default display screen that is shown when the **MSSB** is initially selected.

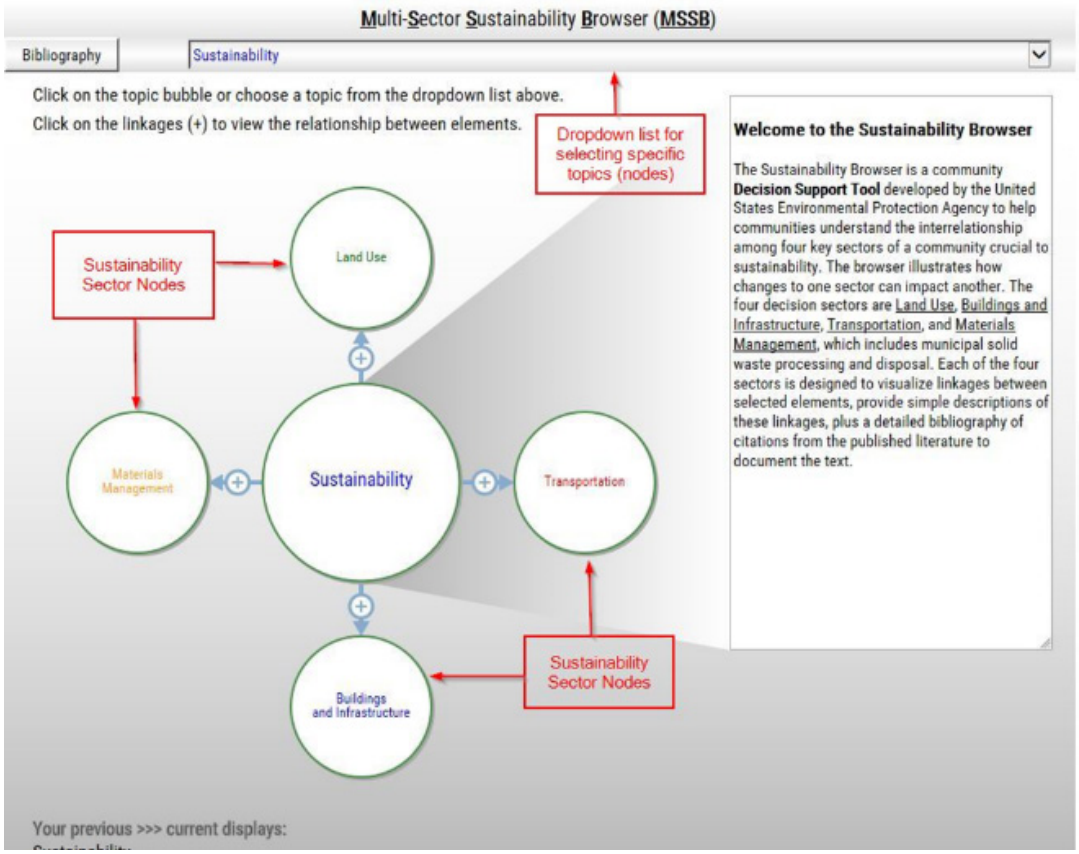


Figure 1. MSSB Main Screen (Sustainability)

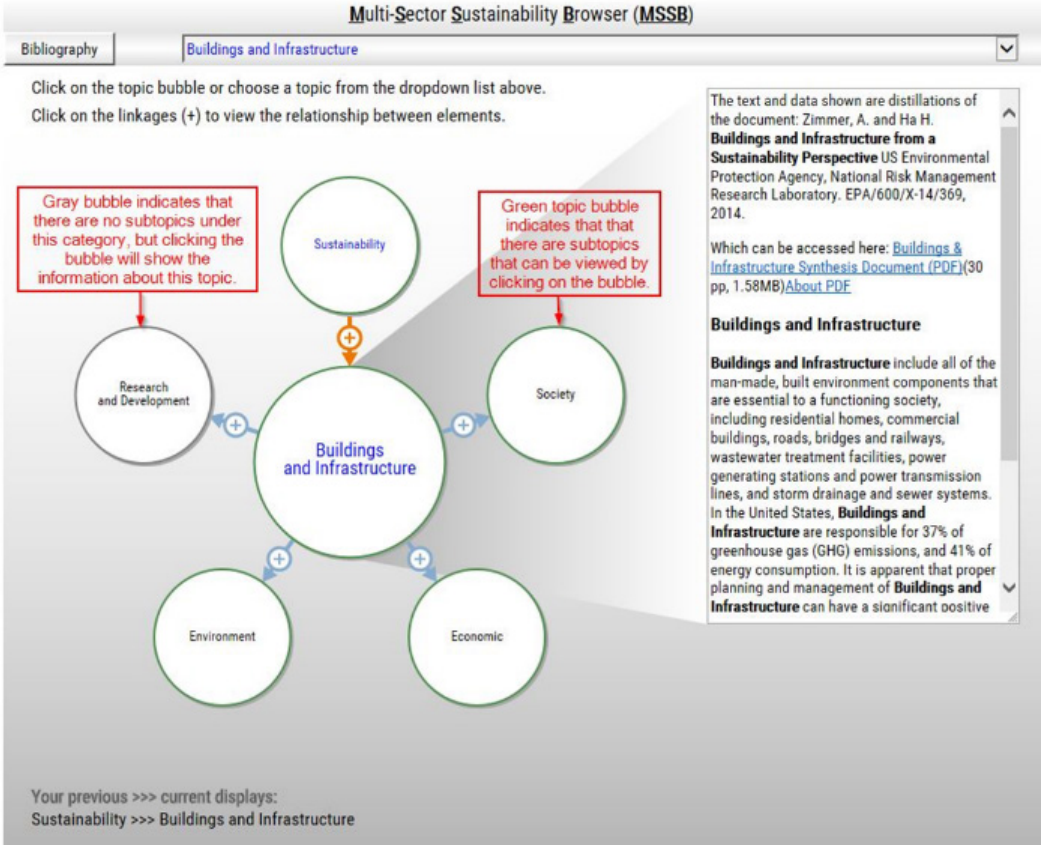


Figure 2. Buildings and Infrastructure Main Screen

Main display screen is shown with text labels illustrating the display elements and the drop-down menu selection list.

4.1. Navigating and Using MSSB Displays (Example)

If a user is interested in collecting information to determine approaches or considerations that are important in enhancing sustainability through intelligent land use, selecting the 'Land Use' display element shown in Figure 1 would provide a new display that has nine sub-displays representing concepts that relate sustainability and land use. If the user required information on the neighborhood-level land use qualities that are important for implementing sustainability, the '***What Neighborhood Scale Land Use Qualities Are Most Important For Advancing Sustainability?***' display element would be selected. From that new display, if the user had an interest in information on the intersection of climate change and extreme heat events and sustainability, the user would the select the 'Climate Change and Extreme Heat Events' display, which would provide an explanation, along with weblinks to five peer-reviewed scientific journal articles containing more detailed information for the user.

The **MSSB** has multiple levels of displays, with top-level displays representing primary sustainability concepts, and subordinate displays representing supporting concepts, questions, or relationships between different concepts. The display 'nodes' are outlined either in green or in gray. Green outlining indicates that selection of the display will reveal additional lower levels of displays (and related concepts). Gray outlining indicates that there are no additional or subordinate displays under the selected display, although more information is provided. This is illustrated in Figure 2. Each display that is selected has a text box with information explaining or defining the major concept in the selected display. Important resources, such as technical reports, scientific journal articles, and websites containing tools, models, databases, and calculators, can be accessed in the **MSSB** through the weblinks that are provided in the applicable display text boxes.

Displays the Buildings and Infrastructure main screen with text labels identifying a green outline on a display node ('bubble') and a gray outline on a display node ('bubble').

The **MSSB** has a bibliography that contains literature references for each of the four sustainability decision domains, Land Use, Transportation, Buildings and Infrastructure, and Materials Management. The references in the bibliography are arranged in the order in which they were cited in each of the four associated sustainability reports (Land Use, Transportation, Buildings and Infrastructure, and Materials Management). Selecting the 'Bibliography' button control, located in the upper left-hand corner of the **MSSB** will display the bibliography webpage (see Figure 4).

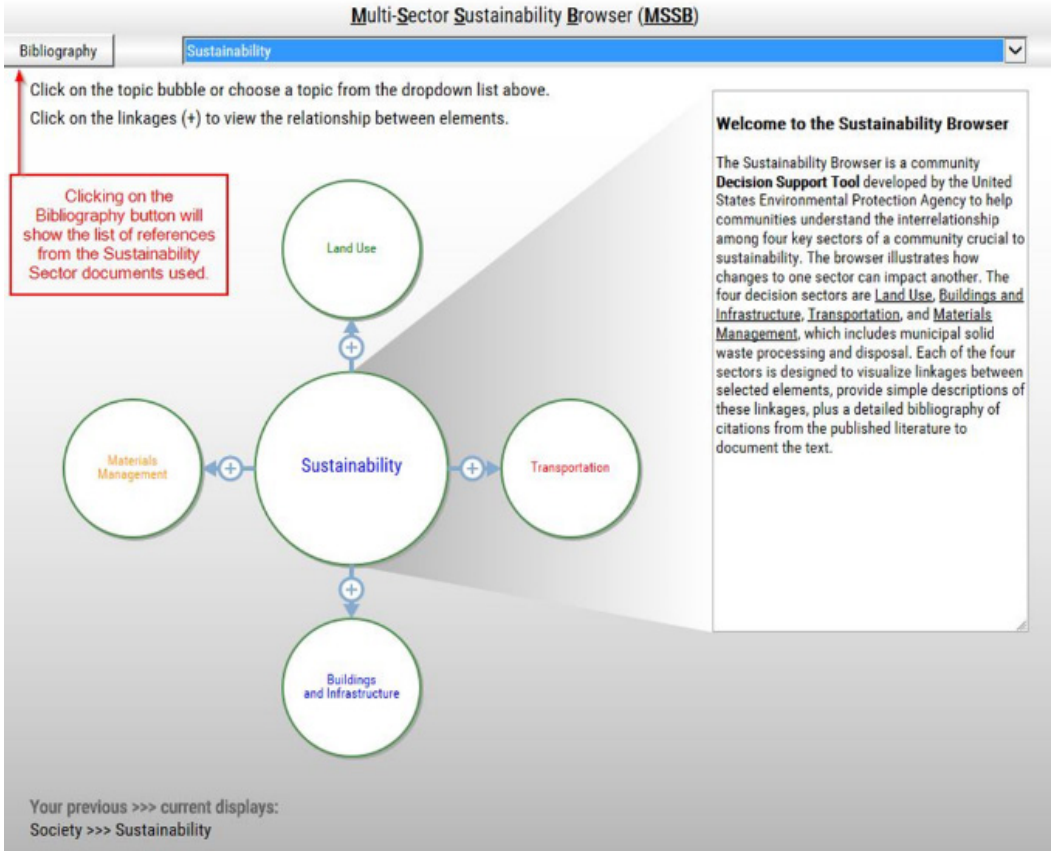
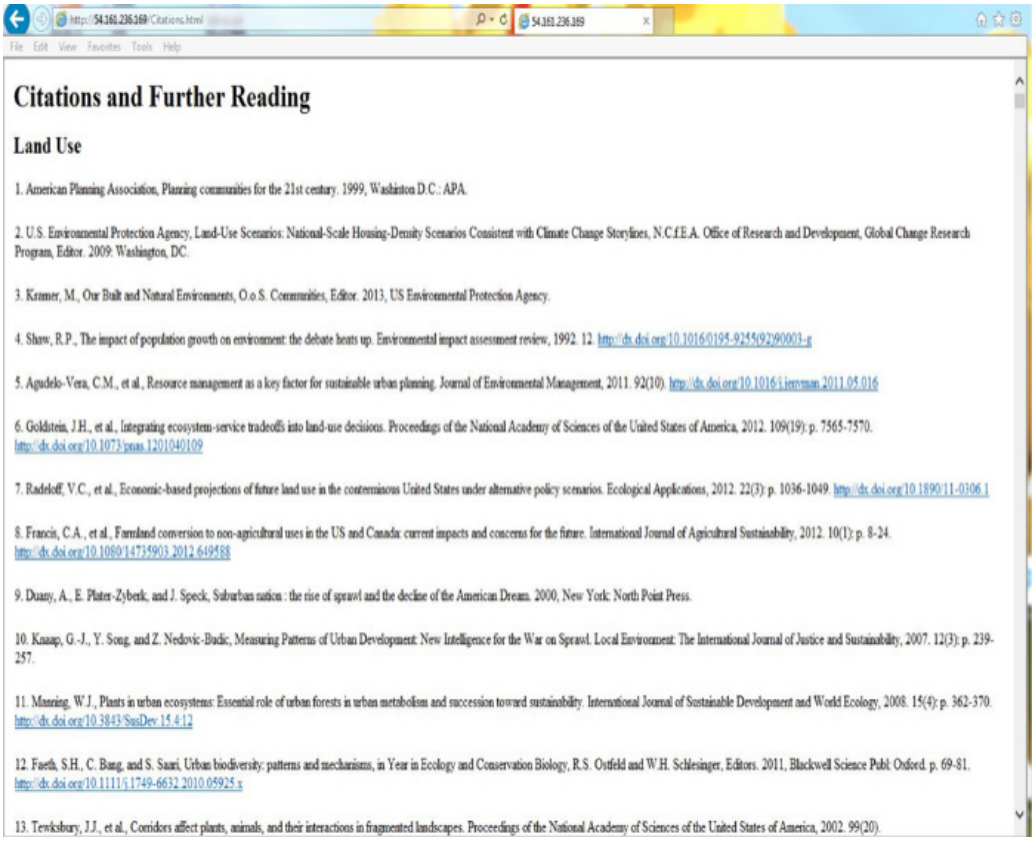


Figure 3. Bibliography Button Control



Citations and Further Reading

Land Use

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Figure 4. Bibliography Page

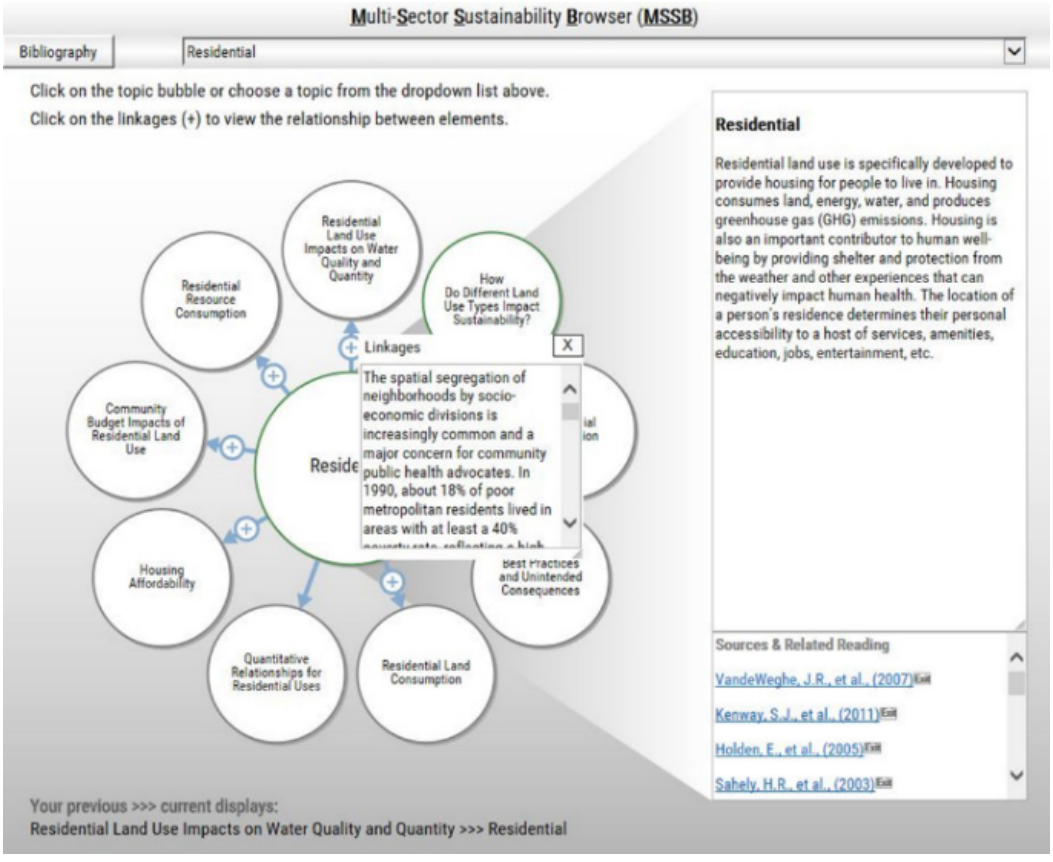

Figure 5. Display: Link between Residential (Land Use) and Residential Segregation

Displays the **MSSB** main screen with a text label pointing to the Bibliography button control.

When the 'Bibliography' button control shown in Figure 3 is selected, the bibliography webpage is displayed as shown in Figure 4. This webpage contains the citation information for the references, and provides weblinks to the references for those users who wish to learn more information and possibly download the reference(s), as applicable. **Note:** Some of the references may be obtained at no cost, while others may have a cost associated with them. EPA is not responsible for the potential cost of obtaining the references linked to in the **MSSB**. The publically released version of the **MSSB** will include weblinks for each reference in the bibliography.

Displays result of selecting the Bibliography button control. **MSSB Bibliography** Section can be printed and is approximately **75 pages** long.

The **Bibliography** section is organized by topic area (Land Use, Buildings and Infrastructure, Transportation, and Materials Management) and the individual references are presented in the order that they were cited in each of the four sustainability reports.

Displays an expanded text box with information on the relationship between two displays/concepts when the plus "+" sign is selected. ***Note***: The plus "+" sign denotes that there is some type of relationship between the two linked display elements and does not indicate or designate the 'strength' or the nature of the relationship.

The **MSSB** has a type of display element that is shown as a 'plus sign' surrounded by a circle. This type of display element indicates that there is some type of relationship, linkage, or connection between the displays that are connected by the 'plus sign'. When the 'plus sign' is selected, a text box is displayed that provides information on the relationship between the two connected displays. Figure 5 illustrates the text box that provides information on the relationship between residential land use and residential segregation.

Weblinks to the applicable references are displayed in the lower portion of the text box area. The 'Sources and Related Reading' are directly applicable to the topic area/sustainability concept under which it is found/displayed. The 'Sources and Related Reading' links are also placed in the order in which they were cited in the original report texts. Providing the full titles within the main display area would be awkward, and would take up space in the main display component, but the full titles are provided in the Bibliography Section.

5. Discussion

Sustainable development is itself a decision-making strategy, encompassing the issues of interpretation (decisions are contextual), information structuring (complexity of sustainability should be structured to facilitate decisions), and influence (information should influence decisions and implementation sustainable development) [15]. Therefore, sustainability decision-making tools should be capable of influencing and improving decisions. The MSSB contains information that can improve public health decision making and can improve individual knowledge on the relationships between neighborhood-level sustainability features and positive health outcomes. Residential and mixed-use development projects that utilize land in a rational and sustainable manner lead to improved health outcomes for the residents of those areas. Under the land use portion of the MSSB, information is provided on the neighborhood-level land use qualities that support sustainability. A dense street grid with short distances to homes, workplaces and shopping areas (e.g., transit-oriented development [TOD]), along with access to 'greenery', provides a walkable neighborhood, which encourages more walking. This is enhanced with a moderate to high housing density in the neighborhood. The shorter commuting distances facilitated by this type of neighborhood configuration, leads to more social interaction between residents and reduced symptoms of depression. The combination of green space, areas designed for walking, convenient public transportation hubs, along with an increased feeling of safety and community, is shown to enhance both the physical and mental health of residents. The MSSB provides at least eight peer-reviewed scientific journal articles on these relationships between sustainability and public health outcomes.

The **MSSB** greatly reduces the amount of time and research effort that a user must spend to find the current scientific references in sustainability science and engineering on Land Use, Buildings and Infrastructure, Transportation, and Materials Management and to support decision-making. The **MSSB** can be used for the following suggested activities:

1. Exploring the relationships/linkages between the four key sustainability decision domains
2. Obtaining information on a specific sub-discipline/ question area in one of the four key sustainability decision domains
3. Assessing the number of relevant references that should be read/reviewed by subject-matter experts in one or more of the four key sustainability decision domains
4. Determining if there are important system parameters or variables (including their values and/or ranges) that can influence a decision in one or more of the four key sustainability decision domains
5. Learning about the influence of sustainability, practices, activities and/or metrics on human health, the natural environment, and the economy
6. Developing a plan for a scientific literature review in one or more of the four key sustainability decision domains
7. Creating a framework for an approach to build a structured approach to decision-making in the context of one or more of the four key sustainability decision

domains
8. Examining the importance and centrality of Land Use in all sustainability-related activities and decisions
9. Building a database of available resources in the scientific literature related to sustainability
10. Investigating the tools, databases, models, libraries, and browsers that are available for providing information and data for planned sustainability initiatives and decisions
11. Generating a plan for enhancing personal knowledge in one or more of the four key sustainability decision domains
12. Developing a *sustainability case study* for a particular community, region, etc.

The MSSB will be used during the summer of 2017 to develop a *sustainability case study* that will demonstrate how a community with minimal expertise in planning and developing sustainable land use projects can use it to find relevant resources for land use sustainability. This will be accomplished by asking two questions through a structured/guided inquiry approach:

1. *What are best practices for land use management to support sustainability?* – The MSSB provides useful resources in the following selected areas for the use case/scenario:
   - ***Infill Development*** (focus is on redevelopment or use of previously developed land)
   - ***Urban Parks and Greenspace*** (focus is on health, ecosystem, and economic impact of greenspace)
   - ***Brownfield Redevelopment*** (focus is on revitalization of abandoned or remediated land)
   - ***Low Impact Development*** (focus is on stormwater/ watershed management, green infrastructure)
   - ***Transit Oriented Development*** (focus is on integration of mixed use development, transportation)
2. *Are there indices of sustainable development relevant to land use? Note:* The *MSSB* provides information on *13 indices* that can be used to 'measure' sustainable land use development.

The information obtained through this application of MSSB will demonstrate the fact that the information in a sustainability decision support system should provide a focus on the ''triple bottom line'' to facilitate decisions that achieve social, economic and environmental sustainability [16].

6. Conclusions

Designing an environmentally-focused decision-making tool requires an interdisciplinary and analytical approach that incorporates the different values which inform decision-making, and recognizes the complex, context-specific nature of environmental decisions [17]. The **MSSB** is designed for the user to investigate one or more of the four key sustainability decision contexts, explore the available scientific literature references, and from the information, assess the potential impact of planned sustainability initiatives, because decisions made on a sustainability basis must reconcile social, economic, and environmental criteria [18].

The **MSSB** user must note that some of the weblinks for references in **MSSB** provide free access to the journal article (or technical report), while other references require payment for access. For users affiliated with an academic or commercial library, some of the references requiring payment can be accessed at no cost. The **MSSB** provides illustrative graphics to supplement descriptions/explanations for a number of sustainability-related concepts. The user can navigate through **MSSB** in a number of ways, and the desired sustainability information is available for them at each point in their navigation. The **MSSB** serves as a 'visual database' of sustainability information for Land Use, Buildings and Infrastructure, Transportation, and Materials Management. The tool allows users to understand four important influencers of sustainability that are seen in through the **MSSB**, social, economic, environmental, and institutional [19]. The hope is that the **MSSB** can influence decision makers in the understanding that investing in the sustainable use of the ecosystem can provide economic, social, and ecological benefits [20].

ACKNOWLEDGEMENTS

The author wishes to thank the following individuals and organizations for their contributions in developing the four research reports on which this decision support tool is based, **Land Use:** (***Authors***) - Llael Cox, Verle Hansen, James Andrews, John Thomas, Ingrid Heilke, Nick Flanders, Claudia Walters, Scott A. Jacobs, Yongping Yuan, Anthony Zimmer, Jim Weaver, Rebecca Daniels, Tanya Moore, Tina Yuen, Devon C. Payne-Sturges, Melissa W. McCullough, Brenda Rashleigh, Marilyn TenBrink, Barbara Walton; (***Contributors***) - Kathryn Saterson, Bob McKane, Jane Gallagher, Joseph Fiksel, Gary Foley, Sally Darney, Melissa Kramer, Betsy Smith, Andrew Geller, Bill Russo, Susan Forbes, Laura Jackson, Iris Goodman, Michael Slimak, Alisha Goldstein, Laura Bachle, Jeff Yang, Gregg Furie; **Transportation:** (***Authors***) - Nick Flanders; (***Contributors***) - Nick Flanders, Rich Baldauf, Jeff Yang, Rebecca Dodder, Gregg Furie, Laura Bachle, Andrew Bostrum, Laura Berry, Claudia Walters, Jane Bare, Tim Barzyk, Randy Bruins, Ellen Cooter, Francesca DiCosmo, Tarsha Eason, Tom Fontaine, Laura Jackson, Nathan Schumaker, Jim Weaver; **Buildings and Infrastructure:** (***Authors***) - Anthony Zimmer, HakSoo Ha; (**Contributors**) - James Andrews, William Barrett, Chris Choi, Gordon Evans, David Ferguson, Verle Hansen, Mark Mason, Michael Schock, Bob Thompson, Jim Weaver, Scott A. Jacobs, David Kozlowski, John McCready; **Materials Management (2 reports):** (***Authors***) - Anthony Zimmer,

Brian Dyson; (***Contributors***) – Research Triangle Institute (RTI), Innovative Waste Consulting Services, Industrial Economics, Inc.

Disclaimer

The research project described in this document has been funded by the United States Environmental Protection Agency. This document has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of products, companies or trade names does not indicate endorsement or recommendation for use by the Agency.

Conflicts of Interest and Funding

This project and the resulting tool was funded by the United States Environmental Protection Agency under contract EP-C-15-008. The author, Eric S. Hall, declares that he has no conflict of interest or financial conflicts to disclose.

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