ESTABLISHING NATIONAL MEASURABLE GOALS FOR TOTAL QUALITY BUILDING

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ESTABLISHING NATIONAL MEASURABLE GOALS FOR TOTAL QUALITY BUILDING

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ABSTRACT

Modeling tools have been developed to design buildings relative to energy use and pollution impacts in a place specific manner. Life Cycle Analysis (LCA) tracks production, consumption and reuse of materials with at least one design friendly CAD connectable procedure but without accounting for location throughout the life cycle stages. Benchmarking techniques have been applied mostly in production facilities to optimize internal efficiency with some consideration of environmental impact. ISO 14000 attempts to develop international protocols to minimize environmental impacts of production. Total Quality Building ™ (TQB) is an emerging procedure to benchmark building relative to the environment using some techniques mentioned above but correlates them to a GIS input/output based modeling framework so that location sensitive issues regarding material and energy flows relative to environment and resource use can be measured. TQB's main objective is to evaluate a building as a performance system in a site sensitive context. Site is defined in a multiple scalar measurement depending on resource and technology.

1. INTRODUCTION

The Center for Maximum Potential Building Systems (CMPBS) began work in November 1995 under a Cooperative Agreement with the U.S. Environmental Protection Agency (EPA) to execute a project titled "Establishing National Measurable Goals for Total Quality Building". In recent years there have been many, some notable, attempts to design buildings in consideration of their materials, energy usage, and pollutive natures. Optimizations have and are constantly being found and applied. In fact, CMPBS has been actively involved in many of these efforts for over 20 years. One of the principal ingredients to a holistic approach to resource and energy use and pollution is Life Cycle Assessment (LCA). LCA provides a quantitative framework for considering the total resource and pollution burden of a product system. A growing number of designers would incorporate these concerns in their work if they had usable tools to allow them to consider the life cycle environmental and resource consequences of alternative materials and systems to accomplish their designs. This is the essence of Total Quality Building™: to understand these consequences for a specific building for a specific location. No known comprehensive study of the overall impacts and relative importance of design alternatives relative to site has been undertaken on a national basis. Thus, EPA's and the design community's access to detailed information became the objective of the study developed under this Cooperative Agreement.

Specifically, the proposal identified two major tasks over the two-year time frame. The first part, which comprised the majority of the first year's work, was the development of a comprehensive spatial data Geographic Information System for the continental U.S. The first part of the work has been completed, and the result is a working spatial system of tremendous data detail, yet with capabilities to simulate dynamic processes.

2. CURRENT PROBLEM DEFINITION

The objective of the study's second year is to develop a working specification for a Generic Design Model and a prototype set of software that can be tested to allow users, with designers of buildings being the main target user, to obtain information that quantifies their building designs in relationship to Total Quality which refers to how green or sustainable the building is and performs. The complexity of this undertaking can neither be taken lightly nor can it be assumed that there is some definitive measurement which can establish the quality of a building. Building design is multi-contextual both in process and results. Many issues must be taken into account and resolved to obtain a successful design. Issues identified are: 1) impacts to environmental systems; 2) material and energy systems; 3) Life Cycle systems where different phases of the life cycle would have a different relationship to site; and, eventually, 4) monetary flow systems that are affected or impacted by the specification describing a built object. Finally, the current spatial information system is viewed as providing the necessary base line measurements to allow a building to be formally studied in context to its site.

3. SYSTEM CAPABILITIES

To date project researchers have successfully transferred an input/output model developed by Dr. Stephen Casler at Allegheny State University. This model has close ties to Professor Bruce Hannon's modeling efforts over many years at the University of Illinois. Several types of output are available, including energy type use ratios for industries by SIC (Standard Industrial Classification) and BEA (Bureau of Economic Analysis) codes. Energy and pollution calculations can also be made per dollar of output for the producing sectors of the economy.

Additionally, Greg Norris of Decision Dynamics has tabulated industry Input/Output I/O dollar amount tables by 528 IMPLAN business sectors on three scales: 1) U.S.; 2) Texas; and 3) Travis County including Austin, Texas. These numbers have been transferred into the Interpreter and integrated under the modeling sub-system.

One important key to integrating the I/O model with the geographic system was through adding over 12 million U.S. businesses by SIC code. This was accomplished by obtaining their exact location by 8 and 9 digit latitude/longitude coordinates. This accurate, up-to-date data allows us to index by SIC code into both the I/O model and the geographic system. This detailed display of company distributions relative to spatial environmental data is unique to our knowledge, certainly in its detail and in its range of analysis and display capabilities.

The system presently has the capability to present results for "Criteria Air Pollutants". These include VOCs, NOX, SO2, CO, and PM10. These data enable us to answer the following three questions:

1. For each of ten different types of construction (new residential structures; new industrial & commercial buildings; new utility structures; new highways and streets; new farm structures; new mineral extraction facilities; new government facilities; maintenance and repair, residential; maintenance and repair, other facilities; maintenance and repair, oil and gas wells) assumed to be occurring in Travis County, what are the life cycle environmental (i.e., criteria air pollutant) impacts which occur in Travis County, Rest-of-Texas, and Rest-of-U.S.

2. What are the total emissions of each of these air pollutants by county in the U.S.

3. What is the non-attainment status for each of these pollutants by county in the U.S.

4. YEAR TWO: PROJECT DIRECTIONS AND EXPECTATIONS

The capabilities which are due to be added in 1997 are data and results for the full Toxic Release Inventory (each of over 200 chemicals, and releases to air, water, land, and underground); greenhouse gasses; and fuel-specific energy consumption.

With these data in the system, we will be able to answer the following four questions:

1. For each of over 200 different types of toxic chemical in the TRI, how much was released to air, water, land, and underground in 1992, in each county in the US?

2. For each of these chemicals, how much gets released to air, water, land and underground in the Life Cycles of the ten types of construction, for each of our three impact regions

(Travis County Texas, Rest-of-Texas, and Rest-of-US)?

3. How much energy gets consumed, by fuel type, in each of these ten life cycles, for each impact region.
4. What are the greenhouse gas emissions in each of the ten life cycles, from each of the impact regions?

With our current knowledge base, we can now estimate and benchmark the environmental impacts of building construction spatially, in terms of air pollution. Following the completion of tasks in 1997, we will be able to estimate and benchmark the environmental impacts of building construction spatially in terms of air pollution; toxic air, water, land, and underground pollution; greenhouse emissions; and fuel-specific energy consumption.

Additional work undertaken during the second year, for which additional funds will be required, is to create a computer-based information system capable of using the information from the spatial system as necessary input into a system to establish Benchmarks for Total Quality Buildings. Upon completion, we anticipate that the benchmarks derived from the study of many buildings will set specifications for improving the design of new buildings on a location sensitive basis. From these sums of benchmarks, which will reveal patterns, a set of building designer software will be built. This software will be designed to work with commercial Computer-Aided Design (CAD) systems and take data from the data base components of these systems and inform the designer (architect/engineer/quality control specifier) as to its "total quality building" performance, or relative sustainability.

This take-off of building data will provide input to a building's design allowing detailed information access to the descriptions of existing systems of materials, energy and waste for a building in generic form related to the derived benchmarks. The main objective is to evaluate a building as a performance system in a site sensitive context.

The combination of the two main parts of the study will result in an overall set of software that will accomplish the original objectives of the study. These methodologies and information systems are identified as being very valuable when they can be put in a form, in this case, add-on computer programs, that will assist architects, engineers, quality control experts to incorporate the often complex issues regarding Life Cycle Design.

One of the key advances of the present work will be to bring regional and potentially site-specific information into Life Cycle Assessment (LCA). The I/O tables are used to define the production tree, since they define for each branch in the tree what the full set of supplying branches is, and what quantities are required from each of these supplying branches. This project will go beyond the use of national I/O tables alone, by introducing the use of localized I/O tables.

5. ELABORATION OF PROJECT OBJECTIVES

The reasons why I/O based LCA can provide a major advance over conventional LCA have been summarized elsewhere (see, for example, Lave et al., 1995). National scale I/O LCA is a current research topic, both in the U.S. and abroad. The reasons why a regional approach (to I/O LCA) would provide a major advance over both conventional LCA and national scale I/O based LCA include:

• Standard LCA pays no attention to location. However, coming advances in Life Cycle Impact Assessment are making clear that ignoring location, and locational attributes, is no longer tenable in LCA if it is to support meaningful Impact Assessment in categories beyond the global. Location is relevant to both consumption and release flows, as described below.

• In many cases, the location where natural resources are consumed is a strong determiner of what that consumption actually means to the environment. For example, consumption (or conservation) of water in the southwest U.S. is very different from consumption (conservation) of the same quantity of water in the southeast.

• In many cases, the location where environmental releases occur is a strong determiner of what those releases actually mean to the environment. An obvious example is releases of precursors to tropospheric ozone ("smog"). NOx and VOC emissions in non-attainment areas mean something different than equivalent emissions within areas that do not suffer from elevated smog levels. Related to this issue is the fact that some emissions within the life cycle can be meaningful aggregated within regions, but not at a national or global level. In fact, location matters for all release-based life cycle impact categories except global warming and ozone depletion.

• Much decision-making about the environment takes place at a subnational level. Many issues such as criteria air pollutants are addressed at the state level. And some regions are beginning to try to conceptualize or even plan toward sustainable development. Such efforts at defining sustainable levels of resource consumption and of pollution (including "carrying capacity" studies) clearly need to be based on regional regeneration and assimilation capacities.

Equally important, the regional impacts of building design changes upon consumption and pollution flows must be represented by LCAs which hope to link with such carrying capacity studies.

• Transportation of intermediate goods between points of production, and from final producers to the point of sale, can be highly significant contributors to total life cycle burdens. This may be particularly true for a sector such as buildings, for which the weight of materials per dollar of economic value is particularly high. Transportation is an issue unaddressed by I/O LCA efforts to date, and is also poorly treated in standard LCI due to lack of data beyond the first tier of suppliers who are surveyed directly. The present effort will make use of data which is reported along with the I/O data, but not included in the I/O tables themselves, which provides a clear picture of transportation's share of the burden at all stages of the life cycle, not just the first tier. Further, note that environmental impacts of transportation (including emissions, accidents/spills, and those of the supporting infrastructure itself) are all highly place dependent, and therefore will benefit from a regionalized approach.

• Finally, regional decision making is also highly concerned with regional economic impacts of alternative strategies for sustainable development. We should not lose sight of the ability of I/O-based LCA to provide important economic effects data, nor the need for regionalization of these results.

By bringing regional and economic I/O data together in conjunction with LCI analysis, the method should be much more relevant to efforts under the broad heading of "sustainable development". Such analyses often respond to contexts where environment is pitted against economics. The framework should allow for identification of options which are both economically and environmentally beneficial.

6. OVERALL SYSTEM ORGANIZATION

One major characteristic of this effort's information capabilities is the merger of its sub-systems under a single environment with a single data construct. Thus, the spatial, statistical and data aspects of the project are integrated. This integration provides the necessary information management power to define and solve the complexity of the interacting systems important to measuring and benchmarking a Total Quality Building.

One key to fully utilizing this power is in the structure of the sub-systems as arrays and matrices depending on the application. For example, the spatial data management sub-system programs treat the map by geographically dividing it into grid cells of 7 1/2 minutes of latitude and longitude, which provides a mathematical subdivision of the Earth as a sphere stored as an array, or matrices, depending on the application. As econometric models, input/output models, and many other forms of modeling are array and matrix based, there is an isomorphic relationship between the map and the model. Thus, while the results of modeling can be displayed spatially in traditional GIS systems, the project approach allows for the map, the model, and the data base to be used as a single system. This high level of integration is yielding unique and powerful insights into data representing complex systems.

7. COMPUTER APPLICATIONS OVERVIEW

The computer applications are on PCs under DOS and Windows™ by Microsoft Corporation. They utilize several Commercial Off-The-Shelf (COTS) software systems which, as an original objective of the contract, keeps the software developed within existing systems, and reduces unique code which most government agencies have found too difficult to maintain. The main data management and analysis system being used is a set of software titled Speakeasy™ from the Speakeasy Computing Company which is an interpreted system with structured linking capabilities. To implement various aspects of the Geographic Information Sub-System, two other sets of software are used: 1) MicroStation™ by Bentley Systems, Inc., and 2) the Urban Machine™ by Information Design, Inc.

In addition to incorporating traditional commercial GIS capabilities within MicroStation, the project gains capabilities by incorporating the attributes of existing programs which emphasizes finding and revealing patterns in large amounts of spatial and statistical information. These patterns identify and describe the interactions, often complex, between and among human and natural systems. These patterns are new to many users of information systems; however, they provide natural and powerful representations to achieve what project researchers are seeking in their use of information - performance.

8. MODELING SUB-SYSTEM

The interpreter contains over 400 programs for modeling. These programs can support most any type of modeling including, but not limited to: econometric, input/output, time-series, load/stress analysis, fluid dynamics, etc. Mathematical capabilities to support modeling have been tested by the Federal Reserve Board for accuracy against other commercial packages such as SAS and SPSS and found superior.

The Urban Machine is based on an information interrelationship structure formed by interlocking field matrices. This approach to structuring complex data was utilized in a project executed by the Center for Maximum Potential Building Systems (CMPBS) that won an Honours Award at the Rio Earth Summit in 1992. The interlocking field matrices can access data from, or write data to, any of the standard commercial data bases either directly or through their query languages. The overall matrix data organization allows for populations to be seen and analyzed in an urban or rural setting with that site's relationship to the natural environment and to social and health systems.

9. SPATIAL DATA MANAGEMENT SUB-SYSTEM

The spatial data management sub-system is based on grid cells of 7 1/2 minutes of latitude/longitude. This grid, which is stored and analyzed in arrays and matrices, performs many roles. These include showing even distributions of data, providing a rapid sorting method to access data at finer, or coarser, scales, and organizing all our spatial data in an array of grid cells. Programs have been developed to project areas of the Earth, such as the United States, in various conic and poly-conic cartographic projections such as Albers Equal area and Lambert. Combining the grid cell approach with the capabilities of a commercial GIS system, MicroStation, the project has spatial information processing capabilities that are both unique and standard and work together. Utilizing superior array and matrix manipulation capabilities contained in the Interpreter project, researchers have tremendous control over developing many forms of spatial and statistical analysis which are integrated.

Many of today's GIS and CAD systems provide text-based access to their macro languages. Project researchers have implemented links from the Interpreter to not only import and export these text files, these interface files are treated as two-dimensional structured arrays, allowing for indexed string manipulations. Thus, project researchers have benefited tremendously from using these interfaces as data integration capabilities that can return results in the form of macro files that automatically drive the GIS and CAD systems specified to be used later in the project. This is how project researchers have integrated the results from the Urban Machine™ through the Interpreter to MicroStation™ both ways.

10. SOFTWARE SYSTEM CAPABILITIES NOT YET APPLIED TO THE PROJECT MAPVIEW™ WINDOWS USER INTERFACE

The look, feel and functionality of the user interface that will allow for researchers and users to use this system has been given much thought. Certain computer project researchers have over 20 years in user interface technologies with notable successes. These efforts have been prototyped in a set of programs with the working title of MapView, a components sub-system of the Urban Machine. MapView is a Windows™ program that provides user access to the broad range of capabilities and data contained in the computer sub-systems. MapView provides visual linking to data and programs through Object Linking and Embedding (OLE) automation. Customized screens provide a convenient means of accessing and displaying detailed data stored in the Information Bank of the Urban Machines. The Urban Machine, and Speakeasy, also run under Windows NT™ implemented as full sets of 32 bit Dynamic Linked Libraries (DLLs).

MapView provides for bitmaps of any vector and/or imaged data in the Spatial Data Management Sub-System to be displayed as a visual reference for accessing, managing and analyzing data in the Data Organization Sub-System. Thus, under a single Windows program, which has icons, pull-down menus, point-and-click options, and other visual interfaces that have become industry standards, a user will be able to completely control and integrate all the sub-systems of the overall computer systems.

Pattern finding capabilities, generally in the form of clustering, comprise an important part of the system and have yielded profound insights into data and data relationships. Thus, in addition to storing, editing, and displaying large sets of information that can be either spatial or non-spatial, the system can also reveal the dynamics of the interacting systems from which the data was originally measured.

11. ACKNOWLEDGEMENTS

The authors would like to thank the U.S. Environmental Protection Agency for their support, patience, and understanding for the development of the Total Quality Building™ modeling strategy presented in this paper. To our knowledge this work represents the only working prototype functioning on an input/out basis to in order to understand each life cycle step and its impacts individually or in whole and as a result benchmarks that are meaningful due to the variation of geographic location and the ability to backtrack and potentially redesign our life cycle system.

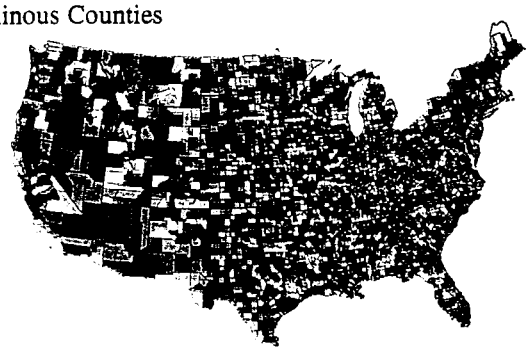
12. REFERENCES

References are too many to be listed in the space remaining . Please contact the Center for Maximum Potential Building Systems for detailed references.

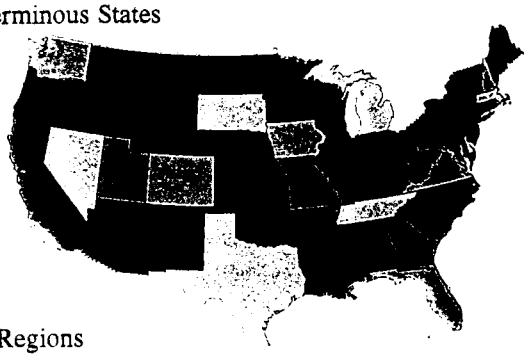
The following printouts demonstrate some of the variations in scale within the Total Quality Building™ procedure. Mathematical capability is built in to the point of a 5 foot by 5 foot grid size with each cell independently or together communicating with all other cells. The 5 foot grid was chosen in order to link to the module used for factory floor planning. Cells are mathematically clusterable to represent each EPA region.

71/2 minute grid totaling 52, 480 grid cells for the contiguous United States.

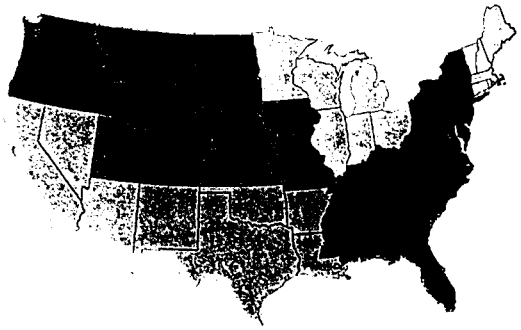
All 3,069
Conterminous Counties



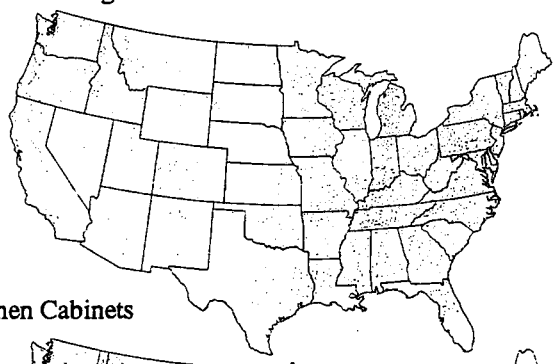
48 Conterminous States



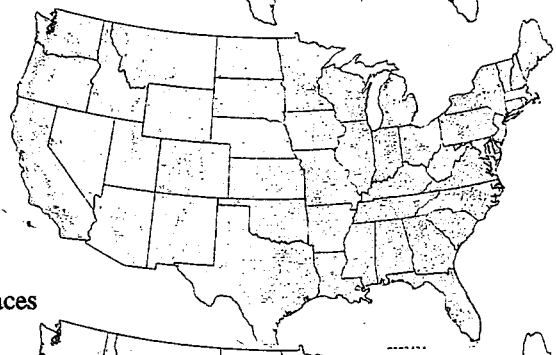
10 EPA Regions



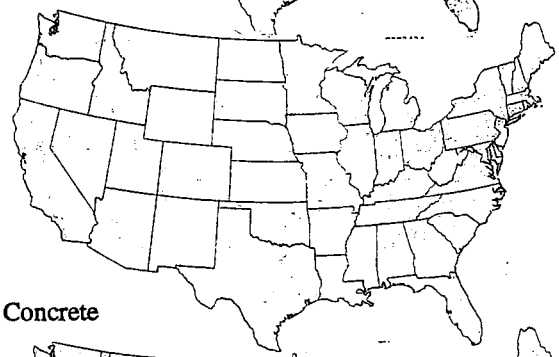
Sawmills and Planing Mills
SIC 2421



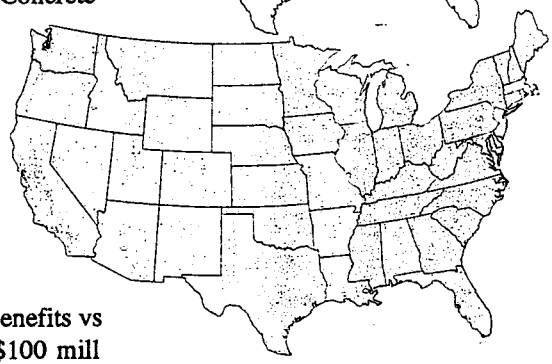
Wood Kitchen Cabinets
SIC 2434



Blast Furnaces
SIC 3312



Ready Mix Concrete
SIC 3273



Financial Benefits vs
Pollution $100 mill
Res. Constr.