Decision Support System of Built Environment for Climate Change Mitigation

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Abstract

According to USA National Climatic Data Center (SOCCR [1]), the buildings sector of North America was responsible for annual carbon dioxide emissions of 671 million tons of carbon in 2003, which is 37% of total North American carbon dioxide emissions and 10% of global emissions. Other countries have similar proportions of energy-related carbon dioxide emissions. Best practices and intelligent systems utilization is a key factor in productively executing climate change mitigation in built environment. The main purpose of this paper is present the Decision Support System of Built Environment for Climate Change Mitigation which the authors of this paper have developed.

Keywords: Decision support system, built environment, climate change mitigation, decision making, quantitative and qualitative analysis

1. Introduction

Different intelligent (neural networks [2, 3], decision support [4-10] and expert [11, 12]) systems for climate change modelling are widely analyzed and developed. Dibike and Coulibaly [2] presented an application of temporal neural networks for downscaling global climate models (GCMs) output. Pasini *et al.* [3] modeled forcings/temperatures relationships at different scales in the climate system. Lautenbach *et al.* [6] presented scenario analysis and management options for sustainable river basin management. Pulido-Velazquez *et al.* [7] set a methodology to diagnose the effect of climate change and to identify adaptive strategies to reduce its impacts in conjunctive-use systems at basin scale. Riverside [8] developed a Web-Based Climate Change Decision Support System. Qin *et al.* [11] developed an MCDM-based expert system for climate-change impact assessment and adaptation planning. Seljom *et al.* [12] described the modelling of the effects of climate change on the energy system. As an example, MCDM-based expert system for climate-change impact assessment and adaptation planning (developed by Qin *et al.* [11] will be briefly analysed.

An MCDM-based expert system was developed to tackle the interrelationships between the climate change and the adaptation policies in terms of water resources management in the Georgia Basin, Canada. A number of processes that were vulnerable to climate change were examined and pre-screened through extensive literature review, expert consultation and statistical analysis. Adaptation policies to impacts of temperature increase, precipitation-pattern variation and sea-level rise were comprehensively explicated and incorporated within the developed system. The MAEAC could be used for both acquiring knowledge of climate-change impacts on water resources in the Georgia Basin and supporting formulation of the relevant adaptation policies. It can also be applied to other watersheds to facilitate assessment of climate-change impacts on socio-economic and environmental sectors, as well as formulation of relevant adaptation policies. The general framework of the developed expert system consists of three levels: (1) graphical user interface to interact with users in a friendly manner, (2) inference engine which drives the knowledge base through reasoning processes, and (3) knowledge, data and model bases which are used to store data, knowledge, information and rules. For the knowledge base, basic information from literature, experts, and empirical observations are transformed and then represented through knowledge acquisition techniques [11].

Based on the analysis of existing intelligent systems [2-12] a Decision Support System of Built Environment for Climate Change Mitigation (DSS-BECCM) consisting of a database, database management system, model-base, model-base management system and user interface was developed.

2. Decision Support System of Built Environment for Climate Change Mitigation

Built environment can be defined in several ways:

- all the structures people have built when considered as separate from the natural environment (the British English definition),
- artificial or man-made surroundings built to serve for a particular purpose, e.g. human activities ranging from the large-scale civic surroundings to the personal places (Biology-Online.org),
- all the structures people have built when considered as separate from the natural environment (the American English definition), etc.

Global Carbon Cycle buildings in North America contribute 37% of total CO2 emissions, while US buildings correspond to 10% of all global emissions. The buildings sector of North America was responsible for annual carbon dioxide emissions of 671 million tons of carbon in 2003, which is 37% of total North American carbon dioxide emissions and 10% of global emissions. Options for reducing the carbon dioxide emissions of new and existing buildings include increasing the efficiency of equipment and implementing insulation and passive design measures to provide thermal comfort and lighting with reduced energy. Current best practices can reduce emissions from buildings by at least 60% for offices and 70% for homes. Technology options could be supported by a portfolio of policy options that take advantage of cooperative activities, avoid unduly burdening certain sectors, and are cost effective (SOCCR 2008). Therefore, best practices utilisation is a key factor in productively executing a climate change mitigation and adaptation in built environment project. The main purpose of this paper is to present the Decision Support System of Built Environment for Climate Change Mitigation which the authors of this paper have developed.

Based on the analysis of existing neural networks, expert and decision support systems a Decision Support System of Built Environment for Climate Change Mitigation (DSS-BECCM) consisting of a database, database management system, model-base, model-base management system and user interface was developed.

The following tables make DSS-BECCM database:

- Initial data tables. These contain general facts about the built environment and climate change considered. The reasons of regenerating of built environment and their significance as well as the money intended to be spent on it are also given.

- Tables assessing refurbishment of built environment solutions. They contain quantitative and conceptual information about alternative of built environment refurbishment solutions (as examples see Equity and Climate Change (Table 1), Climate Change Policies (Table 2), Operationalizing a Resilience to Uncertain Climate Changes (Table 3), etc.).
- Tables of multivariant design. They provide quantitative and conceptual information on the interconnection of the elements of built environment to be regenerated, their compatibility and possible combinations as well as data on complex multivariant design of a of built environment.

Table 1: Table assessing of equity and climate change alternatives

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Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives		
				Approach from the perspective of who benefits most from the public good	Approach based on economics and the social welfare function	Approach from the perspective of who has contributed most to the problem
Egalitarian	+	Units	0.125	5	5	4
Ability to pay	+	Units	0.105	2	3	1
Sovereignty	+	Units	0.029	4	4	3
Maxi-min	+	Units	0.095	2	4	3
Horizontal	-	Units	0.06	4	2	1
Vertical	-	Units	0.064	5	3	1
Compensation (Pareto rule)	+	Units	0.076	3	2	5
Market justice	+	Units	0.089	4	5	3
Consensus	+	Units	0.054	3	3	4
Sovereign bargaining	+	Units	0.032	3	3	3
Polluter pays	-	Units	0.049	2	3	1
Kantian allocation rule	+	Units	0.039	3	4	3
Population	-	Units	0.043	2	3	2
Baseline emissions	+	Units	0.026	2	2	2
Basic trends in energy efficiency	+	Units	0.036	3	4	2
Competitiveness	+	Units	0.033	4	5	3

Table 2: Fragment of a table assessing of climate change policies alternatives

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Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives						
				Regulatory standards	Market-based instruments	Voluntary agreements between public agencies and industry	Informational instruments	Use of subsidies and financial incentives	Removal of subsidies	Demand-side management
Egalitarian	+	Units	0.125	4	3	5	7	6	4	3
Ability to pay	+	Units	0.105	5	7	6	3	10	4	8
Sovereignty	+	Units	0.029	4	6	3	5	5	7	6
Maxi-min	+	Units	0.095	8	9	6	7	5	5	3
Horizontal	-	Units	0.06	3	4	8	1	2	4	6
Vertical	-	Units	0.064	5	2	5	3	6	4	7
Compensation (Pareto rule)	+	Units	0.076	8	7	6	9	10	4	5
Market justice	+	Units	0.089	9	10	7	10	5	6	8
Consensus	+	Units	0.054	8	9	5	10	6	3	4
Sovereign bargaining	+	Units	0.032	6	4	10	8	7	6	5
Polluter pays	-	Units	0.049	1	3	4	4	6	3	5
Kantian allocation rule	+	Units	0.039	8	3	5	5	4	4	7
Population	-	Units	0.043	10	9	9	6	4	6	3
Baseline emissions	+	Units	0.026	10	6	8	9	7	7	5
Basic trends in energy efficiency	+	Units	0.036	6	7	8	10	9	5	9

Table 3: Fragment of a table assessing of operationalizing a resilience to uncertain climate changes alternatives

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Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives					
				Homeostasis	Omnivory	High flux	Flatness	Buffering	Redundancy
Ground subsidence	-	Points	0.032	3	4	3	5	9	5
Water system	+	Points	0.047	8	7	4	5	6	5
Tidal differences	-	Points	0.033	3	4	5	4	7	6
Water barriers	+	Points	0.039	7	6	4	7	8	9
Local ecology	+	Points	0.043	8	7	7	8	8	8
Economical functions	+	Points	0.048	6	9	7	8	7	5
Public spaces	+	Points	0.032	7	8	5	5	6	7
Inland shipping	+	Points	0.034	7	8	6	7	7	7
Port functions	+	Points	0.036	7	8	6	7	7	7
Residential functions	+	Points	0.035	8	8	8	7	6	7
(Para)medical facilities	+	Points	0.08	9	9	8	9	8	8
Cooling	+	Points	0.04	7	5	8	9	7	8
Energy supply	+	Points	0.075	6	9	9	9	7	9
Drinking water	+	Points	0.078	9	7	4	5	7	7
Disaster management organization	+	Points	0.1	9	9	9	9	9	9
Electricity	+	Points	0.07	6	9	9	9	7	8
Sewage system	+	Points	0.06	9	6	7	6	8	9
Main roads leading in/out of the area	+	Points	0.041	8	7	6	8	8	7
Main water barriers	+	Points	0.038	8	7	6	8	9	7
Maeslantkering storm surge barrier	+	Points	0.039	6	6	8	8	9	7

Since the efficiency of a built environment refurbishment variant is often determined taking into account quantitative and qualitative factors a model-base of the DSS-BECCM should include models enabling a decision maker to do a comprehensive analysis of the variants available and make a proper choice. The following models of model-base are aimed to perform this function:

- a model of developing the alternative variants of built environment,
- a model for determining the initial weights of the criteria (with the use of expert methods),
- a model for the criteria weights establishment,
- a model for multivariant design of a built environment refurbishment,
- a model for multiple criteria analysis and setting the priorities (as example see Adaptation to Climate Change (Table 4)),
- a model for determination of built environment utility degree and market price,
- a model for providing recommendations.

Based on the above models, the DSS-BECCM system can make until 100 million built environment refurbishment alternative versions, performing their multiple criteria analysis, determining utility degree, market price and selecting most beneficial variant without human interference.

Table 4: Adaptation to climate change alternative's multiple criteria analysis results

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Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives							
				Enhancing adaptive capacity	Adaptation through local planning	Agricultural production	Weather control	Damming glacial lakes	Geoengineering	Assisting disadvantaged nations	Migration
Economic Efficiency	+	Units	0.175	0.0175 AVG MIN	0.0105 AVG MIN	0.021 AVG MIN	0.0175 AVG MIN	0.0245 AVG MIN	0.0245 AVG MIN	0.0315 AVG MIN	0.028 AVG MIN
Flexibility	+	Units	0.1	0.0135 AVG MIN	0.0096 AVG MIN	0.0154 AVG MIN	0.0192 AVG MIN	0.0096 AVG MIN	0.0115 AVG MIN	0.0154 AVG MIN	0.0058 AVG MIN
Urgency	+	Units	0.65	0.0758 AVG MIN	0.0758 AVG MIN	0.0975 AVG MIN	0.1083 AVG MIN	0.0542 AVG MIN	0.0867 AVG MIN	0.1083 AVG MIN	0.0433 AVG MIN
Low Cost	-	Units	0.16	0.0123 AVG MIN	0.0154 AVG MIN	0.0154 AVG MIN	0.0215 AVG MIN	0.0185 AVG MIN	0.0215 AVG MIN	0.0308 AVG MIN	0.0246 AVG MIN
Equity	-	Units	0.43	0.0614 AVG MIN	0.0307 AVG MIN	0.0717 AVG MIN	0.041 AVG MIN	0.041 AVG MIN	0.0307 AVG MIN	0.0819 AVG MIN	0.0717 AVG MIN
Institutional feasibility	+	Units	0.3	0.0346 AVG MIN	0.0519 AVG MIN	0.0404 AVG MIN	0.0462 AVG MIN	0.0346 AVG MIN	0.0288 AVG MIN	0.0288 AVG MIN	0.0346 AVG MIN
Unique or Critical Resources	+	Units	0.142	0.0152 AVG MIN	0.0203 AVG MIN	0.0228 AVG MIN	0.0228 AVG MIN	0.0177 AVG MIN	0.0177 AVG MIN	0.0127 AVG MIN	0.0127 AVG MIN
Health and Safety	+	Units	0.155	0.0152 AVG MIN	0.0229 AVG MIN	0.0254 AVG MIN	0.0203 AVG MIN	0.0178 AVG MIN	0.0152 AVG MIN	0.0203 AVG MIN	0.0178 AVG MIN
Consistency	+	Units	0.5	0.0625 AVG MIN	0.0781 AVG MIN	0.0703 AVG MIN	0.0703 AVG MIN	0.0547 AVG MIN	0.0547 AVG MIN	0.0547 AVG MIN	0.0547 AVG MIN
Private v. Public Sector	+	Units	0.125	0.0172 AVG MIN	0.0147 AVG MIN	0.0147 AVG MIN	0.0172 AVG MIN	0.0123 AVG MIN	0.0196 AVG MIN	0.0123 AVG MIN	0.0172 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0.2515	0.2838	0.3075	0.3218	0.2254	0.2587	0.284	0.2141
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0.0737	0.0461	0.0871	0.0625	0.0595	0.0522	0.1127	0.0963
Significance of the alternative				0.3194	0.3923	0.3649	0.4018	0.3095	0.3545	0.3284	0.266
Priority of the alternative				6	2	3	1	7	4	5	8
Utility degree of the alternative (%)				79.48%	97.63%	90.81%	99.99%	77.02%	88.22%	81.72%	66.2%

*- The sign "+/-" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

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