THE ANALYTICAL HIERARCHY PROCESS (AHP) APPROACH TO MODELLING CORPORATE CLIMATE CHANGE RESPONSE

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Abstract: The heightened risks and opportunities posed by climate change call for increased attention by business executives to employ creative and rigorous methodology in generating strategic response options. Because climate change is influenced by an assortment of multiple and interdependent variables, the search for solutions to this complex challenge ought to be a multi-dimensional trade-off seamlessly integrated into corporate strategy. Analytical hierarchy process (AHP)'s ability to hierarchically structure complexity into homogeneous clusters of factors renders it as an appropriate decision support tool allowing for the interconnectedness of climate change systems, the constraints in time, knowledge and computational abilities that humans face. This paper presents a conceptual view of the approach, exploring key aspects of how AHP assists in deriving a climate change model for businesses.

1 INTRODUCTION

Strategic pressures created by pushes towards sustainable business practices, environmental activism, threats of pledges, laws and regulations being enacted around the world to curb greenhouse gas emissions, and rising demands by consumers for more environmentally friendly products and services (Shove, 2005), mandate an input into corporate strategic planning. The impacts, risks and opportunities for businesses imply that CEOs can no longer afford to pursue strategies geared towards the single objective of shareholder wealth maximisation (Steuer & Na, 2003). Business constraints in terms of resources, capabilities and time, call for well-thought-through strategies that will maximise the opportunities for a business, while minimising the risks, threats and vulnerabilities (Raymond & Brown, 2011). Thus businesses have to come up with the "best-balanced-choice" responses to climate change. AHP lends itself well to solving such a complex problem requiring structuring, measurement and synthesis.

This paper is organised into five major sections. Section 2 explores the suitability of the analytical hierarchy process as a multi-criteria decision making methodology for business' response to climate change. Section 3 describes the climate change challenge, with particular emphasis on the risks and opportunities it presents to businesses. In section 4 the concept of a climate change response ladder is introduced, culminating in the formulation of the corporate climate change response problem using AHP. Particular emphasis is placed on the hierarchal, progressive nature of climate change inculcation into corporate strategy. Section 5 presents a highlight of future work and draws some conclusions.

2 ANALYTICAL HIERARCHY PROCESS (AHP)

First developed by Saaty (1980), AHP is a multi-criteria decision-making methodology based on carefully structured mathematical set of matrices and their associated eigenvectors to compare criteria or alternatives in a pairwise mode against some predetermined objective (Saaty, 1980, 1994). The ability of AHP to decompose a complex problem into a hierarchical structure of homogeneous clusters, coupled with its ability to capture, measure

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and synthesise individual preferences of qualitative and quantitative attributes into ratio scale weights, make the method appropriate in establishing climate change response priorities and subsequently allocating resources to chosen priorities (Hwang & Syamsuddin, 2010).

The flexibility and simplicity of the method has been proven in practice and validated by physical and decision experiments (Vaidya & Kumar, 2006; Saaty, 1994) making it useful in the private and public sectors at strategic and operational levels in broad areas of choice decisions (Lee & Jao-Hong, 2008), prioritisation and evaluation (Hwang & Syamsuddin, 2010; Syamsuddin & Hwang, 2009; Chiu, *et al.*, 2004; Handfield, 2002), resource allocation, benchmarking (Vaidya & Kumar, 2006), public policy (Satty, 2008), health care and strategic planning (Meziani & Rezvani 1990; Ossadnik, 1996; Kurttila *et al.*,2000). It is against this backdrop of a diversity of applications that AHP is proposed as the suitable multi-criteria approach to use to quantify and rank the possible set of initiatives and activities that a business could employ to mitigate and adapt to climate change risks, and capitalise on available opportunities.

3 CLIMATE CHANGE RISKS AND OPPORTUNITIES FOR BUSINESSES

Climate change risks cut across almost every industry, whether directly or indirectly (Stern, 2007). For businesses in certain industries, energy/fuel price fluctuations and security of supply of natural resources are posing significant challenges and risks. The greatest liability with respect to carbon exposure is in carbon-intensive sectors such as oil and gas, basic resources, utilities, heavy manufacturing, etc., where carbon costs could be direct, or are passed down the value chain in the form of higher prices (IRRC Institute).

The pricing of carbon through various market mechanisms (such as carbon tax, cap-and-trade, border tax adjustments, etc.), coupled with the rise of the cost of insurance to curb the physical risks of climate change (e.g. extreme weather patterns, rising sea levels), is increasing the cost of doing business. Restricted access to markets due to climate-change-related legislation (such as the European Union Directive on Aviation) and shifts in consumer preferences towards greener products and services, coupled with mounting legal and regulatory pressures and litigation as well as increasing public and stakeholder activism (Dietz *et al.*, 2009) is affecting business reputations and brand equity, posing threats to revenue, market share and the very existence of certain businesses.

For the agile firm, however, climate change is ushering in opportunities to drive efficiencies and innovations, harness new revenue streams and make new investments, thereby enhancing reputations, gaining market share and significant competitive advantages. This drive towards carbon reduction, combined with a proactive management of systemic climate risks, is defining new levels of environmental stewardship and business competitiveness (Van den Berg *et al*., 2006). New industries that were non-existent a decade ago have been born and are thriving, such as cleaner technologies in energy generation, hybrid and electric vehicles; and sub-sectors in financial markets such as carbon trading, brokerage services, climate exchanges or clean-energy venture capitalism. Long-term investors, asset managers and analysts are also beginning to integrate climate change considerations into investment analysis and decision-making.

It is against this background that a framework for companies to respond to the climate change challenges is proposed. The next section provides a detailed account of how the AHP methodology is applied to design a corporate climate change response framework.

4 CORPORATE CLIMATE CHANGE AHP ALGORITHM

In this section, a mathematical model is formulated for the climate change response decision problem under conditions of three overarching conflicting objectives: environmental, social and economic sustainability (Raymond & Brown, 2011; Steuer & Na, 2003).

4.1 Steps in the Application of AHP in Climate Change Response

The underlying idea is holistic, incorporation of climate change issues into a business, beginning with the neophyte and progressively moving towards full integration into corporate strategy. Herbert Simon's (1972) intelligence, design, choice model for decision making is used in this study. The intelligence gathering phase is about discussions of the problem statement among the executive team members of a firm and experts in order to obtain an enriched and consensual view of the climate change problem. During the design phase the executive team discusses and agrees on the overall objectives and criteria by which alternatives will be rated. They will also identify the clusters; sub-clusters and a list of alternative solutions i.e. construct the AHP hierarchy tree. This is an iterative process because the set of objectives is often dependent on the alternatives being considered; conversely the list of alternatives will likely change based on the defined set of objectives. The choice phase is dedicated to evaluating (using a ratio scale) how well each alternative per cluster contributes to the firm's agreed objectives and finding the best combination of alternatives to mitigate the most risks and threats posed by climate change while simultaneously capitalising on the opportunities presented (Porter & Reinhadart, 2007).

It is this characteristic of AHP, i.e. the ability to measure, synthesise, order and prioritise all the analyses from the different stakeholders using ratio measures (Saaty, 1994), that make the methodology indispensible in this decision problem. AHP brings in the subjective values and preferences of the decision makers, while utilising their varying levels of capabilities, expert knowledge and experiences to bring out a quantitative result that is usable in strategic evaluations.

Step 1: Construction of the climate change response ladder. The first step in the construction of the response framework is the application of the decomposition principle to structure the climate change response problem into a hierarchy of homogeneous clusters, sub-clusters and sub-sub clusters (Saaty, 1980). The executive team discusses and identifies possible alternatives and initiatives which are populated onto the 4 progressive clusters: (1) Raising Awareness, (2) Adaptation and Operational Efficiencies, (3) New Products and Revenue Streams and (4) Fully Integrated Climate Change Strategy.

Depending on the company's knowledge, experience, industry and level of climate change astuteness, different items will be found at each of the four (4) ladder rungs. An example of the possible initiatives and options is provided in Figure 1. Each item might have sub-items, for example Employee Awareness (A1) might have sub-items which would be labelled as A11, A12… etc, forming a tree for each cluster. The process is continued until the ladder is completed, that is A1.. A_n, E1-E_m, P1-P_x and S1-S_y, including the sub-levels where desired. Following on from Kurttila *et al.*'s (2000) use of AHP for SWOT analysis, it is recommended that the number of items on each rung not exceed 10, because any larger will make the number of pairwise comparisons onerous.

Step 2: Pairwise Comparisons between items on each rung of the ladder. The next step in the construction of the climate change response framework is to construct pairwise comparisons of all combinations of alternatives in a cluster relative to the parent cluster. Team members work individually first so that their knowledge and expertise is applied to the process without undue influence from peers. The individual evaluations are then combined by taking geometric means which act as convenient starting points for group discussions. These pairwise comparisons are used to derive local priorities of alternatives in a cluster or sub-cluster. A set of questionnaires is compiled, based on the original Saaty Rating Scale of linguistic variables (Table 1).

Using the linguistic variable measurements to demonstrate the effect of each alternative on corporate objectives, decision makers are presented with a series of pairwise comparison questions of the format, "*How important is alternative E1 relative to alternative E3*? (*… based on some objective, e.g. the risks, threats and vulnerabilities to the business, or the strengths to capitalise on the opportunities*). The choice options are based on the 5 linguistic variables "equally important", "somewhat more important", "much more important", "very much more important", or "absolutely more important". The sum of all the criteria beneath a given parent item on each cluster of the ladder must equal one (1). Its global priority shows its relative importance within the overall ladder.

Step 3: Ranking the pairwise comparisons by calculating the Eigenvalues. The relative importance of one alternative over another is computed using eigenvectors in a matrix of the form:

$$\mathbf{A} = (a_{ij}) = \begin{pmatrix} & \cdots & \\ \vdots & \ddots & \vdots \\ & \cdots & \end{pmatrix} \qquad (1)$$

where in the matrix, the element $a_{ij} = 1/a_{ij}$ and when $i = j$, $a_{ij} = 1$. The value of w_i ranges from 1 to 9 and 1/1 indicates "equally important", while 9/1 indicates "absolutely more important", as shown in Table 1. If the judgments made by decision makers are inconsistent, matrix **A** will yield some inconsistencies which are generally acceptable (Saaty, 1980, 1994). The Eigenvalue method of Eq. 2 is used to resolve the problem.

$$(\mathbf{A} - \lambda_{max}\mathbf{I})\mathbf{q} = 0 \qquad (2)$$

where λ_{max} is the largest Eigenvector of the matrix

A; **q** is the correct Eigenvector (i.e. the estimation of the relative priorities); and **I** is the identity matrix. Each Eigenvector sums up to 1 to obtain the priorities.

Step 4: Pairwise comparisons are made between the four ladder rungs. The last step is the synthesis of priorities (known as hierarchic composition). The team chooses the factors with the highest local optima from each cluster as cluster representatives. The four are then compared and their relative priorities are determined using the Saaty Table and another pairwise comparison process as in Step 2. The production of an analytic evaluation of the possible options within each cluster (local optima) and the combinations to give the best overall optima are the key advantages of using AHP.

5 CONCLUSIONS

The tree structure used to formulate an AHP problem provides a clear, organised and logical view of the climate response problem making it The tree structure used to formulate an AHP problem provides a clear, organised and logical view of the climate response problem making it easy for decision makers to visualise and analyse the problem systematically at each level. The framework proposed in this paper allows for the evaluation of both qualitative and quantitative factors, thereby combining sophistication and realism to solve a practical challenge faced by businesses. While judgments can be very subjective, ratio scale measures of subjective importance and preferences are essential for rational decision making and resource allocation especially for an issue as strategic as climate change response.

The rest of the study will focus on understanding the rationality-irrationality dichotomy of business executives in choosing between diverse and often conflicting strategic options for responding to climate change. A case study research design using the mixed-method strategy of inquiry is employed. By conducting a comparative case study, it will be interesting to see the similarities and differences of strategic choices for two companies in different industries, in the same jurisdiction, confronting similar macroeconomic fundamentals.

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APPENDIX:

Table 1: Saaty Linguistic Variables.

Intensity of Importance	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favours one over the other.
5	Much more important	Experience and judgement strongly favours one over the other.
7	Very much more importance	Experience and judgement very strongly favours one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed

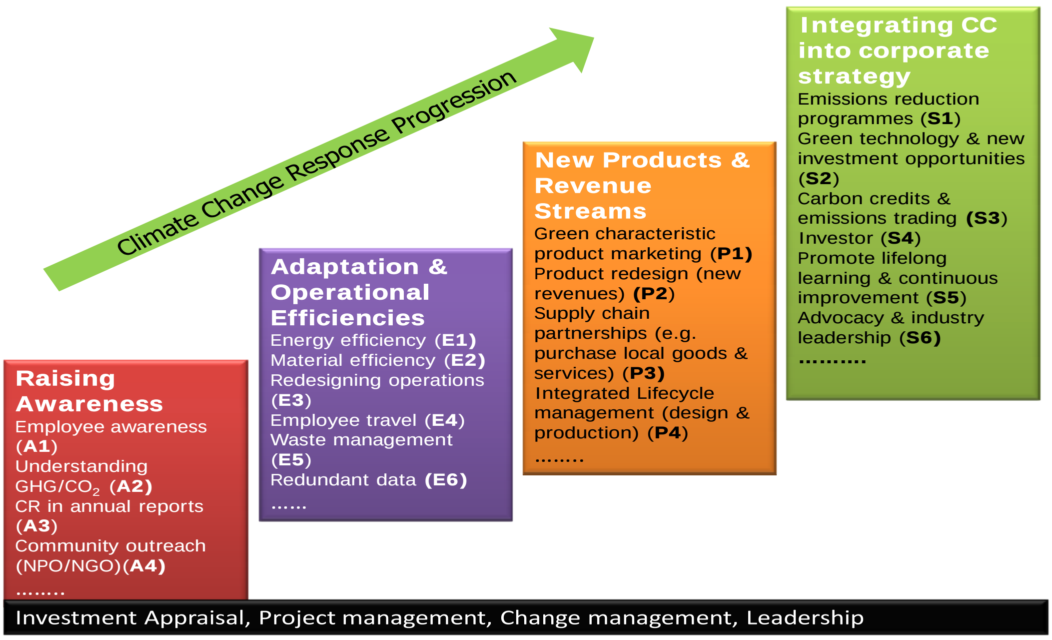

Figure 1: Climate Change Response Ladder.