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Corporate Sustainability Management: An Innovative Model Development

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Abstract. This paper proposes an innovative model developed for enhancing skills and capabilities of the corporate sector requires in formulating sustainability management in response to a highly complex and dynamic environment. Concerning on carbon-dioxide (CO_2) emissions reduction and by using a major cement company in Thailand as a case study, the model involves an integration of human-social thinking in the form of sustainable scenarios building into the system dynamics of Earth sciences. The model accounts for assessing World's driving forces and the future role of technological and efficiency development, associated with cement industry long-term sustainable behavior requires. This model is executed for 50 years span starting from year 2011 on STELLA® software application. The model has demonstrated a highly effectiveness and adaptability, allowing a cement industry to explore a wide-range of sustainability management options of key driving forces to be made. It flexible architecture permits the user expanding its boundaries to include other facets of the holistic adaptation sustainability management.

Keywords: Human-social thinking, sustainability management, sustainable scenario, system dynamics.

1. Introduction

The skills and capabilities to formulate foresight the sustainable behavior is absolutely critical to a corporate sector to make informed decisions to maintain the sustainable nature of our environment now and into the future [1, 2]. Envisioning and evaluation long-term sustainable development of a corporate sector have emerged as a critical component of both science and society decision-making [3, 4].

A corporate sector in general, cement industrial sector in particular can be seen as a critical part of a human-social system operating in a larger complex, and dynamic environmental system of which it is in-separate part, must take greater responsibility for ensuring long-term sustainable future [5, 6]. Theoretically and practically, any method and tool develop need to perform for exploring a set of strategies on the basis of what and how they should do in different and desirable future, taking to account the analysis of how driving forces may influence future global warming reduction and comply with sustainable purposes and contexts that are of co-benefits among the global, nation stakeholders and others [7, 8, 9].

In challenge sustainable future, this paper has taken the task of providing an innovative model for enhancing skills and capabilities of the cement industry needs in formulating sustainability management in response to a highly complex and dynamic environment. The model development is divided into two phases, on the basis for integrating trans-disciplinary (TS) study toward the idea, which requires the learning process to incorporate procedure and state of knowledge gained from different perspectives [10, 11, 12]. These two phases (Figure 1) are developed and applied concomitantly as follows; i) corporate dynamic account analysis (CDA), in the form of dynamics modeling application for identifying a company's sustainability performance; and, ii) the role of human-social system thinking in the form of sustainable scenarios building

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to encourage company's knowledge exchange and development of mutually deeper understanding of complexity and dynamism of the environment important to the future of the business affairs. The synthesis of the resulting company's sustainable scenarios with the dynamic account analysis will constitute the simulation model, which allows a company to capture the ideas and understanding the interacting environment of mutual learning between science and society and the long-term effects of sustainability managerial options.

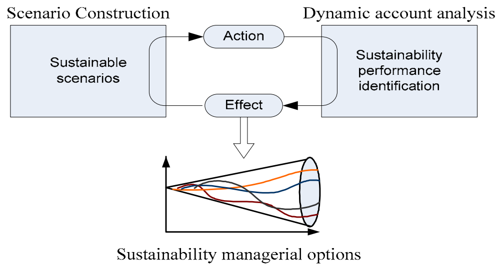

Fig 1: Schematic Framework of the Integrative Approach

Concentrating on carbon dioxide (CO_2) emission reduction, by using one of major cement company based in Thailand (Ta Laung Cement Plant: Siam Cement Group Thailand: SCG Thailand) as a case study, the model accounts for assessing World's driving forces and the future role of technology and efficiency development associated with a cement's industry long-term sustainable behavior requires.

2. Materials and Methods

2.1. Methods applied to the case study

At present the company's cement production (Ordinary Portland Cement: OPC) is estimated at 3.50 million tons annually (company's base year data, 2011 – referred to as base case scenario (BCS) is represented in Table 1). Limestone is a major raw-material used in the production process. It is burnt to make clinker and blended with additives, e.g. fly ash from coal-fired thermal power plants, and then finely grounded to produce different types of cement. To produce the required quantity of one tonne of cement typically requires 100 kWh of electricity, and thermal energy (kiln-fuel) input of 3.14 Gj per tonne clinker produced.

Table 1: Represents a company's base year data.

Data (unit)	Base year in 2011
Cement production (million tons annually)	3.50
Clinker fraction (clinker-gypsums/cement ratio)	0.94
Share of total kiln-fuel energy consumption (type, % share)*	coal 40; lignite 38; natural gas (NG) 0; alternative fuel (AF) 2; and, biomass 20
Electricity energy required (kWh/tonne cement)	100

Note: * Describes type and % share for the thermal energy required per tonne clinker produced.

2.2. Model development and data management

In phase I, a corporate dynamic account analysis (CDA), casual loop diagram (CLD) consisting six interacting environment (sector I-VI), is developed to identify and incorporate a number of feathers associated with cement's industry interacting environment, conducting sustainability performance and making projection for CO_2 emissions based on scenarios construction (Figure 2).

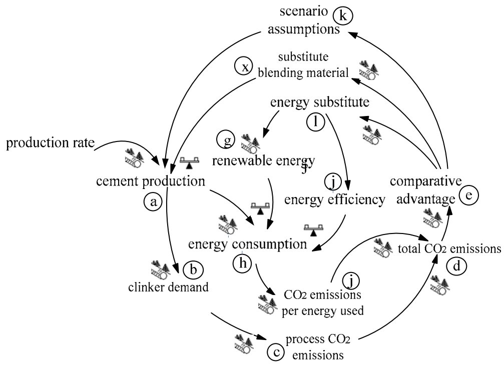

Fig 2: Illustrates the relationships of all variables in CLD of the model.

Figure 2 represents all variables of the company's dynamic hypothesis as follows. In principle, the specific dynamic of total cement production (a – sector i) are influenced the level of company's cement production desired rate and added capacity in the future. All of these create demands of raw-material (clinker) used (b – sector ii) and energy (kiln-fuel and electricity energy) consumption (h – sector iii), all of which effect the level of process (c – calcinations process) and per unit energy consumption CO_2 emissions (i) and total CO_2 emissions (d – sector iv). The performance comparative advantage variable (e – sector v) is put to identify the prominent sustainability practices, which include; 1) the pressure use of lower carbon-based or substitute with renewable energy (l and g) and level of energy efficiency improvement (j); and, 2) pressure to substitute of blending material for cement production (x). These two pressures are hypothesized for a dual benefit of lower energy-intensive of cement production (h), with lower CO_2 emissions per unit energy consumption (i), total emissions (d) and the use of raw-material consumption (b) which leads to lower process CO_2 emissions of a company (c). For the scenario assumption (k – sector vi), this variable is hypothesized as to translate a company's sustainable scenarios into a dynamic hypothesis model.

In phase II, the cement's industry four different sustainable scenarios are developed (S1-S4) with the several spatial and temporal scales to describe as the cement industry challenge on a distinctly different direction for future development (Block 1). Together with the methods of selection scenarios' parameters and key driving forces of changes that company needs to put emphasize, focusing on human-social and support systems on the consequences of changes (mitigation/adaptation strategy) in the natural system (Table 2). In this phase some adjustments in the specification (quantification test calculation) of scenario drivers are made, focusing on company's internal consistency of different assumptions and the linkage to the model. In other words, it is an iteration process between scenarios development and quantification.

Block 1: Scenarios describe the challenge for cement industry developments.

- The S1 scenario family describes a future world of vary rapid of technical/efficiency progress that would lead to lower demand for the resources and switching to more sustainable energy sources. In this scenario family, four sub-scenarios are considered in reflecting the challenge for cement industry lives as follows.
  - ✓S1A scenario evolves along the current development strategy of cement industry.
  - ✓S1B scenario intensifies a dependence on un-conventional fossil fuels in long-run.
  - ✓S1C scenario envisages a shift toward renewable energy and an inclination of nuclear energy.
  - ✓S1D scenario assumes a balanced mix of raw-material (clinker) and technologies.
- The S2 scenario describes a very divergent world toward stronger sustainable system. The challenge of cement industry needs to orient toward resources efficiency, use of substitute inputs and energy mix (conventional kiln-fuel) consumption.
- The S3 scenario describes a world in which the emphasis is on sustainable development, but less rapid and more diverse technological change than in the S1 and S2 scenarios. This scenario challenges the cement industry to improve efficiency research and development (R&D) of resources use and environmental protection.
- The S4 scenario describes the world as one of increased environmental, social sustainability and business strategy at the national and local levels. It is assumed that, globally investment in R&D continues its current declining trend for international diffusion of technology (weaker than S1 scenario but higher than the S2 and S3 scenarios). This scenario challenge cement industry a gradual transition moves away from the current share of fossil fuels in world energy supply.

Table 2: Shows the parameters and values of drivers in all scenarios.

Parameter / Scenarios	Raw-material (i)	Thermal kiln energy (ii)					Electricity (iii)	Technology (iv)	Nuclear Energy
		Coal	Lignite	NG	AF	Biomass			
S1A	10	BCS	BCS	BCS	BCS	BCS	30	15	BCS
S1B	10	40 – 10	38 – 18	2 – 18	2 – 15	20 - 40	30	15	BCS
S1C	10	40 – 15	38 – 14	0 – 12	2 – 20	20 – 40	30	15	0-50 (v)
S1D	15	40 – 20	38 – 20	0 – 20	2 – 15	20 – 30	30	15	BCS
S2	20	40 – 20	38 – 20	2 – 15	2 – 15	20 – 35	30	5	BCS
S3	35	40 – 15	38 – 15	2 – 15	2 – 20	20 – 40	30	3	BCS
S4	40	40 – 20	38 – 10	2 – 20	2 – 25	20 – 40	30	10	BCS

Note: The BCS stated values same as company's base year data (Table 1).
All values are defined as a percent % probability change (increase/decrease) on the likelihood what will happen steadily as compare to BCS throughout simulation periods otherwise specific.

(i) Describes the requirement of blending % share increase (clinker/cement ration), with industrial by-products, e.g. coal-fired and blast furnace slag material.

(ii) Describes a systematic framework for mapping company's trends and anticipating change in thermal energy mix options (% share reduction from conventional to non-conventional thermal energy and % share increase for AF and biomass energy). It is worth noting here that, for the NG which is one type of conventional thermal energy and as one major source of CO_2 emissions, the value is set to increase as comparing to company's BCS on the assumption that the future role of country's energy security as a reduction in conventional-based energy (coal and lignite) supply for the cement industry.

(iii) Describes the % increase by cement industry efficiency improvement from country's grid supply or substitution from alternative electric power sources produced from company internally.

(iv) Including the role of company technology/efficiency/R&D (% increase) use of thermal and electricity energy.

(v) The nuclear power which expected to employ as the future role of energy source of the country (increasing 50% gradually starting from year 2025 the end of simulation periods).

3. Results and Discussion

3.1. The model execution and validation

At first, the model is executed under the assumption that the company's current practices are maintained without any substantial change taking place (Table 1). Results obtained from the execution (Figure 3) indicated that a company's CO_2 emissions per tonne cement produced is projected at 0.47 tons from process emissions (calcinations process) and 0.05 tons from electricity consumption. Whereas, the CO_2 emissions from the use of thermal energy is projected at 0.32 tons (0.30 tons per tonne clinker produced), which included 0.24 tons from conventional kiln-fuel (coal, lignite and NG) and 0.08 tons from the non-conventional kiln-fuel (AF and biomass) consumption. Thus each tonne of cement produced is associated with 0.83 tons CO_2 emissions.

Following, the model is validated regarding to the theoretical assumptions and the real world cement production capability, focusing on clinker demand (Table 3) as follows. Initially, the model simulated the company's clinker demand under the BCS (scenario A), and then switch to the ratios describes the two alternative blending % share (scenarios B and C).

Table 3: Describes the relationship among three alternative scenarios.

Scenarios	Validate assumptions
A: Simulate under the BCS.	The clinker should be comprised of blending at 6% of gypsum.
B: Locked to the model.	The clinker should be comprised of blending at 3% of gypsum.
C: Locked to the model.	The clinker should be comprised of blending at 10% of gypsum.

Results of validation indicated that (Figure 4), by the year 2060, for scenario B a company's cumulative clinker demand is projected at 3% (5 million tons) higher than scenario A, and 4% (7 million tons) reduction in scenario C as compared to scenario A.

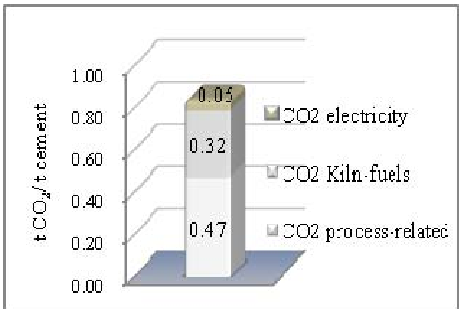

Fig 3: Illustrates level of CO_2 emissionsper tonne cement production.

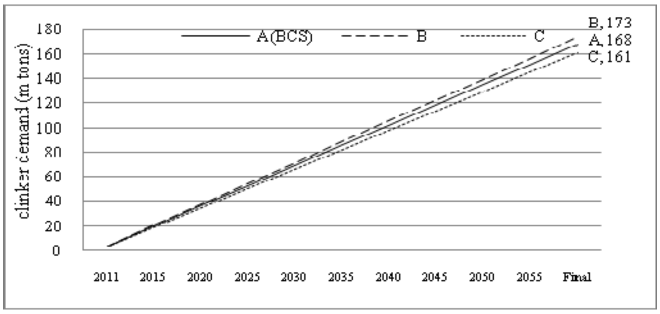

Fig 4: Illustrates clinker demand of all validation components.

3.2. Integrated assessment execution

Concerning all company's scenarios parameters and its values, three sustainability managerial options are chosen to execute and discuss focusing on the following areas; (1) specific gross CO_2 emissions kiln-fuel component; (2) specific gross CO_2 emissions raw-material component; and, (3) CO_2 emission per tonne of cement production.

Results from simulation (Figure 5, 6, and, 7) can be acknowledged that, if S1 scenario family are taken into projection the sustainability performance related to specific gross CO_2 emissions of kiln-fuel component is reduced by the factors affecting technological innovation; even in S1A scenario's values of thermal kiln-fuel energy consumption (Table 2) is taken for simulation at same as BCS's. Focusing on CO_2 emissions regarding the raw-material component and CO_2 emissions per tonne cement production, the results indicated that there is no technological innovation effecting the reduction in CO_2 emissions; but it is from the alterative % share of kiln-fuel components and blending, especially in S1D scenario which is projected at the highest rate of blending % share in S1 scenario family.

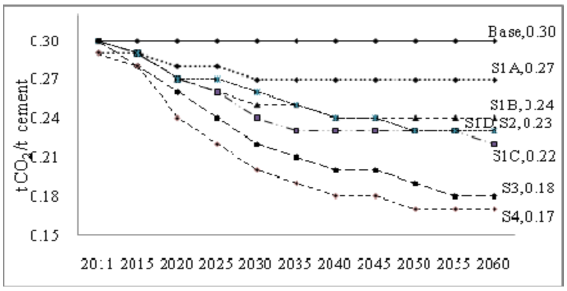

Fig 5: Illustrates specific gross CO_2 emissions kiln-fuel component.

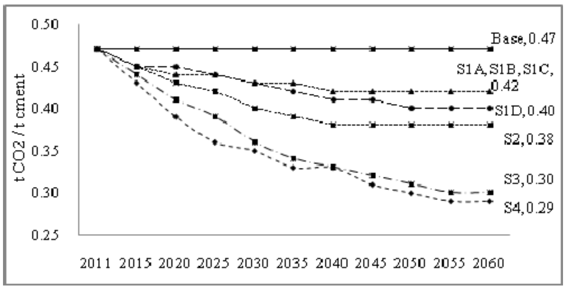

Fig 6: Illustrates specific gross CO_2 emissions raw-material component.

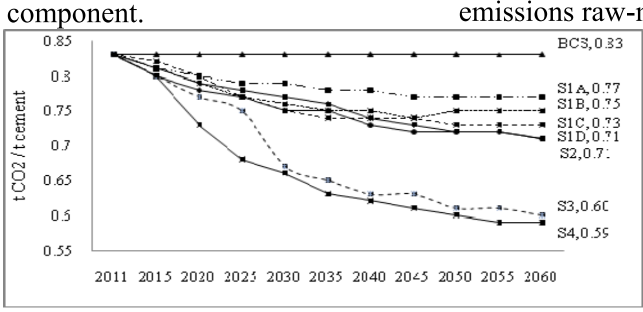

Fig 7: Illustrates the level of ton CO_2 emissions per tonne cement production.

Above results, some observations can be made as the follows. For S1 scenario family, the incremental innovation of future technology innovation did not significantly affecting in reduction of CO_2 emissions regarding to raw-material components. Whereas, for S1C scenario, nuclear power which is expected to play a future substantial role for thermal kiln in cement industry, leads to a decrease at the lowest value of specific CO_2 emissions of kiln-fuel consumption and conventional kiln, but not of the raw-material components and CO_2 emissions per tonne cement production aspect.

Consider S2, S3 and S4 scenarios, the results indicated that, in future the incremental innovation of technology (simulated lower than S1 scenario family) would not significantly improve the reduction of CO_2

emissions associated with the kiln-fuel and raw-material components. The reduction of specific CO_2 emissions from raw-material components and CO_2 emissions per tonne cement production can be improved by enhancing the blending percent share for cement production.

3.3. Discussion

Key applicable of company's dynamic model execution is highlighted in the point of system analysis. It allows the company to identify on the current occurrence theoretical and real world cement industry capability. It provides a company's level of sustainability performance and offers valuable clues for future trend strategy initiatives. Results obtained from the simulation show that the model developed is adequately validated and shown satisfactory with the real system's property. Results obtained from the integrated assessment represented an important of sustainability pathways. It provides company's decision-makers with scientific information about linkages between human-social and environmental systems. This assists the cement company to be more precise in their skills and competency concerning the ability to generate more effective strategy formulation in response as follows. The methods applied offers the company to re-examine the driving forces which may influence future environmental impacts and leverage points of CO_2 emission reduction, and performs in a new perspective for exploring long-term sustainable purposes and contexts, with appropriate mitigation and adaptation foresight sustainability managerial options for the company.

4. Conclusion and future work directions

This study proposes an innovative model to explore and formulate a corporation's sustainability strategy in the sense that it provides insights in a way co-evolution may take place between human-social system thinking and environmental systems. Grounded on the case study, the model and methods applied are designed to build a holistic view on sustainability performance and formulation of plausible sustainable futures upon which the cement industry can make choices to live.

In this paper, the ultimate aim is not to provide the corporation with a set of technical solutions, but rather the development a methodology that would enhance the ability of a corporation to stretch their mental maps – a paradigm-shift, in creating alternative categories of sustainability managerial options with a high degree of adaptability in differently elements, scales and actors in differently constructed and desired futures. The methods applied, with the different levels of detail and an appropriate simulation tool, provides a better chain of visionary thinking allows a corporation to explore and formulate sustainability pathways into a preferred future. Its flexible architecture permits the user expanding its boundaries to include other facets of social, economic and sustainable to be addressed.

Future research priority aiming to contribute to a better understanding of corporate sustainability strategy should include the following issues. Possible structurally different pattern of corporate modeling development should be combined with the dual-complex mathematical analysis, e.g. the corporation's objective function(s) for analyzing minimization and maximization criteria to meet the requirement of sustainability drivers posed by system components and variables. Together, the company's scenario development under the method applied depends on the purpose of the scenario undertaking, which is in turn determines the focus in terms of the key driving forces to be examined.

5. Acknowledgements

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6. Acknowledgment

The corporate dynamic account analysis (CDA) development (casual loop diagram: CLD, stocks and flow diagrams with its mathematical function) and the method of execution are generated by using the

software program, STELLA® and its user interface application. The system dynamics application and method applied here are widely acknowledged in the following resources [13], [14], [15], [16], [17], [18], and the methods for construing scenarios can be found in the literatures [19], [20],[21].

Throughout the study, primary data are obtained from the setting of company specific accounts for cement production process, parameters and proposed data sources for calculation of CO_2 emissions and its baseline, together with the development of company sustainable scenarios. Secondary data are drawn from the literatures review [5], [6], [7], [8], [9]; together with company's yearly report in research and development (R&D) and the future role of cement industry natural resources and technological and efficiency forecast [22], [23].

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