LIFE CYCLE MANAGEMENT AND ASSESSMENT OF HIGH-TECH CONSTRUCTION PROJECTS

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Abstract: The development and performance of construction industry are strongly relative with citizens' living quality in each country. Such is meaning that the life cycle management (LCM) and life cycle assessment (LCA) are important issues to each construction project. In this 21st century, information technology (IT) is an important issue for economic growth. The professional knowledge of IT and construction are key factors to develop high-tech industry. The constructional characteristics of high-tech projects are such as the location, size, main construction method, team organization, and the construction management techniques applied in planning, design, procurement, construction, and maintenance phases. This paper will introduce algorithms of LCA and LCM, investigates and illustrates several practice high-tech construction projects including retrieved from the expert interviews. Based on the collected sample information, a database retrieving system is developed for supporting management in understanding the performance of the historical projects with similar high-tech project characteristics.
Keywords: Life cycle management, life cycle assessment, information technology, high-tech.

1. PREFACE

Up to today, the growth of high-tech industrial facilities has been increasing due to recent booming in electrical and semi-conduct technology markets, the construction of these facilities is still experience-based and no enough knowledge to fit well statistically analyzed and well documented. Without professional knowledge sharing of IT and construction between high-tech project practitioners, construction management techniques may not be appropriately applied to future projects. In each country, construction projects use the professional technology in civil engineering and relevant facilities to change land renovate the environment and prevent calamity from occurring. It is one of the main factors to the nation to determine the nation's competitive advantages [1]. By following the feedback and analysis of the advanced countries, government should make discussions about how to apply public constructions in a suitable way for the operation, management, safeguard and mechanism upgrade to the construction industry.

Life cycle management (LCM) is the way to manage buildings and facilities with considering overall through the viewpoint of developers and users. During the initial planning stage, it is necessary to evaluate the impact to the third party and the surroundings. This kind of the consideration for environment is called life cycle assessment (LCA). "Life-cycle" is considering the whole period of buildings and facilities from the initial evaluation stage, project planning and design stage, construction and installation stage, operation and maintenance stage, the renewal and renovation stage, to the demolishing stage. Some people call the period is "From the cradle to the grave" [2]. LCM is the way to manage buildings and facilities with considering overall through the viewpoint of developers and users (figure1).

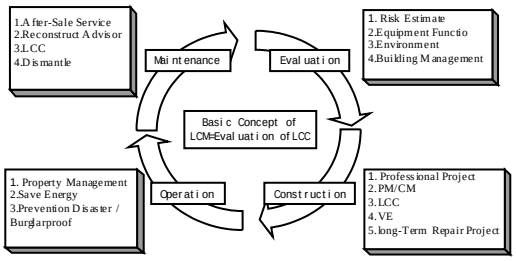


Figure 1. Basic concept of LCM

The development of high-tech projects already had been more than 20 years in Taiwan, but still lots of problems exist. For the best solution to solve those problems, life cycle management and engineering techniques could be one of the most useful tools. LCM is some kind the long-history system developed in Europe, and especially used in the industry. LCA is the method to evaluate and analyze material requirements and CO2 emission accompanied with the construction would be huge. Furthermore, high-tech buildings and facilities must be maintained and scraped when those terms of service are finished. Accordingly, it is important to quantify material requirements and CO2 emission accompanied with each step of life cycle systems of high-tech projects, and to work out countermeasures to

reduce consumed materials and CO2 emission [3]. The consumption of energy also should be considered and discussed during the operation and maintenance period of high-tech projects. Meanwhile, engineers also should think about the total cost through the whole life-cycle period of each project. The concept of life cycle cost (LCC) is calculating and analyzing the cost with overall consideration in each phase of the project, including the initial evaluation phase, the planning and design phase, the construction and installation phase, the operation and maintenance phase, the renewal and renovation phase, and the demolishing phase and etc. [4]. The database system should be built up and modified anytime based on the experienced data feed back through the long-term operation and maintenance of the high-tech buildings and facilities.

The objective of this study is to investigate the characteristics of high-tech construction projects and consider how to use the techniques and tools of life cycle engineering in the planning stage according to those characteristics. The results should help construction engineers and users to have a better sense of the characteristics of high-tech construction projects and support their decision-making in facing new projects.

2. DEVELOPMENTS OF LCM AND LCA

Life cycle management is an overall considering of the idea of management, from the proper diagnosis and appraisal to the land; the right development and construction to the building; efficient operation and management of the equipment and the rational way to keep and save the budget. If engineers apply the idea to the upgrading plan of relative industry in construction project, it will improve the competitiveness and the life of vision for the construction industry [5]. This will also guarantee the value of the structure and to suit the demand of safe and comfortable. The algorithm of LCM was first announced in Europe and had been used for more than twenty years [6]. It is an old but novel philosophy and using method in the history of management. In this issue, LCA is making assessment and calculation for the structure itself and the outer environment in the life cycle of a construction project. It combines the designing method and idea in securing environment and to proceed with the best project planning. Therefore, it will not only reach the full project management of the quality, progress, cost security and environmental protection, but also the idea of long-term management for the government or non-government investment enterprise.

LCA began from the late 1960s' and the early 1970s'. In Taiwan, until 1990, it was become popularizing and making research development to understand its algorithms [7]. According to the relative research show that the first popularizing and training study, "The Conference of Life Cycle Analysis" was held by Industrial Technology Research Institute on November 11th, 1995. Also sponsored by Environmental Protection Administration on November 11th 1995, the 1995 International Conference on Industrial Waste Minimization was held and it was the first time to invite international experts to give speech on the conference in Taiwan.

3. LIFE CYCLE ASSESSMENT AND EVALIONATION STRATEGY

The idea and application of the LCA mainly emphasize on power analyzing, resource demand and estimating the disposal of pollutants, etc.. In 1969, Coca Cola Co. asked Midwest Research Institute (MRI) to do a research on comparing resources consume and environmental disposal of pollutants with different containers. Almost at the same time, similar analysis equipment called Ecobalance is developed [2]. In 1979, an English scholar, Ian Boustead, developed a way to show the condition of energy resource used in the procedure of make different materials. The LCA was applied to reduce of industry waste and the tactic assessment of environmental management in 1990. In 1993, International organization for Striations (ISO) formed a technique committee TC207. It is specialized and responsible for 14040, it is a relative standard of life cycle assessment [6].

The result of assessment for the company can be the decision basis of product development. This will suit the customers of their need with environmental products. The main research purpose of the government is a new product using rule, gathering environmental information and even to make it an important reference when making construction and environmental decisions. In ISO 14040 the LCA is divided into: goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA), and life cycle interpretation [4]. The goal and scope definition is to clearly define the goal and scope of the assessment work. Life cycle inventory analysis includes gathering information, calculation procedure and making quantification of the overall procedure to become the analyze target of every income. Life cycle impact assessment uses the result of inventory analysis to estimate how the life cycle makes environmental impact to human. Life cycle interpretation is the basis of improving the production or proceeding to apply directly.

4. DEVELOPMENT AND CHARACTERISTICS OF HIGH-TECH INDUSTRIES

In general, most high-tech. companies are located at industrial parks for their appropriate development due to their manufacturing process or quality is more important than other products. The development of industrial parks in Taiwan has expanded from the simple provision of factory land initially to coordination with the national policy of balanced regional development and upgrading of the overall production environment, being adjusted in line with the stages of economic development policy. With a general high-tech plant, it contains several characteristics [1]:

(1) Large research and development (R & D) budget.

(2) Huge equipment and investment cost.

(3) High technology and quality products.
(4) Integration and cooperation.
(5) Continuously innovation and competition.

Up to today, the development of high-tech industry in Taiwan has expanded from the simple provision of factory land initially to coordination with the national policy of balanced regional development and upgrading of the overall production environment. As shown in table 1, the total area of high-tech industry is about 11,900 hectares [8].

Table 1. Regional distribution of high-tech industries (Area unit: hectare)

Area/Administering agency	Government agencies	Public and private enterprises	Total
All Taiwan	9,670	2,225	11,895
Northern area	2,823	755	3,578
Central area	2,428	593	3,021
Southern area	4,231	843	5,074
Eastern area	188	34	222

5. IMPLEMENTS OF LCM AND LCA INTO HIGH-TECH CONSTRUCTION PROJECTS

In Taiwan, for the shortage of land, the plants of high-tech were almost designed to put two or three FAB in one building. New plants also will be designed being located next to further plants still manufacturing, and the distance between each building is always very close, such situation will cause serious difficulties of design and construction activities. In the following, this paper will introduce several improvement applications of computing or high technology into high-tech construction project during its life cycle.

5.1 Designing Phase

For the designing improvement, there are several examples applied with practice high-tech construction projects in Taiwan.

1) The steel gird and steel beam composed structure for high-raised free access floor is the system which could match with catenary-arch structure and make the layout more flexible and valuable (figure 2). The special steel panel system could be designed and picked up to meet the specification and requirement of equipments, also matching with steel gird system (figure 3).

Figure 2. Steel gird composed structure floor

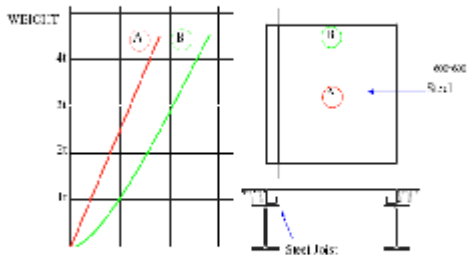


Figure 3. Section for steel panel and steel gird system

The high-raised free access floor with special steel panel system is especially designed for heavy and sensitive machines and equipments. The red area shows the location of those equipments, such as scanner, stepper, and etc. (figure 4). At the clean room, besides the area equipments occupied, the others are for air-through and air circulation. During the period of construction or after the free access floor completed, the change for the location of the equipments is still acceptable. While structure designing stage, the loading factor for designer to input and analyze could be picked up according to different areas and conditions.

Figure 4. High-raised free access floor with composed steel panel system

In general, the life cycle time of high-tech production is very short; the layout might change anytime by following with the change of IC-design to catch for market in time. Even though the project already starts to construct, owner or user still could not make sure the exact position for heavy and sensitive machines and equipments to install. For this system, user could change or relocate the position for equipments by changing the panels to new place and installing again as new layout, but still following the specification and requirements of equipments (figure 5 and figure 6).

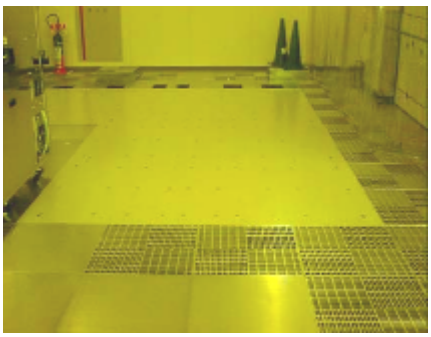


Figure 5. Foundation plate for installation of machine and equipments

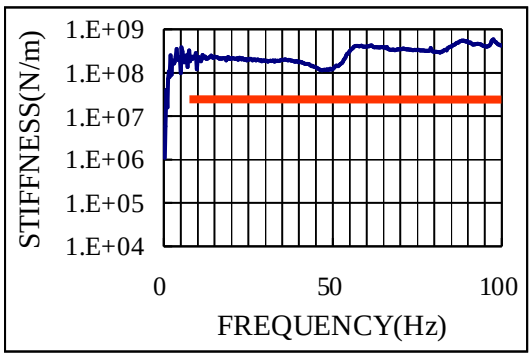
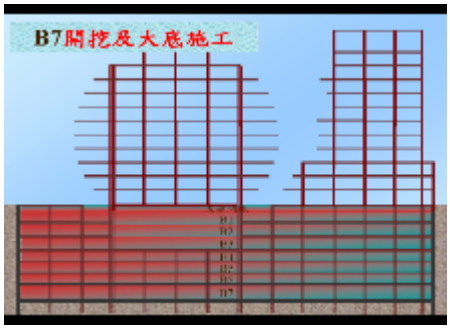


Figure 6. Test for stiffness

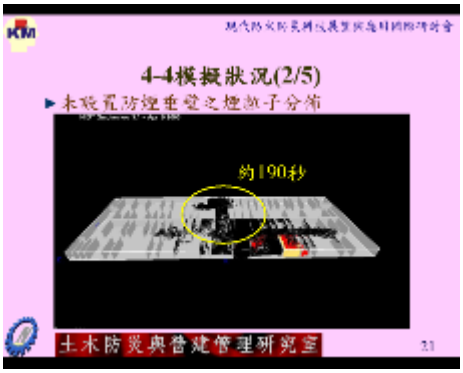
2) As shown in table 2, because several fire and natural disasters had happened during past 15 years, the scenario simulation and risk analysis with computer software are used with each high-tech construction project (figure 7). Meanwhile, the performance specification of fire prevention is discussing in Taiwan.

Table 2. Fire loss examples of high-tech industries in Asia

Time	Place	Loss (million US dollars)
1991	Taiwan	10
Dec. 1995	Singapore	10
Oct. 1996	Taiwan	250
Apr. 1997	Taiwan	4
Oct. 1997	Taiwan	325
Nov. 1997	Taiwan	50-60
Oct. 1997	Singapore	2
Nov. 1998	Singapore	Unknown

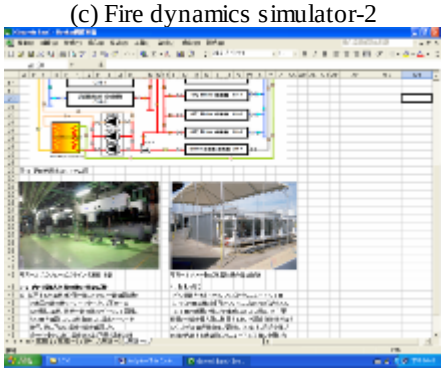


(a) Construction simulation

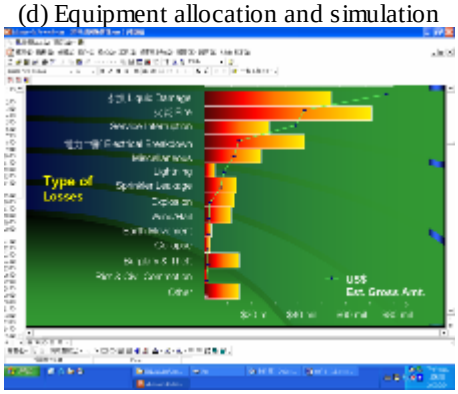


(b) Fire dynamics simulator-1

(c) Fire dynamics simulator-2



(d) Equipment allocation and simulation



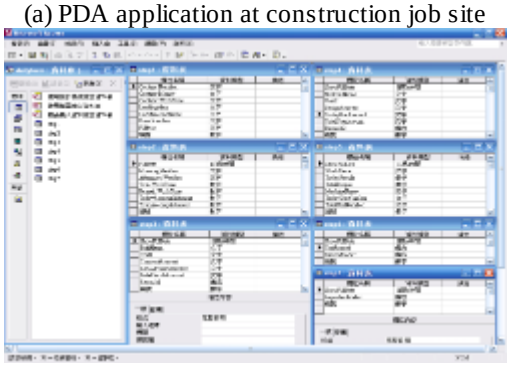
(e) Fire risk analysis

Figure 7. Computing analysis

5.2 Construction Phase

As shown in figure 8 and figure 9, there are PDA and wireless transmission applications at specific construction job site, those studies are still continuing in Taiwan.

(a) PDA application at construction job site



(b) Inspection daily report transmitted from PDA

Figure 8. PDA applications

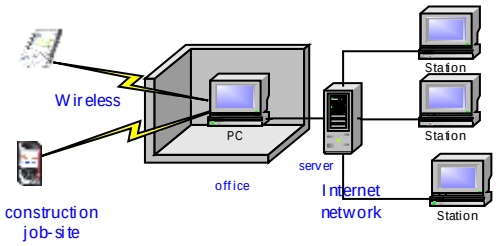


Figure 9. Wireless transmission at construction job site

6. ESTIMATION OF LCA

Construction consumes and discards resources and energy in enormous quantities. There are several methods for evaluating the environmental performance of construction builds, such as:

(1) Building research establishment environmental assessment method (BREEAM): It was developed in 1990 by Building Research Establishment in the UK.

(2) Leadership in energy and environment design (GB tool): It was developed in 1997 by Us Green Building Council.

(3) Green building tool (GB tool): It was announced at "Green Building Challenge" by Natural Resources Canada in 1998.

In August 2004, two authors of this paper were visited in Japan. Therefore, this paper will introduce the comprehensive assessment system for building environmental efficiency manual (CASBEE Manual) in Japan. CASBEE has been developed as an assessment system; it is intended to serve applications such as those listed below (JSBC, 2003):

(1) For designers to employ DfE (Design for Environment) in building design.

(2) Environment labeling that can be used in the asset valuating of building.

(3) Environment performance diagnosis, upgrade design with a view to ESCO (Energy Service Company) project and renovation for existing buildings.

(4) Building administration.

CASBEE is a suite of four basic assessment tools that deal with building life cycles. The four tools have the following roles, and the framework of CASBEE is shown in figure 10 [9]. Its result can show analysis information about "Building outline", "CASBEE assessment results", and "Optional assessment items" (figure 11).

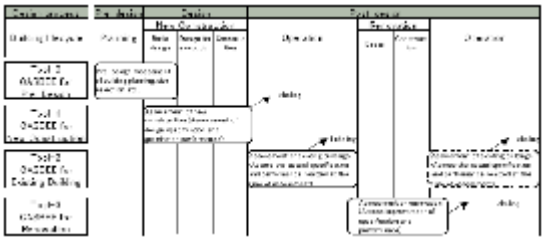


Figure 10. CASBEE and building life cycle

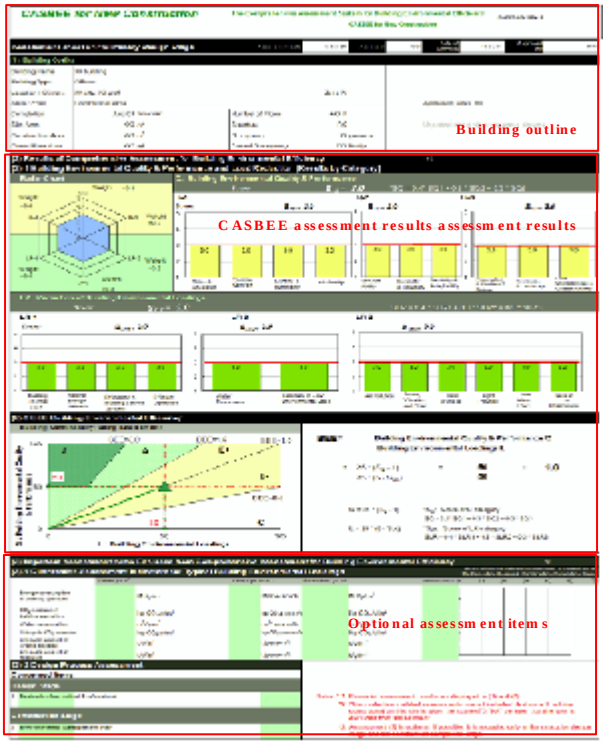


Figure 11. Assessment results sheet of an example

7. ILLUMILLATION DATABASE OF HIGH-TECH CONSTRUCTIONS

For some cases, the plant of high-tech is designed to put two or three FAB in one building. New plants also will be designed being located next to further plants still manufacturing, and the distance between each building is always very close. The total schedule of each project is tight, about 12 months, including the installation of machines and equipments for process. The period of structure construction is done within 6 months, and sometimes for

marketing consideration, the clients will request to reduce to 4 months. As a new 12" wafer manufacture factory project, the total amount of investment is about 90 billions NT dollars. The total floor area should be over 250,000 m2, and the weight of steel used in structure is more than 25,000 ton. That is the reason why engineers study how to combine the concept of LCM and use the tools of life cycle engineering to solve those problems as mentioned.

Although in high-tech industry, the detail information of spending cost and environmental pollution are sensitivity issues. This research still tries to collect several real cases and derive the following data by using Excel and Assess as analysis software.

(1) Net construction unit cost of FAB factory is around 17,420 N.T. dollar/m2 (about 527.88 US dollar/m2)

(2) Construction cost of clean room (grade < 100) is between 18,200 to 30,300 N.T. dollar/m2 (about 551.52 to 918.18 US dollar/m2)

(3) The increase percentage by comparing construction cost of high-tech project to general building project:

1) Temporary cost is increased about 5 to 10 %.
2) Safety and environment protection cost is increased about 10 to 15%.
3) Steel structure cost is increased about 2.7 to 3 %.
4) Fire proofing cost is increased about 10 to 15%.
5) Rebar work activity cost is increased about 3 to 5%.
6) Form work activity cost is increased about 5 to 8%.
7) Concrete work activity cost is increased about 2%.
8) Water proofing cost is increased about 6 to 10%.
9) Utility cost is increased about 2%.
10) Total management cost is increased about 3 to 5%.

8. CONCLUSIONS

There are many life cycle engineers, techniques, tools, and materials still researching and developing. For example, good performance-design method in fire protecting plan could create more merits and value than traditional design only by following the governmental regulation. LCM is the way to manage buildings and facilities with considering overall through the viewpoint of developers and users. It is very important to collect the information and build up the database system for LCA from the results of long-term operation and maintenance of exit buildings and facilities. Based on that, designers could do proper designs and plans following the data for decision making of high-tech developers to choose the best option. From the theoretical implementation thinking, the quantity and manufacturing situation of cooling water, solid waste, polluting gas, air condition, and chemistry waste within every high-tech project are possible issues to illustrate the idea of LCA. Also can involve the concept of formula (1), such study will be a valuable research in high-tech industry. Based on that, designers could do proper designs and plans following the data for decision making of high-tech developers to choose the best option.

$$\text{LC Design} = (\text{Function \& Safety}) + \frac{LCC}{LCA}\ (LCCO_2, LCW) \quad (1)$$

LC Design=Life Cycle Design Method
LCA=Life Cycle Assessment
LCCO2=Life Cycle CO2. The assessment index includes CO2, NOx, and SOx.
LCW=Life Cycle Waste. The assessment index includes waste amount.

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