Chapter III
Project Environmental Performance Assessment

Li-yin Shen, Xiong Ou, J Jian-li Hao and Yu-zhe Wu

1 Introduction

The project environmental performance (PEP) prototype model has been described in Chapter 2. It is a system dynamics model, in which various parameters will be provided with specific values. As assumed, the weighting factors WEI, WER and WCS in the model are constants, and the values of these parameters need to be specified in particular applications. As different decision makers are in different environments where various types of projects have different characteristics, different decision makers may allocate weighting values to WEI, WER and WCS differently. For example, when a decision maker is in a situation where the environmental impact is considered more important, and the weight of environmental impact, WEI, will be more than 1/3. In another application, all the three weighting factors may be considered equally important and be given with the same value (namely, 1/3). On the other hand, the parameters IEI, IER, ICS in the PEP model are defined as the functions with time, indicating that the implementation of a construction project will have different environmental impacts, different utilization of environmental resources and different contribution to the mission of sustainable development at different stages across the project life cycle. The values of IEI, IER, ICS are affected by a wide range of factors. Furthermore, the application of PEP prototype requests for the establishment of the relationships between the system elements in the prototype in a specific application, including stock, flows, converters and connectors. These relationships can be adjusted in different applications.

It is considered that simulation is an effective approach to conduct analysis on a system dynamics model such as the PEP prototype model. For this purpose, there are existing computing softwares, such as DYNAMO, ‘ithink’, and Matlab. The software ithink is a well developed simulation tool by High Performance Systems, Inc. (HPS, 1997). This software was selected for supporting the analysis in this example discussion. The procedures for applying the software 'ithink' to the model PEP are presented in Fig.3-1.

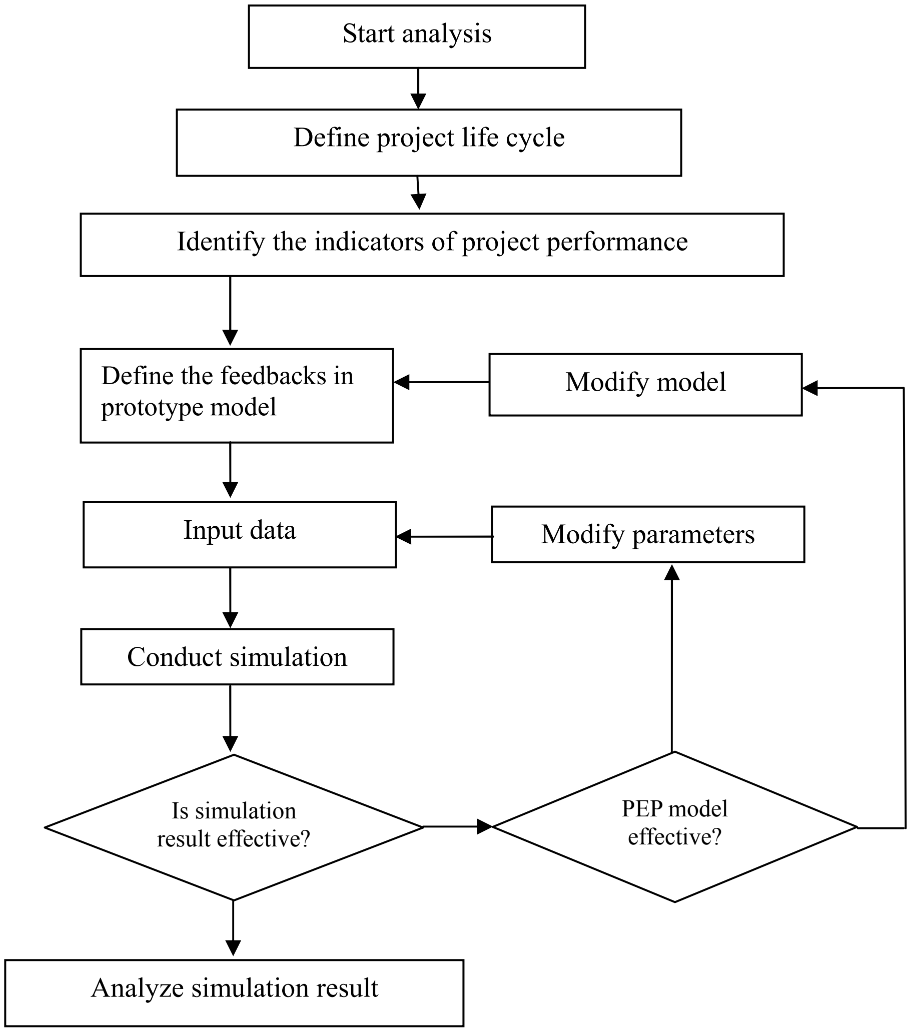
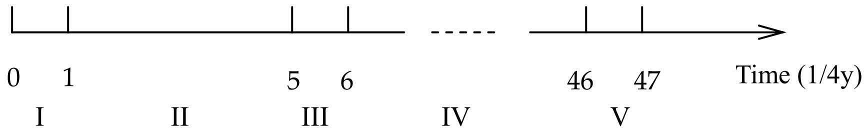


Fig. 3-1 Procedures of simulating PEP prototype model using system dynamic

In PEP prototype model, project environmental performance is measured by three indicators, namely, environmental impact (EI), utilization of environmental resources (ER), and contribution to sustainability (CS) (Shen et al., 2005b). The performance of these attributes is affected by various factors at different stages across its life cycle which is divided into five stages: inception stage; construction stage; commission stage; operation stage; and demolition stage.

A real-life case is simplified to demonstrate the application of the simulation procedures described in Fig.3-1. The project was a manufacture innovation project. The data used for application in this study are from the project feasibility study, which includes economic, social, environmental, and technical assessments. According to the feasibility study, the project life cycle includes (I) inception stage (1/4 year); (II) construction stage (1 year); (III) commission stage (1/4 year); (IV) operation stage (10 years); and (V) demolition stage (1/4 year). The definition of the project life cycle is graphically shown in Fig.3-2.



I: inception stage; II: construction stage; III: commission stage

IV: operation stage; V: demolition stage

Fig. 3-1 Procedures of simulating PEP prototype model using system dynamics

2 Defining the feedbacks in the prototype model

In the PEP prototype model shown in Figure 2-3, the feedbacks indicate that the stock of PEP and project performance flows will interact. For example, if PEP stock value is reduced and becomes lower than specification, actions or measures will be taken to reduce out-flows (negative impacts) or to increase the in-flows (positive impacts). If PEP is very high, increase of certain level of negative impacts (out-flows) may be allowed, and management efforts can be allowed to look after social and economic aspects. Therefore, it is important to define a benchmark of the stock value.

For the sample case, when PEP is less than its lower limit, denoted by L4PEP (with "L4" denotes "lower limit for"), an adjustment LA (“lower limit adjustment”) will be applied to reduce the negative impacts (out-flows) and increase the positive impacts (in-flows). On the other hand, when PEP is more than its upper limitation, denoted by U4PEP (with "U4" denotes "upper limitation for"), an adjustment UA ("upper limit adjustment") will be applied to allow for certain negative impacts (out-flows) and reduce the positive impacts (in-flows). For the purpose of demonstration, assume that L4PEP=-50 and LA=15% are applied. When PEP<-50, the converters will decrease 15% from those negative impacts and increase 15% from those positive flows. These adjustment values will be applied to all five stages across project life cycle. The processes of adjusting PEP value in the prototype are graphically presented in Fig.3-3. There are other codes used in the figure. For examples, I4EI, II4EI, III4 EI, IV4 EI and V4 EI denote respectively the environmental impact for stage 1, 2, 3, 4, and 5. I4ER, II4 ER, III4 ER, IV4 ER and V4 ER denote respectively the utilization of environmental resources for stage 1, 2, 3, 4, and 5. I4CS, II4 CS, III4 CS, IV4 CS and V4 CS denote respectively the contribution to sustainability for stage 1, 2, 3, 4, and 5; I4EI0, II4EI0, III4EI0, IV4EI0, and V4EI0 denote respectively the initial values of I4EI, II4EI, III4EI, IV4EI and V4EI; I4ER0, II4ER0, III4ER0, IV4ER0, and V4ER0 are for the initial values of I4ER, II4ER, III4ER, IV4ER and V4ER; I4CS0, II4CS0, III4CS0, IV4CS0, and V4CS0 are for the initial values of I4CS, II4CS, III4CS, IV4CS and V4CS. For processing the simulation analysis on the model, all the initial values need to be provided.

Concerning weighting parameters (WEI, WER, WCS), four scenarios are considered: (1) WEI=WER=WCS=1/3, indicating that environmental impacts, utilization of environmental resources and contribution to sustainability are considered as equally important; (2) WCS= 1/2, WEI= WER =1/4, considering that contribution to sustainability is more important than environmental impacts and utilization of environmental resources; (3) WER= 1/2, WEI= WCS=1/4, considering that utilization of environmental resources is more important than environmental impacts and contribution to sustainability; and (4) WEI=1/2, WER= WCS=1/4, considering that the environmental impact is more important than utilization of environmental resources and contribution to sustainability. For the control limit, the lower limit L4PEP=-50 and the upper limit U4PEP=100 are adopted. The adjustment values LA=15% and UA=10% are used. To simplify the demonstration, it is assumed that L4PEP, U4PEP, LA and UA are constants across project life cycle. The values of these parameters are summarized in Table 3-1.

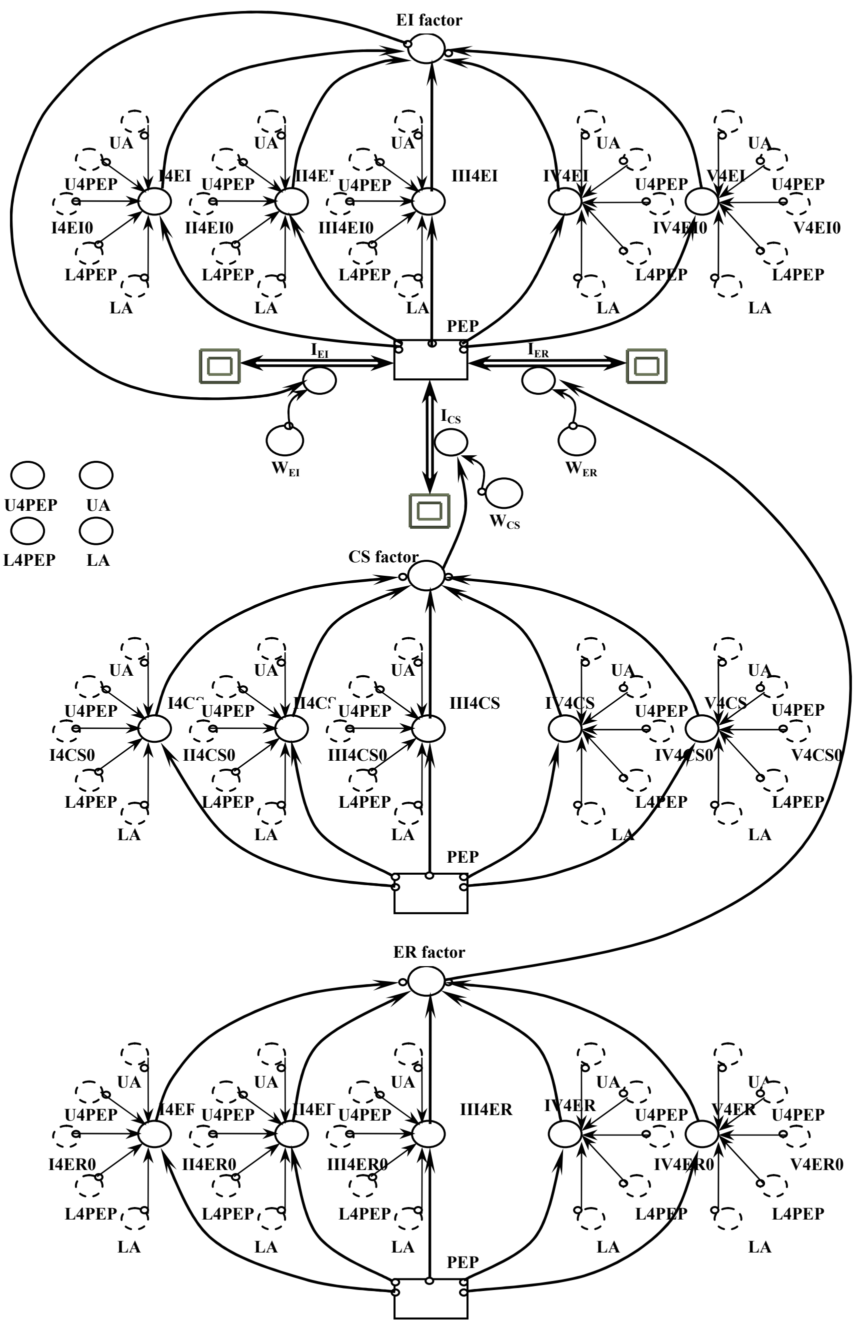


Fig.3-3 Modeling PEP for the sample project (Shen et al, 2005)

Table 3-1 Specifications on the parameters in the PEP prototype for the sample project

Scenarios	Parameters
(1) $W_{EI} = W_{ER} = W_{CS} = 1/3$	LA=15%
(2) $W_{CS} = 1/2$, $W_{EI} = W_{ER} = 1/4$	L4PEP=-50
(3) $W_{ER} = 1/2$, $W_{EI} = W_{CS} = 1/4$	UA=10%
(4) $W_{EI} = 1/2$, $W_{ER} = W_{CS} = 1/4$	U4PEP=+100

Notes: LA: Lower limitation adjustment; L4PEP: Lower limitation for PEP; UA: Upper limitation adjustment; U4PEP: Upper limitation for PEP

3 Simulation Analysis

The data defined in the above discussion enable us to conduct the simulation based on the model equation (5) by applying the function described in Table 3-2.

$$I_{CS}(t) = \begin{cases} -10 & t \in (0,1] \\ -100 & t \in (1,5] \\ 0 & t \in (5,6] \\ 60 & t \in (6,46] \\ 10 & t \in (46,47] \end{cases}$$

$$I_{ER}(t) = \begin{cases} -60 & t \in (0,1] \\ 50 & t \in (1,5] \\ -20 & t \in (5,6] \\ 30 & t \in (6,46] \\ -50 & t \in (46,47] \end{cases}$$

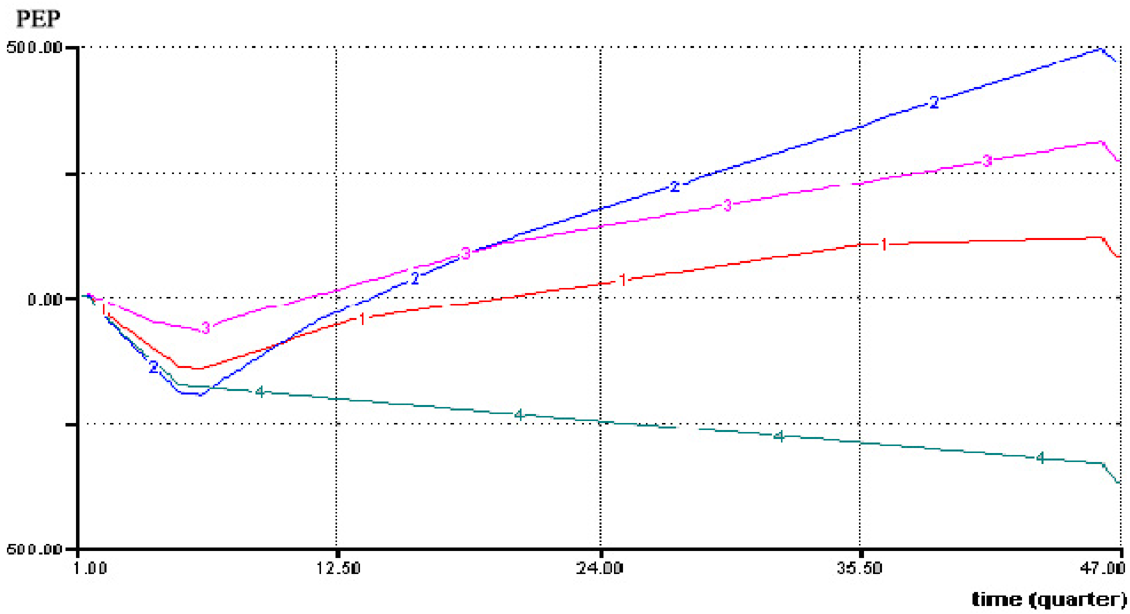
$$I_{EI}(t)=\begin{cases}-50 & t\in(0,1]\\ -80 & t\in(1,5]\\ 0 & t\in(5,6]\\ -70 & t\in(6,46]\\ -100 & t\in(46,47]\end{cases}$$

By applying the software 'ithink', simulation results can be generated, as shown in Table 3-2, and presented graphically in Fig.3-4.

Table 3-2 Simulation results on PEP prototype for the sample project (Shen et al 2005)

Time (1/4y)	Scenario (1)	Scenario (2)	Scenario (3)	Scenario (4)
1	0	0	0	0
2	-32.5	-43.75	-11.25	-42.5
3	-70.08	-91.97	-31.25	-86.28
4	-101.92	-137.09	-51.25	-127.16
5	-133.75	-182.22	-60.75	-168.03
6	-145.96	-196.69	-69.5	-181.44
7	-136.37	-176.56	-56.91	-185.41
8	-121.71	-148.31	-40.84	-189.28
9	-107.04	-120.06	-28.34	-193.16
10	-92.37	-91.81	-15.84	-197.03
11	-77.71	-63.56	-3.34	-200.91
12	-63.04	-39.44	9.16	-204.78
13	-48.37	-19.44	21.66	-208.66
14	-41.71	0.56	34.16	-212.53
15	-35.04	20.56	46.66	-216.41
16	-28.37	40.56	59.16	-220.28
17	-21.71	60.56	71.66	-224.16
18	-15.04	80.56	84.16	-228.03
19	-8.37	100.56	96.66	-231.91
20	-1.71	115.06	106.78	-235.78
21	4.96	129.56	114.53	-239.66
22	11.63	144.06	122.28	-243.53
23	18.29	158.56	130.03	-247.41
24	24.96	173.06	137.78	-251.28
25	31.63	187.56	145.53	-255.16
26	38.29	202.06	153.28	-259.03
27	44.96	216.56	161.03	-262.91
28	51.63	231.06	168.78	-266.78
29	58.29	245.56	176.53	-270.66
30	64.96	260.06	184.28	-274.53
31	71.63	274.56	192.03	-278.41
32	78.29	289.06	199.78	-282.28
33	84.96	303.56	207.53	-286.16
34	91.63	318.06	215.28	-290.03
35	98.29	332.56	223.03	-293.91
36	102.29	347.06	230.78	-297.78
37	103.63	361.56	238.53	-301.66
38	104.96	376.06	246.28	-305.53
39	106.29	390.56	254.03	-309.41
40	107.63	405.06	261.78	-313.28
41	108.96	419.56	269.53	-317.16

42	110.29	434.06	277.28	-321.03
43	111.63	448.56	285.03	-324.91
44	112.96	463.06	292.78	-328.78
45	114.29	477.56	300.53	-332.66
46	115.63	492.06	308.28	-336.53
47	78.29	468.13	270.66	-375.19



(1) Scenario one: $W_{EI}=W_{ER}=W_{CS}=1/3$; (2) Scenario two: $W_{CS}=1/2$, $W_{ER}=W_{EI}=1/4$; (3) Scenario three: $W_{ER}=1/2$, $W_{EI}=W_{CS}=1/4$; (4) Scenario four: $W_{EI}=1/2$, $W_{ER}=W_{CS}=1/4$

Fig.3-4 Simulation results on PEP prototype for the sample project (Shen et al 2005)

Scenario one: $W_{EI}=W_{ER}=W_{CS}=1/3$

The Curve 1 in Fig.3-4 represents the simulation results of the value PEP for the project FD NaCN Innovation Project when the scenario WEI = WER = WCS = 1/3 is considered. It can be seen that the Curve 1 is flat, indicating that the environmental performance of the project is relatively consistent along the project life cycle. This implies that the project is acceptable from the viewpoint of environmental performance across project life cycle when the decision-maker gives equal weights to environmental impacts, utilization of environmental resources and contribution to sustainability of the project.

Scenario two: $W_{CS}=1/2$, $W_{EI}=W_{ER}=1/4$

The Curve 2 in Fig.3-4 gives the simulation results when it is assumed that

WCS =1/2, and WEI = WER = 1/4. It can be seen that the value PEP increases when the project proceeds. It indicates that the environmental performance of this project is very good when the contribution to sustainability is given higher weight than those given to environmental impacts and utilization of environmental resources. This project can be considered feasible and good in environmental performance.

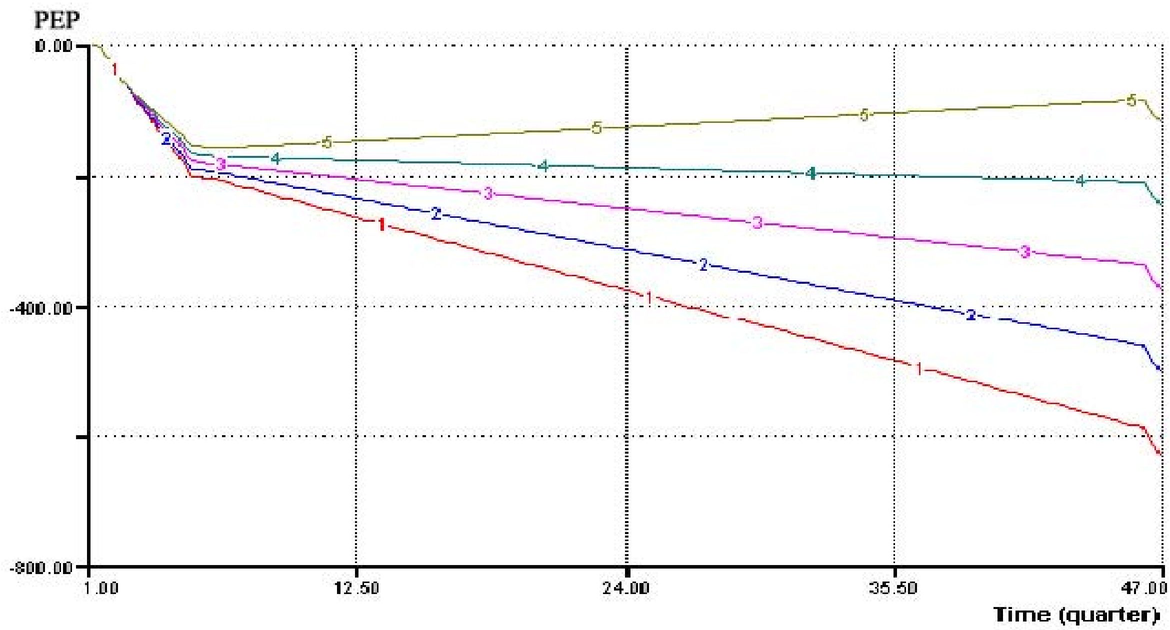
Scenario three: W_{ER} = 1/2, W_{EI} = W_{CS} = 1/4

When the scenario of WER = 1/2, and WEI = WCS = 1/4 is considered, the simulation results are generated and represented by the Curve 3 in Fig.3-4. It can be seen that the value of PEP increases when the project proceeds, but slope of the increase is lower compared to the results in scenario two. The result indicates that the environmental performance of this project is good and acceptable when the utilization of environmental resources of the project is given higher weight than that given to environmental impacts and contribution to sustainability.

Scenario four: W_{EI} = 1/2, W_{ER} = W_{CS} = 1/4

The Curve 4 in Fig.3-4 represents the PEP simulation results when it is considered that WEI= 1/2, and WER= WCS = 1/4. It can be seen that the PEP decreases when the project proceeds. According to Tab.3-2, the value of PEP by the end of the project life is -375.19. It indicates that the environmental performance of this project is very poor when the environmental impacts of the project are given higher weight. This project may not be acceptable in an environment where environmental protection is emphasized or have higher priority.

Furthermore, the parameters in the prototype model, including WEI, WER, WCS, L4PEP, LA, U4PEP and UA, can be provided with different values based on the project conditions, project nature and client requirement. Sensitivity analysis can be conducted by applying different values of these parameters. Assume that the parameters L4PEP, U4PEP and UA remain their values (namely, L4PEP=-50, U4PEP=+100 and UA=10%), the weighting parameters are WCS =WER = 1/4 and WEI= 1/2. Sensitivity analysis can be conducted by change the value of the parameter LA to 5%, 10%, 15%, 20%, and 25%. The simulation results of the sensitivity analysis generated accordingly are shown in Fig.3-5. It can be seen that the value PEP of the project will be improved when LA increases. In fact, the value PEP becomes positive and the project becomes feasible when LA assumes the value of 25%.



Curve 1 for LA = 5%; 2 for LA = 10%; 3 for LA = 15%; 4 for LA = 20%; 5 for LA = 25%

Fig.3-5 Results of sensitivity analysis on parameter LA for the sample project

References

Adeli H., Karim A., 1997, *Scheduling-cost optimization and neural dynamics model for construction*, Journal Of Construction Engineering And Management, 123(4), 450-458.

APCO (Air Pollution Control Ordinance Chapter 311), 1997, *Air Pollution Control Ordinance*, http://www.justice.gov.hk/blis_export.nsf/home.htm.

BD, LD & PD., (Buildings Department, Lands Department & Planning Department), 2001, *Joint Practice Note No.1 (JPN 1) Green and Innovative Building*, 1-5 & Appendix A, 1-5.

Camp, Robert C., 1989, *Benchmarking: the search for industry best practices that lead to superior performance*, Quality Press.

Camp, Robert C., 1995, *Business Process Benchmarking: finding and implementing best practices*, Quality Press.

Center of Environmental Technology (CET), 1999, *The Hong Kong Building Environmental Assessment Method*, Center of Environmental Technology Limited.

Chen, Zhen, Li, Heng, 2002, *Environmental management of urban Construction project in China*, Journal of Construction Engineering and Management, Vol. 126, No.4, July/August, 2000, 320.

CIB, 1998, *Sustainable Development and the Future of Construction – A Comparison of Visions from Various Countries*, pp13.

CIRIA (Construction Industry Research and Information Association), 1999, *Environmental Issues in Construction – Sustainability Indicators for the Civil Engineering Industry*, Construction Industry Research and Information Association, London.

Connolly, E., 2001, *Smoky Skies Will Cause Deaths*, Environmental Experts Warn, The Sydney Morning Herald, 28th December, 4.

DGO(B) (Dangerous Goods Ordinance Chapter 295 Sub-legislation B), 2000, *Dangerous Goods (General) Regulations*, Hong Kong, http://www.justice.gov.hk/blis_export.nsf/home.htm.

Dolol H.K., Jaafarl A., 2002, *Toward a dynamic simulation model for strategic decision-making in life-cycle project management*, Project Management Journal, 33(4), 23-38.

D. Wathey, M. O'Reilly, 2000, *ISO 14031: A practical to developing environment performance indicators for your business*, The Stationary Office Limited.

EI-Rayes K., Moselhi O., 1999, *Optimizing resource utilization for repetitive construction projects*, Journal of Construction Engineering and Management, ASCE, 127(1), 18-27.

Environmental Building News, 1994, *Tropical timber. Seeing the forest for the trees*, 3(5), Brattleboro, VT.

EPD (Environmental Protection Department), 1999, *Environment Hong Kong Annual Report 1999*, Hong Kong Government, 8-15.

ETWB (Environmental, Transportation and Works Bureau), 2000, *Works Bureau Construction Site Safety Manual*, Hong Kong, http://www.etwb.gov.hk.

ETWB (Environmental, Transportation and Works Bureau), 1999, *General Conditions of Contract for Civil Engineering Works*, Hong Kong, http://www.etwb.gov.hk.

Ford D.N., 1995, *The dynamic project management: an investigation of the impacts of project process and coordination on performance*, PhD Thesis, MIT, USA, 22-33, 255-257.

GBC, 2000, website: http://www.greenbuilding.ca.

Gonzalez, J., 2002, *Study Found Awful Air Downtown*, New York Daily News, 14th February, 37.

Hendrickson, C. and Horvath, A., 2000, *Resource use and environmental emissions of U.S. construction sectors*, Journal of Construction Engineering and Management, 126(1), 38-43.

Hill R.C., Bowen P.A., 1997, *Sustainable construction: principles and a framework for attainment*, Journal of Construction Management and Economics, 1997(15), 223-239.

HKG (Hong Kong Government), 1992, *General Specification for Civil Engineering Works Volume1, 2, 3*, Hong Kong Government.

HK-BEAM (New Offices), 1999, *The Hong Kong Building Environmental Assessment Method for existing office buildings*, Center of Environmental Technology Limited.
Hong Kong Productivity Council (HKPC), 2001, *A Guide to Green Construction Practices*, Hong Kong Productivity Council.
The Hong Kong Performance Assessment Scoring System Working Group (HKPASSWG) , 1997, *Pass Manual (April 1997 Revision)*, The Hong Kong Housing Authority and Housing Department.
HPS (High Performance Systems, Inc), 1997, *ithink technical documentation*, Published by High Performance Systems, Inc.
Kibert, C.J., 1994a, *Preface*, In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6-9 November.
Kibert, C.J., 1994b, *Final Session of First International Conference of CIB TG 16 on Sustainable Construction*, Tampa, Florida, 6-9 November.
Kibert, C.J., 1994c, *Establishing Principles and a Model for Sustainable Construction*, In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6-9 November, pp. 3-12.
Loftness, V., Hartkopf, V., Mahdavi, A. and Shankavaram, J., 1994, *Guidelines for Masterplanning Sustainable Building Communities*, In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6-9 November, pp. 817-26.
Love P.E.D., Holt G.D., Shen L.Y., Li H., Irani Z., 2002, *Using systems dynamics to better understand change and rework in construction project management systems*, International Journal of Project Management, 20(2002), 425-436.
March, M. C., 1992, *Construction and environment – a management matrix*, Chartered Builder, June Issue.
McDonald, B., 1996, *RECON waste minimization and environmental program*, Proceedings of CIB Commission Meetings and Presentations, RMIT, Melbourne, February, 14-16.
Mohapatra P.K.J., 1994, *Introduction to system dynamics modeling*, Sangam Books, London, 25-43.
NCO (Noise Control Ordinance Chapter 400), 1997, *Noise Control Ordinance*, Hong Kong, http://www.justice.gov.hk/blis_export.nsf/home.htm.
NCO (C) (Noise Control Ordinance Chapter 400, Sub-legislation C), 2000, *Noise Control (Air Compressors) Regulations*, Hong Kong, http://www.justice.gov.hk/blis_export.nsf/home.htm.
NCO (D) (Noise Control Ordinance Chapter 400, Sub-legislation D), 2000, *Noise Control (Hand Held Percussive Breakers) Regulations*, Hong Kong, http://www.justice.gov.hk/blis_export.nsf/home.htm.
Pasquire, C., 1999, *The implication of environmental issues on UK construction management*, Engineering, Construction and Architectural Management, 6(3), 276-286.
Pena-More F., Li M., 1999, *Dynamic planning and control methodology for design/build fast-track construction projects*, Journal of Construction Engineering and Management, ASCE, 127(1), 1-17.
Poon, C. S., *2000, Management and Recycling of Demolition Waste in Hong Kong*, Proceedings, 2nd International Conference on Solid Waste Management, Taipei, Taiwan, 2000, 433-442.
RobŠrt, K.H., 1995, *The Natural Step. Sustainability - definition, education and practice. In Proceedings of the Global Leadership Conference*, Management Education and Training for Sustainable Development, Costa Rica, 11-16 September, Management Institute for Environment and Business, Washington DC.
Roodman, D.M. and Lenssen, N., 1994, *Our buildings, ourselves*, World Watch, 7(6), 21-9.
SEPB (China State Environment Protection Bureau), 1998, *China Environment State Report in 1997*, Environmental Protection, Beijing, 249, 3-8.
Shen, L. Y., Bao, Q. and Yip, S. L., 2000, *Implementing innovative functions in construction project*

management towards the mission of sustainable environment, Proceedings of the Millennium Conference on Construction Project Management, Hong Kong Institution of Engineers, 24 October, 77-84.

Shen, L.Y. & Tam, W. Y., 2002a, *Implementation of environmental management in the Hong Kong construction industry*, International Journal of Project Management, 20(7), 535-543.

Shen L.Y., Wu M., Wang J.Y., 2002b, *A model for assessing the feasibility of construction project in contributing to the attainment of sustainable development*, Journal of Construction Research, 3(2), 255-269.

Shen et al., 2005a, *A computer-based scoring method for measuring the environmental performance of construction activities*, Automation in Construction, 14(2005) 297-309.

Shen et al., 2005b, *Application of system dynamics for assessment of sustainable performance of construction projects*, Journal of Zhejiang University SCIENCE, 2005 6A(4): 339-349.

Sidwell A.C., 1990, *Project management: dynamics and performance*, Journal of Construction Management and Economics, 8(2), 159-178.

So, A., 2002, *2002 lost in blanket of smog Causeway Bay again the black spot as air pollution hits highest level for two years*, The South China Morning Post, 2nd January, 1.

S. Uren and E. Griffiths, 2000, *Environment Management in Construction*, Construction Industry Research and Information Association.

Uher, T., 1999, *Absolute indicators of sustainable construction*, Proceedings of COBRA, 1999, *The challenge of Change: Construction and Building for the New Millennium*, 1-2 Sept, University of Salford, U. K., 243-253.

United Nations Environment Programme Industry and Environment, 1994, Company Environmental Reporting, *A Measure of the Progress of Business and Industry Towards Sustainable Development*, Technical Report No. 24, Sustainability Ltd, London.

U.S. Green Building Council (USGBC), 2001, *Leadership in energy and environmental design—rating system version 2.0*, U.S. Green Building Council.

Wyatt, D.P., 1994, *Recycling and Serviceability: The Twin Approach to Securing Sustainable Construction*, In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6-9 November, pp. 69-78.

Wyatt, D.P. and Gilleard, J.G., 1994, *Deconstruction: an environmental response for construction sustainability*, In Proceedings of First International Conference of CIB TG 16 on Sustainable Construction, Tampa, Florida, 6- 9 November, pp. 113- 22.

WCED (World Commission on Environment and Development),1987, *Our Common Future*, Oxford, 47.

WDO (Waste Disposal Ordinance Chapter 354), 1997, *Waste Disposal Ordinance*, Hong Kong, http://www.justice.gov.hk/blis_export.nsf/home.htm.

Wooley, T., Kimmins, S., Harrison, P. and Harrison, R., 1997, *Green Building Handbook*, E & FN SPON.

Yasin, Mahmoud M., 2002, *The theory and practice of benchmarking: then and now*， Benchmarking， Bradford, 2002, volume 9. Issue 3, p217.

Yohanis, Y.G. and Norton, B., 2002, *Life-cycle operation and embodied energy for generic Single-story office building in the UK*, Energy, 27 (2002), 72-92.

Zhang, Z. H. and Shen, L. Y., 2000a, *Promoting urbanization towards sustainable development in China*, Journal Tsinghua University 40(1), 2-6.