Applying Possibilistic Linear Programming to Multi-objective New Ship of Sign on Proceeding Project Management Problem

C.M. Su, K.Y. Chang & Y.H. Chang

Abstract—In this paper, we apply possibilistic linear programming (PLP) [2] to establish a fuzzy model for the multi-objective new ship of sign on proceeding problems and the model try to minimize total project cost, total completion time and total crashing cost in same time with reference to direct, indirect cost and relevant constraints. In addition, the proposed PLP applies the signed distance method [4] to transform fuzzy numbers into crisp values and in the paper we provide a defuzzification PLP model.

Keywords: shipbuilding; PLP method; fuzzy; project management

I Introduction

With new ship demand increasing rapidly, shipbuilding enterprises must be step up cost management practice, and improve the ability of cost control [8]. In order to achieve these goals, researchers introduce project management to achieve the goal and to meet the requirement. But in real-world project management problems, input data and/or related parameters are usually imprecise over the planning horizon owing to incomplete or unavailable information, and the decision maker generally faces a fuzzy project management problems in uncertain environments, so researchers apply fuzzy theory to solve the kind of problem and develop several fuzzy optimization techniques. M.F.Yang and Yi.Lin[1] presented a fuzzy PERT (FPERT) technique that can derive the possibility distribution of the project completion time in the situation when particular activity duration times were given in the form of fuzzy variables on the time space.

In this paper, we consider a fuzzy multi-objective new ship of sign on proceeding project management problem and we utilize the PLP method [2] to develop a model that attempts to simultaneously minimize total project cost, total completion time and total crashing cost with reference to direct, indirect cost and relevant constraints.

Chang Yun-Hsiang is with National Taiwan Ocean University, Taiwan (email: j122597088@gmail.com)

II The model of PLP

The assumptions of PLP model:

1. All of the objective functions and constraints are linear.
2. Direct costs increase linearly as the duration of an activity is reduced from its normal value to its crash value.
3. The normal time and shortest possible time for each activity and the cost of completing the activity in the normal time and crash time are certain over the planning horizon.
4. Indirect cost can be divided into two categories, i.e., fixed cost and variable cost, and the variable cost per unit time is the same regardless of project completion time.
5. The decision-makers adopted the pattern of triangular possibility distribution to represent the imprecise objectives and related imprecise numbers.
6. The minimum operator is used to aggregate all fuzzy sets.

Notation:

(i, j)	activity between event i and event j
$\tilde{Z}_1$	fuzzy total project cost ($)
$\tilde{Z}_2$	fuzzy total completion time (days)
$\tilde{Z}_3$	fuzzy total crashing cost ($)
D_{ij}	normal time for activity (i, j) (days)
d_{ij}	minimum crashed time for activity (i, j)
C_{Dij}	normal (direct) cost for activity (i, j) ($)
C_{dij}	minimum crashed (direct) cost for activity (i, j) ($)

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

$\tilde{k}_{ij}$ fuzzy incremental crashing costs for activity (i, j)(representing the cost-time slopes) ($/day)

t_{ij} duration time for activity (i, j) (days)(difference between normal time and crash time)

Y_{ij} crash time for activity (i, j) (days)(difference between normal time and duration time)

E_i earliest time for event i (days)

E_1 project start time (days)

E_n project completion time (days)

T_o project completion time under normal conditions (days)

$\tilde{T}$ fuzzy specified project completion time (days)

C_I fixed indirect cost under normal conditions ($)

$\tilde{m}$ fuzzy variable indirect cost per unit time ($/day)

$\tilde{b}$ fuzzy total allocated budget ($)

γ cut level

Z_1^m the most likely value of $\tilde{Z}_1$

Z_1^o the most optimistic value of $\tilde{Z}_1$

Z_1^p the most pessimistic value of $\tilde{Z}_1$

Z_3^m the most likely value of $\tilde{Z}_3$

Z_3^o the most optimistic value of $\tilde{Z}_3$

Z_3^p the most pessimistic value of $\tilde{Z}_3$

k_{ij}^m the most likely value of $\tilde{k}_{ij}$

k_{ij}^o the most optimistic value of $\tilde{k}_{ij}$

k_{ij}^p the most pessimistic value of $\tilde{k}_{ij}$

T_γ^m the most likely value of $\tilde{T}$ in γ cut level

T_γ^o the most optimistic value of $\tilde{T}$ in γ cut level

T_γ^p the most pessimistic value of $\tilde{T}$ in γ cut level

Z_{11}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{11}$

Z_{11}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{11}$

Z_{12}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{12}$

Z_{12}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{12}$

Z_{13}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{13}$

Z_{13}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{13}$

Z_2^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_2$

Z_2^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_2$

Z_{31}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{31}$

Z_{31}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{31}$

Z_{32}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{32}$

Z_{32}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{32}$

Z_{33}^{PIS} the positive ideal solutions (PIS) of $\tilde{Z}_{33}$

Z_{33}^{NIS} the negative ideal solutions (NIS) of $\tilde{Z}_{33}$

Z_{kq}^* the optimal solution of objective functions of $\tilde{Z}_{kq}$, $k = 1, \text{and } 3;\ q = 1 \text{ and } 3$

Z_2^* the optimal solution of objective function of Z_2

Mathematical model:

First we establish the multi-objective linear programming model (MOLP model) and the defuzzication method be used in the MOLP model is the signed distance method [4]. In this paper, we provide the defuzzification MOLP model.

Defuzzification objective:

$$\text{Min } Z_{11} = Z_1^m = \sum_i \sum_j C_{Dij} + \sum_i \sum_j k_{ij}^m Y_{ij} + C_I + m^m (E_n - T_o)$$

$$\text{Max } Z_{12} = (Z_1^m - Z_1^o) = \sum_i \sum_j \left(k_{ij}^m - k_{ij}^o\right) Y_{ij} + (m^m - m^o)(E_n - T_o)$$

$$\text{Min } Z_{13} = \left(Z_1^p - Z_1^m\right) = \sum_i \sum_j \left(k_{ij}^p - k_{ij}^m\right) Y_{ij} + (m^p - m^m)(E_n - T_o)$$

$$\text{Min } Z_2 = E_n - E_1$$

$$\text{Min } Z_{31} = Z_3^m = \sum_i \sum_j k_{ij}^m Y_{ij}$$

$$\text{Max } Z_{32} = (Z_3^m - Z_3^o) = \sum_i \sum_j \left(k_{ij}^m - k_{ij}^o\right) Y_{ij}$$

$$\text{Min } Z_{33} = \left(Z_3^p - Z_3^m\right) = \sum_i \sum_j \left(k_{ij}^p - k_{ij}^m\right) Y_{ij}$$

Defuzzification constraints:

$$E_i + t_{ij} - E_j \leqq 0 \qquad \forall i,\ \forall j$$

$$t_{ij} = D_{ij} - Y_{ij} \qquad \forall i,\ \forall j$$

$$Y_{ij} \leq D_{ij} - d_{ij} \qquad \forall i,\ \forall j$$

$$E_1 = 0$$

$$E_n \lesseqgtr \left(T_\gamma^o + 2T_\gamma^m + T_\gamma^p\right)/4$$

$$\sum_i \sum_j C_{Dij} + \sum_i \sum_j \left[\left(k_{ij,\gamma}^o + 2k_{ij,\gamma}^m + k_{ij,\gamma}^p\right)/4\right] Y_{ij} + C_I + \left[\left(m_\gamma^o + 2m_\gamma^m + m_\gamma^p\right)/4\right](E_n - T_o) \leq \left(b_\gamma^o + 2b_\gamma^m + b_\gamma^p\right)/4$$

$$t_{ij}, Y_{ij}, E_i, E_j \geq 0 \qquad \forall i,\ \forall j$$

III Solution procedure

Step 1: Apply defuzzification MOLP model to get $(Z_{kq}^{PIS}, Z_{kq}^{NIS})$ and (Z_2^{PIS}, Z_2^{NIS}); k =1, 3 and q =1, 2, 3.
Step 2: Apply $(Z_{kq}^{PIS}, Z_{kq}^{NIS})$ and (Z_2^{PIS}, Z_2^{NIS}) to define $\mu_{kq}\left(Z_{kq}(x)\right)$ and $\mu_2\left(Z_2(x)\right)$.
Step 3: Apply defuzzification PLP model to get solutions.

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV The new ship of sign on proceeding problem

The new ship of sign on proceeding problem apply PLP model to solve the PM problems. The purpose of this PM decision are to minimize simultaneously total project cost, total completion time and total crashing cost, with reference to direct cost, indirect cost, duration of activities and budget constraint. Table I shows the program of new ship of sign on proceeding and Table II summarizes the basic data of the numerical new ship of sign on proceeding problem.

Table I. Program of new ship of sign on proceeding

new ship of sign on proceeding
1. store proceeding
2. certificate application
3. crewman hire
4. archiving
5. ownership of ship on proceeding
6. insurance arrangement
7. oil proceeding
8. paperwork
9. ship certificate
10. food supply
11. water supply

Table II. Summarized data for new ship of sign on proceeding (in million dollars)

(i , j)	D_{ij} (days)	d_{ij} (days)	C_{Dij} (\$)	C_{dij} (\$)	k_{ij} (\$/days)
1-2	6	4	55	65	(4.5,5,7)
2-3	9	8	20	26	(5,6,7.75)
3-4	6	4	65	78	(6,6.5,7.25)
3-5	6	4	70	81	(4,5.5,8)
4-6	5	3	20	28	(3.25,4,5.125)
5-6	4	2	40	55	(1,2.5,3)
6-7	2	1	50	53	(2.5,3,3.5)
6-8	3	2	40	45	(4.5,5,6)
7-9	2	1	24	27	(2.25,3,4)
8-9	3	2	25	27	(0.5,2,3.25)
9-10	2	1	10	15	(3.5,5,6.75)
10-11	2	1	12	15	(2.25,3,4.25)

Other relevant data are as follows: fixed indirect cost \$15, saved daily variable indirect cost (\$3.5, \$4, \$4.25), total budget (\$400, \$450, \$500), and project completion time under normal conditions 36 days. The project start time (E_1) is set to zero. The γ-cut level for all imprecise numbers is specified as 0.3. The specified project completion time is set to (28, 32, 35) days based on contractual information, resource allocation and economic considerations, and related factors. Figure I shows the Activity On-Arrow network.

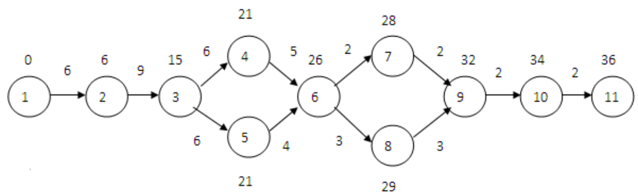

Fig. I. the project network of new ship of sign on proceeding problem.

We run (phase I) to get (PIS, NIS) by using Lingo computer software. Additionally, specify the PIS and NIS of the imprecise/fuzzy objective functions with a payoff table (see Table III).

(phase I)

Min Z_{11}=

$$431+5Y_{12}+6Y_{23}+6.5Y_{34}+5.5Y_{35}+4Y_{46}+2.5Y_{56}+3Y_{67}+5Y_{68}+3Y_{79}+2Y_{89}+5Y_{910}+3Y_{1011}+4(E_{11}-36)+15$$

Max Z_{12}=

$$0.5Y_{12}+Y_{23}+0.5Y_{34}+1.5Y_{35}+1.25Y_{46}+1.5Y_{56}+0.5Y_{67}+1.5Y_{68}+1.25Y_{79}+1.5Y_{89}+1.5Y_{910}+0.75Y_{1011}+0.5(E_{11}-36)$$

Min Z_{13}=

$$2Y_{12}+1.75Y_{23}+0.75Y_{34}+2.5Y_{35}+1.125Y_{46}+0.5Y_{56}+0.5Y_{67}+Y_{68}+Y_{79}+1.25Y_{89}+1.75Y_{910}+1.25Y_{1011}+0.25(E_{11}-36)$$

Min Z_2= $(E_{11}-E_1)$

Min Z_{31}=

$$5Y_{12}+6Y_{23}+6.5Y_{34}+5.5Y_{35}+4Y_{46}+2.5Y_{56}+3Y_{67}+5Y_{68}+3Y_{79}+2Y_{89}+5Y_{910}+3Y_{1011}$$

Max Z_{32}=

$$0.5Y_{12}+Y_{23}+0.5Y_{34}+1.5Y_{35}+1.25Y_{46}+1.5Y_{56}+0.5Y_{67}+1.5Y_{68}+1.25Y_{79}+1.5Y_{89}+1.5Y_{910}+0.75Y_{1011}$$

Min Z_{33}=

$$2Y_{12}+1.75Y_{23}+0.75Y_{34}+2.5Y_{35}+1.125Y_{46}+0.5Y_{56}+0.5Y_{67}+Y_{68}+Y_{79}+1.25Y_{89}+1.75Y_{910}+1.25Y_{1011}$$

s.t. $E_i+t_{ij}-E_j \leqq 0 \quad \forall i=1\sim10,\ \forall j=2\sim11$

$t_{ij} = D_{ij}-Y_{ij} \quad \forall i=1\sim10,\ \forall j=2\sim11$

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

$Y_{ij} \leq D_{ij} - d_{ij}$ $\forall i = 1\sim10$, $\forall j = 2\sim11$

$E_1 = 0$

$E_{11} \lesssim_R \frac{(29.2+2*32+34.1)}{4} = 31.825$

$431+5.2625Y_{12}+6.13125Y_{23}+6.54375Y_{34}+5.675Y_{35}+4.065625Y_{46}+2.325$

$Y_{56}+3Y_{67}+5.0875Y_{68}+3.04375Y_{79}+1.95625Y_{89}+5.04375Y_{910}+3.0875Y_{1011}$

$+3.95625(E_{11} - 36)+15 \leqq 450$

Table III. The corresponding PIS and NIS for the fuzzy objective functions

	LP-1	LP-2	LP-3	LP-4	LP-5	LP-6	LP-7	
Ob	Min Z_{11}	Max Z_{12}	Min Z_{13}	Min Z_2	Min Z_{31}	Max Z_{32}	Min Z_{33}	(PIS,NIS)
Z_{11}	444.17	449.76	447.37	448.77	444.17	449.76	447.37	(444.17 ,449.76)
Z_{12}	3	7.60	2.51	4.44	3	7.60	2.513	(7.60 ,2.51)
Z_{13}	4.68	6.95	3.42	9.95	4.68	6.95	3.42	(3.42 ,9.95)
Z_2	31.825	30	31.825	28.114	31.825	30	31.825	(28.11 ,31.82)
Z_{31}	14.87	27.76	18.07	34.31	14.87	27.76	18.07	(14.87 ,27.76)
Z_{32}	5.08	10.60	4.6	8.38	5.08	10.60	4.6	(10.60 ,4.6)
Z_{33}	5.72	8.45	4.46	11.92	5.72	8.45	4.46	(4.46 ,11.92)

Table IV. PLP solutions for new ship of sign on proceeding

Initial solutions

Y_{ij}(days)

$Y_{12}=0.412$, $Y_{46}=1.241$

$Y_{56}=0.241$, $Y_{68}=1$

$Y_{89}=1$, $Y_{910}=1$, $Y_{1011}=1$, Otherwise is zero.

Objective values

$Z_{11}= 446.016$, $Z_{12}= 4.543$

$\tilde{Z}_1= (441.472, 446.016, 452.194)$

$Z_{13}= 6.178$, $Z_2 = 30.347$

$\tilde{Z}_2= 30.347$

$Z_{31}= 22.630$, $Z_{32}= 7.370$

$\tilde{Z}_3= (15.260, 22.630, 30.221)$

$Z_{33}= 7.591$

Improved solutions

Y_{ij}(days)

$Y_{12}=0.291$, $Y_{23}=0.363$

$Y_{46}=1$, $Y_{68}=1$

$Y_{89}=1$, $Y_{910}=1$, $Y_{1011}=1$, Otherwise is zero.

Objective values

$Z_{11}= 446.016$, $Z_{12}= 4.181$

$\tilde{Z}_1= (441.834, 446.016, 452.193)$

$Z_{13}= 6.177$, $Z_2 = 30.347$

$\tilde{Z}_2= 30.347$

$Z_{31}= 22.629$, $Z_{32}= 7.008$

$\tilde{Z}_3= (15.621, 22.629, 30.219)$

$Z_{33}= 7.591$

Final we run to get initial solutions by using Lingo computer software. The initial solutions are $\tilde{Z}_1$= (441.472, 446.016, 452.194), $\tilde{Z}_2$= 30.347 and $\tilde{Z}_3$= (15.260, 22.630, 30.221). Besides, if the decision-maker is dissatisfied with the initial solutions, they can try to modify the results by adjusting the related parameters (PIS, NIS) until a set of preferred satisfactory solution is found (see Table IV.).

V Conclusion

In real-world Project Management (PM) decision problems of shipbuilding, input data and related parameters are frequently imprecise due to incomplete or unavailable information over the shipbuilding proceeding planning horizon. This work utilizes a PLP approach to solve PM problems with multiple imprecise goals having triangular possibility distribution. The Proposed approach attempts to simultaneously minimize total project costs and completion time with reference to direct costs, indirect cost, relevant activities time and costs, and budget constraints consideration. An industrial case demonstrates the feasibility of applying the proposed approach to real PM decisions.

ISBN: 978-988-14047-6-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Consequently, the proposed PLP approach yields a set of efficient compromise solutions and the overall degree of DM satisfaction with determined goal values. Based on the results of examples, the proposed PLP model and two-phase approach can minimize total project costs, total completion time, and total crashing costs. Based on our results, this article provides a practical example of a project which we obtain the data by using Lingo computer software to prove the validity of the method, and the method can be applied in more issues to get more appropriate solution.

References

[1] M.F. Yang and Yi Lin, Applying fuzzy multi-objective linear programming to project management decisions with the interactivetwo-phase method, Computers & Industrial Engineering 66, (2013) 1061-1069.

[2] S.H. Yang, M.F. Yang, M.Z. Wang, Application of Signed Distance Method to Integrated Linear Programming for Fuzzy Multi-Objective Project Management Problems, National Taipei University of Technology (2009).

[3] Dlugokecki Victoria, Fanguy Dennis, Hepinstall Lisa, Tilstrom David, Transforming the shipbuilding and ship repair project environment, Journal of Ship Production 26 (2010) 265-272.

[4] Yao J.S., K. Wu, Ranking fuzzy numbers based on decomposition principle and signed distance, Fuzzy Sets and Systems 116 (2000) 275-288.

[5] Liang, T.F., Application of fuzzy sets to multi-objective project management decisions, International Journal of General Systems (2008).

[6] M.J. Wang and M.F. Yang, Application of signed distances method to integrated linear programming for fuzzy multi-objective project management, International Journal of Innovative Computing Information and Control (2011), ISSN 1349-4198, 237-252

[7] T. F. Liang, T. S. Huang, and M. F. Yang, Application of fuzzy mathematical programming to imprecise project management decisions, Quality and Quantity (2012) Volume 46, Issue 5, 1451-1470.

[8] Qinghe Cheng, Haijun Li, Qi Zhang, Research and development of shipbuilding cost accounting management system based on project life cycle, RINA-ICCAS 30 (2009) 1890-1895.