Facility layout design selection by the technique of precise order preference

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Abstract

Facility layout highly affects effectiveness of the production systems. Different approaches are proposed to solve facility layout problemin the literature. The proposed approaches generate more than one alternative layout to be applied in practice. Therefore, it is necessary to select the most appropriate facility layout design among alternatives. The technique of precise order preference (TPOP) is a new method and developed in 2015 to sort alternatives considering inconsistency in the ranking order of the alternatives generated by multiple conventional approaches. In this study, an example taken from previous researchers' work is conducted to show how the TPOP works for facility layout design selection problem. The example composed of 18 alternative facility layout designs. The results of the study show that the TPOP can be easily and effectively conducted to select more appropriate facility layout design alternatives.

1. Introduction

Decision makers in manufacturing and service systems are looking for developing new methods to design appropriate facility layout. Because, enterprises have to make suitable location planning to decrease the product cost and to increase their productivity (Aksaraylı and Altuntas, 2009). The layout design highly affect the productivity and production flow. It is a strategic issue and impact on the efficiency of a manufacturing system (Yang and Hung, 2007).

Facility layout deals with the question of where m numbers of machines are arranged within a given location (Altuntas and Selim, 2012). Much of the proposed approaches/methods are aimed to decrease the flow time and increase the adjacency among facilities. Basically, different alternative locations may be appropriate to locate a facility in the facility layout. There may be generated different number of alternative facility layout designs based on the usage of the method and alternative locations. Choosing the most appropriate method for facility layout design alternatives is significant in practice. Therefore, a selection of facility layout design among alternatives is not an easy activity.This study focuses on the selection of the alternative facility layout designs.

Bairagi *et.al* (2015) proposed a De Novo multi-approaches multi-criteria decisionmaking method namely Technique of Precise Order Preference (TPOP) to sort alternative solutions obtained by the application of multiple conventional approaches. The present study conducts the TPOP to sort facility layout design alternatives considering inconsistency in the ranking order of the alternatives generated by multiple conventional approaches.

The rest of the paper is organized as follows. Section 2 briefly introduces the TPOP. Application of the TPOP to the selection of the facility layout design alternatives is presented in Section 3. Conclusions and future research directions are provided in Section 4.

2. The technique of precise order preference (TPOP)

The technique of precise order preference (TPOP) was proposed by Bairagi et al. (2015) to find the precise ranking order of alternatives. The TPOP is basically developed to solve multi criteria decision making problem. In the first step, the TPOP uses the final selection values taken from the results of multi criteria decision making methods to construct initial decision matrix. The subsequent steps aim to compute precise selection index (PSI) which shows the relative distance of an alternative from the ideal reference point (Bairagi et al., 2015). Figure 1 illustrates steps of the TPOP. Basic definitions related to the TPOP is given in the following to go into the details of the Figure 1.

i= 1,2,….., m
A_i = i^{th} alternative
j= 1, 2, ..., t
f_{ij} = final selection value of i^{th} alternative (A_i) obtained by j^{th} conventional approach.
e_j = the entropy of the final selection value for j^{th} approach.
s_j = the apparent weight of j^{th} approach ($1 \leq s_j' \leq 2$).
w_j =the precise weight of the final selection value for j^{th} approach ($\frac{1}{t+\sqrt{t}} \leq w_j \leq \frac{2}{t+1}$) .
$f_{ij} \in H$ imply that higher value of f_{ij} is desirable.
$f_{ij} \in L$ imply that lower value of f_{ij} is desirable.
EWNFSW =the exponentially weighted normalized final selection values.
PSI = precise selection index

Step 1: Construct decision matrix

$$S = \begin{array}{c} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{bmatrix} f_{11} & \cdots & f_{1j} & \cdots & f_{1t} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots & f_{it} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ f_{m1} & \cdots & f_{mj} & \cdots & f_{mt} \end{bmatrix}$$

Step 2: Normalize the final selection values

$$\tau_{ij} = \frac{|f_{ij}|}{\sum_{i=1}^{m} |f_{ij}|}$$

Step 3: Calculate the entropy value

$$e_j = \frac{1}{\ln m} \sum_{i=1}^{m} |\tau_{ij} \ln \tau_{ij}|$$

Step 4: Determine the apparent weight

$$s_j = \frac{1 - e_j}{\sum_{j=1}^{t} (1 - e_j)}$$

Step 5: Calculate s_j'

$$s_j' = 1 + \sqrt{s_j}$$

Step 6: Sum all s_j' values

$$S_j' = \sum_{j=1}^{t} s_j' = \sum_{j=1}^{t} (1 + \sqrt{s_j}) = t + \sum_{j=1}^{t} \sqrt{s_j}$$

Step 7: Compute the precise weight

$$w_j = \frac{s_j'}{S_j'} = \frac{1 + \sqrt{s_j}}{t + \sum_{j=1}^{t} \sqrt{s_j}}$$

Step 8: Normalize the final selection values

$$g_{ij} = \left\{ \begin{array}{ll} \dfrac{(f_j)_{max} - f_{ij}}{(f_j)_{max} - (f_j)_{min}}, & f_{ij} \in H \\ \dfrac{f_{ij} - (f_j)_{min}}{(f_j)_{max} - (f_j)_{min}}, & f_{ij} \in L \end{array} \right\}$$

Step 9: Compute EWNFSW

$$h_{ij} = exp(w_j + g_{ij})$$

Step 10: Compute PSI for each alternative

$$PSI_i = \sum_{j=1}^{t} h_{ij} = \sum_{j=1}^{t} exp(w_j + g_{ij})$$

Step 11: Sort the alternatives in increasing order of their PSIs

Figure 1. Steps of the TPOP

3. Application of the TPOP

In this section, application of the TPOP is presented to rank facility layout design alternatives in descending order with respect layout criteria. The example considered in this paper is taken from Yang and Kuo (2003). 18 facility layout design alternatives were generated by Yang and Kuo (2003) based on six layout criteria, namely distance (m), adjacency, shape ratio, flexibility, accessibility and maintenance.Yang and Kuo (2003) proposed a hierarchical AHP/DEA methodology to sort these facilitylayout design alternatives. The final efficiency scoresbased on hierarchical AHP/DEA methodologyfor facility layout design alternativesare given in the last column in Table 1. Yang and Hung(2007) usedTechnique for order preference by similarity to ideal solution (TOPSIS) and fuzzy TOPSIS to rank facility layout design alternatives provided by Yang and Kuo (2003)' study. The TOPSIS and Fuzzy TOPSIS calculate the distance between each facility layout design alternative and positive ideal solution first. Then, they compute the distance between each facility layout design alternative and negative ideal solution. Similarities to ideal solution in TOPSIS and fuzzy TOPSIS for 18 facility layout design alternatives are given in column 4 and 5 of Table 1.

Table 1. Final selection values for facility layout design selection problem (FLDSP)

Alternative	PSI (Maniya and Bhatt, 2011)	GRA (Kuo et al., 2008)	TOPSIS (Yang and Hung, 2007)	Fuzzy TOPSIS (Yang and Hung, 2007)	DEA (Yang and Kuo, 2003)
A1	0.6774	0.4835	0.2273	0.257363	91.69
A2	0.7112	0.5302	0.3864	0.291787	98.45
A3	0.6680	0.4599	0.3714	0.253592	86.39
A4	0.6946	0.4810	0.6176	0.312995	89.94
A5	0.6506	0.4688	0.3056	0.269424	86.44
A6	0.5138	0.4552	0.4884	0.241983	96.62
A7	0.6998	0.4450	0.1064	0.221744	80.77
A8	0.7535	0.5325	0.2653	0.282981	96.51
A9	0.7677	0.5663	0.2558	0.273092	95.69
A10	0.6852	0.5004	0.6765	0.255136	87.44
A11	0.8487	0.7145	0.9836	0.491252	100
A12	0.6823	0.4440	0.1707	0.249527	85.72
A13	0.6932	0.4616	0.2632	0.216823	86.29
A14	0.7121	0.4748	0.6061	0.27137	86.66
A15	0.9292	0.7890	0.9286	0.432104	100
A16	0.7455	0.5424	0.4706	0.275485	96.74
A17	0.8610	0.7703	0.4865	0.272469	94.63
A18	0.8027	0.6017	0.3421	0.342584	100

In addition, Kuo *et al.* (2008) proposed grey relational analysis (GRA) for the solution of the FLDSP introduced by Yang and Kuo (2003). The grey relational grade obtained by Kuo *et al.* (2008)' study is given in column 3 of Table 1. Furthermore,Maniya and Bhatt(2011)proposed an alternative multiple attribute decision making methodology, namely Preference selection index (PSI) method forthe FLDSP. The PSI method was conducted by Maniya and Bhatt(2011) to rank 18 facility layout design alternatives generated by Yang and Kuo (2003) considering previous mentioned six layout criteria. A facility layout design selection values based on the PSI method are shown in column 2 of Table 1. The output of five different approaches, namely the PSI, GRA, TOPSIS, Fuzzy TOPSIS and DEA are used to conduct the TPOP in this study. As stated previously, the TPOP is quite appropriate if there are inconsistency in the ranking order of the alternatives generated by multiple conventional approaches. Final selection values obtained from these five approaches are given in Table 1 for the FLDSP. As can be seen from Table 1, it is not possible to suggest a consistent ranking order of the facility layout design alternatives. Table 1 is a decision matrix for the TPOP in Step 2. After normalizetion of the final selection values in Step 2, the entropy of the final selection value(e_i), the apparent weight (s_j) and the precise weight of the final selection values are computed in Step 3 -7 and given in Table 2.

Table 2. Weights of various approaches

Alternative	PSI (Maniya and Bhatt, 2011)	GRA (Kuo et al., 2008)	TOPSIS (Yang and Hung, 2007)	Fuzzy TOPSIS (Yang and Hung, 2007)	DEA (Yang and Kuo, 2003)
e_j	0.9973	0.9937	0.9523	0.9915	0.9993
$1- e_j$	0.0027	0.0063	0.0477	0.0085	0.0007
s_j	0.0404	0.0957	0.7235	0.1295	0.0109
$\sqrt{s_j}$	0.2011	0.3094	0.8506	0.3598	0.1043
$1+\sqrt{s_j}$	1.2011	1.3094	1.8506	1.3598	1.1043
w_j	0.1760	0.1918	0.2711	0.1992	0.1618

The Step 8 and Step 9 calculate the exponentially weighted normalized final selection values (EWNFSV) based on the weights of the approaches. The EWNFSV are shown in Table 3.

Table 3. The exponentially weighted normalized final selection values(EWNFSV)

Alternative	PSI (Maniya and Bhatt, 2011)	GRA (Kuo et al., 2008)	TOPSIS (Yang and Hung, 2007)	Fuzzy TOPSIS (Yang and Hung, 2007)	DEA (Yang and Kuo, 2003)	**TPOP**
A1	2.1862	2.9369	3.1059	2.8620	1.8111	12.9021
A2	2.0153	2.5651	2.5907	2.5246	1.2743	10.9700
A3	2.2362	3.1448	2.6354	2.9016	2.3858	13.3038
A4	2.0975	2.9583	1.9905	2.3368	1.9836	11.3667
A5	2.3318	3.0647	2.8407	2.7389	2.3796	13.3558
A6	3.2413	3.1880	2.3063	3.0270	1.4015	13.1641
A7	2.0714	3.2836	3.5649	3.2586	3.1957	15.3742
A8	1.8202	2.5480	2.9743	2.6069	1.4096	11.3590
A9	1.7590	2.3102	3.0066	2.7026	1.4710	11.2494
A10	2.1455	2.7965	1.8612	2.8853	2.2590	11.9475
A11	1.4474	1.5035	1.3115	1.2205	1.1756	6.6584
A12	2.1605	3.2932	3.3129	2.9449	2.4704	14.1819
A13	2.1046	3.1294	2.9814	3.3176	2.3983	13.9312
A14	2.0110	3.0119	2.0167	2.7196	2.3526	12.1117
A15	1.1924	1.2115	1.3963	1.5140	1.1756	6.4899
A16	1.8556	2.4760	2.3536	2.6791	1.3928	10.7571
A17	1.4052	1.2790	2.3113	2.7087	1.5543	9.2585
A18	1.6169	2.0850	2.7249	2.0980	1.1756	9.7004

Comparison of ranking order of facility layout design alternatives are given in Table 4. As can be seen from Table 4, alternative 15 (A15) ranked first among facility layout designs by the TPOP. This alternative was also ranked first with respect to the PSI (Maniya and Bhatt, 2011) and GRA (Kuo et al., 2008). In addition to this, alternative 7 (A7) ranked last among the alternatives by the TPOP. A7 was also ranked last by TOPSIS (Yang and Hung, 2007) and DEA (Yang and Kuo, 2003). Figure 2 illustrates precise ranking order of facility layout design alternatives based on the TPOP.

Table 4. Comparison of ranking order

	TPOP(Bairagi et al., 2015)	Rank by TPOP(Bairagi et al., 2015)	PSI (Maniya and Bhatt, 2011)	GRA (Kuo et al., 2008)	TOPSIS (Yang and Hung, 2007)	Fuzzy TOPSIS (Yang and Hung, 2007)	DEA (Yang and Kuo, 2003)
A1	12.9021	12	15	10	16	13	10
A2	10.9700	6	9	8	9	9	4
A3	13.3038	14	16	15	10	14	15
A4	11.3667	9	11	11	4	4	11
A5	13.3558	15	17	13	12	12	14
A6	13.1641	13	18	16	6	16	6
A7	15.3742	18	10	17	18	17	18
A8	11.3590	8	6	7	13	6	7
A9	11.2494	7	5	5	15	11	8
A10	11.9475	10	13	9	3	7	12
A11	6.6584	2	3	3	1	1	1
A12	14.1819	17	14	18	17	15	17
A13	13.9312	16	12	14	14	18	16
A14	12.1117	11	8	12	5	8	13
A15	6.4899	1	1	1	2	2	1
A16	10.7571	5	7	6	8	10	5
A17	9.2585	3	2	2	7	5	9
A18	9.7004	4	4	4	11	3	1

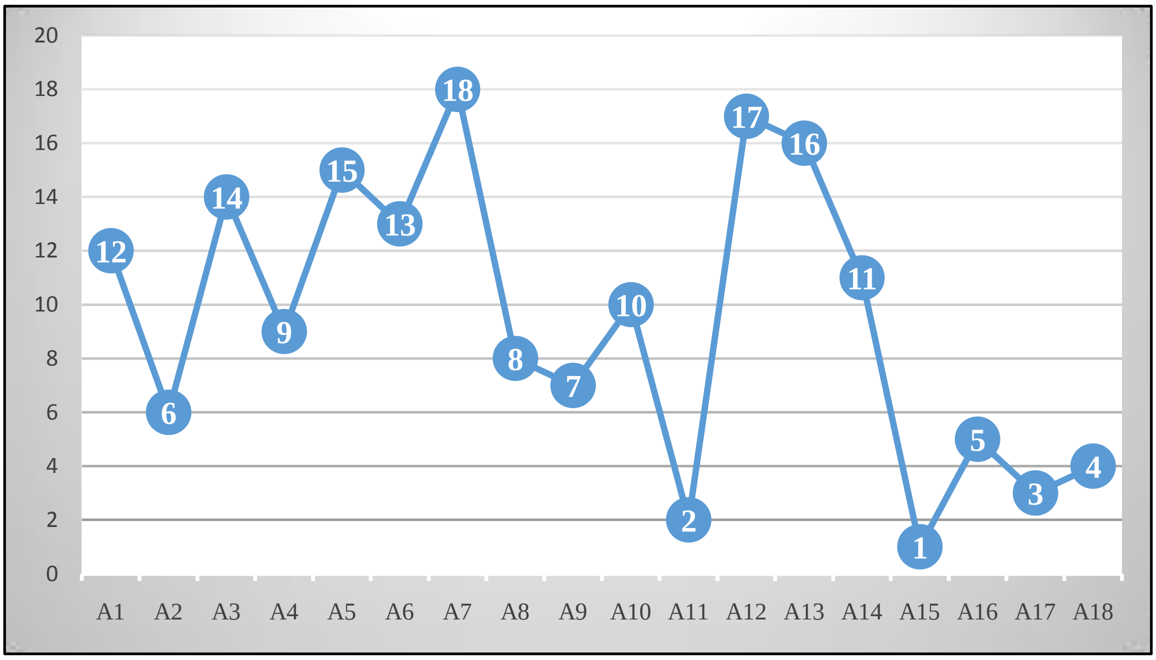

Figure 2. Precise ranking order of facility layout design alternatives

4. Conclusion

Facility layout has considerable effect on productivity in manufacturing systems. Engineers, researchers and decision makers in manufacturing systems try to develop novel methods/approaches to locate their facilities in appropriate locations in the layout. Most of the methods proposed for the solution of the facility layout problem generate more than one alternative layout design in practice. Facility layout design selection problem (FLDSP) arose in the literature because of the alternative layouts. To date, multiple conventional approaches such as PSI, GRA, TOPSIS, Fuzzy TOPSIS and DEA have been proposed to solve the FLDSP. However, there are inconsistencies in the ranking order of the alternatives generated by these multiple conventional approaches in the literature. A novel method namely the technique of precise order preference (TPOP) was proposed by Bairagi *et al.* (2015). The TPOP ranks alternatives considering inconsistency in the ranking order of the alternatives generated by multiple conventional approaches. In this study, an example related to the FLDSP, which was taken from previous researchers' work, was conducted to show how the TPOP works in practice. The results of the study show that the FLDSP can be easily solved by the TPOP. In future research, more than one example will be conducted to go into the details of the TPOP and to show the viability of the TPOP for the FLDSP.

References

1) Aksaraylı, M., & Altuntas, S. (2009). "The comparison of layout arrangements for the material flow ordering planning in production systems through simulation analysis" Pamukkale University Journal of Engineering Sciences, 15, 203-214.

2) Yang, T., & Hung, C. C. (2007). "Multiple-attribute decision making methods for plant layout design problem" Robotics and Computer-Integrated Manufacturing, 23, 126–137.

3) Altuntas, S., &Selim, H. (2012)."Facility layout using weighted association rule-based data mining algorithms: Evaluation with simulation". Expert Systems with Applications, 39, 3-13.

4) Bairagi, B., Dey, B., Sarkar, B., & Sanyal, S.K. (2015).“A De Novo multi-approaches multi-criteria decision making technique with an application in performance evaluation of material handling device” Computers & Industrial Engineering, 87, 267–282.

5) Yang, T., Kuo, C. (2003).“A hierarchical AHP/DEA methodology for the facilities layout design problem” European Journal of Operational Research, 147, 128–136.

6) Yang, T., Hung, C.C. (2007).“Multiple-attribute decision making methods for plant layout design problem” Robotics and Computer-Integrated Manufacturing, 23, 126–137.

7) Kuo, Y., Yang, T., Huang, G.V. (2008).“The use of grey relational analysis in solving multiple attribute decision-making problems” Computers & Industrial Engineering, 55, 80–93.

8) Maniya, K.D., Bhat, M.G. (2011). “An alternative multiple attribute decision making methodology for solving optimal facility layout design selection problems” Computers & Industrial Engineering, 61, 542–549.