Selection of Refrigerant Using-TOPSIS Method

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Abstract: ***One of the biggest challenges facing the companies and entrepreneurs is development of new winning products. The new challenges demand decreasing costs, better customer satisfaction, reducing development time, on time delivery, production of quality products, optimizing design specifications, and improving revenues. The customers may not know what they want or be reluctant to commit and may change their requirements mid-stream in the development process. Rapidly altering products requirements has resulted in companies resorting to different tools and techniques for addressing the customer needs. Multi-criteria approach may offer valuable tools to handle complex situations with multiple objectives, incorporating the imprecise and uncertain information. Evaluation and selection of a refrigerant is a complex decision-making problem involves many multiple conflicting criteria. This paper mainly focuses to multiple criteria decision approach for modeling and solving problem using TOPSIS method. Further designing of the model for TOPSIS is done using program written in C. Application of the TOPSIS method is used to enhance the COP (coefficient of performance) of refrigeration system by selecting refrigerant on the basis of available criteria. Also the results are compared by using SDI tool software.***

Keywords: TOPSIS, SDI Tool, COP (Coefficient of performance)

1. Introduction

Multi-Attribute Decision Making is the most well known branch of decision making. It is a branch of a general class of Operations Research models which deal with decision problems under the presence of a number of decision criteria. This super class of models is very often called multi-criteria decision making (MCDM). The Multi criterion Decision-Making (MCDM) are gaining importance as potential tools for analyzing complex real problems due to their inherent ability to judge different alternatives (Choice, strategy, policy, scenario can also be used synonymously) on various criteria for possible selection of the best/suitable alternative. These alternatives may be further explored in-depth for their final implementation. Multi criterion Decision-Making (MCDM) analysis has some unique characteristics such as the presence of multiple non-commensurable and conflicting criteria, different units of measurement among the criteria, and the presence of quite different alternatives. This paper mainly focuses to multiple criteria decision approach for modeling and solving problem using TOPSIS method. R. A. Krohling et al.[1] researched on an approach Based on TOPSIS for Ranking Evolutionary Algorithms. In this paper, an alternative novel method based on the TOPSIS to solve the problem of ranking and comparing algorithms. D. joshi et al.[2] 2014 researched on Intuitionistic fuzzy entropy and distance measure based TOPSIS method for multi-criteria decision making. In this paper, an intuitionistic fuzzy TOPSIS method for multi-criteria decision making (MCDM) problem to rank the alternatives is proposed. The proposed method is based on distance measure and intuitionistic fuzzy entropy. I. Igoulalene et al.[3] researched on Consensus-based Fuzzy TOPSIS Approach for Supply Chain Coordination: Application to Robot Selection Problem. A.A. Zaidan et al.[4] researched on Evaluation and selection of open-source EMR software packages based on integrated AHP and TOPSIS. W. Huang et al.[5] researched on the Performance Evaluation of Chongqing Electric Power Supply Bureaus Based on TOPSIS. M. Behzadian et al.[6] researched on a state-of the-art survey of TOPSIS applications. In this paper, a state-of-the-art literature survey to taxonomize the research on TOPSIS applications and methodologies.X. Zhongyou[7] 2011 studied on the Application of TOPSIS Method to the Introduction of Foreign Players in CBA Games. This paper introduces the current situation of the introduction of foreign players in CBA games, presents the principles and calculation steps of TOPSIS method in detail. R. Mikaeil et al.[8] researched on Sawability ranking of carbonate rock using fuzzy analytical hierarchy process and TOPSIS approaches. The aim of this paper is developing a new hierarchical model to evaluate and rank the sawability (power consumption) of carbonate rock with the use of effective and major criteria, and simultaneously taking subjective judgments of decision makers into consideration. The proposed approach is based on the combination of Fuzzy Analytic Hierarchy Process (FAHP) method with TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods.

Now a day's market offers many more choices refrigerant alternatives. There are also many factors one should consider as part of the refrigerant selection process, including Freezing Point, Condensing Pressure, Evaporator Pressure, Critical Pressure, cost, Vapour Density etc. Evaluation and selection of a refrigerant is a complex decision-making problem involves many multiple conflicting criteria. This paper mainly focuses to multiple criteria decision approach for modeling and solving problem using TOPSIS method. Further designing of the model for TOPSIS is done using program written in C.

2. Methodology

Over the past decades, many efforts have been made to facilitate the selection of the most appropriate decision making method for a given problem. TOPSIS (for the Technique for Order Preference by Similarly to Ideal Solution) was developed by Hwang and Yoon in 1981 as an alternative to the ELECTRE method and can be considered as one of its most widely accepted variants. The basic concept of this method is that the selected alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in some geometrical sense.

2.1. Steps involves in TOPSIS

Step1. In the first step, we have to determine the objective and to identify the attribute values for each alternative.

Step2. This step involves the development of matrix formats. The row of this matrix is allocated to one alternative and each column to one attribute.

Step3. Then using the above matrix to develop the normalized decision matrix with the help of the formula given below.

$$X_{ij}^{*} = X_{ij} / \sqrt{\sum_{i=1}^{n} (Xij^2)}$$

Step4. The variance of each attribute which can be calculated by the formula below.

Variance of each attribute is given by mathematical formula given below:

$$V_j = (1/n) \sum_{i=1}^{n} (X_{ij}^* - X_{ijmean}^*)^2$$

Weight of each attribute is given by mathematical formula given below:

$$W_j = V_j / \sum_{i=1}^{m} (V_j) \ \& \ \sum_{i=1}^{m} (W_j = 1)$$

Step5. Then obtain the weighted normalized matrix bymultiplying weight of each attributes (W_j) with all the values normalized matrix by using formula given below and find out the weight normalized matrix.

$$V_{ij} = W_j X_{ij}^*$$

Step6. This step determines the ideal (best) and negative ideal (worst) solutions.which can be calculated by the formula given below.

a) The positive ideal solution: $A^+ = \{V_1^+ ...., V_m^+\}$ $= \{(\max v_{ij} | j \in I'), (\min v_{ij} | j \in I'')\}$

b) The negative ideal solution:

$A^- = \{V_1^- \text{ ....} V_m^-\} = \{(\min v_{ij} | j \in I'), (\max v_{ij} | j \in I'')\}$

Step7. Obtain separation (distance) of each alternative from the ideal solution and negative ideal solution which is given by the Euclidean distance equations. **a)** Distance of positive ideal solution from ideal solution is calculated by formula given below:

$$D_i^+ = \sqrt{\sum_{i=1}^{m}} (V_{ij} - V_j^+)^2$$

b) Distance of negative ideal solution from ideal solution is calculated by formula:

$$D_i^- = \sqrt{\sum_{i=1}^{m}} (V_{ij} - V_j^-)^2$$

Step8. Calculate the relative closeness to the ideal solution of each alternative which is calculated by formula given below.

Relative closeness to the ideal solution is given by formula:

$$C_j^* = D_j^- / (D_j^- + D_j^+)$$

3. Case Study

Coefficient of performance of refrigeration system depends on various parameters and refrigerant is one of the process parameters in the system to enhance performance of refrigeration system. Refrigerant consists many chemical and physical properties, they varies refrigerant to refrigerant so if we optimize chemical and physical properties of the refrigerant, it will optimize our system. Some of Physical and chemical properties of the refrigerant is given, and there respective parameters on which the system will improve.

3.1 Physical Properties of Refrigerant

3.1.1. Low Freezing Point

Refrigerants should have low freezing point than the normal operating conditions. It should not freeze during application. Water for example cannot be used below 0° C.

3.1.2. Low Condensing Pressure

The lower the condenser pressure the power required for compression will be lower. Higher condenser pressure will result in high operating costs. Refrigerants with low boiling points will have high condenser pressure and high vapour density. The condenser tubes have to be designed for higher pressures which also give raise to capital cost of the equipment. If Boiling Point is Low, High Condenser Pressure – Reciprocating Compressor is used. e.g: Ammonia, R22, R12 etc. If Boiling Point is High, Low Condenser Pressure – Centrifugal Compressor is used. Eg: R11, R13 & R114 etc.

3.1.3. High Evaporator Pressure

This is the most important property of refrigerant. In a negative pressure evaporator Atmospheric air or Moisture will Leak into the system. The moisture inside the system will starts freezing at low temperature zones and clogs and chokes the system. Atmospheric air ingression into the system will occupy the heat transfer area and results in poor heat transfer rates. Presence of air will reduce the partial pressure of refrigerant and the condensation temperature will rise. It increasers the condenser pressures and thereby the power consumption for the compressor will also rise. Atmospheric air ingression inside the system may sometime results in explosions if the flammability values of the refrigerants are in wide range. Due to the above disadvantages, Positive evaporator pressure is preferred. Leak outside the system results in refrigerant loss and it can be identified easily and refrigerant loss can be topped up. Moderately high evaporator pressure boosts the compressor suction pressure thus reduces the power costs.

3.1.4. High Critical Pressure

Critical pressure of the refrigerant should be higher than the condenser pressures. Otherwise the zone of condensation decreases and the heat rejection occurs.

3.1.5. High Vapour Density

Refrigerants with High vapour density/ Low specific volume will require a smaller compressors and velocity can be kept small and so the condenser tubes used will also be in smaller diameter.

3.1.6. High Dielectric Strength

In hermetically sealed compressors refrigerant vapor contacts with motor windings and may cause short circuits. Therefore dielectric strength should be high to avoid short circuits.

3.1.7 High Latent Heat of Vapourization

Higher latent heat of vapourization of the refrigerant will result in lower mass flow rates according to the Heat transfer equation. If the mass flow is very small it is difficult to control the flow rates. Therefore ammonia cannot be used for small refrigeration systems.

3.1.8 High Heat Transfer Coefficient

Higher heat transfer coefficient requires smaller area and lower pressure drop. This makes the equipments compact and reduced the operating cost.

3.2. Chemical Properties

3.2.1 Toxicity

Toxicity is the important properties of refrigerants. The refrigerants should be non poisonous to humans and food stuff. The toxicity depends upon the concentration and exposure limits.

3.2.2. Oil Solubility

The lubricating oils must be soluble in Refrigerants. If the oil is not miscible in the refrigerant used and it is heavier it will settle down in the evaporator and reduces the heat transfer. Therefore oil separators are to be employed. If the oil density is less than the refrigerant used and it if it is immiscible, the oil will float on the surface of the refrigerant. Therefore overflow drain is to be provided to remove oil. If the refrigerant velocity is not sufficient, then it cannot carry all oil back into the compressor. It may accumulate in evaporator. This phenomenon is called Oil logging.

3.2.3. Low Water Solubility

Most of the refrigerants form acids or bases in the presence of water. This will cause corrosion and deteriorates valves, Seals and Metallic parts. Insulation of windings in hermetic compressors will also get damaged. The free water apart from the dissolved water in refrigerant freezes below 0^0 C and chokes the narrow orifice of expansion valve. This may also cause bursting of the tubes.

3.2.4. Low Water Solubility

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After the discussion of chemical and physical properties of refrigerant we have a clear that if we improve those properties which are beneficial to our refrigerant system and minimize those which are harmful to our system or environment. There are many refrigerant available in the market. All the data regarding to refrigerant's properties are taken from National Refrigerant Reference Guide Book. National Refrigerants programs and publications are designed solely to help customers maintain their professional competence. In dealing with specific technical matters, customers using National Refrigerants publications or orally conveyed information should also refer to the original sources of authority. The manufacturer's recommendations should always be followed to assure optimum performance and safety. Some of the refrigerant and there Properties given in the Table 1

Table 2: Properties of refrigerants

Physical Properties of Refrigerants	R-11	R-22	R-123	R 134a
Environmental Classification	CFC	HCFC	HCFC	HCFC
Critical Pressure (psia)	639.3	723.7	531.1	588.3
Critical Temperature (F)	388	205.1	362.6	213.8
Critica lDensity(lb./ft^3)	34.6	32.7	34.3	32.0
Liquid Density (70 F, lb./ft^3)	92.73	75.3	91.95	76.2
Vapor Density (bp, lb./ft^3)	0.365	0.294	0.404	0.328
Heat of Vapourization (bp, BTU/lb.)	77.9	100.5	73.2	93.3
Specific Heat Liquid (70 F, BTU/lb. F)	0.2093	0.2967	0.2329	0.3366
Specific Heat Vapour (1atm,70F, BTU/lb. F)	0.1444	0.1573	0.1645	0.2021
Ozone Depletion Potential(CFC11 =1.0)	1.0	0.05	0.0015	0

Now our challenge is to find the best refrigerant in R-11,R-22,R-123,R-134a with respect to these attribute given in the Table 1.Now it is clear that we have four alternative(Critical Pressure Heat of vapourization Vapour density Specific heat of vapour) and four attributes (R-11,R-22,R-123,R-134a) to

Table 2: Development Matrix

optimize our design and development matrix given in the table 2

Alternatives /Criteria	*Critical Pressure*	*Heat of Vaporization*	*Vapour density*	*Specific heat of vapour*
R-11	639.3	77.9	0.365	0.1444
R-22	723.7	100.5	0.294	0.1573
R-123	531.1	73.2	0.404	0.1645
R-134a	588.3	93.3	0.328	0.2021

3.3 Results and analysis

After the development of decision matrix, inter the value of all the parameters in to the program design in C-Language, which makes our calculation essay and takes less time to conclude our result. Step wise result of TOPSIS is as given below:

```
Development matrix is
639.299988   77.900002   0.365000  0.144400
723.700012   100.500000  0.294000  0.157300
531.099976   73.199997   0.404000  0.164500
588.299988   93.300003   0.328000  0.202100
```

Figure 1: Development Matrix Making From C Programming.

```
Normalised matrics is:
0.511750  0.448028  0.521183  0.428618
0.579310  0.578008  0.419803  0.466909
0.425137  0.420997  0.576872  0.488280
0.470925  0.536599  0.468351  0.599887
```

Figure 2: Normalized Matrix From C-Programming

```
Variance of attributes:
0.003209   0.004075   0.003436  0.004060

Weight of diff attributes:
0.217130   0.275719   0.232474  0.274678
```

Figure 3: Variance and Weight of each attributes from C-Programming

```
Weight normalised matrix
0.111116   0.123530   0.121162  0.117732
0.125785   0.159368   0.097593  0.128249
0.092310   0.116077   0.134108  0.134120
0.102252   0.147950   0.108880  0.164776
```

Figure 4: Weight normalized matrix from C-Programming.

```
Positive Ideal Solutions:
0.125785   0.159368  0.134108  0.164776
Negative Ideal Solutions:
0.092310   0.116077  0.097593  0.117732
```

Figure 5: Ideal positive and Ideal negative solutions from C-Programming.

```
Distance from positive ideal solution
0.062292 0.051648    0.062726    0.036341
Distance from Negative ideal solution
0.031059 0.055726    0.040023    0.058781
```

Figure 6: Distance of ideal solution by C-programming.

```
Relative Closeness to the Ideal solution:
0.332716   0.518990   0.389526   0.617957
```

Figure 7: Relative closeness to ideal solution from C-Programming.

The result obtained by TOPSIS method design in C-Programming were utilized in finding the ranking of refrigerant for refrigeration system using variances and weights as given above. By TOPSIS design in C-Programming method, the relative closeness coefficient ranking was found to be in the order R-134a, R-22, R-123, R-11. It is clear from the figure7 that R-134a have the largest value (Tending to unit) followed by R-22, R-123 and R-11.for cross-verification of result TOPSIS using SDI TOOLS methods were utilized in finding the ranking of refrigerant for refrigeration system using variances and weights as given above. The relative closeness coefficient ranking was found to be in the same order as in TOPSIS method design in C programming. The result TOPSIS using SDI TOOLS is given in the figure 8.

TOPSIS

Project: OPTIMIZATION PROCESS
Program: PROJECT
Facilitator: ER. JITENDRA KUMAR
Date: 5/11/2016

Team Members:
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AJAY KUMAR SONAKAR
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PRIYANKA KUMARI

Criteria		Units	Importance	Options 1 R-11	2 R-22	3 R-123	4 R-134a	Goal	- Ideal	+ Ideal
1	CRITICAL PRESSURE	Psia	1	639.3	723.7	531.1	588.3	maximize	531.1	723.7
2	HEAT OF VAPOURISATION	BTU/lb	1	77.9	100.5	73.2	93.3	maximize	73.2	100.5
3	VAPOUR DENSITY	lb/ft^3	1	0.365	0.294	0.404	0.328	maximize	0.294	0.404
4	SPECIFIC HEAT OF VAPOUR	BTU/lb	1	0.1444	0.1573	0.1645	0.2021	maximize	0.1444	0.2021
			Score	0.37	0.52	0.41	0.58			

Figure 8: Result obtained by SDI Tool

The Figure 9 clearly depicts the correlation coefficient between TOPSIS using C-Programming and TOPSIS method using SDI TOOL. Here, p-value is 0.002 which is more less than 0.05 which clearly indicates TOPSIS using C-Programming and TOPSIS method using SDI TOOL method highly correlates with each other.

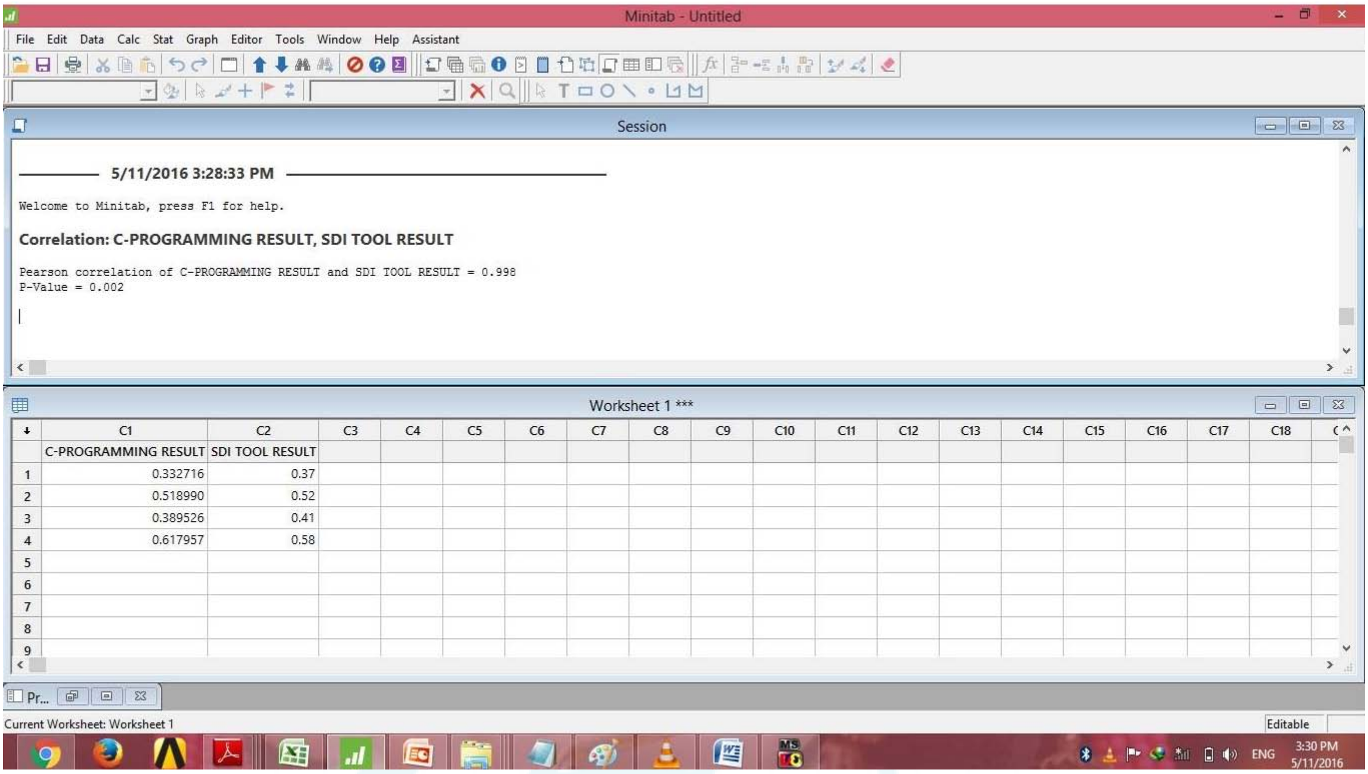

Figure 9: correlation coefficient by MINITAB

4. Conclusion

The most popular multi-criteria decision making algorithms TOPSIS becomes very complicated and calculative when there is greater than 4 alternatives and Criteria for a particular problem. So, TOPSIS design in C-Programming not only increases the accuracy of result but also make easy to calculate any number of alternatives and criteria. The TOPSIS modelling using C-Programming for solution quality when applied to a benchmarking problem in refrigerant selection for refrigeration system on the basis of some selected criteria which enhance the efficiency of refrigeration system. With the help of normalized decision matrix methods we estimate criteria weights so that human judgment can be avoided by assigning weights to different attributes. The results show that one of the refrigerant is the highest ranked by both methods. Being the highest ranked alternative by the TOPSIS modelling in C-Programming method indicates that this refrigerant is the best in terms of the ranking index. In addition, being the highest ranked alternative by the TOPSIS using SDI TOOL method indicates that it is the closest to the ideal solution, and to be as close as possible to the ideal is the rationale of human choice. Both the methods result in same preference of selecting a refrigerant for refrigeration system. As discussed above, TOPSIS method design in C-Programming and TOPSIS method using SDI TOOL software indicates that refrigerant R-134a is the best in terms of the ranking index C_j^*.

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