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A Meta Heuristic Method Representation for Selection of Alternative Energy Production Methods

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Abstract

In the science of operation research and decision theory, selection is the most important process. Selection is a process that studies multiple qualitative and quantitative criteria, related to the science of management, which are mostly incompatible with each other. The multi criteria selection of a renewable energy portfolio is one of the main issues considered in multi criteria literature. In the present study to form a portfolio of renewable energy, first, the KOHONEN neural network algorithm was used, and then each portfolio was evaluated using multi criteria decision-making methods. Further, through Meta heuristic multi objective algorithms Pareto rank analysis was conducted and social acceptance of renewable energy production methods was assessed. Finally, the portfolio for studied energies was composed. The results indicated that Cuckoo Search Algorithm and Grey Relational Analysis are effective and efficient for the selection of optimal Pareto portfolio of renewable energy.

Keywords: Energy; Portfolio; Algorithm; KOHONEN; Cuckoo Search Algorithm.

Introduction

Energy is vital for human survival. It is the decisive element in the economic development of communities and lack of energy directly reduces economic growth. As such human life is linked with energy (Yang, 2015). 81% of current energy is supplied by traditional methods, based on fossil energy. It is predicted that between the years of 2007 and 2030 the demand for fossil fuels will rise. The largest growth rate belongs to the consumption of coal, oil and gas, which are respectively 53%, 42% and 24% (Tasri, 2014). However, the use of fossil fuels releases carbon dioxide and other environmental pollutants, which in turn have a negative impact on the atmosphere. Because of this, politicians, business leaders, consumers, and researchers focus their efforts on the establishment and operation of renewable energies such as solar, wind and biomass energy. Social responsibility is another reason for corporations to pay more attention to sources of energy (Shaikh,2015).

The goal of this study is to design such a multi objective programming model, using first, KOHONEN neural network, based on data envelopment analysis; second, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS); third, Grey Relational Analysis; and, finally, VIKOR analysis, that will enable to determine the most reliable methods for the renewable energy production. The multi criteria decision making is the main problem of the study. These criteria can be qualitative or quantitative. A quantitative factor such as the cost of the project is essentially measurable by a ratio scale, while qualitative factors such as flexibility in the project can be converted into numbers by an ordinal scale. The goal of multi criteria decision making is to find the best possible solution. The formation of multi criteria decision making models can be divided into four categories based on philosophical and intellectual principals: clustering, ranking, descriptive and ordinal (Belton, 2002). Recently, researchers of quantitative management models are trying to find a way to combine data mining and clustering with multi criteria decision making theory and consequently expand the theoretical and practical atmosphere in both fields (Kantardzic, 2011). KOHONEN neural network is considered to be an algorithm which belongs to the field of data mining, artificial neural network and data clustering. This study performs a Pareto analysis with two objectives of rank and social acceptance of renewable energy projects and composes a portfolio of renewable energy based solutions. First, effective factors on renewable energies based on environmental risk factors are identified and limited using a feature selection algorithm. Second, energy types under study are clustered using the KOHONEN neural network. Then, each cluster is ranked independently using the grey relational analysis, data envelopment analysis, TOPSIS and VIKOR method. Finally the Pareto optimal solution ranking and socially acceptability of studied energy types are analyzed and examined in multi criteria selection mode using cuckoo, bees, moss and fireflies algorithms and biogeography based optimization.

This paper is structured as follows: literature review, research tools, a framework for portfolio selection**,** results, and conclusion.

Literature Review

This section discusses previous researches in the field of renewable energy production methods. Afghan and Karavalo have used the multi criteria decision-making model to assess the renewable energy types. The aim of their study was to describe the indexes used in energy systems related to sustainable development. Assessment indexes in this study include efficiency, the cost of installation of utilities, the cost of electricity and the desired area, which are described based on energy resources, potential environmental resources and economic and social factors (Afgan,2002).

Alcaraz and Shibli used the game theory to model the energy market. The main variables studied in this research are consumer's cost in the fuel market, the amount of fuel purchased by a customer, consumer's cost in the market, the heat factor of the fuel and the heat factor of electricity. The study investigates the fuel and electricity market and consumers behavior (Gutiérrez-Alcaraz,2009). Ghahreman et. al. used the analytic hierarchy process model and axiomatic design for the problem of proposed methods of estimation of the best alternative renewable energy. Main factors of the study were related to the technical, environmental, social, political and economic aspects (Kahraman,2009). Kaya and Ghahreman used the analytic hierarchy process model and VIKOR model for the renewable energy analysis. Indicators were rated based on technical, economic, environmental and social factors. The research population in this study will face energy shortages, rising energy prices and instability in the energy markets in the next decades. In addition, dependence on fossil fuels will result in global warnings and environmental consequences (Kaya, 2010). Beccali used a multi objective decision making model and approximate control method to study renewable energy and power plant construction. Variables of the study were ranked based on technical, economic, environmental and social factors. According to the study, approximate control method helps the decision makers to choose the most appropriate modern technologies related to the production of energy (Beccali, 2003). Cristobel used the VIKOR model to select the suitable renewable energy type. In 2005, the Spanish government approved a new law for the use of a renewable energy type to be selected from wind power, hydroelectric power, solar heating, generating electricity from heat, light, power generation, biomass, natural gas and biofuels, and the model has been presented in response to the law (San Cristóbal, 2011). Amer and Dayem used the analytical hierarchy process model to study the renewable energy issue. The population of the study is a country, which faces problems, resulted from the shortage of energy. Shortage of energy and especially electricity had a negative impact on the economy. Due to a significant increase in the use of fossil fuels and therefore increase of imports especially crude oil a heavy burden is imposed on the economy. That is why this study aims to come up with a comprehensive strategy and to promote the indigenous and compatible aspects of it. In this study the energies of wind, sunlight, solar heat and biomass energy are analyzed as alternatives fuels in generation of electricity, in terms of technical, economic, social, environmental and political aspects. Variables of the study include research and development cost, finance, maintenance cost, electricity, technology maturity, capacity, reliability, expansion time, availability of expert personnel and availability of distribution networks (Amer, 2011). The aim of the study was to design and model a steam generation factory using solar energy and to predict the performance of solar hot water systems (Kalogirou, 2001). Yazdani et al (2014) used the analytical hierarchy process model and Kupras model to study the renewable energy type. The results of this study show the impact, effectiveness and efficiency of the model in the selection of the most suitable option for renewable energy (Yazdani-Chamzini, 2013). Ghahreman and colleagues used the analytical hierarchy process model, axiomatic design theory, and CHOQET integral for the renewable energy selection problem. The main purpose of this study was to analyze the interactions between the criteria set by CHOQET integral (Kahraman, 2010).

Research Tools

The method included two descriptive - mathematical modeling approaches. The study population consists of all renewable energy production technologies. The following research tools have been used for this study:

- **KOHONEN algorithm:** KOHONEN algorithm organizes the network nodes into local neighbors so that they can classify the characteristics of the input data. Network topographic map is automatically formed by periodic comparison between each nod and the vector, which is saved in its communication lines by that nod.
- **The Technique for Order of Preference by Similarity to Ideal Solution:** The Technique for Order of Preference by Similarity to Ideal Solution is a compromising decision making method based on minimizing the alternative evaluation vector from the positive ideal spot and maximizing it from the negative ideal point (Hwang,1981). Based on this concept the best option or factor is the one which is closest to the positive ideal spot and furthest from negative ideal spot (Wang, 2006).
- **Data envelopment analysis:** In this model the evaluated system has n decision making units which are DMU_1, DMU_2,…, DMU_n .Each m consumes one of the input DMU_j $X = (x_{1j}, x_{2j}, ..., x_{mj})$ in order to create the output S $Y = (y_{1j}, y_{2j}, ..., y_{nj})$. Inputs and outputs of each DMU are always positive and each DMU always has at least one positive input and output in other words $X \geq 0, X \neq 0, Y \geq 0, Y \neq 0$ (Farrell,1957). According to the model 1 efficiency is the sum of the weighted outputs divided by the sum of weighted inputs. This ratio is calculated for each organizational unit j which has m inputs and S outputs are calculated by model 1.

Model 1

$$Max\, Z_p = \frac{\sum_{r=1}^{n} u_r v_{rp}}{\sum_{i=1}^{m} v_i x_{ip}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r v_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$j = 1, 2, ..., n$$

$$V_i \geq 0$$

$$U_r \geq 0$$

X_{ij} : The amount of the i[th] input and j[th] unit) i=1,2,…m)

Y_{rj} : The amount of the r[th] output and j[th] unit (r=1,2,….s)

U_r : The output weighs of r.

V_i : The input weigh of i. the number of analyzed units are (j=1,2.…,n)

- **Gray relational analysis:** Gray relational analysis defines a multi criteria decision making in the form of a system of m sequence and length n and introduces the sequence of reference. Furthermore, offers a quantitative method to measure the distance between each corresponding sequence to each option and a reference sequence (Chen,2004). Grey relational analysis is a model that measures the effect of changes between two systems or two components of the same system at the same time. Therefore gray relational analysis studies the unrecognized relationships among the objects, component and system behavior (Tzeng,2011).
- **VIKOR:** VIKOR method has been developed for multi criteria optimization of complex systems. The focus of this method is on the ranking and selection of options despite of conflicting criteria. This method offers a compromising solution and is able to stabilize the process of decision making by replacing the compromised solution with initially obtained weight. The compromise theory solution is a practical solution that is close to the ideal solution, and compromise means an agreement, which is formed by mutual rankings. VIKOR method provides the maximum productivity of the "majority" group and the minimum of personal regret of the "Disagree" group and the compromising solution can easily be accepted by decision makers (Bazzazi,2011).
- **Feature Selection:** Data mining problems may involve hundreds and thousands of features that could potentially act as a predictor and so a lot of time and effort must be spent to determine which features should be included in the model. Selection of features includes sorting and removing non-critical records like predictors that have many missing values, ranking the remaining predictors and selection of a subset of features to use in subsequent models (Lin,2008).
- **Cuckoo Search algorithm:** Similar to all other algorithms of evolution, this algorithm starts with an initial population, a population of cuckoos. The population of cuckoos lay some eggs in the nests of other birds. Some of these eggs that are more similar to the host bird's eggs are more likely to hatch and become mature cuckoos. Other eggs are identified and destroyed by the host bird. The number of hatched eggs is an indication of the suitability of the area. The more the number of survived eggs are in the area, the more beneficial that area becomes for the cuckoos. So, the Cuckoo is trying to optimize the parameters of a condition in which maximum eggs can survive. Cuckoos are looking for the best area to maximize their survival. After the chicks were hatched and matured into adult cuckoos, they form communities and groups. Each group has a special residential area to live. The best residential area for all cuckoos is the

next destination for other groups. All existing groups migrate to the best existing area. Each group will be living in an area close to the current best position. Considering the number of eggs that each cuckoo lays and the distance between cuckoos and the optimum point a number of egg laying radiuses are formed. The cuckoo begins to lay eggs randomly in nests within their own radius of laying egg. This radius is defined as follow:

$$ELR = a' \frac{number\ of\ current\ cuckoos\ eggs}{total\ number\ of\ eggs} ' (var_{hi} - var_{low}) \qquad (1)$$

a is the variable that determines the maximum radius of laying egg.
Var_{hi} is the maximum and Var_{low} is the minimum of the variables. This process will continue until the best area for laying eggs is determined. This optimum point is the point, which the most cuckoos will gather in. After some repetitions, the population of cuckoos will convert to one point with the most similarity of eggs with the host's eggs and with the most food. This area will have the total benefit and the minimum number of eggs will be destroyed. The convergence of more than 95 % of all birds to one area indicates the end of the cuckoo search algorithm. In nature, each cuckoo lays 5 to 20 eggs. These numbers are used as the maximum and minimum values of eggs for each cuckoo in different repetitions (Rajabioun, 2011).

A Framework for Portfolio Selection

Figure 1 presents a new framework for the selection of renewable energy types.

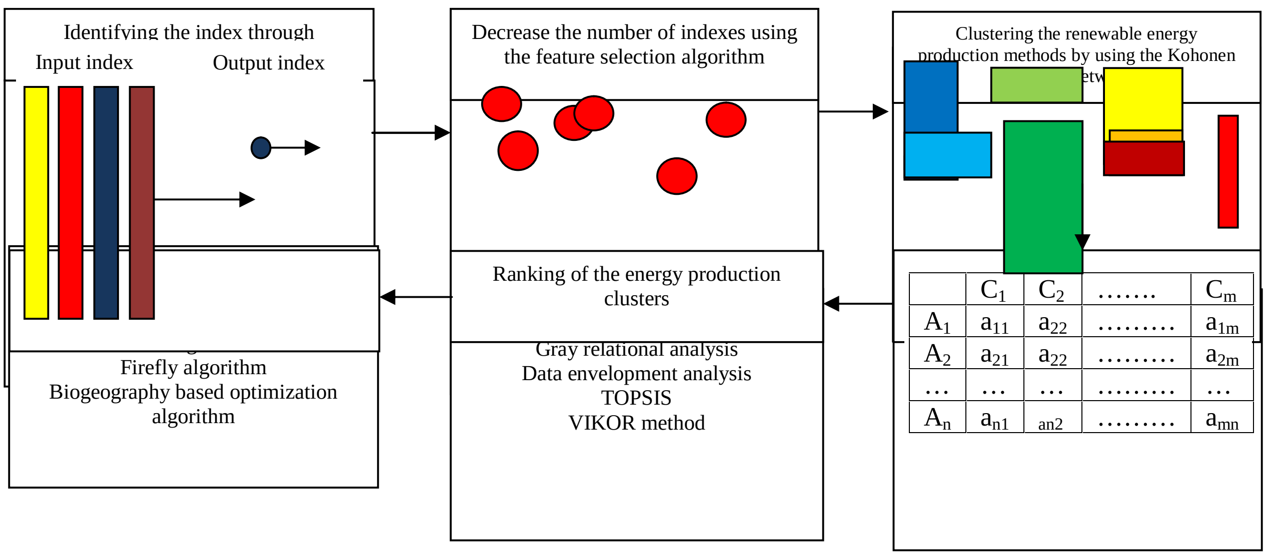

Figure 1: New Framework for the Selection of Construction of Renewable Energy Production Plant Project

According to the figure 1 the new framework for the selection of construction of renewable energy production plant project includes 6 steps:

- **Initial identification of the indexes**: In this step, 32 main indexes with the most impact on construction of renewable energy production project are selected through interview with experts and study of existing literature.

- **Decreasing the number of indexes using the feature selection algorithm:** Considering the multiplicity of factors affecting the selection of an optimal portfolio of projects and the complexity of the different aspects of the problem the feature selection algorithm is used.

- **Clustering the renewable energy**: In this step, 15 methods of renewable energy production are categorized into nine ranks using the KOHONEN neural network.

- **Forming the independent decision matrix for each cluster**: In this step, the Kohonen neural network was used and a decision matrix was formed for each of the nine clusters with multi-criteria using feature selection algorithm.

- **Ranking of the energy production clusters**: Each of the decision matrixes is ranked using the gray relational analysis, data envelopment analysis, TOPSIS and VIKOR methods.

- **Pareto analysis of rank and social acceptability of renewable energy projects:** Pareto analysis was carried out using meta heuristic multi criteria algorithms including Cuckoo Search Algorithm, Bees Algorithm, Invasive Weed Optimization Algorithm, Firefly Algorithm and biogeography based optimization. It should be noted that based on the results of VIKOR and gray relational analysis were only two of the mentioned rankings were considered in Pareto analysis at this stage.

Results

In this section, the results and a new approach is presented for the selection of renewable energy. First 15 energy types as alternatives for electricity are studied based on four factors: technical, economic, environmental and social. The total number of indexes is 32. Input data is presented in Table 1.

To reduce the magnitude of the problem the feature selection algorithm in Clementine 12 software is used. The impact of greenhouse gases is considered as output. After applying feature selection algorithm 6, main variables are remained which are shown in Table 2.

Table 1: Input Data

Energy	Feasibility	Risk	Reliability	Energy saving	Technology maturity	Installation cost	Maintenance cost	Social acceptability	Market maturity	Emissions rate	Greenhouse emissions limitation
A_1	VH	L	L	L	H	H	M	VH	H	H	VL
A_2	H	L	M	H	L	VH	M	L	M	VH	M
A_3	L	H	M	VH	M	VH	L	VH	H	M	H
A_4	M	VH	H	H	VH	VL	M	H	VH	بد	H
A_5	VL	M	VH	L	H	H	VH	H	M	M	H
A_6	H	VH	M	M	M	L	VL	M	M	VH	L
A_7	L	L	VL	H	VH	VH	H	H	L	L	L
A_8	VH	L	L	L	H	M	M	VL	VL	M	H
A_9	VH	M	H	L	L	L	H	L	VH	H	L
A_{10}	M	L	H	VL	L	VH	L	H	VL	VH	H
A_{11}	L	L	VH	H	L	L	M	L	M	M	L
A_{12}	H	M	M	VH	VL	M	H	H	H	L	VL
A_{13}	M	H	H	L	M	VH	VH	H	L	H	H
A_{14}	H	VL	M	M	L	L	M	H	L	VH	L
A_{15}	VH	VL	H	H	M	VH	L	L	VL	VH	VL

Table 2: Results of Feature Selection Algorithm

Variables name	Value	Rank
Market maturity	0.772	1
Maturity of the technology	0.625	2
Risk	0.482	3
Installation and commission cost	0.446	4
Maintenance cost	0.436	5
The emissions rate	0.403	6
Feasibility	0.363	7
Social acceptability	0.362	8
Energy saving	0.218	9
Reliability	0.185	10

Table 3: The Clustering of Energies

Alternative	A1	A2	A3	A4	A5	A6	A7
Cluster	1	2	3	4	5	6	7

Alternative	A8	A9	A10	A11	A12	A13	A14	A15
Cluster	1	4	2	6	4	3	6	3

Table 4: The Results of Ranking of Approaches in Each Cluster

Cluster	DEA	TOPSIS	GRA	VIKOR
1	$A_1 > A_8$	$A_1 > A_8$	$A_1 > A_8$	$A_1 > A_8$
2	$A_2 > A_{10}$	$A_2 > A_{10}$	$A_2 > A_{10}$	$A_2 > A_{10}$
3	$A_{13} > A_3 > A_{15}$	$A_3 > A_{13} > A_{15}$*	$A_{13} > A_3 > A_{15}$	$A_{13} > A_3 > A_{15}$
4	$A_4 > A_9 > A_{12}$	$A_4 > A_9 > A_{12}$	$A_4 > A_9 > A_{12}$	$A_4 > A_9 > A_{12}$
5	A_5	A_5	A_5	A_5
6	$A_6 > A_{11} > A_{14}$	$A_6 > A_{11} > A_{14}$	$A_6 > A_{11} > A_{14}$	$A_6 > A_{11} > A_{14}$
7	A_7	A_7	A_7	A_7

The risk index, the cost of installation, maintenance cost and emission are "the less the better" types, while maturity of the technology and market maturity indexes are "the more, the better" types.

The results of the data clustering by KOHONEN algorithms are shown in Table3.

The desired energy types are clustered independently using data envelopment analysis, Supper Efficiency method, TOPSIS, gray relational analysis and VIKOR method. The ranking results are shown in table 4.

For stability analysis, the approaches in each cluster were repeated. For example, in the first cluster, the first, the second and the third approaches are repeated respectively. If there are no changes in the rankings of the first, the second and the third approaches, the approach is robust. The results of this experiment indicated that gray relational analysis and VIKOR are robust. Based on the robustness rankings of these two techniques the models 2 and 3 are presented below:

Model 2

$$\text{Max } z_1=x_1+x_2+0.625x_3+x_4+x_5+x_6+x_7+x_8+0.408x_9+x_{10}+0.388x_{11}+x_{12}+x_{13}+x_{14}+x_{15}$$

$$\text{Max } z_2=9x_1+3x_2+9x_3+7x_4+7x_5+5x_6+7x_7+x_8+3x_9+7x_{10}+3x_{11}+7x_{12}+7x_{13}+7x_{14}+3x_{15}$$

Subject to:

$$3000x_1+1500x_2+2700x_3+3600x_4+99000x_5+44000x_6+7200x_7+6300x_8+2560x_9+1780x_{10}+9930x_{11}+4511x_{12}+1111x_{13}+8690x_{14}+1111x_{15}\leq 40000$$

$$x_1+x_4\leq 1$$

$$x_2+x_5\leq 1$$

$$x_6+x_8\leq 1$$

$$x_{11}+x_{15}\leq 1$$

$$x_{ij}\geq 0$$

$$i=1,2,\ldots,15$$

Model 3

$$\text{Max } z_1=0.972x_1+x_2+0.722x_3+0.908x_4+x_5+0.852x_6+x_7+0.313x_8+0.519x_9+0.285x_{10}+0.522x_{11}+0.377x_{12}+0.783x_{13}+0.368x_{14}+0.28515x_{15}$$

$$\text{Max } z_2=9x_1+3x_2+9x_3+7x_4+7x_5+5x_6+7x_7+x_8+3x_9+7x_{10}+3x_{11}+7x_{12}+7x_{13}+7x_{14}+3x_{15}$$

Subject to:

$$3000x_1+1500x_2+2700x_3+3600x_4+99000x_5+44000x_6+7200x_7+6300x_8+2560x_9+1780x_{10}+9930x_{11}+4511x_{12}+1111x_{13}+8690x_{14}+1111x_{15}\leq 40000$$

$$x_1+x_4\leq 1$$

$$x_2+x_5\leq 1$$

$$x_6+x_8\leq 1$$

$$x_{11}+x_{15}\leq 1$$

$$x_{ij}\geq 0$$

The results of meta heuristic algorithms of Cuckoo Search Algorithm, Bees Algorithm, Invasive Weed Optimization Algorithm, Firefly Algorithm and. Biogeography based optimization are shown in Figure 2. As it can be seen, gray relational analysis ranking results of biogeography based optimization provides better optimization

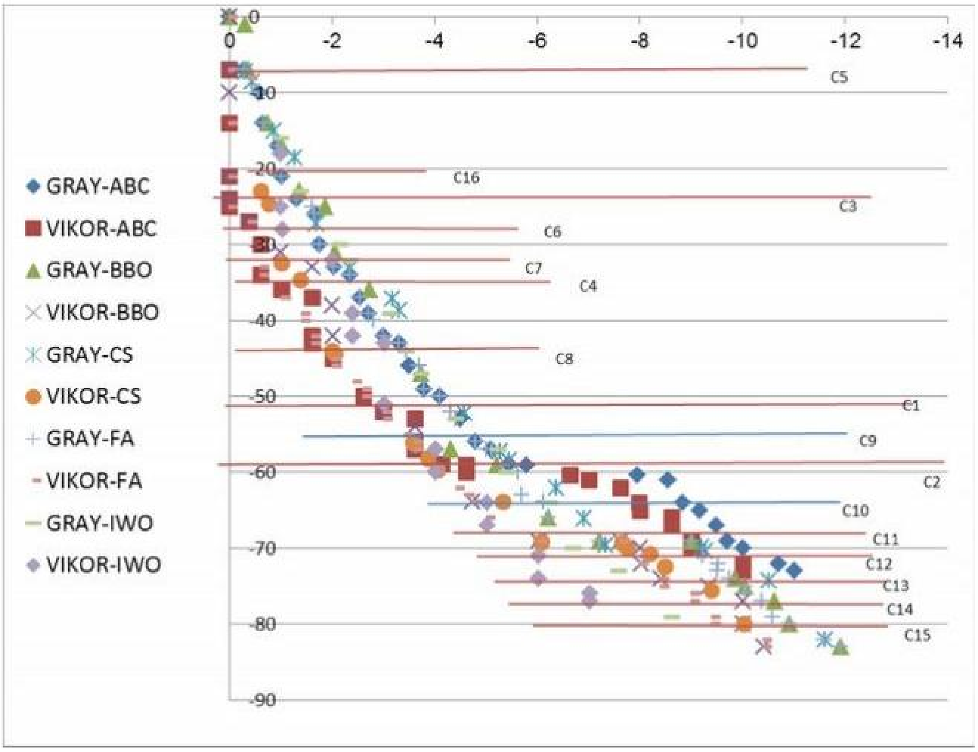

Figure 2: The Results of Meta Heuristic Algorithms

Conclusion

Multi criteria selection of a portfolio of renewable energy is one of the most important issues in the field of energy management. The aim here is to select an optimum portfolio of available energies based on qualitative and quantitative goals, which are mostly incompatible. Obviously if the selection is optimum, it is correct both from economic and managerial viewpoints.

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