SURROGATE WORTH TRADE OFF METHOD'S REVIEW, APPLICATIONS AND EXTENSION

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Abstract: The paper presents the characterization of the family enterprises in the sector of small and medium-sized enterprises (SME). The focus was on the benefits that can be derived by the enterprises from implementation of innovativeness and cooperation within clusters. The aspects of regional development stimulated by creation of clusters and elements of state support in Poland and the EU were also presented.

Keywords: family enterprise, cluster, innovation

Introduction

In recent years , decision makers and analysts face to many problems with more than one objective .There is no single accepted approach to solve the multi-objective optimization problems .Because of the conflicting nature of objective functions, using one objective method to solve the multi- objective , lead us to situation where the optimization of one of these, may adversely affect the optimization of others. Due to this, decision making methodologies under conflicting multiple objectives have been developed . Multiple objectives decision making (MODM) methods are often used to solve the problems with conflict objectives and large set of alternative.

Among these methods , Surrogate Worth Trade – Off (SWT)method has been used in the several areas of research. This method proposed by Haimes , Hall and Freedom in 1975 for decision making in water resource systems. The original version of SWT is not interactive .Shimizu and others [17] proposed an interactive version of the SWT method .

The general philosophy taken in the interactive approach is that the multi-objective decision making process should follow the three steps procedure[15]:

1) Generate Pareto optimal solution.
2) Obtain meaningful information to interact with the decision maker.
3) use information obtained in step 2 to interact with DM and select the final solution based on the DM preference response.

The "SWT " method uses the ε – constrain problem as a means of generating Pareto solutions. Objective trade- offs , whose values can be easily obtained from the values of some strictly positive multipliers from step 1 are used as the information carrier in step 2.And in step 3 , the DM responds by expressing his

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degree of preference over the prescribed trade – offs by assigning numerical values to each surrogate worth function[16].
SWT emphasizes generation of a range of solutions and trade-offs to be presented to the decision maker for consideration. The main purpose of this method is to produce the set of effective solutions and the analyst helps DM choose the best compromise or most preferred solution.
SWT method could be applied to both discrete and continuous decision-problem scenarios .In continuous problems , a predefined set of alternatives is not available, but discrete problem is characterized by a predefined set of alternatives.This method allows a decision maker to select the best possible options from a larger number of all available alternatives.

Surrogate Worth Trade-Off (SWT) Method

The SWT method is applied to generate surrogate worth functions and can be used in order to guide the decision maker to develop trade-offs among objectives from the set of feasible solutions to find the preferred solution. This technique includes many stages.
After recognition of the problem , another step is to reflect it in the form of a mathematical model, which will take into consideration the limitations of model situation and decision variables and criteria of assessment being the basis for the set of acceptable solutions for the problem[18]. This model determines the value of decision variables and maximize or minimize the objective function(Z) to the specified constraints .The decision variables are represented as $x1,x2,\ldots.xn$. The identification of the decision variables leads to essential answers to the questions that DM is seeking. Constraint functions also restrict and reduce the number of alternatives.
The mathematical model can be represented as follow:

$Z=\max \sum f\, i(x)$

S.t: $gj(x)\leq 0$; $j= 1,2,\ldots..,m$

$xi\geq 0$

After formulating the model ,optimal solution for each objective is computed. Optimal solution can be represented as $f\,1^*, f\,2^*,\ldots.\, f\,n^*$ and $x1^*, x2^*,\ldots..xn^*$.The number of optimization runs for each f ,depends on the number of objectives. In addition this process determines the maximum and minimum values of objectives.
In order to use the SWT method ,one objective should be chosen arbitrarily and others can be expressed as constraint functions. In other words, multi-objective problem is transformed into a single objective problem.

$\text{Max } f\,1(x)$

S.t: $f\,i(x) \geq \varepsilon i$; $i= 2,\ldots..,k$

$gj(x)\leq 0$; $j= 1,2,\ldots..,m$

$xi\geq 0$

εi is expressed below:

$\varepsilon i= f\,i^*(x) - \varepsilon i^*$, $\varepsilon i^*> 0$

εi^* is acceptable deviation from optimal solution of objective i and it is a parametric factor. Maximum and minimum values of objectives determine the lower and upper bounds for the constraint εi values. By this way the analyst ensures that feasible solution to the constraint problem could be generated.

Based on above model, the Lagrange Dual Function is determined .The purpose of Lagrange Duality is to find an upper bounds for a maximization problem or find a lower bounds for a minimization problem.

$L(x,u,\lambda)= f1(x)+\sum\lambda 1i(fi(x)-\varepsilon i)- \sum ujgj(x)$

$i= 2\ldots\ldots k$, $j=1\ldots\ldots\ldots m$, Uj , $\lambda 1i \geq 0$

$\lambda 1i$ and uj are called Lagrange multiplier and they are equal or greater than zero. The variables $\lambda 1i$ are shadow price for the first objective function when εi is changed one unit.

Based on Kuhn Tucker Optimality Condition:

$\partial L/\partial xi \leq 0$

$Xi(\partial L/\partial xi)=0$

$\partial L/\partial\lambda 1i\leq 0$

$\lambda 1i(\partial L/\partial\lambda 1i)=0$

$\partial L/\partial Uj\leq 0$

$Uj(\partial L/\partial Uj)=0$

$xi\geq 0$, $Uj\geq 0$, $\lambda 1i\geq 0$

A set of non-dominated solutions ($x1,x2,\ldots xn$, $f1$, $f2,\ldots$ fn , $\lambda 1i$) is generated and the decision maker's preference is constructed from these solutions .Also $\lambda 1i$ could be determined as follow:

$\lambda 1i= - \partial f1(.) / \partial fi(.)$

The analyst identifies the regression function between the worth (Wij) and trade-off value(λij), by interacting with the DM. Wij ranges from -10 to +10, where +10 means that the DM prefers the change of λij unit of objective i to one unit of objective j. -10 indicates that the DM dose not prefer the change of λij unit of objective i to one unit of objective j. A zero shows that there is no difference between objectives. Finally the preferred solution is defined as the solution with an average worth value close to zero that the DM can not trade between objectives.

Review of Literature

Haimes , Hall and Freedom [8], introduced the SWT method and it has been applied in water resources systems . The SWT method is used to generate surrogate worth functions and it guides the decision maker to develop trade-off among objectives from the set of feasible solutions generated earlier to find the preferred solution.

Hall and Haimes [7],applied the Surrogate Worth Trade-off (SWT) method to multi-objective analyses where multiple decision makers are involved. Three cases are identified; these are the direct group decision-making systems, the representative decision-making systems, and the political decision simulations.

The original version of SWT is not interactive .Shimizu and others [17] proposed an interactive version of the SWT method. In this method , an interactive on-line scheme was constructed in such a way that the values of either the surrogate worth function , and DM must assess his preference at each trail solution.

Sakawa [15] introduced a large-scale multi-objective optimization method for a series-parallel system by applying both the surrogate worth trade-off method and the dual decomposition method in order to obtain the preferred solution of the decision maker. A numerical example for a system composed of 16 subsystems operating in series was solved efficiently by the proposed method.

Sakawa[16],proposed a new interactive multi-objective decision making technique, which is called “ SPOT”. This method combines the desirable features of both the surrogate worth trade – off (SWT)method and multi-attribute utility function(MUF)method .By this method , we are able to drive the preferred solution of the DM efficiently by assessing his marginal rate of substitution and maximizing sequentially the local proxy preference function.

Debeljak ,Haimes and Leach [4] Integrated the SWT method and analytic hierarchy Process (AHP) in order to solve the long term and strategic decision making in multinational companies.

Nangia and others[11], in order to achieve the best compromise between cost of generation and system transmission losses used the surrogate worth trade-off technique (SWT) .The results have been compared with the existing method and they found that the SWT technique gives encouraging results.

Dhilon and Kothari [5],used “SWT” method for multi-objective thermal power dispatch problem. In this study, ϵ-constraint method is used to generate non-inferior solutions along with the trade-off function between the conflicting objectives. The SWT functions are constructed in the functional space and then are transformed into the decision space. So, SWT functions relate the decision maker's preferences to non-inferior solutions. The validity and effectiveness of the method have been proved by analyzing a six-generator system .

Chen and Others [2], presented an interactive surrogate worth trade-off (ISWT) method for multi-objective decision-making in reactive power sources planning. The proposed solution scheme is an interactive architecture, which allows the complex details of the internal structure of the multi-objective decision-making problem to be effectively exploited and, at the same time, provides an effective mechanism for treating other important "subjective" elements. This presented method is based on objective trade-off analysis and can obtain a desirable, global non-inferior solution.

Marsden and others [10],applied the surrogate management framework (SMF),in order to design the shape and minimize aerodynamic noise .Shape optimization is applied to time-dependent trailing-edge flow. Using SMF, design space exploration is performed not with the expensive actual function but with an inexpensive surrogate function. The use of a polling step in the SMF guarantees that the algorithm generates a convergent subsequence of mesh points, each iterate of which is a local minimizer of the cost function on a mesh in the parameter space. Results are presented for an unsteady laminar flow past an acoustically compact airfoil.

Chowdhury and Tan [3], presented a framework based on multi-objective optimization that can be used to generate and analyze the most desirable transportation investment options based on their objectives and constraints. The framework, which is based on the SWT analysis, could be applied to both discrete or continuous decision-problem scenarios. In a discrete problem, a pre-defined set of alternatives is available, whereas continuous problems are not characterized by a pre-defined set of alternatives. This framework was applied with the data generated for a Capital Beltway Corridor investment study. The multi-objective decision-making framework was found to be adaptable to this typical investment case study.

Singn and Dhilon [14],presented an explicit interactive trade-off analysis based on the SWT function to determine the best compromised solution in the multi-objective framework thermal power dispatch problem. This Problem is undertaken in which four objectives viz. cost, NO_x emission, SO_x emission and CO_x emission are minimized simultaneously. The SWT functions were constructed in the functional space and then transformed into the decision space, so the SWT functions of objectives relate the decision maker’s preferences to non-inferior solutions through optimal weight patterns. The optimal solution of thermal power dispatch problem was obtained by considering real and reactive power losses. Decoupled load flow analysis was performed to find the transmission losses. The validity of the proposed method was demonstrated on 11-bus, 17-lines IEEE system, comprising of three generators.

Zhang ,Kwok and Yeung , [19] demonstrated the usefulness of surrogate maximization(SM) algorithms by taking logistic regression models. They devised several SM algorithms ,including the standard SM, generalized SM, gradient SM and Quadratic SM algorithms, and their two variants called the conditional surrogate maximization(CSM) and surrogate conditional maximization (SCM) algorithms, by using different surrogate function construction methods.

Perić and Babić [12],by setting the model of multiple criteria program in order to find a solution for a given problem and revised the SWT method ,presented an efficient application of MLP methods to determine an optimal production plan includes product program and technological variants in the metal industry enterprise Richi and Sharma [13], presented a multi-objective decision framework to support decision making process in transportation investment analysis . Instead of transforming all objectives into monetary values, these objectives can be approached on equal basis in their own measures effectiveness ,either in monetary or non-monetary terms. In this study the framework which is based on surrogate worth trade – off analysis , applied to both discrete and continuous decision problem and the combination of the two. This framework applies to a wide range of decision that are required in transportation investment scenarios.

Ghaleh Khondabi and Fallah Tafti [6]used fuzzy theory and surrogate worth trade off method in group decision making problem .The results have shown that it is possible to use linguistic variables to apply SWT method.
Brizzi.A , et.al [1],applied SWT to increase security and certainty factors in power plant in short term.In this study many multi-objective solving methods were offered to DM and optimal operation point was obtained based on worth trade off between objective function.
Iwasawa and others [9],used the SWT method to select preferred solutions to a MO-MDNLP problem with the intent of investigating how this might assist in selecting technology from discrete alternatives. A version of the three-bar truss problem combining discrete material selection and continuous cross sectional areas represented a possible technology selection problem. The non-dominated sets of design points were generated for Aluminum , Titanium and Steel, to represent a material choice problem to the DM.

Applications

Surrogate worth trade off method is used to solve the problem in different situations to both discrete and continuous decision- Scenarios by analysts.SWT is applied to solve the following problems:

1) *The SWT method for static two-objective problems.* The procedure of surrogate worth trade-off method can be divided into two segments. The first one involves the development of information about the trade-off function . The second part uses the information provided by the DM's choices to find the preferred solution.
2) *The SWT method for dynamic two-objective problems* . The SWT method can be used for dynamic systems where the objectives are functions of the state of the system as well as of the decision variables, with both states and decisions time dependent.
3) *The SWT method for static n-objective problems.* Analyst can be extended the algorithms of static two-objective problems for static n- objective problems. In this situation the c-constraint approach is useful for linear problems, and in other problems analyst should generate enough values to have valid approximations to the worth functions.
4) *The SWT method for dynamic n-objective problems.* In this situation L-constraint method is useful for linear problems, and in other problems analyst should try to generate enough values to have valid approximations to the worth.

In addition the SWT technique can be applied in several areas of studies such as :

- To solve the Reid and Vemuri multi-objective problem in water resources.
- To solve the problems of economic factors and financial return on the investment and other factors such as quality of life and preservation of the environment in transportation projects.

- To evaluate the safety of automobile designs in terms of crash occurrence and severity of injury.
- To solve the long term and strategic decision making in multinational companies.
- To solve multi-objective thermal power dispatch problem.
- To design the shape of plant in order to minimize the noise ,time and cost .
- For planning of the reactive power sources.
- To select the facilitate technology.
- To solve the problem of pollution control.

Extension of SWT

Due to the development of the Surrogate Worth Trade-Off method , a feasible way is generated to solve the problem of multi-objectives. Many analyzing systems are based on concept of a single decision –maker, whereas in most systems ,decision are made by group of individuals, such as board of directors, civil systems , parliament and so on. Each member of group has special view, idea and interest. Due to the importance of group decision making, development of techniques in order to make decision by group should be considered.

As explained above ,SWT method includes 3 steps. In first and second steps Pareto optimal solution and meaningful information are obtained. In third step the information of second step is used to interact with DM and select the final solution based on the DM preference response.

In this paper we propose a method to use the SWT technique with group of decision makers(DMs) and demonstrate it with a numerical example. This method has seven steps as follows:

1) After Pareto optimal solution and meaningful information are obtained , trade off functions λli are computed.
2) λli are given to DMs and search a preferred solution among effective solutions.
3) Apply the simple scale enables DMs to express individually their opinion and preference about λli. This scale has 5 concept in order to explain the DMs opinion; Strongly Preferred , Preferred, Indifference, Not Preferred and Strongly not Preferred.
4) Each of the five response would have a numerical value which would be used to measure the DM’s attitude.

Table 1. Numerical Value

Concept	Numerical Value
Strongly Preferred(SP)	5
Preferred(P)	4
Indifference(I)	3
Not Preferred(NP)	2
Strongly Not Preferred(SNP)	1

1) Calculate the Mean and Standard Deviation of each solution. If a DM's opinion is more important than others ,apply weight for each DM. Low Standard Deviation means that the DM's opinions are similar and the high Standard Deviation indicates that there is deference between the DMs ideas about the each solution. If the Standard Deviation would be high ,analyst provides an anonymous summary of the DM's idea from the results in order to express to DMs. Decision-makers are encouraged to revise their earlier answers in light of the replies of other members . The during of this process, the range of the answers will decrease and the group will converge towards the "similar" answer. Finally the mean score of the final step determines the results.
2) Apply Wij ranges from -10 to +10 for the Mean score based on follow:

Table 2. Mean score and Wij

Mean score	Wij
1.00- 1.50	-10
1.51 – 2.0	-8
2.10 - 2.25	-6
2.26 -2.50	-4
2.51-2.75	-2
2.76-3.25	0
3.26-3.50	+2
3.51-3.75	+4
3.76-4.0	+6
4.01-4.5	+8
4.51-5.0	+10

7) Choose the solution which has no deference and the Mean score is between 2.76 and 3.25 .Optimal Values (xi* , fi*) are the final solution for multi-objective problem with group decision –makers.

An example is presented to show these steps. We assume that the number of DMs is 6 and the results of the first step are calculated.

Table 3. Results of the first step

X1	X2	F1	F2	λ12
2.00	1.33	9.50	21.00	0.105
3.10	2.00	11.20	38.00	0.173
4.00	2.67	12.55	45.50	0.253
5.50	3.35	14.32	52.90	0.410

6.25	4.20	18.65	60.30	0.590
7.18	6.25	28.90	77.80	0.833
8.00	5.45	39.07	90.03	0.942
9.86	6.50	45.75	96.95	1.120
10.00	6.80	51.08	101.45	1.623
11.50	7.80	58.50	106.05	1.890
12.20	8.50	64.00	109.04	2.030

In this section λli are given to DMs and search a preferred solution among effective solutions.

Table 4. Results of preferred solution by DMs(steps 2 and 3)

λ12	DM1	DM2	DM3	DM4	DM5	DM6
0.105	SNP	SNP	SNP	P	SNP	SNP
0.173	SNP	NP	SNP	P	SNP	NP
0.253	SNP	NP	NP	P	NP	NP
0.410	NP	NP	NP	P	NP	NP
0.590	NP	I	NP	P	NP	I
0.833	NP	P	I	P	NP	P
0.942	I	P	P	I	I	P
1.120	P	P	P	NP	P	P
1.623	P	P	SP	NP	P	P
1.890	P	SP	SP	NP	P	SP
2.030	SP	SP	SP	NP	SP	SP

Each of the five response has a numerical value as below:

Table 5. Numerical value of response(step 4)

λ12	DM1	DM2	DM3	DM4	DM5	DM6
0.074	1	1	1	4	1	1
0.173	1	2	1	4	1	2
0.253	1	2	2	4	2	2
0.410	2	2	2	4	2	2
0.590	2	3	2	4	2	3
0.833	2	4	3	4	2	4
0.942	3	4	4	3	3	4
1.120	4	4	4	2	4	4
1.623	4	4	5	2	4	4
1.890	4	5	5	2	4	5
2.030	5	5	5	2	5	5

the Mean and Standard Deviation of each solution are calculated:

Table 6. Mean and Standard Deviation of each solution(step 5)

λ12	**Mean**	**Standard Deviation**
0.074	1.50	1.22
0.173	1.83	1.16
0.253	2.16	0.98
0.410	2.33	0.81

0.590	2.67	0.82
0.833	3.16	0.98
0.942	3.50	0.55
1.120	3.67	0.81
1.623	3.83	0.98
1.890	4.17	1.17
2.030	4.50	1.22

Due to the forth DM's opinion ,Standard Deviation is between 0.55 – 1.22.Analyst should express the results to the forth DM in order to revise the earlier answer in light of the replies of other members.
Wij ranges from -10 to +10 for the Mean score are applied:

Table 7. Final Wij(step 6)

Mean score	Wij
1.50	-10
1.83	-8
2.16	-6
2.33	-4
2.67	-2
3.16	0
3.50	+2
3.67	+4
3.83	+6
4.17	+8
4.50	+10

Optimal Values (x1*= 7.18 , x2*=6.25 , f1*=110.5, f2*=66) are the final solution for multi-objective problem with group of decision –makers in the seventh step.

Summary

In recent years, organizations face to multi-objective decision making due to variable , dynamic and complex environment. There is no single accepted approach to solve the multi-objective optimization problems .Because of this, several techniques have been developed. One of these techniques , is Surrogate Worth Trade – Off (SWT) method that is interested to solve the multi-objective problem by analysts and researchers . SWT method proposed by Haimes , Hall and Freedom in 1975 for decision making in water resource systems .It is an interactive approach that includes 3 steps ,such as; Generate Pareto optimal solution , Obtain meaningful information to interact with the decision maker and use information obtained in step 2 to interact with DM and select the final solution based on the DM preference response.
Surrogate worth trade off method is used to solve the problem in different situations and several areas of studies by analysts and researchers. SWT method is applied to solve the static two-objective problems, static n-objective problems, dynamic two-objective problems and dynamic n-objective problems .

This paper, intends to describe the SWT method ,review of literature, applications and extension of this method to solve the multi-objective problems with group decision making.

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PRZEGLĄD METODY „SURROGATE WORTH TRADE-OFF", APLIKACJE I ROZSZERZENIA

Streszczenie: Jednym z najbardziej ważnych obszarów badań w ciągu ostatnich lat, jest metodologia podejmowania decyzji w przypadku wielu sprzecznych celów. W związku z tym, opracowano kilka technik. Wśród nich występuje metoda Surrogate Worth Trade-off – która koncentruje się na rozwiązaniu złożonego przez wielu naukowców i analityków. Niniejszy artykuł ma na celu przegląd i sposób stosowania tej metody. Metoda SWT to podejście, które zapewnia zakłócenia między preferencjami decydenta i modeli matematycznych związanych z niedominującymi rozwiązaniami. W końcowej części artykułu, zaproponowana została metoda w celu wykorzystania SWT przy podejmowaniu wielu decyzji.
Słowa kluczowe: Funkcjonowanie Surrogate Worth, funkcje trade-off, cele wielorakie, grupa decydentów

SURROGATE WORTH 折衷方法的回顧，應用與推廣

摘要：本文提出的家族企業中的小型和中小型企業（SME）的行業特性。重點是，可以由企業來源於實現集群內的創新和合作的好處。通過創建集群和在波蘭和歐盟國家的支持元素的刺激區域發展等方面進行了介紹。

關鍵詞：家族企業，產業集群，創新。