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APPLICATION OF GOAL PROGRAMMING IN THE MANAGEMENT OF THE INSTALLATION OF THE HEATING SYSTEM IN NON-BUSINESS FACILITIES

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Abstract: Contemporary economic and engineering analysis constantly focuses on the application of models with a higher criteria for decision-making. One of the analytical tools that can provide further knowledge, for multi-purpose problems, is known as the "goal programming" (PQ) method for solving multiple-criteria problems to analyze and solve multi-purpose applied problems. Hence, multiple goals and qualitative nature of the scope of managerial and engineering performance require the use of multi-criteria decision-making. For this purpose, this paper discusses a sustainable example to make decisions in the Company "FTTHERMO", which is the area of operation for the management and installation of components for heating systems, respectively with the installation of piping network radiators (RRRG) including installation of electric boiler (EC) in a residential complex. The company operates with small groups of workers, in particular in the case of installing heating equipment in different spaces and different radiators. Company Manager "FTTHERMO" for engaging a group of workers aims to achieve two goals where goal 1 is to make a profit equal to a certain value and goal 2 is to minimize the total time of RRRG and EC testing. During the assembly process of heating equipment, there are limitations on the number of radiators and electric boilers according to the type of dwelling, working hours per one day, working time to install and test RRRG and EC, of course including specific gain from the RRRG installation and EC in euros. Therefore, finding an optimal solution to engaging a group with a certain number of employees is required to achieve an efficient goal-setting solution. The analysis will be done by looking for solutions using the programming of the goals with the help of the PHP Simplex program.
Keywords: Goal Programing, Managing, Descision Making, Thermal Energy.

1. INTRODUCTION

City heaters mainly supply the denser parts of cities and public buildings, such as hospitals, schools and administrative buildings. To this end, the central heating company supplies about 10,000 customers in the services and economy sector in Pristina. While other parts of the city are mainly heated with wood, coal, electricity, pellets, briquettes, and other alternatives. Electric heating is dissipated through the internal installations of buildings, respectively the

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secondary network. In the existing circumstances the new residential construction is mainly installing heating with electric boilers. With this activity, the Company "FTTHERMO" is successfully engaged, which successfully assembles the components for electric heating systems in a residential complex on the outskirts of the city. Connection to the installation of the heating piping system and the commissioning of the boiler The company must perform according to the applicable technical standards by an expert who takes responsibility for this. The company has a certain number of employees divided into small groups. Company management is interested in increasing profits and reducing the length of assembly and testing of components for heating systems. Therefore, in this case, multi-purpose decision-making can be used, respectively, the goal programming. CS seems to be an appropriate technique for decision-making analysis of decision-makers who is in charge of achieving numerous objectives under complex constraints. Decision-making models and modeling of multi-criteria goals are important tools of scientific research in the field of management with extensive applications in engineering and social sciences. Selecting a renewable energy source portfolio is an uncertain multi-criteria decision-making (MCDM) problem[1] So, PQ is the most widely used way of decision-making with many criteria as mentioned by Romero (1991). The PQ modeling structure is easy to understand and apply and can be solved using commercial software for mathematical programming. For detailed mathematical treatment and solutions we refer to readers for some interesting works on the PQ models by Tamiz, Jones and Romero (1997) then by Jones and Tamiz, (2010). Also, this paper deals with the problem of optimal management of energy flow [2] and its distribution to the final consumer

2. GOAL PROGRAMMING APPLICATION TO INSTALL RRRG AND ASSEMBLY OF EC

Community energy system optimization model has great contribution to formulate community energy planning indexes. [3]. Global concerns about climate change and its environmental consequences, social factors and economic constraints require pursuit of a new approach to supply chain planning at strategic, tactical and operational levels. [4] Undoubtedly, in this logic, the part of current energy resource management should be addressed - regardless of whether we are talking about thermal energy.

Multi-criteria decision analysis using a goal programming approach, is a popular and widely used technique to study real world problems involving conflicting objectives due to modelling simplicity and elegance. [5] That’s why we've applied a goal programming model that integrates efficient allocation of labour resources to achieve sustainability objectives relating to economic, energy. [5]

In any case, goal programming is usually applied to linear models. Its main difference from the LP's task is that many purposes are formalized not as goal functions, but as constraints on a more general pattern. For this purpose, the expected quantitative values of goal functions and the so-called variables deviations (variables) are introduced that characterize the degree of achievement of the goals for that decision. The FTTHERMO company assembles components for heating systems, respectively, the installation of radiant grid radiators (RRRG) and installation of electric boiler (EC). RRRG installation depending on the type of flat is limited to 5 radiators per day. For one working day, more than one electric boiler is installed per day. At the same time, it takes 2 hours to install a RRRG, and 8 hours to install a KE. Daily assembly options involving 4 employees are limited to 24 hours of work per day. After assembling, each radiator with grid ring and electric boiler passes the test of control. For the control and testing of a RRRG takes 1 hour, and for KE it takes 2 hours. Based on the norms the Company team, with relevant equipment and apartment type, conducts the testing for less than 8 hours. The specific profit from the RRRG installation is 90 euros and for EC 200 euros.

FTTHERMO managers aim to achieve two goals:

• Goal 1 is to make a profit equal to 800 euros per day for four employees;

• Goal 2 is to minimize the total testing time for the assembled products.

The application of linear programming to solve the problem of maximizing company profits looks like this:

Maximize Profits: $\max(90x_1 + 200x_2)$

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$x_1 \le 5$ –number of RRRG for mounting;

$x_2 \ge 1$ –number of KE for mounting;

$2x_1 + 8x_2 \le 24$ –Intaletion time of RRRG and mounting of KE;

$1x_1 + 2x_2 \le 8$ –Testing time of RRRG and KE;

$x_1, x_2 \le 0$ $x_1, x_2 \ge 0$.

By applying the PHP Simplex software, the optimal solution value is Z = 760, X1 = 4, X2 = 2. The optimal solution of LP problem is: 4 RRRG and 2 KE, while the overall profit of the plan is 760 euros per day for four employees according to Figure 1 and Table 1[6].

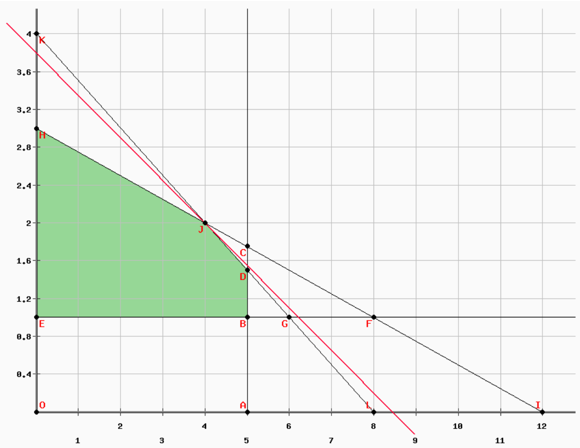


Figure. 1

Point	X coordinate (X_1)	Y coordinate (X_2)	Value of the objetive function (Z)
O	0	0	0
A	5	0	450
B	5	1	650
C	5	1.75	800
D	5	1.5	750
E	0	1	200
F	8	1	920
G	6	1	740
H	0	3	600
I	12	0	1080
J	4	2	760
K	0	4	800
L	8	0	720

Table. 1

The optimal solution to the LP problem is: 4 RRRG and 2 KE, while the overall profit of the plan is 760 euros.

Consider Purpose 1 by introducing two variable deviations [7]:

d_1^- –"insufficient" variable that indicates the amount of profit less than the value of 800 euros,

d_1^+ –is an "excessive" variable, which shows how much the amount of profit exceeds the value of 800 euros.

The variable d_1^- is responsible for the degree of achievement of the first goal, if = 0, then the goal is achieved. If $\min d_1^-$ – is a positive value then the goal is inaccessible.

Then the limitation of the purpose (soft) can be written.

$$90x_1 + 200x_2 + d_1^- - d_1^+ = 800$$

$$d_1^- \geq 0, d_1^+ \geq 0$$

Assuming that 8 hours is the standard testing time, we can formulate a second limitation by introducing new variable variables:

d_2^- – "insufficient" variable indicating how much testing time is less than 8 hours;

d_2^+ –is an "oversized" variable that shows how long the test lasts 8 hours.

The variable is responsible for the degree of achievement of the second goal if, then, the goal is achieved. If □ the value is positive then the goal is inaccessible.

Then you can write down the second goal limitation (soft).

$$1x_1 + 2x_2 + d_2^- - d_2^+ = 8$$

$d_2^- \geq 0, d_2^+ \geq 0$

The flexibility to select "inadequate" and "excessive" values enables the programming of the goal to reach compromise solutions.

There are several goals programming methods, but we consider the method of weight ratios and the method of priorities [8].

2.2. THE METHOD OF WEIGHT COEFFICIENTS

In the weight coefficient method, a single objective function is formalized as the weighted (weighed) sum of the specific resource functions of the goal. In the task we are considering, if Goal 1 takes precedence over Purpose 2. This weighted function takes the form:

$\min(P_1 d_1^- + P_2 d_2^+)$ with limitations:

$x_1 \leq 5$,

$x_2 \geq 1$

$2x_1 + 8x_2 \leq 24$,

$x_1, x_2 \geq 0$,

$90x_1 + 200x_2 + d_1^- - d_1^+ = 800$,

$1x_1 + 2x_2 + d_2^- - d_2^+ = 8$,

$d_1^- \geq 0,\ d_1^+ \geq 0,\ d_2^- \geq 0,\ d_2^+ \geq 0.$

Here is $P_1 > P_2 \geq 0$ the weight of criteria in the aggregate criterion (weighed). The disadvantage of this method is the subjectivity of weighing, but methods are developed that reduce the value of the subjective factor when they are selected.

2.3 APPLYING THE PRIORITY METHOD

In the priority method, the functions of private intentions are ranked in order by importance, then the tasks with a goal function are sorted by sequence, starting with the task having the highest priority and ending with the lowest priority task. In the process of solving the successive tasks, solving the problem with a function of the goal that has the lowest priority cannot aggravate the early resolution of the problem of taking the highest priority. [9] [10]

In the simplest case, solving the problem can be graphically found.

Using the method of priorities, we analytically and graphically solve the problem of the FTTHERMO company (Figure 1). According to the method we have to follow some steps until the results are achieved.

• **Step 0**. Building a set of permissible solutions to the problem is determined by a system of strong constraints that for the given problem has the form:

$x_1 \le 5$

$x_2 \ge 1$

$2x_1 + 8x_2 \le 24$

$x_1, x_2 \ge 0$

• **Step 1**. In this step, solve the problem of finding the minimum deviation from goal 1 in the possible solutions group: $\min d_1^-$ with limitations:

$x_1 \le 5$,

$x_2 \ge 1$

$2x_1 + 8x_2 \le 24$,

$x_1, x_2 \ge 0$,

$90x_1 + 200x_2 + d_1^- - d_1^+ = 800$,

$1x_1 + 2x_2 + d_2^- - d_2^+ = 8$,

$d_1^- \ge 0,\ d_1^+ \ge 0,\ d_2^- \ge 0,\ d_2^+ \ge 0.$

There are infinitely many values of X_1, X_2, X_3, X_4, X_5, X_6 for the optimal value Z = -0, which are contained in the space region $0\ X_1 + 0\ X_2 + 1\ X_3 + 0\ X_4 + 0\ X_5 + 0\ X_6 = -0$ that meet the limitations of this problem. One of them is: $X_1 = 5$, $X_2 = 1{,}75$, $X_3 = 0$, $X_4 = 0$, $X_5 = 0$, $X_6 = 0.5$. As a result of problem solving, we have (Figure 2 and Table 2) and the minimum deviation from goal 1 is reached in point C (5, 1.75).[6].

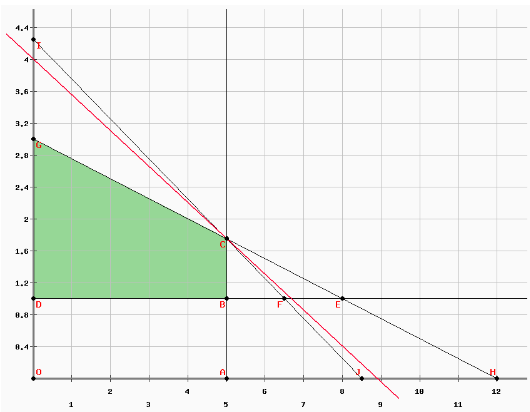


Figure. 2

Point	X coordinate (X1)	Y coordinate (X2)	Value of the objetive function (Z)
O	0	0	0
A	5	0	450
B	5	1	650
C	5	1.75	800
D	0	1	200
E	8	1	920
F	6.5	1	785
G	0	3	600
H	12	0	1080
I	0	4.25	850
J	8.5	0	765

Table. 2

• Step 2. In this step, we solve the problem of finding a minimal deviation from goal 2, provided that the deviation from goal 1, which is achieved in step 1, is preserved:

$$\min d_2^+$$

with limitations:

$d_1^- = 0,$

$x_1 \le 5,$

$x_2 \ge 1,$

$2x_1 + 8x_2 \le 24,$

$x_1, x_2 \ge 0,$

$90x_1 + 200x_2 + d_1^- - d_1^+ = 800,$

$1x_1 + 2x_2 + d_2^- - d_2^+ = 8,$

$d_1^- \ge 0,\ d_1^+ \ge 0,\ d_2^- \ge 0,\ d_2^+ \ge 0.$

Finally, we have a solution: and reach the point C (5, 1.75). Goal 1 is reached but goal 2 is not achieved, deviation from goal 2: hour.

The optimal solution value is Z = 0.5, X_1 = 5, X_2 = 1,75, X_3 = 0, X_4 = 0, X_5 = 0, X_6 = 0.5.If we change the priorities of the objectives and consider the main purpose to minimize testing time, then the optimal solution would be C (4, 2).

Deviation from Goal 1 will be, the deviation from Goal 2 will be equal to.

2.4. APPLICATION OF MULTI-CRITERIA LINEAR PROGRAMMING (LAP)

Linear multi-criteria programming is based on the construction of the entire Pareto optimal set of groups and their graphical presentation This approach can be applied to problems with a small number of criteria n = 2 or two-variable problems. In the first case, the effective margin is found for the group of possible estimates, while in the second the effective margin for the possible solutions group. After building an effective boundary (curve), the problem is reduced to choosing one of the most unresponsive solutions. It should be noted that in the case of a linear problem, it makes sense to solve solely by effective extreme solutions, therefore, in the linear case, the problem of choice itself greatly simplifies. [11] [12]

We examine the problem by changing the purpose. It is assumed that we have to choose a solution according to two criteria (maximize short-term profit of H1 and maximize long-term profit from H2), ie, we have the task:

$\max H_1(x_1, x_2) = \max(100x_1 + 200x_2),$

$\max H_2(x_1, x_2) = \max(4x_1 + 8x_2)$

with limitations:

$x_1 \leq 5$,

$x_2 \geq 1$

$2x_1 + 8x_2 \leq 24$,

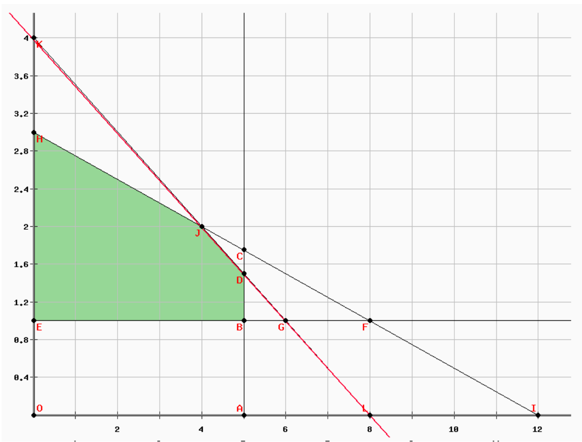
$1x_1 + 2x_2 \leq 8$,

$x_1, x_2 \geq 0$.

2.4.1. Solution according to maximization criteria of long-term profit $\boldsymbol{H_1(x_1, x_2) = \max(100x_1+200x_2)}$

There are infinite multiple values of X1, X2 for the optimal value Z = 800, which are included in the line segment $100\ X_1 + 200\ X_2 = 800$ that meet the limitations of this problem. One of them $X_1 = 4$, $X_2 = 2$.

Let's graphically describe the set of possible solutions to the problem under Figure 3 and Table 3[6]



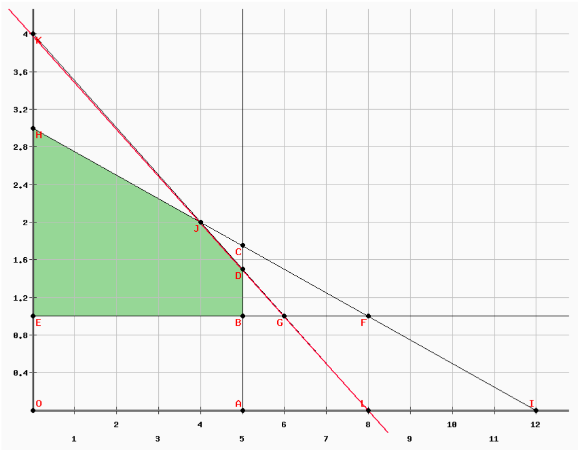
Point	X coordinate (X1)	Y coordinate (X2)	Value of the objetive function (Z)
O	0	0	0
A	5	0	500
B	5	1	700
C	5	1.75	850
D	5	1.5	800
E	0	1	200
F	8	1	1000
G	6	1	800
H	0	3	600
I	12	0	1200
J	4	2	800
K	0	4	800
L	8	0	800

Figure. 3 Table.3

2.4.2. SOLUTION ACCORDING TO THE MAXIMAL PROFIT MAXIMIZATION CRITERIA $\boldsymbol{H_2(X_1, X_2) = \max(4X_1+8X_2)}$

There are infinite multiple values of X_1, X_2 for the optimal value Z = 32, which are included in the line segment 4 X1 + 8 X2 = 32 that meet the limitations of this problem. One of them is: $X_1 = 4$, $X_2 = 2$.

Let's graphically describe the set of possible solutions to the problem under Figure 4 and Table 4[6]



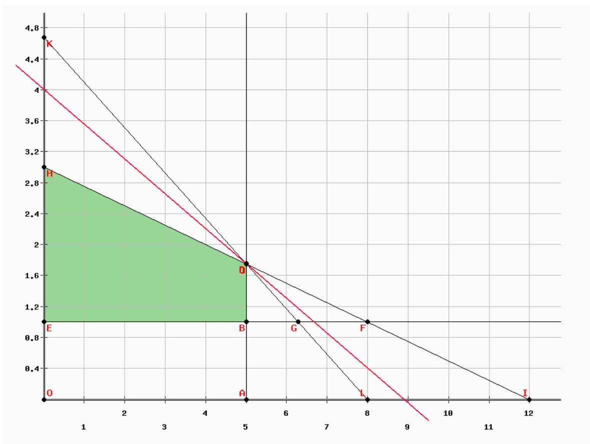
Point	X coordinate (X1)	Y coordinate (X2)	Value of the objetive function (Z)
O	0	0	0
A	5	0	20
B	5	1	28
C	5	1.75	34
D	5	1.5	32
E	0	1	8
F	8	1	40
G	6	1	32
H	0	3	24
I	12	0	48
J	4	2	32
K	0	4	32
L	8	0	32

Figure. 4 Table.4

Point D is the optimal solution of the problem under the first criterion, point B is the optimal solution according to the second criterion. The effective point group (Pareto Optimal) is a line consisting of BC and CD segments. Extreme non-dominant solutions are points B, C and D, and the value of the goal functions in these points are listed in the table:

2.4.3. A SPECIFIC SOLUTION ACCORDING TO THE SHORT-TERM MAXIMIZATION CRITERIA $H_3(X_1, X_2) = \max(1X_1+1.71X_2)$

The optimal solution value is Z = 800, $X_1 = 5$, $X_2 = 1{,}75$. [6]



Point	X coordinate (X1)	Y coordinate (X2)	Value of the objetive function (Z)
O	0	0	0
A	5	0	450
B	5	1	650
C	5	1.75	800
D	5	1.7543859649123	800.87719298246
E	0	1	200
F	8	1	920
G	6.29	1	766.1
H	0	3	600
I	12	0	1080
J	5.0131004366812	1.7467248908297	800.52401746725
K	0	4.6783625730994	935.67251461988
L	8	0	720

Figure. 5 Table.5

Point extrem	X coordinate (X_1)	Y coordinate (X_2)	Value of the objetive function (H1)	Value of the objetive function (H2)
D	5	1.5	800	32
J	4	2	800	32
C	5	1.75	800	32

When deciding on an optimal production plan, managers should limit their choice to one of the extreme points. For the example given for a residential unit with five heating / radiator units for the team, it is appropriate to point C. Therefore, the team of four employees performs the assembly of all radiators with the piping network and electric boiler for a dwelling and follows the works in installing the boiler in the next living quarters and achieving the profit goal of 800 euros and shortens the time of testing the electric boiler from 2 hours to 1.75 hours.

3. CONCLUSION

• The methodology discussed in this paper provides an efficient solution that works when there are multiple optimal solutions.

• The main problem with the optimization of many criteria is the uncertainty of choosing the "optimal solution".

• Setting goals appropriately is a skill of its kind. In cases where the goals set are too high, they are disappointed if they are not achievable.

• The optimal solution of the multi-criteria optimization problem should be understood as one of the most effective (pre-optimal) solutions.

• Goal programming is used to build an optimal solution, mainly in multicriteria and linear problems.

• Solving the problem can be optimal based on goal satisfaction but not optimal on the highly objective ground due to inefficiency. In order to fix the problem of inefficient solutions, in some cases, we change a bit of the function of the goal. Reaching the new goal will not be greatly influenced, but the solution will be efficient

• In multi-criteria linear problems, only effective extreme solutions should be considered optimally.

• For the example given, the optimal solution for the team of 4 employees that performs assembly of 5 radiators with the grid and electric boiler is considered a solution when they realize the profit goal of 800 euros and shorten the time of the electric boiler testing from 2 hours to 1.75 hours.

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