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Comparison of Software Decision Support Systems for Solving a Multicriteria Optimization Problem

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***Abstract*: *This article describes in details how multicriteria optimization can be applied to solve a typical business problem for resources planning and manufacturing process optimization in a battery factory. We solve the problem by using an interactive software decision support system WebOptim developed at the Institute of information and communication technologies. The entire problem solving process is described step by step in order to point out the problem specific features as well as to demonstrate the capabilities of the WebOptim software system. For comparison, we have solved the same problem by means of another popular decision support system WWW NIMBUS and both solutions are analyzed and discussed.*

***Keywords*: *Multicriteria optimization, decision support systems, resource planning.*

1. Intoduction

In nowadays business and economy, many problems in complex systems management and control, planning, analysis and monitoring, can be described and solved as multicriteria decision-making problems [1, 16, 17, 19]. These problems on the other hand can be divided into two large classes [2, 3], depending on their formal statement.

First class contains a finite number of explicitly set constraints as functions. These functions define an infinite number of feasible alternatives [4]. These are so called continuous multicriteria optimization problems.

In the second class of problems, there is finite number of alternatives, described in tabular form [5]. These problems are called discrete multicriteria decision making problems or multicriteria analysis problems.

In this paper the focus is on the first class – multicriteria optimization problems. Their specific characteristics are briefly described as follows.

Multicriteria optimization problems are non-formalized or weakly formalized, the solution of which requires active participation of the so-called Decision Maker (DM) [6, 7]. Usually, solutions that are obtained depend very much on the DM's personal preferences. In multicriteria optimization problems, several criteria (objective functions) are simultaneously optimized into a feasible set of alternatives. Normally a single alternative does not exist that optimizes all the criteria. However, a small subset of alternatives exist, where each improvement in the value of one criterion, leads to deterioration in the value of at least one other criterion. Each solution from this subset is called Pareto-optimal solution [8]. Therefore, when we speak about multicriteria optimization, we speak about finding a good Pareto-optimal solution. What is a "good solution" is a decision, taken by the decision maker.

Two main approaches are used to solve multicriteria optimization problems: scalarizing approach [9] and approximation approach [10]. The scalarizing approach is more popular. In that case, the multicriteria optimization problem is reduced to a single-criteria optimization problem. This approach uses interactive algorithms, where the decision maker has the most important role in the solution finding process. Each interactive algorithm contains two steps - optimization and evaluation, which are repeated in cycle until a final decision is made. In the evaluation step, the decision maker evaluates the current Pareto-optimal solution. If it satisfies his personal preferences the process stops and that current solution becomes a final one. In the other case, the decision maker defines certain preferences concerning changes in criteria values in order to obtain a new Pareto-optimal solution. Based on those preferences in the optimization step a new scalarizing problem is generated and solved, which gives the new consecutive Pareto-optimal solution. As mentioned before - the scalarizing problem is a single-criteria optimization problem, which makes possible using the well-known theory and algorithms for solving single-criteria optimization problems.

Many interactive algorithms are developed, each one heaving advantages and disadvantages, concerning the type of information that the decision maker provides as a reflection of his personal global and local preferences.

The most important aspect in multicriteria optimization is that the process involves heavy mathematical calculations repeated in multiple iteration cycles. Those calculations are practically impossible to make without the help of so-called decision support systems. They are software systems that provide the decision maker with the tools and ability to solve such problems by implementation of the two steps – optimization and evaluation. These systems are classified in two classes – software systems with general purpose and problem-oriented software systems.

The general-purpose software systems aid the process of finding an optimal solution by different decision makers with different level of experience and knowledge. The systems usually implement one method or several methods from the same group.

Problem-oriented software systems are part of other software systems and serve to aid the solution of one or several types of specific multicriteria optimization problems. Specialized methods and algorithms are also developed in the cases of group and fuzzy multicriteria decision making [20, 21].

Well-known general-purpose software systems, which support the solving of multicriteria optimization problems, are VIG, DIDAS, DINAS, MOLP-16, LBS, SOMMIX, MOIP, WWW-NIMBUS [15], MOLIP, NLPJOB and MOMILP [11,12].

This article demonstrates how to solve a real problem for production planning by using the software decision support system WebOptim [13]. It is an interactive software system for multicriteria optimization, developed at the Institute of information and communication technologies, Bulgarian Academy of Sciences. It implements some of the most well-known algorithms, and one interactive algorithm developed at the same institute [14]. The first author of this article is one of the leading developers of the WebOptim software system. The system is contemporary, user friendly for many users and provides the decision maker with a large variety of instruments to solve multicriteria optimization problems [18].

2. Problem description

The problem under consideration is a benchmark example taken from a book with case studies of typical multicriteria optimization problems [17] and it is adapted for the demonstration purposes of this article. The problem description is as follows.

A Battery fabric is manufacturing three types of batteries for selling on internal and international market:

- Standard capacity battery
- High capacity battery
- Rechargeable battery

The manufacturing process defines certain requirements and dependencies between manpower and machine power for a specific period of time. These dependencies are shown in Table 1.

Table 1. Resources and prices

Parameter	Manpower hours	Machine power hours	Price on internal market	Price on international market
Standard capacity battery	32	19	340	350
High capacity battery	38	21	362	368
Rechargeable battery	39	23	374	378
Available resources	16,000	9,000		
Resource price	4	2.5		

Goal: To optimize the manufacturing process: resources; prices; profit.

Initial Constraints:

Company policy requires selling each battery type on both markets – internal and international. There are also requirements concerning the minimum quantities of each battery type units. They are as follows:

- Minimum 30 units of standard capacity batteries
- Minimum 20 units of high capacity batteries
- Minimum 10 units of rechargeable batteries

Varaibles:

- ib1 – standard capacity batteries quantity for internal market
- eb1 – standard capacity batteries quantity for international market
- ib2 – high capacity batteries quantity for internal market

- eb2 – high capacity batteries quantity for international market
- ib3 – rechargeable batteries quantity for internal market
- eb3 – rechargeable batteries quantity for international market
- r1 – variable specifying the constraint of manpower resources
- r2 – variable specifying the constraint of machine power resources

Objective functions:

- Maximize the profit F1 (manufacturing price-expenses) –

$$MaxF1 = 164.5\times ib1 + 174.5\times eb1 + 157.5\times ib2 + 163.5\times eb2 + 160.5\times ib3 + 164.5\times eb3,$$

where each coefficient is the difference between the selling price and the manufacturing expenses defined with the following formulae:

Coefficient of ib1 = 340 – (4×32 + 2.5×19) = 164.5;
Coefficient of eb1 = 350 – (4×32 + 2.5×19) = 174.5;
Coefficient of ib2 = 362 – (4×38 + 2.5×21) = 157.5;
Coefficient of eb2 = 368 – (4×38 + 2.5×21) = 163.5;
Coefficient of ib3 = 374 – (4×39 + 2.5×23) = 160.5;
Coefficient of eb3 = 378 – (4×39 + 2.5×23) = 164.5.

Next task is to optimize the using of manpower and machine power resources. This is done through minimizing the difference between the total available resource and the sum of all resource hours necessary for the manufacturing process.

- Minimizing manpower resource F2:

$$MinF2 = 32\times ib1 + 32\times eb1 + 38\times ib2 + 38\times eb2 + 39\times ib3 + 39\times eb3 - 16{,}000\times r1.$$

- Minimizing machine power resource F3:

$$MinF3 = 19\times ib1 + 19\times eb1 + 21\times ib2 + 21\times eb2 + 23\times ib3 + 23\times eb3 - 9{,}000\times r2.$$

Constraints:

- Manpower resource constraint:
  $32\times ib1 + 32\times eb1 + 38\times ib2 + 38\times eb2 + 39\times ib3 + 39\times eb3 <= 16{,}000.$
- Machine power constraint:
  $19\times ib1 + 19\times eb1 + 21\times ib2 + 21\times eb2 + 23\times ib3 + 23\times eb3 <= 9{,}000.$

After a solid business analysis, managers have settled minimum battery quantity requirements for internal and external market as follows:

$ib1 \geq 40$
$eb1 \geq 40$
$ib2 \geq 40$
$eb2 \geq 30$
$ib3 \geq 20$
$eb3 \geq 20$

3. Solving the problem and making a decision with WebOptim

After entering the problem definition in the WebOptim decision support system (Fig. 1), we obtain auto generated first initial solution (Fig. 2).

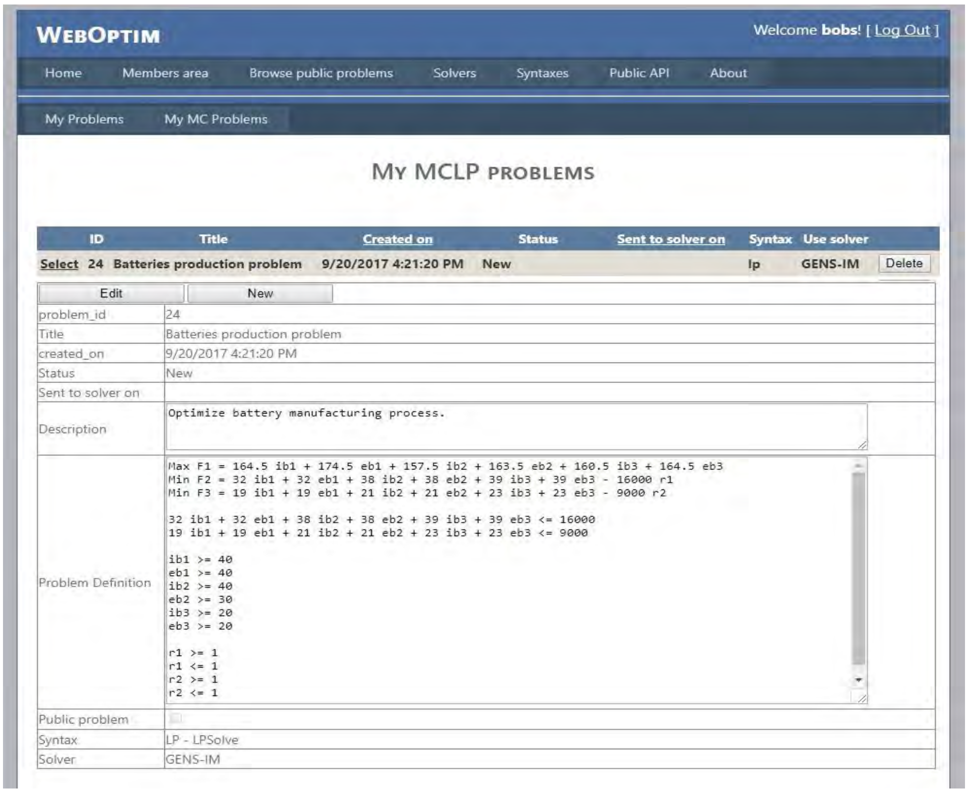

Fig. 1. WebOptim system – problem definition interface

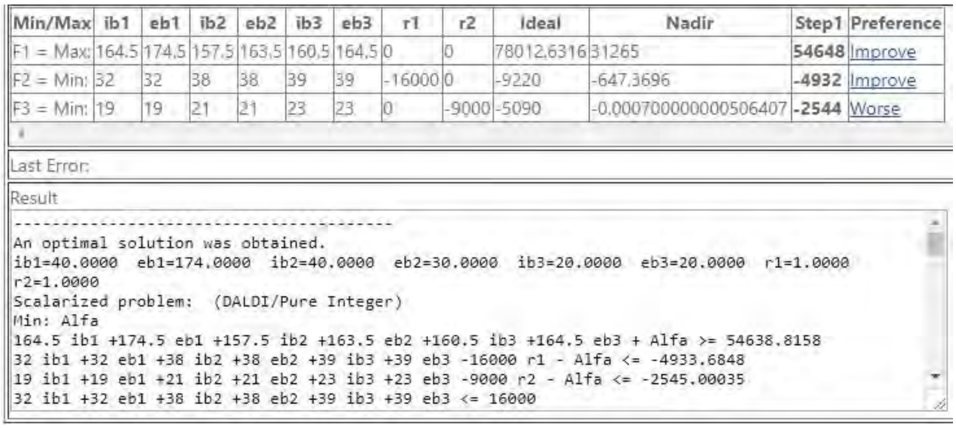

Fig. 2. WebOptim system – initial solution and preferences set for the next step

Result values related to batteries quantity are given in Table 2 and objective function values are in Table 3.

Table 2. Battery quantity – initial values

Market	Standard capacity	High capacity	Rechargeable
Internal	40	40	20
International	174	30	20

Table 3. Objective function initial values

F1	F2	F3
54,648	–4,932	–2,544

The first conclusion is that here we have optimized the resources (F2 and F3), but the profit (F1) seems to be unsatisfying. From mathematical viewpoint, this solution is Pareto-optimal, but in business terms, we could ask for more. Here comes the decision maker's active role. It is obvious that the highest profit comes after selling on international market. In our case, the battery quantities for international market are too low. In order to improve the value of objective function F1 (profit), we have to choose which other criterion to worsen and how to worsen. The manager's decision is to worsen the objective function related to machine power resources (F3), because they are cheaper. On the other hand, if we just set preferences to worsen this value, it might go right to its bottom point and we do not want that.

However, as a beginning, we would like to do exactly that – worsen the use of resources, just to see what values will come when maximizing the profit. Later we will do some more changes.

After choosing free improvement of F1 and free worsening of F2 and F3, we obtain the next values shown in Fig. 3, Table 4 and Table 5.

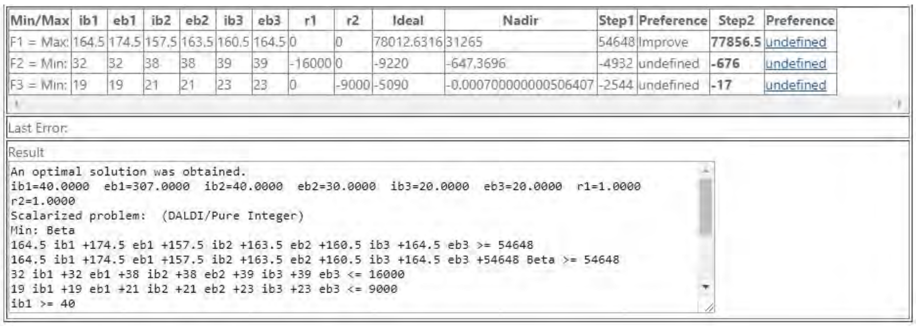

Fig. 3. WebOptim system – second step results

Table 4. Battery quantity – Step 2 values

Market	Standard capacity	High capacity	Rechargeable
Internal	40	40	20
International	307	30	20

Table 5. Objective function – Step 2 values

F1	F2	F3
77,856.5	–676	–17

As expected – we have maximized the quantity of standard capacity batteries for export, because they have the highest profit rate. Again as expected – the difference in resources usage functions values is too big compared to the initial solution (Fig. 4). Now we have to optimize that too. Manpower resources (F2) are expensive and we would like to keep them at better value. From the current point, we choose to improve that value with aspiration level of at least –6,000.

Machine power resources (F3) are cheaper and we choose to set their value to be improved to aspiration level of at least –1,500. And in order to control the worsening of F1 function, we choose to worsen it to aspiration level of no more than 40,000 (Fig. 4).

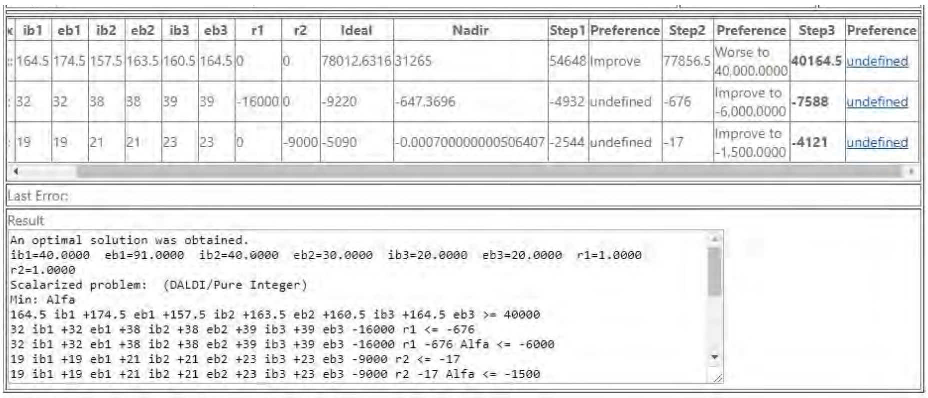

Fig. 4. WebOptim system – third step results

After solving the new problem, we obtain the values given in Tables 6 and 7.

Table 6. Battery quantity – Step 3 values

Market	Standard capacity	High capacity	Rechargeable
Internal	40	40	20
International	91	30	20

Table 7. Objective function – Step 2 values

F1	F2	F3
40,164.5	–7,588	–4,121

At that point, we are satisfied with the value of the objective function that is related to manpower resources and we would like to keep it as it is. The profit can be improved more on the account of the cheaper machine resources. In order to improve F1, we choose to worsen F2 to a level of –5,000 and worsen F3 to a level of –1,500. After solving, we obtain the values given in Tables 8 and 9.

Table 8. Battery quantity – final step values

Market	Standard capacity	High capacity	Rechargeable
Internal	40	40	20
International	171	30	20

Table 9. Objective function – final step values

F1	F2	F3
54,124.5	–5,028	–2,601

Our decision is to keep those values as a final solution, where we garantied the maximum profit and optimal resources usage.

4. Solving the problem with Nimbus

To compare the problem solving process, obtained results and overall user experience, we choose to solve the same task with another popular decision support system that solves similar problems – WWW NIMBUS (wwwnimbus.it.jyu.fi) [15].

The input interface of Nimbus is presented on Fig. 5.

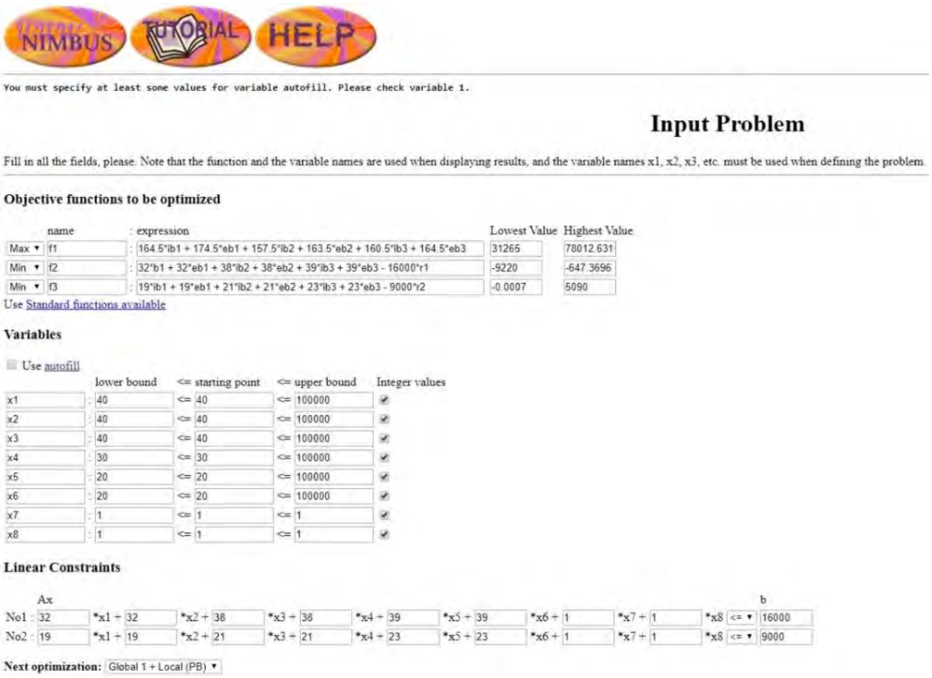

Fig. 5. Nimbus system – problem definition interface

The initial solution that is generated from Nimbus has exactly the same values as this from WebOptim. After two more iterations with similar preferences, the obtained results are given in Table 10.

Table 10. Comparison between obtained solutions from WebOptim and WWWNimbus by steps

Step	System	ib1	eb1	ib2	eb2	ib3	eb3	F1	F2	F3
1	**WebOptim**	**40**	**174**	**40**	**30**	**20**	**20**	**54,648**	**–4,932**	**–2,544**
1	Nimbus	40	174	40	30	20	20	54,648.0	–4,932	–2,544
2	**WebOptim**	**40**	**91**	**40**	**30**	**20**	**20**	**40,164.5**	**–7,588**	**–4,121**
2	Nimbus	40	40	40	30	20	20	31,265	–9,220	–5,090
3	**WebOptim**	**40**	**171**	**40**	**30**	**20**	**20**	**54,124.5**	**–5,028**	**–2,601**
3	Nimbus	40	174	40	30	20	20	54,648.0	–4,932	–2,544

It is seen from the results in Table 10, that at the first step of optimization both software systems WebOptim and Nimbus give exactly the same Pareto-optimal solution. However, applying the specific decision maker's preferences described in the previous section, we obtain different alternatives in the next two steps.

In particular, at Step 2 the solution obtained by WebOptim is characterized by a substantially better value of the obtained profit (objective function F1) and relatively worse values of the manpower and machine power resources (objective functions F2 and F3) as compared to the respective values in the solution of the Nimbus system. At this step it can be concluded that both solutions are acceptable as they satisfy all constraints of the optimization problem and the decision maker's preferences. Thus, the decision maker can chose one of them depending on some additional economic preferences and/or production process specifics.

At Step 3 it is seen that the solution obtained by Nimbus actually repeats the initial Pareto-optimal solution. At the same time the WebOptim system produces a solution which is characterized by a slightly worse value of the objective function F1 and better values of objective function F1 and F2. Thus at this step the software system WebOptim provides another more alternative which gives the decision maker more possibilities to find the most appropriate final decision.

5. Conclusion

In this work we presented and analysed in details the solving process of a multicriteria optimization problem and the corresponding decision making for an efficient resources planning and production process optimization in a battery manufacturing company. The entire solving process involves three main components: mathematical model of the production process and business requirements, specialized software implementing algorithms for multicriteria optimization and the active participation of the decision maker. We have used an interactive decision support system WebOptim in order to find a Pareto optimal solution of the problem together with several alternative solutions corresponding to different preferences of the decision maker. For comparison, the same task is solved with another software system WWW Nimbus supporting the decision making in similar problems. An analysis of both solutions indicates that WebOptim is advantageous in providing more alternatives for making the most appropriate final decision. In a future perspective, it would be useful to develop and implement new exact and heuristic algorithms for solving wider range of complex optimization problems. Finally, as a general conclusion it should be noted that real life decision making problems are difficult to solve and only the combination of exact mathematical model, efficient software tools and active participation of the decision maker is a guarantee for finding a scientifically justified solution.

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