12th International Research/Expert Conference
"Trends in the Development of machinery and Associated technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

PRODUCTION PROGRAM OPTIMIZATION AND HARMONIZATION OF DECISION MAKERS' CONFLICT INTERESTS

Ranko Božičković, Ph.D.
University of Eastern Sarajevo, Faculty of Transport and Traffic Engineering
Doboj
Bosnia and Herzegovina

Ilija Nikolić, Ph. D.
Union University of Belgrade, Faculty of Entrepreneurial Business Studies
Cara Dušana 62, Belgrade
Serbia

ABSTRACT
The work refers to the approach to an optimal planning procedure for special tools in a case of individual production with interruptions for material flows. Using the group analysis it is possible to shape the group production and thus approach to the small amount and assembly-line production where we can use optimization methods which refer to economical production of certain kinds of special tools. The researches are conducted in huge industrial systems with wide production programs as the production of low-voltage equipments, electrical household items. Certain solutions refer to several conflict interests when several aim functions are observed. The work expounds the application of multi-criteria optimization and goal programming for determination of production planning variations in order to choose the most suitable plan.
Key words: production planning, multi-criteria optimization, goal programming, conflict interests

1. INTRODUCTION
Planning the production program of special tools requires a particular attention in complex industrial systems. It is conducted for achieving effects of organizational and techno-economical character as: improving productivity, exploiting installed capacities, reducing production cycle, reducing cycle of new products inclusion, producing products by order, production without storages etc. For solving these problems it is possible to create certain models of optimization production program for development of special tools, that is, determine optimal values of those tools which provide profit maximization and more production capacity exploitations. In this case, products as representatives of tool groups are determined as conditional products with certain amounts using the method of ABC analysis and group technology. Capacity exploitation maximization does not lead to the maximal profit at the same time, which means that profit maximization does not provide always expected products which could be produced and sold on the market, and which presents a certain conflict that should be solved.

2. THE MULTICRITERIA MATHEMATICAL PROBLEM FORMULATION
The mathematical model formulating process of multi-criteria planning consists of 6 steps defined in [1]. Initial data are shown in Table 1. *(1)* ***Definition of variables*** p_j *[number].* On the basis of previous analysis it is concluded that there is a justification for examination of the represent n=7 for sorts or groups of special tools p_j, for which we need to determine the unknown amounts of p_j of the observed problem variables in aim functions and restrictions of special tool group types p_j, (j = 1,2,…,7). So, the following tools are: p_1 – tools for piercing and cutting, p_2 – tools for folding, p_3 – tools form

thermoplastic masses, p_4 – tools for thermo-stable masses, p_5 – tools for casting under the pressure, p_6 – tools for gravitational casting, p_7 – tools for holding in the process of production and installation. Choosing the values of these variables, $p = \{p_1, p_2, ..., p_7\}$, we influence on the capacity exploitation and greater income realization. *(2)* ***Definition of the aim function f_k.*** The observed aim determines 5 aim functions which is shown in [1] and from which we will present here q=3 function f_k (k=1,2,3). They are: $f_1(p)$ – criterion function which reflects the income or profit of manufactured j product, $f_2(p)$ – criterion function which reflects the total capacity exploitation, f(p) – criterion function which reflects the total number of products. Criterion vector is $f = \{f_1, f_2, f_3\}$. *(3)* ***Formulation of restriction b_i*** *[hours/years]*. Analyzing production conditions, the restrictions m=12 are defined which could be observed from the following aspect. (a) Restrictions conditioned by production system itself. These are available, that is, effective capacities b_i of production equipment A_i (i = 1,2,…,12) used for special tool developments, in [hours/years]: b_1 – planes, b_2 – milling cutter, b_3 – rough milling cutter, b_4 – circular grinding, b_5 – flat grinding b_6 – geometrical grinding, b_7 – coordinate piercing and grinding, b_9 – erosive cutting, b_{10} – gravure machine, b_{11} – heat treatment, b_{12} – manual machine tool treatment. (b) Restrictions conditioned by production equipment usage degree. Overtime work is not allowed, unless for 1% of b_8 and b_9. (c) Restrictions conditioned by production program structure. That is, for certain, adopted on the base of decision maker's preference and mostly has influence on the optimal solution. *(4)* ***Formulation of parameters a_{ij}*** *[hour/pieces]* ***in restriction inequalities.*** Parameters in restriction inequalities presents times required for i production equipment type for j special tool manufacturing, expressed in work hours – a_{ij} (i=1,…,12; j=1,2,…,7). Data are obtained by researches in real industrial system, and given in [1]. *(5)* ***Definition of parameters c_{kj} in aim functions f_k*** (k=1,2,3; j=1,2,...,7). The parameters c_{1j} presents the income or profit from produced j special tools expressed in value units [v.u./pieces]; c_{2j} presents the total time of engagement of all capacities for production of j tool [h/numb]; c_{3j}=1. *(6)* ***Mathematical model formulation***. According to the examined data and adopted presumptions, the mathematical model of the problem is defined with the model of multi-criteria linear programming (MLP) as following:

$$\max\left\{\sum_{j=1}^{7} c_{kj}\, p_j\,, \quad k = 1, 2, 3\right\} \qquad \text{…. (1)}$$

With restrictions:

$$p = \begin{cases} \sum_{j=1}^{7} a_{ij}\, p_j \le b_i\,, & i = 1, 2\ldots, 12 \\ p_j \ge 0, & j = 1, 2, \ldots, 7 \end{cases} \qquad \text{…. (2)}$$

Table 1: Initial data for mathematical model MLP with q=3, n=7, m=12

Products, P_j		P_1	P_2	P_3	P_4	P_5	P_6	P_7	Available capacities b_i	
Criteria f_k	f_1	529,71	141,95	606,97	965,77	1458,55	213,14	30,75		
	f_2	321,32	88,74	379,60	604,57	912,16	133,26	19,25		
	f_3	1,00	1,00	1,00	1,00	1,00	1,00	1,00		
Capacities A_i	A_1	26,83	7,18	30,74	48,97	73,88	10,80	1,56	≤	5714,00
	A_2	51,68	13,84	59,22	94,31	142,30	20,80	3,00	≤	11428,00
	A_3	27,83	7,46	31,89	50,78	76,62	11,20	1,62	≤	5714,00
	A_4	16,24	4,34	18,60	29,52	44,70	6,53	0,95	≤	2855,00
	A_5	17,83	7,45	31,89	50,79	76,62	11,20	1,62	≤	5714,00
	A_6	44,40	11,89	50,87	81,01	122,23	17,87	2,58	≤	8571,00
	A_7	8,62	2,31	9,87	15,72	23,72	3,40	0,50	≤	2855,00
	A_8	34,46	9,23	39,48	62,88	94,86	13,87	2,00	≤	5714,00
	A_9	15,90	4,26	18,22	29,02	43,78	6,40	0,92	≤	2855,00
	A_{10}	5,96	1,60	6,83	10,88	16,42	2,40	0,35	≤	2855,00
	A_{11}	6,96	1,86	7,97	12,70	19,16	2,79	0,40	≤	2855,00
	A_{12}	64,61	17,30	74,02	117,89	177,87	26,00	3,75	≤	11424,00
Variables, p_j		p_1	p_2	p_3	p_4	p_5	p_6	p_7		

3. THE SELECTED MULTICRITERIA METHODS

Optimization methods of planning production program for special tools are conducted with the interaction between the upper and lower level of planning and making decisions. That means that every plan as a draft goes to the management of industrial systems for the final approval, that is,the production program structure and machinery capacity exploitation which are often in a conflict relation. In order to select an optimization method, the following phases of approach to the solution of this problem need to be determined: (1) Applying the method of linear optimization determine (variation I): p^{k*} – marginal solutions for variables of initial pareto-optimal problem solutions, (k=1,2,3); $f_k* = \max f_k(p)$ – ideal values of criterion functions (k=1,2,3); and $f_{ks} = f_s(p^{k*})$ – consequences p^{k*} and f^{k*} of other *s* criteria (k=1,2,3; s=1,2,3 i s≠k). We provide these solutions by maximization of every criterion aim function individually for certain group of restrictions by the application of software WinQSB (the instruction for Linear and Integer Programming model is given in [2]) or GAMS (used in [1]). In variation II enlarge capacities b_8 and b_9 for 1%, determine product profitability order and define their maximal percentage involvement in f_3. (2) Applying the relaxed lexicographic method determine new pareto-optimal solutions with the solutions of variation II and certain value of criterion functions. (3) Using the method of goal programming (GP) implement the determined analysis (variation III) by the application of Linear and Integer Goal Programming program of WinQSB or realization of method with GAMS and using conditions of variation II.

4. THE MULTICRITERIA SOLUTIONS AND GOAL PROGRAMMING SOLUTIONS

Solving the defined model MLP in concordance with given approaches for determination of pareto-optimal solutions and variations for product amount restrictions, in other words, application of LGP, the results given in Table 2 are observed: (1) The result analysis shows that criterion functions f_1 and f_2 have not significant aberration for individual solutions which implies that there is harmonization between total profit and total capacity exploitation. The criterion function f_3 has greater oscillations depending on required product program structure and total physical amount of products. Starting with p^1* with $f^1* = 87.867,05$ and $p_1 = 619$ of variation I, the variation II is used for product profitability order 2–7–5–3–1–6–4, if capacities are enlarged for two kinds of equipment for 1% (of values b_8=5771, b_9=2883) and percentage product representation restriction z_j for total number $\sum p_j$ from following upper limits $p_j \leq z_j \cdot \sum p_j$, $[z_2,z_7,z_5,z_3,z_1,z_6,z_4]$ = [30%;12%;5%;27%;27%,30%,30%]. Now, optimal criterion values have different production programs, but for everyone there are tools which need not be manufactured. For this reason, sub-variation of solutions are determined with requirements that every product is to be present with at least 5 pieces: $p_j \geq 5$ (j=1,2,...,7). It is observed that there is no worse deterioration of criterion functions f_1 and f_2, independently whether they are optimized or observed as optimization consequences of other criteria, while f_3 has values in range from 204 to 312 (pieces). (2) Quoted dependency of f_1 and f_2 with close values for optimization consequences of opposite criteria is obstructed by application of lexicographic method for criterion importance order $f_1 >> f_2 >> f_3$. That is the reason why the examination of lexicographic order $f_3 >> f_2 >> f_1$ is illustrated with relaxation ε_k=–5 (k = 3,2). Further introduction of condition $p_j \geq 5$ (j=1,2,...,7) enlarges the value for f_1 and f_2. (3) The extremely important analysis is implemented by Linear Goal Programming (LGP). The request for implementation of expected criterion values by priority order $\underline{f}_1 >> \underline{f}_2 >> \underline{f}_3$ with variations of conditions is illustrated: *(i) Enable the capacity exceeding* for positive deviations dp_i (i=1,2,...,7) and determine minimal capacity needs with required percentage product structure (with and without $p_j \geq 5$, j=1,2,...,7), model (3)(4). For example, profit $\underline{f}_1$ = 95000 with the condition $p_j \geq 5$ for all tools is achieved by small additional annual capacities 628,53 [hour] with $[dp_4, dp_8, dp_{12}]$ = [53,12; 410,37; 165,04]. For $\underline{f}_1$ = 100000 it is determined $[dp_4, dp_8, dp_9\ dp_{12}]$ = [208,98; 734,34; 118,82; 772,27], total 1834,41 [hours]. Harder conditions $p_j \geq 10$ for all tools require slightly enlarged total additional capacities 1835,53 [hour/year] *(ii) Allow the aberration from the percentage product structure* z_j for positive defiations dp_j (j=1,2,...,7) and determine adequate amount of products with available capacities (with and without $p_j \geq 5$, j=1,2,...,7), model (5)(6). In this case, it is not possible to determine expected criterion values, greaten then the initial ideal values f_k* (k = 1,2,3).

$$\min\left\{h_1 = dn_{13};\ h_2 = dn_{14};\ h_3 = dn_{15};\ h_4 = \sum_{i=1}^{12} dp_i\right\} \quad \ldots (3)$$

$$p = \begin{cases} \sum_{j=1}^{7} a_{ij} p_j + dn_i - dp_i \le b_i, & i = 1, 2 \ldots, 12 \\ \sum_{j=1}^{7} c_{kj} p_j + dn_{12+k} - dp_{12+k} = \underline{f}_k, & k = 1, 2, 3 \\ 0 \le p_j - \sum_{j=1}^{7} p_j \le 0, & j = 1, 2, \ldots, 7 \\ dn, dp \ge 0 & \end{cases} \qquad \ldots. (4)$$

$$\min \left\{ h_1 = dn_{13};\ h_2 = dn_{14};\ h_3 = dn_{15};\ h_4 = \sum_{j=1}^{7} (dn_j + dp_j) \right\} \qquad \ldots. (5)$$

$$p = \begin{cases} \sum_{j=1}^{7} a_{ij} p_j \le b_i, & i = 1, 2 \ldots, 12 \\ \sum_{j=1}^{7} c_{kj} p_j + dn_{12+k} - dp_{12+k} = \underline{f}_k, & k = 1, 2, 3 \\ 0 \le p_j - z_j \cdot \sum_{j=1}^{7} p_j + dn_j - dp_j \le 0, & j = 1, 2, \ldots, 7 \\ dn, dp \ge 0 & \end{cases} \qquad \ldots. (6)$$

Table 2: Solutions of multi-criteria model and Goal Programming model

Methods and solutions			Values p_i							Criterion function values			b*/b
			p_1	p_2	p_3	p_4	p_5	p_6	p_7	f_1	f_2	f_3	[%]
Marginal solutions	I	p^1*	-	619	-	-	-	-	-	87.867,05	54.936,12	619	80,11
		p^2*, p^3*	-	-	-	-	-	-	2.857	87.852,75	54.997,25	2.857	80,22
	II	p^1*	55	62	56	-	11	-	25	88.724,23	54.938,43	209	80,04
		$p_j \ge 5$	42	63	56	5	11	9	24	88.719,66	55.067,57	204	80,23
		p^2*	-	41	40	48	8	-	18	88.681,45	55.487,88	155	80,83
		$p_j \ge 5$	5	44	45	39	9	5	20	88.689,45	55.437,61	167	80,76
		p^3*	91	102	5	-	-	102	40	88.687,64	54.552,12	340	79,47
		$p_j \ge 5$	74	93	5	5	5	93	37	88.516,13	54.617,58	312	79,57
Lexicograph.		$f_3 > f_2 > f_1$	41	97	52	-	-	96	39	88.715,77	55.068,18	325	94,50
$\varepsilon_k = -5$, II		$p_j \ge 5$	13	89	61	5	5	89	35	88.720,13	62.285,70	296	80,64
LGP, III		(i) b_i*	-	73	14	54	4	74	30	95.000,00	59.439,29	250	85,80
$\underline{f}_1 = 95.000$		$p_j \ge 5$	5	73	8	54	6	72	29	95.000,00	59.389,52	247	85,60
$\underline{f}_2 = 60.000$		(ii) p_j*	-	625	-	-	-	-	1	88.753,35	55.484,16	626	80,82
$\underline{f}_3 = 300$		$p_j \ge 5$	5	490	5	5	5	5	10	88.742,16	55.334,95	525	77,96
$\underline{f}_1 = 100.000$		(i) b_i*	93	103	-	15	-	96	38	100.000,00	61.615,76	345	87,69
		$p_j \ge 5$	82	85	5	5	12	85	33	100.000,00	61.720,31	307	87,58
		$p_j \ge 10$	78	64	10	10	10	86	31	100.000,00	61.763,75	289	87,64

5. CONCLUSION

In this work it is determined that all methods provide almost same solutions for values of total profit and capacity exploitation while the number of products varies depending on solutions. Taking into account the complexity of methods and required previous knowledge at one side, and practical experiences that every plan and production program is a reflection of certain preferences on the other side, the method of optimal planning program for development of special tools is accepted, and in the basis of its MLP model it consists of method combinations for searching non inferior solutions and GLP, and which annuls the conflict of solutions using classic methods of LP.

6. REFERENCES

[1] Božičković, Ranko; Addition to the method of optimal program planning for special tool developments in complex industrial system; Work for master degree (in Serbian); Faculty of Technical Sciences, Novi Sad, 1997.

[2] Nikolić, Ilija & Božičković, Ranko; Optimization methods in transport type problems with one or more criteria – application of the software WinQSB – Quantitative Systems For Business (in Serbian); Faculty of Transport and Traffic Engineering, Doboj, 2007.