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Optimization of a Bi-objective Scheduling for Two Groups of Experienced and Inexperienced Distribution Staff Based on Capillary Marketing

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ABSTRACT

Developing an appropriate plan for distribution department is significant because of its influence on company's other costs and customers' satisfaction. In this study, a new bi-objective mix-integer linear programming model developed for scheduling two groups of experienced and inexperienced distribution staff based on capillary marketingin Pak Pasteurized Dairy Products Company of Guilan province in order to reduce costs and increase sales along with customer satisfaction. Several constraints are taken into account at the model.The model solving results using the epsilon constraint method, which provides a set of Pareto responses and solved by GAMS software, shows efficiency of the model to solve small-size problems. In order to evaluate the validity of model in large scale problem, with respect to NP-hardness of the problem, a multi objective water flow-like optimization (MOWFO) algorithm was expanded. For evaluation the suggested method, several problems were expanded and the efficiency of the method was compared with a multi-objective invasive weed optimization (MOIWO) algorithm based on the planned factors. For better algorithms performance, their input parameters were set using RSM technique; furthermore, in order to compare parameters statistically, the Tukey's 95% confidence interval method was used. The results show the superiority of MOWFA compared to MOIWO algorithm in comparison indicators.

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1. INTRODUCTION

Distribution is one of the elements of marketing which can be defined as the process of moving products from a manufacturer to the final consumer. In the other words, the most important duty of the distribution channel management is to send goods in the right place at the right time to the customers [1]. The company's success depends on its own distribution channel and sales, but most companies do not pay enough attention to their distribution channel which often leads to very harmful consequences [2]. On the other hand, several companies have been able to reach a competitive advantage using creative distribution structures. Therefore, one of the most important decisions regarding product supply is made based on determining the number of intermediaries. Three choices are presented in this regard: Exclusive distribution: In this method, an intermediary is chosen in each area as the exclusive representative of the company. Selective distribution: In this method, some retail sellers are chosen to supply the respective product in different areas. Intensive distribution (capillary distribution): This strategy which includes distributing products in a high number of retail shops is common in the field of consumers and daily goods. This is the most appropriate way of distributing consumable goods. Capillary distribution can have lots of advantages if its background and context have been prepared well in strategy planning time and its consistency with other tactics such as communication, price setting and more importantly recruiting. In fact, educating qualified labor force has been considered in advance. Paying attention to this fact is important that, in the capillary distribution part of a company, like most of the organizations, manpower and

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best use of it can be significant and inevitable. Therefore, in order to have an efficient organization, having enough employees at the appropriate time is a key factor to satisfy customers' demands. Labor force planning is the subcategory of production planning and is one of the most challenging cases in production and service environments. The final objective of labor force scheduling is to set fair shifts for the staff, paying attention to law, legal limitations, staff's goals and preferences. An appropriate scheduling increases the efficacy, maximizes the potentials of resources, minimizes the time needed to finish the work and maximizes the efficiency. With respect to the importance of the topic, this study tries to develop a new mathematical model in order to schedule the capillary distribution staff in Pak Pasteurized Dairy Products Company of Guilan province, Iran. At first, the suggested model was solved using epsilon constraint method by GAMS softwareand two meta heuristic algorithms, then the answers were all compared with each other. In this regard some studies in this field are as follow; Naso et al. [3] proposed genetic algorithms for supply chain scheduling in order to deliver the products to distributed customers in a right time. Pak Seresht et al. [4] studied a fuzzy modeling airline crew scheduling problem and solving by particle swarm optimization. In Adem and Dagdervuren's study [5], tour scheduling was taken into account that consists of both shift and days off. Chen et al. [6] proposed A multi-objective model for multi-project scheduling and multi-skilled staff assignment for Information Technology (IT) product development. In another research by Valeva et al. [7] they investigated the problem of assigning workers to tasks, seeking to maximize profits. Robust optimization techniques to the shift generation problem in workforce planning applied by Van Hulst et al.[8]. An integrated staff scheduling at a medical emergency service studied by Vermuyten et al.[9]. The staff scheduling in job rotation environments considering ergonomic aspects and preservation of qualification presented by Hochdorffer et al.[10]. Finally, Leggate et al. [11] propsed Modeling crew scheduling in offshore supply vessels. As can be seen from the conducted studies, staff scheduling problem's studied in subjects such as, airline crew [4], medical emergency service [9] and offshore supply vessels [11]. But no research was found to scheduling the capillary marketing staff. Therefore, the present study attempts to consider the possibility of scheduling two groups of experienced and inexperienced distribution staff based on capillary marketing by taking into account aims such as decreasing the costs and increasing the sales of this section. For this purpose, a new mathematical model based on assumptions and included objectives and constraints which make possible achieving purposed aims is designed. In the final step, the presented model will be solved by different methods and the results will be analyzed.

2. MATHEMATICAL MODEL

In this study, the multi-objective scheduling problem (MOSP) for scheduling between two groups of experienced and inexperienced staff in the capillary marketing department of Pak Pasteurized Dairy Products Company of Guilan province will be discussed. Minimizing company costs in the marketing sector is considered as the first goal of the study. Maximizing sales is also considered as the second goal of this study. Maximizing sales volume as a major goal of the company is in the direction of greater profitability. The issue under consideration is subjected to two types of concentrations. The first set of constraints are those whose results directly affect the target functions because they contain the main decision variable in the model; and other categories are concentrations that do not affect the target functions, but affect the performance of the company in order to achieve customer satisfaction. On the other hand, scheduling the distribution staff creates an opportunity for the management to use the employees in an optimal way and manage costs as well. Moreover, in concept the equations designed in a way that provide more possibility to connect with customers' network, so creating an opportunity to make management aware of their necessities in order to provide their satisfaction.

2. 1. Model Assumptions In this regard, the assumptions of the problem are as follows: marketers were divided into two groups: experienced and inexperienced subjects. Because groups of experienced subjects performed better than inexperienced groups at the time of receiving and processing the quantity of rial order, and; but it's important to note that the amount of sales is independent on the number of invoices and it depends on the number inserted on the invoice. Days are divided into three categories; holiday is Friday that sales equal to zero, overtime day is a day that is holiday based on calendar but due to some customers such as supermarkets and hypermarkets' demand goods, the firm should work on those days but the company does not employ all employees on overtime day because the selling volume is not the same as ordinary days and they have to pay overtime these days, therefore, it is not economical that all employee work at overtime days. While fixed costs (salaries) are paid to all employees during all the days of the month. Variable expenses (lunch, commute and overtime) are payable only if the employee is present at the workplace; and the combined cost (insurance) which is a percentage of the total amount of sales during the month and fixed costs that is considered for each employee all days of month. The tasks are as follows: receiving and processing each order every day should be answered in a working time equal to or less than the time it is considered per employee per day. Furthermore, because selling on an overtime day is not like a normal day, it is not possible to use all employees on an overtime work day for the company because the overhead costs are imposed on the company. The company has a certain amount of employee each day, which should not exceed the maximum specified; also, the number of people who can be employed on an ordinary or overtime day cannot be lower than the minimum. However, the average ordinary workday for each employee should not be less than the minimum. The important thing is that the amount of sales per month for each employee is minimal, which should not be less than that.

2. 2. Proposed Mathematical Model

Table 1 shows the model's indexes and parameters also decision variables. This model has two main objective functions and twelves constraints, which are as follows:

$$min\ Z1 = [\ ((\sum_{i1\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i1jp} * M_{i1jp} * C) + (\sum_{i2\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i2jp} M_{i2jp} * C)) + (\sum_{i\epsilon I}\sum_{j\epsilon J}\sum_{p\epsilon P} x_{ijp} * F_c) + (\sum_{i\epsilon I}\sum_{j\epsilon Je\cup Jd\cup Jh}\sum_{p\epsilon P} x_{ijp} * V_{ijp}) + (((\sum_{i1\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i1jp} * M_{i1jp} * C) + (\sum_{i1\epsilon I}\sum_{j\epsilon J}\sum_{p\epsilon P} x_{i1jp} * F_c)) * e) + (((\sum_{i2\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i2jp} * M_{i2jp} * C) + (\sum_{i2\epsilon I}\sum_{j\epsilon J}\sum_{p\epsilon P} x_{i2jp} * F_c)) * e)] \quad (1)$$

$$max\ Z2 = \sum_{i1\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i1jp} * M_{i1jp} + \sum_{i2\epsilon I}\sum_{j\epsilon Je\cup Jd}\sum_{p\epsilon P} x_{i2jp} * M_{i2jp} \quad (2)$$

S.t.

$$\sum_{j\epsilon Jd} a_{i1} * N_{i1jp+} k_{i1jp} \leq R_{ip_d} \qquad \forall i_1, p_d \qquad (3)$$

$$\sum_{j\epsilon Je} a_{i1} * N_{i1jp+} k_{i1jp} \leq R_{ip_e} \qquad \forall i_1, p_e \qquad (4)$$

$$\sum_{j\epsilon Jd} a_{i2} * N_{i2jp+} k_{i2jp} \leq R_{ip_d} \qquad \forall i_2, p_d \qquad (5)$$

$$\sum_{j\epsilon Je} a_{i2} * N_{i2jp+} k_{i2jp} \leq R_{ip_e} \qquad \forall i_2, p_e \qquad (6)$$

$$\sum_{j\epsilon Je\cup Jd}\sum_{i\epsilon I} x_{ijp} \geq Q_p \qquad \forall p \qquad (7)$$

$$\sum_{j\epsilon Jd}\sum_{i\epsilon I} x_{ijp} \leq G_p \qquad \forall p \qquad (8)$$

$$\sum_{i\epsilon I}\sum_{j\epsilon Je} x_{ijp} \leq O_p \qquad \forall p \qquad (9)$$

$$\sum_{j\epsilon Jd}\sum_{p\epsilon p} x_{ijp} \geq w_p \qquad \forall i \qquad (10)$$

$$\sum_{p\epsilon P}\sum_{j\epsilon Je} x_{ijp} \leq b_i \qquad \forall i \qquad (11)$$

$$\sum_{j\epsilon J}\sum_{p\epsilon P} M_{ijp} * x_{ijp} \geq L_i \qquad \forall i \qquad (12)$$

$$X_{i1jp} \epsilon \{0,1\} \qquad \forall i_1, j, p \qquad (13)$$

$$X_{i2jp} \epsilon \{0,1\} \qquad \forall i_2, j, p \qquad (14)$$

$$k_{i1pd}, k_{i11pe}, k_{i2pd}, k_{i21pe} > 0 \qquad (15)$$

TABLE 1. Indexes, Parameters and Decision Variablrs

Indexes	
i_1	experienced employee index (*i=1,2,….,N*)
i_2	inexperienced employee index (*i=1,2,….,N*)
P	index of days of month
P_d	ordinary day index
P_e	overtime day index
P_h	holiday index (Friday)
j_h	holiday condition index
j_d	ordinary condition index
j_e	overtime condition index
Parameters	
F_c	The fixed cost of assigning an employee per day
V_{ijp}	The variable cost of assigning an employee on day *p* with *j* status
M_{i1jp}	experienced employee sales on *P* day with *J* status
M_{i2jp}	inexperience employee sales on *P* day with *J* status
N_{i1jp}	Order quantity (invoice issued) an experienced employee on day p with status j
N_{i2jp}	Order quantity (invoice issued) an inexperienced employee on day p with status j
L_i	Minimum sales of per employee each month
C	Percentage of sale
E	The share of firm that should be paid for insurance
b_i	The upper bound for the maximum days of overtime for each employee per month
a_{i1}	The amount of time required to process each order by an experienced employee
a_{i2}	The amount of time required to process each order by an inexperienced employee
Q_p	Minimum number of people required for ordinary and overtime day
G_p	Min number of people required for ordinary day
O_p	Max number of people who can work on an extra day
W_p	Min ordinary working days for each employee during the month
R_{ip_d}	Max work time each employee per ordinary day
R_{ip_e}	Max work time each employee per overtime day
DecisionVariable	
X_{i1jp}	If employeei_1 on day *p* is in position *j* is equal to 1 and otherwise 0.
X_{i2jp}	If employeei_2 on day *p* is in position *j* is equal to 1 and otherwise 0.
K_{i1pd}	Time to receive orders on the market by an experienced employee on an ordinary day
$K_{i1pe:}$	Time to receive orders on the market by an experienced employee on an overtime day
K_{i2pd}	Time to receive orders on the market by an inexperienced employee on an ordinary day
K_{i2pe}	Time to receive orders on the market by an inexperienced employee on an overtime day

The first goal of Equation (1) attempts to minimize company costs in the distribution sector. It includes four sections; the first section tries to minimize sales costs for two groups of marketing (experienced and inexperienced) which are calculated based on the percentage multiplying by the amount of sales. In the second part of the function, the fixed costs assigned to each customer (monthly salary) are minimized. In the third part, the variable cost of each employee (e.g. overtime, lunch, commute), will become minimal. In the fourth and final part, the insurance cost of each employee, which is a percentage of the fixed cost combination and sales reward, will be minimized. Equation (2) tries to maximize the number of sales that this issue improve the distribution channel's relationship with customers and increase the customers' network and in fact it is something more than maximizing the number of sale. Equations (3) to (6) express that the responsibility of each marketer, including the receipt and processing of orders, must be done at least equal to or less than the hours worked for per employee each day. The remarkable thing is that the amount of working time each day is the same for both experienced and inexperienced worker groups. Constraint (7) appoints a lower bound to the requisite number of the employee for each ordinary and overtime day. Constraint (8) determines an upper bound for the requisite number of the employee on an ordinary day. Constraint (9) indicated that there is an upper bound for assigning the number employees on an overtime day. Constraint (10) proposes a lower bound for minimum ordinary days for each employee. Constraint (11) appoints an upper bound to maximum overtime day for every employee during the month. Constraint (12) indicates that the total sale for each employee cannot be lower than the determined amount. Constraints (13) and (14) show binary variables. For example, if an employee with j condition on p day works, it is 1, if not it is 0. Constraint (15) shows non-negative variables. Defining each of these constraints for creating a rational model is necessary because by eliminating any of them, the model will lose its logical and economic purpose.

3. PROBLEM SOLVING METHOD

In this research, for solving the two-objective equation, epsilon constraint by GAMS software and then two meta-heuristic algorithms including multi-objective water flow like algorithm (MOWFA) and multi-objective invasive weed optimization (MOIWO) algorithm were used.GAMS software plays an important role in engineering disciplines as a powerful and comprehensive tool for solving mathematical models, that is, wherever we need to make optimal decisions, as well as mathematical modeling with respect to constraints of time, cost, and resources, GAMS, which is very effective for solving these types of models is used. Given the capabilities of this software and the features of the problem, GAMS was chosen as a tool for solving the model. The results of model solving using the epsilon constraint method by GAMS software on real-world data were obtained from the case study indicating the effectiveness of the proposed model in response to all the objectives and constraints presented. Therefore, in order to demonstrate the efficiency of the mathematical model in larger dimensions, problems generated by using two meta-heuristic algorithms called the multi-objective water flow like algorithm (MOWFA) and multi-objective invasive weed optimization (MOIWO) algorithm developed for this problem will be solved. These two algorithms were chosen because they responded to similar problems as mentioned in literature [12-14].

3. 1. Multi-objective Water Flow Like Algorithm (MOWFA)

This algorithm is inspired by the natural behavior of water flow from high points to low-lying areas. WFA simulates solution agents as water flows traversing the terrain mapped from the objective function. Governed by the gravitation force, water flows from higher attitudes to lower ones. Driven by the fluid momentum, water flows adjust their compositions and directions against the landforms by splitting into and merging from other flows. Water flows are allowed to move upward to higher attitudes once they possess enough momentum to overcome the potential barrier. Mostly, at least one flow can travel to the lowest region of the terrain under the consideration. In the atmosphere, some water of a flow will evaporate and return to the ground by precipitation. Inspired by the water flowing of the nature, WFA is designed as an optimization algorithm performing the water flow splitting, merging, and dropping (precipitation) operations to traverse the solution space. WFA is an evolutionary algorithm involving four water flow operations: splitting and moving, merging, evaporation, and precipitation. Such a natural behavior of water flows is used in WFA design [15]. This algorithm operator's works as follow: first, a set of flows as initial population are randomly distributedon some positions on the ground, which represent random solutions of the optimization problem. As mentioned earlier, flows are mapped as solutions and so must be a representative of decision variables. We present each flow is presented by an $N*T$ vector in which N is the number of workers and T is the number of day. A set of random numbers between 0 and 1 is generated. Then these values are rounded. The value 1 shows that worker is used in that day. For example, Table 2 shows a solution in which worker 1 is used in days 2, 4 and 5.

Driven by flow momentum, the flows start to move to new locations and explore the solution space for better solutions. A flow with higher momentum generates more streams of sub-flows than one with less momentum. The number of sub-flows split from a flow can be expressed through the Equation (16).

$$n_i = min\left\{\bar{n}, int\left(\frac{M_i V_i}{T}\right)\right\} \quad (16)$$

where $\overline{n}$ is an upper limit imposed on the number of sub-flows, M_i is the mass and V_i is the velocity of the flow 'i'. When the momentum of a flow is lower than a predefined base momentum *T*, no splitting happens and the flow moves as a single stream to the neighboring location. Also, if a flow has a zero velocity, it will stagnate at its location. The locations of the split sub-flows are derived from the neighboring locations of the original flow. In reality, a flow movement is a search procedure from the current location to a neighboring one. The design of the flow-moving operation is problem-dependent. For more efficiency of proposed MOWFA, we have designed two neighborhood strategies which are capable of keeping the feasibility of solutions. In neighborhood strategy type 1, after randomly selecting a cell, its value in reduced by 1. For example if it is equal to 0.44 it will be changed to 1-0.44= 0.56. Neighborhood strategy type 2, is just like neighborhood type 1 but all the cells will change. Table 3 is an exampleof neighborhood strategy type 2.

As mentioned previously, the mass of flow *i* must be reasonably distributed to its sub-flows. To this aim, the sub-flows of flow *i* are ranked based on non-dominated sorting and crowding distance metric. The allocated mass to sub-flow *j* distributed flow *i*, U_{ij}, is then calculated by Equation (17) Where $rank_j$ is the rank of sub-flow *j* respecting to the other sub-flows distributed flow *i*. Also velocity of sub-flow j split from flow *i* is calculate by Equation (18).

$$U_{ij} = \left(\frac{n_i+1-rank_j}{\sum_{r=1}^{n_i} r}\right) \times M_i \quad (17)$$

$$\mu_{i,j} = \begin{cases} \sqrt{V_i^2 + 2g\overline{\delta_{i,j}}} & if\ V_i^2 + 2g\delta_{i,j} > 0 \\ 0 & otherwise \end{cases} \quad (18)$$

$$\overline{\delta_{i,j}} = \underset{k}{\text{mean}}\, \delta_{i,j}^k \quad (19)$$

where 'g' is the gravitational acceleration and $\delta_{i,j}^k$is the altitude drop from flow *i* to its sub-flow *j* in objective function *k*, that is, the improvement of *k*th objective function when moving from current solution *i* to neighborhood solution *j*. The value of $\delta_{i,j}^k$ for each of minimization and maximization objective functions is computed separately (Equation (20)) and then is averaged.

$$\delta_{i,j}^k = \begin{cases} f_i^k - f_{i,j}^k, for\ minimization \\ f_{i,j}^k - f_i^k, for\ maximization \end{cases} \quad (20)$$

where f_i^k is objective function value *k* of flow *i* and $f_{i,j}^k$ is *k*th objective function values sub-flow *j* distributed flow *i*. When more than two flows arrive at the same location, they will merge into a single flow with bigger momentum. Whether the location of two flows are the same or not is investigated by our proposed criterion called similarity coefficient (SC). If the SC between two flows is greater than a predefined threshold, their locations are supposed to be identical and the merging takes place. If SC_{ab} exceeds a predefined threshold the flows a and b are recognized as identical flows and merged. Suppose that the flows a and b are sharing the same location, then both flow a and flow b will be removed and the new flow will be generated based on the characteristics presented in Equations (21) and (22). The new generated flow is quite similar to flow a.

$$M_{new} = M_a + M_b \quad (21)$$

$$V_{new} = \frac{V_a M_a + V_b M_b}{M_a + M_b} \quad (22)$$

It is natural that flows of water evaporate after possible movement and return to the ground through precipitation. In MOWFA, water evaporation and precipitation mechanism help the algorithm to escape from local optimum. If a flow falls into a local optimum, it will be stagnated and so loss the capability of moving, merging or splitting. To overcome this problem and release the flow from the local optimum, the trapped flow is forced to evaporate into the atmosphere. The proposed MOWFA establishes a velocity-based evaporation according to the flows with smaller velocities so that they will evaporate more speedily than flows with larger velocities. The formulation of the velocity-based evaporation is presented in Equations (23) and (24).

TABLE 2. An example of proposed solution representation (a water flow)

	0.31	0.71	0.49	0.72	0.59
	0.18	0.62	0.69	0.86	0.68
	0.34	0.34	0.97	0.28	0.36
	0.21	0.94	0.33	0.73	0.62
	0.51	0.12	0.84	0.14	0.81
Worker 1	0	1	0	1	1
Worker 2	0	1	1	1	1
Worker 3	0	0	1	0	0
Worker 4	0	1	0	1	1
Worker 5	1	0	1	0	1

TABLE 3. An example of proposed solution representation (a water flow)

0.712	0.809	0.935	0.712	0.615
0.871	0.357	0.479	0.017	0.377
0.329	0.073	0.232	0.801	0.877
0.650	0.591	0.396	0.143	0.785
0.975	0.910	0.705	0.478	0.465
0.288	0.191	0.065	0.288	0.385
0.129	0.643	0.521	0.983	0.623
0.671	0.927	0.768	0.199	0.123
0.350	0.409	0.604	0.857	0.215
0.025	0.090	0.295	0.522	0.535

$$M_i = (1 - \rho_i)M_i \tag{23}$$

$$\rho_i = \begin{cases} 1, & if\ \mu_{i,j} = 0 \\ 0, & if\ \frac{\mu_{i,j}}{V_i} \geq 1 \\ 1 - \frac{\mu_{i,j}}{V_i} & if\ 0 \leq \frac{\mu_{i,j}}{V_i} \leq 1 \end{cases} \tag{24}$$

After a number of iterations, the evaporated water will return to the ground by precipitation operator. In this paper, a seasonal rainfall is applied periodically in which the precipitation takes place when the number of evaporated flows reaches to a predefined level. In order to enhance the algorithm's diversity, the location of returned flow is deviated far away from the location of flow before evaporation. In this way, the bits of flow are generated just like a new flow.

3. 2. Multi-objective Invasive Weed Optimization Algorithm (MOIWO) This numerical stochastic search algorithm mimicking natural behavior of weed colonizing in opportunity spaces for function optimization. In this algorithm, the goal is to find the best point of a certain environment for the living of seeds. Parent plants do the search with seed propagation. In the first stage, parts of the environment that are candidates for the best region to live in are determined, and in the next step, searches for areas with better biological conditions are done. Therefore, the main idea of the method, increasing the focus and the power of search with the passage of time in the areas with the probability of having a better answer. The process is addressed in details as follows:

A population of initial solutions is being dispread over the d dimensional problem space with random positions. A member of the population of plants is allowed to produce seeds depending on its own and the colony's lowest and highest fitness: the number of seeds each plant produce increases linearly from minimum possible seed production to its maximum. In other words, a plant will produce seeds based on its fitness, the colony's lowest fitness and highest fitness to make sure the increase is linear. Randomness and adaptation in the algorithm is provided in this part. The generated seeds are being randomly distributed over the d dimensional search space by normally distributed random numbers with mean equal to zero; but varying variance. This means that seeds will be randomly distributed such that they abode near to the parent plant. However, standard deviation (SD), σ, of the random function will be reduced from a previously defined initial value, σinitial, to afinal value, σfinal, in every step (generation). In simulations, a nonlinear alteration has shown satisfactory performance, which is given in Equation (25).

$$\sigma_{iter} = \frac{(iter_{max} - iter)^n}{(iter_{max})^n}\left(\sigma_{initial} - \sigma_{final}\right) + \sigma_{final} \tag{25}$$

If a plant leaves no offspring then it would go extinct, otherwise they would take over the world. Thus, there is a need of some kind of competition between plants for limiting maximum number of plants in a colony. After passing some iterations, the number of plants in a colony will reach its maximum by fast reproduction. However, it is expected that the fitter plants have been reproduced more than undesirable plants. By reaching the maximum number of plants in the colony, P_{max} a mechanism for eliminating the plants with poor fitness in the generation activates. The elimination mechanism works as follows: when the maximum number of weeds in a colony has reached, each weed is allowed to produce seeds. The produced seeds are then allowed to spread over the search area. When all seeds have found their position in the search area,they are ranked together with their parents' (as a colony ofweeds). Next, weeds with lower fitness are eliminated to reach the maximum allowable population in a colony. In this way, plants and offspring are ranked together and the ones with better fitness survive and are allowed to replicate. As mentioned in step (2), this mechanism give a chance to plants with lower fitness to reproduce, and if their offspring has a goodfitness in the colony then they can survive. The population control mechanism also is applied to their offspring to the end of a given run, realizing competitive exclusion. To conclude this section it's necessary to say that the structure of seed is completely the same as flow so the solution construction of two algorithms is exactly like each other.

3. 3. Response Surface Methodology The goal of setting the input parameters to algorithms is to increase the level of performance of meta- heuristic algorithms as much as possible. Each of these parameters has a special significance and affects the algorithm's performance. Response surface methodology (RSM) has been used to identify the appropriate values of the parameters such a way that the performance of the algorithms can be ideal. RSM consists of a group of mathematical and statistical techniques that are based on the fit of empirical models to the experimental data obtained in relation to experimental design.

With respect to this objective, linear or square polynomial functions are employed to describe the system studied and, consequently, to explore (modelling and displacing) experimental conditions until its optimization [3]. This technique is useful for modelling and analyzing the problems that the response is affected by several variables and aims to optimize this response. In order to apply the RSM method, you must first specify the scope of the search for all agents. Table 4 shows the search domain of the input parameters of the two algorithms. Due to the choice of two-level factor design for each experiment, two high and low levels are considered.

TABLE 4. Controllable Factors and Their Levels

Solved algorithm	Parameters		High level	Low level
MOWFA	M_0	Primary mass flow	50	100
	V_0	Initial flow rate	30	50
	n	Max number of flows	3	7
	Iteration	Iteration	50	150
	Pop size	Pop size	30	60
MOIWO	MaxIt	Iteration	50	150
	P_{init}	Primary population size	5	15
	P_{max}	Max population size	50	100
	m	The correction factor	1	3
	sd_{min}	Final Standard Deviation	0	0.75
	sd_{max}	First Standard Deviation	1	5
	S_{min}	Min number of leaves	1	3
	S_{max}	Max number of leaves	5	10

4. EXPERIMENTAL RESULTS

The results of this experimental design with the criteria introduced by Design Expert 7 software were achieved and reviewed. Regarding the results of ANOVA, it could be concluded that the linear effect of all factors was significant, but the interaction and exponential effects of some factors had statistically no significant effect on the response variables and should not be considered in statistical analyzes. Therefore, the stepwise regression method with a confidence level of 0.95% as well as significant factors were used to create the final equation. The reason for choosing the stepwise regression is that the evaluation of all possible regressions is difficult, so only a few subsets of regression models are expanded by adding or removing one by one regression variables. Tables 5 and 6 are presented the results of statistical analysis without regard to ineffective factors.

5. COMPUTATIONAL RESULTS

Proposed multi-objective algorithms perform the search space based on the Pareto optimal set. In order to evaluate multi-objective algorithms, various criteria have been introduced so far; in this study, seven of them are used. In the following, 30 sample problems were generated and solved by algorithms and the results were recorded. Finally, the performance of the proposed algorithms was compared with each other based on the proposed criteria. To analyze and compare the results of proposed algorithms, the criteria described below are used. In the spacing criterion, in an algorithm with a final non-dominated response with the small-spacing value would be better. Max Spread: this criterion is used to compute the spread of the optimal Pareto-front responses which is concluded from the algorithm, the high magnitude of this criterion indicates the higher priority of the algorithm. The number of Pareto solutions: the value of this criterion represents the number of Pareto optimal solutions that can be found in each Algorithm, so the higher values represent the higher priority of the algorithm. Mean ideal distance (MID): this criterion, in order to calculate the average distance of Pareto solutions from the origin of coordinates is used; the lower values of this criterion represent the greater efficiency of the algorithm.

TABLE 5. The results of ANOVA and fitting the response of MOWFA algorithm using effective factors

Source	Sum of Squares	df	Mean Square	F Value	p-value	
Model	280.3591	9	31.15101	251.6824	< 0.0001	Significant
A-M0	7.540139	1	7.540139	60.92001	< 0.0001	
B-V0	3.297312	1	3.297312	26.64039	< 0.0001	
C-n	193.6512	1	193.6512	1564.591	< 0.0001	
D-Iteration	61.93845	1	61.93845	500.4272	< 0.0001	
E-Popsize	5.500139	1	5.500139	44.43798	< 0.0001	
AE	2.0736	1	2.0736	16.7535	0.0005	
BC	2.0736	1	2.0736	16.7535	0.0005	
BD	2.0736	1	2.0736	16.7535	0.0005	
A^2	2.211094	1	2.211094	17.86437	0.0003	
Residual	2.722965	22	0.123771			
Lack of Fit	2.722965	17	0.160174			
Pure Error	0	5	0			
Cor Total	283.0821	31				

0.9680 R-Squared 0.9904 Pred R-Squared
71.745 0.9864 Adeq Precision Adj R-Squared

TABLE 6. The results of ANOVA and fitting the response of MOIWO algorithm using effective factors

Source	Sum of Squares	df	Mean Square	F Value	p-value	
Model	1486.097	10	148.6097	293.1533	< 0.0001	Significant
A-MaxIt	238.4917	1	238.4917	470.4582	< 0.0001	
B-Pinit	261.0226	1	261.0226	514.9035	< 0.0001	
C-Pmax	62.76126	1	62.76126	123.8053	< 0.0001	
E-sdmin	21.86302	1	21.86302	43.12786	< 0.0001	
F-sdmax	4.020275	1	4.020275	7.930553	0.0070	
G-Smin	475.5139	1	475.5139	938.0175	< 0.0001	
H-Smax	177.0571	1	177.0571	349.2698	< 0.0001	
AB	66.64744	1	66.64744	131.4714	< 0.0001	
GH	49.52454	1	49.52454	97.69406	< 0.0001	
B^2	2.529574	1	2.529574	4.989937	0.0301	
Residual	24.83982	49	0.506935			
Lack of Fit	24.83982	44	0.564541			
Pure Error	0	5	0			
Cor Total	1510.937	59				

0.9836 Pred R-Squared 0.9735 R-Squared

78.48 0.9802 Adeq Precision Adj R-Squared

The Rate of Achievement to two objectives simultaneously (RAS): this criterion is looking for a balance in achieving each goal, and the smaller values of this indicate the higher priority of the algorithm. TIME also considers the implementation time of the algorithm as a quality evaluation criterion, so the smaller values indicate the higher quality. Number of Pareto solutions and their diversity: this criterion shows the dispersion of Pareto queue responses to their quality, so the larger of this criterion indicates the higher priority of the algorithm. Moreover, all computations were performed by a laptop with 4 MB RAM and a 2 duo 2.2 GHz, Core i5 processor, also the Design Expert 7 software was used to set parameters for the algorithm. The meta-heuristic algorithms programming has also been done in MATLAB software. In this regard, the precision method of epsilon constraint was implemented in the GAMS software and the solutions were obtained for the exact calculation of small size problems. Since precise methods do not have the ability to solve medium and large sized problems at a reasonable time, the MOWFA and MOIWO meta-heuristic algorithms have been used to solve the problem and to find approximate justified solutions. Also, the results are presented in Figures 1 to 7 based on the criteria used in this study.

According to Figure 1, both meta–heuristic algorithms had the same performance in the Max-Spread criterion, but in problems 21 through 30 the efficiency of the MOWFA algorithm was higher. Under NPF criterion (Figure 2), the MOWFA has a better performance than MOIWO. Also, the efficiency is even better on some problem than GAMS results. In the SNS criterion (Figure 3), both meta-heuristic algorithms had the same performance. Also, in most problems of 1-10, the GAMS performed better. In the spacing criterion (Figure 4), the MOWFA performed better than MOWFA. The efficiency of this algorithm was also close to GAMSin most problems.

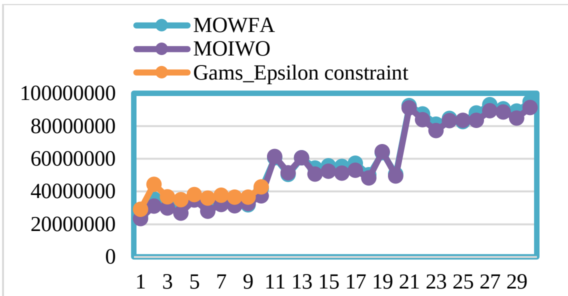

Figure 1. Comparison of algorithms in Max- Spread

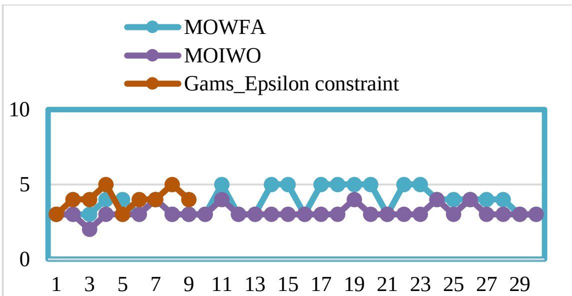

Figure 2. Comparison of algorithms in NPF

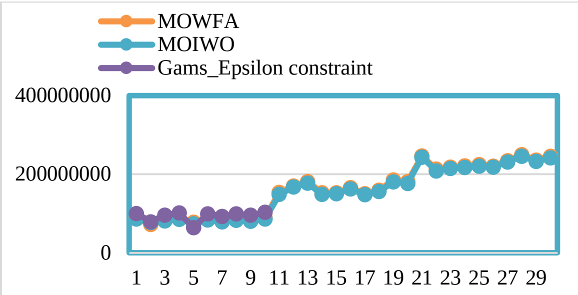

Figure 3. Comparison of algorithms in SNS

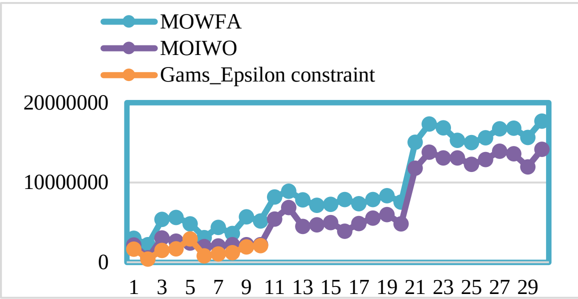

Figure 4. Comparison of algorithms in Spacing

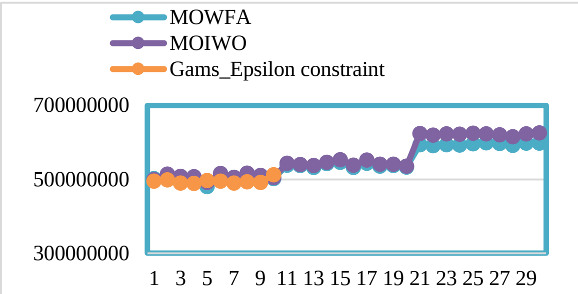

Figure 5. Comparison of algorithms in MID

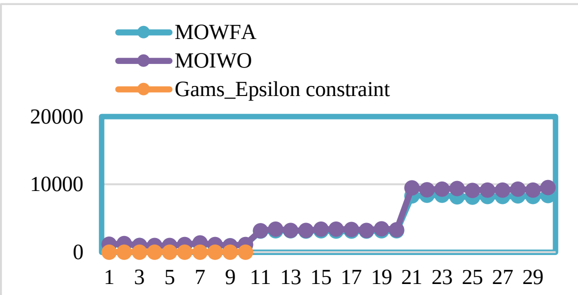

Figure 6. Comparison of algorithms in TIME

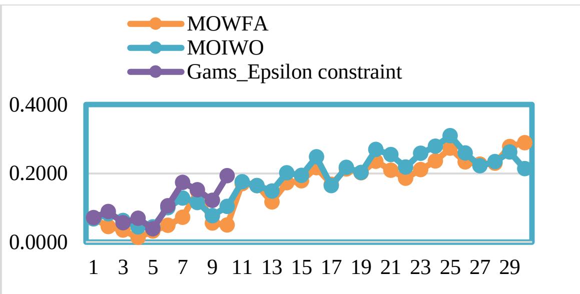

Figure 7. Comparison of algorithms in RAS

In the MID criterion (Figure 5) the MOWFA meta-heuristic algorithm performed better than MOIWO. Moreover, the efficiency of this algorithm was not only close to GAMS in most problems, but also performed better in two problems. In the TIME criterion (Figure 6), the MOWFA performed better than MOIWO. In addition, GAMS 'performance was far beyond meta-heuristic algorithms.

Finally, in the RAS criterion (Figure 7), meta-heuristic algorithms were at the same level of efficiency. The meta-heuristic algorithms had the ability to compete with GAMS on this criterion. In general, based on these results, it can be claimed that the proposed algorithms in all the criteria except the TIME criterion, had the highest ability to find the global optimal solution and can be used to find efficient solutions to large-size problems.

6. CONCLUSIONS AND RECOMMENDATION

The study was conducted to optimize the costs and sales volume of the capillary distribution channel in Pak Pasteurized Dairy Products Company of Guilan province. The analysis of the results showed the model responded to the goals and limitations desired in the best possible way with regard to the data and information available. Therefore, present work has provided an opportunity for the managers to take under control financial stuff also have wider relationship with costumers' network so that satisfying their needs. This model examined only the company's one-month data but the stated problem had the ability to be extended to other months of the year or other parts of the company; even companies with a much larger number of employees in different industries, especially those operating in a single shift, for example, banks, insurance companies can be considered as a case study. The only point that should be considered as a constraint is that the upper or lower bounds of each constraint must be determined according to the calendar and conditions of each month, as well as the number of people in each section. Comparing the results of the study with the literature review indicated that the model, like the examples mentioned, had the capability to cover and respond to the goals and constraints mentioned. The following constraints can also be added to the model in future studies: Satisfaction constraint, for any reason some employees may not be satisfied with the division of days for being used or not. Therefore, to planning for days this issue should be considered as a constraint. It is also possible for employees of this section to be divided into multi-member groups and in each group, one of them determined as a supervisor. In this way, there should be a limitation on the basis of which, the supervisor of a group and a member of the same group cannot go on vacation simultaneously. But, if this was inevitable, what kind of policy can be implemented.

7. REFERENCE

1. Christopher, M., Logistics and Supply Chain Management, Pearson UK, (2016).
2. Fürst, A., Leimbach, M., and Prigge, J.K., "Organizational Multichannel Differentiation: An Analysis of Its Impact on Channel Relationships and Company Sales Success", ***Journal of Marketing***, Vol. 81, No. 1, (2017), 59–82.
3. Naso, D., Surico, M., Turchiano, B., and Kaymak, U., "Genetic algorithms for supply-chain scheduling: A case study in the distribution of ready-mixed concrete", ***European Journal of Operational Research***, Vol. 177, No. 3, (2007), 2069–2099.
4. Pak Seresht, M., Mahdavi, I., and Shirazi, B., "Fuzzy Modeling Airline Crew Scheduling Problem and Solving by Particle Swarm Optimization", ***Journal of Transportation Engineering***, Vol. 07, No. 1, (2015), 1–12.
5. Adem, A., and Dagdeviren, M., "A Mathematical Model For the Staff Scheduling Problem With Ergonomic Constraints", In Proceedings of The IRES 25th International Conference, Istanbul, (2016).
6. Chen, R., Liang, C., Gu, D., and Leung, J.Y.T., "A multi-objective model for multi-project scheduling and multi-skilled staff assignment for IT product development considering competency evolution", ***International Journal of Production Research***, Vol. 55, No. 21, (2017), 6207–6234.
7. Valeva, S., Hewitt, M., Thomas, B.W., and Brown, K.G., "Balancing flexibility and inventory in workforce planning with learning", ***International Journal of Production Economics***, Vol. 183, No. 183, (2017), 194–207.
8. Van Hulst, D., Den Hertog, D., and Nuijten, W., "Robust shift generation in workforce planning", ***Computational Management Science***, Vol. 14, No. 1, (2017), 115–134.
9. Vermuyten, H., Rosa, J., Marques, I., Beliën, J., and Barbosa-Póvoa, A., "Integrated Staff Scheduling at a Medical Emergency Service: An Optimisation Approach", ***Expert Systems with Applications***, (2018), 62-76.
10. Hochdörffer, J., Hedler, M., and Lanza, G., "Staff scheduling in job rotation environments considering ergonomic aspects and preservation of qualifications", ***Journal of manufacturing systems***, Vol. 46, , (2018), 103–114.
11. Leggate, A., Sucu, S., Akartunalı, K., and van der Meer, R., "Modelling crew scheduling in offshore supply vessels", ***Journal of the Operational Research Society***, Vol. 69, No. 6, (2018), 959–970.
12. Yang, F.C., and Wang, Y.P., "Water flow-like algorithm for object grouping problems", ***Journal of the Chinese Institute of Industrial Engineers***, Vol. 24, No. 6, (2007), 475–488.
13. Mehrabian, A.R., and Lucas, C., "A novel numerical optimization algorithm inspired from weed colonization", ***Ecological Informatics***, Vol. 1, No. 4, (2006), 355–366.
14. Zhou, Y., Luo, Q., Chen, H., He, A., and Wu, J., "A discrete invasive weed optimization algorithm for solving traveling salesman problem", ***Neurocomputing***, Vol. 151, (2015), 1227–1236.
15. Wu, G., Cheng, C., Yang, H., and Chena, C., "An improved water flow-like algorithm for order acceptance and scheduling with identical parallel machines", ***Applied Soft Computing***, Vol. 71, (2018), 1072–1084.

Optimization of a Bi-objective Scheduling for Two Groups of Experienced and Inexperienced Distribution Staff Based on Capillary Marketing

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چکیده

تعیین برنامه مناسب برای بخش توزیع صنایع به خاطر اثرگذاری بر سایر هزینه‌های شرکت و تأمین رضایت مشتریان از اهمیت بسزایی برخوردار است. لذا در این پژوهش یک مدل دو هدفه جدید برنامه‌ریزی خطی مختلط عدد صحیح برای زمان‌بندی دوگروه از کارکنان ماهر و غیرماهر کانال بازاریابی مویرگی در شرکت لبنیات پاستوریزه پاک استان گیلان به منظور کاهش هزینه‌ها و افزایش فروش در کنار توجه به رضایتمندی مشتریان توسعه داده شده است. محدودیت‌های مختلف موجود نیز در مدل منظور شده است. نتایج بررسی مدل با استفاده از روش محدودیت اپسیلون که مجموعه‌ای از جواب‌های پارتو را ارائه می‌دهد و حل توسط نرم‌افزار گمز، نشان از کارایی مدل در پاسخگویی به مسائل در ابعاد کوچک دارد. سپس برای سنجش اعتبار مدل ارائه‌شده در ابعاد بزرگ‌تر باتوجه به NP-hard بودن مسئله، الگوریتم تکاملی چندهدفه جریان آب (MOWFO) برای دستیابی به زمان‌بندی بهینه گسترش داده شد. برای ارزیابی روش پیشنهادی، مسائل متعددی توسعه داده شده و کارایی این روش بر پایه شاخص‌های طراحی‌شده، با الگوریتم علف‌های هرز (MOWIO) مورد مقایسه قرارگرفت. به‌منظور کارایی بهتر الگوریتم‌ها، پارامترهای ورودی آن‌ها با تکنیک RSM تنظیم گشتند و همچنین برای مقایسه آماری آن‌ها از فاصله اطمینان ٪۹۵ توکی استفاده شده است. نتایج نشان از برتری الگوریتم MOWFA در مقایسه با الگوریتم MOIWO در شاخص‌های موردمقایسه دارد.

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