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An integrated decision making approach for glass container industries

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Abstract

This paper discusses making decisions in the glass container industry. The production of glass containers for the packaging of food and beverages is one of the most important parts of glass industries. In this research, the decision is made on the production plan for the glass container industries from the perspective of various executive stakeholders. In this regard, two models are initially presented: 1) the first model with a production approach, i.e. considering the objectives and constraints of the production stakeholders, and 2) the second model with a sales approach, taking into account the objectives and constraints of the sales stakeholders. Also, in the sales approach, by defining a new index, the importance of meeting customers' demands is considered separately and according to different criteria. TOPSIS technique as one of the multi-attribute decision making methods is employed to calculate the noted parameter. Then, a multi-objective integrated model with a managerial approach for decision making on the production planning in the glass container industry is proposed, in which it is attempted to consider the viewpoints of various stakeholders. Finally, the proposed approach is implemented in one of the largest companies producing glass containers in Iran. In this regard, compromise programming is used to solve the final model. It is one of the multi-objective optimization methods which are classified under non-preferred methods. The obtained results show the efficiency of the proposed integrated approach for the studied company. It is also worth noting that the obtained results are presented for the management of the studied company and the results are found to be useful.

Keywords: Multi-objective decision making (MODM), glass industry, production planning, semi-continuous industry, multi-objective optimization, compromise programming, TOPSIS, stakeholders.

1- Introduction

The production process of glass containers is divided into two phases: 1) the continuous phase includes melting of the raw materials in the furnace; and 2) the discrete phase includes forming molten glass into containers on unrelated parallel machines (Richard and Proust, 2000).

Production planning is an activity that considers the best use of production resources to meet production goals over a specified period known as planning horizon. It usually includes three long-, medium-, and short-term periods for decision making (Karimi et al., 2003; Hajipour et al., 2014; Saidi-Mehrabad et al., 2017).

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Probably, one of the oldest studies on production planning and scheduling in the glass container industry was conducted by Paul (1979) who addressed the scheduling of parallel production lines in the glass packaging industry using computer simulations (Paul, 1979). In Richard and Proust (2000), the short-term planning in the bottle-glass production industry was examined, in which the total profit was the criterion for performance measurement. They examined the complexity of this problem in three ways; then, they presented a hierarchical approach based on product aggregation and disaggregation as well (Richard and Proust, 2000). In T'kindt et al.'s (2001) paper, a bi-criteria scheduling problem was addressed in the production of bottle glasses. The purpose of this article was to provide a timetable for orders such that the total margin could be maximized, while the machine's workload difference minimized. They provided an algorithm to solve parallel machines' scheduling problem and, then, developed it into an interactive algorithm (T'kindt et al., 2001). In Almada-Lobo et al.'s (2008) paper, a successful application of variable neighborhood search (VNS) was presented for the lot-sizing problem and scheduling of the long-term planning in the glass container industry (Almada-Lobo et al., 2008).

Since the process industries are capital-intensive, the main focus in competition is on reducing costs and improving performance. It is also necessary to meet the demands with the most cost-effective method. The main operational motive is to maximize the output of the facilities by a specialization of processes to reduce downtimes. Almada-Lobo et al. (2010) discussed the short-term production planning in a glassware production company in their research. Glass containers are inherently intermediate and may almost be considered as a commodity. The process of manufacturing glass containers is a semi-continuous process; glass is produced using a furnace that is distributed among a set of parallel machines which shape the containers. Although new furnaces cost millions of euros, the strategy of pulling the maximum glass out of furnaces is not due to the need to reduce the marginal costs associated with fixed furnace charges, but the need for operational competition and gross margins increase (related to variable costs). Moreover, given the economy of scale of natural gas consumption (the main industrial cost in this process) and other technical limitations, it is necessary the furnaces run close to their full capacity. The total amount of renewable and continuous source (molten glass) available at any time is limited. Since the production rate of a product of a machine depends on the amount of its continuous source at any time, the machines may have to produce under capacity. Therefore, the production environment with these conditions does not allow for a development of discrete lotsizing and scheduling problem (DSLP); as a result, researchers have focused on the difficult capacitated multi-item lotsizing problem (CSLP). They believe that it is the first study that has taken into account the production losses due to the total non-use of a resource, which is critical for a number of process industries. In the mentioned paper, researchers solve an MIP model developed from CSLP involved in the design of short-term production planning of glass containers and its scheduling (Almada-Lobo et al., 2010). In another paper, a new evolutionary algorithm was proposed to deal with short-term production planning and scheduling problem, derived from one of the real-world applications in the glass container industry. The challenge involved scheduling and determining the size of the lots in the most economical manner on a set of parallel molding machines fed by a furnace. The process of solving is a multi-population hierarchically structured genetic algorithm (GA) with a simulated annealing and cavity heuristic. The authors argued that the results showed superior performance of the proposed approach to a state-of-the-art commercial solver and compared with a non-hybridized multi-population GA (Toledo et al., 2013). Another study in this industry is an article written by Fachini et al. (2018), in which a new framework was provided for designing and implementing advanced planning and scheduling (APS) systems in a simple and efficient manner using spreadsheets in the glass containers manufacturing industry (Fachini et al., 2018). Also, from among several studies performed on the Iranian companies which are active in glass containers manufacturing, one was conducted to determine the factors affecting the production process of glass bottles using response surface methodology (RSM) in one of the oldest glass companies (Amiri, 2010). Moreover, Fakhim-Hahsmei et al. (2011) addressed strategic planning in one of the large and old glass container production companies in Iran. In the field of production planning, one can also mention Khatami-Firouzabadi et al. (2018).

In this paper, the integrated decision making problem for production planning in the glass container industry is discussed. In this regard, a model is first presented with a production approach based on the views of the executive production stakeholders. Then, by asking for the views of the sales stakeholders, another model with a sales approach is presented. Finally, an integrated model is proposed with a managerial approach based on a comprehensive management perspective. Meanwhile, a new concept called the importance of meeting customers' demands (IMCD) is defined as a criterion used in the proposed models of the sales and management approaches. Figure (1) shows the steps in the research process.

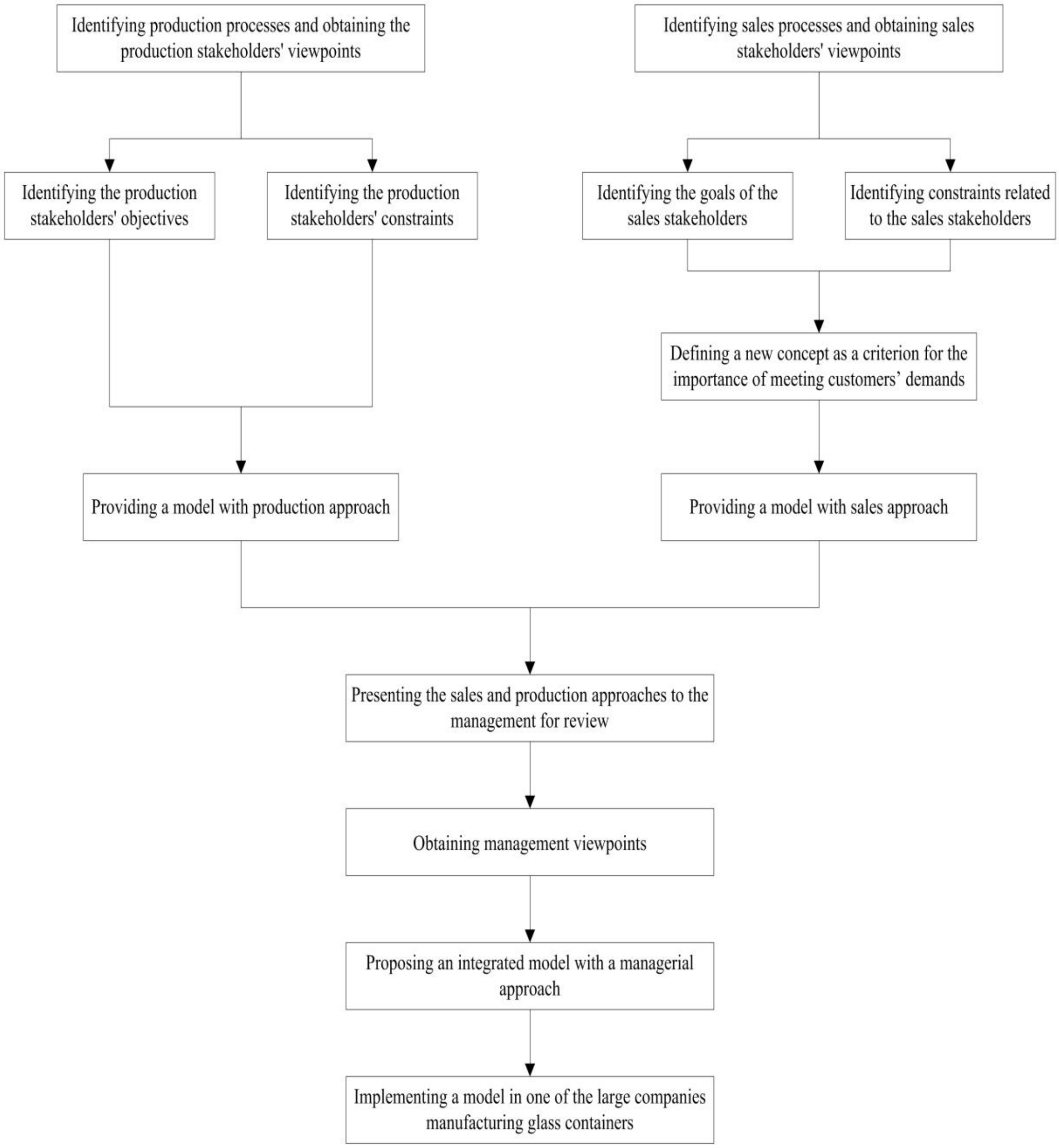

Fig. 1. Sequence diagram of the research process

In this paper, the sales profit of each product is considered in the final integrated model. Indeed, a different benefit is determined for each product. This is because, in Iran, glass container is soled per case, not based on weight. So, the profit from selling different products is not (necessarily) the same (i.e. production with greater unit profit can be prioritized). By assuming this in the model, there will be a closer relationship between the model and existing reality in Iran's glass container industry.

In the proposed model, a concept called "yield" is used and a parameter is specified for it, which is obtained according to the past manufacturing experiences of each product on each machine. Along with the characteristics of machines that affect their output, one of the effective factors in the ration of

weight of packed products to furnace output tonnage is the shape and complexities of the form of each product. The yield can be different; products with a more complex form will usually have a lower yield in practice. Therefore, the yields are considered accordingly in this model.
In this study, a new concept is defined as the importance of meeting customers' demands and the criteria for obtaining its parameter are proposed by getting the comments of experts in the glass containers industry. Defining this index and its maximization could lead the customers' demands to be placed in the meeting priority, so that ultimately, the importance of total met demands could be maximized according to the pre-determined criteria. In other words, the customers' total satisfaction could be finally maximized (considering the index). Finally, a bi-objective integrated model with a managerial approach for decision making in the production of glass containers is proposed, in which it is tried to consider the various stakeholders' viewpoints to the possible extent. It is attempted to provide the model according to the conditions governing the glass container industry in Iran, far from complexities and easy to be used by the noted industries. Also, to evaluate the proposed approach, it was studied in one of the largest companies manufacturing glass containers in Iran.

2- Glass container production

The general process of producing glass containers is semi-continuous; the raw materials were combined and, then, melted in the furnace, i.e. its continuous section. The glass paste (molten glass) flows through the feeders into the discrete manufacturing part (T'kindt et al., 2001).
The glass container manufacturing process begins with the mixing of raw materials transferred to the furnace, in which they melt at the temperature of about 1500°C. Since it takes 24 h for the batch material to pass the melting stage, the furnace capacity is measured as melted ton per day. Natural gas is the energy source used in this process. The glass paste is distributed after the cut in the shape of gobs by feeders among parallel independent sections of glass molding machines, forming the final product at 600°C. Each production line is equipped with molds and each mold has high production capability. In practice, the required setup times to change the equipment of the production lines relative to the process time is insignificant (can be neglected). Then, the formed containers go through conditioning, surfacing treatment, automatic inspection and packaging procedure and are stored (T'kindt et al., 2001; Almada-Lobo et al., 2010; Emami and Fakhim-Hashemi, 2014). Figure (2) shows the manufacturing process of glass containers.

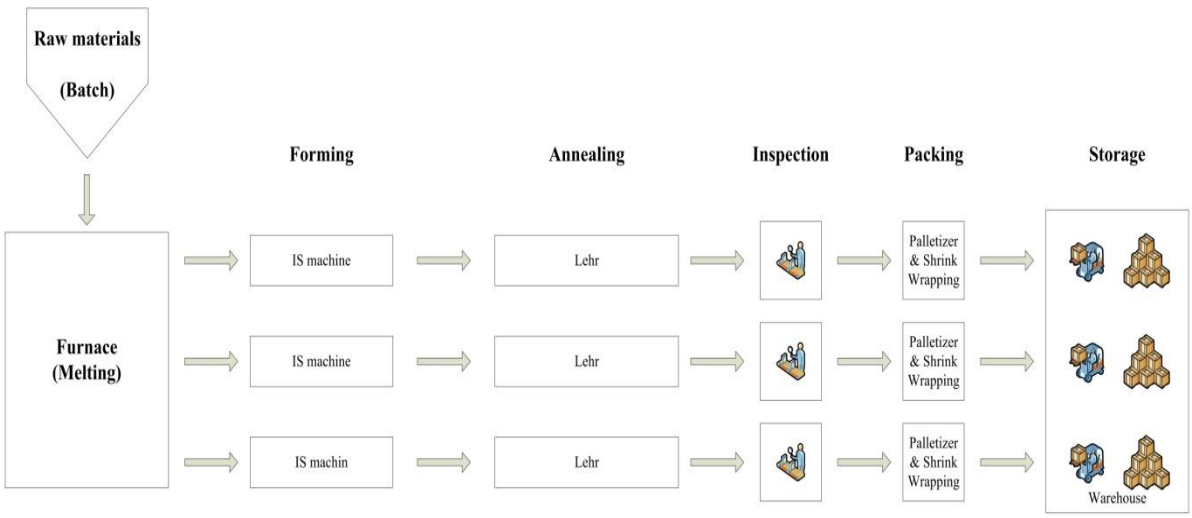

Fig. 2. Glass container manufacturing process

In the glass container industry, two kinds of changeover can be considered: The major-changeover is, in fact, the furnace color changing, which will change the color of all the lines connected to the furnace. So, all the lines are stopped until the process of color change is complete, which is a long-term planning. Another issue is minor-changeover, in which the product is changed on a line. In this case, it is only necessary to stop the line that has product change and its equipment (molds) are changed according to the new product; there is no interruption in the production of other lines; thus, it is referred to as minor-changeover.

For example, color changing from cobalt-blue to emerald-green in the furnace takes about 120 h. Due to the high sequence-dependent setup time imposed for the change in the color of the furnace, a particular color for any furnace is typically used (Almada-Lobo et al., 2008). However, due to the high sequence dependent setup times for color changing, the color of the molten glass per furnace for short- or medium-term is usually constant. The long-term production planning output schedules color campaigns on multi-site furnaces and assigns product orders to furnaces (Almada-Lobo et al., 2010). Since only one color glass is produced at a time in each furnace, the machines connected to the furnace always form a container with the same color. Furnaces work continuously, except when they are being repaired, and machine-lines are also operating 24 h and 7 days of the week. Therefore, there is slight flexibility to change the output for matching with fluctuations in demand. Due to the economies of scale of natural gas as well as structural constraints, it is not allowed to stop the machine. This limitation in machine balance makes machines feeding on the same furnace to have the same amount of operation. A machine can produce only one product at a time (Almada-Lobo et al., 2010). The formed containers are then reheated by passing through a lehr (reheating kiln) for annealing and, finally, the palletizing operation is done after applying a rigorous inspection (Almada-Lobo et al., 2008). There is sufficient capacity downstream of the molding machines to process everything coming from the upstream. Even if problems arise at the end of the production line, the conveyor has buffer zones for temporary storage to avoid stopping the molding machines (Almada-Lobo et al., 2010).

3- Problem statement and formulations

Production planning is one of the most important issues in production systems, which aims at effective planning and coordinating all production activities in such a way to optimize the company goals (Makui et al., 2016a). In fact, production planning is the process of decision making on the resources that the company needs for operating production in the future (Aazami et al., 2018).

In this article, attempts are made to provide an approach which considers different viewpoints of executive stakeholders in production planning. Here, executive stakeholders are individuals or sections (or groups of individuals) who are engaged in the organization operations and activities. Freeman defines “stakeholder” as “any group or individual who can affect or is affected by the achievement of the organization’s objectives”, referred to by Mitchell et al. (1997). The stakeholder can be an individual or an entity such as a department or a group of people, the perspective of whom is important for decision making. A decision making problem with more than one stakeholder can be made of more than one hierarchy with various criteria. There may be a conflict between various stakeholders, or even they might consider conflicting criteria (Khatami-Firouzabadi et al., 2008).

The existence of a production plan that only considers the ideas of a single stakeholder, no matter how important, causes problems for the organization. Nowadays, researchers and managers have found that using different stakeholders' viewpoints is not only a key factor in successful management, but also forms an important aspect of the decision making process in every position and place. Encouraging stakeholders to participate in the planning process will lead to more coordination in implementing the proposed solutions in the organization. Understanding the effectiveness of the viewpoints of individuals and groups of stakeholders in the decision making process makes them feel better. The important point is people's awareness of the process and their sense of partnership in decision making. One of the important tasks of managers is to resolve the conflicts among stakeholders. In the related literature, more attention has been paid to different stakeholders’ participation and solutions for including their views, while less attention has been given to the role of stakeholders in the process of mathematical modeling, especially the mathematical models of production systems. Considering different stakeholder groups has the advantage of allowing for a more satisfactory solution and meeting the opinions of various stakeholders as much as possible (Khatami-Firouzabadi, 2014). In traditional approaches, more attention was paid to the criteria measurable by applying monetary values, and intangible benefits and long-term prospects were usually ignored (Khatami-Firouzabadi et al., 2008).

This paper follows decision making about the medium-term production planning in the glass container industry and seeks to consider the executive stakeholders' perspective as far as possible. To do so, a model is first presented using a production approach, and, then another with the sales approach. Finally, a model with an integrated managerial approach is provided, in which the viewpoints of different executive stakeholders (including their objectives and constraints) are considered as far as possible and based on the management perspective. It is worth noting that all the research steps are proceeded through direct communication with the managers and experts of the noted industry.

3-1- Modeling by production approach

This section deals with modeling using a production approach. From production stakeholders' viewpoints, the first goal is to reach the highest volume of production (maximizing the amount of production). On the other hand, productions stakeholders tend to produce products with less waste, less line stop, and, consequently, higher yield. Therefore, the second goal is considered as maximizing total yield. From the production point of view, there are some constraints that need to be considered in the model. The formulation of the model with the production approach is discussed below.

3-1-1- Notations

x_{im}	1, if product *i* is produced by machine/line *m*; 0, otherwise
d_i	the demand of product *i* (tons)
k_{im}	the yield of the product *i* on the machine *m*
FC_{max}	the maximum melting capacity of the furnace in a period (tons)
Ca_m	the maximum capacity of the machine/line *m* (tons)
P_{max}	the maximum minor-changeovers on each line and in a time period

3-1-2- Model

$$\max z_1 = \sum_{i=1}^{N} \sum_{m=1}^{M} x_{im}\, d_i \tag{1}$$

$$\max z_2 = \sum_{i=1}^{N} \sum_{m=1}^{M} k_{im}\, x_{im} \tag{2}$$

Subject to

$$\sum_{m=1}^{M} x_{im} \le 1 \qquad \forall i = 1.2 \dots . N \tag{3}$$

$$\sum_{i=1}^{N} \sum_{m=1}^{M} \frac{x_{im}\, d_i}{k_{im}} \le FC_{max} \tag{4}$$

$$\sum_{i=1}^{N} \frac{x_{im}\, d_i}{k_{im}} \le Ca_m \qquad \forall m = 1.2 \dots . M \tag{5}$$

$$\sum_{i=1}^{N} x_{im} \le P_{max} \qquad \forall m = 1.2 \dots . M \tag{6}$$

$$x_{im} \in \{0.1\} \qquad \forall i \quad . \quad \forall m \tag{7}$$

The first objective function (1) is to maximize the volume of production and the second objective function (2) is to maximize total yield. The set of first constraints (3) ensures the production of each product only on a single line. The second constraint (4) considers the furnace capacity. Each machine also has a specific capacity, which is taken into account by the set of third constraints (5). To change the manufactured product, it is necessary to replace the production equipment (molds). Since such a replacement requires skilled human resources for switching molds and line stopping at the time of the changeover, there is a constraint for the mold change on each line and in a time period, as stated by the fourth constraints (6). The last constraint (7) defines the type of decision variable.

3-2- Modeling based on sales approach

In this section, modeling with the sales approach is addressed. Since the products of the glass container industry are considered to be intermediary products used to pack food products and beverages, their customers including food and soft drink industry companies will have particular importance. Furthermore, considering the point that it is impossible to stop the glass production and also the large volume of glass containers that fill the warehouse(s) in a short time, paying attention to the main customers and maintaining them will be very important. From the sales perspective, meeting the customers' demands is in priority. However, since production limitations do not allow for meeting all the demands, it is preferred to achieve maximum possible satisfaction of customers. Thus, a new concept called "importance of meeting customers' demands (IMCD)" is proposed in order to be an index for decision making in this regard. Accordingly, an objective function is also defined for this purpose, in which an importance coefficient is considered for every customer in order to place their demands in the meeting priority, so that the maximum sum of importance of demands' meeting could be achieved considering the defined index. This seems to be the most important goal from a sales viewpoint. Another objective that is usually considered by sales stakeholders is the profit of selling products. It is worth noting that since glass containers in Iran are sold for each unit price, considering profit maximization as one of the objectives will be a good choice. Hence, to achieve higher profit, another objective function is defined to maximize the profit of sales. A constraint from a sales viewpoint is the nominal capacity of production. Naturally, it will not be possible to produce more than this capacity because, in this industry, glass melting furnaces have a specified capacity and output. Accordingly, the model with the sales approach (or sales-oriented model) is proposed as follows.

3-2-1- Notations

x_i	1, if product *i* is produced; 0, otherwise
b_i	the benefit of product *i*
d_i	the demand of product *i* (tons)
v_i	the parameter of IMCD for product i
FC_{max}	the maximum melting capacity of the furnace in a period (tons)

3-2-2- Model

$$max\, z_1 = \sum_{i=1}^{N} v_i\ x_i \tag{8}$$

$$max\, z_2 = \sum_{i=1}^{N} b_i\, x_i\, d_i \tag{9}$$

Subject to

$$\sum_{i=1}^{N} x_i\, d_i \leq FC_{max} \tag{10}$$

$$x_i \in \{0.1\} \qquad \forall i \tag{11}$$

The results of this model could not be feasible in practice, because some of the production constraints have not been considered.

3-3- Modeling by managerial approach

In this section, the final and comprehensive model is presented according to the management view. In fact, two previous approaches are reviewed by the management and, then, their viewpoint is obtained. It is clear that all the manufacturing constraints must be considered in the model. Maximizing profit and, at the same time, maximizing the total IMCD are the most important objectives from the managerial point of view. Hence, a model with a managerial approach is proposed as follows:

3-3-1- Notations

x_{im} 1, if product *i* is produced by machine/line *m*; 0, otherwise
b_i the benefit of product *i*
d_i the demand of product *i* (tons)
k_{im} the yield of the product *i* on the machine *m*
v_i the parameter of IMCD for product *i*
FC_{max} the maximum melting capacity of the furnace in a period (tons)
Ca_m the maximum capacity of the machine/line *m* (tons)
P_{max} the maximum minor-changeovers on each line and in a time period

3-3-2- Model

$$\max z_1 = \sum_{i=1}^{N} \sum_{m=1}^{M} b_{im}\, x_{im}\, d_i \tag{12}$$

$$\max z_2 = \sum_{i=1}^{N} \sum_{m=1}^{M} v_i\, x_{im} \tag{13}$$

Subject to

$$\sum_{m=1}^{M} x_{im} \le 1 \qquad \forall i = 1.2 \ldots . N \tag{14}$$

$$\sum_{i=1}^{N} \sum_{m=1}^{M} \frac{x_{im}\, d_i}{k_{im}} \le FC_{max} \tag{15}$$

$$\sum_{i=1}^{N} \frac{x_{im}\, d_i}{k_{im}} \le Ca_m \qquad \forall m = 1.2 \ldots . M \tag{16}$$

$$\sum_{i=1}^{N} x_{im} \le P_{max} \qquad \forall m = 1.2 \ldots . M \tag{17}$$

$$x_{im} \in \{0.1\} \qquad \forall i \;\; . \;\; \forall m \tag{18}$$

The first objective function (12) is to maximize the profit. The second objective function (13) is to maximize the importance of meeting customers' demands. The set of first constraints (14) ensures the production of each product only on a single line. The second constraint (15) considers the limitation of furnace capacity. Each machine/line also has a specific capacity, which is considered by the set of third constraints (16). A set of fourth constraints (17) represents the maximum changeovers (minor-changeovers). The last constraint (18) defines the type of decision variable.

In the model proposed above, the important point is how to obtain parameter v_i, which will be dealt with in the next section.

3-4- Determining the IMCD index

It is necessary to select an appropriate method for assigning importance to “meeting the company customers’ demands”. For this purpose, the TOPSIS technique is suggested to get the importance coefficient of each customer.

3-4-1- Using the TOPSIS Method

TOPSIS (technique for order preference by similarity to ideal solution) is one of the popular multiple attribute decision making (MADM) methods, in which the alternatives are ranked by their distance from a positive ideal solution and a negative ideal solution (Ahi et al., 2009; Ashtiani et al., 2009). An ideal solution is the one that maximizes profit criteria while minimizing cost criteria (Saati et al., 2007). In short, an ideal solution involves all the best values of the achievable criteria, while the anti-ideal solution is a combination of the worst values of achievable criteria (Saati et al., 2007; Ahi et al., 2009). The optimal alternative has the shortest distance from the ideal solution and the farthest distance from the anti-ideal solution (Saati et al., 2007).

In this study, according to the viewpoints of experts, the following four attributes are selected for customer evaluation:

- Brand
- History of the purchase volume in the past
- Credit-worthiness (timely payment)
- Financial capability (credit)

4- Solution approach

One of the most important methods among the non-preferred methods is compromise programming method (Makui et al., 2016b), which will be explained below.

4-1- Compromise programming

Compromise programming was proposed by Zeleny in 1973 and Romero described it as one of the most popular methods. In this method, the first step is to identify ideal point or ideal alternative. The best compromise solution is obtained by the efficient solution, which is closest to the Zeleny's axiom of choice. The degree of proximity between the i^{th} attribute and the anchor value is defined as follows (Romero, 1991):

$$|f_i^* - f_i(x)| \tag{19}$$

When the measurement units of attributes are different, it is necessary for them to be normalized to prevent a meaningless summation. The normalized form below can be used (Romero, 1991):

$$d_i = \frac{|f_i^* - f_i(x)|}{|f_i^* - f_i^-|} \tag{20}$$

where f_i^- is anti-ideal or nadir point for the i^{th} attribute, i.e. the worst value for the i^{th} attribute of an efficient set (Romero, 1991).

To measure the distance between each solution and the ideal alternative, compromise programming (CP) defines the family of the distance functions as follows (Romero, 1991):

$$L_p(w) = \left[\sum_{i=1}^{q} w_i^p \left|\frac{f_i^* - f_i(x)}{f_i^* - f_i^-}\right|^p\right]^{1/p} \tag{21}$$

For L_∞ metric (p=∞), the maximum individual deviation is minimized. For this metric, the best compromising solution is obtained by solving the following problem (Romero, 1991):

$$Min\ L_\infty = d \quad (22)$$

Subject to

$$w_i \frac{|f_i^* - f_i(x)|}{|f_i^* - f_i^-|} \leq d \quad (23)$$

$$x \in F \quad (24)$$

Where d is the maximum deviation.

Yu indicated that the distance function L_p for $1 \leq p \leq \infty$ was monotone non-decreasing. So, L_1 and L_∞ metrics were defined as a subset of an efficient set that Zeleny called compromise set. Other best compromise solutions fell between those related to L_1 and L_∞ metrics, i.e. $L_p \epsilon [L_1, L_\infty]$. It could be said that the real purpose of the CP is to produce a compromise set for an array of given weights w. It is highly unlikely that the optimal decision would be placed outside the compromise set bands (Romero, 1991).

5- Model implementation and results

In this section, the model is implemented in one of the large and old glass container manufacturing companies and, then, the obtained results are reported.

5-1- Case study (A real-world application)

The studied glass container company was established in 1975 and its unit 1 became operational in 1981. Due to the growing demand of the country for glass packing containers, especially high-quality containers, the development plan (unit 2) of the company began in 1999. The company is one of the oldest and largest producers of glass packing containers (bottles and jars) for the food and beverage industry in Iran.

The planning was done for a three-month (seasonal), i.e. 90-day, period. Unit 2 of the plant including a furnace with three connected lines was considered for study. Furnace output per day was 130 T and the capacity of the machines was considered to be about 50 T per day due to their uniformity in unit 2. The maximum changeover (minor-changeover) time was reported by production experts to be twice a month (6 times in the mentioned three-month period). Moreover, 11 products of the company were considered here which were related to seven customers. Information on these products is given in Table (1). It is worth noting that, to observe the rights of the studied glass container company as well as their customers' rights, their identity remained confidential in this paper.

Table 1. Parameters of real-world instance

Product	b_i	k_{im}	Customer	Demand (ton)
P.1	4,657	0.72	C.1	3100.5
P.2	2,178	0.81	C.1	1782
P.3	3,232	0.84	C.4	1730
P.4	1,986	0.84	C.2	590
P.5	2,412	0.78	C.2	704
P.6	1,859	0.77	C.2	654
P.7	2,433	0.76	C.3	800
P.8	4,704	0.87	C.4	1585.5
P.9	1,944	0.72	C.5	666
P.10	1,990	0.81	C.6	555
P.11	1,562	0.75	C.7	1750

5-2- Computational results

Computational results are presented in the following two sub-sections: First, the calculation results of the parameters related to the IMCD-index and, then, the resulted of the model solving are given in this section.

5-2-1- IMCD index

As previously mentioned, the TOPSIS technique was suggested to calculate the v_i parameter. In this regard, the weight of the attributes was determined by the managing director (0.15, 0.35, 0.25 and 0.25, respectively) and the decision matrix was completed. It is worth noting that, for the second attribute, which was a quantitative attribute, the volume of customer purchase in the last five years was considered. Also, for qualitative attributes, the Likert scale was employed. The results are presented in table (2).

Table 2. IMCD index

	C.1	C.2	C.3	C.4	C.5	C.6	C.7
IMCD parameter	0.7801	0.3837	0.2131	0.5997	0.3436	0.2477	0.3381
Rank	1	3	7	2	4	6	5

5-2-2- The computational results of solving the example

The obtained information of the real case study was placed in the final proposed model; due to the bi-objective nature of the model, the previously mentioned compromise programming method was employed. The results are presented in table (3).

Table 3. Computational results

	Single-objective (Z_1)	Single-objective (Z_2)	Bi-objective (Z_1, Z_2)
Z_1	82748000096.5*	73151500000	77291500000
Z_2	3.208	3.9355*	3.559
Product → Machine	1 → 1	3, 4, 5 → 1	2, 8 → 1
	4, 5, 8 → 2	7, 8, 9 → 2	1 → 2
	3, 7, 10 → 3	2, 6, 10 → 3	4, 5, 6, 10 → 3

Final results are reported in three states. In the first state, the model is single-objective and aims to achieve maximum profit. In the second case, it is single-objective, but aims to maximize the total IMCD. In the final state, the results are presented with the simultaneous consideration of both of the mentioned objectives using compromise programming method. As could be observed, in the bi-objective state, in addition to profit, the importance of meeting the demands, i.e. achieving the satisfaction of customers via meeting their demands, (simultaneously) has been also taken into account.

6- Conclusions

In this work, the problem of integrated decision making for production planning in the glass container industry was discussed. In this regard, at first, a model with a production approach taken from production stakeholders' viewpoints was presented. Then, another model with a sales approach was introduced, in which the viewpoints of the sales stakeholders was considered. In this model, a new concept called the importance of meeting customers’ demands (IMCD) was defined, which was also included in the final model. Finally, an integrated model was proposed with a managerial approach based on a comprehensive management viewpoint. In fact, senior management of the company also considered the viewpoints (goals and/or constraints) of other stakeholders in line with the strategic objectives of the organization. In this paper, it was tried to perceive and consider the conditions of the glass container industries in Iran by direct communication and to propose approaches that could be simply applied by them without any complexity and while taking into account their circumstances. The proposed model was examined at a large glass container company in Iran. Given the multi-objectiveness of the proposed model, the compromise programming method was used to solve it. The final results were reported in three states: first, the goal was to achieve maximum profits (single-objective mode), while in the latter case the goal was to maximize the total IMCD (single-objective). Ultimately, in the final state, the results were obtained by considering both of these objectives. As observed, integration and considering different stakeholders' viewpoints led to comprehensive decision making.

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