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## Proposing an Aggregate Production Planning Model by Goal Programming Approach, a Case Study

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### Abstract

Production planning is one of the most important functions in the process of production management. Production planning in the intermediate range of time is termed as “aggregate production planning (APP)”. Aggregate production planning is an important upper level planning activity in a production management system. The present study tries to suggest an aggregate production planning model for products of Hafez tile factory during one year. Due to this fact that the director of the company seeks 3 main objectives to determine the optimal production rate, the linear goal programming method was employed. After solving the problem, in order to examine the efficiency and the distinctiveness of this method in compare to linear programming, the problem was modeled just by considering one objective then was solved by linear programming approach. The findings revealed the goal programming with multi objectives resulted more appropriate solution rather than linear programming with just one objective.

**Keywords:** Goal programming, Aggregate planning, production planning

### 1 Introduction

Production planning is one of the most important functions in the process of production and operation management. In production planning, managers of manufacturing firms need to make crucial decisions on which specific aggregate levels of production, inventory and work force have to be produced to meet possible demands. Such decisions are traditionally interpreted as finding a best combination of the production, inventory and work force quantities that yields a minimum overall cost [1]. Production planning in the intermediate range of time is termed as ‘aggregate planning’. It is thus called because the demand on facilities and available capacities is specified in aggregate quantities. This means that the total demand (excepted) is measured without regard to the product mix that makes up the figure [2]. Aggregate planning is the determination of production rate and the best strategy to meet the demand by considering sales forecasts, production capacity, inventory levels and work force for a medium period, often from 3 to 18 months in advance [3]. The aims of aggregate production planning (APP) are; to set overall production levels for each product category to meet fluctuating or uncertain demand in the near future and to set

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decisions concerning hiring, layoffs, overtime, backorders, subcontracting, inventory level and determining appropriate resources to be used [4]. Other forms of family disaggregation plans such as master production schedule, capacity requirements planning and material requirements planning all depend on APP in a hierarchical way [5].

In many important ‘real – world’ decision-making situations, it may not be feasible, or desirable to reduce all the goals of an organization in to a single objective. For example, instead of focusing only on optimizing profits, the organization may simultaneously be interested in maintaining a stable work force, increasing its share of market and limiting price increases. Goal programming is an extension of linear or nonlinear programming involving an objective function with multiple objectives. While developing a goal programming model, the decision variables of the model are to be defined first. Then the managerial goals related to the problem are to be listed down and ranked in order or priority. Since it may be very difficult to rank these goals on a cardinal scale, an ordinal ranking is usually applied to each of the goals. It may not always be possible to fully achieve every goal specified by the decision – maker. Thus, goal programming is often referred to as a lexicographic procedure in which the various goals are satisfied in order of their relative importance [6].

The main objective of this study is aggregate production planning for the products of Hafez Tile factory during one year. The prime products of this tile factory are divided to groups of floor and wall tiles. As a national factory, it is regarded as one of the sub-categories of Iran's National Industry Organization. Here, the manager follows 3 goals in determining the optimal production rate. As a result of this fact that he has determined an ideal level of the goals, linear goal programming approach is employed. After solving the model and determining the optimal production rate, the efficiency and capability of the suggested model will be examined. Thus, in next phase, the problem will be modeled through one goal and will be solved by Lingo Software. The findings indicate that goal programming model cause a plan which covers all manager's goals, whereas in one objective linear model, just one of the manager's goal is taken into account. In fact, it is possible to conclude that goal programming model suggests more appropriate results than one objective one. The organization of this paper is as follows. After this introduction, in Section 2 background of the goal programming and aggregate production planning is described. In Sections 3 and 4 explanations about the goal programming and production planning are given. A goal programming model based on the data of Hafez Tile factory is presented and solved in Sections 5 and 6. Our conclusions are given in the final section.

## 2 Literature review

Wang and Liang [4] suggested a fuzzy multi-objective linear programming model in the multi-product APP problem. A numerical example demonstrated the feasibility of applying the proposed model to APP problem. The proposed model yielded a compromise solution and the decision maker's overall levels of satisfaction. In particular, in contrast to other APP models, several significant characteristics of the proposed model were presented. Leung and Ng [7] developed a preemptive goal programming model to solve aggregate production planning problem for perishable products. A set of Hong Kong data was applied to evaluate the ability of the proposed model. Results displayed that the decision-makers can find the flexibility and robustness of the proposed model. Leung and Chan [8] presented the aggregate production planning problem with different operational constraints and three production plants in North America and one in China. A preemptive goal programming model was applied to maximize profit, minimize repairing cost and maximize machine utilization of the Chinese production plant hierarchically. Results demonstrated the ability of the proposed model. Mirzapour Al-e-hashem et al. [9] studied a supply chain problem by considering multiple a multi-site, multi- period, multi-product aggregate production planning (APP) problem under uncertainty. In order to deal with APP including two conflicting objectives simultaneously, the proposed model was solved as a single-objective mixed integer programming model

applying the LP-metrics method. The results showed the proposed model can achieve an efficient production planning in a supply chain. Ramezani et al. [10] presented a mixed integer linear programming (MILP) model for general two-phase aggregate production planning systems. For solving this problem a genetic algorithm and tabu search was applied. The results showed that these proposed algorithms could obtain good quality solutions for APP and could be efficient for large scale problems. Zhang et al. [11] applied a mixed integer linear programming (MILP) model to the problem of aggregate production planning (APP) with capacity expansion in a manufacturing system including multiple activity centers. They used the heuristic based on capacity shifting with linear relaxation to solve the model. The computational results showed that the heuristic based on the capacity shifting with CLR is very fast but yields low-quality solution whereas the capacity shifting with PLR provides high-quality solutions but at the cost of considerable computational time. Raa et al. [12] considered the aggregate production–distribution problem for a manufacturer of plastic products produced using injection moulding. A mixed integer linear programming formulations for the planning problem, and a metaheuristic solution approach based on the models were presented. Computational experiments demonstrated that the suggested matheuristic generated solutions that capture most of significant savings potential.

### 3 Goal programming approach

Goal programming (GP), which is an extension of LP, is commonly applied to deal with multi-objective problems [13]. Basically, structures of GP and LP are the same. The concept of GP is to introduce extra auxiliary variables called deviations, which act not as ‘decision-makers’ but as ‘facilitators’ to formulate the model. These deviations represent the distance between aspiration levels of goals (target values) and the realized results. Two kinds of deviations are considered, under-achievement of the goal as represented by negative deviation ( $d^-$ ) and over-achievement of the goal as represented by positive deviation ( $d^+$ ). Each goal is expressed as a linear equation with deviation(s). As opposed to linear programming, which directly optimizes objectives, goal programming attempts to minimize the unwanted deviations between aspiration level of a goal and the optimal solution. GP model consists of two sets of constraints – system constraints and goal constraints. System constraints are formulated following the concept of LP, whilst goal constraints are auxiliary constraints, which determine the best possible solution with respect to a set of desired goals [14].

With  $m$  goals, the general goal linear programming model may be stated as:

$$\text{Minimize } Z = \sum_{i=1}^m \sum_{r=1}^k P_r (W_i^- d_i^- + W_i^+ d_i^+)$$

s.t

$$\sum_{j=1}^n a_{ij} x_j + d_i^- - d_i^+ = b_i ; \quad i= 1, 2, \dots, m$$

$$x_j, d_i^-, d_i^+ \geq 0$$

Where  $x_j$  represents a decision variable which is under the control of the decision maker, whereas ranking coefficient  $P_r$ ; weights  $W_i$ ; matrix of coefficients  $a_{ij}$  and the constant  $b_i$  are not under the direct control of decision maker.  $d_i^-$  and  $d_i^+$  are deviational variables representing the amount of under and over achievement of  $i$ th goal, respectively. Since both under and over achievement of goal cannot be achieved simultaneously, one or both of these deviational variables ( $d_i^-$  or  $d_i^+$ ) be zero in the solution, i.e.  $d_i^- * d_i^+ = 0$ . In other words, if one assumes a positive value in the solution, the other must be zero and vice versa [15].

## 4 Production Planning

In the last century, there has been a remarkable evolution in production control. From early material requirement planning (MRP), sequential manufacturing resource planning (MRP-II) to enterprise resource planning (ERP), their fundamental structure on production planning and scheduling system is structured in hierarchical way. While production planning determines a tentative plan for “how much should be produced in subsequent time periods in order to satisfy the sale plans”, the result of scheduling is the detailed sequencing and timing of production line or workstation that can finish the production before the shipping due date [16]. It is viewed as the plans and arrangements of the production mission and progress in production scheduled time [17]. Production planning provides a tactical function that integrates information across forecasting, order, manufacturing and inventory. The result of planning is a decision on production quanta that fulfill those operational requirements. Then, the planned quantum of each product in a period is disaggregated among several timeframes. Because of limited manufacturing resources such as regular manpower, overtime and out-sourcing, “disaggregating products” quanta into each timeframe is reciprocal [18]. Production planning is such a key issue that both directly and indirectly influences on the performance of the facility [19].

## 5 The mathematical model of the problem

In this section, the goal programming approach has been used to suggest a mathematical model for aggregate production planning of products in Tile Hafez factory. In this model, the factory manager's goals which will be described in detail in 5.2, as well as, all possible limitations are considered. Using this model, the optimal production rate of factory will be determined during one year.

### 5.1. Variables and parameters of the Problem

In Hafez Tile factory, floor and wall tiles are produced in various sizes that each size is regarded as one family (one product type). It is worth noting that production operation is done in several production halls that each one is called j-type phase. The products of each phase can vary. As mentioned before, the present study follows three goals and each one includes some negative and positive deviational variables. In each goal, the deviational variables are defined based on specific indexes. Due to the condition of the problem, the definition of indexes for the deviational variables is changed from one goal to another goal. All variables and parameters will present in table 1.

Table 1: Variables and parameters of the Problem

<b>Indices</b>	
<b>Product Type</b>	<b>p</b>
<b>Production Phase Type</b>	<b>j</b>
<b>Machinery Type</b>	<b>k</b>
<b>Goal Type</b>	<b>i</b>
<b>Parameters</b>	
<b>Time Capacity of Machinery of Type k in Phase j (minute in one year)</b>	<b>b<sub>kj</sub></b>
<b>Completion Time of Production Operation of Product Type p in Phase j in Machinery of Type k (minute)</b>	<b>a<sub>pjk</sub></b>
<b>Demand Rate of Product Type p in Phase j in One Year (square meter)</b>	<b>d<sub>pj</sub></b>
<b>Production Capacity of Products in Phase j in One Year (square meter)</b>	<b>p<sub>j</sub></b>
<b>Production Cost of One Square Meter of Product Type p in Phase j (Rial)</b>	<b>c<sub>pj</sub></b>
<b>Aspiration Level of first goal</b>	<b>g<sub>1</sub></b>
<b>Decision Variables of the problem</b>	
<b>Production Rate of Product Type p in Phase j (square meter)</b>	<b>X<sub>pj</sub></b>
<b>Auxiliary variable of the problem</b>	
<b>Positive Deviation Variable of first goal</b>	<b>d<sub>1</sub><sup>+</sup></b>
<b>Negative Deviation Variable of first goal</b>	<b>d<sub>1</sub><sup>-</sup></b>
<b>Positive Deviation Variables of second goal for product type p</b>	<b>d<sub>2p</sub><sup>+</sup></b>
<b>Negative Deviation Variables of second goal for product type p</b>	<b>d<sub>2p</sub><sup>-</sup></b>
<b>Positive Deviation Variables of third goal for phase j</b>	<b>d<sub>3j</sub><sup>+</sup></b>
<b>Negative Deviation Variables of third goal for phase j</b>	<b>d<sub>3j</sub><sup>-</sup></b>

### 5.2. Objectives of the Problem

This factory follows three objectives in determining the optimal production rate that are:

- Minimizing the total production cost
- Providing the customers' demand without any shortage
- Maximizing the use of production capacities in workstations

Due to this fact, goal programming approach is employed to solve the problem; Problems' Objectives need convert to goals, as well. Hence, the goals are defined as:

- The total production cost needs to be equal g<sub>1</sub> value
- The production rate of each product at least needs to be equal to the its demand rate
- The production rate of each tile size at most needs to be equal to production capacity of workstations

### 5.3. Problems Limitations

Raw materials as well as machinery are two production resources of the factory. In this case study, the number of machinery is so limited that in comparison with product variability it is not responsive enough. Therefore, in this model a time capacity limitation is considered for each machine. As to raw materials, the factory doesn't have any limitation to buy the raw materials obedient to production planning in a way that every needed raw material will be purchased.

### 5.4. The mathematical model

After defining some of parameters and variables, the mathematical model is presented as model1.

**Model 1**

$$\text{Minimize } Z = (d_1^- + d_1^+) + \sum_i \sum_p d_{ip}^+ + \sum_i \sum_j d_{ij}^- \tag{5.1}$$

*S.to*

$$\sum_p \sum_j C_{pj} \cdot X_{pj} + d_1^- - d_1^+ = g_1 \tag{5.2}$$

$$X_{pj} - d_{2p}^+ = D_{pj} \quad p = 1,4, \quad j = 2 \tag{5.3}$$

$$X_{pj} - d_{2p}^+ = D_{pj} \quad p = 5, \quad j = 4 \tag{5.4}$$

$$X_{pj} - d_{2p}^+ = D_{pj} \quad p = 7, \quad j = 5 \tag{5.5}$$

$$X_{p2} + X_{p3} - d_{2p}^+ = 496 \quad p = 2 \tag{5.6}$$

$$X_{p2} + X_{p4} - d_{2p}^+ = 1313 \quad p = 3 \tag{5.7}$$

$$X_{p3} + X_{p5} - d_{2p}^+ = 1212 \quad p = 6 \tag{5.8}$$

$$\sum_{p=1}^4 X_{pj} + d_{3j}^- = 1642452 \quad j = 2 \tag{5.9}$$

$$X_{2j} + X_{6j} + d_{3j}^- = 1614816 \quad j = 3 \tag{5.10}$$

$$X_{3j} + X_{5j} + d_{3j}^- = 15717247 \quad j = 4 \tag{5.11}$$

$$X_{6j} + X_{7j} + d_{3j}^- = 2127856.5 \quad j = 5 \tag{5.12}$$

$$\sum_p a_{pjk} \cdot X_{pj} \leq b_{kj} \quad (\forall k, j) \tag{5.13}$$

$$X_{pj}, d_{im}^+, d_{im}^- \geq 0 \tag{5.14}$$

Objective (5.1) is aiming at minimizing the total deviations between aspiration level of goals and the optimal solutions. Constraint (5.2) ensures that total production costs with their deviations variables will be equal to the determined budget (level of budget goal). Constraints (5.3)-(5.8) indicate the production rate of product type p in phase type j with the positive deviation variable will satisfy the demand rate. Constraints (5.9)-(5.12) show that total production rates in phase type j with the negative deviation variable will be equal to

capacity production of that phase in the factory. Constraint (5.13) ensures that total production rates won't be more than the production capacity of the factory. Constraint (5.14) states the type of decision variables.

## 6 Case study and computational results

### 6.1. Variables and parameters values of the problem

As stated before, in Hafez Tile factory, various wall and floor tile sizes are produced considered as a separate family. Moreover, the factory includes 5 several phases. Due to development and change, phase 1 doesn't work. Other phases are as below:

- Phase 2 produces 4 different sizes of floor tiles.
- Phase 3 is used to produce 2 different sizes of wall and floor tiles.
- Phase 4 produces 2 different sizes of floor tiles.
- Phase 5 is applied to generate 2 different sizes of wall tiles.

So, there are only 10 decision variables for the problem. All needed data dealing with modeling will be shown in tables 2 to 7. Regarding this fact that determining the value of model parameters takes time as a separate project, if they are not precise, this defect can be ignored by model sensitivity analysis. The production processes in phases 2, 3, 4 and 5 are as following:

Table 2: Production Process in Phase j

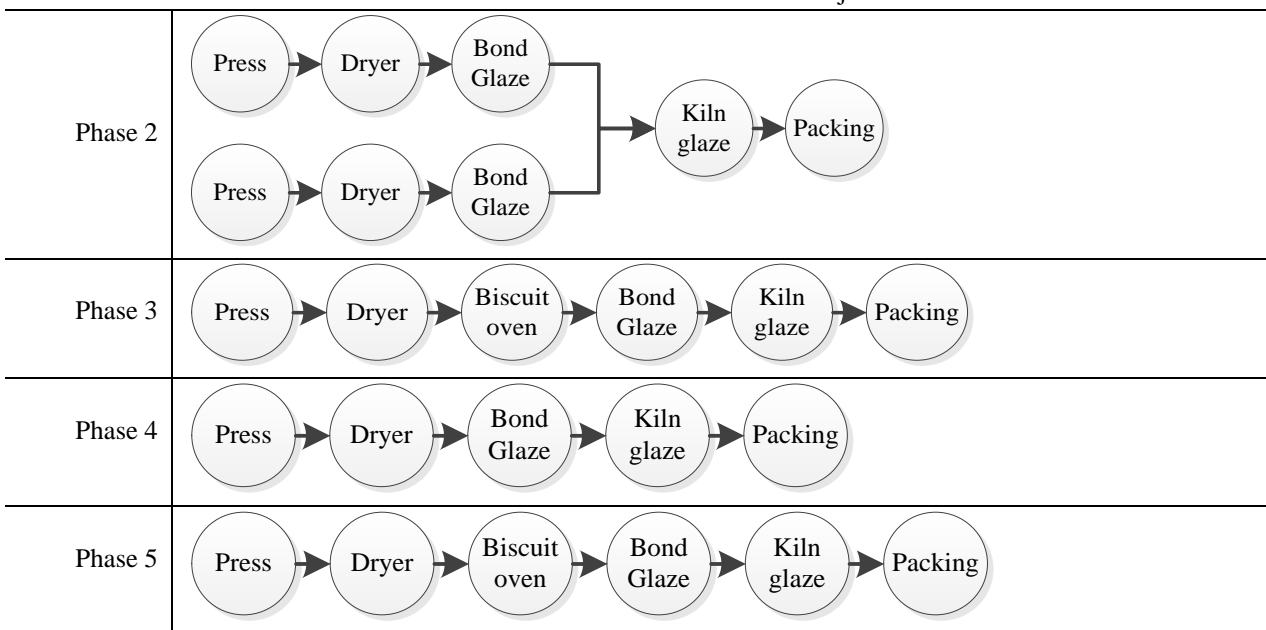


Table 3, introduces available products along with machinery in the factory. As noted before, there are several halls in this factory defined by phase name. Available production phases are introduced, as well. In last part of the Table, the level of each goal will be revealed.

Table 3: Indexes of the Problem

<b>Product Type</b>	P
Tile in Size of 20*20 (centimeter)	1
Tile in Size of 33*33 (centimeter)	2
Tile in Size of 40*40 (centimeter)	3
Tile in Size of 30*60 (centimeter)	4
Tile in Size of 45*45 (centimeter)	5
Tile in Size of 25*33 (centimeter)	6
Tile in Size of 25*40 (centimeter)	7
<b>Production Phase</b>	$j= 2, \dots, 5$
<b>Machinery Type</b>	k
Press	1
Dryer	2
Kiln glaze	3
Biscuit oven	4
Bond Glaze	5
<b>Goal Type</b>	i
Total Production Cost Be Equal to 300000000 Rial	1
Production Rate of every Tile Size At Least Equalize to its Demand Rate	2
Production Rate utmost Equalize to the Production Capacity of Workstations	3

Regarding production process in table 2, every product needs time to complete the process on. The needed time to complete the operation for each product on each machine is suggested thoroughly in Table 4.



Table 4: Completion time of production operation of products (minute)

<b>a<sub>121</sub></b>	<b>0.45</b>	<b>a<sub>631</sub></b>	<b>0.21</b>
<b>a<sub>221</sub></b>	<b>0.31</b>	<b>a<sub>632</sub></b>	<b>0.23</b>
<b>a<sub>321</sub></b>	<b>0.35</b>	<b>a<sub>633</sub></b>	<b>0.23</b>
<b>a<sub>421</sub></b>	<b>0.35</b>	<b>a<sub>634</sub></b>	<b>0.19</b>
<b>a<sub>122</sub></b>	<b>0.30</b>	<b>a<sub>635</sub></b>	<b>0.19</b>
<b>a<sub>222</sub></b>	<b>0.24</b>	<b>a<sub>636</sub></b>	<b>0.23</b>
<b>a<sub>322</sub></b>	<b>0.30</b>	<b>a<sub>341</sub></b>	<b>0.19</b>
<b>a<sub>422</sub></b>	<b>0.34</b>	<b>a<sub>342</sub></b>	<b>0.20</b>
<b>a<sub>123</sub></b>	<b>0.22</b>	<b>a<sub>343</sub></b>	<b>0.23</b>
<b>a<sub>223</sub></b>	<b>0.24</b>	<b>a<sub>344</sub></b>	-
<b>a<sub>323</sub></b>	<b>0.23</b>	<b>a<sub>345</sub></b>	<b>0.15</b>
<b>a<sub>423</sub></b>	<b>0.10</b>	<b>a<sub>346</sub></b>	<b>0.18</b>
<b>a<sub>124</sub></b>	-	<b>a<sub>541</sub></b>	<b>0.22</b>
<b>a<sub>224</sub></b>	-	<b>a<sub>542</sub></b>	<b>0.17</b>
<b>a<sub>324</sub></b>	-	<b>a<sub>543</sub></b>	<b>0.27</b>
<b>a<sub>424</sub></b>	-	<b>a<sub>544</sub></b>	-
<b>a<sub>125</sub></b>	<b>0.27</b>	<b>a<sub>545</sub></b>	<b>0.19</b>
<b>a<sub>225</sub></b>	<b>0.22</b>	<b>a<sub>546</sub></b>	<b>0.19</b>
<b>a<sub>325</sub></b>	<b>0.23</b>	<b>a<sub>651</sub></b>	<b>0.21</b>
<b>a<sub>425</sub></b>	<b>0.28</b>	<b>a<sub>652</sub></b>	<b>0.16</b>
<b>a<sub>126</sub></b>	<b>0.31</b>	<b>a<sub>653</sub></b>	<b>0.19</b>
<b>a<sub>226</sub></b>	<b>0.26</b>	<b>a<sub>654</sub></b>	<b>0.17</b>
<b>a<sub>326</sub></b>	<b>0.33</b>	<b>a<sub>655</sub></b>	<b>0.22</b>
<b>a<sub>426</sub></b>	<b>0.37</b>	<b>a<sub>656</sub></b>	<b>0.28</b>
<b>a<sub>231</sub></b>	<b>0.23</b>	<b>a<sub>751</sub></b>	<b>0.17</b>
<b>a<sub>232</sub></b>	<b>0.24</b>	<b>a<sub>752</sub></b>	<b>0.14</b>
<b>a<sub>233</sub></b>	<b>0.24</b>	<b>a<sub>753</sub></b>	<b>0.16</b>
<b>a<sub>234</sub></b>	<b>0.22</b>	<b>a<sub>754</sub></b>	<b>0.17</b>
<b>a<sub>235</sub></b>	<b>0.24</b>	<b>a<sub>755</sub></b>	<b>0.19</b>
<b>a<sub>236</sub></b>	<b>0.25</b>	<b>a<sub>756</sub></b>	<b>0.25</b>

$a_{pjk}$  : Completion time of production operation of product type p in phase j on machinery of type k. According to table 4, some homes are empty and they relate to completion time of production operation products in phases 2 and 4 on machine type 4. Pursuant to table 2, in these phases, machine type 4 is not deployed so these homes are empty.

All needed costs of production every (square meter) product type p in each phase are calculated before and are presented as production cost of one Square meter of product type p in Phase j in table 5.

Table 5: Production cost of one square meter of product (Rial)

<b>C<sub>12</sub></b>	<b>31638.84</b>	<b>C<sub>54</sub></b>	<b>42731.336</b>
<b>C<sub>22</sub></b>	<b>36464.11</b>	<b>C<sub>23</sub></b>	<b>34321.897</b>
<b>C<sub>32</sub></b>	<b>32711.898</b>	<b>C<sub>63</sub></b>	<b>32535.337</b>
<b>C<sub>42</sub></b>	<b>32392.158</b>	<b>C<sub>65</sub></b>	<b>33275.132</b>
<b>C<sub>34</sub></b>	<b>42731.336</b>	<b>C<sub>75</sub></b>	<b>33035.132</b>

$C_{pj}$  : Production cost of one square meter of product type p in phase j .As mentioned before, there are only 10 decision variables for the problem so just 10 Production costs are considered for them.

Demand rate of every product in each phase is presented comprehensively in table 6.

Table 6: Demand Rate of product type p in phase j in one year (Square meter)

<b>D<sub>12</sub></b>	<b>254</b>	<b>D<sub>63</sub></b>	
<b>D<sub>22</sub></b>	<b>212</b>	<b>D<sub>34</sub></b>	
<b>D<sub>32</sub></b>		<b>D<sub>54</sub></b>	<b>801</b>
<b>D<sub>42</sub></b>	<b>200</b>	<b>D<sub>65</sub></b>	
<b>D<sub>23</sub></b>	<b>284</b>	<b>D<sub>75</sub></b>	<b>2354</b>

In table 6, for every product type in each phase a demand rate is considered but as for product types 2, 3 and 6, demand rate is defined only based on product type. Hence, in table 6, some homes are empty and demand rates of these products are defined as below:

$$D_{22} + D_{23} = 496, D_{32} + D_{34} = 1333, D_{63} + D_{65} = 1212$$

Total production capacity in each phase is presented comprehensively in tables 7.

Table 7: Production Capacity in phase j during one year (Square meter)

<b>P<sub>2</sub></b>	<b>1642452</b>	<b>P<sub>4</sub></b>	<b>1571724</b>
<b>P<sub>3</sub></b>	<b>1614816</b>	<b>P<sub>5</sub></b>	<b>2127856.5</b>

## 6.2. Computational Results

In order to solve the problem, Lingo software is used. The computational results obtained are as following:

Table 8: Computational Results of Goal Programming problem

<b>X<sub>12</sub></b>	<b>245</b>	<b>X<sub>63</sub></b>	<b>0</b>	<b>d<sub>11</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>24</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>22</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>27</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>32</sub><sup>+</sup></b>	<b>0</b>
<b>X<sub>22</sub></b>	<b>212</b>	<b>X<sub>34</sub></b>	<b>0</b>	<b>d<sub>11</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>25</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>23</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>32</sub><sup>-</sup></b>	<b>1640462</b>	<b>d<sub>33</sub><sup>+</sup></b>	<b>0</b>
<b>X<sub>32</sub></b>	<b>1333</b>	<b>X<sub>54</sub></b>	<b>801</b>	<b>d<sub>21</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>26</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>24</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>33</sub><sup>-</sup></b>	<b>1614532</b>	<b>d<sub>34</sub><sup>+</sup></b>	<b>0</b>
<b>X<sub>42</sub></b>	<b>200</b>	<b>X<sub>65</sub></b>	<b>1212</b>	<b>d<sub>22</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>27</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>25</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>34</sub><sup>-</sup></b>	<b>1570923</b>	<b>d<sub>35</sub><sup>+</sup></b>	<b>0</b>
<b>X<sub>23</sub></b>	<b>284</b>	<b>X<sub>75</sub></b>	<b>2354</b>	<b>d<sub>23</sub><sup>+</sup></b>	<b>0</b>	<b>d<sub>21</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>26</sub><sup>-</sup></b>	<b>0</b>	<b>d<sub>35</sub><sup>-</sup></b>	<b>2124290</b>		

### 6.2.1. Comparison of Goal programming model of the problem with one objective model

In this section, the mentioned problem is modeled just by one objective then the results are compared with goal programming model. In new problem, maximizing the use of production capacities in workstations is considered as the objective.

Mathematical model of new problem are as following:

$$\text{Maximize } Z = \sum_p \sum_j X_{pj} \tag{6.15}$$

S.to

$$\sum_p a_{pjk} \cdot X_{pj} \leq b_{kj} \quad (\forall k, j) \tag{6.16}$$

$$X_{pj} \geq 0 \tag{6.17}$$

Objective (6.15) is maximizing the total production rates. Constraint (6.16) ensures that total production rates won't be more than the production capacity of the factory. Constraint (6.17) states the type of decision variables.

Also for solving the problem, Lingo software is employed. Computational results are as following:

Table 9: Computational results of single objective problem

$X_{12}$	<b>0</b>	$X_{63}$	<b>1285653</b>
$X_{22}$	<b>1512000</b>	$X_{34}$	<b>2081739</b>
$X_{32}$	<b>0</b>	$X_{54}$	<b>0</b>
$X_{42}$	<b>0</b>	$X_{65}$	<b>0</b>
$X_{23}$	<b>368191.6</b>	$X_{75}$	<b>1795200</b>

In this section, the computational results in conditions of goal programming and single objective are presented in table 10.

Table 10: Comparing Computational results of the problem in conditions of goal programming and single objective

<b>Single objective Model</b>	<b>Goal Programming Model</b>
<b>Total Production cost :257860079751.23 (Rial)</b>	<b>Total Production cost : 91337702.35 (Rial)</b>
<b>Total Production Rate: 7042783.6 (Square meter)</b>	<b>Total Production Rate: 6641 (Square meter)</b>

As shown in Table 10, total production rate in one goal model is more than one in goal programming model, whereas in goal programming model total production cost is less and production level is near to demand rate. Hence, it is possible to put that although in comparison to one goal model, goal programming model doesn't show the optimal solution, it makes a production plan that fulfills several goals of management simultaneously. Unlike it, in one goal model, just one goal was optimized and consequently other ones were ignored. The goal programming model made all 3 goals approach optimal case, instead.

## 7 Conclusions

The research deals with aggregate production planning of the products in Hafez Tile factory during one year. In this factory, the manager seeks 3 goals in determining the optimal production rate. These goals are minimizing production cost, the maximum use of production capacity of factories and also providing the market 'demands. Thus, goal programming was adopted to go through the research. After modeling, the problem was solved by Lingo software. Thus, the problem was solved again by means of a one objective model to examine the efficiency and the superiority of suggested approach.

The findings indicate that in goal programming model, the answers include the less production cost and also the production level has approached the demand rate, while in one objective model the total production rate is more. In fact, in one objective model, the manager optimizes only one goal of the factory that uses the maximum capacity of production machinery but in goal programming model, several goals are examined simultaneously. At last it could be stated that goal programming model can represent more appropriate solutions than one objective model.

By keeping the related definitions to aggregate production planning in mind, the findings can be considered as input for other planning hierarchies such as Master Scheduling Planning, Material Requirement Planning, etc.

In this research, the same priority was considered for the model goals while it would be better if a different weight were kept in consideration for each goal to the importance it has for the manager and its results

were compared with conditions that all goals have the same priorities. Only 3 goals were selected for the case study due to the difficult and time-consuming process of data collection in a way that more objectives and limitations can be found in the production system. In case study of the research, all parameters were considered deterministic while in real condition, every working and producing environment might face lack of certainty.

It is suggested ranking the problem's goals using Multi Criteria Multi Decision (MCDM) method and giving different weights to each goal and comparing the results. Moreover, it is suggested that the case study to be modeled in a problem or fuzzy situation by considering other objectives and limitations and use super innovative method to solve, in case of its complexity and bigness.

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