Journal of Turkish

Operations Management

# Ergonomic staff scheduling problem with goal programming in glass industry*

**Safiye Özlem KAÇMAZ[a], Hacı Mehmet ALAKAŞ[b**], Tamer EREN[c]**

[a]Industrial Engineering Department, Kırıkkale University, Kırıkkale, Turkey
e-mail: ozlemkacmazz@hotmail.com, ORCID No: https://orcid.org/0000-0002-3200-9750
[b]Industrial Engineering Department, Kırıkkale University, Kırıkkale, Turkey
e-mail: hmalagas@kku.edu.tr, ORCID No: https://orcid.org/0000-0002-9874-7588
[c]Industrial Engineering Department, Kırıkkale University, Kırıkkale, Turkey
e-mail: teren@kku.edu.tr, ORCID No: https://orcid.org/0000-0001-5282-3138
**Corresponding author

**Article info**

**Article History:**
Received: 26.04.2020
Revised: 11.05.2020
Accepted: 09.06.2020

**Keywords:**

Scheduling,
Ergonomic risk,
Assignment of staffs,
Goal programming model

**Abstract**

Ergonomic is a science that deals with identifying and improving the factors that affect the health of people in their work and social life. When scheduling activities, ergonomic planning is often neglected. Consequently, discomfort caused by working postures occurs in people and adversely affect their health. It is essential to include an ergonomic assessment in the personnel scheduling activities in the production area. In this study, a factory in the manufacturing sector is discussed. The positions of personnel during the study were analyzed by the REBA method. At the same time, a mathematical model has been established using goal programming. The study aims to reduce the ergonomic risk levels of the personnel. With the application, it is predicted that the musculoskeletal problems experienced by the people will be improved, and the satisfaction levels of the employees will increase.

## 1. Introduction

Personnel scheduling is the most appropriate assignment of the staff by taking into consideration the expectations and wishes of the staff. Scheduling activities are essential for the continuation of production and production of quality products. Proper scheduling will increase staff satisfaction as well as benefit the business (Bedir et al. 2017). However, ergonomics is often overlooked in personnel scheduling. The more human factor is handled, the more success will be achieved in scheduling activities.

The human factor is the most important source of production both in service and manufacturing. The productivity of the staff is also very effective in the profitability of the enterprise. Staff productivity depends on physical and psychological well-being. Physically appropriate conditions can be achieved by making ergonomic arrangements. Therefore, it is crucial to consider and improve ergonomics in every field of production.

* This article is produced from the master thesis titled "Shift scheduling application with goal programming in the glass industry" presented by the first author in 2019.

Some studies on ergonomic personnel planning: Swat and Krzychowicz (1996) discussed the computer-aided ergonomics system based on the ergonomic stress assessment method. The system has been tested at several machine design centers in Poland and has had positive results. Hignett and McAtamney (2000) examined the Rapid Entire Body Assessment Method (REBA), which is used to measure physical workload. They have practiced on a team of physiotherapists, occupational therapists, and nurses. Akay et al. (2003) analyzed the working stops in an auto-service station using the OWAS (Ovako Working Postures Analysis System) method. They offered alternatives for improving postures. David (2005) discussed the methods used to evaluate the risk factors exposed to musculoskeletal disorders. It provides an overview by comparing all methods with each other. Bard and Wan (2006) addressed the problem of assigning tasks for full-time and part-time workers in a US postal service. They benefited from integer programming and taboo search methods. Santos et al. (2007) discussed the issue of ergonomics in a furniture factory. Using the simulation method, they evaluated the advantages and disadvantages of the works ergonomically. Özel and Çetik (2010) grouped the risk assessment tools in terms of ergonomics and compared their superiority and weakness to each other. They conducted sample analysis for workers in the loading department of a factory and evaluated the results. Esen and Fığlalı (2013) conducted a study dealing with musculoskeletal disorders. In this study, the risk factors causing these disorders are discussed, and the types and symptoms of the diseases are summarized. To prevent disturbances, some principles have been presented, and some scientific methods have been introduced for the detection of risk factors. Rossi et al. (2013) aimed to select the best material handling method for portable materials. They used the Ahp (Analytic Hierarchy Process) method. In the study, they evaluated ergonomic criteria and production performance measurements. Guimaraes et al. (2015) analyzed a furniture company in southern Brazil. They have improved the system both in terms of ergonomics and production with their cellular work design. Bedir et al. (2017) made a personnel chart that takes into account ergonomic conditions in a store in Kırıkkale. They used AHP and Goal Programming methods to solve the problem. The study aimed to balance ergonomic risk factors and working hours. Felekoğlu and Taşan (2017) proposed a systematic approach consisting of four main steps for the enterprise in the metal sector. They used the REBA method. Mengoni et al. (2017) presented a methodology that evaluates ergonomic factors, together with safety factors. They also considered efficiency. They used the simulation method. Özder et al. (2017) Solved the scheduling problem of cleaning staff working in a hospital with the goal programming method. Polat et al. (2017) discussed workers in a furniture factory in Denizli. They examined the image records of thirty-two workers and made measurements. They used the REBA method. As a result, it was determined that approximately 60% of workers were working at risk for the musculoskeletal system. Gür et al. (2019) conducted a study aiming for the effective and balanced use of equipment and resources used in operating theaters. Goal programming and constraint programming methods were used in the study. Özcan et al. (2019) analyzed the scheduling problem of eight radiology technicians working in a hospital with goal programming. They aimed to assign technicians to an equal number of shifts. Özder et al. (2019) evaluated the personnel in natural gas combined cycle power plant with ANP method and planned their shifts with goal programming. Kaçmaz et al. (2019) addressed the shift scheduling problem of personnel in a glass factory. In this study, it is aimed to work in the jobs where the staff are the best and in an equal number of shifts. A goal programming method is used. However, assignments were made without considering ergonomic evaluations. This study was carried out in a glass factory in Ankara. Personnel assignments were realized by integrating personnel skills and ergonomics. There is no necessary for legal or special permission in the work carried out. The aim is to assign each employee the appropriate level of competence and risk during the day. Risk assessment of each personnel's posture-related positions was performed by the REBA method. Goal programming was used for scheduling according to ability. The established mathematical model considers reducing the ergonomic risk factors and the capabilities of the personnel. In the second section of the study, REBA and Goal Programming methods are explained. In the third section, the application is given. In the fourth section, the results of the study are presented, and suggestions are made.

## 2. Method

### 2.1. Reba method

Ergonomics is a science that evaluates the characteristics of individuals physically and psychologically and works to be compatible with the environment. For the production sector, the concepts considered are human and machine. Ergonomics aims to increase the productivity of the employees, at the same time, to prevent the discomfort to the health of the employees and to prevent the excessive strain of the body. Although the general purpose of ergonomics is the same, there are multiple methods used in analysis and solutions. In the study, the REBA method was used to evaluate the posture of the individuals. REBA is an analysis method for measuring staff risk levels. The steps of the method are given in Figure 1. There are two different groups in the REBA method. As a result of the evaluation made for the body, neck, and legs, the scores are given as Group A; The ratings for the upper arm, lower arm and wrist represent Group B.

If the person is carrying a load or exerting a force, an additional score will be awarded and added to Group A. If there is a grip on the person's movement, a score is also given and added to Group B. The person who obtains A and B points obtains the C point by finding the intersection of the marks obtained from a matrix containing Group A and Group B scores. Finally, if there is a repetition of the movements, it is added to the C score and finally, the REBA score is found. More detailed information can be found in the application of the method from Koç and Testik (2016).

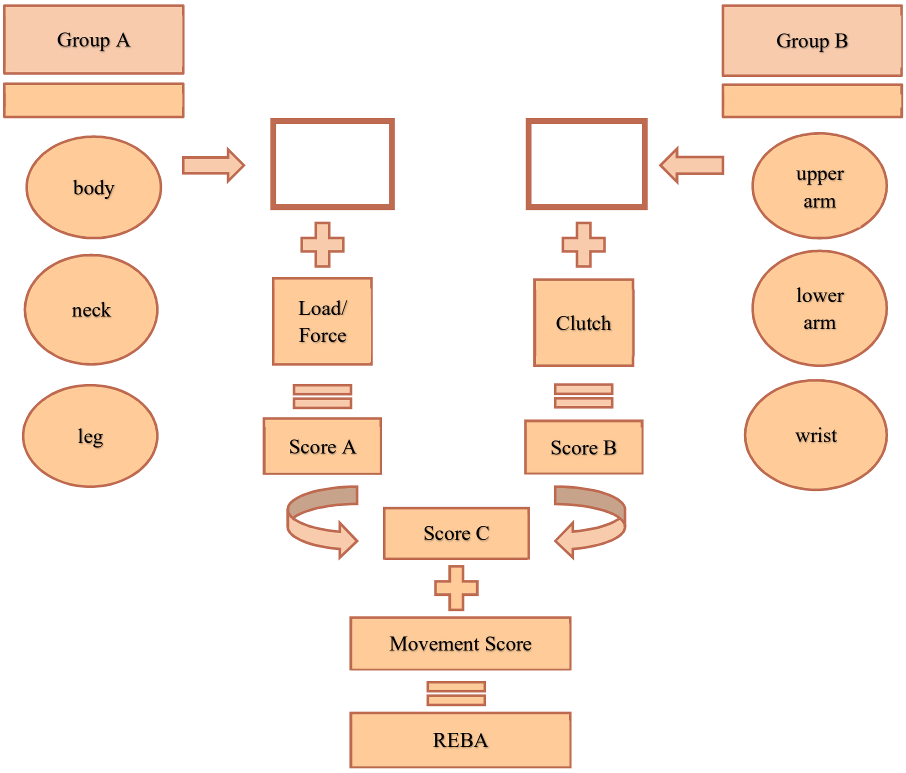


**Figure 1.** REBA method scoring stages

## 2.2. Goal programming

Multi-criteria decision-making is the most appropriate choice for the decision-maker among multiple alternatives. One of the most important multi-criteria decision-making techniques is goal programming. Goal programming has many areas of application, such as labor planning, transportation and logistics, scheduling and production activities planning, resource planning and financial analysis. Goal Programming ensures the realization of the aims and goals simultaneously. For this purpose, objectives are established, and goal values are determined for each aim. The solution that minimizes deviations from the determined values is the solution preferred by the decision-maker. The general constraints of the problem are also taken into account. The method aims to provide all constraint equations and to reach as many goals as possible (Kaçmaz et al. 2019).

A general Goal Programming model is given below.

$$Min\ Z = \sum_{i=1}^{k} (d_i^+ + d_i^-) \quad (1)$$

$$\sum_{j=1}^{n} a_{ij}X_j + d_i^- + d_i^+ = b_i \quad (2)$$

$$X_j, d_i^+, d_i^- \geq 0 \qquad i=1\ldots k \quad j=1\ldots n \quad (3)$$

Variables
$X_j$: j.decision variable
$a_{ij}$: coefficients of i[th] goal in variable j
$b_i$: desired goal value of the i[th] goal
$d_i^+$: the deviation values in the positive directions from the i[th] goal
$d_i^-$: the deviation values in the negative directions from the i[th] goal

Research and publication ethics were followed in this study.

## 3. Application

The application was made in a glass factory in Ankara. There are 7 processes in the factory where 35 personnel are employed. The finished products are obtained from the plate glass. Plate glasses are processed through various means in the factory. Untreated glass takes its final form through different means according to customer requirements. All processes used in glass production are given in Figure 2. Staffs have different competency scores, 1, 2 and 3 for each task. These scores are also taken into consideration in the assignments tasks to the staff. 1 point is best, 2 points are moderate and 3 points are insufficient for that task.

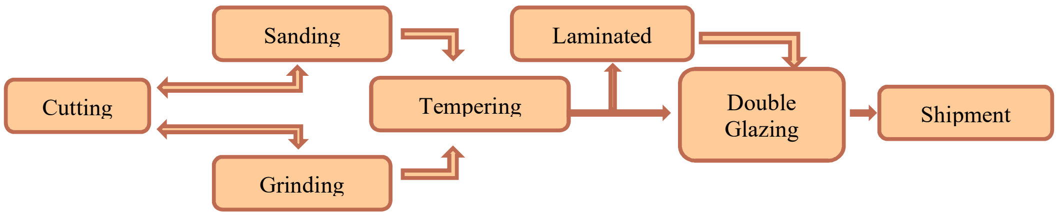


**Figure 2.** Processes

**Table 1.** Task numbers in processes

| Cutting | Sanding | Grinding | Tempering | Laminated | Double Glazing | Shipment |
|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 4 | 8 | 7 | 3 |

Processing times and the number of personnel required to perform the tasks were determined for each process. Processing times are in minutes and the same for each staff. Table 1 shows how many tasks are in each section. Table 2 shows the duration of the tasks and the number of personnel required.

**Table 2.** Tasks, processing time and number of staff required

| No | Tasks | Time | Required Staff | No | Tasks | Time | Required Staff |
|---|---|---|---|---|---|---|---|
| 1 | Removing cut glass from the table | 236 | 3 | 17 | Latching of laminated glass | 315 | 2 |
| 2 | Placing the glass in a coffee table or car | 142 | 2 | 18 | Placing the latched glasses on the stands | 315 | 2 |
| 3 | Tying the glass with rope and pulling them to the other section | 72 | 3 | 19 | Connecting the glass to the stands with rope | 90 | 1 |
| 4 | Placing the glasses on the sanding line | 360 | 2 | 20 | Placement of tripods in autoclave with suspended crane | 60 | 3 |
| 5 | Placing the sanded glass in the car | 380 | 2 | 21 | Edge cleaning of glass after autoclave | 220 | 2 |
| 6 | Tying the glass with rope and pulling them to the other section | 72 | 3 | 22 | Placing the glass on the double glazing line | 360 | 2 |
| 7 | Lifting the windows by hand and loading horizontally on the line | 358 | 2 | 23 | Cutting of laths according to glass dimensions | 120 | 1 |
| 8 | Manual lifting of grinding glass | 370 | 2 | 24 | Filling the laths with dehumidifier | 90 | 1 |
| 9 | Tying the glass with rope and pulling them to the other section | 72 | 3 | 25 | Butyl withdrawal to the edges of the slat | 250 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10 | Lifting the windows by hand and loading horizontally on the line | 320 | 2 | 26 | Gluing the laths on the glass | 354 | 2 |
| 11 | Lifting the tempered glass by hand and placing it in the car | 332 | 2 | 27 | Peeling off and filling the glass edge | 375 | 2 |
| 12 | Measurement of glass and putting paper between glass | 330 | 1 | 28 | Lifting the filled glass to the tables and taping | 360 | 3 |
| 13 | Tying the glass with rope and pulling them to the other section | 72 | 3 | 29 | Pulling the tables to the other section | 30 | 2 |
| 14 | Lifting the windows by hand and loading horizontally on the line | 300 | 2 | 30 | Tie-down and stretching of the glass | 165 | 2 |
| 15 | Spreading and cutting PVB | 120 | 2 | 31 | Loading and placing on forklifts | 150 | 3 |
| 16 | Placing the other glass on the laid PVB with the suction cup | 180 | 2 | | | | |

REBA scores for the tasks identified in Table 2 were calculated. Information on the calculation of points is given in the REBA method section. Table 3 shows the REBA scores.

**Table 3.** REBA points of tasks

| | | Group A | | | | | Group B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Tasks | Body | Neck | Leg | Load/ Force | Score A | Upper Arm | Lower Arm | Wrist | Grip | Score B | Score C | Movement Score | REBA Score |
| 1 | Removing cut glass from the table | 4 | 1 | 1 | 2 | 5 | 3 | 2 | 0 | 0 | 4 | 5 | 1 | 6 |
| 2 | Placing the glass in a coffee table or car | 2 | 2 | 2 | 2 | 6 | 1 | 2 | 2 | 0 | 2 | 6 | 0 | 6 |
| 3 | Tying the glass with rope and pulling them to the other section | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 4 | Placing the glasses on the sanding line | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 0 | 2 | 3 | 1 | 4 |
| 5 | Placing the sanded glass in the car | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 0 | 2 | 3 | 1 | 4 |
| 6 | Tying the glass with rope and pulling them to the other section | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 7 | Lifting the windows by hand and loading horizontally on the line | 3 | 1 | 1 | 2 | 4 | 2 | 1 | 2 | 0 | 2 | 4 | 0 | 4 |
| 8 | Manual lifting of grinding glass | 2 | 1 | 1 | 2 | 4 | 2 | 1 | 1 | 0 | 1 | 3 | 0 | 3 |
| 9 | Tying the glass with rope and pulling them to the other section | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 10 | Lifting the windows by hand and loading horizontally on the line | 3 | 1 | 1 | 2 | 4 | 2 | 1 | 2 | 0 | 2 | 4 | 0 | 4 |
| 11 | Lifting the tempered glass by hand and placing it in the car | 2 | 1 | 1 | 2 | 4 | 2 | 1 | 1 | 0 | 1 | 3 | 0 | 3 |
| 12 | Measurement of glass and putting paper between glass | 1 | 1 | 1 | 0 | 1 | 3 | 1 | 1 | 0 | 3 | 1 | 0 | 1 |
| 13 | Tying the glass with rope and pulling them to the other section | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 14 | Lifting the windows by hand and loading horizontally on the line | 3 | 1 | 1 | 2 | 4 | 2 | 1 | 2 | 0 | 2 | 4 | 0 | 4 |
| 15 | Spreading and cutting PVB | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 16 | Placing the other glass on the laid PVB with the suction cup | 1 | 1 | 1 | 0 | 1 | 2 | 2 | 2 | 0 | 3 | 1 | 0 | 1 |
| 17 | Latching of laminated glass | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 2 |
| 18 | Placing the latched glasses on the stands | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 1 | 0 | 1 | 2 | 0 | 2 |
| 19 | Connecting the glass to the stands with rope | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 20 | Placement of tripods in autoclave with suspended crane | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 21 | Edge cleaning of glass after autoclave | 3 | 3 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 22 | Placing the glass on the double glazing line | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 0 | 2 | 3 | 1 | 4 |
| 23 | Cutting of laths according to glass dimensions | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 2 |
| 24 | Filling the laths with dehumidifier | 1 | 2 | 1 | 0 | 1 | 4 | 1 | 1 | 0 | 4 | 2 | 0 | 2 |
| 25 | Butyl withdrawal to the edges of the slat | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 2 |
| 26 | Gluing the laths on the glass | 1 | 1 | 1 | 0 | 1 | 4 | 1 | 1 | 0 | 4 | 2 | 0 | 2 |
| 27 | Peeling off and filling the glass edge | 1 | 3 | 1 | 0 | 3 | 1 | 1 | 2 | 0 | 2 | 3 | 0 | 3 |
| 28 | Lifting the filled glass to the tables and taping | 4 | 1 | 3 | 2 | 9 | 1 | 2 | 1 | 0 | 1 | 9 | 0 | 9 |
| 29 | Pulling the tables to the other section | 1 | 2 | 1 | 2 | 3 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 2 |
| 30 | Tie-down and stretching of the glass | 3 | 2 | 2 | 0 | 5 | 1 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |
| 31 | Loading and placing on forklifts | 2 | 2 | 1 | 2 | 5 | 2 | 1 | 1 | 0 | 1 | 4 | 0 | 4 |

The goal programming model of the problem is as follows:

## Goal programming model

### Parameters

n: number of staff working in the factory n=35
m: number of tasks in the factory m=31
i: staff index i=1,2,…,n
j: task index j=1,2,…,m

$t_j$: time of task j j=1,2,…,m
$l_j$: Reba score of task j j=1,2,…,m
$K_j$: staff need of task j j=1,2,…,m
$C_{ij}$: ability assessment of staff i for task j i=1,2,…,n j=1,2,…,m

**Decision variables**

$$X_{ij} = \begin{cases} 1, & \text{i. staff j. is assigned to the task,} \\ 0, & \text{otherwise} \end{cases} \quad i=1,2,\dots,n \quad j=1,2,\dots,m$$

$d_{1i}^{+}$: Positive deviation of staff i for the goal 1 i=1,2,…,n
$d_{1i}^{-}$: Negative deviation of staff i for the goal 1 i=1,2,…,n
$d_{2j}^{+}$: Positive deviation of task j for the goal 2 j=1,2,…,m
$d_{2j}^{-}$: Negative deviation of task j for the goal 2 j=1,2,…,m

**Constraints**

Staff need for tasks:

$$\sum_{i=1}^{n} X_{ij} = K_j \quad j=1,2,\dots,m \quad (4)$$

Restrictions of each staff to a maximum of three tasks:

$$\sum_{j=1}^{m} X_{ij} \leq 3 \quad i=1,2,\dots,n \quad (5)$$

Maximum and minimum time each staff can work during the day:

$$\sum_{j=1}^{m} X_{ij} * tj \leq 480 \quad i=1,2,\dots,n \quad (6)$$

$$\sum_{j=1}^{m} X_{ij} * tj \geq 370 \quad i=1,2,\dots,n \quad (7)$$

**Goal constraints**

Equal reba points for each staff member:

$$\sum_{j=1}^{m} X_{ij} * t_j * l_j + d_{1i}^{-} - d_{1i}^{+} = \sum_{j=1}^{m} X_{ij} * t_j * 4 \quad i=1,2,\dots,n \quad (8)$$

Assignment of competent staff for each task:

$$\sum_{i=1}^{n} X_{ij} * c_{ij} + d_{2j}^{-} - d_{2j}^{+} = \sum_{i=1}^{n} X_{ij} * 1 \quad j=1,2,\dots,m \quad (9)$$

**Objective function**

$$\text{Min } Z = \sum_{i=1}^{n} d_{1i}^{+} + \sum_{j=1}^{m} d_{2j}^{+} \quad (10)$$

Eq. (4) ensures the number of staff needed for the assigned tasks, Eq. (5) not to assign each staff to more than three tasks during the day, Eq. (6) refers to the assignment of each staff to the tasks not exceeding the daily working time. Eq. (7) prevents it from working under a certain period. In terms of goal constraints, Eq. (8) states that staff should work as equally as possible in terms of risk factors. Eq. (9) provides the assignment according to the abilities of the staff, taking into account the competence factor. The objective function is given in Eq. (10) and minimizes the REBA scores of each staff and maximizes staff competencies that perform the tasks.

**Table 4.** Task schedule assigned to personnel

| Task/ Staff | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Total Term of Duty | Average REBA Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | x | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | 430 | 4,00 |
| 2 | | | | | | x | | | | | x | | | | | | | | | | | | | | | | | | | | | 404 | 3,18 |
| 3 | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | 416 | 3,84 |
| 4 | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | x | | | 390 | 3,85 |
| 5 | | | | | | | | | | | | | | | | | | x | x | | | | | | | | | | | | | 405 | 2,44 |
| 6 | | | | | | | | | | | | | | | | | x | | | x | | | | | | | | | | | | 375 | 1,84 |
| 7 | | | | x | | x | | | | | | | | | | | | | | | | | | | | | | | | | | 432 | 4,00 |
| 8 | | | | | | | | | | | x | | | | | | | | | x | | | | | | | | | | | | 392 | 2,69 |
| 9 | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | 416 | 3,84 |
| 10 | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | 386 | 5,22 |
| 11 | | | | | | | | | x | x | | | | | | | | | | | | | | | | | | | | | | 392 | 4,00 |
| 12 | | | | | | x | | | | | | | | | | | | | | | | x | | | | | | | | | | 432 | 4,00 |
| 13 | | | | | | | | | x | | | | | | | | | | | | | | | | | x | | | | | | 426 | 2,34 |
| 14 | | | | | | | | | | | | | | | x | | | | | | | | | | | | | x | | | | 480 | 7,00 |
| 15 | | | | | | | x | | x | | | | | | | | | | | | | | | | | | | | | | | 430 | 4,00 |
| 16 | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | 370 | 3,00 |
| 17 | | | | | | | | | | | | | | | x | | | | | | | | | | | | | x | | | | 480 | 7,00 |
| 18 | | | | | | | | | | | | | x | | | | | x | | | | | | | | | | | | | | 387 | 2,37 |
| 19 | | | | | | | | | | | | | x | x | | | | | | | | | | | | | | | | | | 372 | 4,00 |
| 20 | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | 457 | 3,24 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | x | 370 | 4,00 |
| 22 | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | 380 | 4,00 |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | 315 | 4,00 |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | 375 | 3,00 |
| 25 | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | x | | | 390 | 3,85 |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | 375 | 3,00 |
| 27 | | | | | | | | | | | | | | x | | | | | | | | | | x | | | | | | | | 390 | 3,54 |
| 28 | | | x | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | 426 | 2,34 |
| 29 | | | | | | | | | | x | | | | | | | | | | x | | | | | | | | | | | | 380 | 3,53 |
| 30 | | x | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | 392 | 3,45 |
| 31 | | | | | | | | | | | | | | | | | | | | | | | x | | | | | x | | | | 480 | 7,25 |
| 32 | | | | | | | | | | | | x | x | | | | | | | | | | | | | | | | | | | 402 | 1,54 |
| 33 | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | x | | 385 | 4,00 |
| 34 | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | 370 | 3,00 |
| 35 | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | 380 | 4,00 |
| REBA Score | 6 | 6 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 1 | 4 | 4 | 1 | 1 | 2 | 2 | 4 | 1 | 4 | 4 | 2 | 2 | 2 | 2 | 3 | 9 | 2 | 4 | 4 | | |
| Task Time | 236 | 142 | 72 | 360 | 380 | 72 | 358 | 370 | 72 | 320 | 332 | 330 | 72 | 300 | 120 | 180 | 315 | 315 | 90 | 60 | 220 | 360 | 120 | 90 | 250 | 354 | 375 | 360 | 30 | 165 | 150 | | |

The model results are shown in Table 4. When Table 4 is examined, it is observed that the REBA score of the personnel assigned to the 28th position is high. In this task belonging to the heat glass department, it is the process of lifting double glazed glasses by using physical force after drying. The weight of the glass and the need for an excessive bending motion caused the REBA score to be high. The total deviation in personnel competencies is 11.88%. This deviation was considered to be acceptable, given that the other goal was also achieved simultaneously.

## 4. Conclusion and discussion

The problem of ergonomic personnel scheduling is the matching of personnel to the tasks that they are appropriate and sufficient for, according to particular objectives. This scheduling requires more cost for the enterprise when it is planned manually, and it is a waste of time. However, planning activities in terms of requirement needs and expectations are of great importance in terms of efficiency. Although the problem of ergonomic personnel scheduling varies for each sector being addressed, the goal is usually to provide high productivity from staff through the minimization of labor and costs. In recent studies, ergonomic evaluations have been included in planning activities with more consideration.

In this study, ergonomic factors were taken into consideration, and staff assigned to the glass factory. Processes in processes are observed, and tasks are defined for each process. The duration of the tasks and the number of persons required for the tasks were determined. The study aims to reduce the ergonomic risk levels of the personnel. At the same time, the staff was asked to be assigned to tasks according to their qualifications, and each person was given a qualification score by experts. Risk analysis of the tasks was determined by the REBA method. The other method used is goal programming. The reason for using goal programming is that the problem is complex, and there are multiple overlapping constraints. The goal programming model is solved with ILOG CPLEX. As a result of the solution, the ergonomic task distribution reduced the workload of the personnel. Decreased or absent health problems related to their working stance predicted that staff would be more productive.

In future studies, better analysis can be done on the work stops by using simulation analysis. Working positions can be evaluated using different risk analysis methods. The same research can be solved with more than one method, and the results can be compared.

## Contribution of researchers

Safiye Özlem Kaçmaz: She made literature researches. She enabled the data to be collected and analyzed, created and analyzed the mathematical model stages. She was effective in the writing of the article.
Hacı Mehmet Alakaş: The mathematical model provided benefits during the editing and solution phase and in the article management section. Evaluated the results, contributed to the formation of the article order. Scientific publications have explored.
Tamer Eren: He was an article consultant. He has contributed to the execution and evaluation of the article.

## Conflict of Interest

The authors declared that there is no conflict of interest.

## References

Akay, D., Kurt, M., & Dağdeviren, M. (2003). Ergonomic analysis of working postures. *Journal of The Faculty of Engineering and Architecture of Gazi University 18*(3), 73-84. url:https://dergipark.org.tr/tr/download/article-file/76208

Bard, J.F., Wan, L. (2006). The task assignment problem for unrestricted movement between workstation groups. *Journal of Scheduling 9*(4):315-341. doi:https://doi.org/10.1007/s10951-006-7038-7

Bedir, N., Eren, T., & Dizdar, E.N. (2017). Ergonomıc staff scheduling and an application ın the retail sector. *Journal of Engineering Sciences and Design 5*(3):657-674. doi:https://doi.org/10.21923/jesd.331259

David, G.C. (2005). Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occupational Medicine 55*(3):190-199. doi:https://doi.org/10.1093/occmed/kqi082

Esen, H., Fığlalı, N. (2013). Working posture analysis methods and the effects of working posture on musculoskeletal disorders. *Sakarya University Journal of Science 17*(1):41-51. url:http://www.saujs.sakarya.edu.tr/tr/download/article-file/192676

Gür, Ş., Eren, T., & Alakaş H.M. (2019). Surgical operation scheduling with goal programming and constraint programming: a case study. *Mathematics 7*(3):251. doi:https://doi.org/10.3390/math7030251

Felekoğlu, B., Taşan, S.Ö. (2017). Ergonomic risk assessment for work-related musculoskeletal disorders: a systematic reactive/proactive ıntegrated approach. *Journal of the Faculty of Engineering and Architecture of Gazi University, 32*(3):777-793. doi:https://doi.org/10.17341/gazimmfd.337625

Guimaraes, L.B.d.M., Anzanello, M.J., Ribeiro, J.L.D., & Saurin, T.A. (2015). "Participatory ergonomics intervention for ımproving human and production outcomes of a brazilian furniture company." *International Journal of Industrial Ergonomics 49*:97-107. doi:https://doi.org/10.1016/j.ergon.2015.02.002

Hignett S., McAtamne, L. (2000). Rapid entire body assessment (REBA). *Applied Ergonomics 31*(2):201-205. doi:https://doi.org/10.1016/S0003-6870(99)00039-3

Kaçmaz, S.Ö., Alakaş, H.M., & Eren, T. (2019). Shift scheduling with the goal programming method: a case study in the glass industry. *Mathematics 7*(6):561. doi:https://doi.org/10.3390/math7060561

Koç, S., Testik, Ö.M. (2016). Investigation and minimization of musculoskeletal risks in furniture ındustry with different methods. *Journal of Industrial Engineering 27*(2):2-27. url:https://www.mmo.org.tr/sites/default/files/0bbc3c6992b5523_ek.pdf

Mengoni, M., Matteucci, M., & Raponi, D. (2017). A multipath methodology to link ergonomics, safety, and efficiency in factories. Procedia Manufacturing 11:1311-1318. doi:https://doi.org/10.1016/j.promfg.2017.07.259

Özcan, E., Danışan, T., Yumuşak, R., Gür, Ş., & Eren, T. (2019) Goal programming approach for the radiology technician scheduling problem. Sigma *Journal of Engineering and Natural Sciences 37*(4):1407-1416

Özder, E., Varlı, E., Eren, T. (2017). Hedef programlama yaklaşımı ile temizlik personeli çizelgeleme problemi için bir model önerisi. *Karadeniz Fen Bilimleri Dergisi 7*(2), 114-127. doi: https://doi.org/10.31466/kfbd.342344

Özder, E.H., Özcan, E., Eren, T. (2019). Staff task-based shift scheduling solution with an ANP and goal programming method in a natural gas combined cycle power plant. *Mathematics 7(2)*, 192. doi:https://doi.org/10.3390/math7020192

Özel, E., Çetik, O. (2010). Tools used ın the analysis of occupational duties and a sample application. *Dumlupınar University Journal of Institute of Science 22*:41-56. url:https://birimler.dpu.edu.tr/app/views/panel/ckfinder/userfiles/16/files/Dergiler/22/sayi5pdf.pdf

Polat, O., Mutlu, Ö., Çakanel, H., Doğan, O., Özçetin, E., & Şen, E. (2017). Working posture analyses of workers with reba method in a furnıture factory. *Journal of Engineering Sciences and Design 5*:263-268. doi:https://doi.org/10.21923/jesd.41742

Rossi, D., Bertoloni, E., Fenaroli, M., Marciano, F., & Alberti, M. (2013). A multi-criteria ergonomic and performance methodology for evaluating alternatives in “manuable” material handling. *International Journal of Industrial Ergonomics 43*(4):314-327. doi:https://doi.org/10.1016/j.ergon.2013.04.009

Santos, J., Sarriegi, J.M., Serrano, N., & Torres, J.M. (2007). Using ergonomic software in non-repetitive manufacturing processes: A case study. *International Journal of Industrial Ergonomics 37*(3):267-275. doi:https://doi.org/10.1016/j.ergon.2006.10.022

Swat, K., Krzychowicz, G. (1996). Ergonom: Computer-aided working posture analysis system for workplace designers. *International Journal of Industrial Ergonomics 18*(1):15-26. doi:https://doi.org/10.1016/0169-8141(95)00031-3