

# **Helsa Nurse Scheduling Application User Manual**

Version 1.0

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# 1 Introduction

Nurse scheduling (or shift management) is a long-standing challenge in hospitals and healthcare systems. Although this problem has been widely studied in academic fields like operations research, there are still very few software tools that are used by hospital staff in practice.

Based on our interviews with nurses from three different hospitals in Iran, we found that nurse scheduling is still often done manually by a volunteer nurse. This process is not only time-consuming but also inefficient, especially when multiple constraints need to be considered, such as department-specific shift requirements, fairness (based on seniority, weekend and night shifts), individual preferences, and off-day requests.

From a technical perspective, this is a variation of the classic "assignment problem" in operations research. To address this problem, we developed an integer programming model in Python using the Gurobi optimization library.

To generate the optimal nurse schedule, the application uses three sets of inputs:

1. **Nurse Information:** Includes ID, name, and seniority level.
2. **Shift Requirements:** specifying the number of nurses needed for each shift on each day.
3. **Nurse Preferences:** optional input where each nurse can indicate preferences for shifts and request off-days.

Users can provide inputs in two ways: by uploading files or by entering data manually. Manual entries will override any matching entries from uploaded files.

After solving the scheduling problem, the application provides three main types of reports:

1. **Optimal Schedule:** A detailed CSV table listing all nurse-shift assignments. This table can be used for further analysis and is the source for all other reports.
2. **Gantt Chart:** A visual overview of the entire schedule, showing all nurses and their assigned shifts across the planning horizon.
3. **Nurse-Based Reports:** A two-page PDF report for each nurse, including:
  - Page 1: A table listing assigned shifts, shift details, and colleagues on each shift.
  - Page 2: A calendar view highlighting assigned shifts using different colors for Morning, Evening, and Night shifts.

## 2 Template Inputs

After a general overview of the application and a download link for this manual, users will find a "Download Input Templates" section (see Figure 1).

### 2.1 Nurse Information

For each nurse, three fields are required: ID, Name, and Seniority (levels 1, 2, 3, or 4). See Figure 2 for a sample nurse input CSV.

- ID should be numeric (only digits).
- Name can include any string, with or without spaces or special characters.
- Seniority should be one of the following numbers: 1, 2, 3, or 4. Note: In the current web-based version, only two seniority types (1 and 2) can be used.

## 2.2 Shift Requirements

See Figure 3 for a sample shift requirement CSV. Each shift requirement entry must include four items:

1. Start Date and End Date
2. Shift ID: 1 (Morning), 2 (Evening), or 3 (Night)
3. Nurse Type Required: based on seniority
4. Minimum and Maximum number of nurses required
  - To define a requirement for a single day, users can set the start and end date to the same day.
  - The scheduling horizon is determined automatically based on the earliest and latest dates in the shift requirements.
  - Users can define a flexible staffing range using different min/max values, or set them equal for exact staffing needs.
  - Higher seniority levels can fulfill requirements meant for lower levels, but not vice versa.

## 2.3 Preferences

See Figure 4 for a sample preferences input CSV. Each preference entry includes four items:

1. Nurse ID
2. Date of the preferred or off shift
3. Shift ID (1, 2, or 3)
4. Preference Level

Preference levels range from:

- 0: Off-day request / Unavailable
- 1 to 10: Increasing levels of preference (1 = least preferred, 10 = most preferred)

## 3 File Upload and Manual Input

After the template input section, the application presents two ways to enter data: File Upload and Manual Input (Figure 5 and 6).

In the **File Upload** section:

- The file names and headers should be kept unchanged.
- Users may skip the file upload if they prefer to enter everything manually.
- If both file and manual inputs are used, manual entries will override matching entries from the uploaded files before being sent to the backend optimization model.

In the **Manual Input** section:

- Users can add, edit, or delete entries directly in the UI.
- Once all data is entered (via file, manual input, or both), by clicking the "Generate Schedule and Reports" button, the application will process inputs, run the optimization in the backend, and generate the schedule and reports within a few seconds. After the first schedule is generated, users can still edit inputs and click the button again to generate an updated optimal schedule.

## 4 Outputs

Below the "Generate Schedule and Reports" button, users will find template outputs and a Gantt chart preview. Once a new schedule is created based on uploaded inputs, these templates will be replaced with the actual results. The five outputs include:

1. **Optimal Schedule Table:** One of the key outputs is a detailed CSV table showing nurse-shift assignments (see Figure 7 for a sample). Each row represents a unique (date, shift, nurse) assignment from the input requirements. For example, if the input requirements span 7 days, with 3 shifts per day and 8 nurses required per shift, the resulting table would have  $7 \times 3 \times 8 = 168$  rows.
2. **Gantt Chart:** This visual output is one of the most useful tools for reviewing the schedule (see Figure 8 for a sample). The Y-axis lists the nurses. The X-axis shows the dates within the planning horizon (automatically determined based on the earliest and latest dates in the requirement input). Each colored box represents an assigned shift: green for morning, yellow for evening, red for night. If a nurse has a shift on a specific date, it will appear as a colored box at the intersection of that nurse and that date. The data used to generate this chart comes directly from the optimal schedule table.
3. **Nurse-Based Output (PDF Reports):** The application generates a two-page PDF report for each nurse (see Figures 9 and 10 in the Appendix for a sample).
  - **Page 1** includes Summary statistics (total shifts, total hours, morning, evening, night, and weekend shift counts). In addition, a detailed table listing all assigned shifts, each with a unique ID, shift date and type, and names of colleagues on the same shift.
  - **Page 2** presents a calendar view, making it easy to visually understand each nurse's schedule over time. Shifts are labeled with different colors based on shift type.
4. **Nurse Statistics:** A summary CSV file with key metrics for each nurse: total number of shifts, total hours, number of morning/evening/night shifts, and weekend shifts.
5. **Shift Coverage:** A summary CSV showing how many nurses are assigned to each shift, which is particularly useful for higher-level management.

## 5 Mechanism of the Application

On the UI side, the application first collects manual and file inputs, merges them, and sends the combined data to the backend optimization model. The backend is built using an integer programming model developed in Python with the Gurobi optimization library. We currently use pythonanywhere.com (one of Anaconda's free services) as our backend server. Once the model is solved based on the input data, five output files are generated and sent back to the UI.

At a high level, the model defines a binary decision variable  $x_{i,j,d}$  which indicates whether nurse  $i$  is assigned to shift  $j$  on date  $d$ . The optimization model has two main components: the objective function and the constraints.

- The **objective function** determines how good a schedule is in terms of fairness and nurse satisfaction. For example, if Nurse A has a higher preference level than Nurse B for a specific date and shift, or if both have equal preference but Nurse A has higher seniority, the model will prioritize assigning that shift to Nurse A.
- The **constraints** are a set of logical and operational rules, some general and some customized to the hospital's needs. These are:
  1. **Coverage Requirements:** Ensures all defined shift requirements are satisfied.

2. **Unavailability:** Prevents assigning nurses to shifts they marked as unavailable (preference level set to 0).
3. **One Shift per Day:** Prevents a nurse from being assigned to more than one shift per day.
4. **Minimum Rest Between Shifts:** Ensures at least one off-shift between consecutive working days, particularly between a night shift and the following morning.
5. **Maximum Consecutive Working Days:** Ensures nurses have adequate rest by limiting the number of back-to-back working days.
6. **Weekly Working Hours:** Keeps the weekly workload within a reasonable range, not too few, not excessive.
7. **Weekend Assignments:** Distributes weekend shifts fairly among all nurses.

## A Appendix

### A.1 Screenshots of the Template Inputs

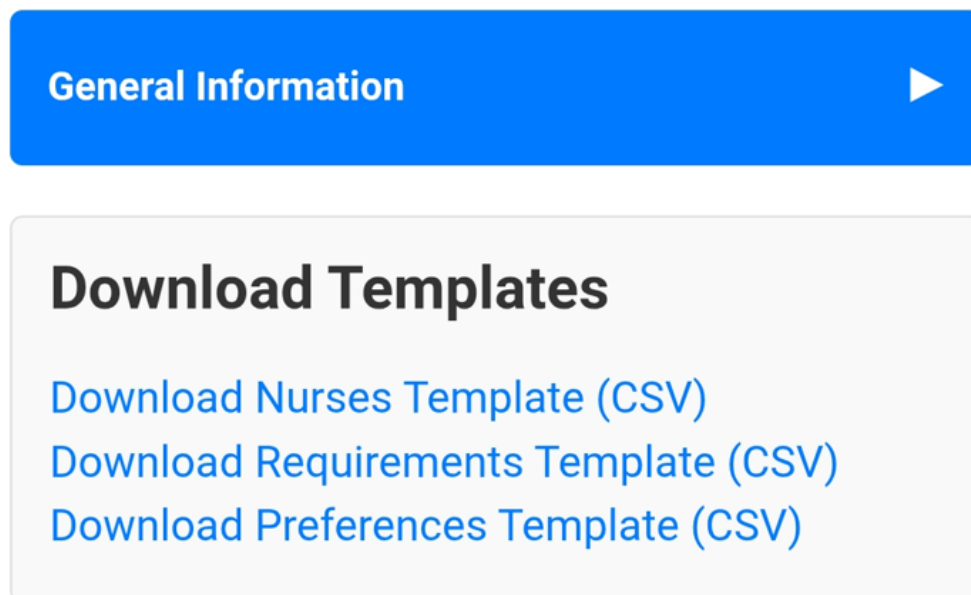


Figure 1: Screenshot of the UI for "Download Templates" section.

	A	B	C
1	Nurse ID	Nurse Name	type (1 for normal, 2 for senior)
2	1001	Nika	2
3	1002	Sarina	1
4	1003	Hannaneh	1
5	1004	Hanna	2
6	1005	Kian	1
7	1006	Ayda	2
8	1007	Hossein	1
9	1008	Hamed	1
10	1009	Sina	2
11	1010	Milad	1
12	1011	Anastasiia	2
13	1012	Mahsa	1
14	1013	Atash	2
15	1014	Ghazaleh	1
16	1015	Maryam	2
17	1016	Alice	1
18	1017	Elif	1
19	1018	Ariana	2
20	1019	Nilloofar	1
21	1020	Narges	2

Figure 2: Screenshot of the template CSV input file for nurse information.

	A	B	C	D	E	F
1	start_date	end_date	shift_id	nurse_type	min_req	max_req
2	4/1/2025	4/4/2025	1	1	8	8
3	4/5/2025	4/6/2025	1	1	5	5
4	4/7/2025	4/11/2025	1	1	8	8
5	4/12/2025	4/13/2025	1	1	5	5
6	4/14/2025	4/18/2025	1	1	8	8
7	4/19/2025	4/20/2025	1	1	5	5
8	4/21/2025	4/25/2025	1	1	8	8
9	4/26/2025	4/27/2025	1	1	5	5
10	4/28/2025	4/30/2025	1	1	8	8
11	4/1/2025	4/30/2025	2	1	4	4
12	4/1/2025	4/30/2025	3	1	4	4

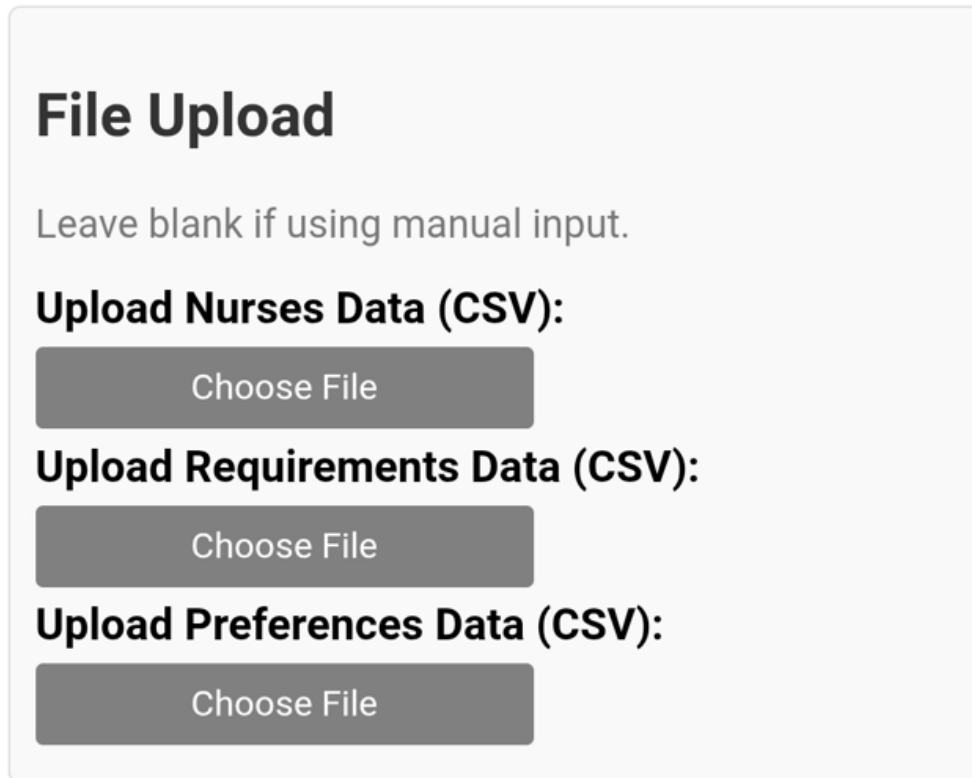
Figure 3: Screenshot of the template CSV input file for shift requirements.

	A	B	C	D
1	nurse_id	shift_id	date	preference
2	1004	1	4/1/2025	0
3	1001	2	4/1/2025	0
4	1001	3	4/1/2025	0
5	1002	1	4/1/2025	10

Figure 4: Screenshot of the template CSV input file for preferences



## A.2 Screenshots of File Upload and Manual Input



**File Upload**

Leave blank if using manual input.

**Upload Nurses Data (CSV):**

Choose File

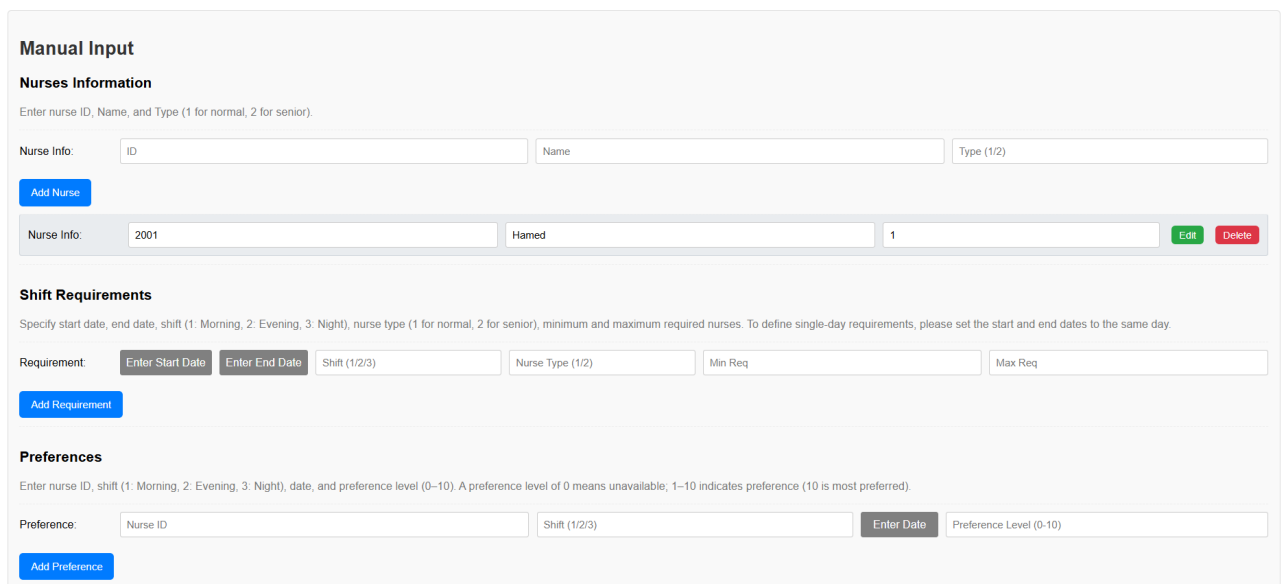
**Upload Requirements Data (CSV):**

Choose File

**Upload Preferences Data (CSV):**

Choose File

Figure 5: Screenshot of the file upload section of the UI



**Manual Input**

**Nurses Information**

Enter nurse ID, Name, and Type (1 for normal, 2 for senior).

Nurse Info:

[Add Nurse](#)

Nurse Info:	<input type="text" value="2001"/>	<input type="text" value="Hamed"/>	<input type="text" value="1"/>	<a href="#">Edit</a>	<a href="#">Delete</a>
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**Shift Requirements**

Specify start date, end date, shift (1: Morning, 2: Evening, 3: Night), nurse type (1 for normal, 2 for senior), minimum and maximum required nurses. To define single-day requirements, please set the start and end dates to the same day.

Requirement:

[Add Requirement](#)

**Preferences**

Enter nurse ID, shift (1: Morning, 2: Evening, 3: Night), date, and preference level (0–10). A preference level of 0 means unavailable; 1–10 indicates preference (10 is most preferred).

Preference:

[Add Preference](#)

Figure 6: Screenshot of the manual input section of the UI

### A.3 Screenshots of template outputs

	A	B	C	D	E	F
1	nurse_id	nurse_name	shift_id	shift_name	date	is_senior
2	1001	Nika	1	Morning	4/3/2025	1
3	1001	Nika	1	Morning	4/4/2025	1
4	1002	Sarina	1	Morning	4/6/2025	0
5	1002	Sarina	1	Morning	4/7/2025	0
6	1002	Sarina	1	Morning	4/8/2025	0
7	1002	Sarina	1	Morning	4/9/2025	0
8	1003	Hannaneh	1	Morning	4/21/2025	0
9	1003	Hannaneh	1	Morning	4/22/2025	0
10	1004	Hanna	1	Morning	4/5/2025	1
11	1004	Hanna	1	Morning	4/10/2025	1
12	1004	Hanna	1	Morning	4/14/2025	1
13	1004	Hanna	1	Morning	4/15/2025	1
14	1004	Hanna	1	Morning	4/16/2025	1
15	1004	Hanna	1	Morning	4/19/2025	1
16	1004	Hanna	1	Morning	4/24/2025	1
17	1004	Hanna	1	Morning	4/25/2025	1
18	1004	Hanna	2	Evening	4/11/2025	1
19	1004	Hanna	3	Night	4/1/2025	1
20	1004	Hanna	3	Night	4/2/2025	1
21	1004	Hanna	3	Night	4/3/2025	1
22	1004	Hanna	3	Night	4/6/2025	1
23	1004	Hanna	3	Night	4/7/2025	1
24	1004	Hanna	3	Night	4/8/2025	1
25	1004	Hanna	3	Night	4/12/2025	1
26	1004	Hanna	3	Night	4/17/2025	1

Figure 7: Screenshot of the template optimal schedule CSV file



Figure 8: Screenshot of the template Gantt Chart PNG file

## Nurse Report: Nika (ID: 1001) - Page 1 of 2

### General Statistics:

Total Shifts: 22 | Total Hours: 176 | Is Senior: No | Morning Shifts: 21 | Evening Shifts: 1 | Night Shifts: 0

### Shift Details Table:

#	Date	Shift	Colleagues
1001_1	2025-04-03	E	Sarina, Kian, Ariana
1001_2	2025-04-04	M	Sarina, Hanna, Hamed, Anastasiia, Ghazaleh, Niloofar, Narges
1001_3	2025-04-05	M	Kian, Sina, Ariana, Narges
1001_4	2025-04-07	M	Hanna, Hossein, Sina, Atash, Elif, Niloofar, Narges
1001_5	2025-04-08	M	Toomaj, Sina, Milad, Atash, Maryam, Elif, Niloofar
1001_6	2025-04-09	M	Hannaneh, Sina, Milad, Anastasiia, Mahsa, Ghazaleh, Narges
1001_7	2025-04-10	M	Sarina, Hanna, Toomaj, Anastasiia, Mahsa, Maryam, Narges
1001_8	2025-04-12	M	Sarina, Hossein, Ghazaleh, Maryam
1001_9	2025-04-13	M	Kian, Milad, Alice, Narges
1001_10	2025-04-14	M	Hannaneh, Milad, Mahsa, Atash, Elif, Niloofar, Narges
1001_11	2025-04-15	M	Sarina, Hannaneh, Kian, Hossein, Atash, Ariana, Narges
1001_12	2025-04-17	M	Sarina, Hossein, Hamed, Mahsa, Maryam, Ariana, Niloofar
1001_13	2025-04-18	M	Hannaneh, Kian, Milad, Mahsa, Alice, Ariana, Narges
1001_14	2025-04-19	M	Hamed, Ghazaleh, Alice, Elif
1001_15	2025-04-21	M	Toomaj, Hossein, Sina, Milad, Atash, Alice, Narges
1001_16	2025-04-22	M	Sarina, Hamed, Anastasiia, Atash, Ghazaleh, Elif, Narges
1001_17	2025-04-23	M	Hannaneh, Milad, Anastasiia, Mahsa, Alice, Ariana, Narges
1001_18	2025-04-24	M	Sarina, Hanna, Anastasiia, Mahsa, Alice, Elif, Niloofar
1001_19	2025-04-26	M	Sarina, Kian, Alice, Narges
1001_20	2025-04-27	M	Sarina, Hannaneh, Hossein, Elif
1001_21	2025-04-28	M	Kian, Sina, Milad, Alice, Elif, Niloofar, Narges
1001_22	2025-04-29	M	Kian, Sina, Anastasiia, Alice, Ariana, Niloofar, Narges

Figure 9: Screenshot of the first page of the template nurse-based PDF report

## Nurse Report: Nika (ID: 1001) - Page 2 of 2

*Calendar View:*

*April 2025*

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3 E	4 M	5 M	6
7 M	8 M	9 M	10 M	11	12 M	13 M
14 M	15 M	16	17 M	18 M	19 M	20
21 M	22 M	23 M	24 M	25	26 M	27 M
28 M	29 M	30				

Figure 10: Screenshot of the second page of the template nurse-based PDF report