Optimizing Power Outages and Surgical Performance: A C++ Prototype Solution

ESE 224 Final Project

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1 Introduction

This report presents a C++ program designed to enhance the reliability of five substations (EB, OF, RL, TM, and HD) in Central New York by managing power outages and optimizing crew allocation. The program implements two databases: one to track outage tickets and another to monitor hospital surgical teams. The goal is to reduce downtime for the customer, including hospitals, under resource constraints. Algorithms are implementeded to optimize crew assignments for outage repairs while managing hospital backup power for surgical teams.

Table 1: Substation Interruption Characteristics

	Total Interruptions	**# Customers Interrupted**	**Customer Hour Interruptions**
EB	27	5,769	16,224
OF	22	4,413	12,780
HD	18	5,990	12,621
TM	16	3,436	11,415
RL	12	3,529	11,980

2 Class Aggregation with Company

The Company help link together the substation object and the hospital object. Additionally, the purpose of company class will be necessary for the implementation of search algorithm for attributes across multiple substations and hospital object. The company will also control the update order for all the substation and likewise the hospital. Methods such as `Z_Search` and `display_team` will interact with all the stations and hospital to search for a unique member of their respective class.

2.1 Function across all Substation

Z_Search identifies the Z most similar tickets across all substations in the power grid network, extending the scope of Y_search beyond a single substation. While Y_search finds similarities within one station, Z_search aggregates results from multiple substations into a dummy station that provides a system-wide perspective on similar outage patterns.

The implementation first clears the temporary station's similarity ranking list, then iterates through each station in the company's network. For each station, it calls the station's Y_search method with the input ticket, collecting all similar tickets into a consolidated list. After gathering all matches, the system sorts them by similarity score using bubble sort to ensure the most relevant tickets appear first, regardless of their originating substation.

The Z parameter focus on the Z relevant tickets across all the substation or the dummy station to be display with complete details including their similarity scores and originating substations.

Show all teams in the five hospitals in order of their average number of points per hour

2.2 Function across all Hospital

Display_Team presents an aggregated performance analysis of surgical teams across all hospitals in the power grid network, organized by efficiency ratings. The system leverages performance metrics calculated from each team's historical surgery data, including difficulty points earned and total operation hours, to generate meaningful comparisons between teams.

The implementation begins by collecting team information from all hospitals into a centralized ranking system. For each team, the system calculates a points-per-hour efficiency metric based on completed surgeries, then sorts these teams using a bubble sort algorithm to ensure the highest-performing teams appear first. The ranking can be used to predict the team with the greatest patient outcomes per unit of energy.

2.3 Company Crew Allocation Scheme

The company will allocate a number, `N`, of `TOT` crew members to a substation based on a pre-set "priority". The "priority" of a substation can be deduced from Table 1, to allow the Company to efficiently allocate TOT to each substation. The `N` crew members will be assigned tickets to resolve power outages at the designated substation. The company will also set the `CAP` of each hospital to a fixed value.

2.4 Priority Allocation of TOT

Each substation receives at least $N = 1$. The remaining share is distributed proportionally to the inverse of the total rank to formulate priority:

Priority of all 5 substations is calculated as follows:

$$I_{\text{hour}} = \frac{\text{Total Hours Interrupted}}{\text{Number of Interruptions}} \tag{1}$$

$$I_{\text{customers}} = \frac{\text{Total Customers Interrupted}}{\text{Number of Interruptions}} \tag{2}$$

These metrics represent:

- I_{hour}: Average hours of interruption per incident.
- $I_{\text{customers}}$: Average number of customers affected per incident.

The allocation of `TOT` aim at reducing both I_{hour} and $I_{\text{customers}}$, where a rank-sum method is applied. Each entry is ranked in both metrics, and the total rank is the sum of the two. Lower total ranks indicate higher priority for resource allocation.

The proportional share is based on the inverse of the total rank:

$$w_i = \frac{1/R_i}{\sum_j (1/R_j)} \tag{3}$$

$$P_i = w_i \times 100 \tag{4}$$

Entry	I_{hour}	$I_{\text{customers}}$	**Rank** I_{hour}	**Rank** $I_{\text{customers}}$	**Total Rank** R_i	**Allocated** P_i
RL	998.33	294.08	1	2	3	33.1%
HD	701.17	332.78	3	1	4	24.8%
TM	713.44	214.75	2	3	5	19.9%
EB	600.89	213.67	4	4	8	12.4%
OF	580.91	200.59	5	5	10	9.9%

Table 2: Metric values, ranks, and final allocation percentages based on inverse total rank.

3 Substation Databases

In the event that there is a shortage of total crew members (`TOT` provided by the company), the Company should allocate `TOT` efficiently to minimize interrupted hours. One way to reduce interrupted hours is to reduce repair time, which can vary depending on the "difficulty" of a job. When a power outage occur, the crew must first survey the area to assess the nature of an outage, which is recorded to produce a ticket as shown below.

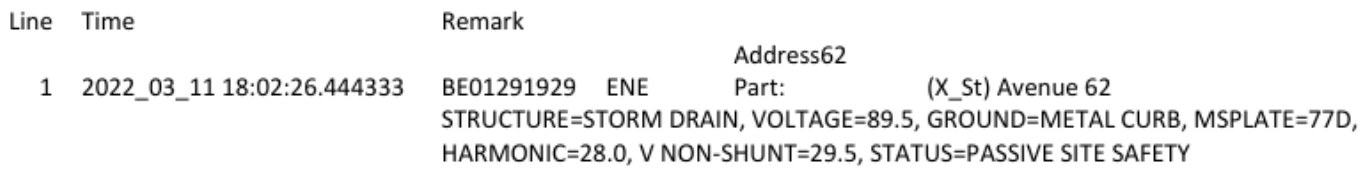


Figure 1: Incomplete Ticket with no comment, ready for repair steps

Since the number of customers affected by the power outage is not readily quantifiable on the ticket, it will not be used to measure the "difficulty" of a ticket. Therefore, our main parameter for the "difficulty" of a ticket is measured by the repair time. A longer repair time means a "hard" ticket, whereas a shorter repair time means an "easy" ticket. Using historical data, the difficulty of a ticket will be analyzed and predicted prior to assigning it to a crew member. This prediction is based on the status report made by the crew.

Line	Time	Remark
1	2022_03_11 18:02:26.444333	BE01291929 ENE Address62 Part: (X_St) Avenue 62 STRUCTURE=STORM DRAIN, VOLTAGE=89.5, GROUND=METAL CURB, MSPLATE=77D, HARMONIC=28.0, V NON-SHUNT=29.5, STATUS=PASSIVE SITE SAFETY
2	2022_03_11 20:00:58.244333	BE01291929: Comment: CREW NOTIFIED
3	2022_03_11 20:37:29.444333	BE01291929: Comment: CREW REPORTS VEHICLE NEEDS TO BE MOVED
4	2022_03_11 22:55:05.444333	BE01291929: Comment: ADDITIONAL ASSISTANCE NEEDED
5	2022_03_12 01:50:04.244333	BE01291929: Comment: 22.9 VOLTS
6	2022_03_12 04:24:45.644333	BE01291929: Comment: FLUSH NEEDED
7	2022_03_12 04:48:16.844333	BE01291929: Comment: SURVEY CONDUCTED, REPORTS 14BQ
8	2022_03_12 05:51:22.844333	BE01291929: Comment: BFS REQUIRED ON SITE
9	2022_03_12 06:15:52.244333	BE01291929: Comment: INFORMED I&A, CREW WILL BE ON LOCATION UNTIL 5PM
10	2022_03_12 07:10:36.044333	BE01291929: Comment: ELECTRICIAN RELEASED AT 11:36HRS
11	2022_03_12 08:14:58.244333	BE01291929: Comment: FROM 20T TO 26U

Figure 2: A completed ticket describing a power outage at a substation

3.1 Defining a Difficult Ticket

Y_Search identifies the Y most similar tickets by comparing seven status fields (structure, voltage, ground, msp, harmonic, v_non_shunt, status) between the input ticket and archived tickets. Each matching field increases the similarity score by 1, with the method selecting the Y tickets with highest scores.

The average repair time of the Y similar tickets, using `Y_time_score_avg()` becomes the predicted repair time for the new ticket. This prediction is compared against a dynamically calibrated threshold (average total repair time across all archived tickets) using `calculate_difficulty()`. Tickets with predicted repair times above the threshold are classified as "hard," while those below are "easy," enabling optimal crew assignment through the Top-and-Bottom scheme that matches crew capabilities with ticket difficulty. This approach ensures that "difficulty" is independent to each substation's historical performance rather than based on a fixed, arbitrary value.

$$\text{Predicted Repair Time}_{\text{new}} = \frac{1}{Y}\sum_{i=1}^{Y}\text{Repair Time}_{\text{similar},i} \tag{5}$$

$$\text{Difficulty}_{\text{ticket}} = \begin{cases}\text{Hard} & \text{if Predicted Repair Time}_{\text{new}} > \text{Average Repair Time}_{\text{all}} \\ \text{Easy} & \text{otherwise}\end{cases} \tag{6}$$

3.2 Substation Crew Assignment Scheme

Assume that every `N` crew members allocated to each substation are capable of performing fieldwork, so that only one member is assign per ticket.

1. **First survey and produce tickets:**
   - All members are assigned to a ticket
   - members surveys all tickets
   - Comment status (nature of damage)
   - Substation predicts "difficulty" based on status
   - Based on "difficulty," the crew continues the job or returns to the substation for reassignment

   Lets assume that
2. [**Top-down**] **Reassignment scheme:**
   - All members are re-assigned a ticket
   - Wait until a member finishes to reassign
   - Reassign members to another tickets

3. [**Top-and-Bottom**] **Reassignment scheme:**
   - Half of the members are assigned to "Hard" tickets
   - The other half are assigned to "Easy" tickets
   - Reassign members to matching difficulty
   - Otherwise assign members to mismatching difficulty
4. **Ideal Reassignment scheme:**
   - All tickets are evenly grouped with `TOT` members.

The [**Top-down**] approach focuses on resolving the most "difficult" tickets first, potentially reducing the hours without service. However, this delay repairs for "easier" tickets, increasing interrupted hours. The [**Top-and-Bottom**] approach prioritizes completing more tickets to reduce the hours without service by first resolving "hard" and "easy" ticket. This allow the "hard" ticket to be address with more time, while not delaying the time for "easier" ticket because there are more "hard" ticket. Mismatch occur when there is a imbalance of ticket difficult so that all member will be assign a ticket regardless of difficulty if all the ticket difficulty are the same.

3.3 Other Function

K_Search identifies the K most frequently occurring words in the comments section of tickets from a specific substation's historical record. The functionality ultize dictionary-based system where each word encountered in ticket comments is tracked in a word_dict data structure that maintains word-count pairs to be sorted in descending order of frequency.

When processing a ticket, words in the comments will be added with add_word(). The system then store the word and either increments the count for existing words or adds new words to the dictionary. The sorting mechanism ensures that high-frequency words sort to the top of the dictionary as new words are being added. The K_words(n) method then displays the top K most frequent words along with their occurrence counts.

The K parameter determine top K high-frequency list of words terms. The list ignore words such as "comment:" or any potential empty space that is not part of the main content of the comment.

4 Hospital Databases

During power outage, each hospital has backup generators, CAP that can be distributed so that the surgeon teams of the hospital can continue their surgery. The CAP, total backup energy in the generator of a hospital, must be distribute efficiently to achieve the best "performance" with the available resource.

4.1 Defining best "performance"

In the context of hospital operations during power outages, **best performance** is defined as maximizing patient outcomes through efficient allocation of limited backup generator capacity (CAP). This efficiency-based model prioritizes surgical teams that can achieve the greatest benefit per unit of energy consumed.

Each surgical team's performance is quantified using a **points-per-hour efficiency** metric calculated from historical data. This metric is derived by dividing the total difficulty points of completed surgeries by the total hours spent, creating an objective measure of team productivity.

$$\text{Efficiency} = \frac{\text{Total Points}}{\text{Total Hours Spend}} \tag{7}$$

Teams with higher points-per-hour ratings are considered more efficient and thus better candidates for receiving priority access to limited power resources during outages.

4.2 Hospital Energy Distribution Scheme

The algorithm distributes CAP **proportionally** based on each team's contribution to the hospital's total efficiency. For example, if a team represents 40% of a hospital's total efficiency rating, they receive approximately 40% of the available backup power. This proportional allocation ensures that the most productive teams receive sufficient resources to maintain their high-efficiency operations, maximizing the hospital's overall ability to deliver critical surgical services despite power constraints. When teams lack historical performance data, the system defaults to an **equal distribution**, ensuring fairness while collecting metrics for future optimization.

5 Initialization and Simulation with Existing Database

At initialization, a company object is created linking the connection of each of the five station objects with the five hospital objects. Then the program initializes by pathing to the folder and reading the files for all of the station and hospital that will be stored into their respective database. The completed tickets of `_tickets.csv` for each of the stations are archived and the completed surgery of `_HospitalDatabase_V1.1.csv` for each of the hospitals (file named by station) are stored and organized into Teams. At the same time, the parameters: Y, Z, K, CAP, and TOT can be set and only be set at this state.

6 Execution and Update

Once the file are read and the parameter are set for program, additional functions are available to the user. The user can call to "display" and "identify" the station tickets or hospital team, which does not modify pervious parameter or state, so will be update immediately. While, the functions to "induce outrage" and "add/delete team or surgeon" will have a impact on how `TOT` of station and `CAP` can be distributed, so will be process on the next update. The purpose of "induce outrage" help to simulate a new ticket to be added. The users are also provided the option to "forward" or "quit" the simulation. The "quit" option will terminate the program, deleting objects and freeing memory. While, the "forward" option will start an update cycle and process any changes necessary. The changes made during the update phase will be displayed at the end of each update.

During update, if there is an "induce outage" designated to a station, the protocol for an outage is realized. Crew members will have to survey and add a ticket. Then the difficulty of the ticket will be calculate for the substation to distribute their crew member. The following updates may add new line or comment on the ticket as the crew members step through the repair process. Crew members may also be reassign a new tickets when repair is done.

Similarly, if a team or surgeon is remove or added to a hospital, the corresponding hospital must redistribute `CAP` to fit the new ranking of expected team performance. The new expected team performance is constant to each team, regardless if a surgery was completed during the outage, unless a completed surgery is added to a team.

7 Substation: Result and Performance Analysis from Parameters

To simulate a typical outage amount expected for each station, the amount of outage set by simulator, using "Quick Start" will be double of the allocated TOT in each station or 2N outage to be resolve by N crew members. The option "Quick Start", aviable during execution state, repeatedly induce outage by selecting random file from a pool of possible outage. For purpose of testing, the pool of possible outage consists of all of the historical ticket from all of the substation. This mean it is possible for station "EB" to be assign an random outage that was assigned to "HD", "OF", "RL", or "TM".

7.1 Simulation Parameters

```
==== SIMULATION PARAMETERS ====
--------------------------------
   TOT: 29
   CAP: 31
   K: 5
   Y: 3
   Z: 2
--------------------------------
```

7.2 Allocation of TOT to substation

```
EB, N:3 | H1, CAP:31
OF, N:3 | H2, CAP:31
RL, N:12 | H3, CAP:31
TM, N:5 | H4, CAP:31
HD, N:6 | H5, CAP:31
```

7.3 Add random Ticket by Inducing Power Outage

```
------------------------------
>> I

==== Select Station ====
------------------------------
   {EB, HD, OF, RL, TM}
------------------------------
>> EB
random_index: 176
Path: C:\Users\jinyc\OneDrive\Documents\ESE224\final-project-jin_project\Build\test_tickets\TM30468182.csv

Call-In Ticket:
------------------------------
Line,Time,Remark
1, 2022_04_23 02:44:03, TM30468182:ENE, Address175 Part:,RL 175
, , STRUCTURE=na, VOLTAGE=na, GROUND=na, MSPLATE=na, HARMONIC=na, V NON-SHUNT=na, STATUS=na
```

7.4 Begin Survey and Assign All Member

```
>> 1

==== Select Station ====
--------------------------------
   {EB, HD, OF, RL, TM}
--------------------------------
>> EB
--------------------------------
Crew: na8909
        assigned: 1 - survey
        on hard: 1
--------------------------------
--------------------------------
Crew: na6422
        assigned: 1 - repair
        on hard: 0
--------------------------------
--------------------------------
Crew: na24946
        assigned: 1 - repair
        on hard: 0
--------------------------------
```

Figure 3: Any idle Crew is assign to survey a new outage

The survey are randomly completed with a 50% success rate. The repairs are completed once there are no comments left in the file.

7.5 Comment Update Per Report Step

```
--------------------------------
   Station: EB
   STATE: REPORT, step: 36

[Survey]: na8909        - surveyed ticket: EB04706280, Path: C:\Users\jinyc\OneDrive\Documents\ESE224\final-project-jin_project\Build\test_tickets\EB04706280.csv
[Repair]: na6422        - repaired ticket: EB56991793
[Repair]: na24946       - is still repairing
--------------------------------
Line,Time,Remark
1, 2022_04_22 21:50:53, RL90910672:ENE, Address69 Part:,HD 69
, , STRUCTURE=DIRT, VOLTAGE=45.9, GROUND=HYDRANT, MSPLATE=97ER, HARMONIC=18.0, V NON-SHUNT=81.6, STATUS=PASSIVE SITE SAFETY
2, 2022_04_22 23:02:50, RL90910672: Comment: ELECTRICIAN RELEASED AT 11:18HRS
3, 2022_04_22 23:24:00, RL90910672: Comment: MAINTENANCE PERSON REQUIRED TO SHUT BREAKER OFF
4, 2022_04_23 02:11:57, RL90910672: Comment: FLUSH NEEDED
5, 2022_04_23 03:01:31, "RL90910672: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 2PM"
6, 2022_04_23 04:45:13, RL90910672: Comment: SERVICE VEHICLE REQUESTED
7, 2022_04_23 05:17:53, RL90910672: Comment: CREW REPORTS VEHICLE NEEDS TO EB MOVED
8, 2022_04_23 07:32:38, RL90910672: Comment: EXPECTED SCAFFOLDING GOT STREET LIGHT
9, 2022_04_23 08:41:49, RL90910672: Comment: BFS REQUIRED ON SITE
10, 2022_04_23 09:27:36, RL90910672: Comment: LOAD TEST SUCCEEDED AT 5:19HRS
11, 2022_04_23 11:33:38, RL90910672: Comment: ADDITIONAL ASSISTANCE NEEDED
12, 2022_04_23 12:49:09, "RL90910672: Comment: SURVEY CONDUCTED, REPORTS 78BQ"
13, 2022_04_23 15:43:12, RL90910672: Comment: 5.7 VOLTS REMAINING
```

Figure 4: One comment are add per Report step after Survey

```
--------------------------------
   Station: EB
   STATE: REPORT, step: 38

[Survey]: na8909        - surveyed ticket: TM30468182, Path: C:\Users\jinyc\OneDrive\Documents\ESE224\final-project-jin_project\Build\test_tickets\TM30468182.csv
[Repair]: na6422        - is still repairing
--------------------------------
Line,Time,Remark
1, 2022_04_23 02:41:01, EB04706280:ENE, Address170 Part:,TM 170
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=75.6, GROUND=STREETSIGN, MSPLATE=13XQ, HARMONIC=4.3, V NON-SHUNT=52.8, STATUS=CREW WAITING
2, 2022_04_23 04:38:23, EB04706280: Comment: 79.3 VOLTS

Time score: 692
Difficulty: Easy
--------------------------------
[Repair]: na24946       - is still repairing
--------------------------------
Line,Time,Remark
1, 2022_04_22 21:50:53, RL90910672:ENE, Address69 Part:,HD 69
, , STRUCTURE=DIRT, VOLTAGE=45.9, GROUND=HYDRANT, MSPLATE=97ER, HARMONIC=18.0, V NON-SHUNT=81.6, STATUS=PASSIVE SITE SAFETY
2, 2022_04_22 23:02:50, RL90910672: Comment: ELECTRICIAN RELEASED AT 11:18HRS
3, 2022_04_22 23:24:00, RL90910672: Comment: MAINTENANCE PERSON REQUIRED TO SHUT BREAKER OFF
4, 2022_04_23 02:11:57, RL90910672: Comment: FLUSH NEEDED
5, 2022_04_23 03:01:31, "RL90910672: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 2PM"
6, 2022_04_23 04:45:13, RL90910672: Comment: SERVICE VEHICLE REQUESTED
7, 2022_04_23 05:17:53, RL90910672: Comment: CREW REPORTS VEHICLE NEEDS TO EB MOVED
8, 2022_04_23 07:32:38, RL90910672: Comment: EXPECTED SCAFFOLDING GOT STREET LIGHT
9, 2022_04_23 08:41:49, RL90910672: Comment: BFS REQUIRED ON SITE
10, 2022_04_23 09:27:36, RL90910672: Comment: LOAD TEST SUCCEEDED AT 5:19HRS
11, 2022_04_23 11:33:38, RL90910672: Comment: ADDITIONAL ASSISTANCE NEEDED
12, 2022_04_23 12:49:09, "RL90910672: Comment: SURVEY CONDUCTED, REPORTS 78BQ"
13, 2022_04_23 15:43:12, RL90910672: Comment: 5.7 VOLTS REMAINING
14, 2022_04_23 15:58:15, RL90910672: Comment: I&A WILL NOTIFY IF CREW IS AVAILABLE
```

Figure 5: After 2 steps from step step 36, one comment is added

7.6 End Result, All Ticket Resolved

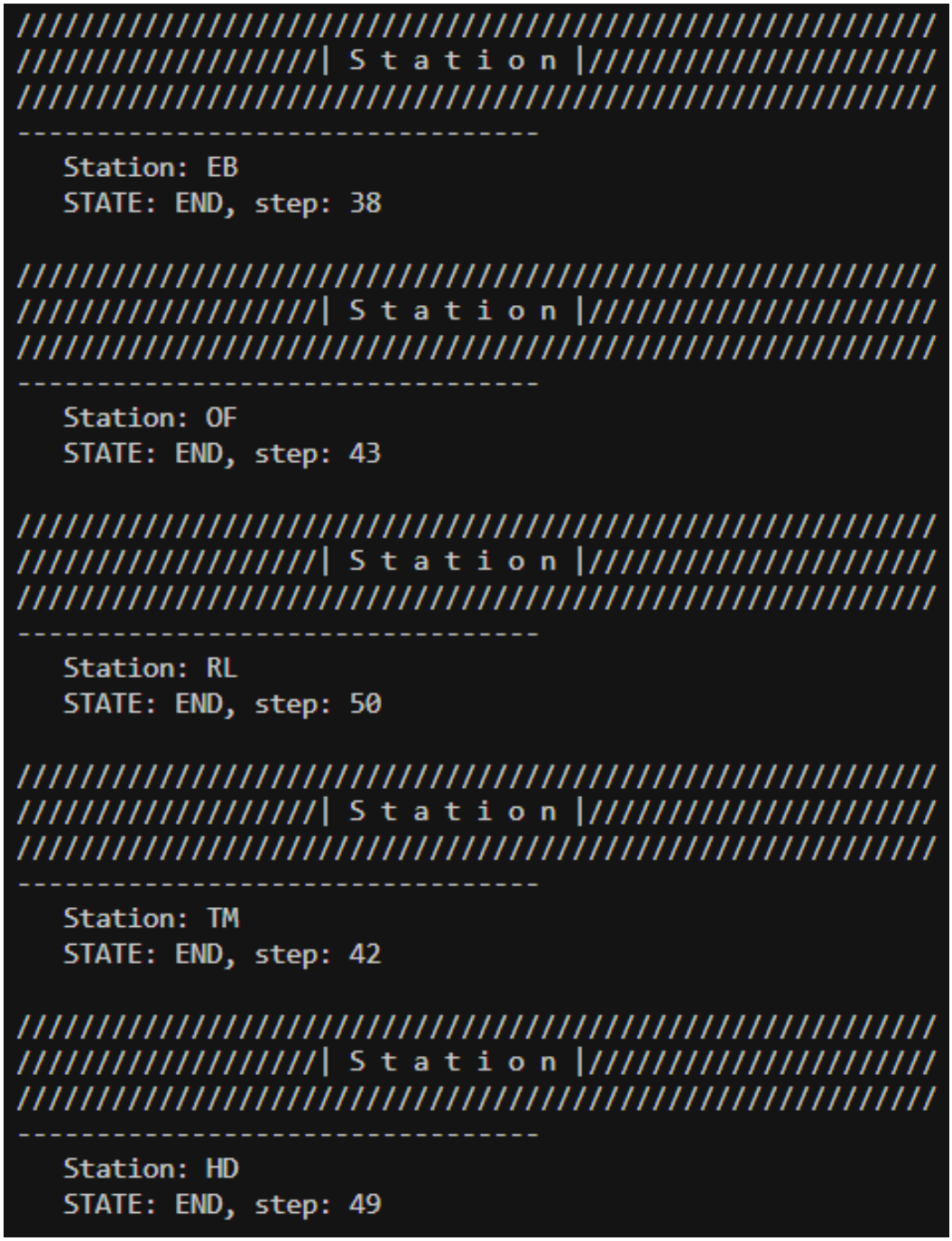


Figure 6: End steps with no extra outage induced

The step amount for each station to resolve their respective tickets are relative the same, around the range of 40 steps. Notice station RL, ranking the highest in interrupted hours (table 2), still take greatest of 50 step in the simulation. But station OF, consider to be less prioritized still finish in 43 step. This indicate the allocation of TOT is substitutable to balance the step size to a minium for all the station, thus reducing the realistic repair time and time interrupted for all the station.

7.7 Search for a specific Ticket

```
[o]Search within station: EB

==== Status Value Search ====
Enter status values for each field (leave blank to ignore that field).
The system will find the top 3 tickets with the most matching fields.

STRUCTURE: ROLLDOWN GATE
VOLTAGE: 75.6
GROUND: STREETSIGN
MSPLATE: 13XQ
HARMONIC: 4.3
V NON-SHUNT: 52.8
STATUS: CREW WAITING
Searching for top 3 most similar tickets...

==== TOP 1 SIMILAR TICKETS ====

--- Rank #1 (Similarity Score: 7) ---
--------------------------------
Line,Time,Remark
1, 2022_04_23 02:41:01, EB04706280:ENE, Address170 Part:,TM 170
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=75.6, GROUND=STREETSIGN, MSPLATE=13XQ, HARMONIC=4.3, V NON-SHUNT=52.8, STATUS=CREW WAITING
2, 2022_04_23 04:38:23, EB04706280: Comment: 79.3 VOLTS
3, 2022_04_23 04:56:44, EB04706280: Comment: ELECTRICIAN RELEASED AT 3:41HRS
4, 2022_04_23 07:28:40, EB04706280: Comment: FLUSH NEEDED
5, 2022_04_23 08:56:37, "EB04706280: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 7PM"
6, 2022_04_23 11:50:19, EB04706280: Comment: CREW NOTIFIED
7, 2022_04_23 12:46:44, EB04706280: Comment: 1.6 VOLTS REMAINING
8, 2022_04_23 13:13:04, EB04706280: Comment: SERVICE VEHICLE REQUESTED
```

7.8 Search Tickets by Date Range

```
==== ARCHIVE TICKETS BETWEEN 2022_04_23 02:41:01 AND 2022_04_23 13:13:04 ====

Ticket:1
--------------------------------
Line,Time,Remark
1, 2022_04_23 02:41:01, EB04706280:ENE, Address170 Part:,TM 170
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=75.6, GROUND=STREETSIGN, MSPLATE=13XQ, HARMONIC=4.3, V NON-SHUNT=52.8, STATUS=CREW WAITIN
G
2, 2022_04_23 04:38:23, EB04706280: Comment: 79.3 VOLTS
3, 2022_04_23 04:56:44, EB04706280: Comment: ELECTRICIAN RELEASED AT 3:41HRS
4, 2022_04_23 07:28:40, EB04706280: Comment: FLUSH NEEDED
5, 2022_04_23 08:56:37, "EB04706280: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 7PM"
6, 2022_04_23 11:50:19, EB04706280: Comment: CREW NOTIFIED
7, 2022_04_23 12:46:44, EB04706280: Comment: 1.6 VOLTS REMAINING
8, 2022_04_23 13:13:04, EB04706280: Comment: SERVICE VEHICLE REQUESTED
```

Figure 7: Ticket 1 out of 9 with specified date range

7.9 Search Y=3 most similar Ticket within station

```
--------------------------------
   {EB, HD, OF, RL, TM, ALL}
--------------------------------
>> EB
[o]Search within station: EB

==== Status Value Search ====
Enter status values for each field (leave blank to ignore that field).
The system will find the top 3 tickets with the most matching fields.

STRUCTURE: ROLLDOWN GATE
VOLTAGE: 75.6
GROUND: STREETSIGN
MSPLATE: 13XQ
HARMONIC: 4.3
V NON-SHUNT: 52.8
STATUS: CREW WAITING

Searching for top 3 most similar tickets...

==== TOP 3 SIMILAR TICKETS ====

--- Rank #1 (Similarity Score: 7) ---
--------------------------------
Line,Time,Remark
1, 2022_04_23 02:41:01, EB04706280:ENE, Address170 Part:,TM 170
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=75.6, GROUND=STREETSIGN, MSPLATE=13XQ, HARMONIC=4.3, V NON-SHUNT=52.8, STATUS=CREW WAITING
2, 2022_04_23 04:38:23, EB04706280: Comment: 79.3 VOLTS
3, 2022_04_23 04:56:44, EB04706280: Comment: ELECTRICIAN RELEASED AT 3:41HRS
4, 2022_04_23 07:28:40, EB04706280: Comment: FLUSH NEEDED
5, 2022_04_23 08:56:37, "EB04706280: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 7PM"
6, 2022_04_23 11:50:19, EB04706280: Comment: CREW NOTIFIED
7, 2022_04_23 12:46:44, EB04706280: Comment: 1.6 VOLTS REMAINING
8, 2022_04_23 13:13:04, EB04706280: Comment: SERVICE VEHICLE REQUESTED
```

```
--- Rank #2 (Similarity Score: 2) ---
--------------------------------
Line,Time,Remark
1, 2022_04_22 20:58:51, EB13956409:ENE, Address137 Part:,RL 137
, , STRUCTURE=ASPHALT, VOLTAGE=22.0, GROUND=STREETSIGN, MSPLATE=25H, HARMONIC=13.6, V NON-SHUNT=65.8, STATUS=CREW WAITING
2, 2022_04_22 22:15:13, EB13956409: Comment: CREW NOTIFIED
3, 2022_04_23 00:18:08, EB13956409: Comment: FLUSH NEEDED
4, 2022_04_23 00:35:26, EB13956409: Comment: 89.4 VOLTS
5, 2022_04_23 01:25:07, EB13956409: Comment: MAINTENANCE PERSON REQUIRED TO SHUT BREAKER OFF
6, 2022_04_23 04:04:36, EB13956409: Comment: 41% HARMONICS
7, 2022_04_23 05:41:26, EB13956409: Comment: LOAD TEST SUCCEEDED AT 4:19HRS
8, 2022_04_23 08:05:16, EB13956409: Comment: SERVICE VEHICLE REQUESTED

Time score: 590
Difficulty: Easy
--------------------------------

--- Rank #3 (Similarity Score: 2) ---
--------------------------------
Line,Time,Remark
1, 2022_04_23 00:57:43, EB17941035:ENE, Address91 Part:,EB 91
, , STRUCTURE=DIRT, VOLTAGE=48.8, GROUND=STREETSIGN, MSPLATE=63L, HARMONIC=19.4, V NON-SHUNT=6.8, STATUS=CREW WAITING
2, 2022_04_23 03:00:11, EB17941035: Comment: ADDITIONAL ASSISTANCE NEEDED
3, 2022_04_23 04:12:14, EB17941035: Comment: 15% HARMONICS
4, 2022_04_23 04:46:15, EB17941035: Comment: SERVICE VEHICLE REQUESTED
5, 2022_04_23 06:17:55, EB17941035: Comment: MAINTENANCE PERSON REQUIRED TO SHUT BREAKER OFF
6, 2022_04_23 07:01:36, EB17941035: Comment: LOAD TEST SUCCEEDED AT 5:38HRS
7, 2022_04_23 09:03:15, EB17941035: Comment: ELECTRICIAN RELEASED AT 2:28HRS
8, 2022_04_23 10:51:35, EB17941035: Comment: CONTACT S&R
9, 2022_04_23 11:04:54, EB17941035: Comment: CREW NOTIFIED
10, 2022_04_23 13:24:02, EB17941035: Comment: BFS REQUIRED ON SITE
11, 2022_04_23 14:18:50, EB17941035: Comment: FROM 61Z TO 15I
12, 2022_04_23 17:01:36, EB17941035: Comment: EXPECTED SCAFFOLDING GOT SCAFFOLDING
```

7.10 Search K=2 most similar Ticket across all station

```
==== Select Station ====
--------------------------------
   {EB, HD, OF, RL, TM, ALL}
--------------------------------
>> ALL
[o]Search across all stations

==== Status Value Search ====
Enter status values for each field (leave blank to ignore that field).
The system will find the top 3 tickets with the most matching fields.

STRUCTURE: ROLLDOWN GATE
VOLTAGE: 75.6
GROUND: STREETSIGN
MSPLATE: 13XQ
HARMONIC: 4.3
V NON-SHUNT: 52.8
STATUS: CREW WAITING

Searching across all stations for top 2 most similar tickets...

Searching for similar tickets across all substations...

==== TOP 2 SIMILAR TICKETS ACROSS ALL STATIONS ====

--- Rank #1 ---
--------------------------------
Line,Time,Remark
1, 2022_04_23 02:41:01, EB04706280:ENE, Address170 Part:,TM 170
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=75.6, GROUND=STREETSIGN, MSPLATE=13XQ, HARMONIC=4.3, V NON-SHUNT=52.8, STATUS=CREW WAITING
2, 2022_04_23 04:38:23, EB04706280: Comment: 79.3 VOLTS
3, 2022_04_23 04:56:44, EB04706280: Comment: ELECTRICIAN RELEASED AT 3:41HRS
4, 2022_04_23 07:28:40, EB04706280: Comment: FLUSH NEEDED
5, 2022_04_23 08:56:37, "EB04706280: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 7PM"
6, 2022_04_23 11:50:19, EB04706280: Comment: CREW NOTIFIED
7, 2022_04_23 12:46:44, EB04706280: Comment: 1.6 VOLTS REMAINING
8, 2022_04_23 13:13:04, EB04706280: Comment: SERVICE VEHICLE REQUESTED
```

```
--- Rank #2 ---
--------------------------------
Line,Time,Remark
1, 2022_04_22 12:58:34, OF27553093:ENE, Address169 Part:,EB 169
, , STRUCTURE=ROLLDOWN GATE, VOLTAGE=9.2, GROUND=STREETSIGN, MSPLATE=52R, HARMONIC=18.1, V NON-SHUNT=39.9, STATUS=CREW WAITING
2, 2022_04_22 15:10:49, "OF27553093: Comment: SURVEY CONDUCTED, REPORTS 16BQ"
3, 2022_04_22 16:05:50, "OF27553093: Comment: INFOROFD I&A, CREW WILL EB ON LOCATION UNTIL 6PM"
4, 2022_04_22 17:44:44, OF27553093: Comment: EXPECTED SIDEWALK GOT SCAFFOLDING
5, 2022_04_22 18:53:14, OF27553093: Comment: ELECTRICIAN RELEASED AT 1:35HRS
6, 2022_04_22 20:58:59, OF27553093: Comment: SERVICE VEHICLE REQUESTED
7, 2022_04_22 23:38:12, OF27553093: Comment: FROM 39AC TO 61MX
8, 2022_04_23 01:25:57, OF27553093: Comment: CREW NOTIFIED
9, 2022_04_23 02:07:53, OF27553093: Comment: FLUSH NEEDED
```

7.11 Search for most Frequency word within Station

```
==== TOP 5 FREQUENT WORDS IN EB ====
1. CREW (92)
2. TO (65)
3. NEEDED (48)
4. WILL (48)
5. VEHICLE (45)
```

8 Hospital: Result and Performance Analysis from Parameters

8.1 Add a Complete Surgery to a Team

```
==== Status Value Search ====
Enter values for a complete surgery.
Team Name: T11
Surgery Type: test
Start Date(YYYY-MM-DD): 5/12/2025
End Date(YYYY-MM-DD): 5/13/2025
Difficulty (1-10): 6
Time(minutes): 60

==== Team Information ====
---------------------------------
Team Name: T11

Team Members:

Surgeries:
Surgery Type, Start Date, End Date, Difficulty, Minutes
Arm, 1/5/2022, 1/12/2022, 1, 70
Arm, 1/5/2022, 1/11/2022, 6, 90
Arm, 1/8/2022, 1/11/2022, 8, 140
Arm, 1/7/2022, 1/11/2022, 3, 75
Arm, 1/2/2022, 1/11/2022, 7, 75
Arm, 1/5/2022, 1/11/2022, 7, 95
Arm, 1/7/2022, 1/10/2022, 5, 60
Arm, 1/10/2022, 1/10/2022, 6, 50
Arm, 1/2/2022, 1/11/2022, 9, 95
Arm, 1/9/2022, 1/10/2022, 7, 190
Arm, 1/6/2022, 1/12/2022, 7, 250
Arm, 1/8/2022, 1/10/2022, 2, 140
Arm, 1/5/2022, 1/12/2022, 5, 35
Arm, 1/3/2022, 1/11/2022, 3, 30
Arm, 1/3/2022, 1/11/2022, 8, 245
test, 5/12/2025, 5/13/2025, 6, 60

Average Points per Hour: 3.17647
```

8.2 Add a Team and or member

```
Enter team name: T11

Adding to existing team: 'T11'
Member (or press Enter to finish): m1
Surgeon 'm1' has been added to team 'T11'.
Member (or press Enter to finish): m2
Surgeon 'm2' has been added to team 'T11'.
Member (or press Enter to finish): m3
Surgeon 'm3' has been added to team 'T11'.
Member (or press Enter to finish):

==== Team Information ====
--------------------------------
Team Name: T11

Team Members:
- m1
- m2
- m3

Surgeries:
Surgery Type, Start Date, End Date, Difficulty, Minutes
Arm, 1/5/2022, 1/12/2022, 1, 70
Arm, 1/5/2022, 1/11/2022, 6, 90
Arm, 1/8/2022, 1/11/2022, 8, 140
Arm, 1/7/2022, 1/11/2022, 3, 75
Arm, 1/2/2022, 1/11/2022, 7, 75
Arm, 1/5/2022, 1/11/2022, 7, 95
Arm, 1/7/2022, 1/10/2022, 5, 60
Arm, 1/10/2022, 1/10/2022, 6, 50
Arm, 1/2/2022, 1/11/2022, 9, 95
Arm, 1/9/2022, 1/10/2022, 7, 190
Arm, 1/6/2022, 1/12/2022, 7, 250
Arm, 1/8/2022, 1/10/2022, 2, 140
Arm, 1/5/2022, 1/12/2022, 5, 35
Arm, 1/3/2022, 1/11/2022, 3, 30
Arm, 1/3/2022, 1/11/2022, 8, 245
```

Figure 8: Enter Caption

8.3 Remove a Team and or member

```
Enter team name: T11

==== Team Information ====
--------------------------------
Team Name: T11

Team Members:
- m1
- m2
- m3

Surgeries:
Surgery Type, Start Date, End Date, Difficulty, Minutes
Arm, 1/5/2022, 1/12/2022, 1, 70
Arm, 1/5/2022, 1/11/2022, 6, 90
Arm, 1/8/2022, 1/11/2022, 8, 140
Arm, 1/7/2022, 1/11/2022, 3, 75
Arm, 1/2/2022, 1/11/2022, 7, 75
Arm, 1/5/2022, 1/11/2022, 7, 95
Arm, 1/7/2022, 1/10/2022, 5, 60
Arm, 1/10/2022, 1/10/2022, 6, 50
Arm, 1/2/2022, 1/11/2022, 9, 95
Arm, 1/9/2022, 1/10/2022, 7, 190
Arm, 1/6/2022, 1/12/2022, 7, 250
Arm, 1/8/2022, 1/10/2022, 2, 140
Arm, 1/5/2022, 1/12/2022, 5, 35
Arm, 1/3/2022, 1/11/2022, 3, 30
Arm, 1/3/2022, 1/11/2022, 8, 245

Average Points per Hour: 3.07317
--------------------------------


==== Remove Option ====
--------------------------------
 1 | Remove member from team
 2 | Remove whole team
--------------------------------
>> 1
Enter member name(press Enter to finish): m1
Surgeon 'm1' has been removed from team 'T11'.
Enter member name(press Enter to finish):
```

==== UPDATE RESULT====

//
//////////////////| H o s p i t a l |//////////////////////
//

   Hospital: H1
   STATE: END, step: 3

[POWER ALLOCATION BASED ON EFFICIENCY]
Available capacity (CAP): 31
Team T11 (Efficiency: 3.07317) allocated 7.42036 units (23.9366% of CAP) - Expected points:
22.804
Team T15 (Efficiency: 2.84123) allocated 6.86031 units (22.13% of CAP) - Expected points:
19.4917
Team T12 (Efficiency: 2.81707) allocated 6.802 units (21.9419% of CAP) - Expected points:
19.1617
Team T13 (Efficiency: 2.1365) allocated 5.15871 units (16.641% of CAP) - Expected points:
11.0216
Team T14 (Efficiency: 1.9708) allocated 4.75862 units (15.3504% of CAP) - Expected points:
9.37831

Total allocation: 31/31
This allocation maximizes patient outcomes based on team efficiency.
//
//////////////////| H o s p i t a l |//////////////////////
//

   Hospital: H2
   STATE: END, step: 3

[POWER ALLOCATION BASED ON EFFICIENCY]
Available capacity (CAP): 31
Team T25 (Efficiency: 2.05917) allocated 6.81455 units (21.9824% of CAP) - Expected points:
14.0323
Team T21 (Efficiency: 2.04082) allocated 6.75381 units (21.7865% of CAP) - Expected points:
13.7833
Team T22 (Efficiency: 1.83621) allocated 6.07668 units (19.6022% of CAP) - Expected points:
11.158
Team T24 (Efficiency: 1.79667) allocated 5.94585 units (19.1802% of CAP) - Expected points:
10.6827
Team T23 (Efficiency: 1.63448) allocated 5.4091 units (17.4487% of CAP) - Expected points:
8.84109

Total allocation: 31/31
This allocation maximizes patient outcomes based on team efficiency.
//
//////////////////| H o s p i t a l |//////////////////////
//

   Hospital: H3
   STATE: END, step: 3

[POWER ALLOCATION BASED ON EFFICIENCY]
Available capacity (CAP): 31
Team T32 (Efficiency: 2.00826) allocated 7.36643 units (23.7627% of CAP) - Expected points: 14.7937
Team T35 (Efficiency: 1.75546) allocated 6.43913 units (20.7714% of CAP) - Expected points: 11.3036
Team T33 (Efficiency: 1.66252) allocated 6.09823 units (19.6717% of CAP) - Expected points: 10.1384
Team T34 (Efficiency: 1.64602) allocated 6.03769 units (19.4764% of CAP) - Expected points: 9.93814
Team T31 (Efficiency: 1.37907) allocated 5.05852 units (16.3178% of CAP) - Expected points: 6.97608

Total allocation: 31/31
This allocation maximizes patient outcomes based on team efficiency.
//
//////////////////| H o s p i t a l |//////////////////////
//

   Hospital: H4
   STATE: END, step: 2

[POWER ALLOCATION BASED ON EFFICIENCY]
Available capacity (CAP): 31
Team T44 (Efficiency: 2.28306) allocated 7.20633 units (23.2462% of CAP) - Expected points: 16.4525
Team T42 (Efficiency: 2.10811) allocated 6.6541 units (21.4648% of CAP) - Expected points: 14.0276
Team T43 (Efficiency: 1.86885) allocated 5.8989 units (19.0287% of CAP) - Expected points: 11.0242
Team T45 (Efficiency: 1.84017) allocated 5.80838 units (18.7367% of CAP) - Expected points: 10.6884
Team T41 (Efficiency: 1.72102) allocated 5.43229 units (17.5235% of CAP) - Expected points: 9.34908

Total allocation: 31/31
This allocation maximizes patient outcomes based on team efficiency.
//
//////////////////| H o s p i t a l |//////////////////////
//

   Hospital: H5
   STATE: END, step: 3

[POWER ALLOCATION BASED ON EFFICIENCY]
Available capacity (CAP): 31
Team T54 (Efficiency: 2.04484) allocated 7.47022 units (24.0975% of CAP) - Expected points: 15.2754
Team T53 (Efficiency: 1.69672) allocated 6.19846 units (19.995% of CAP) - Expected points: 10.5171
Team T52 (Efficiency: 1.68379) allocated 6.15124 units (19.8427% of CAP) - Expected points:

10.3574
Team T51 (Efficiency: 1.55152) allocated 5.66799 units (18.2838% of CAP) - Expected points: 8.79398
Team T55 (Efficiency: 1.50884) allocated 5.51209 units (17.781% of CAP) - Expected points: 8.31687

Total allocation: 31/31
This allocation maximizes patient outcomes based on team efficiency.

//

[o]COMPLETED update_event()

8.4 Search for a Specific Team by Name

```
Enter team name: T11

==== Team Information ====
------------------------------
Team Name: T11

Team Members:

Surgeries:
Surgery Type, Start Date, End Date, Difficulty, Minutes
Arm, 1/5/2022, 1/12/2022, 1, 70
Arm, 1/5/2022, 1/11/2022, 6, 90
Arm, 1/8/2022, 1/11/2022, 8, 140
Arm, 1/7/2022, 1/11/2022, 3, 75
Arm, 1/2/2022, 1/11/2022, 7, 75
Arm, 1/5/2022, 1/11/2022, 7, 95
Arm, 1/7/2022, 1/10/2022, 5, 60
Arm, 1/10/2022, 1/10/2022, 6, 50
Arm, 1/2/2022, 1/11/2022, 9, 95
Arm, 1/9/2022, 1/10/2022, 7, 190
Arm, 1/6/2022, 1/12/2022, 7, 250
Arm, 1/8/2022, 1/10/2022, 2, 140
Arm, 1/5/2022, 1/12/2022, 5, 35
Arm, 1/3/2022, 1/11/2022, 3, 30
Arm, 1/3/2022, 1/11/2022, 8, 245

Average Points per Hour: 3.07317
```

Figure 9: Display of a specific team of Hospital H1

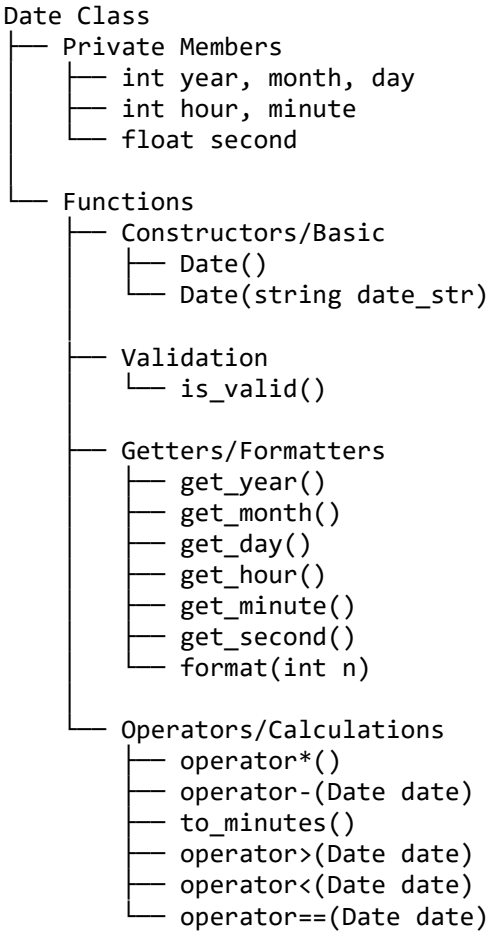
8.5 Search surgeries by Date Range

```
==== SURGERIES IN H1 HOSPITAL ====
----------------------------------------
Date Range: 1/5/2022 to 1/6/2022
----------------------------------------

Team: T11
Surgery Type, Start Date, End Date, Difficulty, Minutes
Arm, 1/5/2022, 1/12/2022, 1, 70
Arm, 1/5/2022, 1/11/2022, 6, 90
Arm, 1/5/2022, 1/11/2022, 7, 95
Arm, 1/6/2022, 1/12/2022, 7, 250
Arm, 1/5/2022, 1/12/2022, 5, 35
----------------------------------------

Team: T12
Surgery Type, Start Date, End Date, Difficulty, Minutes
Heart, 1/6/2022, 1/12/2022, 9, 60
Heart, 1/6/2022, 1/10/2022, 8, 40
Heart, 1/5/2022, 1/10/2022, 5, 65
----------------------------------------

Team: T13
Surgery Type, Start Date, End Date, Difficulty, Minutes
Neurological, 1/6/2022, 1/11/2022, 4, 80
Neurological, 1/6/2022, 1/10/2022, 7, 80
Neurological, 1/6/2022, 1/11/2022, 2, 160
----------------------------------------

Team: T14
Surgery Type, Start Date, End Date, Difficulty, Minutes
Spine, 1/6/2022, 1/12/2022, 5, 90
Spine, 1/6/2022, 1/12/2022, 5, 75
Spine, 1/5/2022, 1/10/2022, 1, 65
Spine, 1/5/2022, 1/10/2022, 3, 200
----------------------------------------

Team: T15
Surgery Type, Start Date, End Date, Difficulty, Minutes
Orthopedic, 1/5/2022, 1/12/2022, 8, 75
Orthopedic, 1/6/2022, 1/12/2022, 7, 265
----------------------------------------
```

8.6 Rank all the Team from all the hospital by efficiency

```
==== RANKING TEAMS BY POINTS/HOUR ====
This function displays all surgical teams across all hospitals
ranked by their average number of points per hour.


==== TOP 25 TEAMS RANKED BY POINTS PER HOUR ====

--- Rank #1 (Points/Hour: 3.07317) ---
Hospital: H1
Team: T11

--- Rank #2 (Points/Hour: 2.84123) ---
Hospital: H1
Team: T15

--- Rank #3 (Points/Hour: 2.81707) ---
Hospital: H1
Team: T12

--- Rank #4 (Points/Hour: 2.28306) ---
Hospital: H4
Team: T44

--- Rank #5 (Points/Hour: 2.1365) ---
Hospital: H1
Team: T13

--- Rank #6 (Points/Hour: 2.10811) ---
Hospital: H4
Team: T42

--- Rank #7 (Points/Hour: 2.05917) ---
Hospital: H2
```

9 Complete Structure

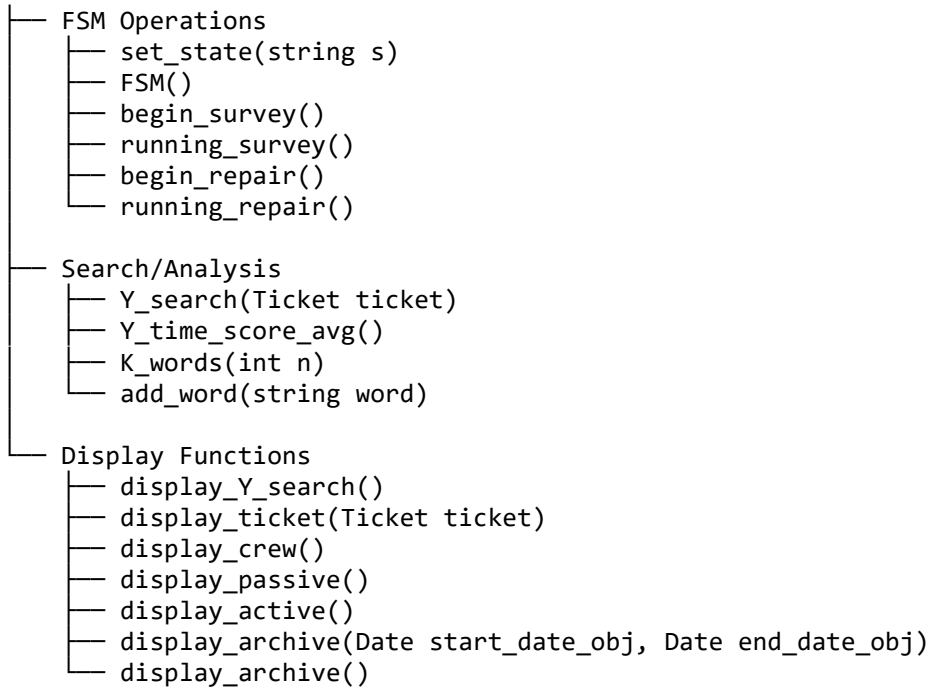

Date Class
Private Members
int year, month, day
int hour, minute
float second
Functions
Constructors/Basic
Date()
Date(string date_str)
Validation
is_valid()
Getters/Formatters
get_year()
get_month()
get_day()
get_hour()
get_minute()
get_second()
format(int n)
Operators/Calculations
operator*()
operator-(Date date)
to_minutes()
operator>(Date date)
operator<(Date date)
operator==(Date date)

```
Company Class
├── Private Members
│   ├── struct Net
│   ├── int TOT, CAP, K, Y, Z
│   ├── string test_folder_path
│   ├── vector<string> test_files_path
│   └── Station temp_station
│
├── Public Members
│   ├── struct TeamInfo
│   ├── vector<TeamInfo> ranked_teams
│   └── vector<Net> nets
│
└── Functions
    ├── Constructors/Basic
    │   ├── Company()
    │   ├── clear_nets()
    │   └── connect(Station station, Hospital hospital)
    │
    ├── Parameter Management
    │   ├── set_parameter(int TOT, int CAP, int K, int Y, int Z)
    │   ├── get_TOT()
    │   ├── get_CAP()
    │   ├── get_K()
    │   ├── set_K(int k)
    │   ├── get_Y()
    │   ├── set_Y(int y)
    │   └── get_Z()
    │
    ├── File Operations
    │   ├── set_test_folder_path(string path)
    │   ├── file_exist(string path)
    │   ├── file_test_ticket()
    │   └── select_random_file()
    │
    ├── Network Component Access
    │   ├── select_station(string station_name)
    │   └── select_hospital(string hospital_name)
    │
    ├── Resource Allocation
    │   └── allot_TOT()
    │
    ├── Event Simulation
    │   └── update_event()
    │
    ├── Station Analysis
    │   ├── Z_search(Ticket ticket)
    │   └── display_Z_search()
    │
    └── Team Analysis
        ├── team_search()
        └── display_team()
```

```
Document Class (Base)
├── Protected Members
│   ├── string index
│   ├── Date date
│   ├── string id
│   └── string remark
│
├── Friend Classes
│   └── Date
│
└── Functions
    ├── Constructors/Basic
    │   └── Document(string remark)
    │
    ├── Getters/Setters
    │   ├── get_id()
    │   ├── get_date()
    │   ├── set_line(string index)
    │   ├── set_id(string id)
    │   ├── set_date(string timestamp)
    │   └── get_remark()
    │
    └── Display
        └── display()

Header Class (Extends Document)
├── Private Members
│   ├── string address
│   └── string ENE
│
├── Friend Classes
│   └── Ticket
│
└── Functions
    ├── Constructors/Basic
    │   └── Header(string address)
    │
    └── Getters/Setters
        ├── get_address()
        ├── set_ENE(string new_ENE)
        ├── set_address(string new_address)
        └── set_remark()

Status Class (Extends Document)
├── Private Members
│   ├── string structure, voltage, ground
│   ├── string msp, harmonic, v_non_shunt
│   └── string status
│
├── Friend Classes
│   └── Ticket
│
└── Functions
    ├── Constructors/Basic
    │   └── Status(...)
```

```
    │
    ├── Getters/Setters
    │   ├── set_structure(), get_structure()
    │   ├── set_voltage(), get_voltage()
    │   ├── set_ground(), get_ground()
    │   ├── set_msp(), get_msp()
    │   ├── set_harmonic(), get_harmonic()
    │   ├── set_v_non_shunt(), get_v_non_shunt()
    │   ├── set_status(), get_status()
    │   └── set_remark()
    │
    └── Display
        └── display()

Comment Class (Extends Document)
├── Private Members
│   └── string comment
│
├── Friend Classes
│   └── Ticket
│
└── Functions
    ├── Constructors/Basic
    │   └── Comment(string comment_text)
    │
    ├── Getters/Setters
    │   ├── set_comment(string new_comment)
    │   └── set_remark()
    │
    └── Utility
        └── to_word_string()

Ticket Class
├── Private Members
│   ├── string col_names
│   ├── Header header
│   ├── Status status
│   ├── vector<Comment> comment
│   ├── bool hard, surveyed, repaired
│   ├── int time_score, sim_value
│   ├── int comment_line
│   └── string file_path
│
├── Friend Classes
│   └── Station
│
└── Functions
    ├── Constructors/Basic
    │   ├── Ticket(Header, Status, vector<Comment>, bool, bool)
    │   ├── Ticket(const Ticket&)
    │   └── operator=(const Ticket&)
    │
    ├── Getters/Setters
    │   ├── get_sim_value()
    │   ├── get_id()
```

```
    │   ├── operator*()
    │   ├── get_date()
    │   └── set_status(Status status)
    │
    ├── Ticket Processing
    │   ├── is_surveyed()
    │   ├── is_repaired()
    │   └── write_comment()
    │
    └── Analysis
        ├── calculate_difficulty(int time_threshold)
        └── calculate_time_score()

Station Class
├── Private Members
│   ├── string name
│   ├── float priority
│   ├── int allot_TOT, hard_threshold, Y, K
│   ├── struct Crew
│   ├── struct Word
│   ├── struct Database db
│   ├── vector<Crew> crew
│   ├── vector<Ticket> passive, active
│   ├── vector<Ticket> sim_rank
│   └── enum State {START, ASSIGN, REPORT, END}
│
├── Friend Classes
│   ├── Ticket
│   └── Company
│
└── Functions
    ├── Constructors/Basic
    │   ├── Station(string name, float priority)
    │   ├── set_name(string name)
    │   ├── set_file_path(string folder_name)
    │   ├── set_TOT(int TOT)
    │   ├── set_Y(int Y)
    │   ├── set_K(int K)
    │   ├── get_name()
    │   ├── get_TOT()
    │   ├── get_priority()
    │   ├── add_TOT(int amount)
    │   └── clear_ticket()
    │
    ├── File Operations
    │   ├── file_exist(string path)
    │   ├── file_ticket()
    │   ├── file_test(string file)
    │   └── file_to_ticket(Ticket ticket, string file)
    │
    ├── Ticket Management
    │   ├── archive_ticket(Ticket ticket)
    │   ├── activate_ticket(Ticket ticket)
    │   └── calbrate_hard_threshold()
    │
```


FSM Operations
set_state(string s)
FSM()
begin_survey()
running_survey()
begin_repair()
running_repair()
Search/Analysis
Y_search(Ticket ticket)
Y_time_score_avg()
K_words(int n)
add_word(string word)
Display Functions
display_Y_search()
display_ticket(Ticket ticket)
display_crew()
display_passive()
display_active()
display_archive(Date start_date_obj, Date end_date_obj)
display_archive()

```
Team Class
├── Private Members
│   ├── struct Surgery
│   ├── string name
│   ├── vector<string> member
│   ├── vector<Surgery> surgery
│   ├── float avg_point_hour
│   ├── int total_points
│   └── float total_hours
│
├── Friend Classes
│   └── Hospital
│
└── Functions
    ├── Constructors/Basic
    │   ├── Team(string name, vector<string> member)
    │   ├── add_member(string member)
    │   ├── get_name()
    │   ├── add_surgery(...)
    │   └── operator*()
    │
    └── Performance Analysis
        ├── average_points()
        ├── get_efficiency()
        ├── get_surgery_count()
        ├── analyze_surgery_types()
        ├── analyze_difficulty_levels()
        └── calculate_energy_need()

Hospital Class
├── Private Members
│   ├── string name
│   ├── string substation
│   ├── int CAP
│   └── vector<Team> team
│
├── Friend Classes
│   ├── Company
│   └── Team
│
└── Functions
    ├── Constructors/Basic
    │   ├── Hospital(string name, int CAP)
    │   ├── set_name(string name)
    │   ├── set_file_path(string folder_name)
    │   ├── set_substation(string substation)
    │   ├── set_CAP(int CAP)
    │   ├── get_CAP()
    │   ├── get_name()
    │   └── search_team(string team_name)
    │
    ├── File Operations
    │   └── file_team()
    │
    ├── Team Management
```

```
│   ├── add_complete_surgery(...)
│   ├── add_team(string name)
│   ├── add_member(string team_name, string member)
│   ├── remove_team(string team_name)
│   ├── remove_member(string team_name, string member)
│   ├── add_surgery()
│   └── clear_team()
│
├── FSM Operations
│   └── FSM()
│
└── Display Functions
    ├── display_team(const Team* team)
    ├── display_team(string team_name)
    ├── display_teams()
    └── display_surgery(string start_date_str, string end_date_str)
```