Air Traffic Services Operations staff/personnel Rostering Best Practices and Tools Guidelines

Released issue: Edition: 1.0
Edition date: 26-04-2023
Classification: Green
Reference nr: NMD/SAF/2653

DOCUMENT CONTROL

Document Title	Air Traffic Services Operations staff/personnel Rostering Best Practices and Tools Guidelines
Document Subtitle	This field is automatically updated
Document Reference	NMD/SAF/2653
Edition Number	1.0
Edition Validity Date	26-04-2023
Classification	Green
Status	Released Issue
Supplementary Document	This document is accompanied by a supplementary document on Fatigue Management - GUIDELINES ON FATIGUE MANAGEMENT IN ATC ROSTERING SYSTEMS Ref NMD/SAF/2611
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EDITION HISTORY

Edition No.	Validity Date	Author(s)	Reason
0.1	24.10.2022	Una Mellett	Initial layout of the doc
0.2	01.11.2022	Una Mellett & Tony Licu	Internal NMD/SAF review
0.3	07.02.2023	Una Mellett & Tony Licu	Following Guidelines meeting 25.01.2023
0.4	30.01.2023	Una Mellett & Tony Licu	Annex 1 and quality control of the document
0.5	09.02.2023	Una Mellett & Tony Licu	Review of all document
0.6	27.02.2023	Una Mellett & Tony Licu	Review after the meeting on 16.02.2023
0.7	06.03.2023	Una Mellett & Tony Licu	Integrating Austro Control comments
0.8	17.03.202.	Una Mellett & Tony Licu	Integrating ENAIRE comments
0.9	23.03.2023	Una Mellett & Tony Licu	Quality control after the 8th ATC Roster Ad-Hoc Group
1.0	26.07	Una Mellett & Tony Licu	Creation of Released Issue v1.0

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1. Introduction

1.1 Background

In 2006 EUROCONTROL provided a set of guidelines on shift work. In addition, in 2020 the European Aviation Safety Agency/European Union (EASA/EU) introduced requirements on managing fatigue for ATCO during shifts.

Following the COVID pandemic, a number of Network Manager ANSPs Chief Operations Officers (NM COOs) round table meetings were carried out in 2020-2022 who requested a study on shift work practices in European Air Navigation Services Providers (ANSPs) and responses to staffing to managing the COVID pandemic context on operations to share experience and capture lesson learned.

Following this survey results, the NM COOs requested that the 2006 guidelines to be updated to reflect key requirements for rostering practices and rostering tools.

In addition, this document is accompanied by a supplement document covering “Guidelines on Fatigue Management in ATC Rostering”.

These guidelines are for the cohort defined as Air Traffic Services (ATS) Operations staff/personnel and refers to rostering practices for any operations staff (ATCOs, ATSEPs, MET, AIS, Flow etc) on duty working in 24/7 shift environment

1.2 Objective

The objective of these guidelines on Rostering practices is to define:

- key requirements for Rostering practices and requirements for Rostering Tools primarily for the ATS Operations staff/personnel context with a possible application to aviation staff that work 24/7 shifts.
- the steps to customise a Rostering Tool.
- rostering planning workflow and key considerations/factors.

1.3 Document Structure

The document is structured as follows:

- **Chapter 2**: Defines the rationale for a software solution for rostering;
- **Chapter 3:** Outlines the key objectives for a rostering software solution;
- **Chapter 4:** Outlines the key fatigue regulatory considerations and provides a link to the supplementary document on “Guidelines on Fatigue Management and ATC Rostering System”;
- **Chapter 5:** Defines ten best practices required from a rostering software solution;
- **Chapter 6:** Identifies some key initialisation steps to customise the software solution.

2. Rostering Definition

ATS Operations staff/personnel rostering is defined as the process of allocating operations staff working within a 24/7 shift work framework for any services e.g., ATCOs and ATSEPs and other OPS staff to shifts, while ensuring all constraints are met and ensuring performance delivery i.e., the best possible (lean) allocation with Sector Opening Times (SoTs) in case of ATCOs, considering all scheduling constraints and aiming to optimise different (competing) Key Performance Indicators (KPIs) like:

- staff leakage (costs with the workforce),
- right skills for the job (competency requirements),
- fatigue risk mitigation,
- labour regulation,
- rotating staff on different working positions to maintain license validity,
- human factors,
- staff availability (leaves, training needs, medical checks, etc.),
- staff working preferences (e.g. no night shift for staff over xx age, less shifts on weekends per month for staff with small children, etc.),
- fair distribution of workload,
- shift swaps,
- staff long-term health and wellbeing,
- dealing with exceptional cases (e.g., pandemics crisis, short notice sick leaves,) etc.

Managing all these constraints and variables is considered too complex to be handled by human mind alone and computers support is needed to solve this problem better and faster.

3. Rostering Tools

From the 2021 survey, it was evident that most ANSPs still use Excel or even pen and paper as their main tool for rostering. Most ANSPs lack a proper tool and acknowledge the need to have one.

According to market research, a common misconception between the 24/7 workforce planners and decision-makers is that the purchase of an integrated rostering automation solution for managing shift work is an **expensive investment**. An assessment of rostering tools on the market indicated that:

- Most of them are not tailored to industry specifics.
- Most of them require some degree of human intervention in the rostering and allocation process, lacking complete automation.
- Most general-purpose staff scheduling / rostering software tools have demonstrated limited flexibility, being similar in capabilities with spreadsheet scheduling (Excel), only adding a nicer User Interface.

In particular, the software solution investment should be able to demonstrate the following to ensure the application is ‘fit for purpose:

- How does the software solution allocate ATS Operations Staff/Personnel on working positions as safely and efficiently as possible?
- How does the software solution increase flexibility (dealing with staff unavailability, traffic variations/dynamic SoTs) and at the same time preserve safety (fatigue management)?
- How will the software solution reduce the costs associated with workforce management and planning?
- How does the software solution deal with different Air Traffic Control (ATC) units of different “shapes” and “sizes”?

Sections 3.1 to 3.3 outlines the key goals that a rostering tool (software solution) should be able to demonstrate for

- Top Management,
- Planning Managers,
- Staff Amenities.

3.1 Performance goals for Top Management

- **Maximize staff productivity and efficiency**
  - How does the software solution demonstrate aligning staff scheduling with actual traffic demand (flexible SoTs)?

- **Decrease overall costs with workforce**
  - How does the software solution illustrate solutions for less overtime, less paid boredom?

- **Roster management effectiveness**
  - How does the software solution minimize time spent with manual rostering/shift changes each month/year?
  - Does the software solution provide some measurement of this?

- **Ensure Full compliancy with regulation (now and future changes)**
  - How does the software solution integrate Sleep Science Principles and Fatigue rules?
    How does the software solution facilitate controlling and mitigating fatigue risks?

- **Increase workforce flexibility and resilience**
  - How does the software solution integrate the extensive set of rostering constraints (fatigue rules, labour regulation, competency, etc)?
  - Does the software solution provide an integrated package (People Management, Competency Management integrated within the rostering software solution)?

3.2 Performance goals for Planning Managers

- **Easier tracking of training needs, renewals, medical checks, etc.**
  - Does the software solution integrate other processes e.g., Competency Management (licenses & ratings) integrated with the rostering tool?

- **Easier tracking of leave balances and worked hours for payroll**
  - How does the software solution compute work hours, leaves, sick days, etc?

- **Increased scheduling flexibility and efficiency**
  - How does the software solution facilitate resource de-confliction (auto-checking staff availability, license validity on sectors, minimum rest time, all rules, and constraints)?

- **Approve requests and plan staff on the go**
  - How does the software solution facilitate staff planning / leave management on the go?

3.3 Staff Amenities

- **Improve staff satisfaction & work-life balance**
  - How does the software solution facilitate taking staff working preference into account at roster generation?

- **Improve staff wellbeing**
  - How does the software solution facilitate managing individually negotiated wellbeing benefits?
  - How does the software solution facilitate the possibility to swap shifts between employees, with different workflows?

- **Increase staff engagement and connectivity to work environment**
  - Does the software solution also include a mobile application for requesting and approving requests?

3.4 Summary Requirements checklist

To summarise, the aim of rostering is to ensure the right number of the right people in the right place at the right time and thus an automated rostering solution should:

1. Generate fully compliant rosters (labour regulation, fatigue rules, staff availability, staff competency, working preferences).
2. Optimize operational efficiency (demand-based rostering) and workforce utilization (less overtime, less staff leakage).
3. Enhance operational safety through integrated Fatigue Risk Management System (FRMS).
4. Compare different roster simulations and optimize them for competing KPIs (not simultaneously), e.g., costs vs. fatigue.
5. Minimise time spent with manual planning processes.

6. Increase flexibility and systemic resilience by quickly readapting plans to overcome disruptions.
7. Increase staff work satisfaction and wellbeing.
8. Prevent allocation conflicts and promote error-free ATS Operations Staff/Personnel planning.
9. Plan staff requests on the go.
10. Auto-tracking working hours, absences, leave allowances, easier integration with payroll.

4. Rostering and Fatigue

As mentioned, a rostering software solution should facilitate controlling and mitigating fatigue risks. This document includes a supplementary document on “Guidelines on Fatigue Management and ATC Rostering System”.

In this section, a recap is given on what is fatigue and key regulatory requirements references.

According to Lock, Bonneti and Campbell (2018) fatigue means a “physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase of work (mental or physical activity, or both) that can impair an individual’s alertness and ability to safely perform his/her tasks.

As concluded in the supplement “Guidelines on Fatigue Management in ATC Rostering Systems” the rules on fatigue can be interpreted differently. To improve fatigue management, there is a need for standards/recommendations, on rostering practices. These fatigue management guidelines have considered the key requirements from regulations/standards together with suggestions on how the eight-shift work fatigue prescriptive limits could be applied.

In designing any shift work, practices or schedules an understanding of the regulatory requirements and the legal framework, that should be applied, is required as it underpins the constraints that the shift schedules need to operate. It is necessary to understand and have an interpretation on:

- What EU legislation should be applied?
- Are these legislations directly applicable through regulation (e.g., EU 2017/373) or transposed into national regulation for Directives (e.g., 2003/88/EC)?
- What national regulation and working agreements needs to be considered?

EU Regulation 2017/373 GM1 ATS.OR.315 and Chapter 2 of the ICAO Doc 9966 “Manual for the Oversight of Fatigue Management Approaches’ are sources of scientific information on fatigue and on its effects on safety-relevant aviation professionals. ATS.OR.320 ATCOs rostering requires that the ATS provider shall develop, implement, and monitor a rostering system and specify:

1. Maximum consecutive working days with duty.

2. Maximum hours per duty period.
3. Maximum time providing air traffic control service without breaks.
4. The ratio of duty periods to breaks when providing air traffic control service.
5. Minimum rest periods.
6. Maximum consecutive duty periods encroaching the night-time, if applicable, depending upon the operating hours of the air traffic control unit concerned.
7. Minimum rest period after a duty period encroaching the night-time.
8. Minimum number of rest periods within a roster cycle.

Rostering within the limits of these 8-shiftwork fatigue prescriptive limits indicated in (EU) 2017/373 shall be considered a **prescriptive approach** and provides the constraints to build a rostering system. In addition, the following considerations should be considered:

- It is necessary to consider the **scientific evidence** when developing a fatigue efficient rostering system.
- **Training** should be provided to be aware of the scientific principles affecting fatigue and sleep science to support developing a rostering system and staff consultation.
- The selection and the **regular revision** of an appropriate structure and values of the rostering system.
- **Consultation with staff** who will be subject to the rostering system, or, as applicable, their representatives, during its development and its application.

In addition to operational knowledge, scientific principles used to construct ATC/Operations rosters and in applying prescriptive limits should provide evidence that those limits are not exceeded and that requirements are met. The process should be data driven from their own real and local data. Collection of data and demonstration of the impact of fatigue risk in the Safety Management System (SMS) will enable ATSUs on a second step to adjust those limits and move towards an optional FRMS.

The supplement document is a guideline derived from scientific studies on mostly busy en-route ATC centres. In most cases, the guidelines will be applicable to less busy ATC units. However, when considering deviating from recommended figures for fatigue elements in this document, it is recommended to perform safety and human factors assessments.

When implementing (or expanding) a FRMS at ANSP level, the document could be considered useful guideline for other categories of staff that perform shift work, such as ATSEP, MET, AIS, Flow, etc..

For further details please refer to the supplement document “Guidelines on Fatigue Management in ATC Rostering Systems” reference nr: NMD/SAF/2611.

5. Rostering Tools Best Practice

5.1 Key Factors in design of better integrated rostering

The main factors to include to design a better integrated rostering experience are:

1. **Flexible, modular, easy to extend & parametrize**
   - Microservices-based architecture.
   - Inherent rostering processes covered by the core platform.
   - The rest added as custom layers, based on each client's needs.

2. **Full rostering automation engine**
   - Constraint-based optimization technics (heuristics, metaheuristics), some Machine Learning (ML) / Artificial Intelligence (AI)-based scheduling algorithms.
   - Customizable hard and soft constraints.
   - New rostering rules => encoded in new constraints plugged into the engine.
   - Auto-solving, check solution, solve planning conflicts, swap suggestions.

3. **Affordable, progressive pricing**
   - Installed on-premises, using client's hardware; or
   - Used from the cloud, Software-as-a-Service.

5.2 Key Components

The rostering tool solution should include full flexibility of the following components to ensure an All-in-One ATS Operations Staff/Personnel Rostering Automation and seen as a living product / keeps evolving.

Human Resources Management (HRM)

- Paperless HR with employee digital contract. No paper files, no spreadsheets. Store all staff info, labour regulation data, competency data (licenses, certifications), medical files, scanned attachments in a centralized & secure database.
- Define organizational chart and manage units, departments, and teams. Assign employees to work cross-teams (multi-unit membership).
- Multi-level management and approval workflows.
- Top-down digital contract inheritance – define once and apply everywhere.

Competency Management

- Define custom requirements, qualifications and ranks to compose staff skill sets and licenses.
- Set personalized validities for license expiration (e.g. if staff over 40, set different validity times, etc.).

- Auto-track expiration dates and send reminders to schedule training.
- Suspend staff license to prevent them from being rostered.
- Complete overview on staff licenses and their validities.
- Schedule the employee with the right skills on the right shift.
- Rotate staff on different shifts needing different qualifications to reach minimum worked hours to maintain the license.
- Ensure full compliancy with regulations.

Leave Management

- Define custom leave and duty types with personal thresholds (annual leave, sick leave, medical check, mission, overtime, training, etc.).
- Allow employees to make leave requests managed or self-service.
- Never schedule employees that are on leave.
- Auto-tracking leave balances and worked hours.
- Collect & verify timesheets.
- Auto-credit staff allowance with a percentage of the amount worked as overtime or in duty (missions, office work, projects, etc.).
- View real-time attendance. Live overview to see who's on shift, who's running late and who's on break.
- Automate wage calculations.
- Compare accurate labor hours, costs with the workforce and profits.
- Seamlessly integrate with organisation's payroll system.
- Manage staff requests on-the-go via a mobile application.
- Assist planners with conflict resolution before approving leaves.
- Lock time intervals to prevent employees from taking leaves.

Workforce Demand Planning

- Custom shift types with embedded minimum rest time after each shift to enforce fatigue risk management.
- On-call shifts.
- Custom shift patterns (forward-rotating, backward-rotating).
- Fix shift patterns or dynamic allocation of shifts based on demand, with no fixed pattern assigned.
- Define manpower requirements on teams or individual employees.
- Correlate manpower requirements with demand prediction (traffic forecast, sector opening timetable).
- Align scheduled staff with traffic demand to minimize staff leakage and costs with the workforce.
- Increased planning flexibility through live updates of the demand, reflected in the staffing plan.

Automated Rostering Engine

- Constraint-based optimization engine with AI scheduling algorithms to deal with the complexity of billions of possible rostering combinations.

- Generate rosters always compliant with fatigue requirements, labor regulation, staff availability, staff working preferences, fair workload distribution.
- Generate multiple versions of the draft roster, compare results and optimize for different KPIs (cost, overtime, aggregated leave days, number of shifts in a roster cycle, fatigue score).
- Team rosters and individual rosters.
- Fixed shift pattern and dynamic allocation.
- Auto-allocate trainees with compatible instructors.
- Backup pool of staff to schedule when demand is higher.
- Auto-detect planning conflicts and suggest compatible replacements.
- Minimise time spent with manual planning.
- Promote error-free rostering.
- Re-adapt rosters in real-time in case of a scheduling disruption (unplanned leaves, demand surge).
- Promote staff wellbeing by helping them get the downtime they need.
- Automate shift swapping with AI-assisted smart suggestions for compatible shifts.

Work & break Planner (Tactical Rostering)

- Define Group of Sectors, Sectors, Subsectors, and different Sector Configurations.
- Define Working Positions and assign them to Sectors (for ATC staff) and Working Positions for other OPS staff on24/7 duties.
- Create the Work & Break plan for the day-of-ops.
- Open or close sectors to adapt to traffic variations.
- Change Sector Configuration accordingly.
- See who’s working on what position, who’s late and who’s on break.
- Rotate staff on different working positions to prevent fatigue and preserve license validity.
- Track minimum worked hours to maintain the license.
- Adjust the roster in real-time to align with changes in demand.
- Allocate on-call staff on positions when demand increases.

Reporting & Analytics

- Build configurable reports to extract and aggregate roster data (worked hours per shift type, qualification, working position, leave days, overtime hours, sick leaves, unplanned leaves, missions, office work, training, medical checks).
- Control the most important performance metrics and steer the company based on real-time data insights, not on assumptions.
- Get instant access to a breakdown of employee performance.
- Build reports on individual employees or on aggregated units, teams, or departments.
- Visualize reports using the built-in visualizations and charts connected directly to the shiftwork software solution or export data

in excel or CSV and feed it into your preferred Business Intelligence tool (e.g. Power BI of Microsoft, or others).
- Reports required for compliance e.g. constraint by (EU) 2017/373 and the collective agreement. Can the Tool provide an internally check for compliance and evidence the requirements are met.
- Work/Break planner – shifts and breaks to make an open schema and may not need to specific to the working position.
- Make it generic for all data in the roster to be available for post ops analysis.
- Allow open parametrization to run experiments (extension points) – open APIs to integrate other corporate systems (SAP, payroll, competency etc.).
- Visualization of the post ops analysis (compliance, visualization options).

Appendix 1 of this document contains analytics and visualisations for several rostering simulations.

iOS & Android Mobile Application

- Make leave or duty requests directly on the go, last minute changes (find a replacement without any phone call) and shift swapping.
- Managers can approve or reject them from anywhere (no need to be at work).
- Personal calendar.
- Working schedule.
- Leave requests status.
- Checking remaining vacation days.
- Checking qualifications status and expiry/renewal dates.
- Get notifications when a new roster is published when requests are approved or rejected.
- Get the updates/briefing before shift start remotely.

Licensing models of rostering tools

- On-premises: using client's hardware and technical infrastructure.
- In cloud: Cloud solution should be European based i.e. to choose a local (European) cloud/hosting provider that follow the laws of the local/European country when it comes to privacy & data protection.
- Be mindful of total cost of ownership for the selected Rostering Automation platform. Cost variables offered by different providers include:
    - Monthly license fee per user account.
    - Custom development costs.
    - Deployment Parameterization.
    - Data input.
    - Custom Integrations with customer IT systems
    - Training.
    - Real-time software updates.
    - Full technical support.

- Ensure that the General Data Protection Regulations (GDPR) requirements based on the ANSPs policy e.g. privacy statement and anonymity of personal data when a person's leave the organization and ensuring the following factors are covered e.g.
  - Limitation of purpose, data, and storage
  - Data subject rights
  - Consent
  - Personal data breaches
  - Privacy by Design
  - Data Protection Impact Assessment
  - Data transfers

Appendix 2 provides more description of factors to consider on Cloud vs. On-premises licensing models.

5.3 Best Practice 1: Customize each unit specifics

The rostering tool should be easily adaptable to the specifics of every service provider and every unit and personnel working in 24/7 shifts. The following should be parametrized e.g.:

- Working hours.
- Shift patterns (fixed vs. flexible patterns, forward vs. backward rotation, teams vs. individual etc.).
- Manning requirements for different SoTs patterns.
- Working days.
- Public holidays.
- Types of unavailability requests.
- Types of duty times (duty requests).
- Individual vs team and competency.

5.4 Best Practice 2: Manage staff availability

Embedded staff availability within the software solution is essential to planning and managing a flexible roster. The roster tool should

- Know when ATS Operations staff/personnel are available to be scheduled for work.
- Not allow scheduling of unavailable staff. Staff unavailability must be built into the rostering tool, with automated synchronization, not via separate spreadsheets and different other systems.
- Be able to respond to changes easily, by offering suggestions of other compatible and available ATS Operations staff/personnel to be called in. This improves flexibility and resilience – i.e., when someone gets sick. This improves flexibility and resilience.
- Allow customization and parametrization of different leave types: annual leaves, missions, training, sick leave, simulator time, etc.

5.5 Best Practice 3: Manage staff competencies

- Should know the competencies of every ATS Operations staff/personnel – licenses & endorsements & qualifications.
- Allow customization of requirements and qualifications for every ATS Operations staff/personnel.
- Alerts and reminders when are close to expire/renewal.
- Filter ATS Operations staff/personnel with expired qualifications / licenses from availability pool.
- Ensure ATS Operations staff/personnel have the needed licenses / qualifications to be scheduled to the right shifts.

- Should suggest available and compatible ATS Operations staff/personnel (same qualifications / licenses) to be scheduled in case of an emergency leave (e.g., 48H needed after a COVID19 vaccination) or shift swapping.

5.6 Best Practice 4: Embed Fatigue Management

- The rostering tool should consider rules and constraints to manage fatigue.
- Should be extensible – allow other rules to be added easily.
- Should be flexible – allow rules to be customized for each unit (not all have the same fatigue requirement
- Parametrize rules like the 8 elements from (EU) 2017/373s). e.g.
    - minimum rest time between different shifts.
    - maximum number of worked hours.
    - maximum number of night shifts.
    - maximum number of consecutive shifts.
    - fair distribution of shifts (nights/weekends) between ATS Operations staff/personnel.
- Allow FRMS short term (ST), medium term (MT) and long term (LT) (post OPS and monitoring) pre tactical. Tactical and post ops monitoring (support Critical Incident Stress Management (CISM), Human Factors (HF) Studies etc.).

5.7 Best Practice 5: Flexible shift patterns

- The rostering tools must support customization of the working hours for every unit.
- Support customization of different shift patterns.
- Fixed shift pattern vs. flexible shifts.
- Team rosters vs. individual rosters.
- Forward rotation vs. backward rotation.
- Support constructive discussions with staff and unions on simulations based on different shift patterns.

5.8 Best Practice 6: Customise manning (manpower requirements)

- Define minimum/maximum manning based on predicted traffic and complexity for different periods and shifts.
- The manning must be flexible; Allow planners to overwrite manning on certain days / periods, if needed (e.g., during industrial actions, specific events such as World Cup Final, Aviation Shows and Displays).
- The roster tool must allocate ATS Operations staff/personnel on shifts based on pre-defined manning requirements.

5.9 Best Practice 7: Manage both team and individual rosters

- The roster tool must be able to roster teams and/or individual ATS Operations staff/personnel.
- Should be flexible for every unit.
- Some make the roster only on teams, only on individual ATS Operations staff/personnel or both.
- Must support the transition from team roster to individual roster.

5.10 Best Practice 8: Maximise automation & provide appropriate assurance

- Must minimize the human intervention in the rostering process.
- Semi-automated or hybrid rostering tools (with leave and competency data aggregated from different systems) have poor performances.
- The rostering tool must process all available data (staff availability, competencies, training needs, manning requirements, etc.) and compute the shift allocation, with minimum human intervention.
- Must alert planners about possible scheduling conflicts when shifts are assigned manually.
- Must support planners to solve scheduling conflicts, by offering suggestions with compatible ATS Operations staff/personnel.
- The tool needs a Safety & Human Resources assurance component if used for tactical decision making e.g., by supervisor (also when roster tool is fed by other online tool like complexity etc.)
- Technical, integrity and HF Assurance

5.11 Best Practice 9: Manage an extensive set of variables/constraints

The rostering software solution must be able to cover an extensive set of variables and constraints for detailed parametrisation:

- Performance and efficiency requirements.
- Fatigue constraints.
- Working preferences (days to work / not to work).
- Union requirements.
- Human factors.
- Legal constraints.
- Labor regulation.
- Adaptable in time of crisis (e.g., pandemics).
- The set of variables must be extensive to cover other future needs e.g., changes of regulation, etc.
- Soft and hard rules. All hard constraints MUST be fulfilled by the engine for the solution to be feasible (ex. Minimum rest time, required qualification for the shift, staff availability). After fulfilling ALL hard constraints, the engine tries to fulfil as many as possible of the soft constraints by prioritising them by associated weights/scores. The greater is the final solution score, the better is the solution.

Appendix 3 provides a detailed description of hard and soft constraints and **Appendix 4** provides some simulations examples of hard and soft settings.

5.12 Best Practice 10: Support experimentation (what-if)

The rostering tool must have built-in support for planners to simulate different scenarios / parametrization and examine outcomes:

- Rosters with shift fixed shift patterns vs flexible patterns.
- Team rosters, individual rosters, team-to-individual rosters.

- Allow different rosters to be saved as drafts and iterating on them before publishing as the “official” roster.
- Allow rosters to be derived / continued from other rosters.
- Possibility to undo/redo changes in a roster.
- Compare different draft rosters at a glance to see how they score for specific KPIs.
- Experiment with different scheduling algorithms to find optimum configuration for each ATC unit.
- Allow open parametrization to run experiments (extension points) – open APIs to integrate other corporate systems (SAP, payroll, competency etc.).
- Visualization of the post ops analysis (compliance, visualization options).
- Being able to develop what if scenarios can facilitate the transition to the new system as well as supporting the collective bargaining process e.g.:
  - Being able to simulate changes and how it helps all parties during collective agreement. This is where BI/Analytics tools which can simulate changes can support the process.
  - Being able to provide an example could be provided from used cases showing the today’s situation and outcome of number of simulations.
  - When procuring a tool to consider not just the tactical and day to day rostering but also strategic requirements and balancing the fatigue and efficiency requirements – this is where what if tools are useful to have in place.

6. Rostering Tools Flow

6.1 Initialize parameters

- Configure working hours.
- Shift cycles.
- Shift patterns (fixed vs flexible patterns, forward vs. backward rotation, etc. types of leaves and duties).
- Manning requirements.
- Working days.
- Public holidays.
- Types of unavailability requests.
- Types of duty requests (missions, training, etc.).

6.2 Input staff data

- Employees information
- Define which ATS Operations staff/personnel work in what ATC unit / team or cross-teams.
- Personal information.
- Licenses and qualifications - associated licenses / endorsements /qualifications /medical.
- Create Org Chart: Units/Teams.

- Fill in staff availability (vacation leaves, sick leaves, training, missions), preferred days to work.

6.3 Input staff availability and working preferences

For every ATS Operations staff/personnel

- Annual leaves.
- Sick leaves.
- Training.
- Simulator time.
- Missions.
- Preferred days to work etc.

6.4 Create a draft roster

- Choose between team roster and individual roster.
- Choose between fixed shift pattern or flexible shift pattern.
- Choose the teams / individual ATS Operations staff/personnel s to be rostered.
- Choose manning requirements.
- Define roster period.
- Parametrize rostering rules and constraints.
- Auto-generate roster based on defined configuration.
- Solve allocation conflicts or manually adjust the generated roster, if necessary.
- Try different scheduling algorithms.
- Save draft roster with different versions, until the final version is ready.

6.5 View a Published roster

- Define standard operating procedures for published rosters:
  - How much time before needs to be published.
  - If and when can be updated.
  - Time in advance for planned leaves.
  - Shift swapping rules.
- When the draft roster is finalized, publish it as the official working schedule.
- The tool must notify staff about the new schedule.

6.6 Adapt to changes in real time

The roster must be able to adapt to changes in real time, due to unplanned leaves or traffic variations:

- Offer planners suggestions of possible shift backups.
- Adjust manning and re-generate a published roster or just a part of it.
- Auto-check for allocation conflicts in case of manually assigned shifts on a published roster.
- Allow shift swaps with AI-assisted smart suggestions to compensate for staff fatigue / unavailability / working preference.
- Validate Managing Day-of-ops changes.
  - Generate work & break plan (Tactical Roster)
  - Adjust manpower to demand (close/open sectors)
  - Auto-solve planning conflicts to cover for absenteeism / unplanned leaves.

6.7 Continuation roster

- ANSPs publish rosters at different intervals e.g.
    - 1 month in advance (30 days) for ATCOs and 5 days in advance for the rest operations staff (ATSEPs, AIS, Flow, etc) on duty working in shift environment
    - 12 months or others for periods e.g. 3-4-6 months

  The tool must allow this flexibility.
- The rostering tool generates a continuation roster starting from the previous published roster.
- All parametrization of rostering rules and constraints is inherited from the previous roster but can be changed.
- The new roster is created as a draft roster.
- When finalized, it is published as the continuation of the previous roster.

7. Conclusions

Rostering is a complex process and involves balancing many parameters and constraints. Managing all these constraints and variables is considered too complex to be handled by human mind alone and computers support is needed to manage to solve this problem better and faster.

It also requires that any rostering system should include and be able to balance the following requirements:

- Integrated fatigue risk management.
- Flexibility & resilience in face of planning disruptions (traffic variations, last minute staff leaves, absenteeism).
- Costs with the workforce (performance-based rostering).

The aim of rostering is to ensure the right number of the right people in the right place at the right time and thus an automated rostering solution should:

- Generate fully compliant rosters (labour regulation, fatigue rules, staff availability, staff competency, working preferences).
- Optimize operational efficiency (demand-based rostering) and workforce utilization (less overtime, less staff leakage).
- Enhance operational safety through integrated FRMS.
- Compare different roster simulations and optimize them for competing KPIs (not simultaneously), e.g.: costs vs fatigue.
- Minimise time spent with manual planning processes.
- Increase flexibility and systemic resilience by quickly readapting plans to overcome disruptions.
- Increase staff work satisfaction and wellbeing.
- Prevent allocation conflicts and promote error-free ATS Operations staff/personnel planning.
- Plan staff requests on the go.
- Auto tracking working hours, absences, leave allowances, easier integration with payroll.

ACKNOWLEDGEMENTS

These guidelines have been developed by practitioners in the fields of Fatigue, Human Factors and roster from ANSPs, academy, consultancy and EUROCONTROL Network Manager.

Organization	First Name	Name
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Skyguide	Johan	Pradel
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ENAV	Alberto	Iovino
ENAV	Alessandro	Ruzzante
DSNA	Pierre	Berolatti
DFS	Dennis	Voß
UK NATS	Mhairi	Balmer
UK NATS	Mike	Culver
UK NATS	Tom	Wilton
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Skyway	Raquel	Martinez
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EUROCONTROL	Steve	Shorrock
EUROCONTROL	Antonio	Licu
EUROCONTROL trainees	Alessandro	Veterini
EUROCONTROL trainees	Stefania	Nastasie

Table 1 - Experts of the EUROCONTROL ATC Roster best practices working group who contributed to the guideline's development.

REFERENCES

Reference 1The psychological and physiological health effects of fatigue
A M Lock, D L Bonetti, A D K Campbell (2018)

ABBREVIATIONS

Term	Definition
ANSP	Air Navigation Service Provider
AI	Artificial Intelligence
APIs	Application Programming Interface
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATSEPs	Air Traffic Safety Electronics Personnel
CISM	Critical Incident Stress Management
COO	Chief Operations officer
EASA	European Aviation Safety Agency
EU	European Union
FRMS	Fatigue Risk Management System
GDPR	General Data Protection Regulation
HF	Human Factors
HRM	Human Resources Management
KPIs	Key Performance Indicators
ICAO	International Civil Aviation Organisation
OJT	On-Job-Training
iOS	Iphone Operating System
ML	Machine Learning
NM	Network Manager
SAP	System Analysis Programme development
SoTs	Sector Opening Times

Table 2 - Abbreviations table

APPENDIX 1: ANALYTICS AND VISUALISATIONS FOR SEVERAL ROSTERING SIMULATIONS

One of the key differences between reporting and analytics is that, while a report involves organizing data into summaries, analysis involves inspecting, cleaning, transforming, and modelling these reports to gain insights for a specific purpose

The steps required to build a report, broadly include:

- Identifying the business need
- Collecting and gathering relevant data
- Translating the technical data
- Understanding the data context
- Creating reporting dashboards
- Enabling real-time reporting
- Offer the ability to drill down into reports

For data analytics, the steps involved include:

- Creating a data hypothesis
- Gathering and transforming data
- Building analytical models to ingest data, process it and offer insights
- Use tools for data visualization, trend analysis, deep dives, etc.
- Using data and insights for making decisions

The main parts of a Rostering Simulation Modelling Report for Strategic and Tactical Roster could be and the following an example of a Table of Content):

- Set up
- Statistical Analysis
- Interpretation of Results
- Conclusions
- Annex A Teams Composition
- Annex B Monthly Roster
- Annex C Employees Working Times.
- Etc.

The following paragraphs outline five case studies related to simulation using analytics and visualisations

The source of Use cases is SkyRoster.

Case Study 1: 10% workforce cost reduction

ANSP – Size of the case study: 75 ATCOs.

Problem

The ANSP wanted to optimize their rosters in one of their ATC units.

Solution

- Data containing ANSP's current working schedules for February and March 202x were provided to the analysts. Using this data, a dedicated server was deployed on the Cloud Platform.
- A target ATC unit was selected. In its target Unit the ANSP was scheduling 10 ATCOs on a fixed shift pattern M-M-A-A-N-N-R-O-O-O.
- The analysts designed two rostering simulations:
- The first scenario was generated using the Fixed Shift Pattern strategy (the classical forward rotation), which was already in place at this unit.
- The second scenario was generated using the Flexible Allocation strategy. This scenario uses no pattern but respects the same manpower requirements as the first scenario.

Results

Fixed pattern MMAANNROOO	Dynamic allocation
Manpower needed: ATCOs with ADS/APP-APS: 5 ATCOs with ADC/APP: 5	Manpower needed: ATCOs with ADS/APP-APS qualifications: 4 ATCOs with ADC/APP qualifications: 5
Unassigned shifts: 1	Unassigned shifts: 0
Accommodated leave days during 30-days cycle: 27 days.	Accommodated leave days during 30-days cycle: 27 days.

Figure 1 - Experts Optimise workforce solution using dynamic allocation of shifts

- The application managed to cover the same traffic demand and accommodated the same number of leave days during a 30-days cycle using 1 less ATCO.
- Extrapolating the simulations to other units, the ANSP managed to cut annual costs with the workforces with 8-12% per ATC unit, translating in an economy of 750.000 EUR / year.

Case Study 2: 1-month Tactical Roster Simulation with the baseline headcount

Problem

An ATC Unit with 96 ATCOs rostered in teams on a fixed shift pattern sees significant variations in terms of overtime distribution per individual staff and increased staff leakage during the night shifts.

Compared to the previous simulation, in which 24 additional ATCOs were used to reduce overtime to under 300 hours per month, how is the workload distributed when deploying only the current headcount of 96 ATCOs?

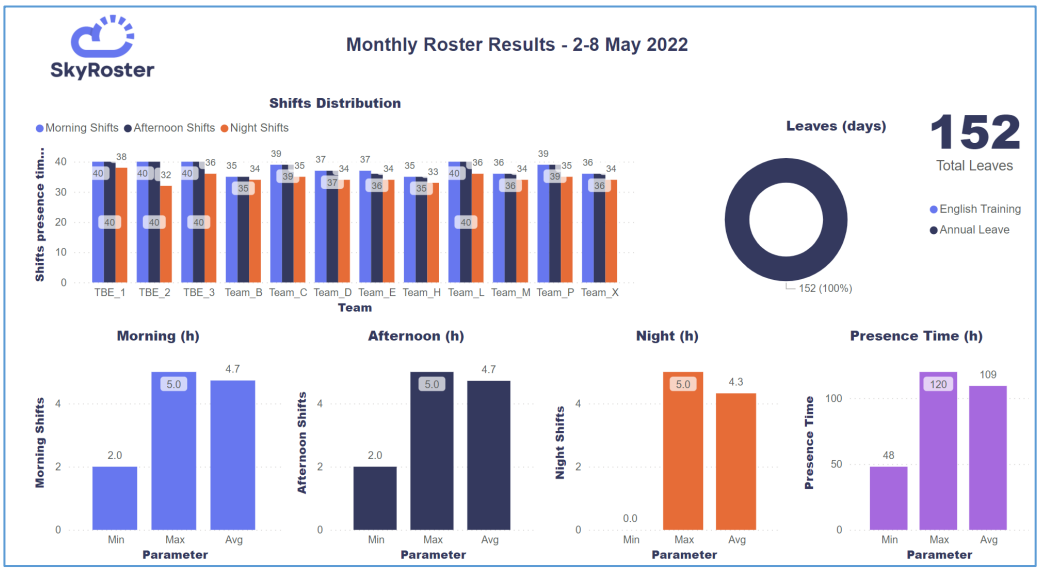

Figure 2 - Sample of Strategic Roster Shifts Distributions

Initial setup

The data used for this modelling was already uploaded to the ANSP's server on the Cloud.

All annual leave days were considered by inputting them into the system for the simulated period (distributed randomly per employee, averaged out per year). Another notable difference with the previous simulation is that no duty leave days were registered for this one.

- **Type of roster:** Team-based.
- **Roster period:** 1st - 31st of May 202y.
- **Shift Allocation:** Fixed Shift Pattern.
- **Pattern**: MANROO (Morning-Afternoon-Nigth-Rest-Off-Off).

Shift configuration:

- Morning shift: 07:00 – 14:00.
- Afternoon shift: 14:00 – 21:00.
- Night shift: 21:00 – 07:00.

Staff: 96 employees grouped equally in 12 teams (8 ATCOs per team).

Manpower Requirements (MPR):
The MPR was updated to accommodate all the necessary positions according to the Sector Opening Timetable and was defined using the Air Traffic Control Officer (ATC) and Supervisor (SUP) qualifications as follows:

For ATC:
- Morning: 15 positions.
- Afternoon: 15 positions.
- Night: 12 positions.

For SUP
- Morning: 2 positions.
- Afternoon: 2 positions.
- Night: 2 positions.

The next step was to generate the tactical roster and solve it for the week of 2nd-8th of May 202y, using the same Sector Opening Timetable:

Figure 3 - "Summer High Demand" Sector Opening Timetable

Working positions to be filled were Executive (EXE), Planner (PLN), Supervisor (SUP) and Air Traffic Flow Manager (AFM). The procedure by which the staff was assigned to the Tactical Roster was the following:
- Maximum of two different worked positions, one hour each, followed by a minimum of an hour break in case of EXE and PLN.
- The employees in the SUP position can perform 100% during the day shifts (M and A) and 50% during the night (N).
- The AFM position is open between 07:00 and 18:00.

Both strategic and tactical rosters were generated using the application AI-powered constraint-based scheduling engine. Afterwards, the data was imported into Power BI to observe the shifts distribution per employee and team, the overtime distribution, the time spent on position and the staff leakage.

Statistical Results

May 202y Strategic Roster

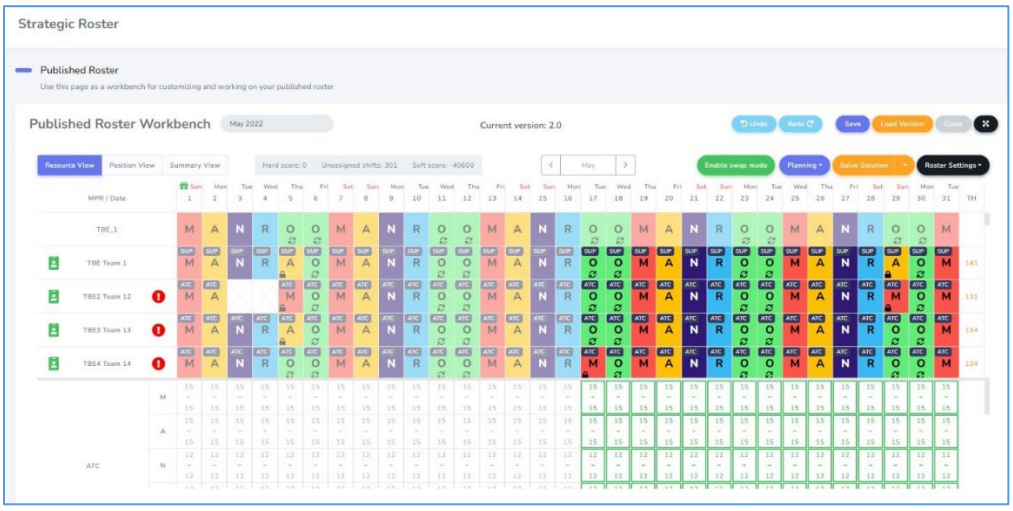

Figure 4 - Sample of Strategic Roster (May 202y)

After solving the Strategic Roster, the entire Manpower Requirements were filled in using an additional 118 overtime shifts: 56 Morning Shifts, 57 Afternoon Shifts and 5 Night Shifts.

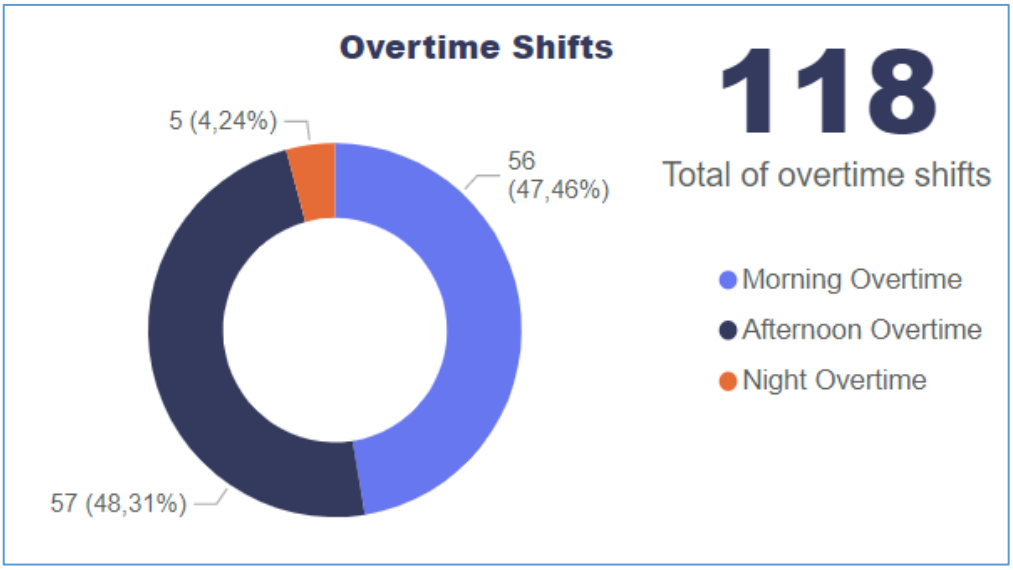

Figure 5 – Planned Overtime Shifts (May 202y Strategic Roster)

Compared to the previous simulation, in which 120 ATCOs would generate 488 leave days (more precisely 326 Annual Leaves and 162 English Training days), in the current simulation, the 96 ATCOs have allocated only 152 leave days for the entire month of May (no English Training days are registered for this period).

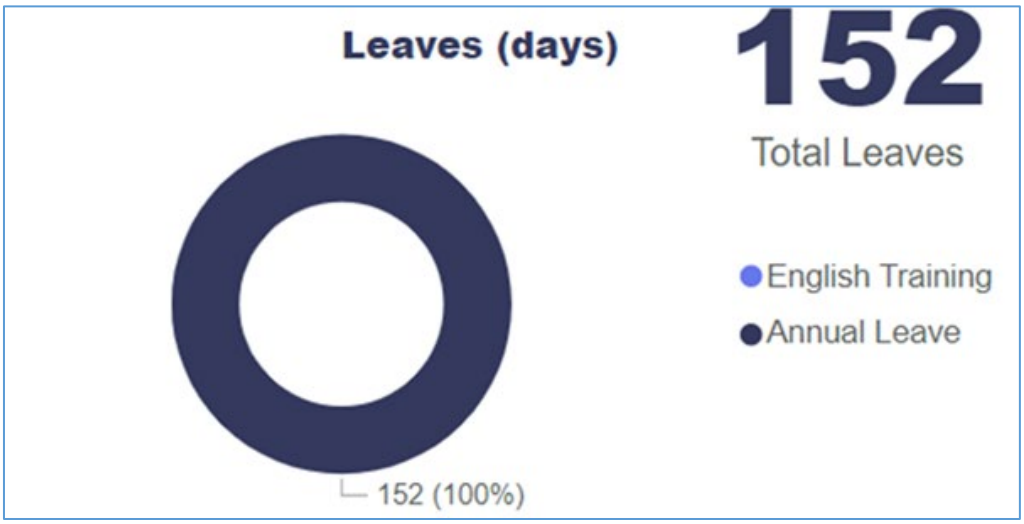

Figure 6 - Planned Leave Days (May 202y Strategic Roster)

May 202y Tactical Roster

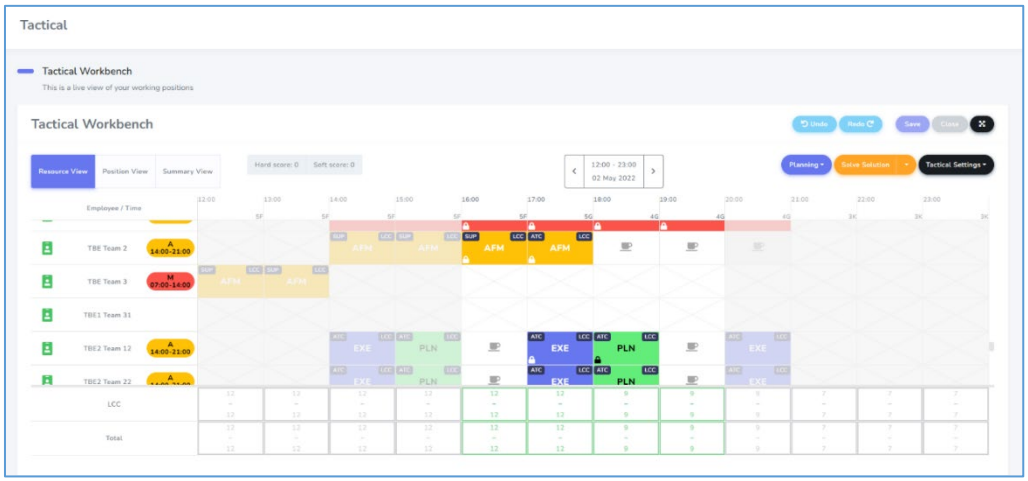

Figure 7 - May 202y Tactical Roster for 2nd of May, 12:00 – 23:00 interval.

The application assigned all positions successfully in the Tactical Roster, as well, respecting the resting time specific to each position.

Analysis

May 202y Strategic Roster

Parameter	Avg	Min	Max
Morning Shifts	4,73	2	5
Afternoon Shifts	4,72	2	5
Night Shifts	4,32	0	5
Morning Overtime	0,58	0	2
Afternoon Overtime	0,59	0	2
Night Overtime	0,05	0	3

Figure 8 - Shift Counts (May 202y Strategic Roster)

It can be observed in *Figure 8* that the number of Morning and Afternoon shifts are almost equally distributed. The lower result for the Night shifts is due to the lower number of needed shifts in MPR for the night time. The same result can be observed for overtime shifts which are almost equally distributed between Morning and Afternoon shifts. The Night Overtime results display the lower number of overtime shifts during the night time (i.e. 5, according to *Figure 5*).

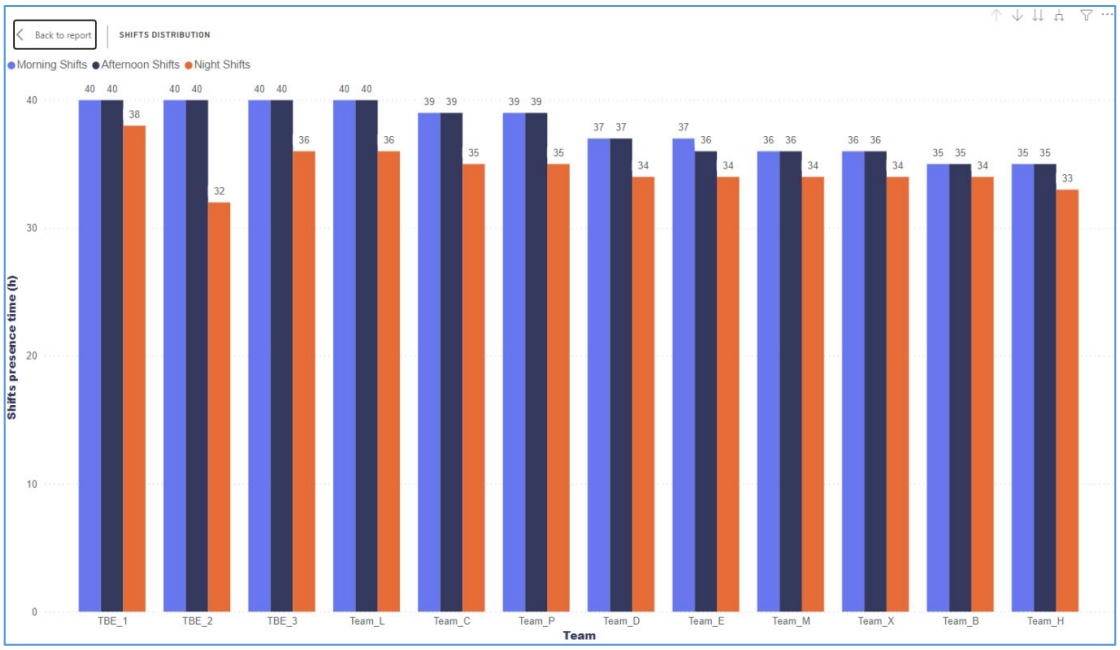

Figure 9 - Shifts Distribution per Team (May 202y Strategic Roster)

Figure 9 shifts are almost evenly distributed between the teams, with only a slight variation due to leaves affecting employees in specific teams.

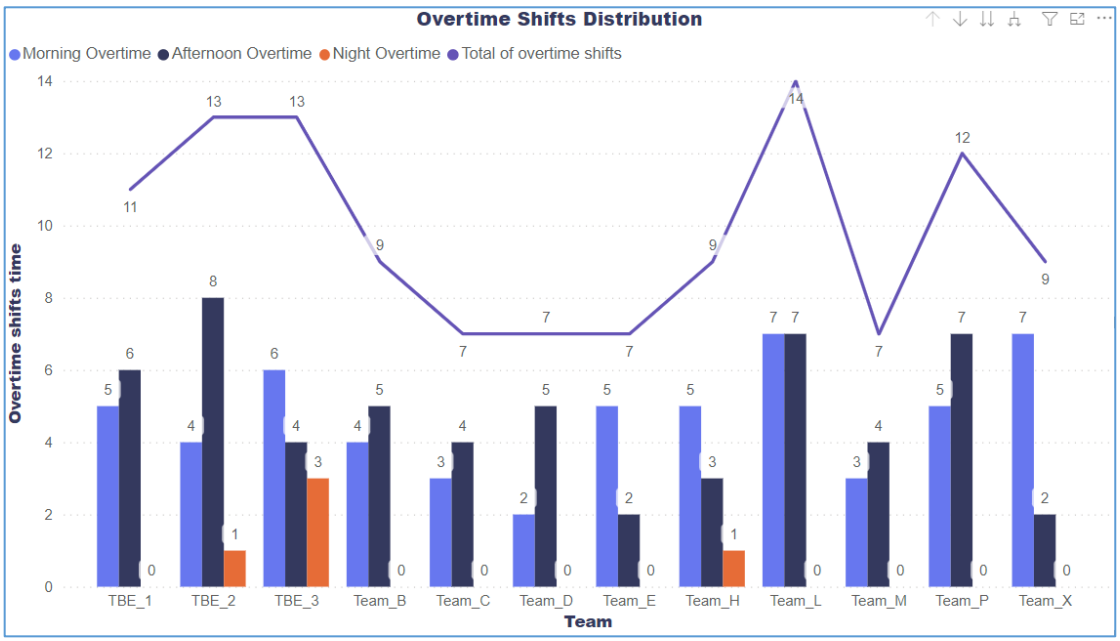

Figure 10 - Overtime Shifts Distribution per Team (May 202y Strategic Roster)

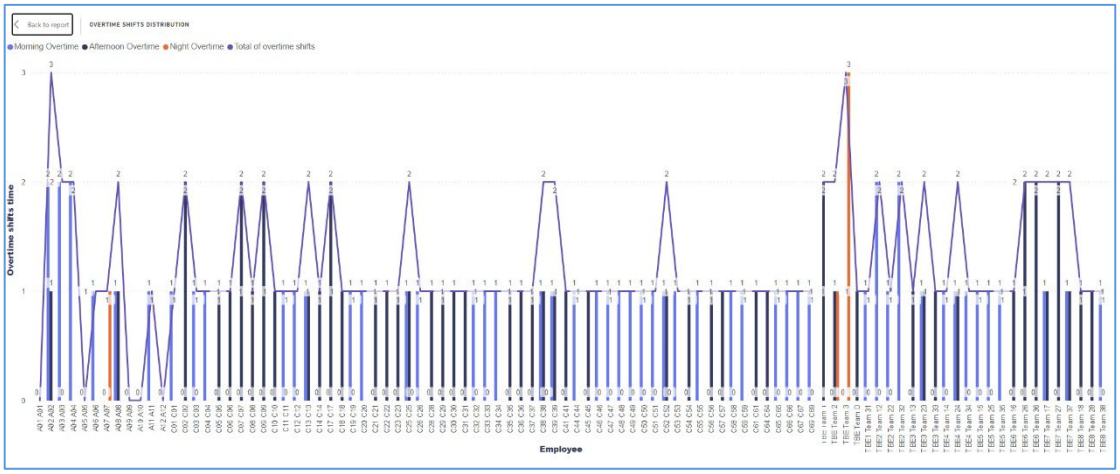

Figure 11- Overtime Shifts Distribution per Employee (May 202y Strategic Roster)

The Overtime Distribution figures show that only 5 out of 96 employees (5.2%) were not assigned to perform overtime shifts. The other employees (94.8%) have been assigned one to three overtime shifts, with only two employees from 91 employees (2.08%) performing three overtime shifts. *Figure 10* shows that all teams have overtime shifts assigned.

May 202y Tactical Roster

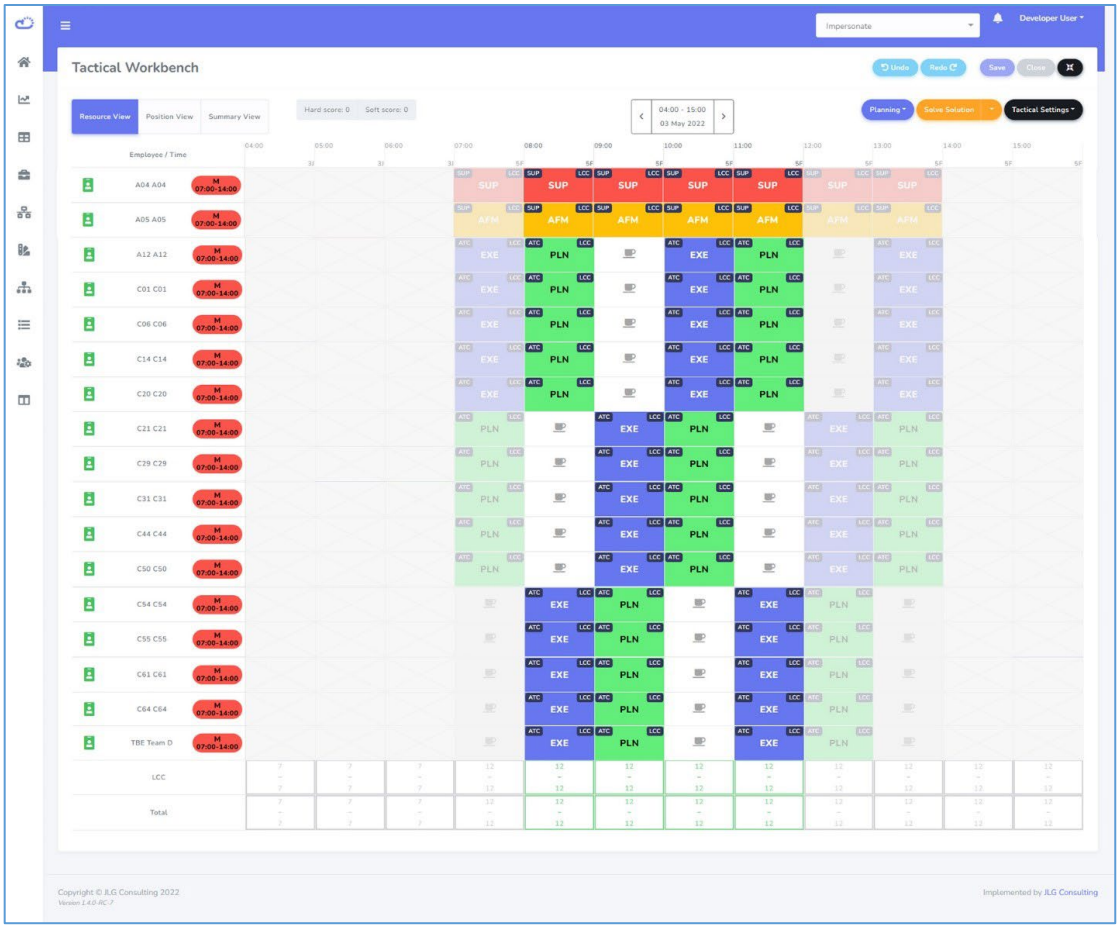

Figure 12 - Tactical Roster for the Morning Shift on the 3rd of May 202y

Figure 12 shows the morning shift schedules and working slots distribution for all employees.

It can be observed that the employees who are assigned to the SUP and AFM positions work 100%, while the employees assigned to EXE and PLN positions spend between 57.14% (4 slots) and 71.42% (5 slots) of the time in position, this percentage varying depending on how the system distributes the necessary positions.

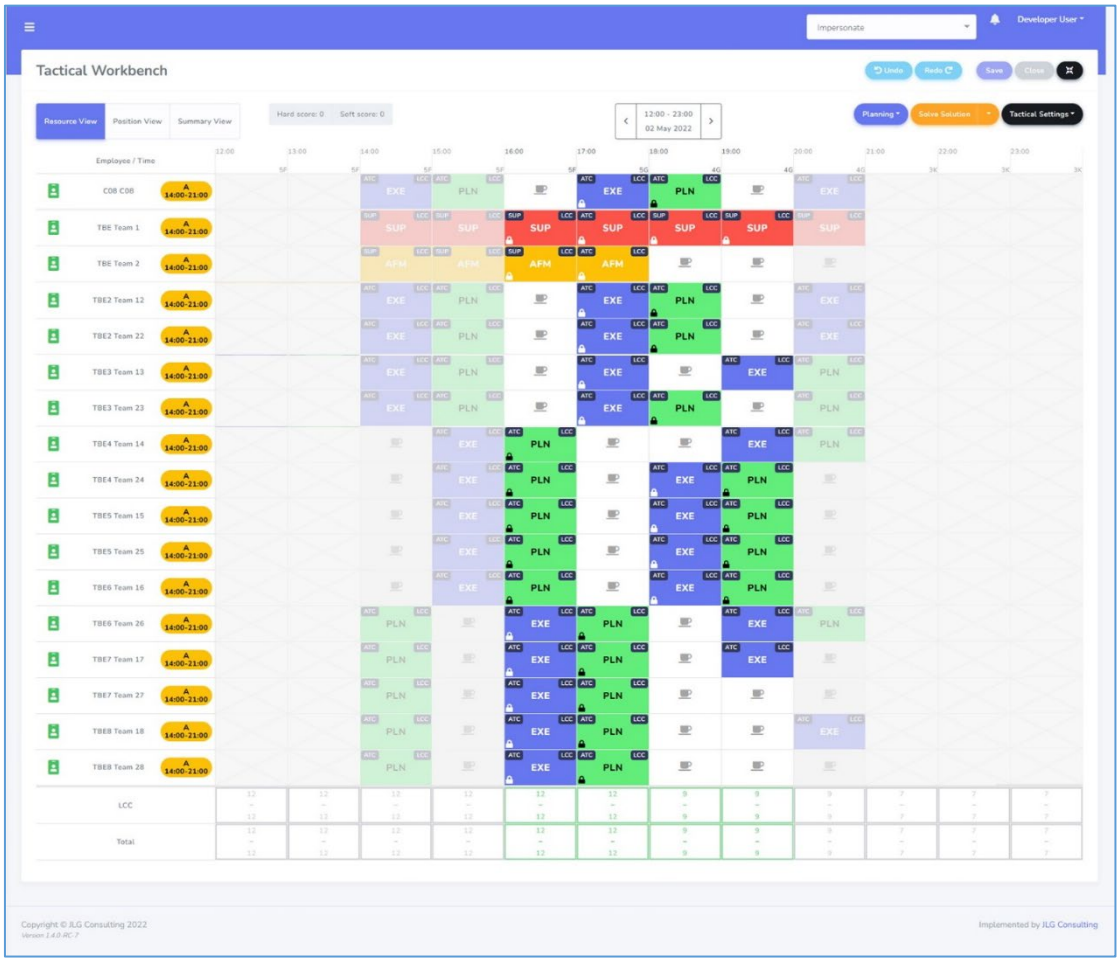

Figure 13 - Tactical Roster for the Afternoon Shift on the 2nd of May 202y

Figure 13 shows the afternoon shift schedules and working slots distribution for all employees. It can be observed that the employee who is assigned to the SUP position works 100%, the one assigned to the AFM position works 57.14%, while the employees assigned to EXE and PLN positions spend between 42.85% (3 slots) and 71.42% (5 slots) of the time in position, this percentage varies depending on how the system distributes the necessary positions.

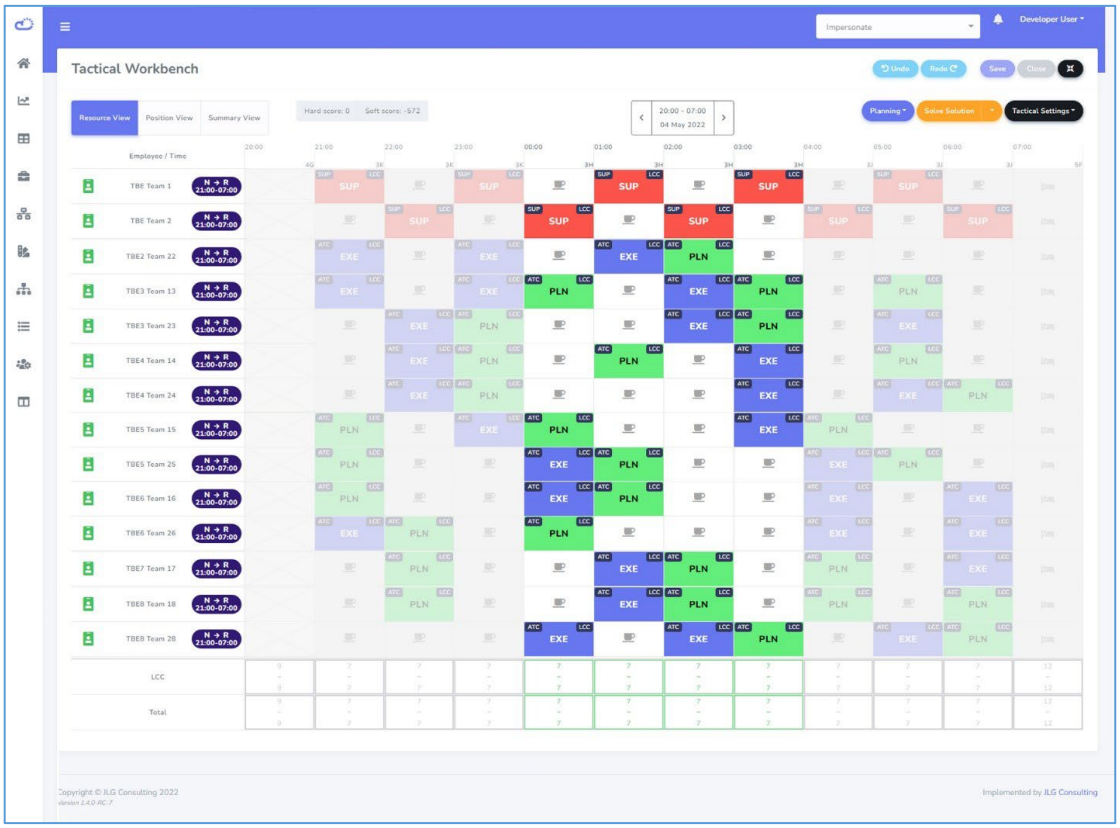

Figure 14 - Tactical Roster for the Night Shift on the 3rd of May 202y

Figure 14 shows the Night shift schedules and working slots distribution for all employees. It can be observed employees assigned to the SUP positions work 50% of their time, and the ones assigned to EXE/PLN positions work between 46% (4 slots), 50% (5 slots) and 54% (6 slots).

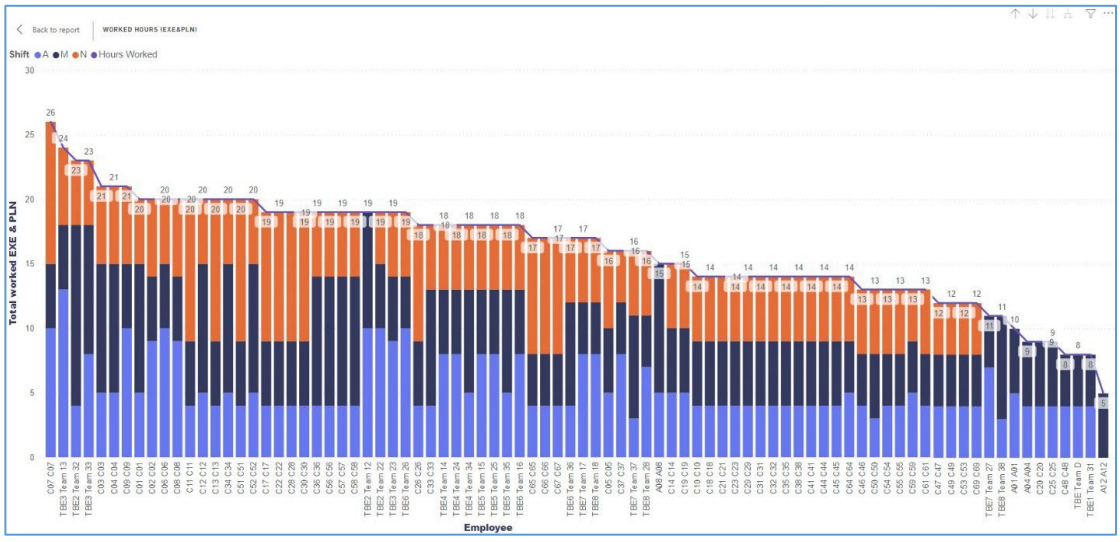

Figure 15 - Distribution of Time at Work (Hours) per week (May 202y Tactical Roster)

The first *Figure 15* shows the entire week's distribution of Time at Work for the EXE and PLN positions. It can be observed that the maximum is 26 hours for employee C07 C07 (dis-identified name), and the minimum is 5 hours for employee A12 A12 (dis-identified name).

Compared with the second Figure, we can observe that A12 A12 works both as EXE & PLN (5 hours) and as SUP & EXE (9 hours). Same case for A04 A04 and A08 A08.

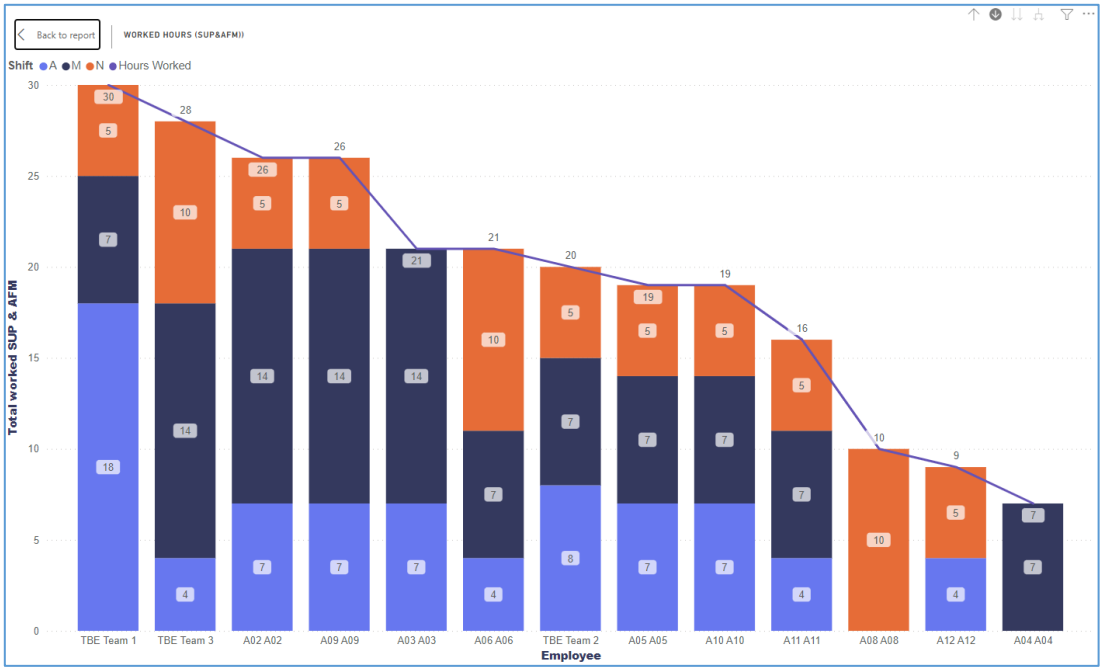

Figure 16 - Distribution of Time at Work (Hours) per Week (SUP & AFM)

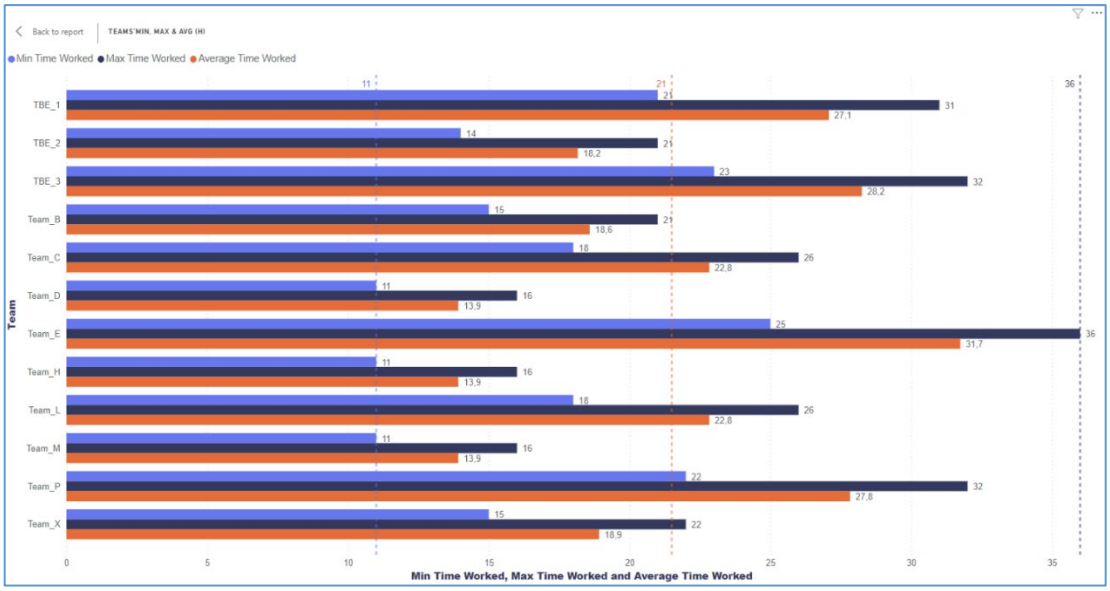

Figure 17 - Teams' Min, Max and Average Time on Position (Hours)

for the week of 2nd-8th of May 202y (EXE & PLN)

Analysing *Figure 17* and *Figure 18,* we can observe the teams' minimum, maximum and average time on position (in hours). In the case of EXE and PLN positions, the minimum worked hours for the teams is 11, the average is 21, and the maximum is 36 (hours).

In the case of SUP & AFM positions, the minimum worked hours for the teams is 16, the average is 28, and the maximum is 47 (hours).

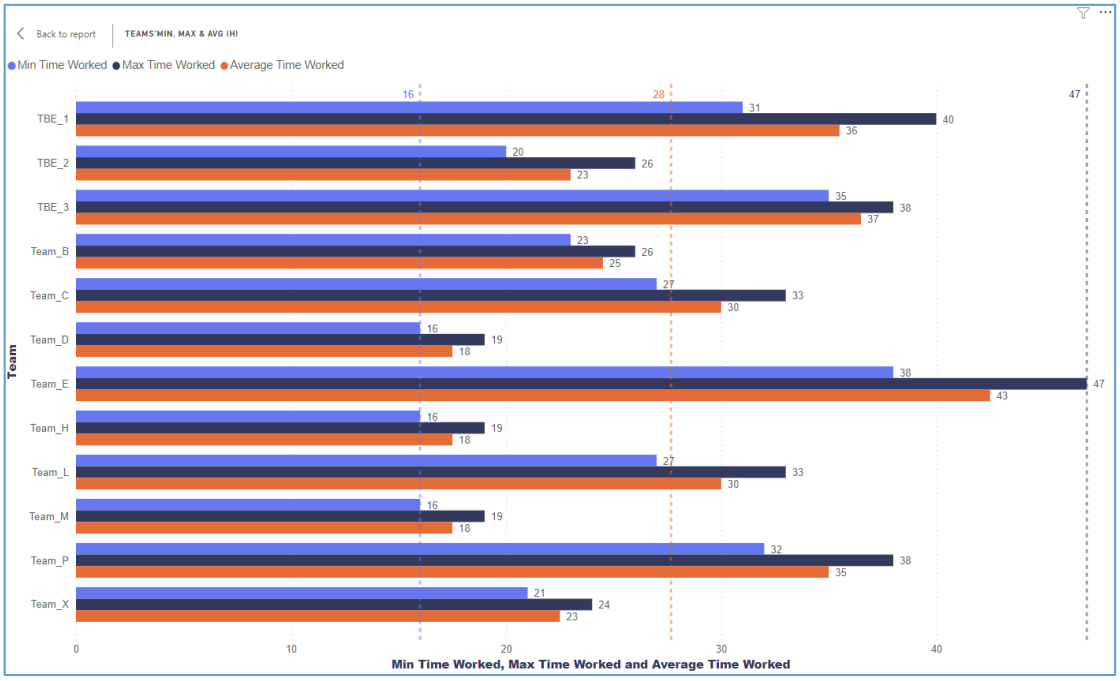

Figure 18 - Teams' Min, Max and Average Time on Position (Hours) for the week of 2nd-8th of May 202y (SUP & AFM)

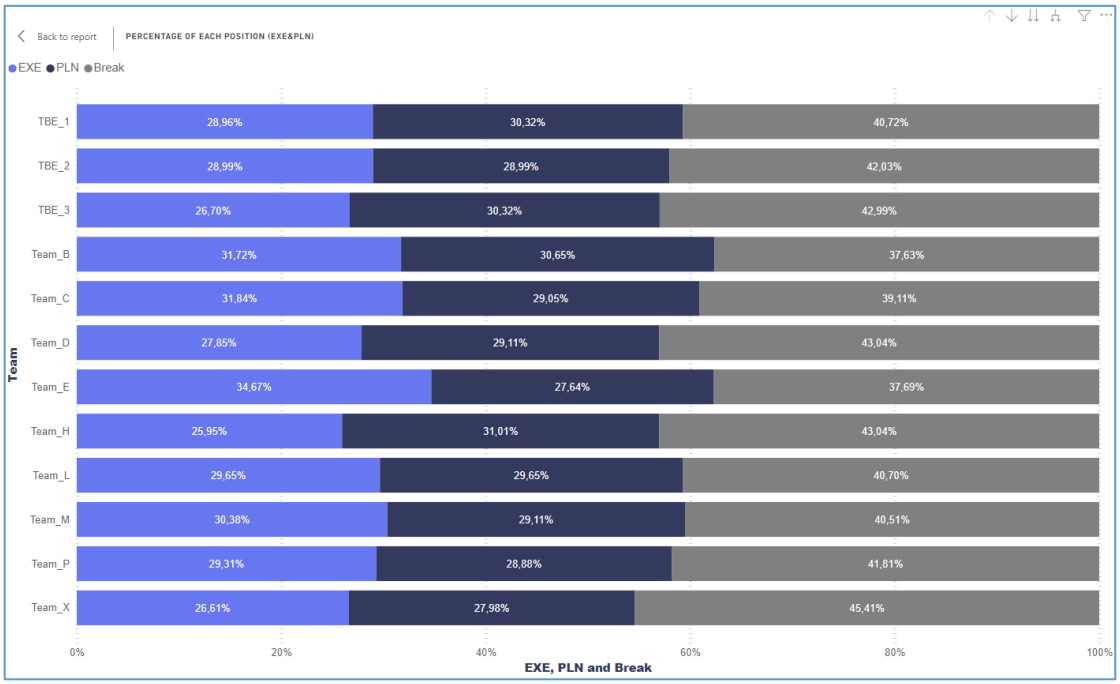

Figure 19 - Time on position vs time on break for EXE and PLN (May 202y Tactical Roster)

Figure 19 shows the percentages of worked time versus breaks for EXE and PLN positions. It can be observed that no team overpasses 62.31% of time spent on position.

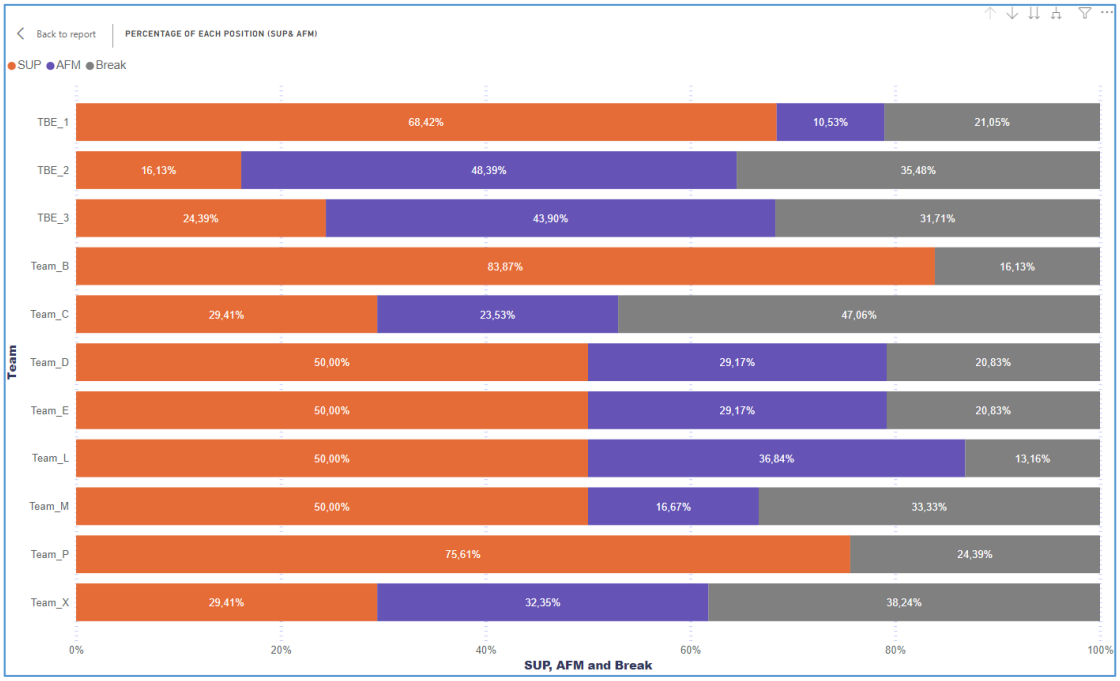

Figure 20 - Time on position vs time on break for SUP and AFM

Figure 20 shows the percentages of worked time versus breaks for SUP and AFM positions. It can be observed that most of the teams' employees performed in both positions.

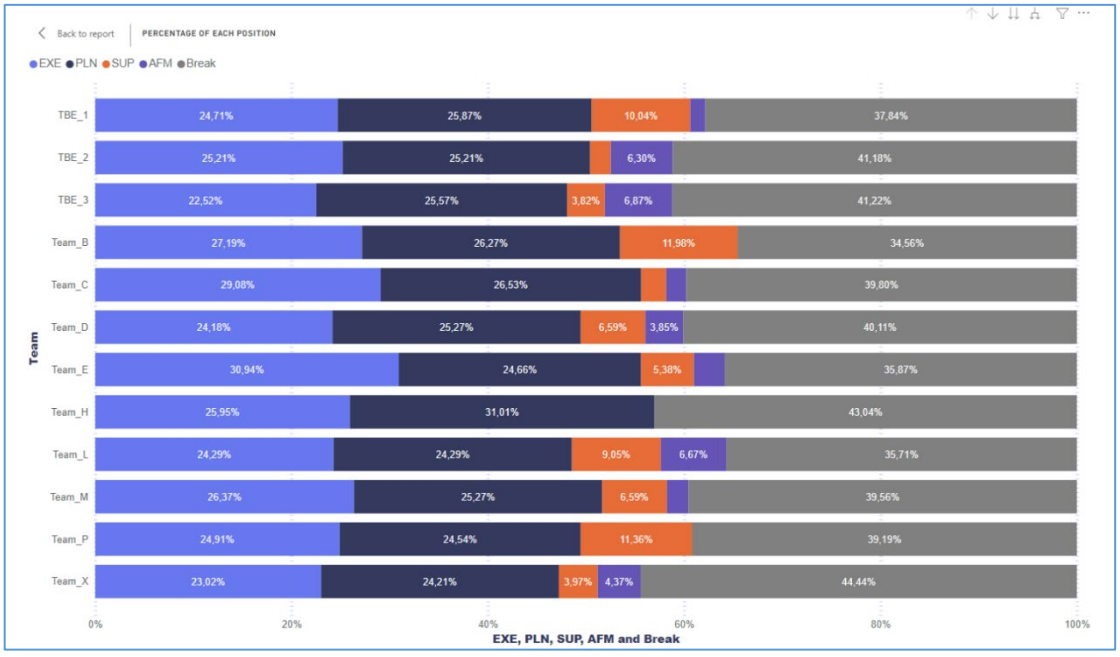

Figure 21 - Time on position vs time on break for all position (May 202y Tactical Roster)

In *Figure 21* we observe that even when including the SUP and AFM time, there is no team to work more than 65.44% of the time and less than 55,56% during the entire period. Some employees work in multiple positions, either SUP or AFM, either mixed (SUP&AFM and EXE & PLN), depending on the system assignation and qualifications.

Conclusions

1. The optimised roster for May 202y, executed with the ANSP's current headcount of 96 ATCOs, minimises the variation of overtime between teams and individual employees by using only 118 overtime shifts for the entire month.
2. All leave days are guaranteed for the entire year, with a proportion of them (152 days) being assigned in May 202y.
3. Compared with the scenario from the previous simulation (i.e. Full month of April), which includes 120 employees, the current modelling uses more overtime shifts to complete all the necessary positions (i.e. 81 more overtime shifts).
4. The minimum, maximum and average results for regular shifts, especially for the overtime shifts, have changed, producing an increase of at least one additional overtime shift per employee apart from the one available in their contract. Only 5 of 96 employees (5.2%) were not assigned to perform overtime shifts, but only two out of 91 employees (2.08%) performed three overtime shifts.
5. Regarding the Tactical Roster, the planned working positions tend to behave similarly to the previous analysis.
6. In the Tactical Roster, the staff works in the Morning and Afternoon shifts at the planned percentage of 66%. The SUPs make the exception, who work 100% of the time in both types of shifts and AFMs, who work 100% of the time in the morning and 57% in the afternoon.
7. In the afternoon, there is a transition from 5 open sectors to 4 open sectors, and the AFM position is closed.
8. No employee or team works more than 71.43% of the time, except for the SUPs in the Morning and Afternoon Shifts.
9. For the night, the time spent on position is 50% for all three positions: SUP, EXE and PLN.
10. On average, the efficiency factor is 50% during the night shifts and 33% during the Morning and Afternoon shifts.

Case study 3 : 94.3% less overtime

ANSP – Size of the analysis: 55 ATCOs.

Problem

The ANSP is understaffed, scheduling overtime shifts to cover the demand. Due to overtime shifts, staff is overworked, resulting in alarming fatigue scores.

"According to a study, nearly two in 10 Air Traffic Controllers have made significant errors in the past year, and over half attribute the mistakes to fatigue. A third of the controllers said they perceived fatigue as a "high" or "extreme" safety risk."

Solution

- The team designed 5 rostering simulations to model their staffing plans in different scenarios.
- In the scenario with the best result, the application managed to decrease the number of overtime days from 247 to only 14 during a 35-day roster cycle.
- The ANSP was paying a significant anount of EUR/month to cover the cost of overtime shifts.

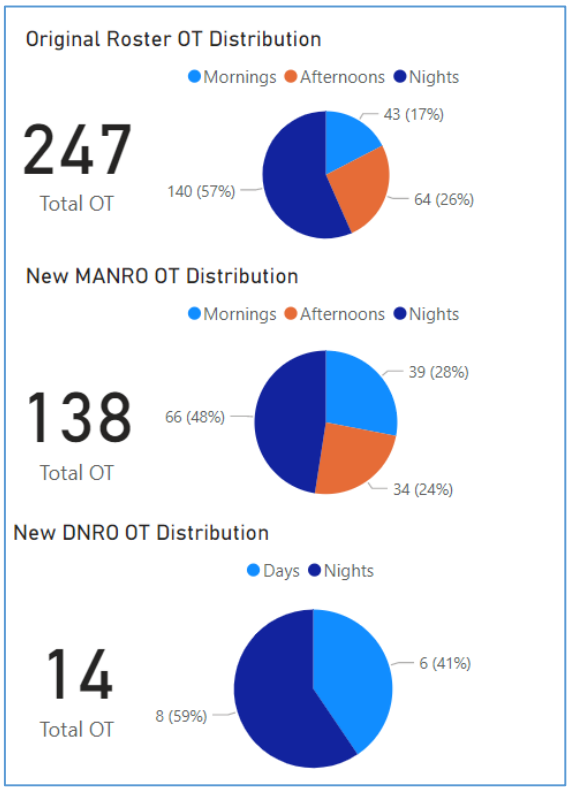

Figure 22 - Redesign of teams and shift distribution to reduce overtime

With the new design shift roster and same amount of staff the number of overtime has been reduced but also the number of shifts and consequently the ATCOs have a better fatigue index scores.

Case Study 4: Automating 60.000 shift swaps to save a ~360 000 EUR/year

ANSP Size for the case study : 450 operational ATCOs.

Problem

- The customer was experiencing a high number of shift swap requests - 60.000 per year.
- For each shift swap request, the planning manager wasted 15 minutes of his time to fill in paper forms and update the roster in a spreadsheet.
- The customer was paying 5 full-time employees only to manage these shift swaps.

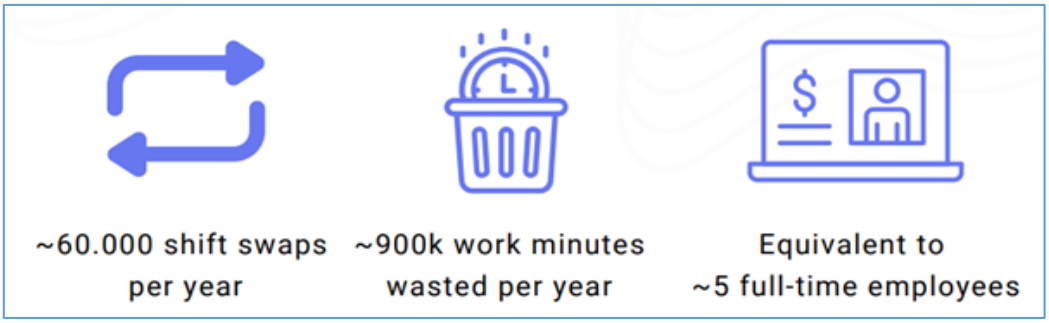

Figure 23 - automation efficiency – saving manual swapping

Solution

- By deploying the application inside their environment, the shift swapping process was reduced to 1.5 minutes on average, counting since the manager receives the swap request in the system.
- Finding a compatible employee is frictionless – the AI-assisted engine suggests the most appropriate employees to swap with.
- Employees were also empowered to swap their shifts self-service, without involving their manager, the Rostering Engine taking care of the responsibility to maintain a safe, compliant roster with every shift swap approved.
- Only by automating the entire shift swapping process, the customer was able to cut costs by 360.000 EUR/year.

Case study 5: 1-month Team-based Roster Simulation with 120 ATCOs

Problem

An ATC Unit with 96 ATCOs rostered in teams on a fixed shift pattern sees significant variations in terms of overtime distribution per individual staff, and increased staff leakage during the night shifts. This simulation focused to look at difference by adding 24 more ATCOs to arrive at 120 ATCOs in total.

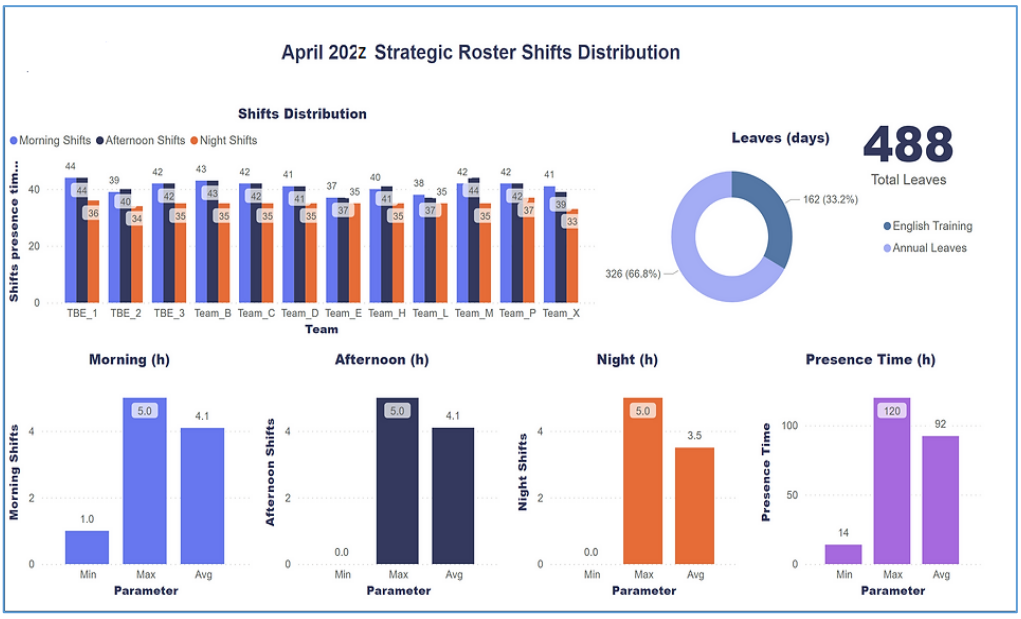

Figure 24 - Strategic Roster Shifts Distribution (April 202z)

How can the roster balance overtime shifts between available employees for a one month period (April 202z) and minimise leakage?

Initial setup

The data used for this modelling was uploaded to the ANSP's server on the Cloud.

All annual leave days and duty days (office work, training, English courses, etc.) were considered by inputting them into the system for the simulated period (distributed randomly per employee, averaged out per year).

As a preliminary step, the roster for April 202z was generated using the entire available staff in the ATC Unit, using a Team-based roster with a Fixed Shift Rotation Strategy.

- **Type of roster:** Team-based.
- **Roster period:** 1st - 30th of April 202z.
- **Shift Allocation:** Fixed Shift Pattern.
- **Pattern**: MANROO (Morning-Afternoon-Nigth-Rest-Off-Off).

Shift configuration:
- Morning shift: 07:00 – 14:00.
- Afternoon shift: 14:00 – 21:00.
- Night shift: 21:00 – 07:00.

Staff: 120 employees grouped equally in 12 teams (10 ATCOs per team).

Manpower Requirements (MPR):
The MPR was updated to accommodate all the necessary positions according to the Sector Opening Timetable and was defined using the Air Traffic Control Officer (ATC) and Supervisor (SUP) qualifications as follows:

For ATC:
- Morning: 15 positions.
- Afternoon: 15 positions.
- Night: 12 positions.

For SUP
- Morning: 2 positions.
- Afternoon: 2 positions.
- Night: 2 positions.

The next step was to generate the tactical roster and solve it for a week. The week chosen for this analysis is 11 – 17 of April 202z and the Sector Opening Timetable was the following:

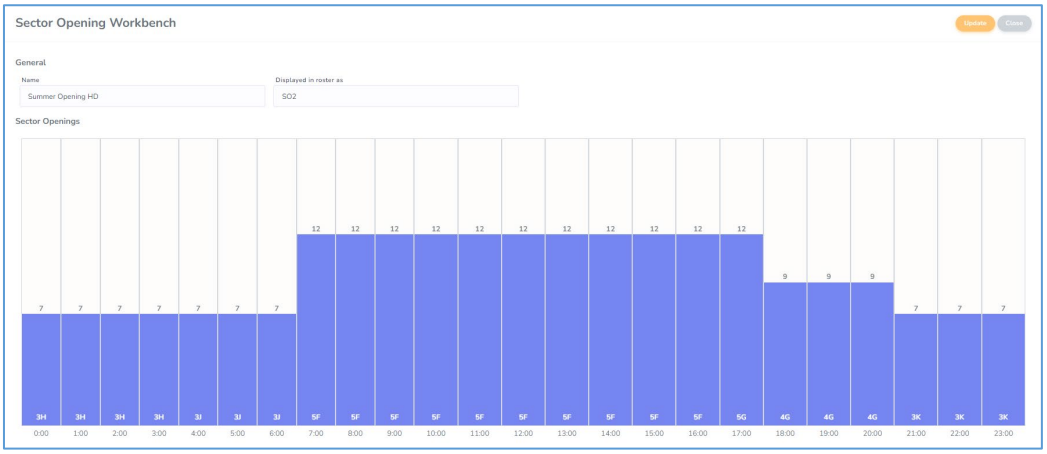

Figure 25 - "Summer High Demand" Sector Opening Timetable

The necessary positions to fill were Executive (EXE), Planner (PLN), Supervisor (SUP) and Air Traffic Flow Manager (AFM). The procedure by which the staff was assigned to the Tactical Roster was the following:
- Maximum of two different worked positions, one hour each, followed by a minimum of an hour break in case of EXE and PLN.
- The employees in the SUP position can perform 100% during the day shifts (M and A) and 50% during the night (N).
- The AFM position is open between 07:00 and 18:00.

Both strategic and tactical rosters were generated using the application's AI-powered constraint-based scheduling engine. Afterwards, the data was imported into Power BI to observe the shifts distribution per employee and team, the overtime distribution, the time spent on position and the staff leakage.

Statistical results

April 202z Strategic Roster

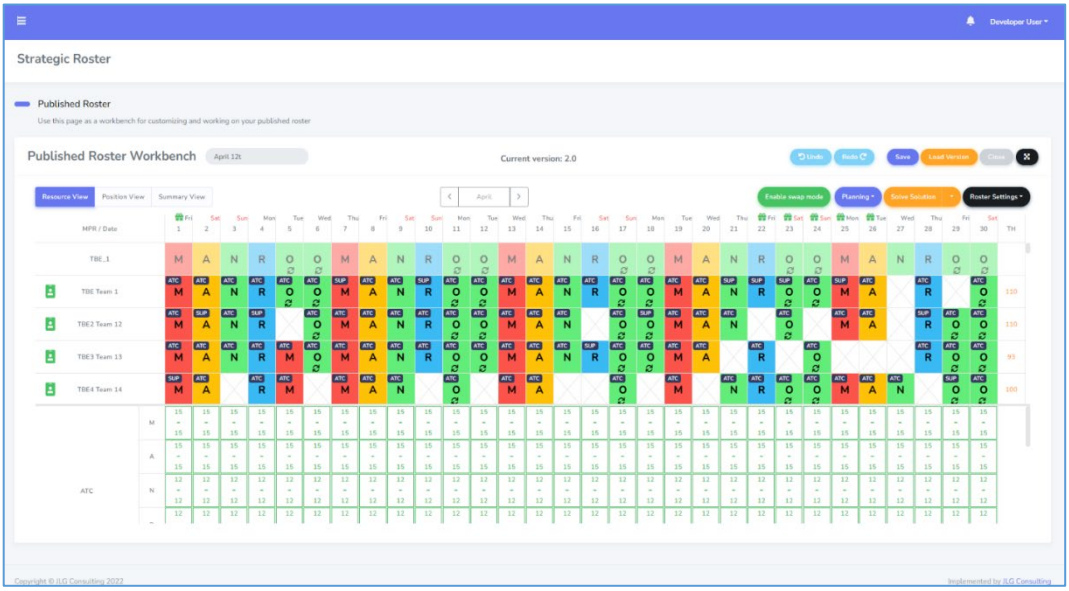

Figure 26 - April 202z Strategic Roster

The application has accommodated the entire MPR using 37 overtime shifts: 19 Morning Shifts and 18 Afternoon Shifts.

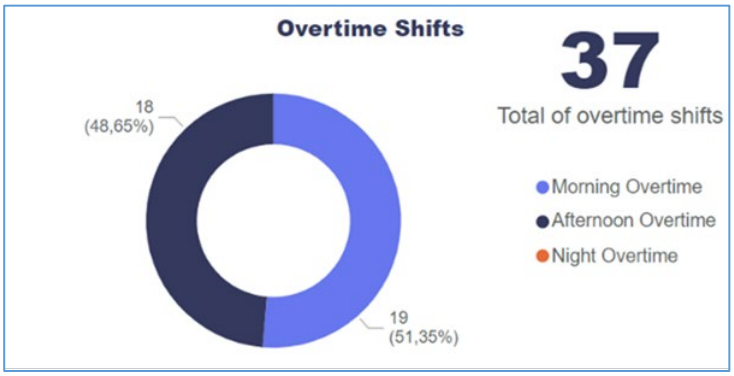

Figure 27 - Planned Overtime Shifts (April 202z Strategic Roster)

The strategic roster includes 488 leave days: 326 Annual Leaves and 162 English Training days.

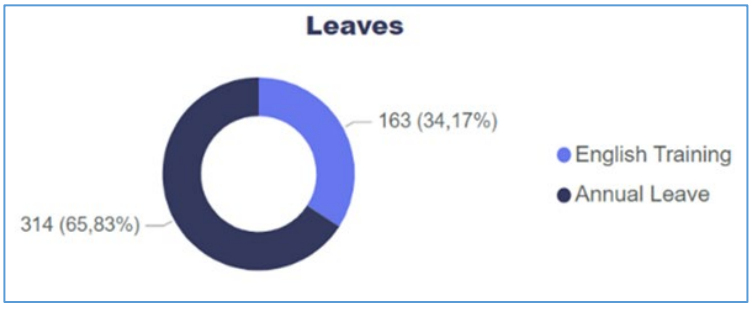

Figure 28 - Planned Leave Days (April 202z Strategic Roster)

April 202z Tactical Roster

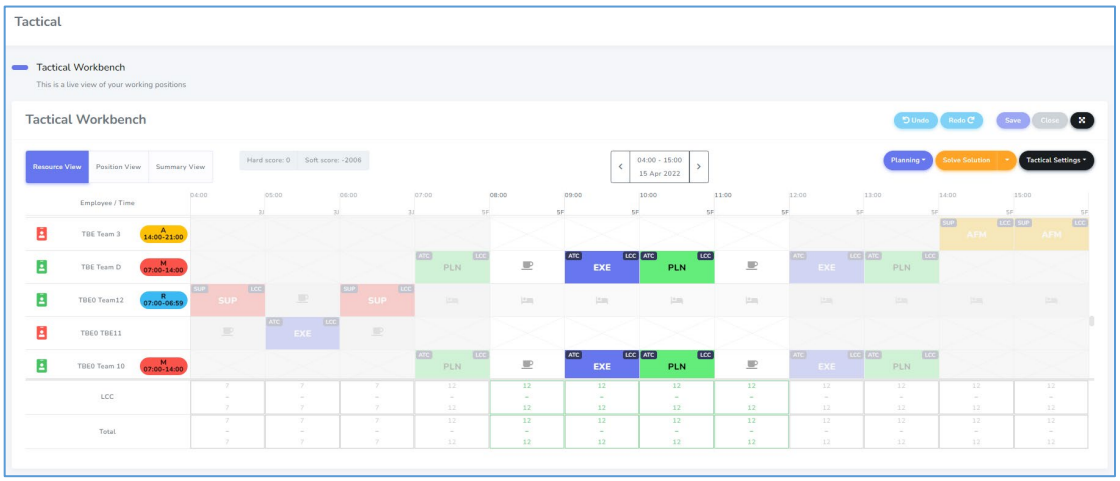

Figure 29 - April 202z Tactical Roster for the 15th of April, 04:00 – 15:00 interval.

The application assigned all positions successfully, respecting the resting time specific to each position.

Analysis

April 202z Strategic Roster

Parameter	Avg	Min	Max
Morning Shifts	4,09	1	5
Afternoon Shifts	4,10	0	5
Night Shifts	3,50	0	5
Morning Overtime	0,16	0	2
Afternoon Overtime	0,15	0	2
Night Overtime	0,00	0	0

Figure 30 - Shift Counts (April 202z Strategic Roster)

It can be observed in *Figure 30* that the number of Morning and Afternoon shifts are almost equally distributed. The lower result for the Night shifts is due to the lower number of needed shifts in MPR for the night time. The same result can be observed for overtime shifts which are almost equally distributed between Morning and Afternoon shifts. A major improvement over the Excel roster: **there is no overtime needed for the Night shift!**

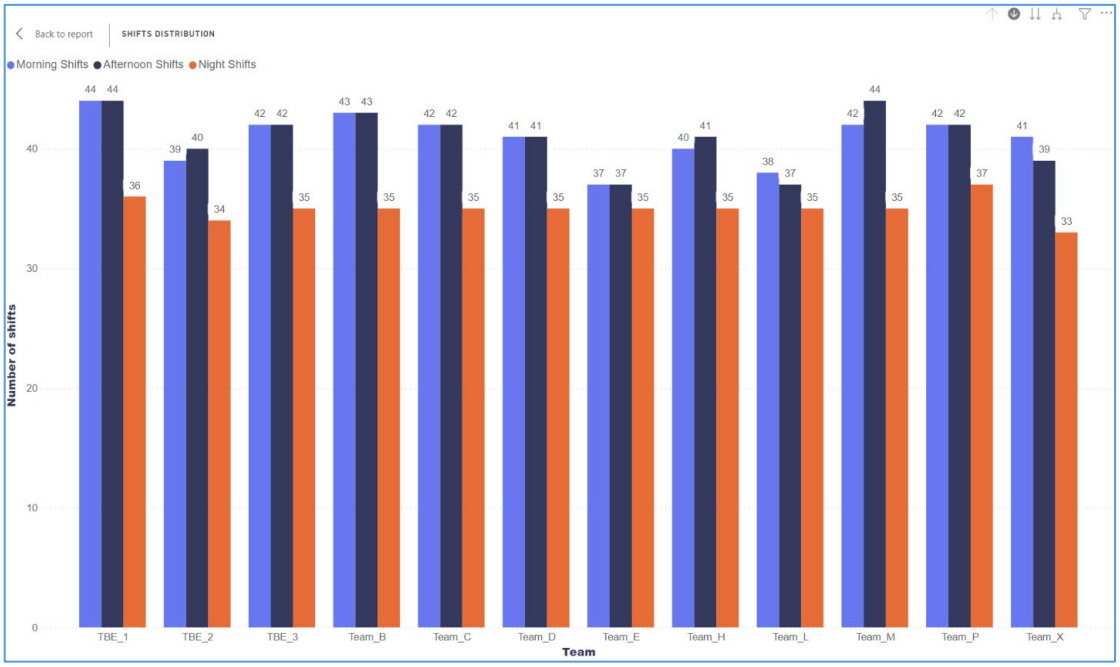

Figure 31 - Shifts Distribution per Team (April 202z Strategic Roster)

From *Figure 31,* it can be seen that shifts are almost evenly distributed between the teams, with only a small variation due to leaves affecting employees in certain teams.

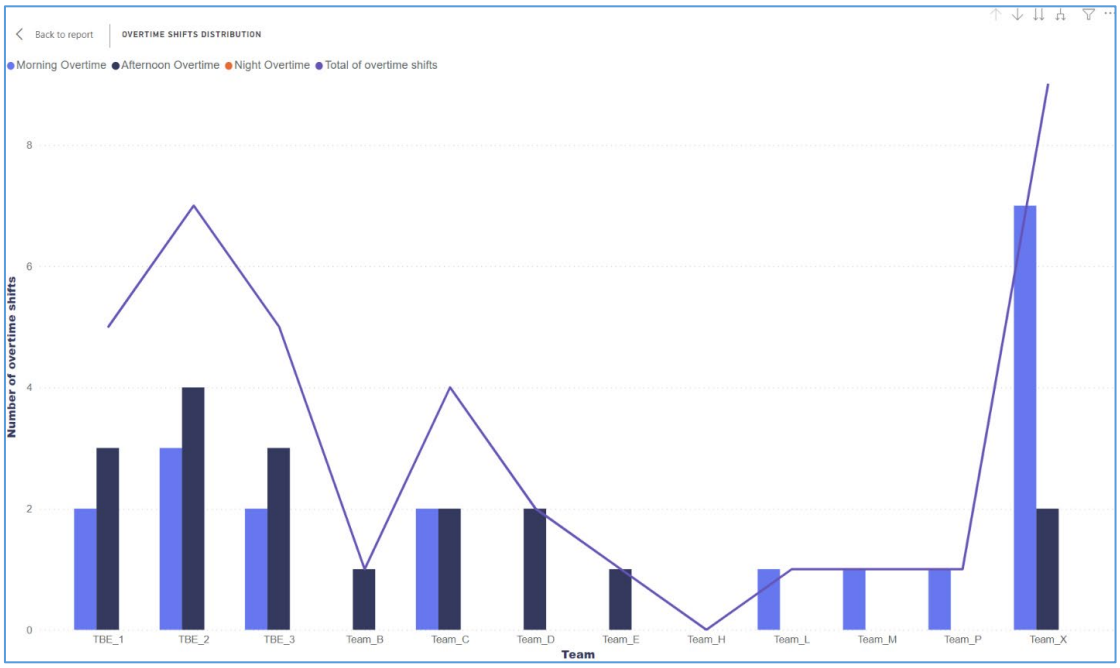

Figure 32 - Overtime Shifts Distribution per Team (April 202z Strategic Roster)

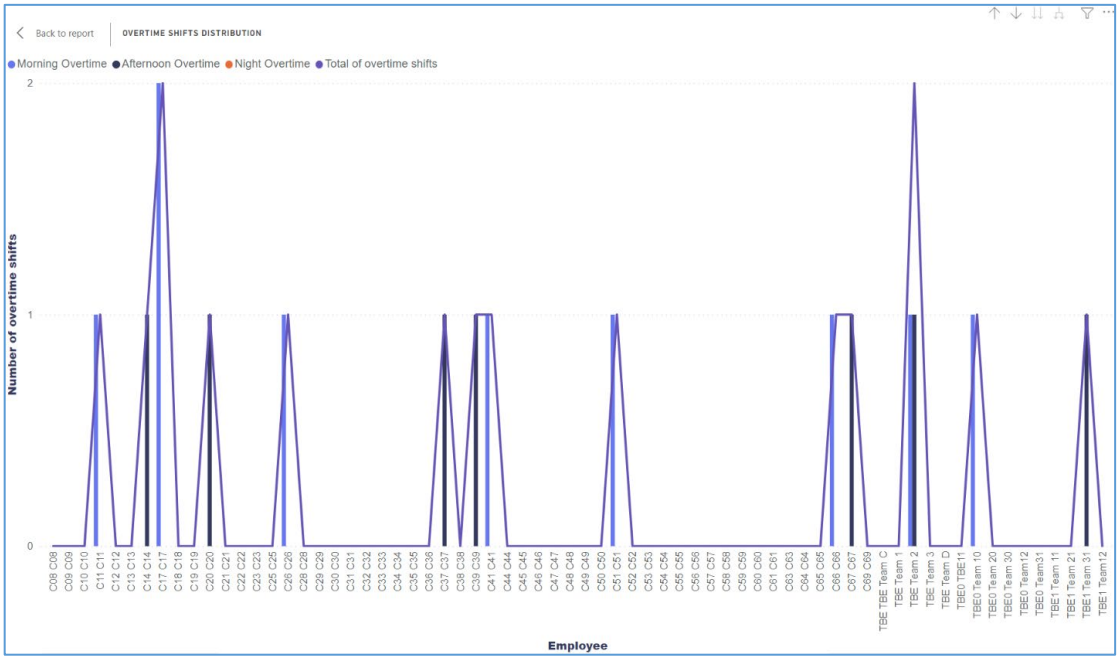

Figure 33 - Fragment of Overtime Shifts Distribution per Employee

The Overtime Distribution figure shows that the overtime shifts in April are evenly assigned to all employees, with only one overtime shift per month. Therefore, the simulation displays 37 employees with overtime shifts. It can be observed that the employees in team H are not performing any overtime shifts.

April 202z Tactical Roster

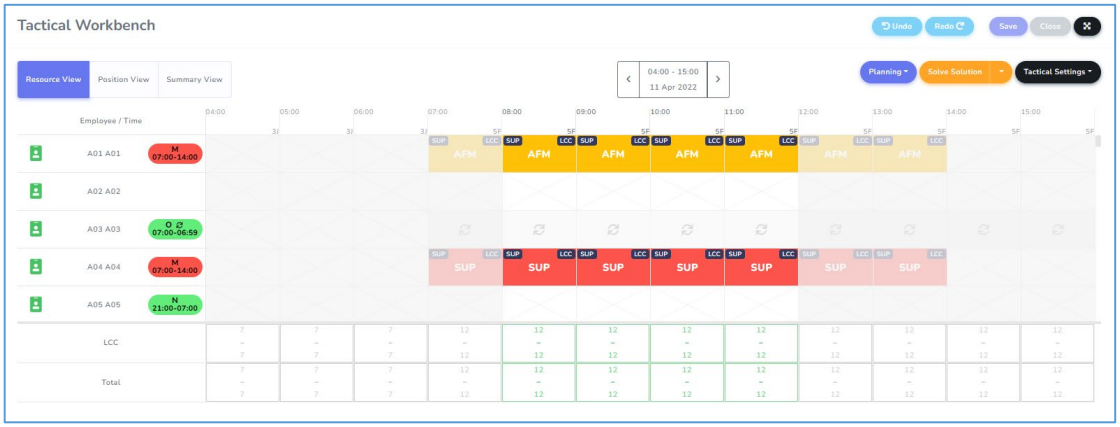

Figure 34 - Extras of AFM and SUP positions in the tactical roster for the Morning shift

Figure 34 shows the employees' schedules for the SUP and the AFM positions. It can be observed that the employees who perform these two shifts work 100% of the time at work, and in Figure 4-5 that the rest of the employees who work on the EXE and PLN positions spend 71.42% or 57.14% of the time in position; this percentage varies depending on how the system distributes the necessary positions.

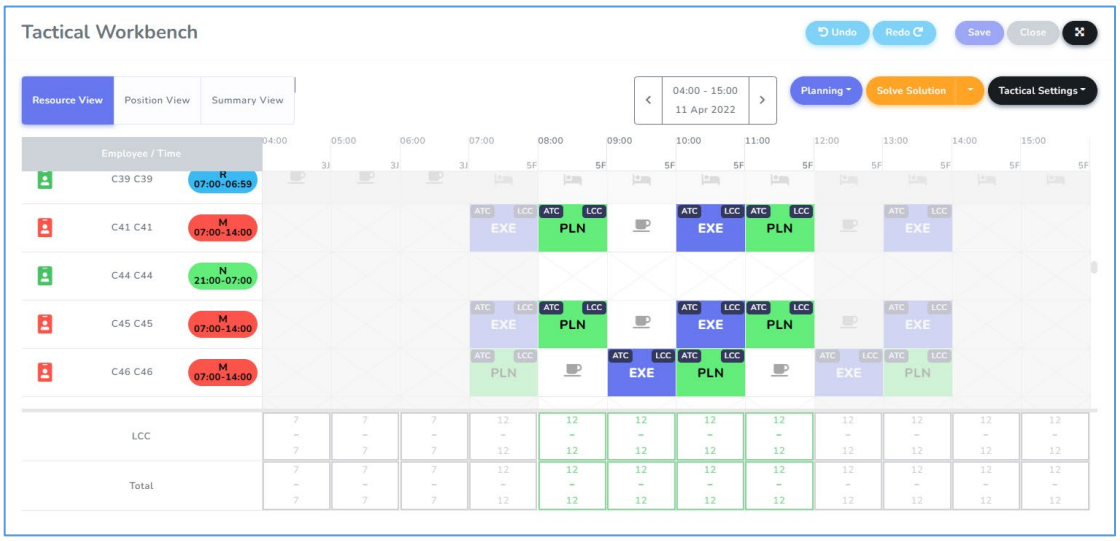

Figure 35 - Extras of EXE and PLN positions in the tactical roster for the Morning shift

Figure 36 below shows the employees' schedules for the SUP and the AFM positions. Same as in the case of Morning Shifts, the employees who work as SUP work 100% of the time. Meanwhile, the employees who work in the AFM work 57.14% of the time. The employees who work in the EXE and PLN positions spend between 42.85% and 71.42% of their time in positions (see next Figure).

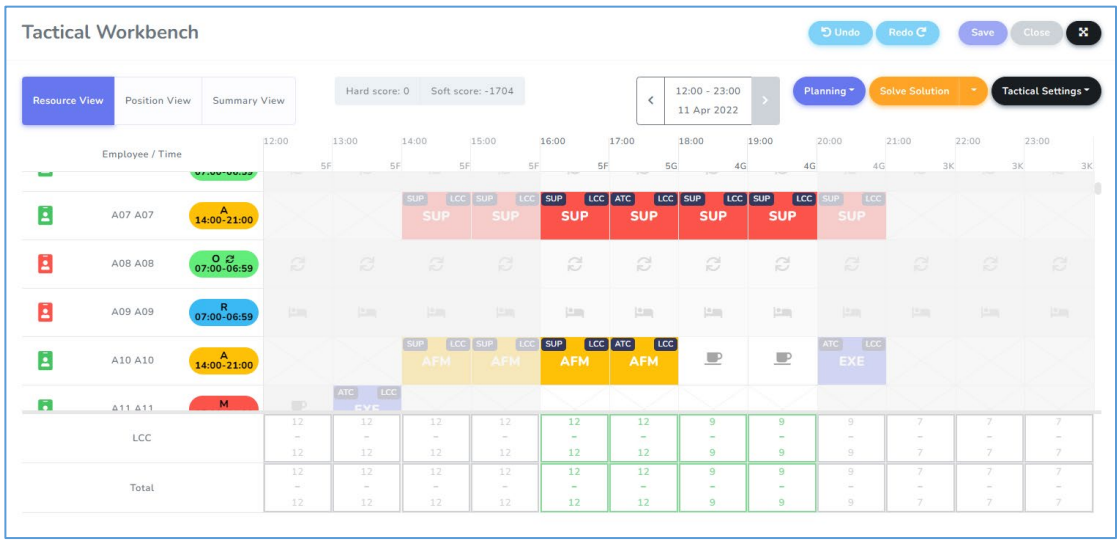

Figure 36 - Extras of AFM and SUP positions in the tactical roster for the Afternoon shift (April 202z Tactical Roster)

The percentage of Night shifts is the closest to the standard of 50%, varying from 46% to 54%. Examples of night shift positions can be observed in *Figure 38* and *Figure 39* below.

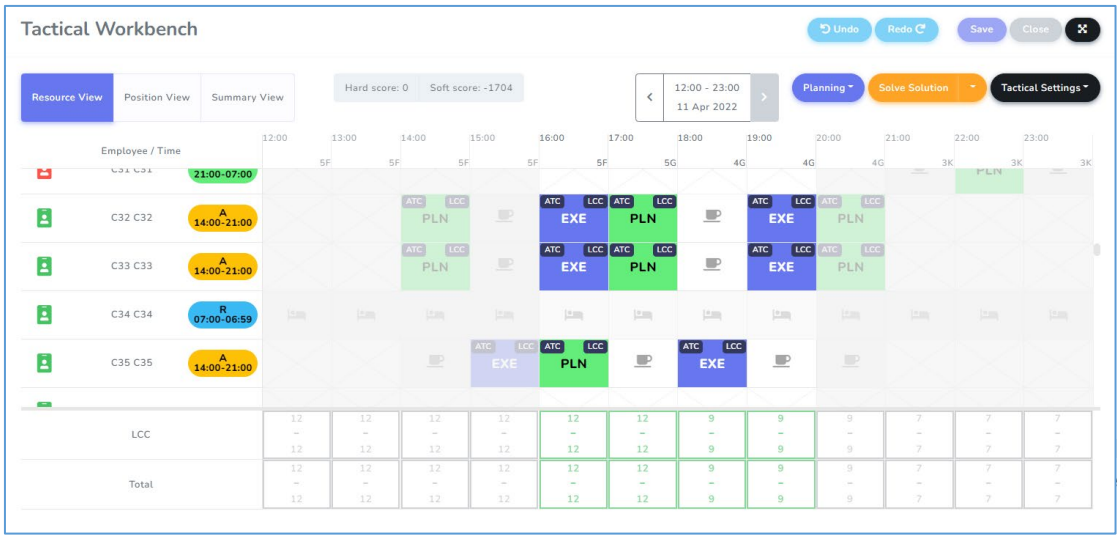

Figure 37 - Extras of EXE and PLN positions in the tactical roster for the Afternoon shift (April 202z Tactical Roster)

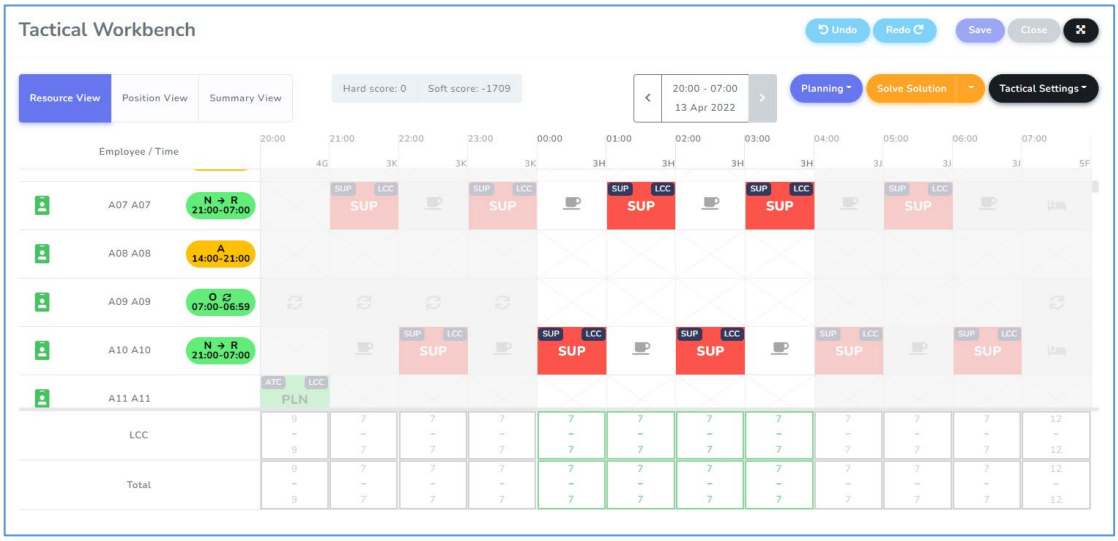

Figure 39 - Extras of SUP positions in the tactical roster for the Night shift

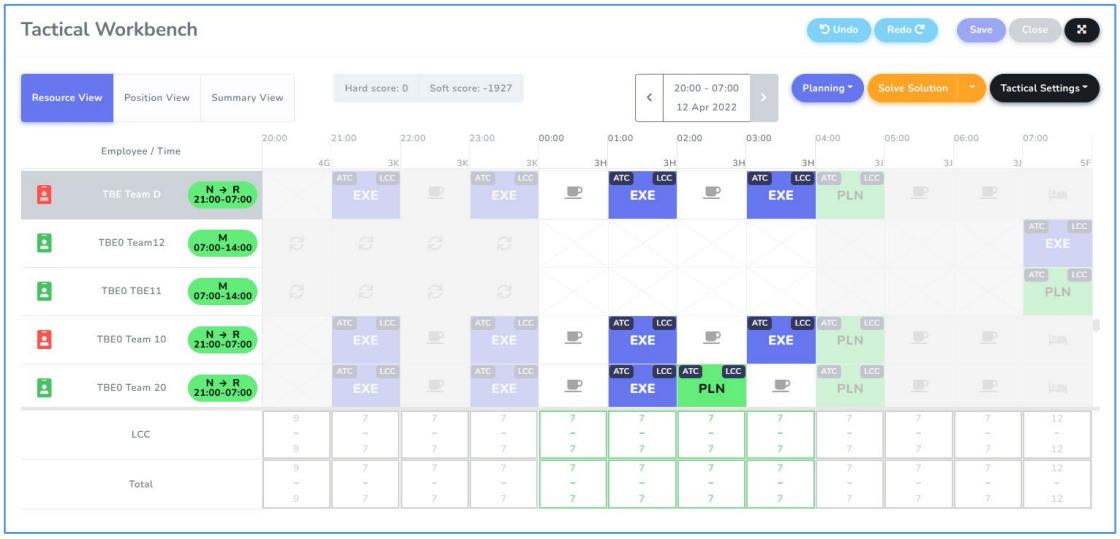

Figure 40 - Extras of EXE and PLN positions in the tactical roster for the Night shift (April 202z Tactical Roster)

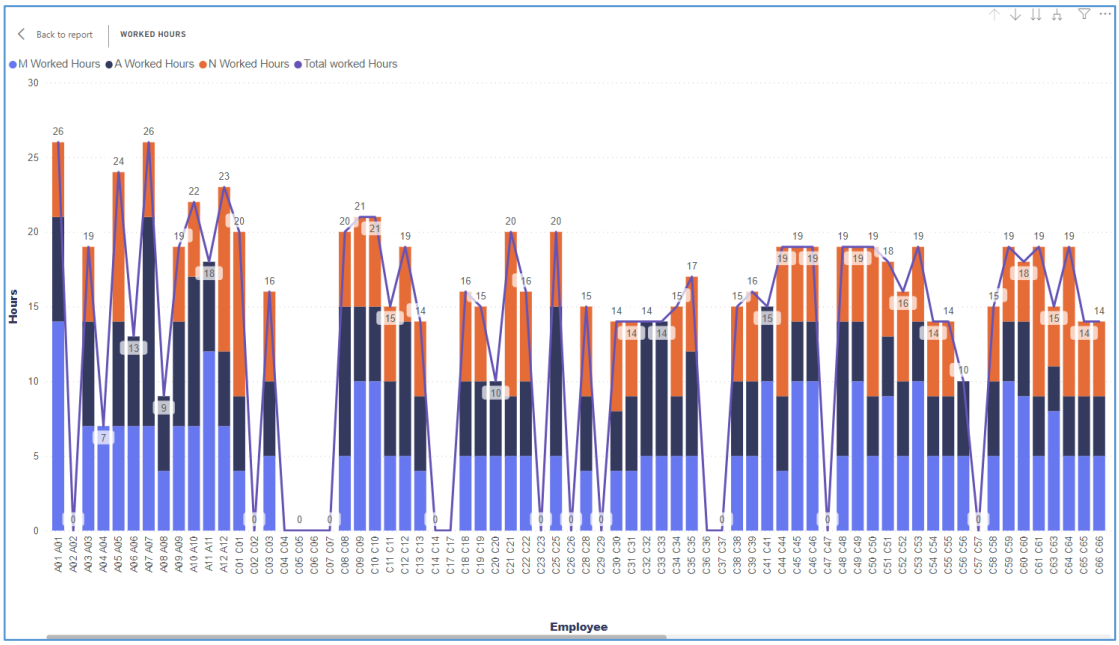

Figure 41 – Distribution of Time Work (hours) per month (April 202z Tactical Roster)

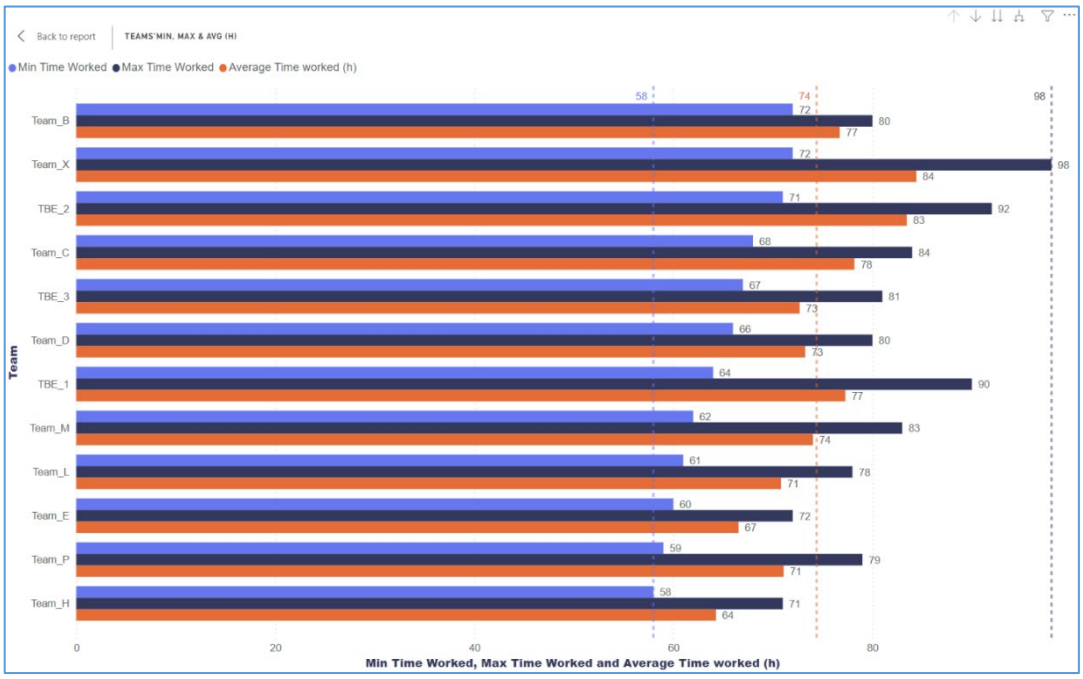

Figure 42 - Teams' Min, Max and Average Time on Position (Hours) (April 202z Tactical Roster)

Analysing *Figure 41,* we can observe the teams' minimum, maximum and average time on position (in hours). The minimum time on position for a team is 58, the average is 74, and the maximum is 98.

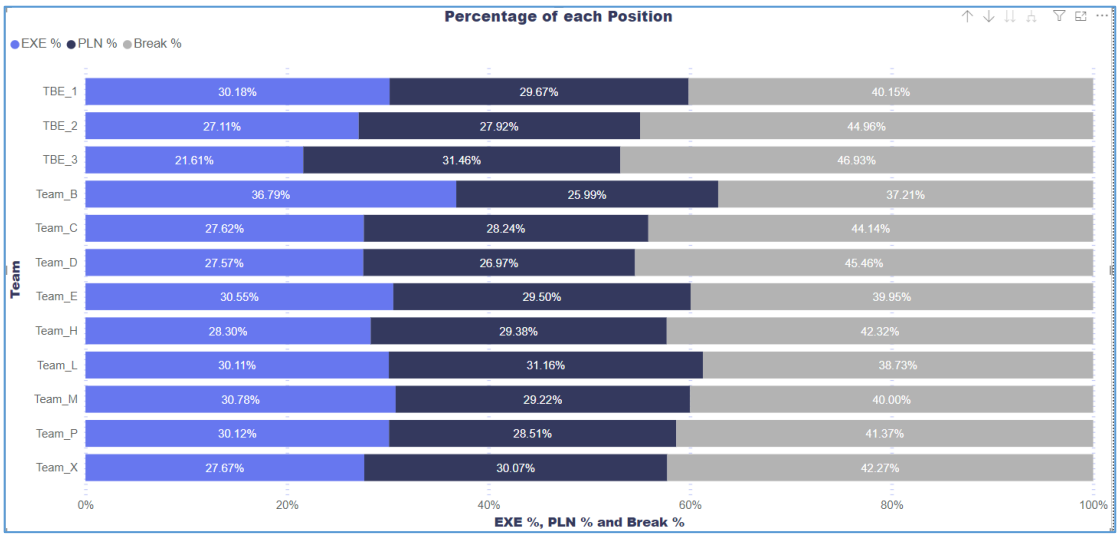

Figure 43 - Time on position vs time on break for EXE and PLN (April 202z Tactical Roster)

Figure 42 shows the percentages of time on position versus breaks for EXE and PLN positions.

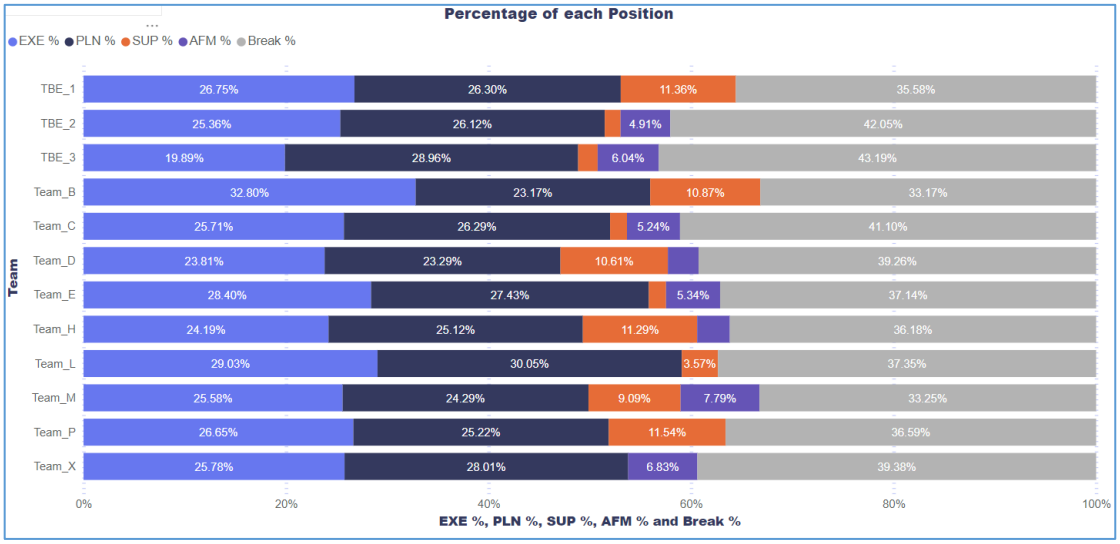

Figure 44 - Time on position vs time on break for all position (April 202z Tactical Roster)

Figure 43 is similar to *Figure 42*, only that it includes the SUP and AFM positions.

In both cases, we can observe that there is no team to work more than 61,10% of the time and less than 55,85% during the entire period.

For the overall statistics (i.e. including SUP and AFM), the teams are not working more than 64% and less than 57%.

A breakdown of each type of working position and breaks is displayed in *Figure 44* and *Figure 45*.

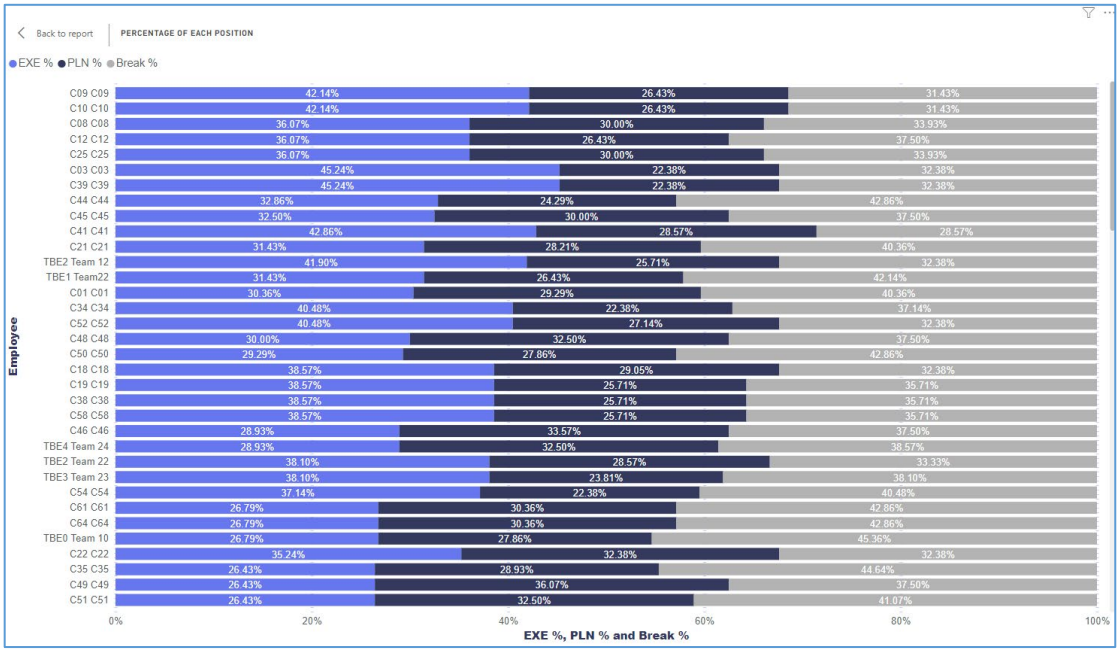

Figure 45 - Time on position breakdown per employee for EXE & PLN (April 202z Tactical Roster)

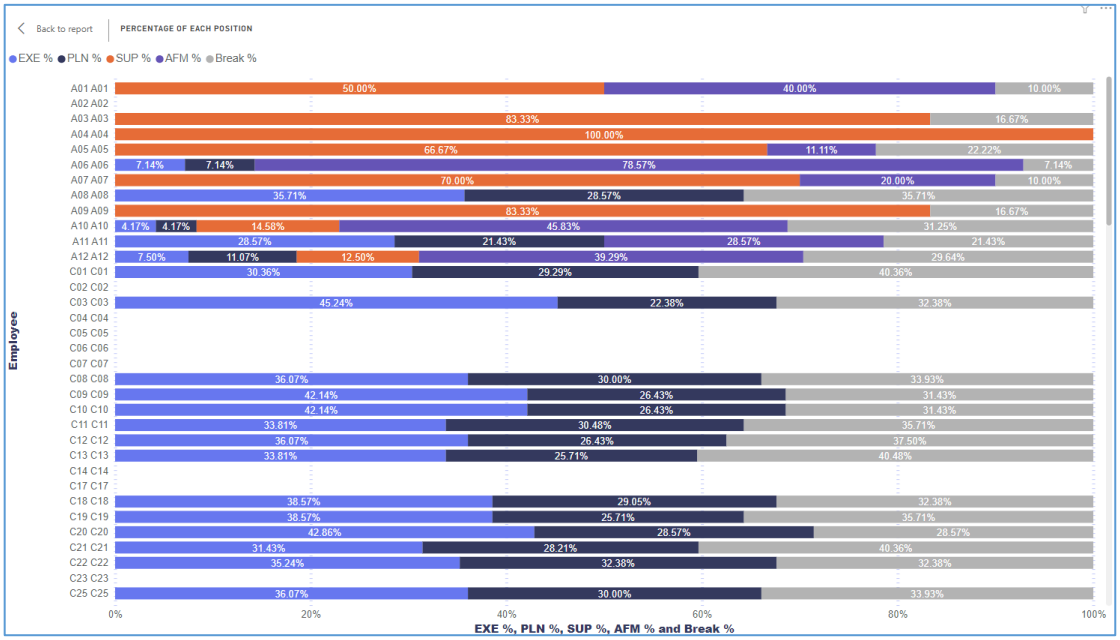

Figure 46 - Time on position breakdown per employee for all positions

It can be observed that there are employees who work in multiple positions, either SUP or AFM, either mixed (SUP&AFM and EXE & PLN), depending on the system assignation and qualifications.

Conclusions

1. The optimised roster for April 202z minimises the variation of overtime between teams and individual employees by using only 37 overtime shifts for the entire month.
2. All leave days are guaranteed for the entire year, with a proportion of them being assigned in April 202z.
3. In the Tactical Roster, staff work in the Morning and Afternoon shifts at the planned percentage of 66%. The SUP makes the exception, who work 100% of the time in both types of shifts and AFM, who work 100% of the time in the morning and 57% in the afternoon.
4. In the afternoon, there is a transition from 5 open sectors to 4 open sectors, and the AFM position is closed.
5. No employee or team works more than 71.43% of the time, except for the SUPs in the Morning and Afternoon Shifts.
6. The time spent on position during the Night shift is 50% for all three positions: SUP, EXE and PLN.
7. On average, the efficiency factor is 50% during the night shifts and 33% during the Morning and Afternoon shifts.

APPENDIX 2: CLOUD VS. ON-PREMISES LICENSING MODELS

Cloud vs. On-premises Rostering Automation software solutions for Air Traffic Controllers and Air Navigation Service Providers both have their own set of advantages and disadvantages.

Cost:

Cloud: Typically, a cloud solution will have a lower upfront cost and a recurring monthly or annual fee based on usage. The total cost of ownership can be more difficult to predict as it will depend on usage and the specific cloud provider.

On-premises: On-premises solutions have a higher upfront cost, including the cost of hardware, software, and maintenance. However, the total cost of ownership can be more predictable as there are no recurring monthly or annual fees.

Control:

Cloud: With a cloud solution, the control over the software and data is limited, as it is managed by the cloud provider. Organizations may have limited customization options and may be dependent on the cloud provider for updates and support.

On-premises: On-premises solutions offer complete control over the software and data, and organizations have complete control over updates and customizations.

Updates:

Cloud: Cloud solutions are typically updated and maintained by the cloud provider, reducing the burden on the IT department.

On-premises: On-premises solutions require ongoing maintenance and updates by the organization's IT department.

Technical Support:

Cloud: Technical support is typically provided by the cloud provider, but the level of support can vary depending on the provider and the specific solution.

On-premises: Technical support is the responsibility of the organization's IT department but can also be outsourced to a third-party vendor.

Security:

Cloud: Cloud solutions typically have strong security measures in place, but security concerns may arise with data stored on remote servers. Organizations must carefully evaluate the security measures in place with their specific cloud provider.

On-premises: On-premises solutions provide complete control over the data, reducing the risk of unauthorized access. However, security measures must be properly maintained and updated by the organization's IT department.

Compliance:

Cloud: Compliance requirements can vary depending on the specific cloud provider and the regulations that apply to the organization.

On-premises: Organizations have complete control over compliance requirements and can ensure that the solution meets their specific needs.

Scalability:

Cloud: Cloud solutions are typically scalable, allowing organizations to easily increase or decrease usage as needed.

On-premises: On-premises solutions may require additional investments in hardware and software to scale, making it more difficult to adapt to changing needs.

Accessibility:

Cloud: Cloud solutions can be accessed from anywhere with an internet connection, making it easy for remote workers or those on-the-go to access the rostering system.

On-premises: On-premises solutions are limited to the physical location where the software is installed, making it difficult for remote workers to access the system.

Reliability:

Cloud: Cloud providers have redundant systems in place to ensure uptime and data recovery in case of an outage.

On-premises: The reliability of an on-premises solution will depend on the organization's IT infrastructure and support.

Flexibility:

Cloud: Cloud solutions are typically more flexible, allowing organizations to quickly adjust to changing needs.

On-premises: On-premises solutions can be less flexible, as changes may require additional investments in hardware and software.

Maintenance:

Cloud: Cloud solutions are typically maintained and updated by the vendor, reducing the burden on IT departments.

On-premises: On-premises solutions require ongoing maintenance and updates by the organization's IT department.

Total Cost of Ownership Detailed analysis

The total cost of ownership for a cloud solution will depend on the specific provider, but is typically lower than an on-premises solution over the long term. On-premises solutions have a higher upfront cost, but may be more cost-effective in the short term (3-5 years). However, organizations must factor in the ongoing maintenance and support costs associated with an on-premises solution, which can add up over time. In contrast, cloud solutions typically have a lower upfront cost, but recurring monthly or annual fees can add up over time. Ultimately, the choice between cloud and on-premises solutions will depend on the specific needs and budget of the organization.

https://www.linkedin.com/pulse/on-premise-vs-cloud-comparing-tco-right-way-tatiana-shchenkova/

https://www.criticalcase.com/blog/calculating-the-tco-cloud-vs-on-premise-infrastructure.html

APPENDIX 3: DESCRIPTION OF HARD AND SOFT CONSTRAINTS

(source SkyRoster)

Constraint Programming

A rostering application/tool should employ Constrained Programming to enforce rules and constraints in identifying feasible and optimal solutions for scheduling shifts.

A feasible solution is considered when all necessary shifts have been assigned and all hard constraints have been met. For instance, minimum rest time after a shift is a hard constraint that must be strictly adhered to.

Once a feasible solution has been established, the roster engines will commence the optimization process by evaluating all soft constraints and exploring alternative solutions to find the best possible outcome.

All constraints possess parameters such as scores or weights, which are utilized to compute the overall score of a solution. The higher the score, the closer the solution is to the theoretical optimum. Each violated constraint will decrease the score.

General Capabilities

The following are some general capabilities that are applicable to all rules, with some variations:

On/Off Toggle

This parameter is available for all rules and enables the user to fully activate or deactivate a particular constraint. This feature is especially useful when generating a multi-stage solution, such as dividing the solving process into two stages: a quick solution generation stage and a longer stage focusing on optimization, such as distributing nights and weekends.

Hard/Soft Rule

This parameter, available for most rules, allows the user to switch between a hard constraint that must be adhered to and a soft constraint that should be respected. Hard constraints are essential for identifying a feasible solution, and their final hard score must be zero. Soft constraints are used during the optimization stage to account for optional or preferred constraints.

Weight

This parameter is available for all rules and enables the user to prioritize a particular rule over others. It is useful in fine-tuning the roster optimization process, allowing the user to determine the importance of a specific distribution. By default, all rules have a 50% weight, implying that no rule is prioritized. However, the distribution rules operate on an algorithm that increases their score faster, potentially impacting the outcome of the solving process.

Additional Values

This parameter is available for some rules and enables the user to directly control specific parameters used by the constraint. It is mainly utilized for customization, such as adjusting the maximum number of consecutive nights or maximum hours worked to account for real-time changes.

💡 Note: Some constraints will exempt shifts considered as non-working shifts, such as off-shifts without the "Can Do Replacement" property.

💡 Note: Some constraints are only applicable for specific strategies (Team/Individual) and will be disregarded for the rest.

Hard and Soft Constraints

The following are some samples of Hard and Soft constraints:

Respect qualification

This constraint is the one responsible for ensuring that an employee has the required qualification to work on a certain shift.

Default: Enabled / Hard

Main Qualification

The assignment of priorities to each of an employee's qualifications using weighting. The qualification with the highest weight is deemed the primary qualification. In the event of a tie, the selection of the primary qualification is randomly made and does not impact the solution. This type of prioritization of qualifications is used for example in the case of the 'Supervisor' qualification, where an employee could work on multiple qualifications, but under normal conditions, the system should assign him/her to a Supervisor position.

Default: Enabled / Soft

Respect Suspension

This constraint manages suspended employees by ensuring that they are not assigned to shifts where they are unable to work. If an employee with suspensions also holds other, non-suspended qualifications that are required for certain shifts, the system will assign those shifts to the employee.

Default: Enabled / Hard

Respect Leaves

This constraint ensures that employees are not assigned to shifts that overlap with their periods of unavailability. It integrates data from our Leave Management module and sets specific periods as unavailable for each employee.

Default: Enabled / Hard

Minimum Rest Time

This constraint ensures that employees receive the minimum required rest time after each shift. The platform adjusts shift assignments to accommodate these regulated rest periods.

Default: Enabled / Hard

Maximum Hours Worked Per Week / Month / Year

This set of constraints allows users to establish upper limits for various periods, in accordance with legal regulations for work an employee may perform.

Default: Disabled / Hard

Not Required Shift Assignments

This constraint is responsible for assigning optional shifts, which can either be specified in the initial Manpower Requirements or dynamically when generating the roster and assign these shifts if staff availability permits.

Default: Disabled / Soft

Prioritize Qualifications

This constraint manages the priority of assigning qualifications. The platform allows the user to arrange qualifications in a list, determining a priority to facilitate a faster and closer to optimum solution.

Default: Disabled / Soft

Maintain Qualification Validity

This constraint is used to ensure that the required number of hours worked in a specified period is met in the proposed roster schedule, to maintain the validity of an employee's qualification. The preference is that this rule to be set as 'Soft,' as we do not wish for it to impede roster generation, but would like it to be taken into account as much as possible.

Default: Disabled / Soft

Maximum Consecutive Nights

These constraints enforce upper limits on consecutive assignments, with night shifts having a separate category due to their impact on employee fatigue. The number of consecutive night shifts can be altered by the user, and our default values are 3, based on available research and best practices in fatigue management.

Default: Disabled / Soft

Total Hours Worked per Template (Roster)

This constraint manages the maximum number of hours an employee works within a roster period (the period should also be a parameter e.g one cycle, 60 days, 90 days, one year etc). It enables the user to set a maximum number of hours for the roster (e.g. derived from the Unit Training Plan to maintain currency) and requires the solution to allocate employee hours accordingly.

Default: Disabled / Soft

Maximum Consecutive Assignments with Off Shifts

This constraint enforces an upper limit on consecutive assignments, including shifts considered "non-working," "replacement," or "off." The user can adjust this limit according to internal policies, legislation, or fatigue guidelines.

Default: Disabled / Soft, with a maximum number of working assignments of 5.

Maximum Consecutive Assignments Without Off Shifts

This constraint enforces an upper limit on consecutive assignments, excluding shifts considered "non-working," "replacement," or "off." The user can adjust this limit based on internal policies, legislation, or fatigue guidelines.

Default: Disabled / Soft, with a maximum number of working assignments of x (where x is parameter adjustable e.g. x=5).

Respect Team Assignments

This rule manages the team membership of employees. Each employee has a designated primary unit or team in which they will primarily work, and this constraint ensures this assignment is respected. However, in cases where a team is unable to meet the demand on a

certain day and the employee's membership allows it, the platform may assign the employee to cover the demand in another team.

Default: Enabled / Soft

Maximize Shift Patterns

This constraint optimizes the selection of staff members to cover shifts by considering which employee can best meet the shift pattern. For instance, if one employee has a day off that coincides with a sequence of shifts and the other does not, the latter employee will be selected to carry out the pattern. The goal of this constraint is to minimize disruptions in the shift sequence and the related fatigue factor.

Default: Disabled / Soft

Substitution Assignments

This constraint enables the system to differentiate better between the primary and secondary qualifications of employees. The substitution property indicates that an employee can work in a certain role if needed, but only if no other employee is available. This is useful for positions like 'Supervisor', where a team may have two staff members qualified as supervisors but only one is responsible for managing the team in the absence of the primary supervisor.

Default: Disabled / Soft

Fair Work Distribution

Advanced algorithms are required to ensure a fair distribution of work among employees. This constraint is specialized and can only be used during the optimization stage of the scheduling process. It considers various key performance indicators to guarantee optimal and fair scheduling. These rules are the following:

Qualification Distribution

This type of distribution ensures a fair distribution of hours worked for each qualification, enabling employees to maintain their competency valid on all of them.

Default: Disabled / Soft

Shift Distribution

This type of distribution ensures that employees work a similar number of each type of shift within a given time frame.

Default: Enabled / Soft

Weekend Distribution

This type of distribution ensures a fair distribution of shifts in weekends, promoting fairness and evenly distributing the social impact of scheduling.

Default: Disabled / Soft

Holiday Distribution

This type of distribution ensures a fair distribution of shifts on national holidays, promoting fairness and evenly distributing the social impact of scheduling between employees.

Default: Disabled / Soft

Minimum Staff

This type of distribution aims to minimize staffing costs, by allocating only the minimum staff necessary to cover the Manpower Requirements (where possible), but may result in penalties from a fatigue management perspective.

Default: Disabled / Soft

Preferences

Provides employees with the ability to express their preferred working schedule and preferences, thereby enhancing employee satisfaction and promoting effective fatigue management.

Desired / Undesired

This set of constraints effectively manages the diverse preferences of each employee, striving to accommodate them within the limitations of the solution.

Default: Disabled / Soft

Distribute Preferences

This constraint ensures an equitable distribution of respected preferences among all staff members.

Default: Disabled / Soft

APPENDIX 4: EXAMPLES OF HARD & SOFT CONSTRAINTS SETTINGS

(source SkyRoster)

Pre-Tactical Rostering

For the following scenarios, a Team based roster of 10 teams, consisting of 8 employees each will be used. The employees in the team are distributed as follows: 1 Supervisor, 3 ACC controllers, 3 APP controllers and 1 TWR controller. The Supervisor can work on all qualifications, the ACC controller can work on all qualifications except as SUPP, the APP controller can work as APP or TWR, and the TWR controller can work only on the TWR qualification.

The rostering strategy is a forward-rotating shift pattern, MANRO, where:

- M = Morning shift
- A = Afternoon shift
- N = Night shift
- R = Rest day (OFF shift)
- =Off day (OFF shift)

H= Hard Constraint

S= Soft Constraint

Scenario 1:

Constraint	Status	Type	Value
Respect Team Assignment	**Enabled**	**H**	N/A
Respect Min Rest Time	**Enabled**	**H**	N/A
Respect Qualification	**Enabled**	**H**	N/A
Respect Leaves	**Enabled**	**H**	N/A
Respect Suspensions	**Enabled**	**H**	N/A
Max consecutive days without OFF	**Enabled**	**H**	**3**
Max consecutive day with OFF	Disabled	N/A	N/A
Max consecutive nights	Disabled	N/A	N/A
Max hours worked per month	**Enabled**	**H**	**160**
Shift Distribution	Disabled	N/A	N/A
Qualification Distribution	Disabled	N/A	N/A

Table 3 – Sample of Soft and Hard constraints – Pre-Tactical Rostering Scenario 1

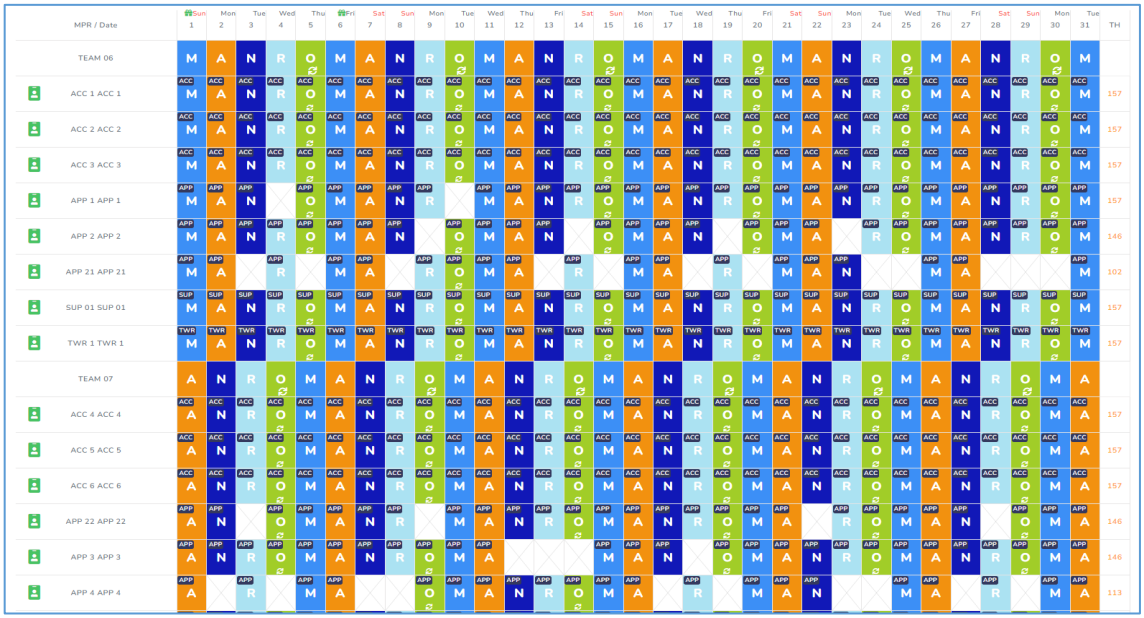

Figure 47 - Pre-Tactical Roster Scenario 1 - results on sift roster distribution

Conclusion

The first scenario is one of the most “default” constraint settings. All enabled rules **must** be respected, and this can be seen in the scheduling. No employee works more than 3 consecutive non-OFF shifts, and no employee works more than 160 hours in the month.

No shifts are assigned to suspended or not available employees and each shift is assigned correctly to a person who owns the necessary qualifications for that respective shift. The minimum rest time between successive shifts is also respected.

All individual employees’ shifts follow strictly the pattern of the Team they are a part of.

No fair distribution rule is enabled, so we can notice the hours worked, shift types and type of qualifications are not evenly distributed across the organization.

Scenario 2:

Constraint	Status	Type	Value
Respect Team Assignment	**Enabled**	S	N/A
Respect Min Rest Time	**Enabled**	H	N/A
Respect Qualification	**Enabled**	H	N/A
Respect Leaves	**Enabled**	H	N/A
Respect Suspensions	**Enabled**	H	N/A
Max consecutive days without OFF	Disabled	N/A	N/A
Max consecutive day with OFF	**Enabled**	H	**7**
Max consecutive nights	Disabled	N/A	N/A
Max hours worked per month	**Enabled**	S	**160**
Shift Distribution	Disabled	N/A	N/A
Qualification Distribution	**Enabled**	S	N/A

Table 4 – Sample of Soft and Hard constraints – Scenario 2

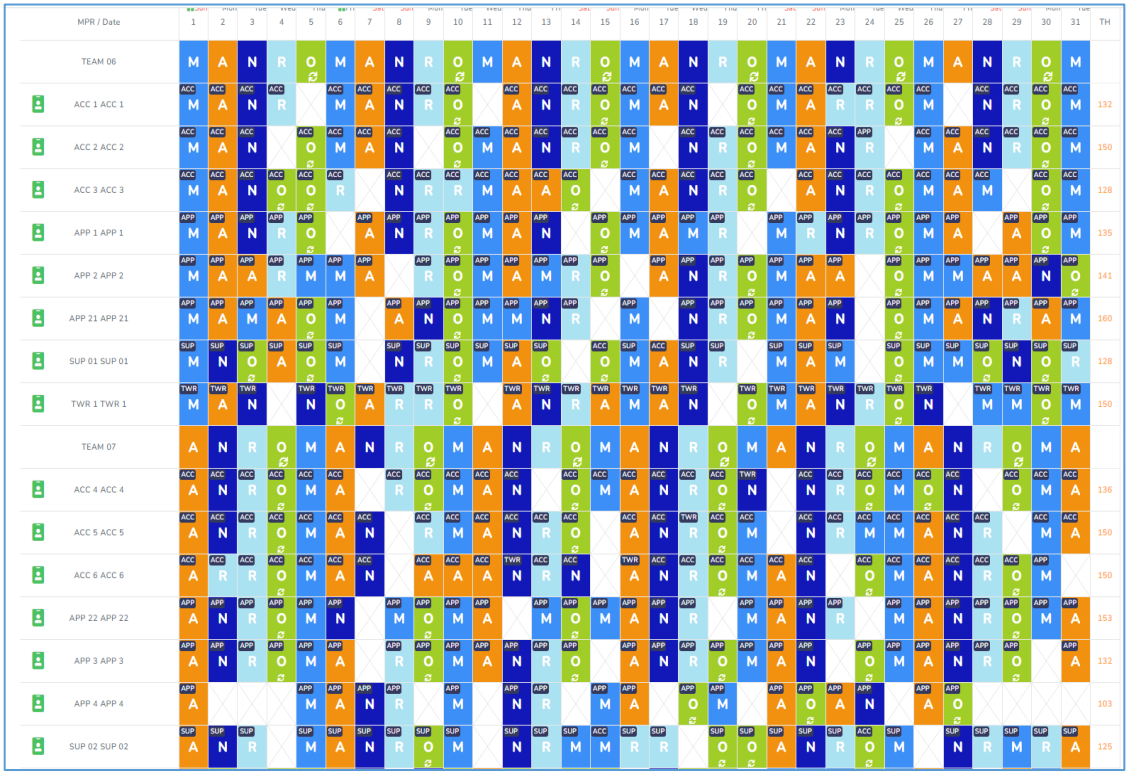

Figure 48 - Pre-Tactical Roster Scenario 2 - results on sift roster distribution

Conclusion

The second scenario is a more diverse one. Some enabled rules **must** be respected, whilst other are only **recommendations**. For example, no employee works more than 7 consecutive shifts, this including the OFF-shift types, and no employee **should** work more than 160 hours in the month, but this is not a hard cap, as the engine can pass over this limit, if needed.

No shifts are assigned to suspended or not available employees and each shift is assigned correctly to a person who owns the necessary qualifications for that respective shift. The minimum rest time between successive shifts is also respected.

The engine tries to assign as much as possible shifts to the controllers according to the shift pattern of their respective team, but this is not a hard constraint, as the engine can deviate the schedule of an individual employee from the one of its team.

The shift distribution rule is disabled, so it can be noticed that the hours worked, and shift types are not evenly distributed across the organization. However, enabling the Qualification Distribution role, there is a more varied assignment of shifts when it comes to qualifications, and Supervisors and ACC controllers assigned on APP or TWR qualifications, along with their main qualifications. This may aid the respective controllers in keeping the license for the secondary qualifications valid.

Scenario 3:

Constraint	Status	Type	Value
Respect Team Assignment	Disabled	N/A	N/A
Respect Min Rest Time	**Enabled**	**H**	N/A
Respect Qualification	**Enabled**	**H**	N/A
Respect Leaves	**Enabled**	**H**	N/A
Respect Suspensions	**Enabled**	**H**	N/A
Max consecutive days without OFF	**Enabled**	**H**	**4**
Max consecutive day with OFF	Disabled	N/A	N/A
Max consecutive nights	**Enabled**	**H**	**2**
Max hours worked per month	Disabled	N/A	N/A
Shift Distribution	**Enabled**	**S**	N/A
Qualification Distribution	**Enabled**	**S**	N/A

Table 5 – Pre-tactical Roster - Sample of Soft and Hard constraints – Scenario 3

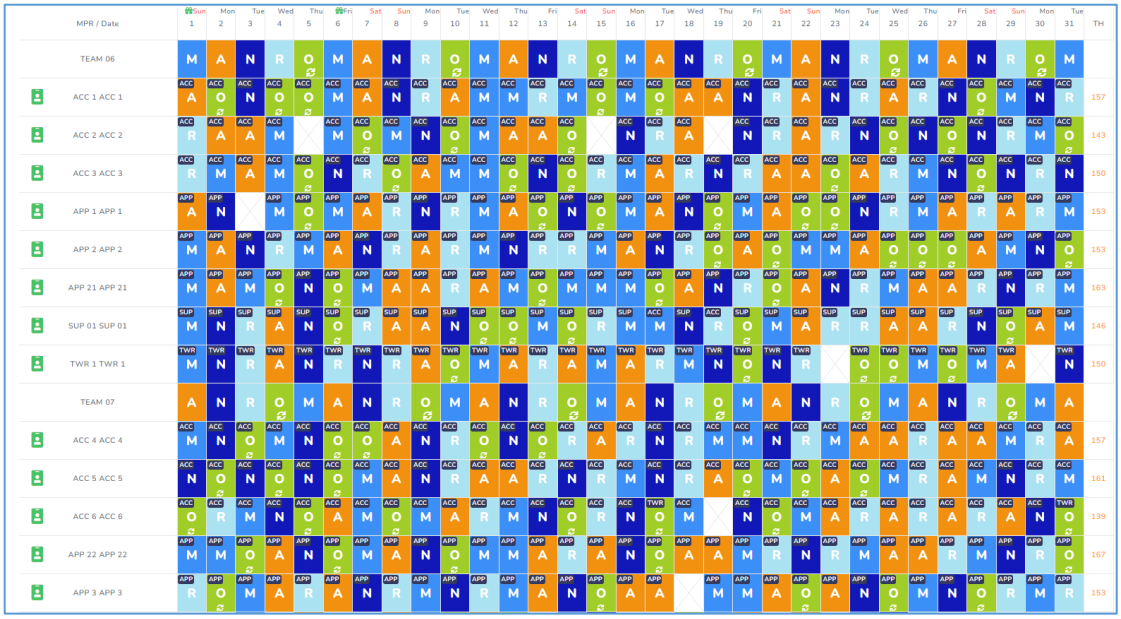

Figure 49 - Pre-Tactical Roster Scenario 3 - results on sift roster distribution

Conclusion

The third scenario is opposite to the first. All enabled rules **must** be respected, moreover there are some distribution rules that are **enabled**, but they are only used for the **optimization** of the schedule. For example, no employee works more than 4 consecutive non-OFF shifts or more than 2 consecutive nights. There is no restriction in terms of maximum hours worked per month.

No shifts are assigned to suspended or not available employees and each shift is assigned correctly to a person who owns the necessary qualifications for that respective shift. The minimum rest time between successive shifts is also respected.

The engine does not consider the pattern of the team when assigning shifts to an employee. The allocation of shifts is done on a purely individual level.

The shift distribution rule is enabled, so it can be noticed the hours worked and shift types are evenly distributed across the organization. Moreover, the qualification distribution rule is enabled, so controllers with multiple qualifications are assigned on multiple qualifications during the month.

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Tactical Rostering

In the tactical roster, the following working positions are considered, with the following constraints:

- Supervisor -> Unlimited time on position, no rest time required before watch,
- ACC EXE -> Minimum 45 minutes time on position, Maximum 45 minutes time on position, 45 minutes rest time required before watch.
- ACC PLN -> Minimum 45 minutes time on position, Maximum 45 minutes time on position, 45 minutes rest time required before watch,
- APP Coordinator -> Minimum 45 minutes time on position, Maximum 45 minutes time on position, 45 minutes rest time required before watch,
- TWR Executive -> Minimum 45 minutes time on position, Maximum 45 minutes time on position, 45 minutes rest time required before watch.

In the following pictures, each slot represents 15 minutes intervals.

Scenario 1:

Constraint	Status	Type
Respect position requirements	**Enabled**	**H**
Respect suspended resource	**Enabled**	**H**
Respect resource availability	**Enabled**	**H**
Respect maximum time on position	**Enabled**	**H**
Respect minimum time on position	**Enabled**	**S**
Minimum rest time before position	**Enabled**	**H**
Working slots distribution	Disabled	N/A
Unwanted patterns	Disabled	N/A

Table 6 – Tactical Rostering - Sample of Soft and Hard constraints – Scenario 1

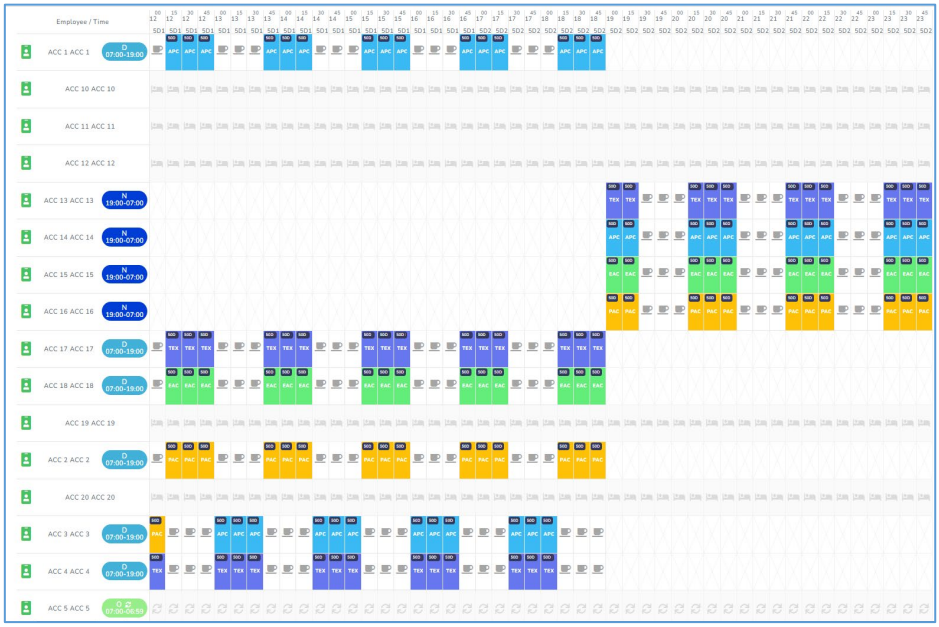

Figure 50 - Tactical Roster Scenario 1 - results on sift roster distribution

Conclusion

The first scenario is one of the most "default" constraint settings. All enabled rules **must** be respected, except the minimum time on position, which is only recommended. On all positions, except the Supervisor one, controllers work 45 minutes ON and 45 minutes OFF, respecting the maximum time on position and the rest time between watches.

No shifts are assigned to suspended or not available employees and each shift is assigned correctly to a person who owns the necessary qualifications for that respective shift.

No fair distribution rule is enabled, so we can notice that controllers do not switch between different working positions during their shift.

Scenario 2:

Constraint	Status	Type
Respect position requirements	**Enabled**	**H**
Respect suspended resource	**Enabled**	**H**
Respect resource availability	**Enabled**	**H**
Respect maximum time on position	**Enabled**	**H**
Respect minimum time on position	Disabled	N/A
Minimum rest time before position	Disabled	N/A
Working slots distribution	**Enabled**	**H**
Unwanted patterns	**Enabled**	**S**

Table 7 – Tactical Rostering - Sample of Soft and Hard constraints – Scenario 2

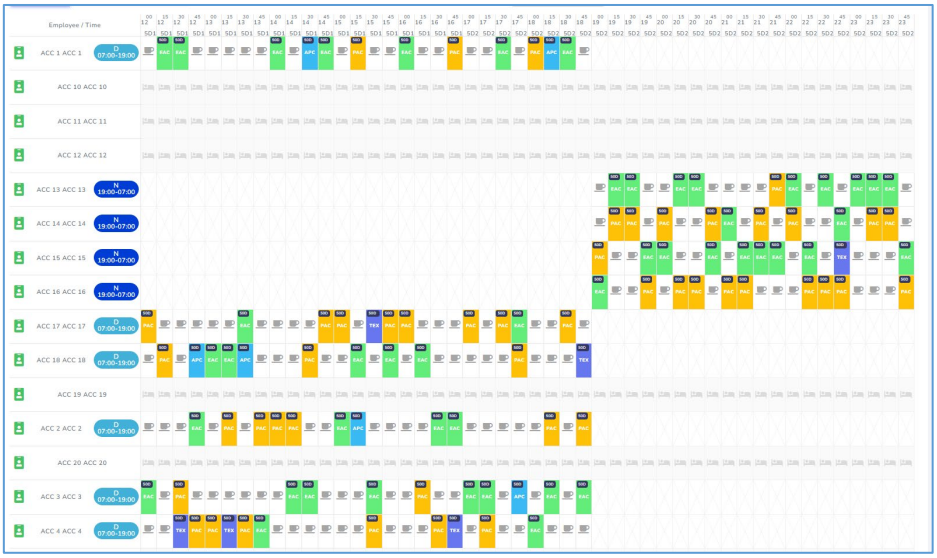

Figure 51 - Tactical Roster Scenario 2 - results on sift roster distribution

Conclusion

The second scenario shows the most differences using various constraint settings. All enabled rules **must** be respected. However, intentionally the minimum rest time is disabled between different watches and removed the minimum rest time constraint, so it can be noticed that even 15-minutes watches. We have kept the maximum time on position constraint, so it can be noticed no controllers works more than 45 minutes on the same positions, except for the supervisor watch.

No shifts are assigned to suspended or not available employees and each shift is assigned correctly to a person who owns the necessary qualifications for that respective shift.

The fair distribution rule is enabled, so we can notice that controllers switching evenly between multiple positions during the shift.

Moreover, an “Unwanted pattern” has been enabled which in this scenario is the EXE ACC -> PLN ACC, so it can be noticed no controller is asked to work as an ACC executive, immediately followed by an ACC planner watch. Multiple unwanted patterns can be added in order to extend this scenario.

(***)

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