**Healthcare Management & Modelling**

**1CK110**

**Management Assignment 6**

Nurse Planning

Dr. Ir. Nico Dellert

13/10/2025

Group 3

Benjamin Ackermans (1796968), Catalina Diaz Nogueira (2207214), Edurne Hesemans Bageneta (1615122), Arianna Perini (1853147), Kiruna De Vleeschouwer Draschner (2108216)

***Introduction***

Effective nurse planning and scheduling are required in order to provide high standards of patient care while efficiently utilizing hospital resources. Nurse staffing in healthcare operations directly affects the quality of service and cost. In this project, quantitative forecasting and optimization techniques are used on real patient data in the general surgery department to develop data-driven nurse planning policies in different hospital wards.

The study is divided into four sections. Part A considers the Daycare Ward, both estimating the nursing demand per hour and constructing an optimal 4 hour and 8 hour shift mix that trades off cost versus coverage. Part B generalizes the analysis to three specialist wards AOS, VTS, and TRS by calculating average workload distributions, computing the needed nurse capacities subject to utilization constraints, and adjusting staffing levels to avoid overutilization. Part C constructs a 13-week rotating schedule that satisfies these staffing requirements at minimum overall cost and with stable coverage. Part D then evaluates the deployment of flexible nurses as an adaptive strategy to cope with forecast uncertainty, comparing their impacts on costs, utilization, and reliability of service with the fixed-schedule strategy.

The objective of the overall analysis is to transform complex patient demand patterns into affordable staffing decisions that are also feasible. In doing this, the study demonstrates how quantitative planning can help healthcare organizations achieve a balance between operational efficiency, staff welfare, and patient centered care.

***Methods***

In Part A of the assignment, the daycare ward is analysed. Specifically, the goal of this section is to consider daycare patients and determine the average hourly nursing demand, optimizing the nurse shift schedule under certain constraints and evaluating the resource utilization and cost efficiency for the daycare ward. To do so, daycare cases were extracted from the dataset, including patients with LOS = 0. For the demand analysis the average required care per hour for the daycare ward was calculated, assuming that the wards were empty at 8 am daily. To allocate 4-hour and 8-hour shifts at minimum cost, a mixed integer linear model was used. This was subject to the constraints that at least one nurse is available and on duty from 8 to 21, and that hourly staffing meets or exceeds the required care. Overlapping is good to consider because it ensures a safe staffing through midday peaks while also minimizing idle hours. The hourly utilization was computed as the ratio of required nurse-hours to available nurse capacity.

In Part B, we analysed three specialist wards AOS, TRS, and VTS to determine the average nursing demand per shift, evaluate utilization levels, and refine staffing to improve care quality.  
Nurses work 8-hour shifts where 75 % of each, are considered effectively available for patient care to have a safe workload buffer. Workloads were aggregated daily for each ward and divided into morning, evening, and night shifts. To verify the adequacy of the initial plan, the actual patient arrivals and length-of-stay data were used to calculate real daily workloads and utilization levels for each ward and shift. To remove the overloads and stabilize workload, refinement was performed with a target of no more than 1 % overutilization.

In part C, a 13-week rotating schedule was developed for the three specialist wards (AOS, VTS, TRS). The goal of this section is to create a cost-efficient nurse scheduling plan that meets the required number of nurses per shift while maintaining balanced workload distribution and continuous coverage. To achieve this, the average daily demand per ward and shift was translated into the corresponding number of nurses needed, forming a weekly template that was repeated over 13 weeks as demand is assumed to be stable across the planning period.

For part D, all instances of overutilisation were collected and analysed on frequency, ward and shift, and utilisation of flexible nurses to cover these instances was considered.

***Results***

**PART A**

Table 1 in the appendix shows that the average number of patients in the daycare ward increases steadily through the morning, peaks between 12 and 14, and gradually declines toward the evening. Moreover, since the patient requires 15 minutes of nursing care per hour, the average hourly nursing demand ranges from 0.09 to 0.59 nurse-hours per hour. This means that the ward experiences a light but continuous workload, with some peaks but never exceeding capacity of one nurse when averaged across working days.

From table 2 in the appendix, the optimal schedule consists of one 8-hour shift from 8 to 16, and two 4-hour shifts covering from 16 to 20 and from 17 to 21. The first shift covers the main daytime workload, while the two overlapping 4-hour shifts are there to maintain continuous presence until the evening and help with creating a short overlap with two nurses on duty. This schedule provides full coverage at a total daily cost of €460 per day.

In table 3, it is shown that the peak utilization is between 12 and 14, while the lowest utilization is in the early morning and late evening. Moreover, the average utilization across the day is around 31%, and the peak staffed nurses are 2 during 17 and 20 when the 4-hour shifts overlap. The results show that demand concentrates around midday when most procedures are performed, while early and late hours show under used capacity. Lastly, a Demand VS Staffing plot was created, showing a smooth curve of required nurse-hours and the stepped staffing profile from the shift allocation (See Appendix, Figure 1).

**PART B**

**Demand and Initial Staffing**  
The average required nurse-hours per shift were low overall, ranging from approximately 0.2 to 4.3 hours. The highest demand is seen in AOS Morning (≈ 4.27 hours), followed by AOS Evening and Night. TRS and VTS shifts presented much lighter workloads, remaining under one nurse’s effective capacity.

Table 4 shows that one nurse per shift is enough for average demand in every ward.  
Morning shifts present the highest workload, especially in AOS, that reflect patient rounds and postoperative recovery. Evening and night shifts require significantly less nursing hours due to lower patient activity.  
Overall, the initial staffing plan provides acceptable coverage, with utilization below the 75 % limit.

**Validation Against Reality**  
We can observe in Table 5 that most shifts operated well below capacity, with mean utilization levels between 5 % and 32 % for TRS and VTS.  
However, AOS Morning showed a higher workload of around 53 % and some short-term overloads on about 3 % of the days (42 events).  
This behaviour matches expectations because mornings are when most admissions, rounds and postoperative checks occur, while evenings and nights are much quieter.  
Overall, the validation results show that the plan is sufficient for almost all wards, but AOS Morning may need extra support during busy periods.

**Refined Staffing Plan**  
As seen in table 6, only AOS Morning required one additional nurse, increasing from 1 to 2 nurses. All other wards and shifts remained unchanged.

The refined plan completely removed the overloads and brought utilization in AOS Morning to safer levels of around 65–70 %.  
This adjustment slightly increases staffing cost but improves service reliability and prevents nurse fatigue.  
The refined plan gives a balanced and realistic baseline for the next stage in Part C, where the weekly schedule will be optimized.

**PART C**

**Weekly Template**

Table 7 shows the weekly template for the required number of nurses per ward and weekday. The results indicate that each ward requires one nurse per shift (morning, evening, and night) throughout the week, confirming a consistent workload pattern across days.

It can be observed that each ward maintains a uniform staffing pattern across all weekdays, implying that patient inflow and care requirements remain stable regardless of the day. The average number of nurses per week is 3 (covering morning, evening, and night shifts). The approximate weekly cost is €1,003 (based on the standard nurse pattern costs provided in the dataset), leading to a total cost of €13,036 for the entire 13-week period.

**13 Week Schedule**

The week demand showed earlier was constant, therefore the weekly template was directly extended into a 13-week rotating schedule. The first week of this rotation is shown in table 8.

All subsequent weeks follow the same structure, as the required staffing pattern does not vary over time. The resulting schedule ensures continuous 24-hour coverage, simplifies planning, and maintains a predictable staffing level that aligns with the utilization limits established in earlier analyses. This consistent structure facilitates easier rotation management, minimizes scheduling complexity, and provides a reliable foundation for integrating flexible nurses in the following section.

**PART D**

When observing table 9, it becomes clear that 42 instances of overutilisation occurred in total. These were all concentrated in the AOS ward during the morning shifts, making up approximately 0.03% of the workload originating from the ward during that shift. These cases are infrequent and sparse, occurring only 42 times over the span of 1785 days (2.3%).

Therefore, it was decided that these cases could be solved by employing flexible nurses when workloads were expected to exceed the capability of 1 nurse. This would result in 1 flexible nurse being contracted for each separate case, which increases the workload capacity to 16 nurse hours as opposed to 8. All overutilisation instances fell well within the 16-hour capacity, so no additional nurse hours were required on any given day. The average utilisation rate of the flexible nurses was 13.2%.

There would be no reduction in the regular weekly cost, however a total variable cost of €6,558.72 must be added to contract flexible nurses. This was calculated using the median income for flexible nurses (Payscale, n.d.). This total cost could be divided by the total number of weeks of the schedule to define a variable weekly cost of approximately €25.72.

***Conclusion***

This project demonstrates the ability of data driven methods to contribute effectively to nurse staffing and scheduling in a hospital setting. Through the analysis of three years' patient data, it became possible to forecast demand, monitor workload variability, and transform these trends into optimal staffing solutions.

In the Daycare Ward, the right combination of one 8 hour and two 4-hour shifts ensured complete coverage at minimum cost with low utilization levels. Within specialist wards, demand analysis revealed clear workload intensity differences, with higher morning capacity requirements for the AOS ward. Adjusting staffing to accommodate these peaks increased service reliability without a spike in cost. The 13-week rotating roster developed in Part C ensured consistent coverage with standardized cost structure, which made planning the workforce over the long term more manageable.

The addition of flexible nurses in Part D provided an adjustable buffer against demand fluctuation at higher variable cost. The comparison between fixed and flexible models highlighted a critical trade-off: flexible staffing enhances responsiveness and overloading risk reduction but should augment rather than replace a well-structured base schedule.

In conclusion, the results present the insight that the integration of forecasting, optimization, and validation allows healthcare organizations to achieve balanced solution maintaining patient care quality, ensuring nurse health, and keeping operational expense within practical levels of available resources.

***Acknowledgement***

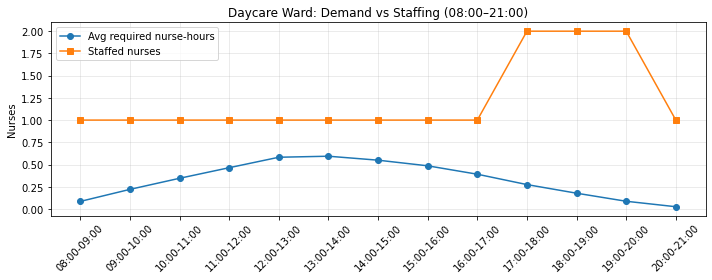
Our group acknowledges the use of AI tools, such as ChatGPT, as a supplementary tutor throughout this assignment. These tools were primarily used to support our understanding of programming concepts and to provide guidance in developing the code. ChatGPT assisted us in creating a program able to analyse and read the patient record data. All the outputs generated using AI were reviewed, tested, and refined by the group.

***Sources***

Payscale. (n.d.). *Registered Nurse (RN) salary in the Netherlands*. Payscale. Retrieved October 13, 2025, from <https://www.payscale.com/research/NL/Job=Registered_Nurse_(RN)/Salary>

***Appendix***

Figure 1: Visualization from Part A “Demand VS Staffing”

  
Table 1: Hourly averages for patients, nurse-hours and required nurses

|  |  |  |  |
| --- | --- | --- | --- |
| **Hour** | **Average Patients** | **Nurse-Hours** | **Required Nurses** |
| 08:00-09:00 | 0.342 | 0.085 | 1 |
| 09:00-10:00 | 0.883 | 0.221 | 1 |
| 10:00-11:00 | 1.382 | 0.345 | 1 |
| 11:00-12:00 | 1.858 | 0.464 | 1 |
| 12:00-13:00 | 2.328 | 0.582 | 1 |
| 13:00-14:00 | 2.374 | 0.594 | 1 |
| 14:00-15:00 | 2.196 | 0.549 | 1 |
| 15:00-16:00 | 1.942 | 0.486 | 1 |
| 16:00-17:00 | 1.564 | 0.391 | 1 |
| 17:00-18:00 | 1.098 | 0.274 | 1 |
| 18:00-19:00 | 0.710 | 0.178 | 1 |
| 19:00-20:00 | 0.347 | 0.087 | 1 |
| 20:00-21:00 | 0.102 | 0.025 | 1 |

Table 2: Nurse scheduling shifts, count and cost

|  |  |  |  |
| --- | --- | --- | --- |
| **Shift** | **Time** | **Count** | **Cost** |
| 8h | 08:00-16:00 | 1 | 220 |
| 4h | 16:00-20:00 | 1 | 120 |
| 4h | 17:00-21:00 | 1 | 120 |
| **Tot daily cost** |  |  | **460** |

Table 3: Nurse utilisation rate per hour

|  |  |  |  |
| --- | --- | --- | --- |
| **Hour** | **Average required Nurse-Hours** | **Staffed Nurses** | **Utilization %** |
| 08:00-09:00 | 0.09 | 1 | 8.54 |
| 09:00-10:00 | 0.22 | 1 | 22.07 |
| 10:00-11:00 | 0.35 | 1 | 34.55 |
| 11:00-12:00 | 0.46 | 1 | 46.45 |
| 12:00-13:00 | 0.58 | 1 | 58.21 |
| 13:00-14:00 | 0.59 | 1 | 59.36 |
| 14:00-15:00 | 0.55 | 1 | 54.89 |
| 15:00-16:00 | 0.49 | 1 | 48.56 |
| 16:00-17:00 | 0.39 | 1 | 39.11 |
| 17:00-18:00 | 0.27 | 2 | 13.72 |
| 18:00-19:00 | 0.18 | 2 | 8.88 |
| 19:00-20:00 | 0.09 | 2 | 4.34 |
| 20:00-21:00 | 0.03 | 1 | 2.54 |

Table 4: Required nurse-hours per shift separated by wards

|  |  |  |  |
| --- | --- | --- | --- |
| **Ward** | **Shift** | **Mean** | **Std** |
| AOS | morning | 4.274623 | 1.806100 |
| AOS | evening | 2.564774 | 1.083660 |
| AOS | night | 1.709849 | 0.722440 |
| TRS | morning | 0.542469 | 0.685082 |
| TRS | evening | 0.325482 | 0.411049 |
| TRS | night | 0.216988 | 0.274033 |
| VTS | morning | 0.943403 | 0.886417 |
| VTS | evening | 0.566042 | 0.531850 |
| VTS | night | 0.377361 | 0.354567 |

Table 5: Validation summary

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ward** | **Shift** | **Utilisation mean** | **Utilisation std** | **Overutilisation fraction** | **Overutilisation count** |
| AOS | evening | 0.320356 | 0.135648 | 0.000000 | 0 |
| AOS | morning | 0.533927 | 0.226081 | 0.031698 | 42 |
| AOS | night | 0.213571 | 0.090432 | 0.000000 | 0 |
| TRS | evening | 0.040632 | 0.051394 | 0.000000 | 0 |
| TRS | morning | 0.067721 | 0.085657 | 0.000000 | 0 |
| TRS | night | 0.027088 | 0.034263 | 0.000000 | 0 |
| VTS | evening | 0.070830 | 0.066637 | 0.000000 | 0 |
| VTS | morning | 0.118050 | 0.111062 | 0.000000 | 0 |
| VTS | night | 0.047220 | 0.044425 | 0.000000 | 0 |

Table 6: Refined Staffing per Ward and Shift

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ward** | **Shift** | **Mean Required Hours** | **Initial Nurses** | **Refined Nurses** | **Overutil After (%)** |
| AOS | Morning | 4.27 | 1 | 2 | 0 |
| AOS | Evening | 2.56 | 1 | 1 | 0 |
| AOS | Night | 1.71 | 1 | 1 | 0 |
| TRS | Morning | 0.54 | 1 | 1 | 0 |
| TRS | Evening | 0.33 | 1 | 1 | 0 |
| TRS | Night | 0.22 | 1 | 1 | 0 |
| VTS | Morning | 0.94 | 1 | 1 | 0 |
| VTS | Evening | 0.57 | 1 | 1 | 0 |
| VTS | Night | 0.38 | 1 | 1 | 0 |

Table 7: Weekly template

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ward** | **Weekday** | **Morning Nurses** | **Evening Nurses** | **Night Nurses** |
| AOS | Monday | 1 | 1 | 1 |
| AOS | Tuesday | 1 | 1 | 1 |
| AOS | Wednesday | 1 | 1 | 1 |
| AOS | Thursday | 1 | 1 | 1 |
| AOS | Friday | 1 | 1 | 1 |
| AOS | Saturday | 1 | 1 | 1 |
| AOS | Sunday | 1 | 1 | 1 |
| VTS | Monday | 1 | 1 | 1 |
| VTS | Tuesday | 1 | 1 | 1 |
| VTS | Wednesday | 1 | 1 | 1 |
| VTS | Thursday | 1 | 1 | 1 |
| VTS | Friday | 1 | 1 | 1 |
| VTS | Saturday | 1 | 1 | 1 |
| VTS | Sunday | 1 | 1 | 1 |
| TRS | Monday | 1 | 1 | 1 |
| TRS | Tuesday | 1 | 1 | 1 |
| TRS | Wednesday | 1 | 1 | 1 |
| TRS | Thursday | 1 | 1 | 1 |
| TRS | Friday | 1 | 1 | 1 |
| TRS | Saturday | 1 | 1 | 1 |
| TRS | Sunday | 1 | 1 | 1 |

Table 8: 13-week schedule excerpt

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Week** | **Ward** | **Weekday** | **Morning Nurses** | **Evening Nurses** | **Night Nurses** |
| 1 | AOS | Monday | 1 | 1 | 1 |
| 1 | AOS | Tuesday | 1 | 1 | 1 |
| 1 | AOS | Wednesday | 1 | 1 | 1 |
| 1 | AOS | Thursday | 1 | 1 | 1 |
| 1 | AOS | Friday | 1 | 1 | 1 |
| 1 | AOS | Saturday | 1 | 1 | 1 |
| 1 | AOS | Sunday | 1 | 1 | 1 |
| 1 | VTS | Monday | 1 | 1 | 1 |
| 1 | VTS | Tuesday | 1 | 1 | 1 |
| 1 | VTS | Wednesday | 1 | 1 | 1 |
| 1 | VTS | Thursday | 1 | 1 | 1 |
| 1 | VTS | Friday | 1 | 1 | 1 |
| 1 | VTS | Saturday | 1 | 1 | 1 |
| 1 | VTS | Sunday | 1 | 1 | 1 |
| 1 | TRS | Monday | 1 | 1 | 1 |
| 1 | TRS | Tuesday | 1 | 1 | 1 |
| 1 | TRS | Wednesday | 1 | 1 | 1 |
| 1 | TRS | Thursday | 1 | 1 | 1 |
| 1 | TRS | Friday | 1 | 1 | 1 |
| 1 | TRS | Saturday | 1 | 1 | 1 |
| 1 | TRS | Sunday | 1 | 1 | 1 |

Table 9: Overutilisation instances

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Ward** | **Date** | **Shift** | **Workload hours** | **assigned nurses** | **available hours** | **Utilization rate (%)** |
| AOS | 2010-04-06 | morning | 9.7500 | 1 | 8 | 1.218750 |
| AOS | 2010-06-01 | morning | 9.4375 | 1 | 8 | 1.179688 |
| AOS | 2010-06-04 | morning | 8.5625 | 1 | 8 | 1.070312 |
| AOS | 2010-06-07 | morning | 8.0625 | 1 | 8 | 1.007812 |
| AOS | 2010-06-08 | morning | 10.6875 | 1 | 8 | 1.335938 |
| AOS | 2010-06-10 | morning | 8.9375 | 1 | 8 | 1.117188 |
| AOS | 2010-06-15 | morning | 10.5000 | 1 | 8 | 1.312500 |
| AOS | 2010-06-22 | morning | 8.0625 | 1 | 8 | 1.007812 |
| AOS | 2010-09-21 | morning | 10.1250 | 1 | 8 | 1.265625 |
| AOS | 2011-02-08 | morning | 8.2500 | 1 | 8 | 1.031250 |
| AOS | 2011-03-21 | morning | 9.3125 | 1 | 8 | 1.164062 |
| AOS | 2011-04-05 | morning | 8.0625 | 1 | 8 | 1.007812 |
| AOS | 2011-04-08 | morning | 8.1250 | 1 | 8 | 1.015625 |
| AOS | 2011-04-12 | morning | 8.8750 | 1 | 8 | 1.109375 |
| AOS | 2011-04-15 | morning | 8.6875 | 1 | 8 | 1.085938 |
| AOS | 2011-04-26 | morning | 8.6250 | 1 | 8 | 1.078125 |
| AOS | 2011-05-06 | morning | 8.0625 | 1 | 8 | 1.007812 |
| AOS | 2011-05-16 | morning | 9.0000 | 1 | 8 | 1.125000 |
| AOS | 2012-01-19 | morning | 8.7500 | 1 | 8 | 1.093750 |
| AOS | 2012-01-26 | morning | 9.6875 | 1 | 8 | 1.210938 |
| AOS | 2012-02-21 | morning | 8.2500 | 1 | 8 | 1.031250 |
| AOS | 2012-02-23 | morning | 8.1875 | 1 | 8 | 1.023438 |
| AOS | 2012-03-01 | morning | 9.8750 | 1 | 8 | 1.234375 |
| AOS | 2012-03-05 | morning | 8.2500 | 1 | 8 | 1.031250 |
| AOS | 2012-04-25 | morning | 8.0625 | 1 | 8 | 1.007812 |
| AOS | 2012-04-26 | morning | 10.6250 | 1 | 8 | 1.328125 |
| AOS | 2012-05-03 | morning | 9.4375 | 1 | 8 | 1.179688 |
| AOS | 2012-05-07 | morning | 8.3125 | 1 | 8 | 1.039062 |
| AOS | 2012-05-08 | morning | 8.1250 | 1 | 8 | 1.015625 |
| AOS | 2012-08-08 | morning | 8.1250 | 1 | 8 | 1.015625 |
| AOS | 2012-11-21 | morning | 8.2500 | 1 | 8 | 1.031250 |
| AOS | 2012-12-17 | morning | 8.5000 | 1 | 8 | 1.062500 |
| AOS | 2013-04-17 | morning | 10.1250 | 1 | 8 | 1.265625 |
| AOS | 2013-04-24 | morning | 9.7500 | 1 | 8 | 1.218750 |
| AOS | 2013-05-01 | morning | 8.6250 | 1 | 8 | 1.078125 |
| AOS | 2013-07-10 | morning | 8.4375 | 1 | 8 | 1.054688 |
| AOS | 2013-07-12 | morning | 8.4375 | 1 | 8 | 1.054688 |
| AOS | 2013-07-16 | morning | 10.8750 | 1 | 8 | 1.359375 |
| AOS | 2013-07-17 | morning | 11.2500 | 1 | 8 | 1.406250 |
| AOS | 2013-07-18 | morning | 9.9375 | 1 | 8 | 1.242188 |
| AOS | 2013-07-19 | morning | 10.2500 | 1 | 8 | 1.281250 |
| AOS | 2013-08-28 | morning | 9.3750 | 1 | 8 | 1.171875 |