Background

The CEO of Edison Cars AG was very satisfied with your work on implementing the new predictive maintenance system. As a result, he has decided to engage your team for a follow-up project.

Given the strong demand for e-mobility vehicle batteries, Edison Cars AG is on the verge of opening another facility for a new customer from the automotive sector with 10 robots. However, due to country-specific requirements, Edison Cars AG cannot use the same robots as in its existing facilities (see week 1). Accordingly, Edison Cars AG purchased robots from the alternative supplier, Kaku. Respective robots work like the ones from Kuka, but not the same (note: still use the system from week 1. No new training is required).

Kaku, a renowned robotics company, strongly advises conducting semi-annual maintenance to ensure their robots' smooth functioning and longevity, specifically recommending maintenance intervals at every 2500 data points. While this approach has proven effective in most cases, it is essential to acknowledge the existence of occasional deviations and unforeseen maintenance requirements that may arise. Further, an employee has extensive hands-on experience with Kaku robots and has encountered various scenarios requiring reactive actions. Their experience working directly with the robots provides valuable insights into the frequency and nature of maintenance. He also points out that there can still be instances of unexpected issues requiring unplanned maintenance (Note: Be aware that in case of maintenance, both the welder and the screws are checked (and replaced if necessary)).

Edison Cars AG operates a new fleet of 10 industrial robots crucial to producing e-mobility vehicle batteries. The flow rate of manufactured batteries is 0.5 batteries per hour. This indicates that, on average, half a battery is manufactured within an hour. Each battery comes at a sales price of 10.000 Euro. However, failure to address maintenance needs promptly can result in downtime and potential profit loss for Edison AG. The estimated lost profit due to maintenance-related downtime is 5.000 Euro per hour. This highlights the significance of efficient maintenance practices to minimize disruptions and maximize productivity. Skilled maintenance personnel are required to execute the maintenance tasks. The hourly wage for the maintenance technician at Edison AG is 50 euros. This professional is responsible for carrying out routine inspections, identifying issues, and performing necessary repairs to ensure the robots' optimal performance. Additionally, Edison AG utilizes various sensors to monitor the robots' health and detect potential problems. A single temperature sensor costs 300 euros, while a vibration sensor costs 200 euros. If the end effector breaks down, additional costs of 10,000 euros are incurred. These sensors play a crucial role in predictive maintenance, enabling the detection of anomalies and helping prevent major breakdowns.

The estimated time required for planned maintenance is approximately 2 hours. During this planned maintenance, the technician performs routine checks, inspections, and necessary adjustments to prevent potential issues and ensure optimal performance. However, unforeseen circumstances can arise, leading to unplanned maintenance requirements. In the case of Edison AG, the estimated time for unplanned maintenance is approximately 5 hours. When unexpected issues occur, the skilled technician is promptly deployed to identify and rectify the problem, minimizing downtime and restoring functionality. Further, to maintain an efficient maintenance process, Edison AG carefully manages its inventory and consumables. The time until the intermediate storage of spare parts or inventory is depleted is approximately 1 hour. Once these intermediate storages are depleted, the production line stops. There are no intermediate storages in reactive maintenance as they are rarely used due to the low frequency of maintenance and, thus, the high storage cost per article. The storage costs for the intermediate storage do not need to be considered. Due to the low frequency of maintenance in reactive maintenance, the technician is on standby and requires one hour to

reach the production facility. During the rework phase, the technician checks the condition of the batteries and, if necessary, corrects the flaws. This is because the quality of the batteries needs to be ensured. Rework time takes 2 hours for planned maintenance and 5 hours for unplanned maintenance.
Please note that the robots are aligned as parts of a production chain, which means that the downtime of one robot will lead to a production stop of the entire line.

Maintenance costs

Material costs encompass the expenses associated with procuring and utilizing various materials required for repairs and maintenance activities. This includes components, spare parts, lubricants, and other consumables to keep equipment and machinery in optimal condition. Material costs are a vital aspect of maintenance budgets as they directly impact the availability of necessary resources to address maintenance needs efficiently. By effectively managing material costs, organizations can ensure the availability of the right parts at the right time, minimizing downtime and optimizing maintenance operations. The Edison Cars AG ensures that these materials are always available to minimize downtime. The material costs are incurred only during unplanned maintenance.

Supervisor costs refer to the expenses incurred in managing and overseeing maintenance activities. This includes the wages, salaries, and benefits of supervisors responsible for coordinating maintenance teams, planning and scheduling maintenance tasks, monitoring progress, and ensuring safety and quality standards compliance. Supervisor costs are essential to maintenance budgets as they represent the human resources required to organize and execute maintenance operations efficiently. Organizations can enhance productivity, streamline workflows, and maintain high maintenance performance standards by investing in competent and skilled supervisors. Due to the low number of robots on the production line, only one technician is required for the maintenance.

Lost profit costs represent the potential revenue or profit forgone due to maintenance-related disruptions. This includes the impact of reduced production capacity, delayed deliveries, canceled orders, or decreased customer satisfaction that may result from equipment downtime or suboptimal performance. Lost profit costs go beyond the immediate financial impact of downtime and can have long-term implications for an organization's overall profitability and competitiveness. Organizations can minimize lost profit costs and protect their bottom line by prioritizing maintenance activities and adopting proactive measures to prevent failures. For Edison Cars AG, only the price for the batteries that can’t be manufactured due to the halted production line must be considered.

Additional costs refer to unexpected or unplanned expenses that arise during maintenance activities. These costs include unforeseen repairs, equipment upgrades or replacements, outsourcing maintenance tasks, hiring specialized contractors, or any other unforeseen expenditures. Additional costs can arise due to factors such as equipment aging, unforeseen breakdowns, changes in maintenance requirements, or evolving regulations. Effective maintenance planning and budgeting aim to minimize additional costs by incorporating contingencies, conducting thorough assessments, and implementing preventive measures to address potential risks or challenges. Only the material costs for the sensor infrastructure are considered for the calculation.

Task

Determine from the given information about predictive, preventive, and reactive maintenance the incurring maintenance costs for one year (note: one year equals 5000 data points). From this, the ecological and social sustainability associated with each type of maintenance is also determined. Research whether the most economical is the most ecological and/or social. Based on your results, provide Edison Cars AG with a specific recommendation when selecting an optimal maintenance strategy.

Input

For this task, you will be provided with the following input:

- Sensor data from 10 robots, each with 4 temperature and 4 vibration sensors.
- Information on individual maintenance strategies as well as their related maintenance intervals and maintenance costs
- Further information for predictive maintenance and machine learning. These are possible approaches that have different advantages and disadvantages. Of course, you can also use other approaches and resources:
    - Code quality: browserstack.com
    - Confusion Matrix:
        - https://towardsdatascience.com/understanding-confusion-matrix-a9ad42dcfd62
        - https://scikit-learn.org/stable/modules/generated/sklearn.metrics.confusion_matrix.html

Submission

The following documents must be emailed to s3g@fim-rc.de as one zip folder by 02:00 PM on 03.06.2024:

- Code to reproduce the results. This includes how the data was labeled, how the model from week 1 was used for the new data, and how maintenance costs were calculated.
- A PowerPoint presentation explaining your calculations, how you applied the model, and how you analyzed the data. You should be able to present your approach in the next lecture.

Keep in mind

The content provided here serves only as a starting point. Feel free to use your own approaches and algorithms to get the best possible maintenance intervals.

The following aspects are important for the assessment of your submission:

- Code quality: The code must be executable, readable, commented, and adhere to the output format.
- Use the data not only for calculating predictive maintenance but also for calculating preventive and reactive maintenance.
- The explanation of why you chose a specific maintenance type should be understandable. Please provide sources that justify your argumentation.