MENGM0056 - Product and Production Systems
Scenario 5: Electric Vehicles - Battery Module and Pack Assembly

Hand-out for Group Coursework (2025/26)

UUID seed: 123e4567-e89b-12d3-a456-426614174001 **Checksum:** 7e4c0fdd748e

Purpose

This scenario covers a mid-volume EV battery module and pack assembly line. You receive seeded baseline parameters and must propose improvements that raise yield and throughput while maintaining safety and compliance, within typical operational constraints.

Narrative

The factory assembles 60 kWh battery packs from twelve 5 kWh modules using 21700 cells. Weld rework and pack end-of-line capacity are jointly constraining output. Field incidents in hot weather highlight thermal gradients at fast charge. Capital expenditure is limited in the short term; process, policy, and design-for-manufacture changes are preferred.

Entities and flow (fixed structure)

Incoming cell grading → Cell grouping → Module frame assembly → Laser tab-welding → Module end-of-line (EOL) electrical test → Pack assembly and busbar fit → BMS integration and firmware flash → Pack EOL (insulation resistance, HV leak, charge/discharge) → Leak test → Pack-out.

Baseline parameters (seeded)

Global

Shifts per day	2
Shift length	8.0 h
Target packs/day	112
OEE target	68%
Demand CV	0.112

Stations and timings

Stage	Count	Cycle/Test time	Notes
Cell grading testers	4	101.8 s/batch	Capacity sets bin inventory
Module assembly lines	1	261.4 s/module	Frame, placement, torque

Laser weld heads	2	42.6 s/module	Weld splash rework loop
Module EOL testers	3	140.6 s/module	Electrical characterisation
Pack assembly line	1	926.0 s/pack	Mechanical fit and busbars
BMS flash stations	2	355.0 s/pack	Firmware load and config
Pack EOL testers	4	2251.0 s/pack	Insulation, charge/discharge
Leak testers	1	465.0 s/pack	Enclosure integrity

Quality, variation, and reliability

Weld defect rate	0.0176
Weld rework success	0.896
Module EOL false fail	0.0037
Pack EOL false fail	0.0044
BMS mis-flash rate	0.0022
Leak test fail (true)	0.0103
Cell capacity σ	2.93% of nominal
TIM thickness σ	0.135 mm

Resource	MTBF (min)	MTTR (min)
CellGrading	320.7	26.5
ModuleAssembly	428.6	19.3
LaserWeld	183.7	12.4
ModuleEOL	277.7	16.2
PackAssembly	609.6	26.1
BMSFlash	375.4	18.0
PackEOL	454.2	14.7
LeakTest	786.6	16.1

Costs

Scrap cost (per pack)	£550.58
Rework labour	£23.16 /h
Electricity tariff	31.9 p/kWh
Nitrogen shield gas	£5.4 /h
TIM material	£6.02 /pack

Required KPIs

- Pack first-pass yield (FPY); module FPY; rolled throughput yield (RTY).
- Throughput (packs/day), EOL tester utilisation, and on-time delivery probability.
- Rework rate and rework hours/day; scrap cost per pack.
- Mean cell-to-cell capacity delta in module; maximum module temperature rise under 2C charge (if analysed).
- Queue length before pack EOL; WIP across welding and EOL.

Techniques to apply (choose appropriately)

- **Modelling & KPIs**: Genealogy/traceability KPI design; RTY ladder; capacity calculations.
- **CAE**: Thermal model of module and cooling interface to evaluate temperature gradients; busbar stiffness if vibration is considered.

- **Mathematical programming**: Cell grouping to minimise module variance; EOL tester scheduling and buffer sizing.
- **Uncertainty modelling**: Cell capacity distribution; weld defect probabilities; mis-flash and false-fail rates; Monte Carlo service-level estimation.
- **Simulation**: Discrete-event simulation of the whole line, including welding rework loop and EOL blocking; optional agent-based detail for operator–cobot interaction.
- **Metaheuristic optimisation**: Weld parameter set search (pulse energy, speed, focus) under FPY and cycle constraints; TIM thickness optimisation with thermal penalty.

Improvement levers (examples, not exhaustive)

- Introduce graded cell-binning rules to reduce intra-module variance and quantify warranty risk impact.
- Reallocate module vs. pack EOL testers by time-of-day to relieve peak blocking; adjust buffers accordingly.
- Tune weld parameters to cut splash while respecting takt; compare search vs. DOE.
- Reduce TIM thickness variance via supplier spec and quantify ΔT reduction at fast charge.
- Evaluate preventive maintenance on weld heads vs. adding a small rework bench; compare cost per additional good pack.

Deliverables

1. A report (max 20 sides of A4 including figures and references; appendices unmarked but admissible as evidence).
2. Executive summary for senior management (max one page).
3. Model files (e.g., simulation, optimisation, CAE) as appendices/evidence.

Assessment emphasis

Clarity of problem framing and KPI choice; correctness and transparency of models; appropriateness of technique selection; quality of experimental design; depth of analysis on yield, EOL capacity, and thermal performance; and persuasiveness of recommendations under operational constraints.

Data ethics and reproducibility

Report your UUID seed and any random seeds used. Include enough detail to allow independent regeneration of your parameter tables.