

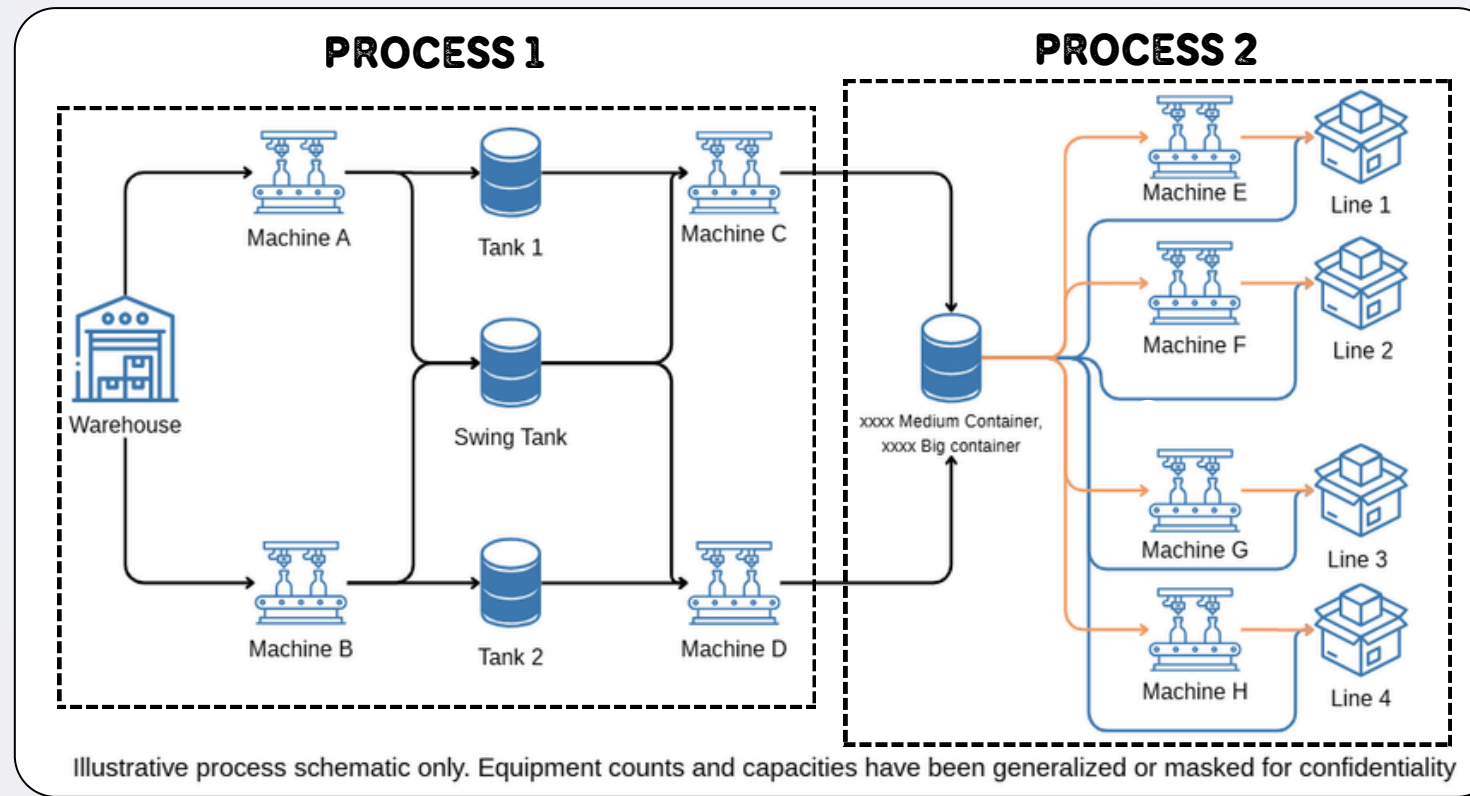
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BACKGROUND & PROBLEM STATEMENT

BACKGROUND

Abbott's plant produces a range of powder products, such as sachets, cans, and pouches, through a multi-stage manufacturing process involving Machines, Tanks, blending lines, and packaging lines. Production planning is complex as different products compete for shared resources while having different processing rates, equipment compatibilities, and cleaning requirements.



Current solution

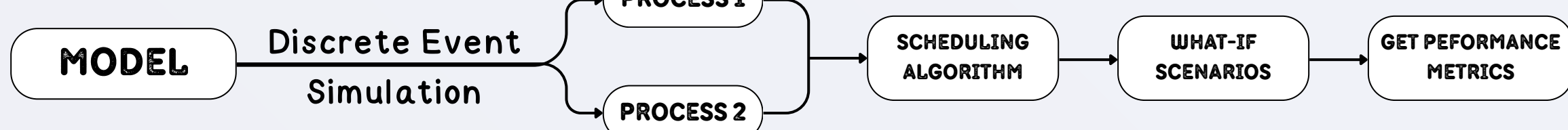
Manual production scheduling by planners

Problem with current solution

Complex production constraints make manual scheduling difficult to optimize, leading to waiting time, machine starvation, longer makespan, and reduced equipment utilization as production complexity increases.

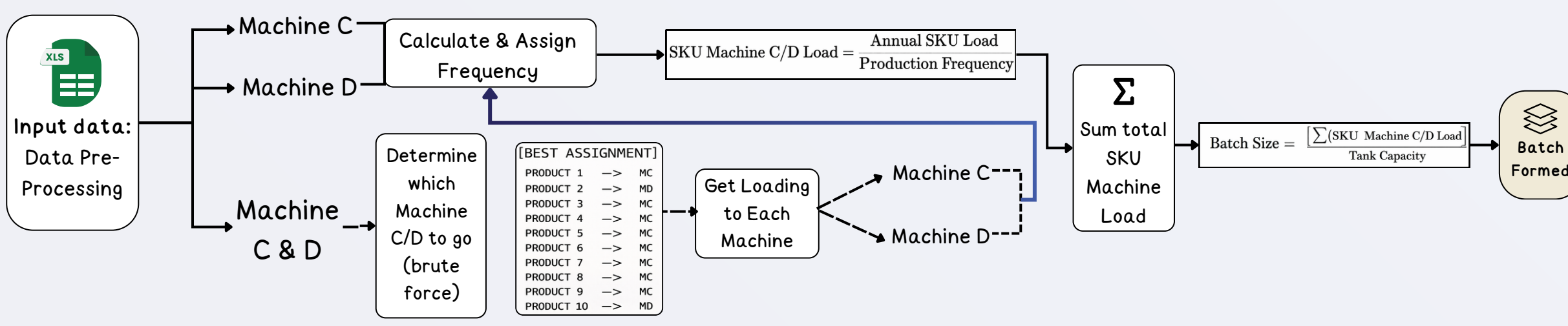
METHODOLOGY

Divided the end-to-end process into two independent workflows (Process 1 & Process 2) and merged them into one at the end.



PROCESS 1 DESIGN

Step 1: Batching Formation



Step 2: Constraints Modeling

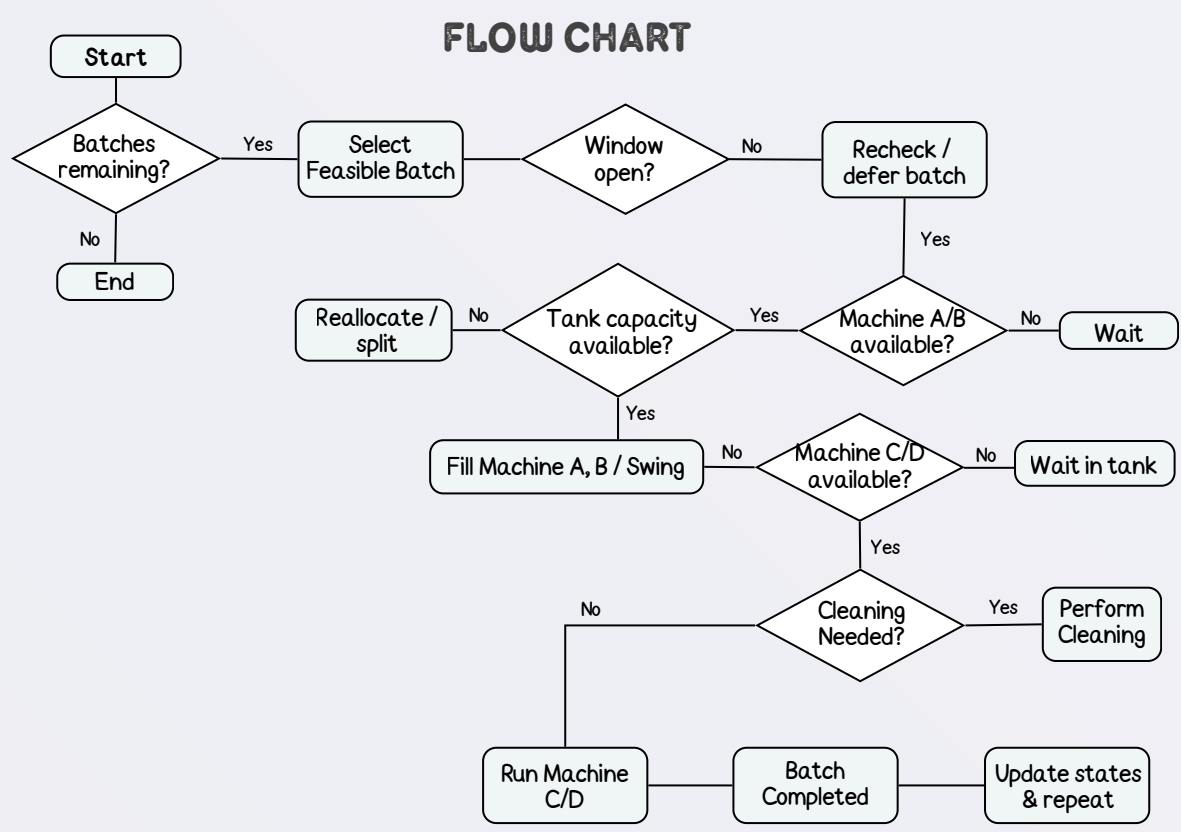
Schedule x satisfies all constraints:

$$x \in \mathcal{F} = C_{cap} \cap C_{seq} \cap C_{cn} \cap C_{time}$$

- C_{cap} = Capacity Constraints
- C_{seq} = Sequence/transition Constraints
- C_{cn} = Cleaning Constraints
- C_{time} = Production Window Constraints

Constraints were enforced implicitly via state-dependent feasibility checks rather than an explicit mathematical program. Thus, each action was executed only if it satisfied all operational conditions

Step 3: Discrete Event Simulation



Step 4: Scheduling Method

A greedy lexicographic rule ranks the most promising next batches. Backtracking then tests these choices recursively and rolls back whenever a branch becomes infeasible or worse than the current best schedule.

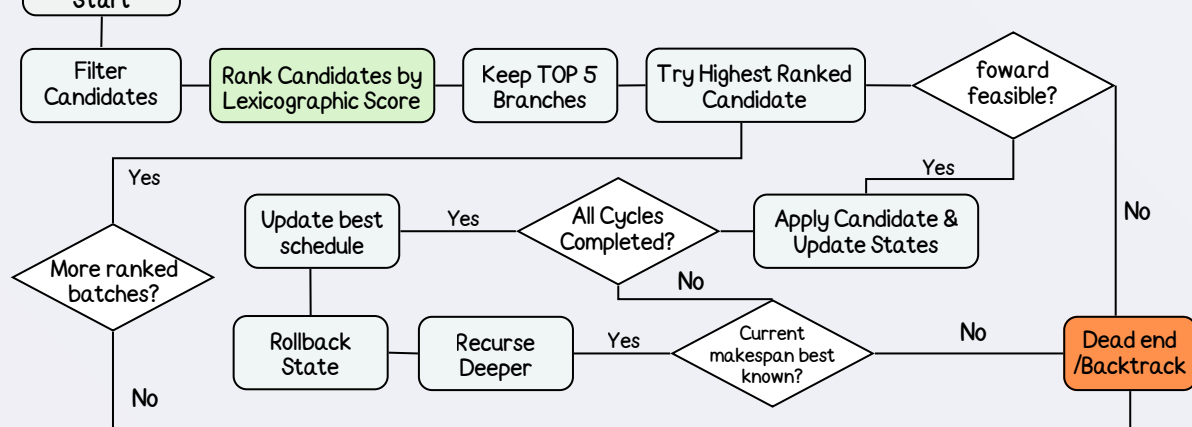
LEXICOGRAPHIC RULE

$$score(c) = \text{lex} (z_c, h_c^{close}, n_c^{cycle}, w_c^{slow}, \rho_c, h_c^{starve}, t_c^{mc-end}, a_c)$$

- z_c = urgency zone
- h_c^{close} = hours to production-window close
- n_c^{cycle} = cycle continuity flag
- w_c^{slow} = Machine AB-slow flag
- ρ_c = Machine AB to Machine CD ratio
- h_c^{starve} = predicted C-D starving hours
- t_c^{mc-end} = predicted C-D completion time
- a_c = fill/C-D alignment term

The scheduler explores the highest-ranked branches first, while depth-first backtracking and rollback are used to recover from infeasible or suboptimal decisions. Branches are pruned if they violate forward feasibility, repeat a previously visited system state, or cannot outperform the current best makespan

SCHEDULING & BACKTRACKING FLOWCHART

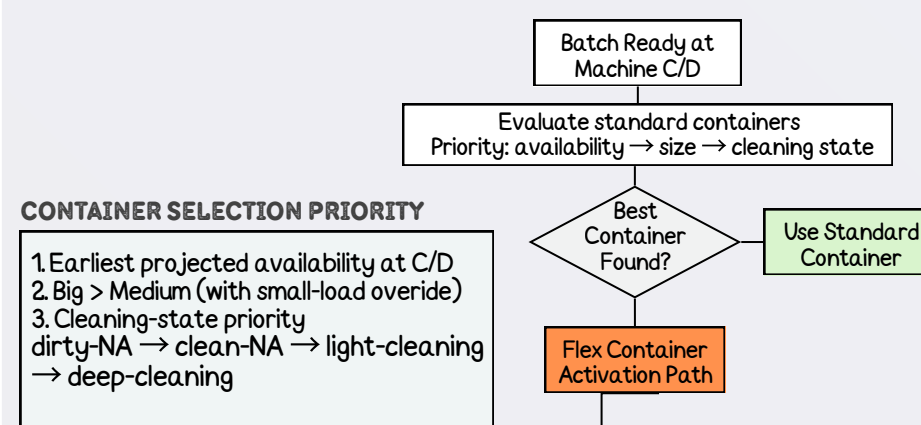


PROCESS 2 DESIGN

Container Lifecycle



Container Choice

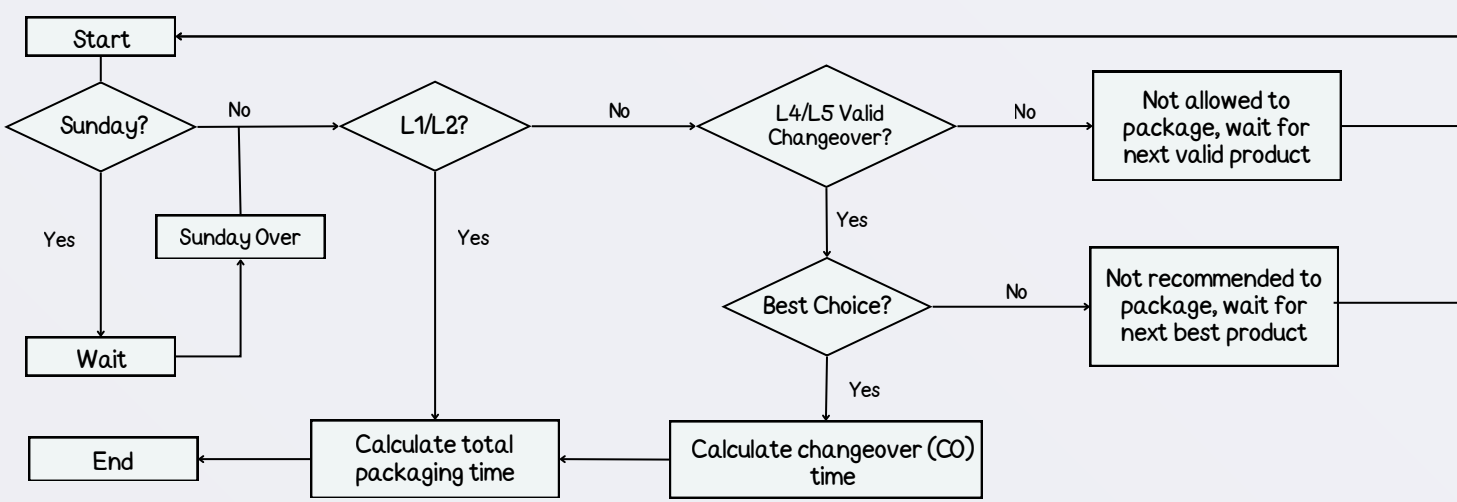


Outputs / Validation

- Generated audit-ready line histories to verify downstream line utilisation and sequencing behaviour.
- Tracked every container trip to validate warehouse movement, line usage, return flow, and reuse consistency.
- Exported cleaning queue states to confirm correct shared-bay contention and cleaning-duration logic.
- Applied legality checks to ensure no forbidden changeovers, valid cleaning states, and consistent downstream execution.

- Containers cycle between the warehouse, Machine C/D, and packaging lines.
- After use, each container may require no cleaning, dry-cleaning, or deep-cleaning before returning to the ready pool.
- All cleaning is handled by a single shared warehouse cleaning bay; container turnaround directly affects downstream feasibility and dryer stall risk.

Line Behaviour



Calculation

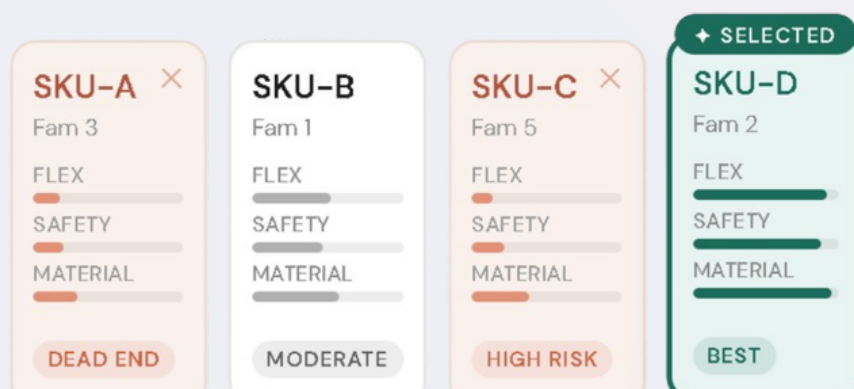
$$\text{Package Units} = \frac{\text{Mass of SKU at line}}{\text{Unit weight of SKU}}$$

$$L1/L2 \text{ Packaging Time} = \frac{\text{Package Units}}{R_{100}} \times \text{POEE} \times SA$$

$$L4/L5 \text{ Packaging Time} = \frac{\text{Package Units}}{R_{100}} \times \text{FOEE}$$

$R_{100} = 100\%$ OEE line rate
 $\text{POEE} = \text{performance OEE factor}$
 $SA = \text{schedule availability factor}$

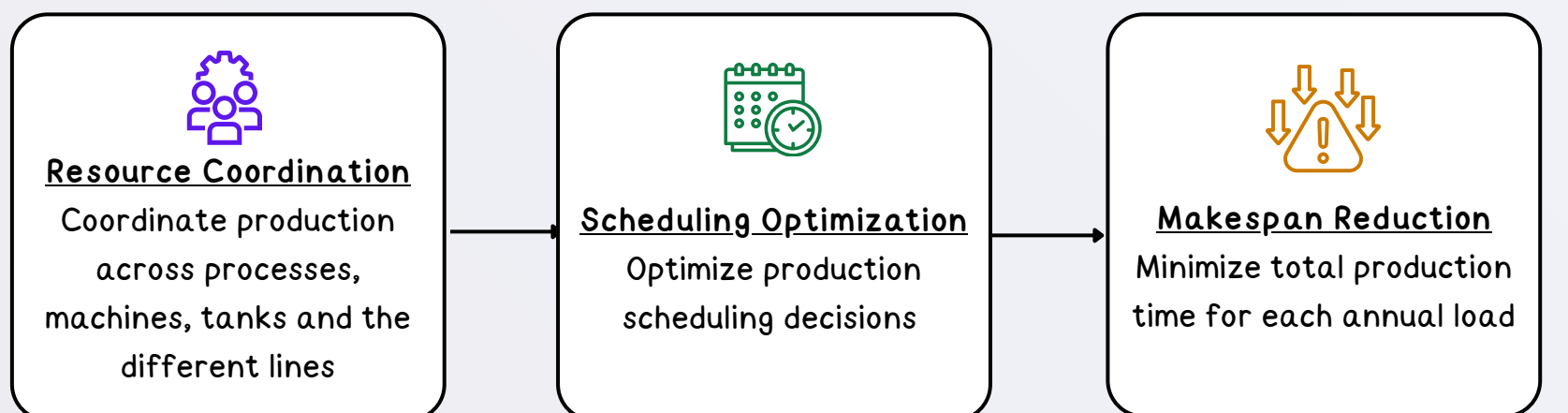
L4/5 Selection Mechanism



L4/5: SKU selection is treated as a constrained heuristic optimisation problem. Instead of assigning the next available SKU directly, the model evaluates **feasible candidates** based on their impact on future line flexibility, transition risk, material support, and downstream stability. The selected option is therefore the one that best sustains packaging flow while reducing the likelihood of disruptive or infeasible future changeovers.

- Feasible Now**: Materials & capacity confirmed available
- Future-Friendly**: Keeps widest range of follow-on options
- Avoids Dead Ends**: No forbidden changeovers locked in
- Uses Available Material**: Aligned with near-future inbound stock
- Lower Changeover Risk - Reduces Downstream Disruption**: Transition stays within safe, low-loss bounds — keeping packaging flow smooth

OBJECTIVES



RESULTS & STATISTICS

PRODUCTION SCHEDULE (EXCERPTED OUTPUT)

This compact view shows the batch-level realization of the discrete-event schedule. For every batch, the model records the selected equipment, start and finish times, intermediate holding resource, and downstream destination, making visible the synchronization logic required to satisfy shared-machine and inter-stage timing constraints.

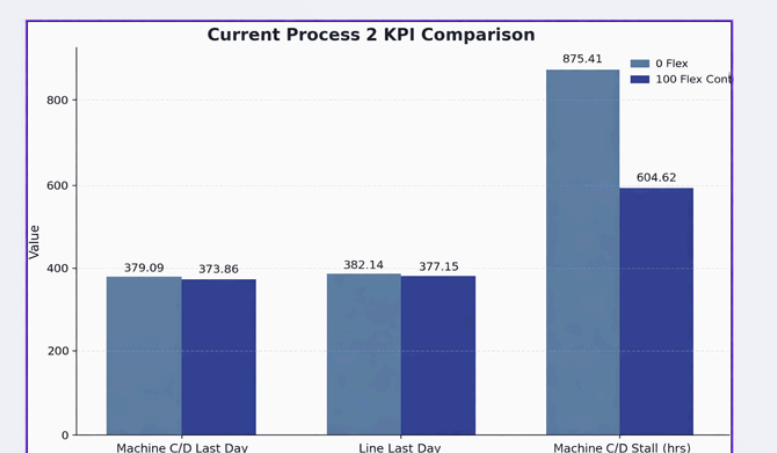
Final Packaging Makespan: 382.14 Days
Final C/D Makespan: 379.09 Days

Product	Load (t)	Machine	A/B Start Hour	A/B End Hour	A/B Wait Hour	Available Tanks	Tanks Seized	Tank Release Hour	Machine C/D	C/D Start Hour	C/D End Hour	C/D Wait Hour	Container	Line(s)	Type of cleaning
A	34.8	A	0.0	64.4	0.0	T1-2, T1-3, 5	T1-1	64.4	C	64.4	147.6	0.0	Big, Medium	L4, L5	—
B	55.1	B	0.0	27.1	0.0	T2-2, T2-3, 5	T2-1	27.1	D	27.1	70.5	0.0	Big, Medium	L2, L4, L5	—
A	24.8	A	24.4	48.8	0.0	T1-3, 5	T1-2	67.6	C	70.6	120.8	16.8	Big, Medium	L4, L5	—
B	65.1	B	27.1	64.2	0.0	T2-3, 5	T2-2	70.5	D	80.5	121.8	10.2	Big, Medium	L2, L4, L5	—
A	24.8	A	48.8	93.2	0.0	T1-3, 5	T1-1	120.8	C	120.8	168	37.6	Big, Medium	L4, L5	—
B	65.1	B	64.2	101.4	0.0	T2-3, 5	T2-1	121.8	D	121.8	161.2	20.4	Big, Medium	L2, L4, L5	—
A	24.8	A	83.2	107.6	0.0	T1-3, 5	T1-2	168	C	160	207.3	49.4	Big, Medium	L4, L5	—

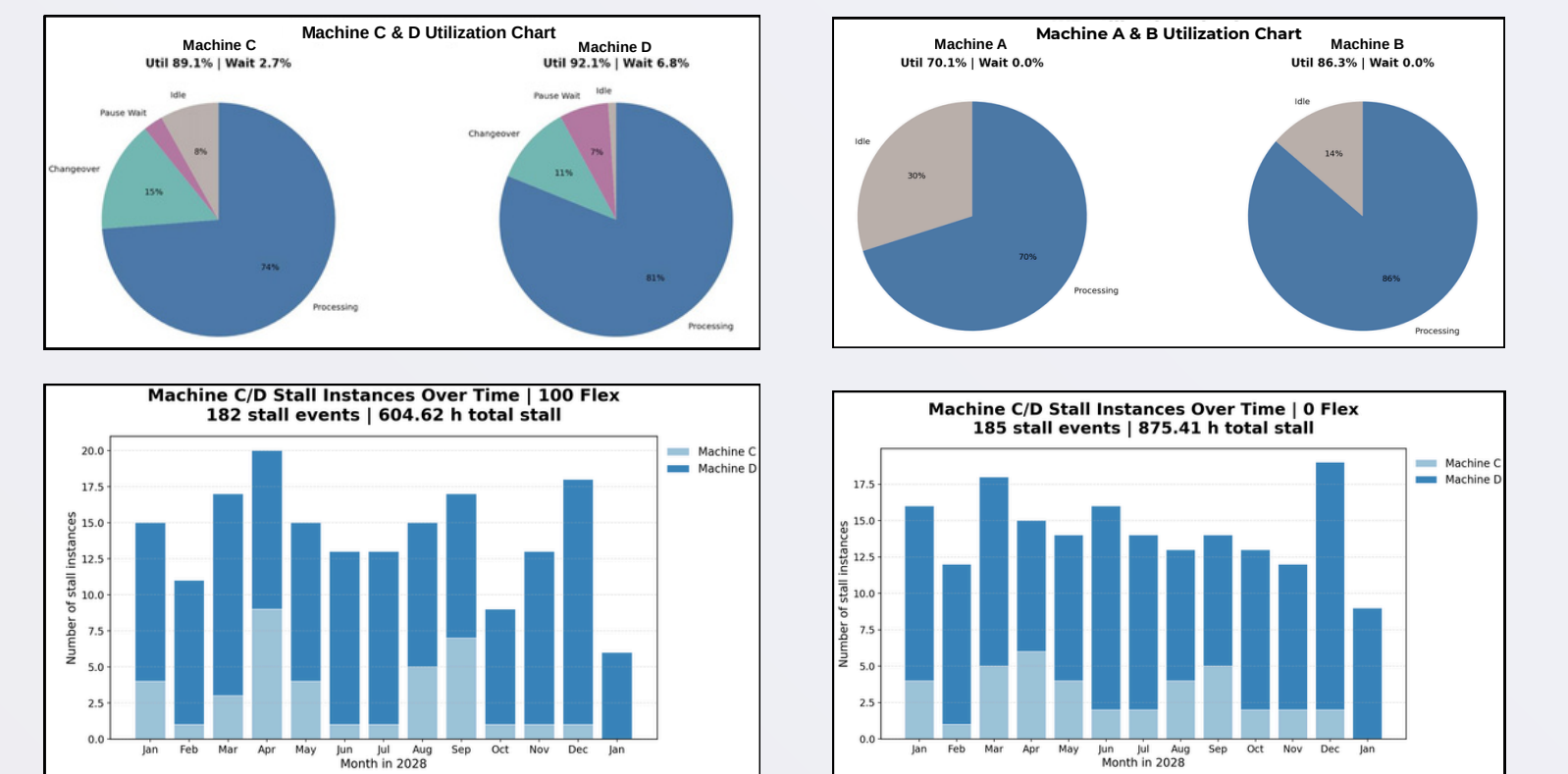
All numbers have been adjusted for confidentiality purposes.

WHAT-IF SCENARIOS WITH ADDITIONAL 100 FLEX CONTAINERS

Adding 100 Flex Container reduces the machine C & D's waiting time for empty tanks. Since the current bottleneck is machine C & D starvation, increasing the number of tanks improves availability and creates more buffer capacity for the machine C & D-tank process, resulting in smoother operations.



COLLECTED STATISTICS FROM MODEL RUN



CONCLUSION

- End-to-end integration of Process 1 and Process 2 has produced schedules that are both efficient and operationally feasible.
- Combining heuristic scheduling with downstream discrete-event simulation reduced both makespan and cumulative dryer stall time.
- Results show that machine C/D and downstream resource constraints are a major driver of plant performance.
- Final model can serve as a practical decision-support tool for future scheduling and optimisation.

TOOLS USED



SKILLS ACQUIRED

- Technical skills:** Constraint-Based Modelling, Data analysis, Data cleaning, Discrete-Event Simulation, Python Programming, Model Validation, Heuristic.
- ISE Knowledge Applied:** Bottleneck Identification, Constraint Modeling Capacity Analysis of Shared Resources, Process Optimisation, Production Planning & Scheduling, Simulation, Operation Research.