Modeling and Analysis of A Modernized Battery Production Line

SJTU Global College

Group 3

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Introduction

Surging Market Demand

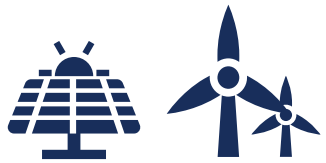
- The rapid growth of renewable energy products has led to a massive surge in demand for Lithium-ion batteries (LIBs).
- Battery producers are under pressure to continuously improve productivity to meet these needs.

Target Product: 18650 Cylindrical Cells

- This project analyzes a plant specifically manufacturing 18650 cylindrical Li-ion batteries.
- These high-capacity cells are a standard format widely used across the markets mentioned above.

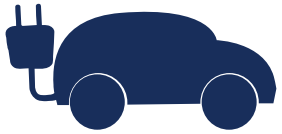
Product Applications

- Due to their high energy density, lightweight nature, and reliability, LIBs are now ubiquitous in:



Renewable energy storage systems

Consumer electronics.



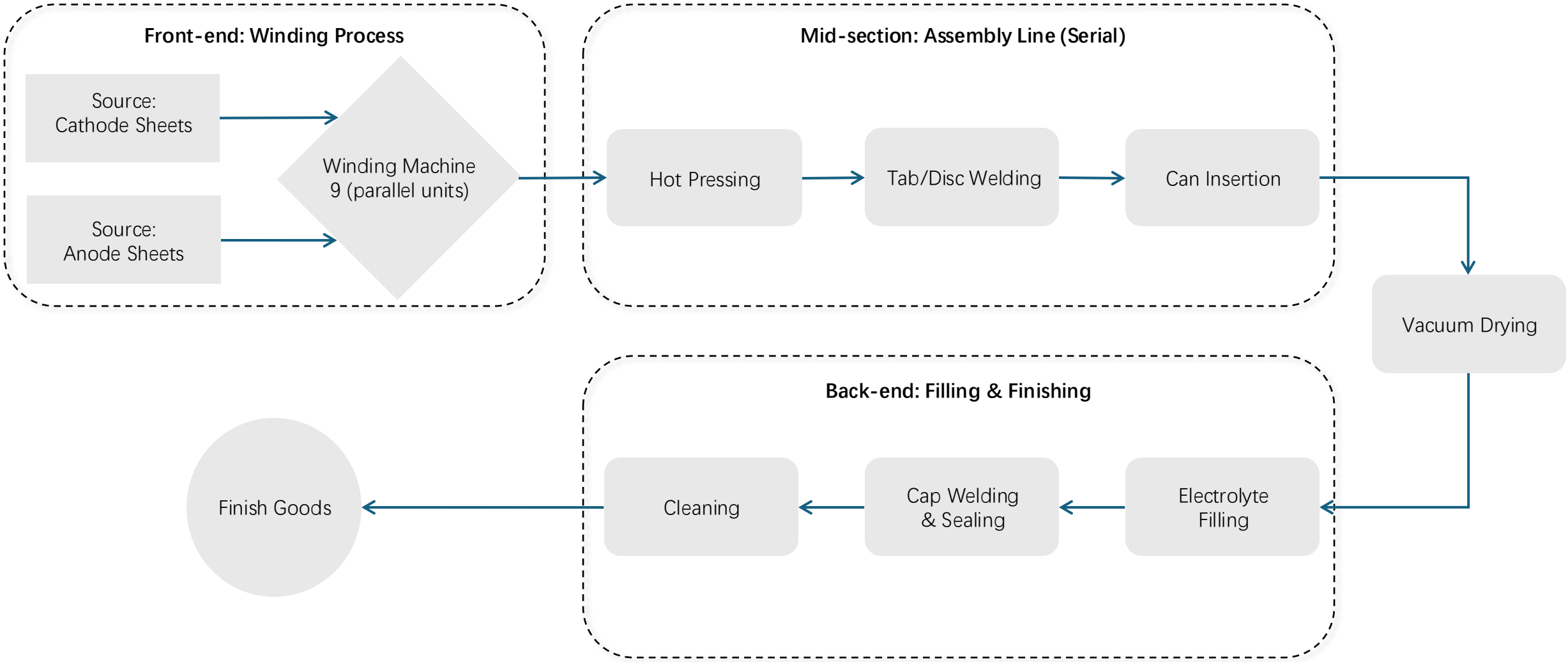
Electric Vehicles (EVs)

Portable power banks

Manufacturing Objectives

- **Throughput:** Increasing output to meet market demand.

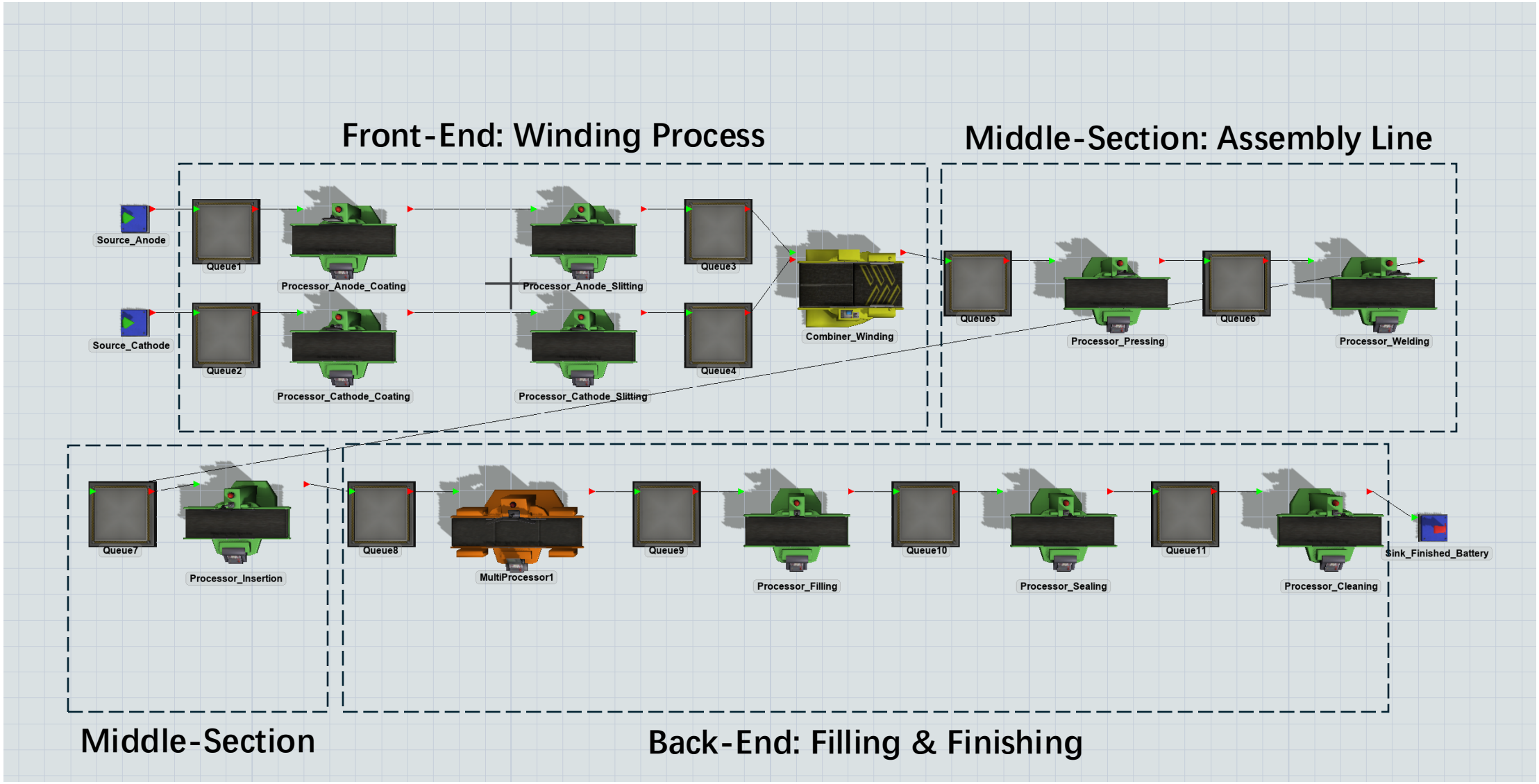
Introduction [1]



Parameter Setting for the Production Line [1]

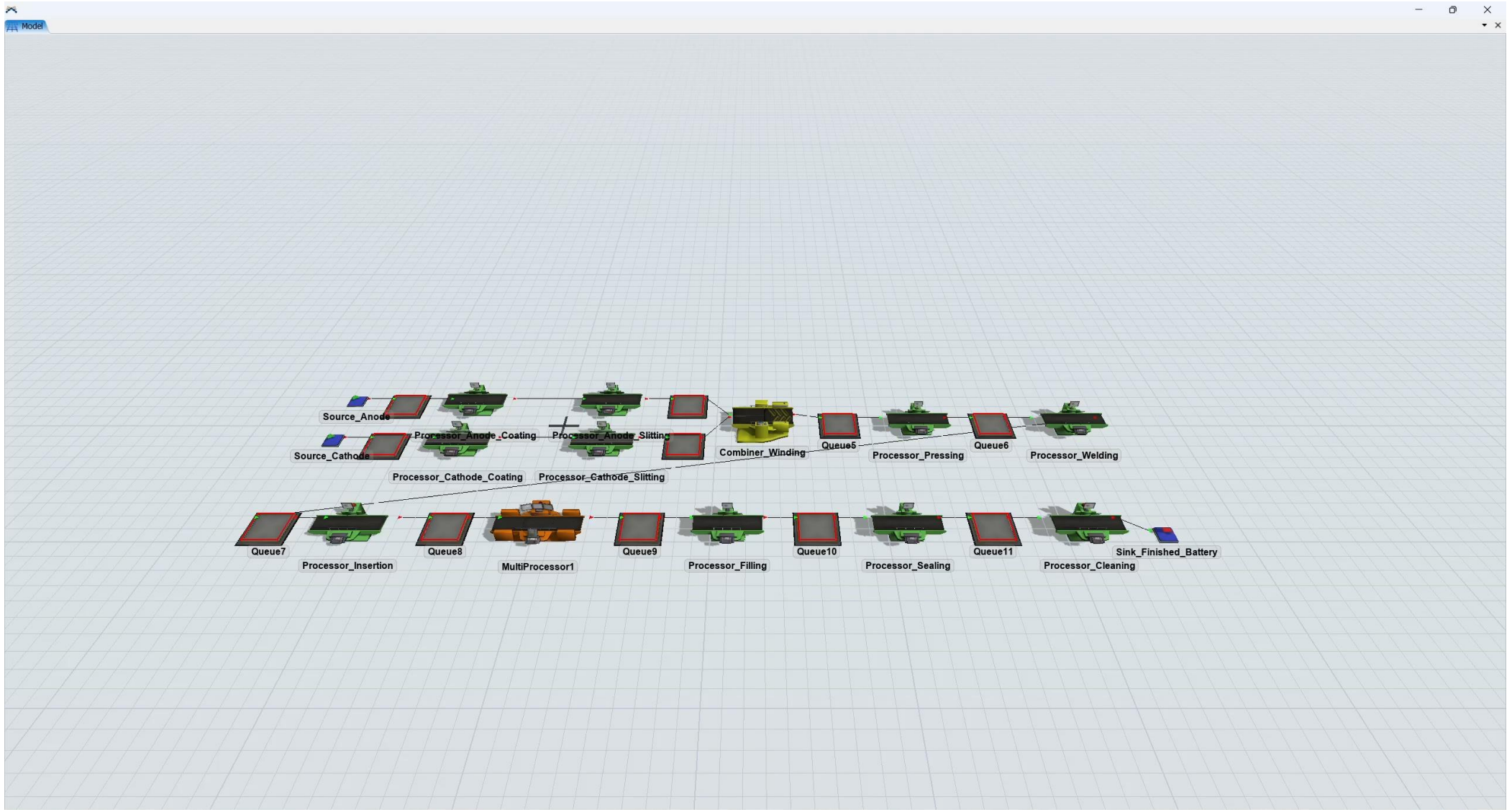
	Process Time (s)	MTTR (h)	MTTF (h)
Coating	0.33	/	/
Slitting	0.33	/	/
Winding	0.40	1	66.67
Pressing	0.40	1.5	150.15
Welding	0.40	1.5	150.15
Insertion	0.40	1	100
Multiprocessing	0.43	1	100
Sealing	0.40	1	100
Cleaning	0.40	0.5	50

Modeling the Production Line [2]



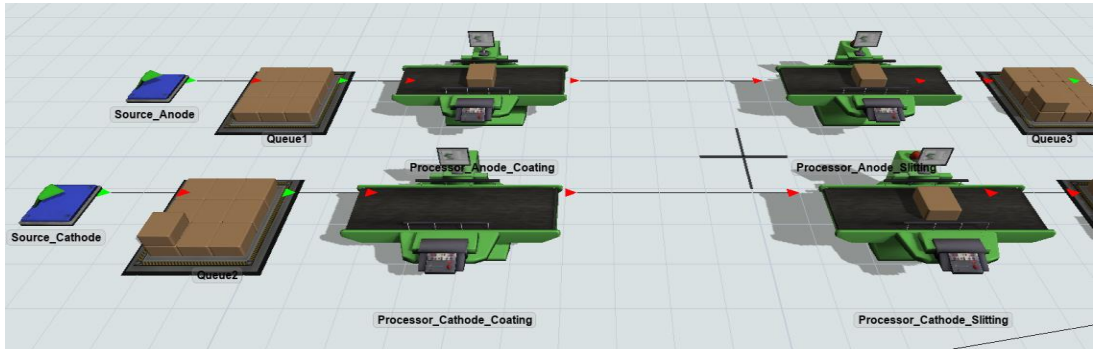
Overall Production Line

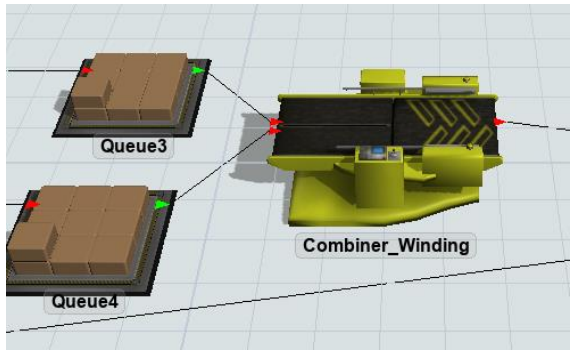
Modeling the Production Line [2]

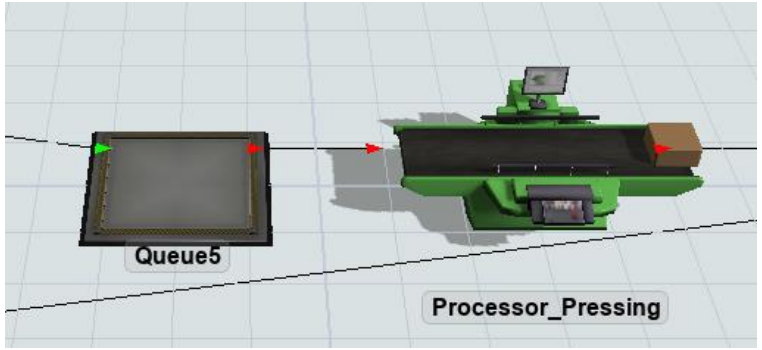


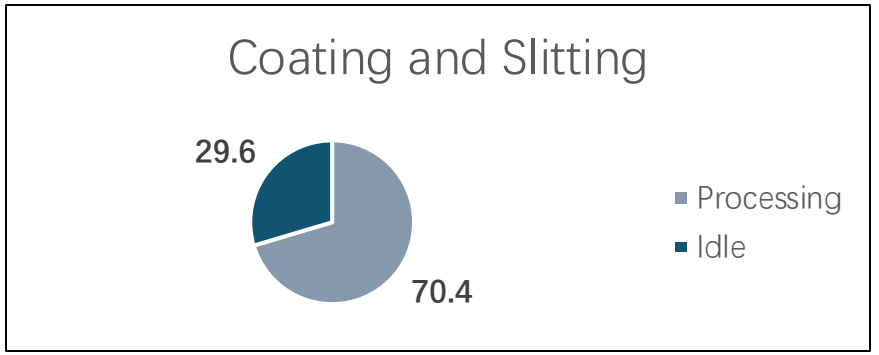
Simulation Real Demo Video

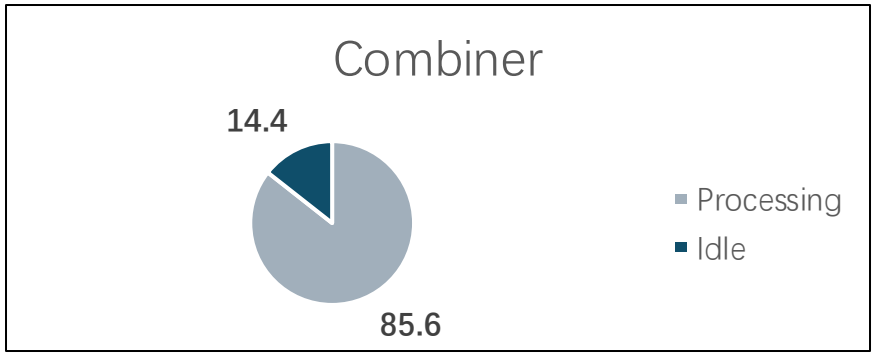
Analysis – Initial Production Line

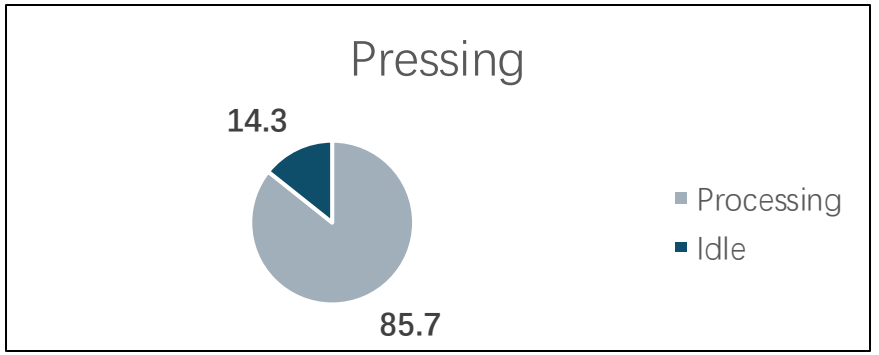












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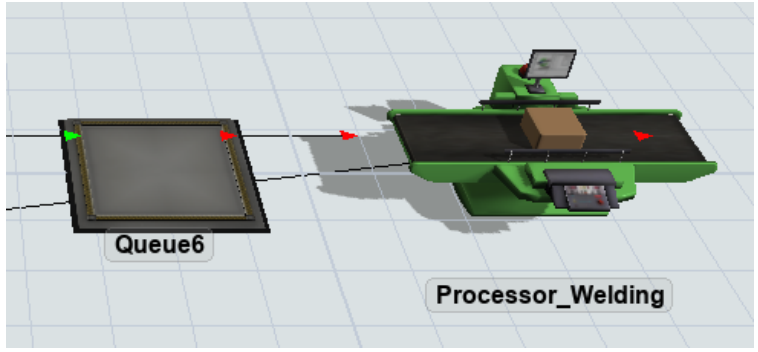
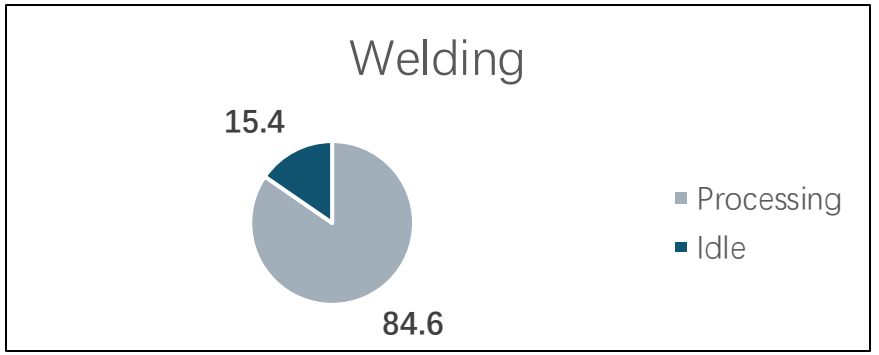
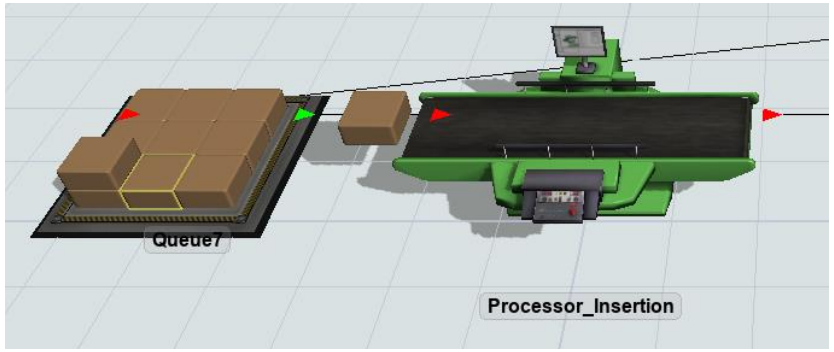
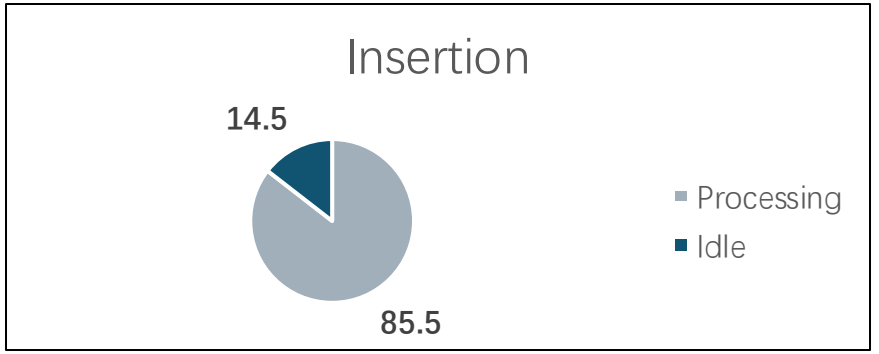
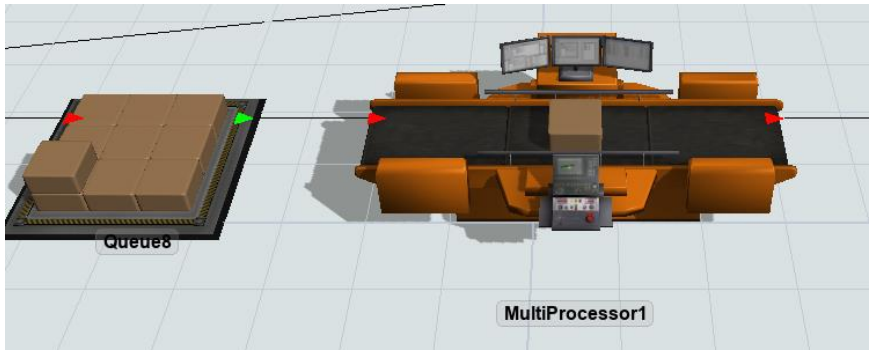
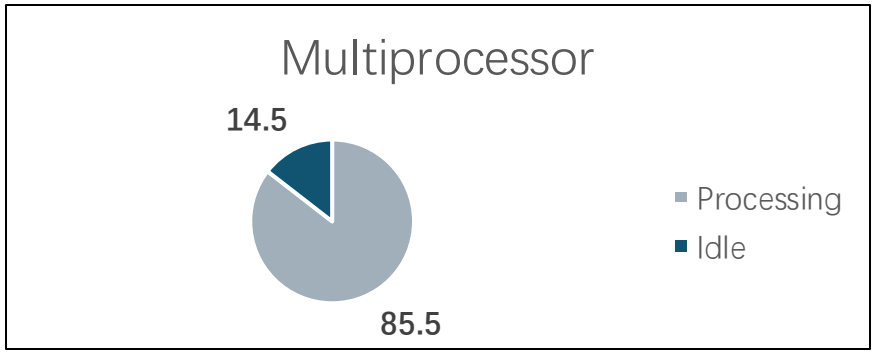




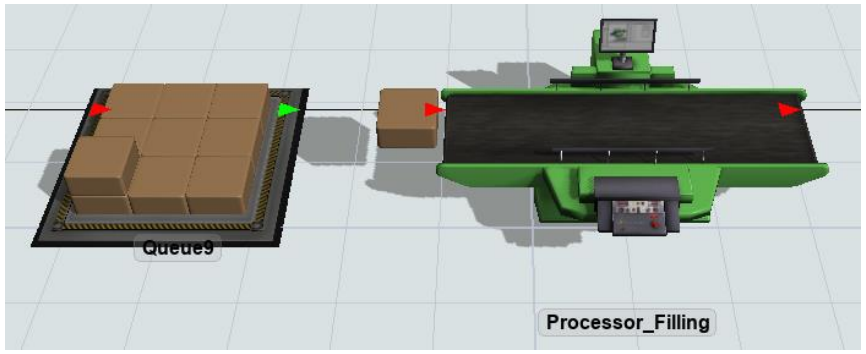


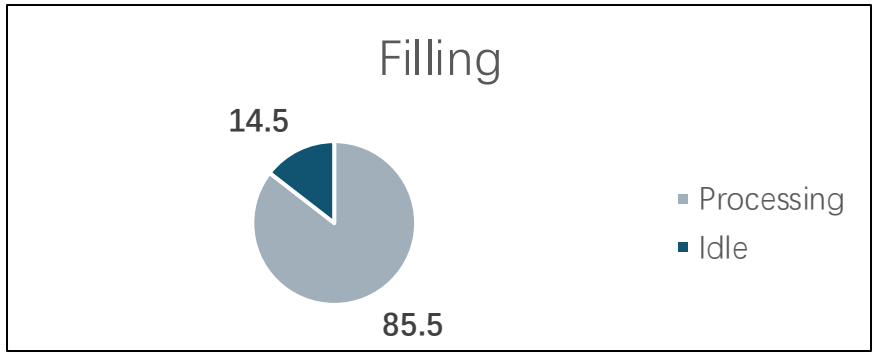


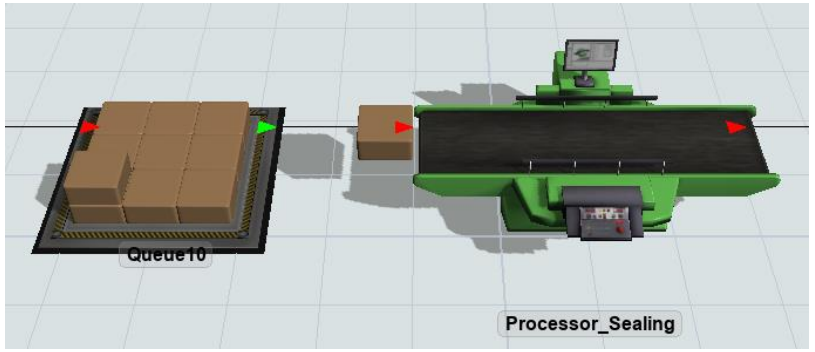


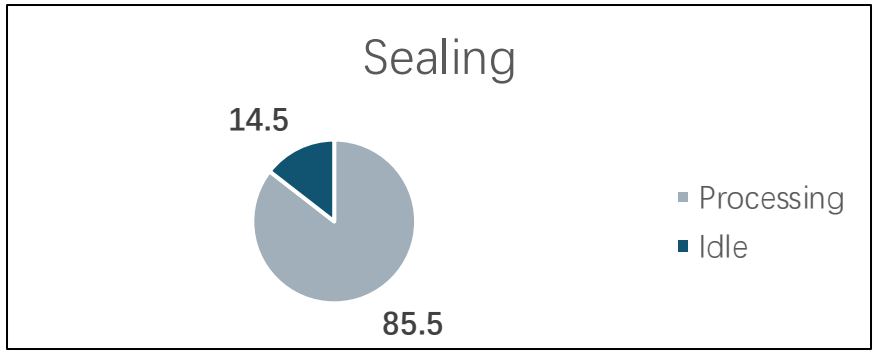


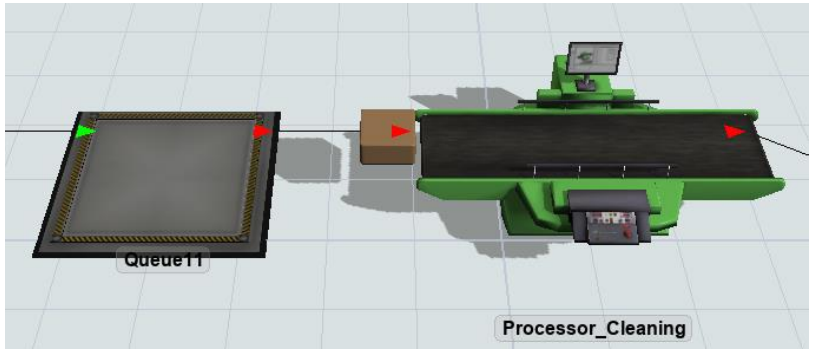
Analysis – Initial Production Line

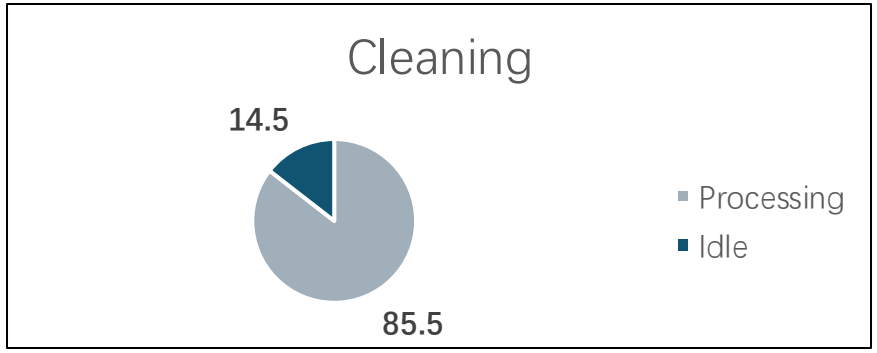








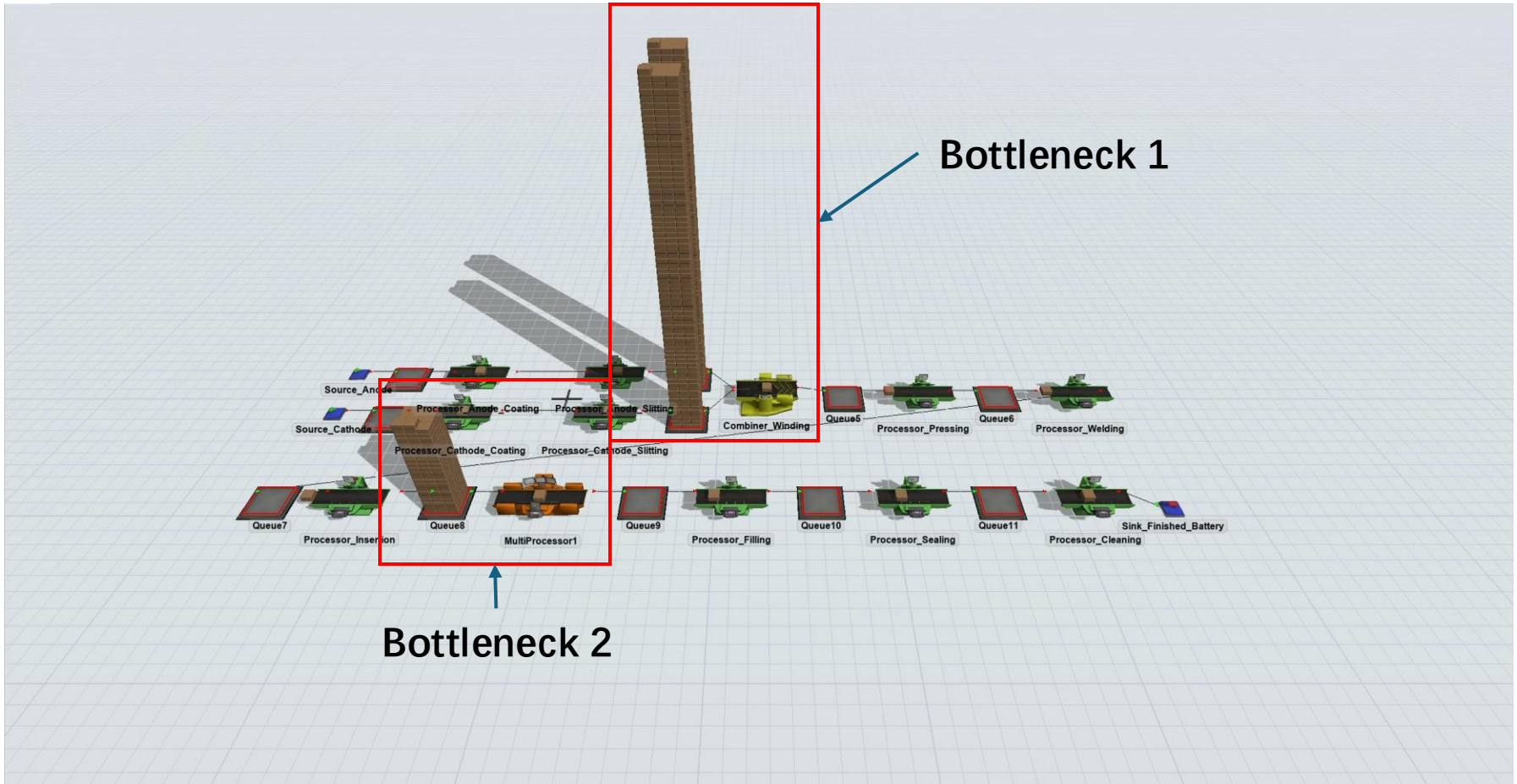




Analysis – Initial Production Line

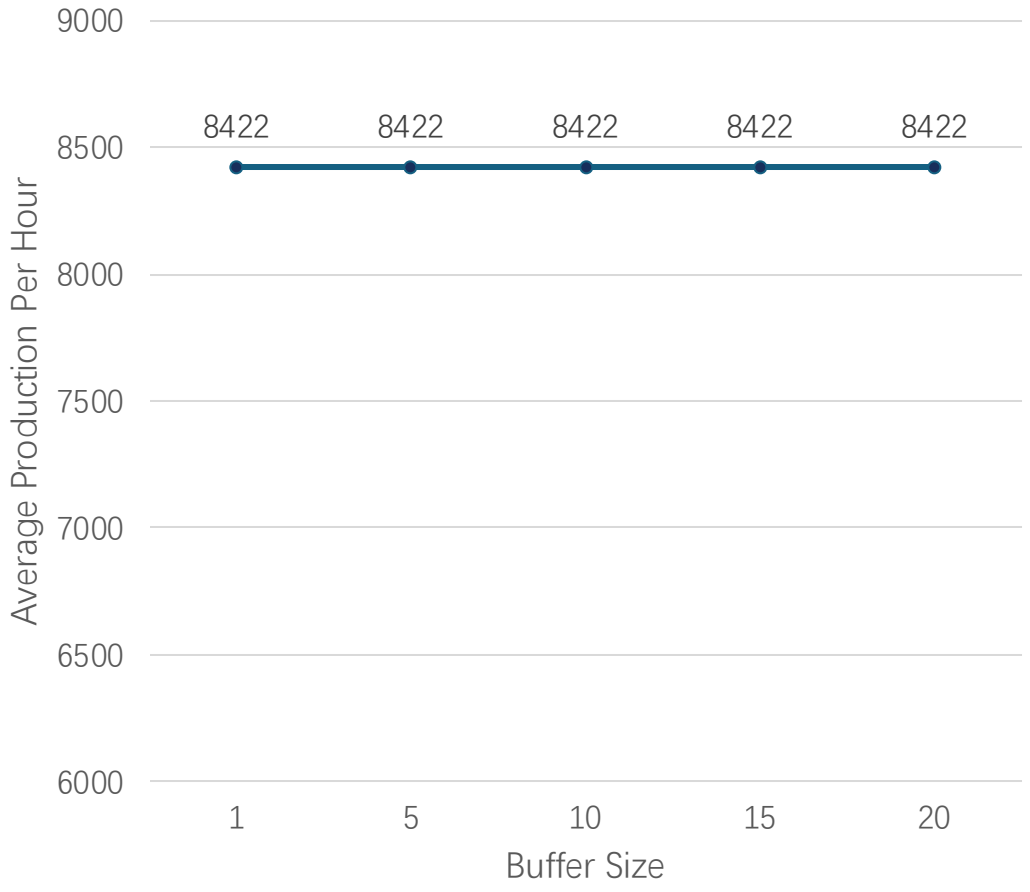
Improvement:

- Buffer Size
- Machine Production Rate

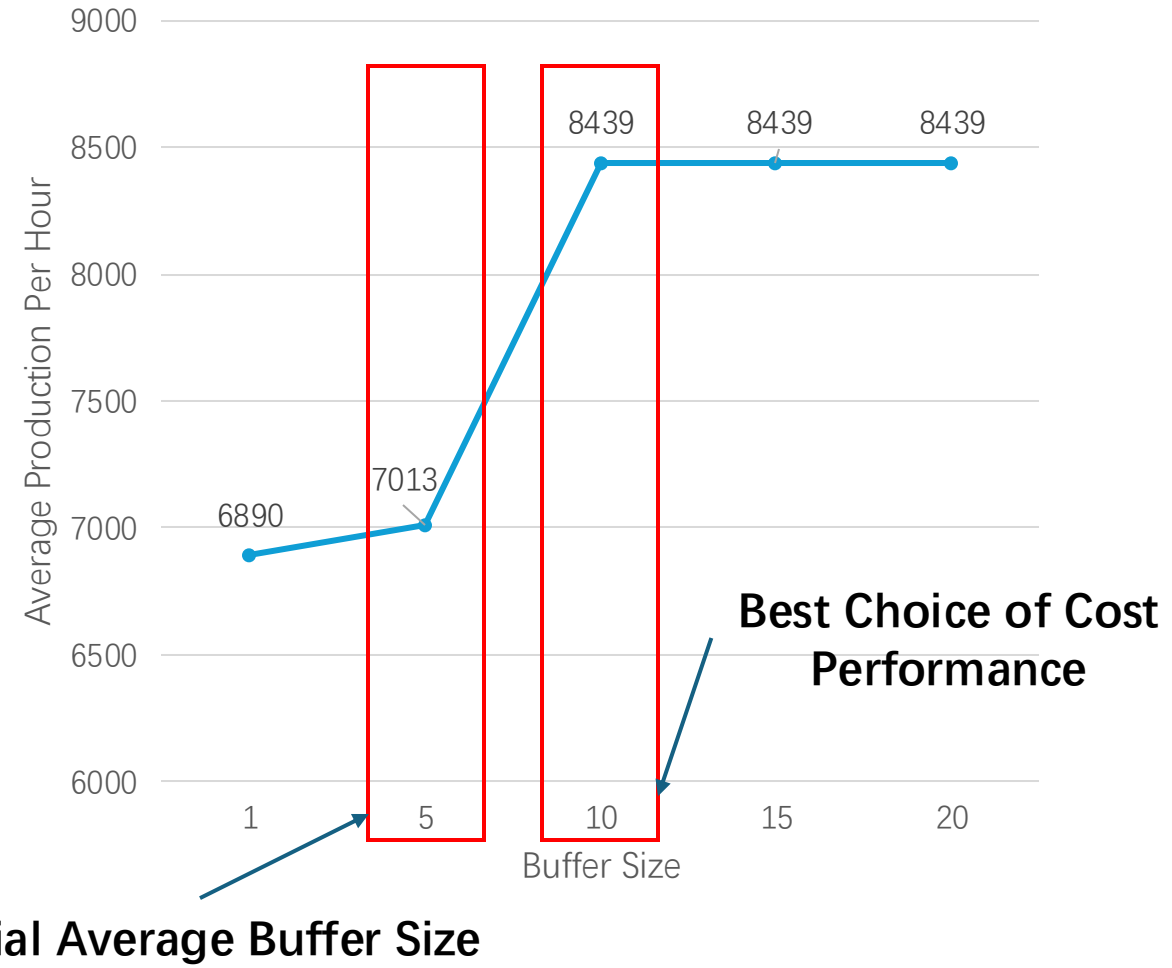


Improvement 1 – Buffer Size

Without MTTR & MTTF



With MTTR & MTTF

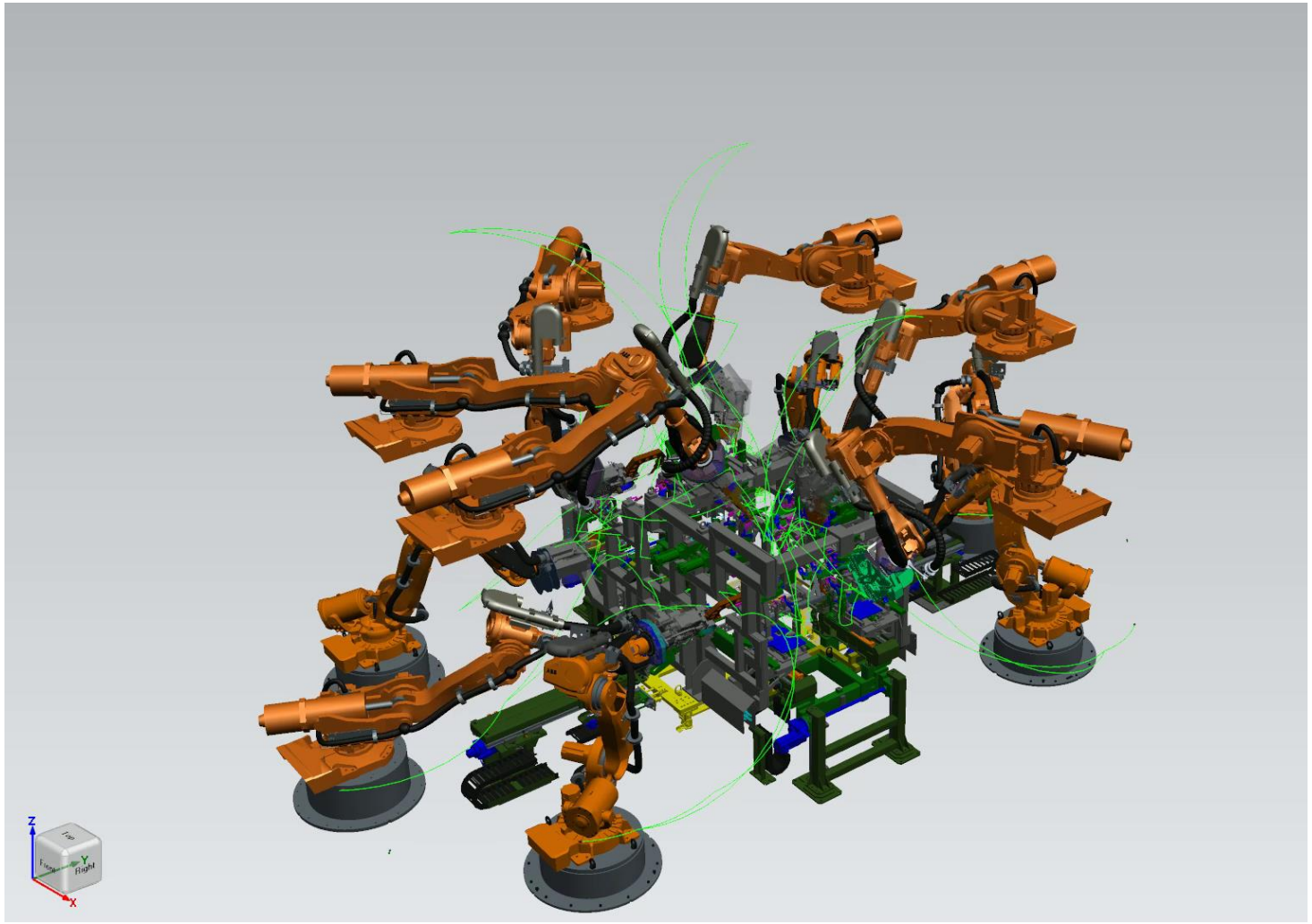


Improvement 2 – Machine Production Rate

Two Bottleneck	Process Time (s)
Winding	0.40
Multiprocessing	0.43

- **Vibration and Settling Time**The machine waits for minute vibrations to disappear before it can execute a high-tolerance movement.
- **Conservative Programming** The path is manually programmed and slow, a safety blanket to ensure quality.

Incorporating Digital Twins



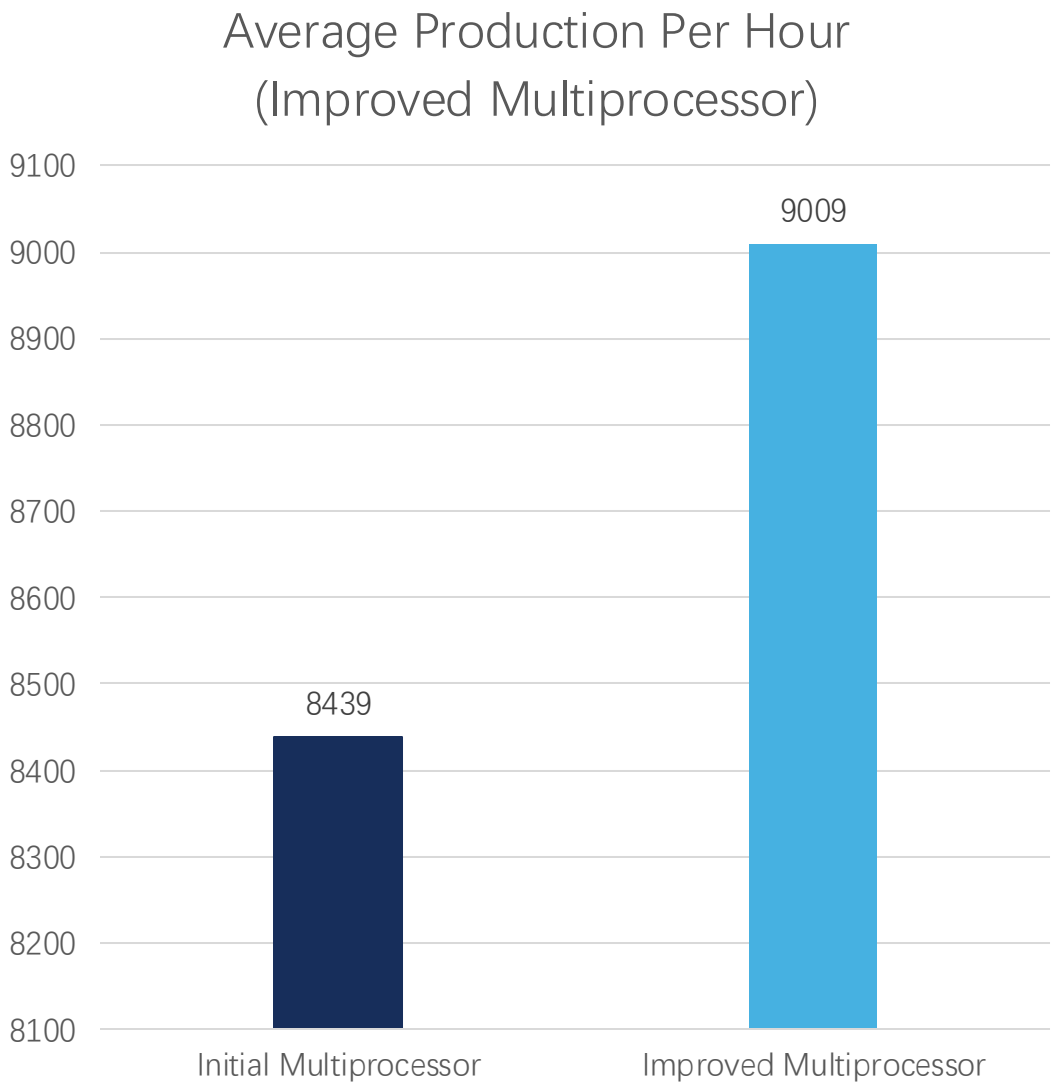
Realtime Robotics Optimization

- **Realtime Robotics Optimization** A software dedicated to adapt and optimize robot path reducing **17%** of cycle time by minimizing unecessary movements.
- **Future Prospect** building an intelligent, adaptive production platform for the next generation of battery manufacturing.

Improvement 2 – Machine Production Rate

- Balance between production rate and cost: **Improve the multiprocessor**
- Decrease the process time of multiprocessor: **0.43s to 0.40s** (Keep the rest condition the same)

Two Bottleneck	Process Time (s)
Winding	0.40
Multiprocessing	0.43



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[1] H. Dong et al., "Modeling, analysis and improvement of production throughput and energy consumption in Li-ion battery manufacturing lines," *International Journal of Production Research*, pp. 1–15, Jul. 2025, doi: 10.1080/00207543.2025.2535518.

[2] "Basics Tutorial Task 1.1 - Build a 3D model." https://docs.flexsim.com/en/25.1/Tutorials/FlexSimBasics/1-1Build3DModel/1-1Build3DModel.html#

[3] Y. Pan, and L.Zhang, "Roles of artificial intelligence in construction engineering and management: A critical review and future trends," Automation in Construction, vol. 122, February 2021, https://doi.org/10.1016/j.autcon.2020.103517.

[4] M. Soori, B. Arezoo, and R. Dastres, "Digital twin for smart manufacturing, A review," *Sustainable Manufacturing and Service Economics*, vol. 2, p. 100017, 2023, doi: https://doi.org/10.1016/j.smse.2023.100017.

Table 1. System parameters.

Process	*Failure* ($\lambda_i \cdot 1000$)	*Repair* ($\mu_i \cdot 10$)	Capacity (C_i)	Batch (B_i)	Lane (k_i)	Buffer (N_i)
Winding	0.25	0.167	0.0144	1250	9	65000
Cathode pressing	0.111	0.111	150	1	1	22
Anode pressing	0.167	0.167	150	1	1	64
Cathode disc welding	0.111	0.111	150	1	1	73
Anode disc welding	0.111	0.111	150	1	1	35
Short test 1	0.167	0.167	150	1	1	20
Sticking tape	0.167	0.167	150	1	1	14
Insertion into casing	0.167	0.167	150	1	1	18
Bottom welding	0.167	0.167	150	1	1	22
Crimping	0.167	0.167	150	1	1	24
Beading	0.167	0.167	150	1	1	26
Short test 2	0.333	0.333	150	1	1	22
Tray filling 1	0.333	0.333	150	1	1	65000
Tray stacking	0.333	0.333	75	1	2	17
Drying	0.167	0.167	0.00139	3888	26	18
Ground rail	0.333	0.333	75	1	2	18
Unloading	0.333	0.333	75	1	2	65000
Feeding	0.333	0.333	150	1	1	51
Short test 3	0.333	0.333	150	1	1	35
X-ray test	0.167	0.167	150	1	1	16
Electrolyte filling	0.167	0.167	150	1	1	24
Cap welding	0.25	0.25	150	1	1	12
Sealing	0.167	0.167	150	1	1	16
Air tightness test	0.333	0.333	150	1	1	14
Cleaning	0.333	0.333	150	1	1	13
Applying antirust oil	0.333	0.333	150	1	1	32
Gluing	0.333	0.333	150	1	1	43
Wrapping	0.333	0.333	150	1	1	30
Labeling	0.333	0.333	150	1	1	45
Tray filling 2	0.167	0.167	150	1	1	–

Thank You

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