INL/CON-22-66168-Revision-0

Self Configuring Digital Twin for Optimizing E-Waste Recycling

March 2022

Md Mamunur Rahman, Damon S Hartley, Ruby Thuy Nguyen

Changing the World's Energy Future

Idaho National Laboratory

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Self Configuring Digital Twin for Optimizing E-Waste Recycling Using CMAT

Industrial Engineering and Operations Management (IEOM)
Annual Conference 2022, Istanbul, Turkey.
Industry Solutions and Industry 4.0

Idaho National Laboratory

Electronic Waste Recycling

Collection
- Max load
- Min costs (time, fuel)

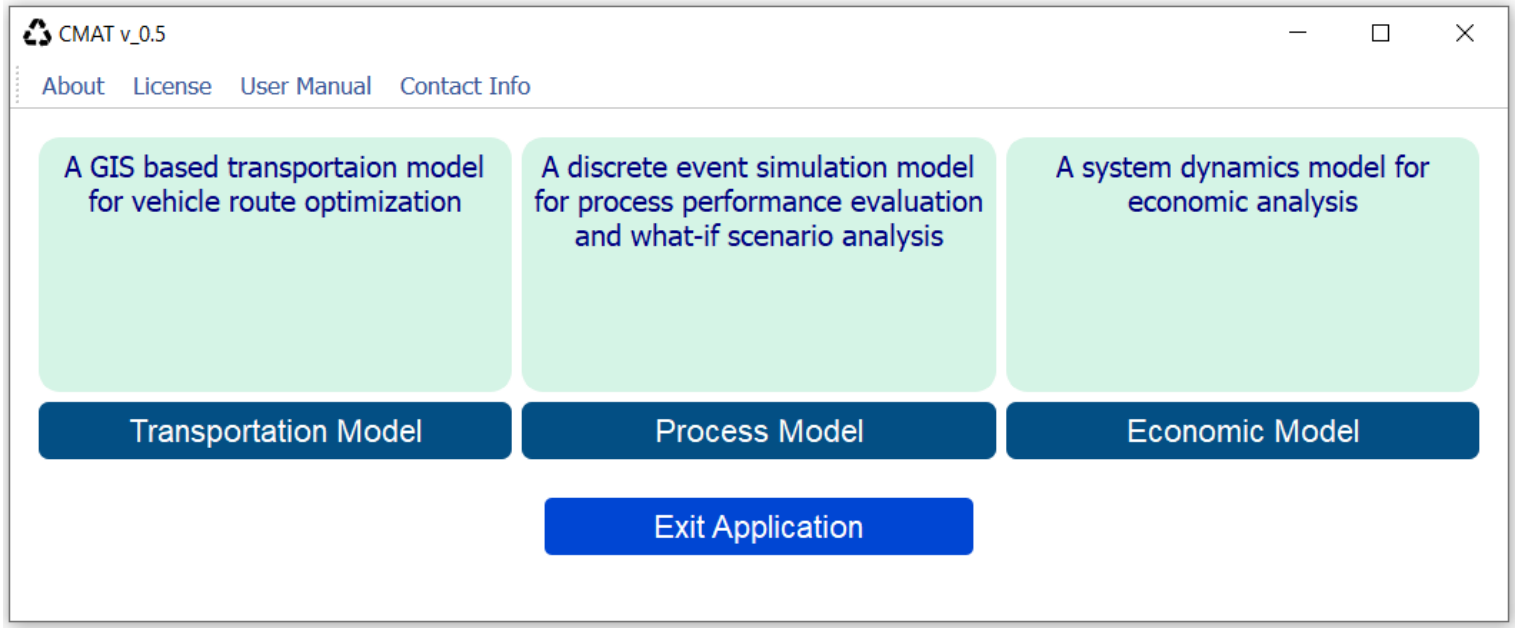
Processing
- Max output
- Min energy, labor

Economic Performance
- Max profit
- Min costs
- Changing prices

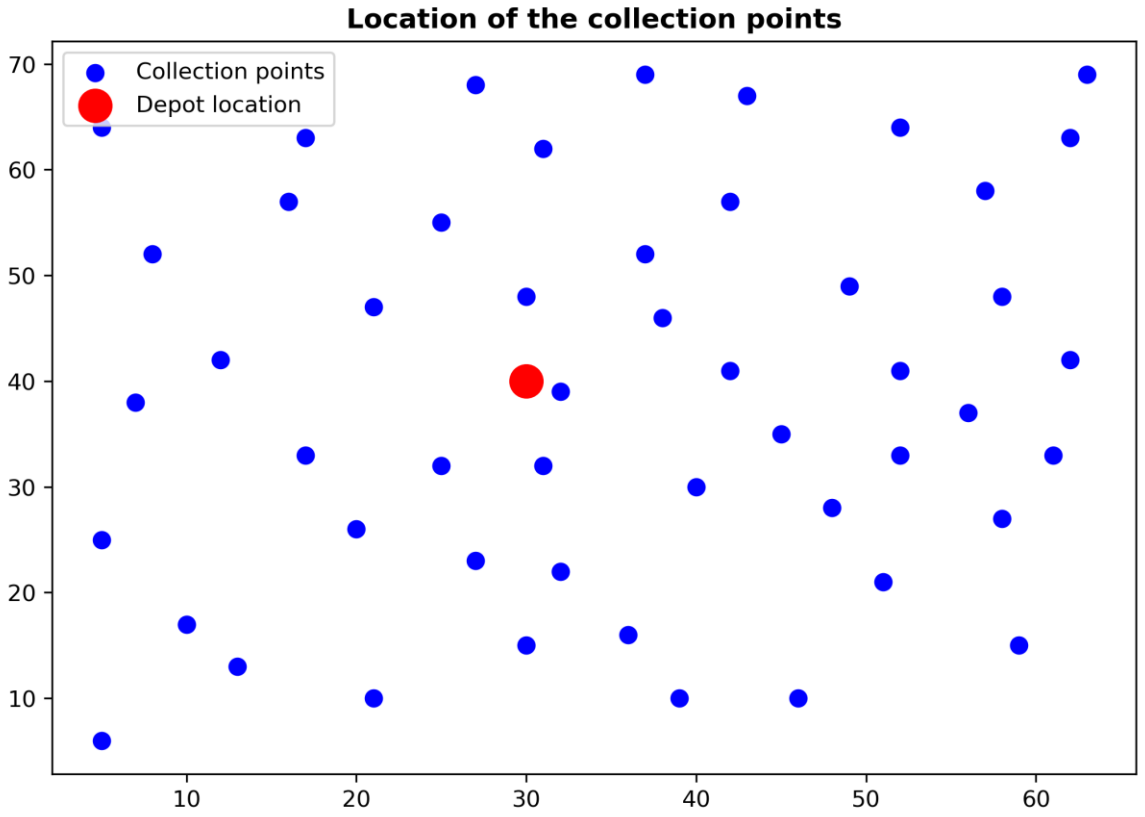
Funded by REMADE INSTITUTE®

Partnered with SUNNKING
We Rule Electronics Recycling

Comprehensive Manufacturing Assessment Tool (CMAT)



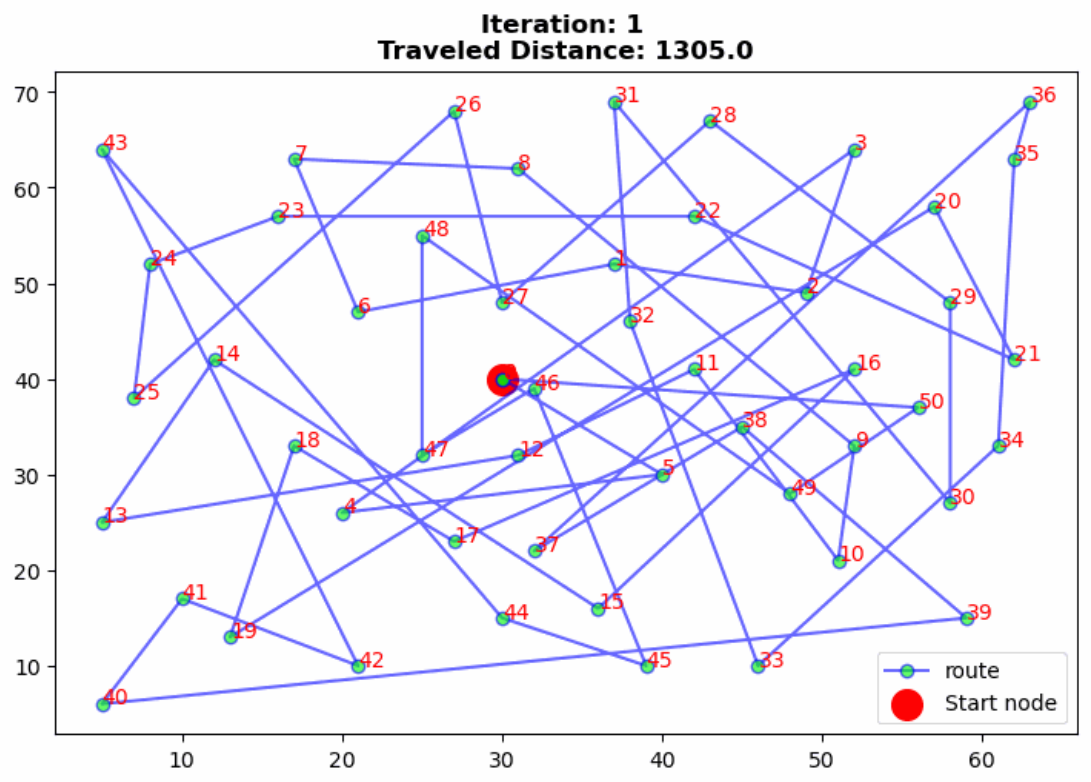
01. Transportation Module



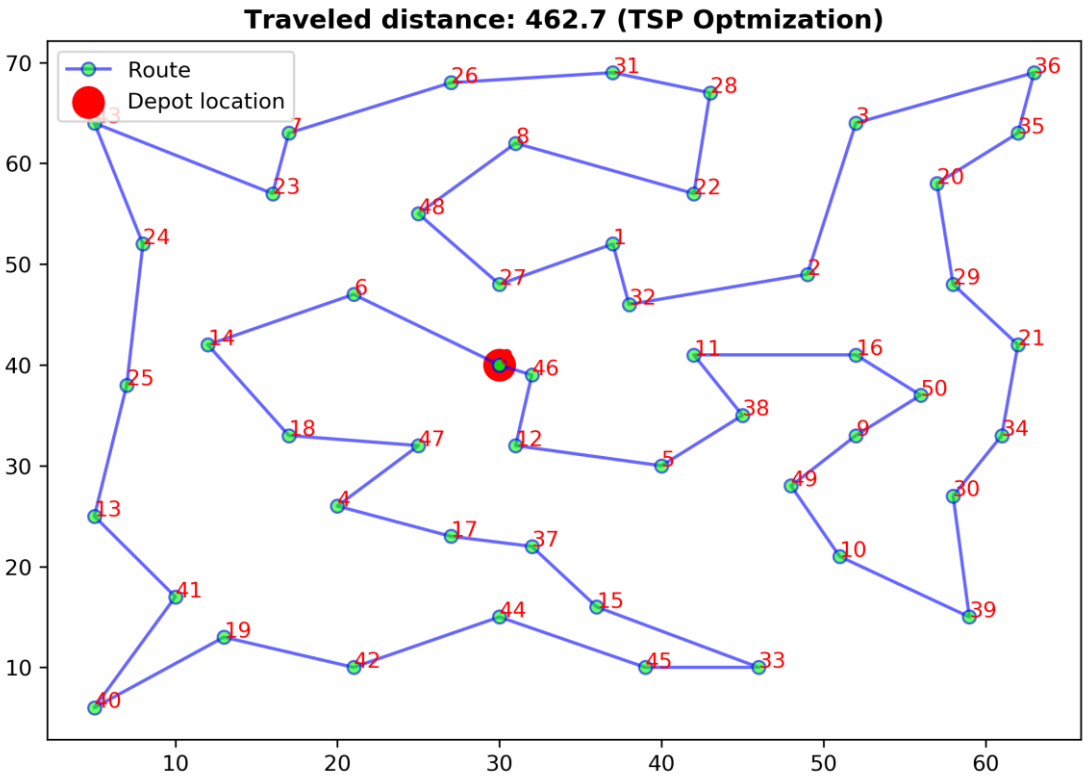
Traveling
Salesman
Problem

01. Transportation Module

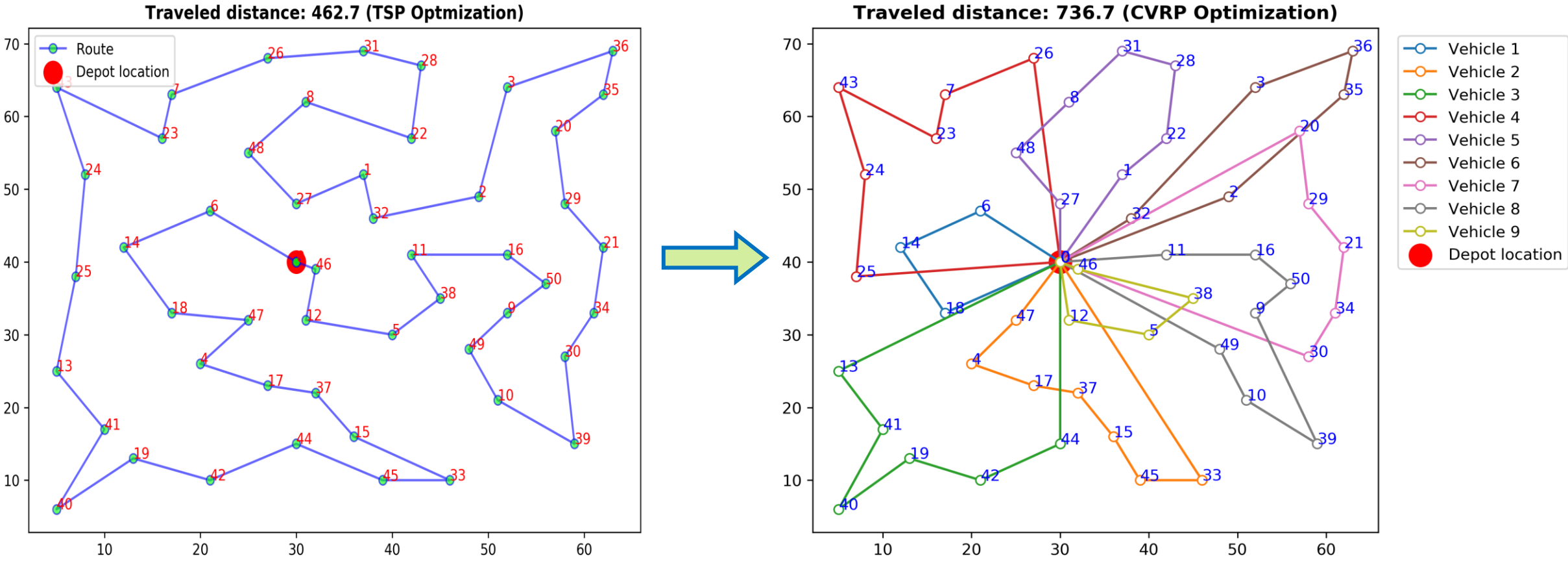
Optimization of TSP Problem



Optimized Route

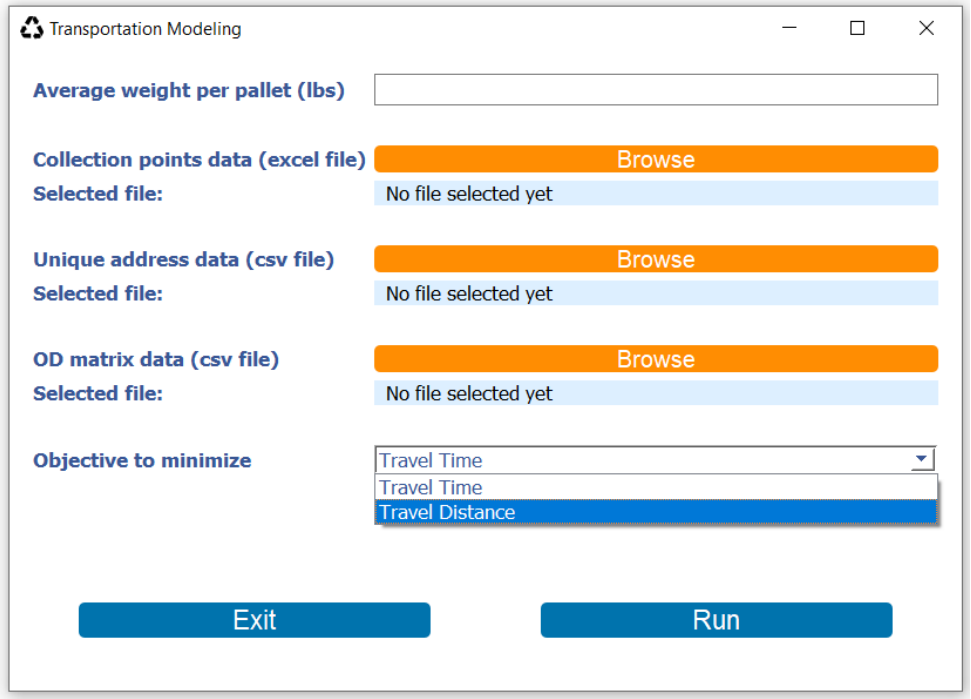


01. Transportation Module



01. Transportation Module

Input Window



Sample Excel File

	A	B	C	D	E	F	G	H
1	Name	Capacity (pallets)	Vehicle Weight (lbs)	Engine Size (Liter)	Engine Efficiency	Idle Engine RPM	Max Engine RPM	Frontal Area (square meter)
2	vehicle_1	20	15000	8	40%	600	2200	5.5
3	vehicle_2	50	16000	9	30%	600	2200	5.5
4	vehicle_3	35	20000	10	35%	600	2200	5.5
5								
6								

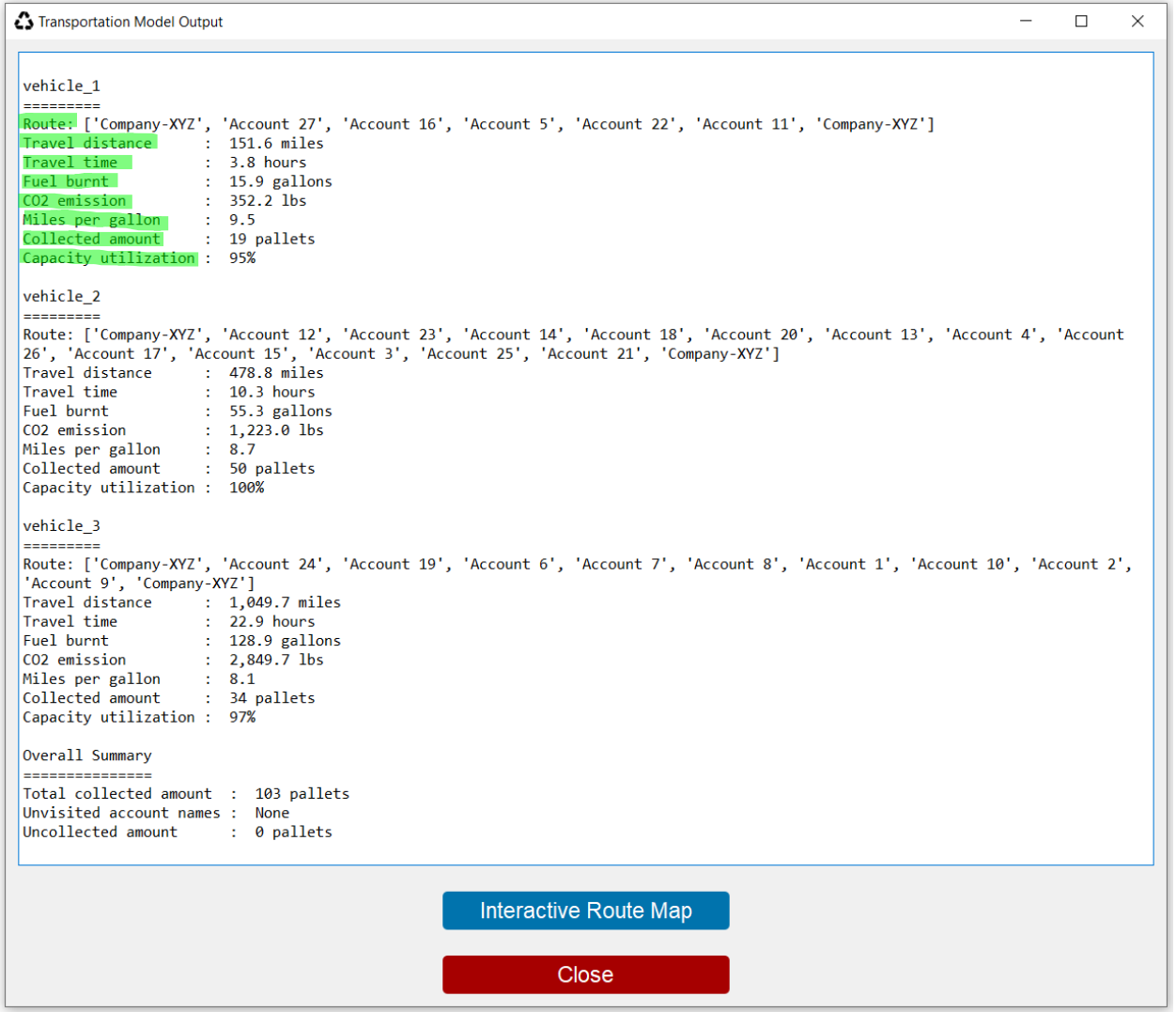
Collection Addresses | Vehicle List

	A	B	C	D	E	F	G
1	Account Name	Amount (pallets)					
2	Company-XYZ	0					
3	Account 1	3					
4	Account 2	5					
5	Account 3	4					
6	Account 4	4					
7	Account 5	3					

Collection Addresses | Vehicle List

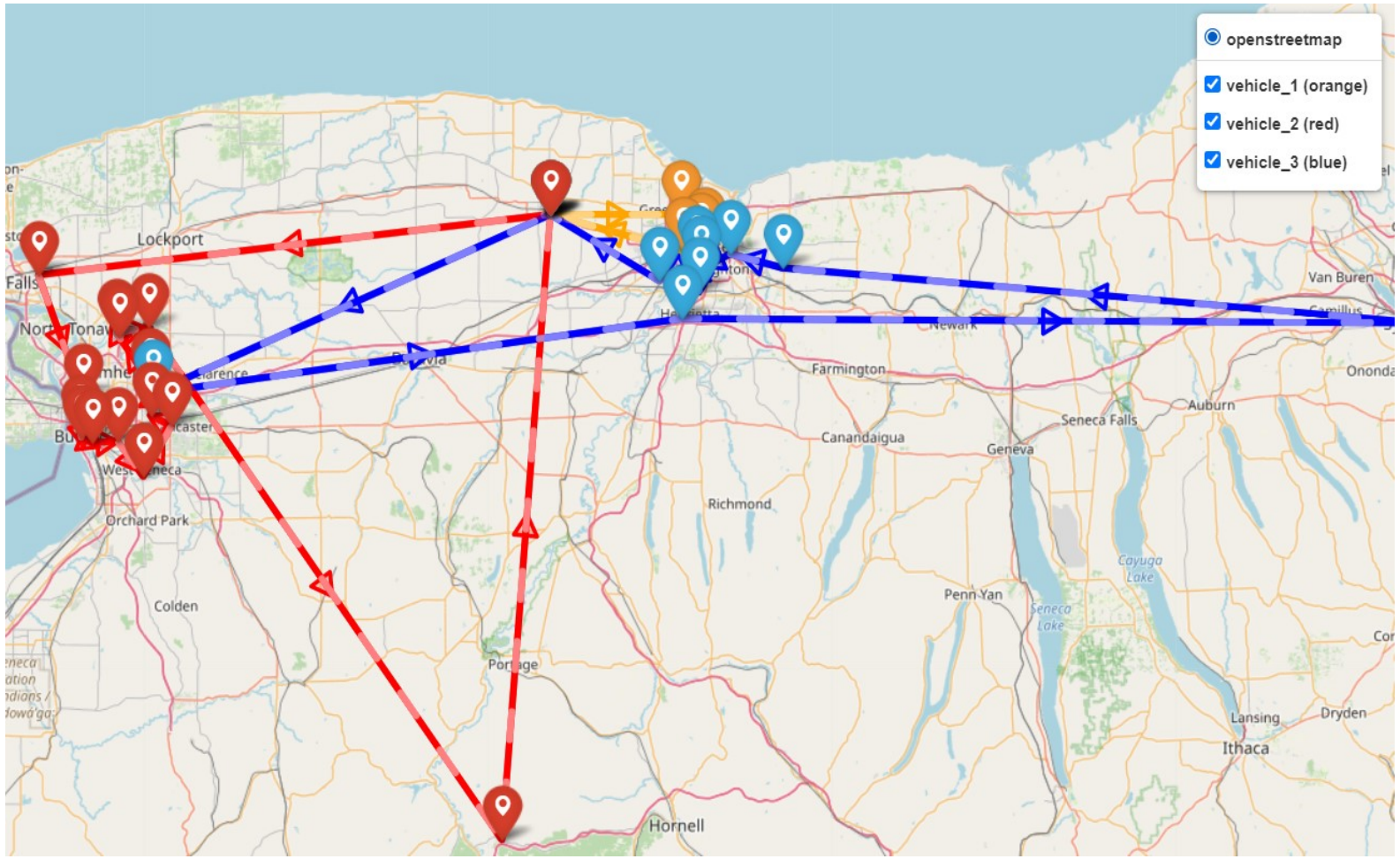
01. Transportation Module

Output Window



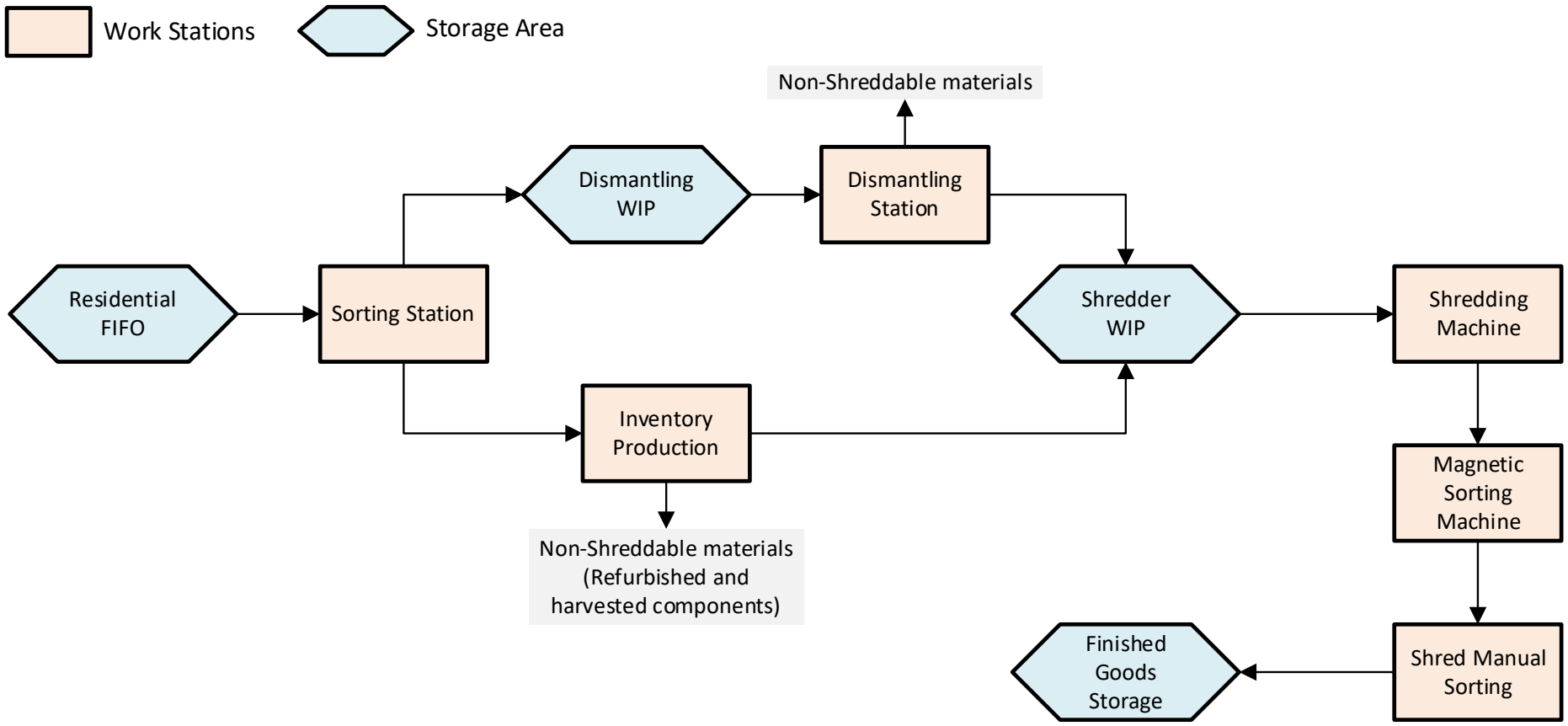
01. Transportation Module

Interactive Route Map



02. Process Module

Sample Shopfloor Layout



02. Process Module

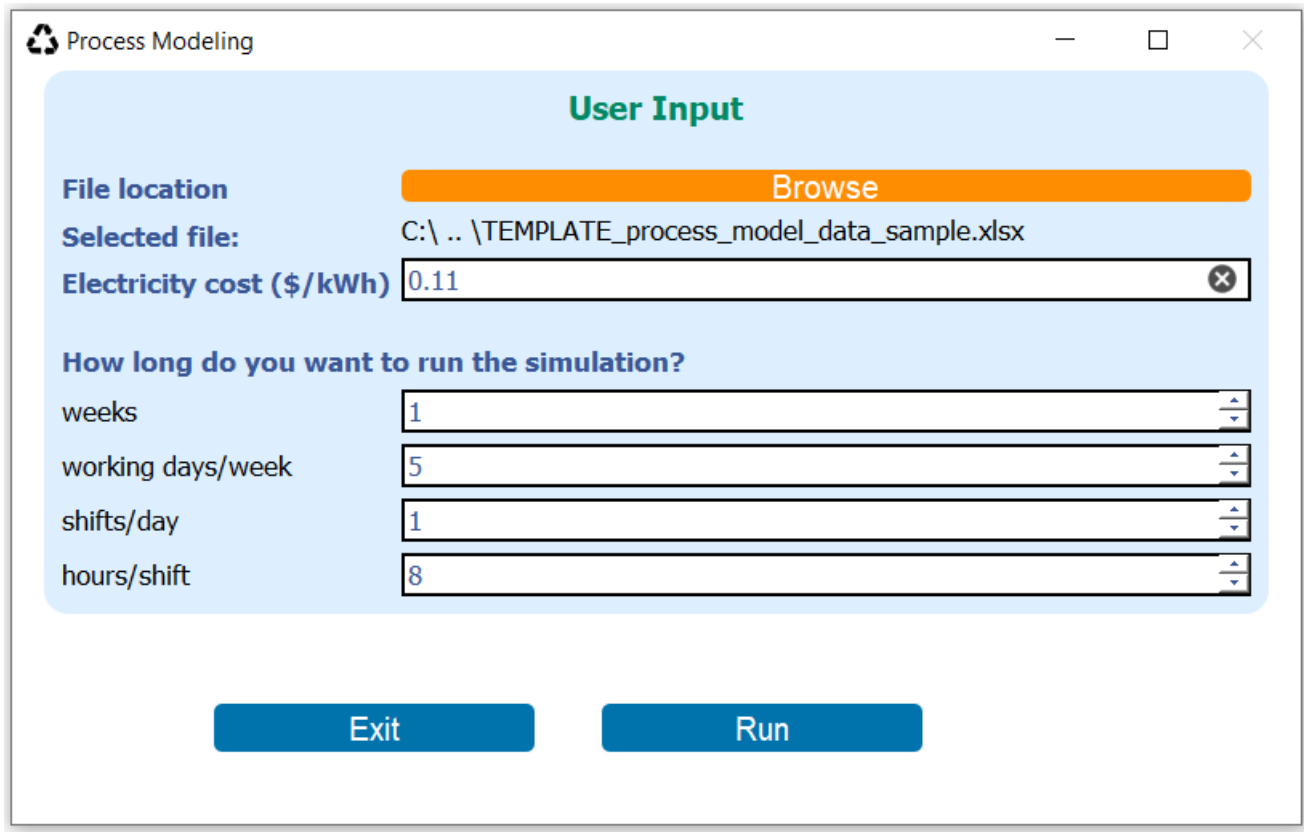
User Input Excel File

	A	B	C	D	E	F	G	H	I	J
1	TYPE	Manual Work Station								
2	NAME	Sorting Station								
3	NO OF OPERATORS	5								
4	OPERATOR WAGE RATE	10								
5	INPUT QUEUE CAPACITY	5000								
6	PRODUCT CATEGORIES	crt_tv	crt_monitor	lcd_tv	lcd_monitor	desktop	laptop	printer	small_cee	peripherals
7	PROCESSING TIME	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1
8	NON SHREDDABLE OUTPUT PROBABILITY	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	NON SHREDDABLE OUTPUT PERCENTAGE	0%	0%	0%	0%	0%	0%	0%	0%	0%
10	OUTPUT QUEUE NAMES	inventory production items	dismantling wip items							
11	OUTPUT QUEUE CAPACITIES	6000	5000							

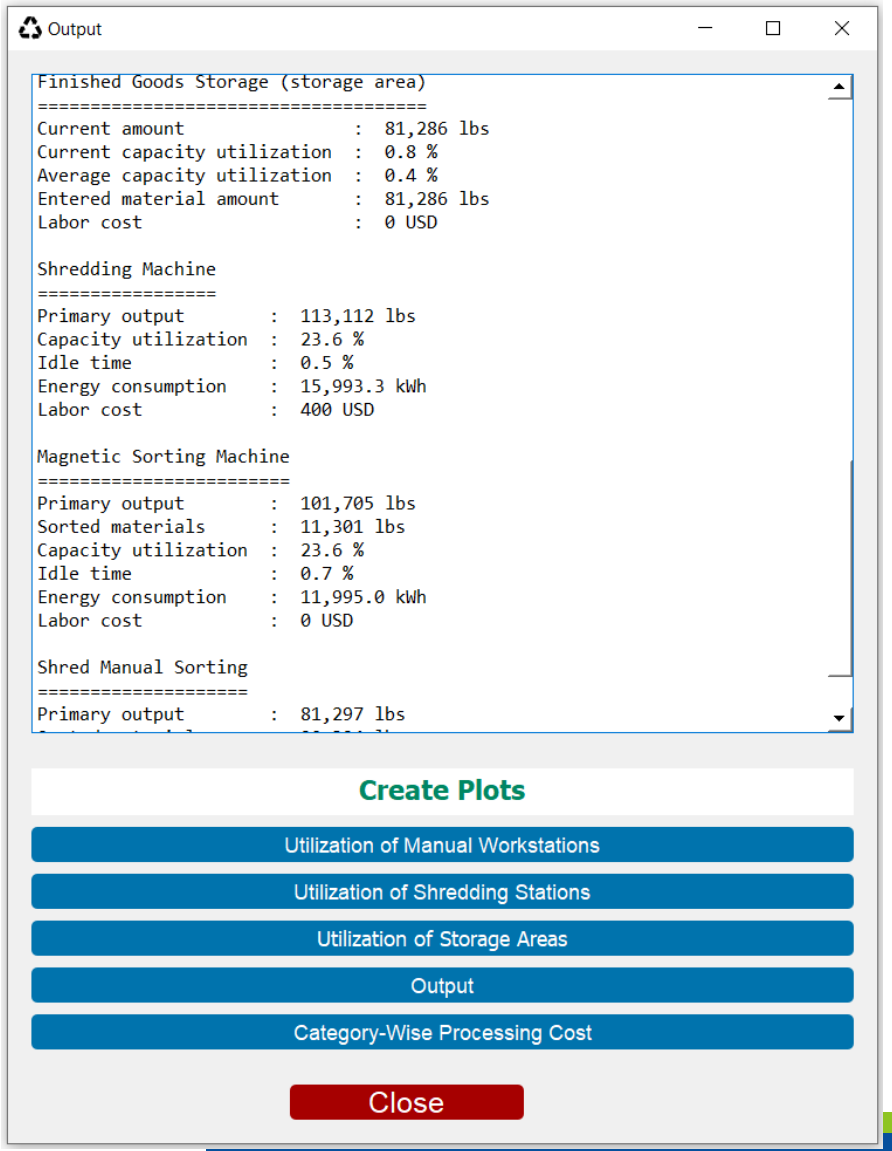
General Data | Product source1 | **Work station1** | Work station2 | Dismantling1 | Shredding Work Stations | Storage Areas | Material Movement

02. Process Module

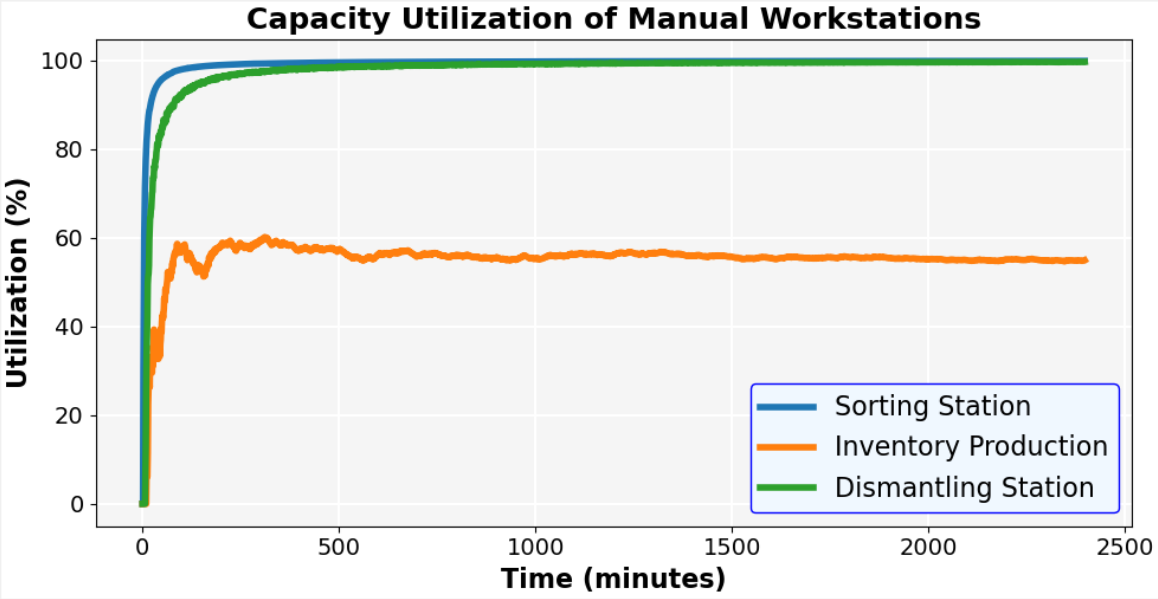
Input Window

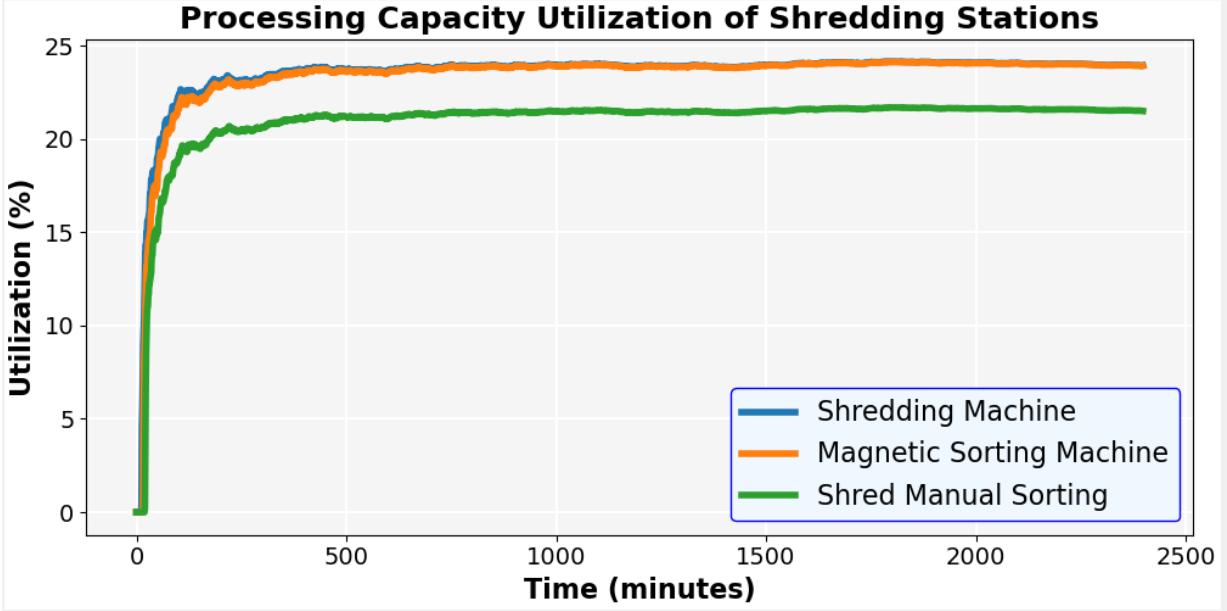


Output Window

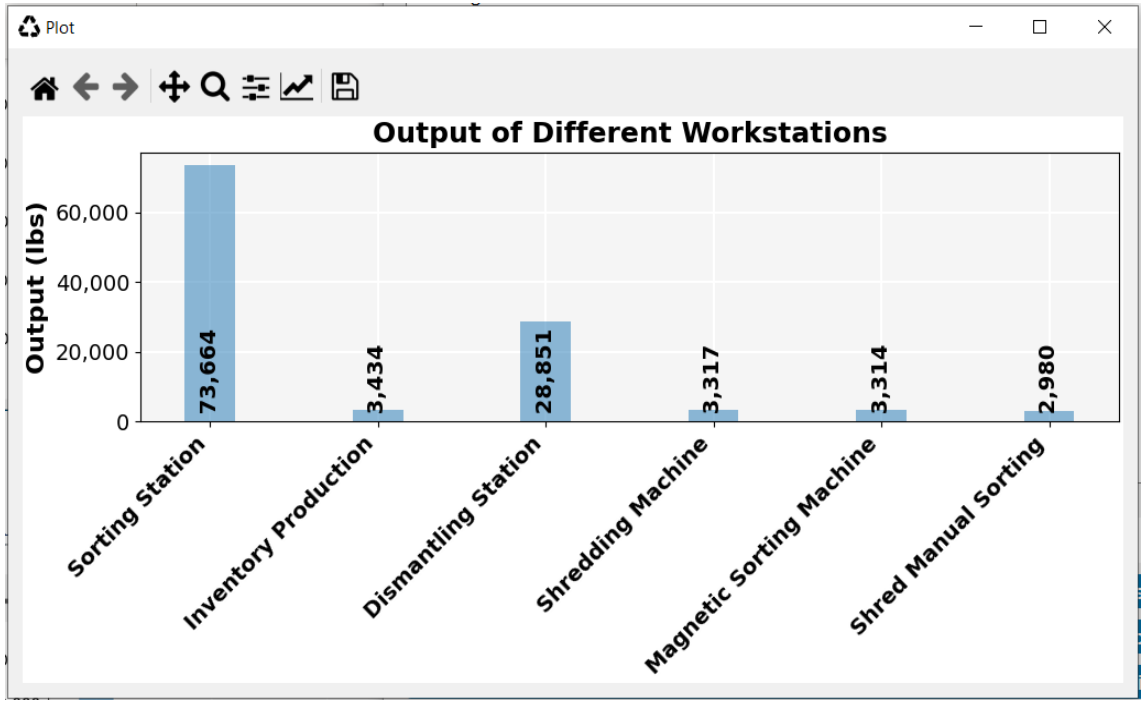


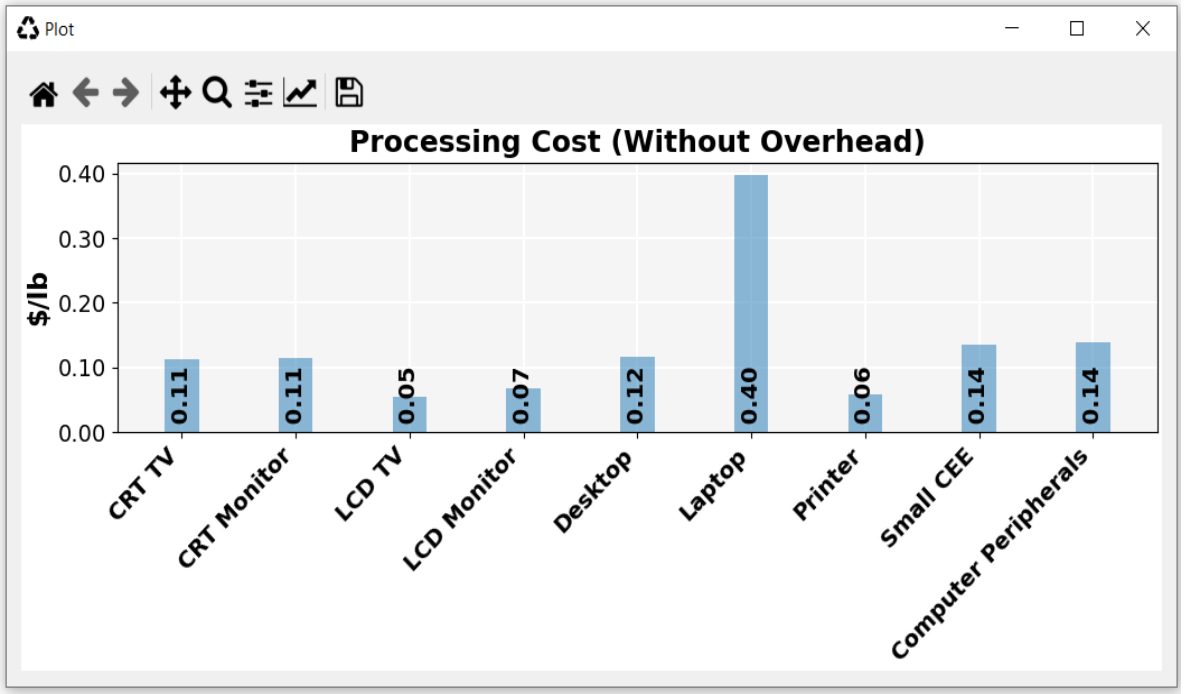
02. Process Module





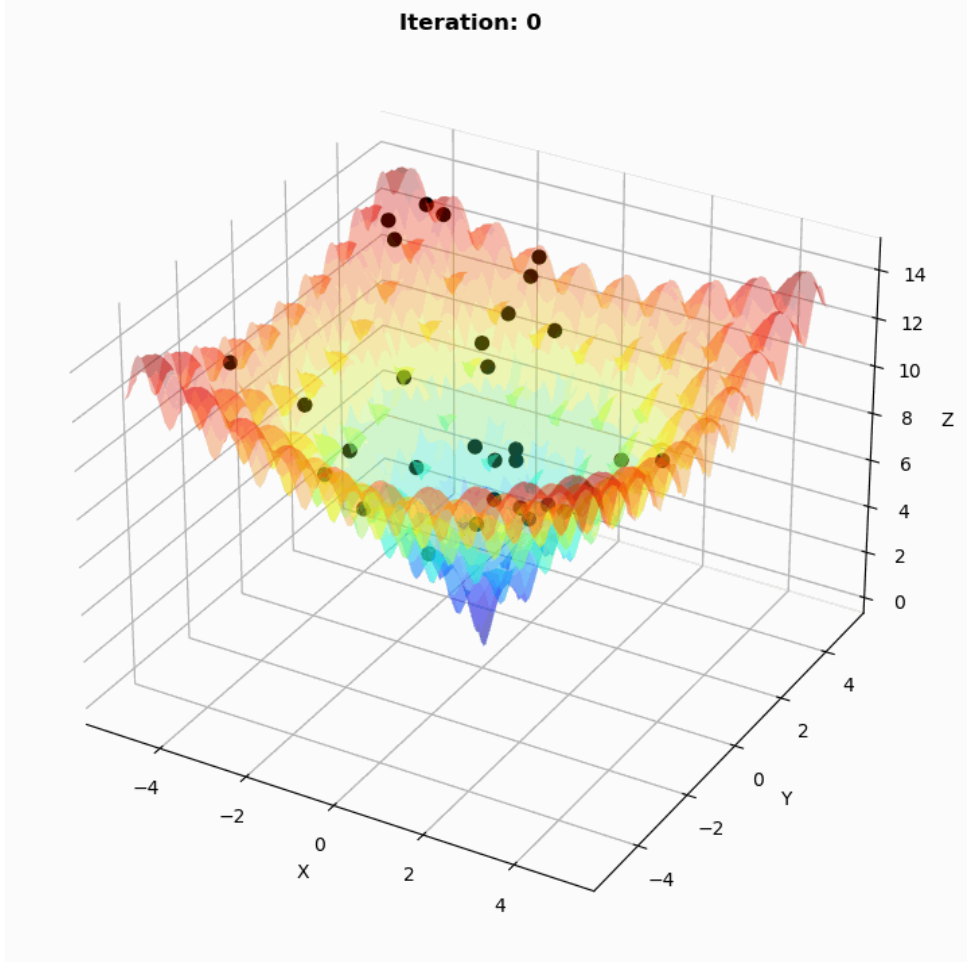
02. Process Module





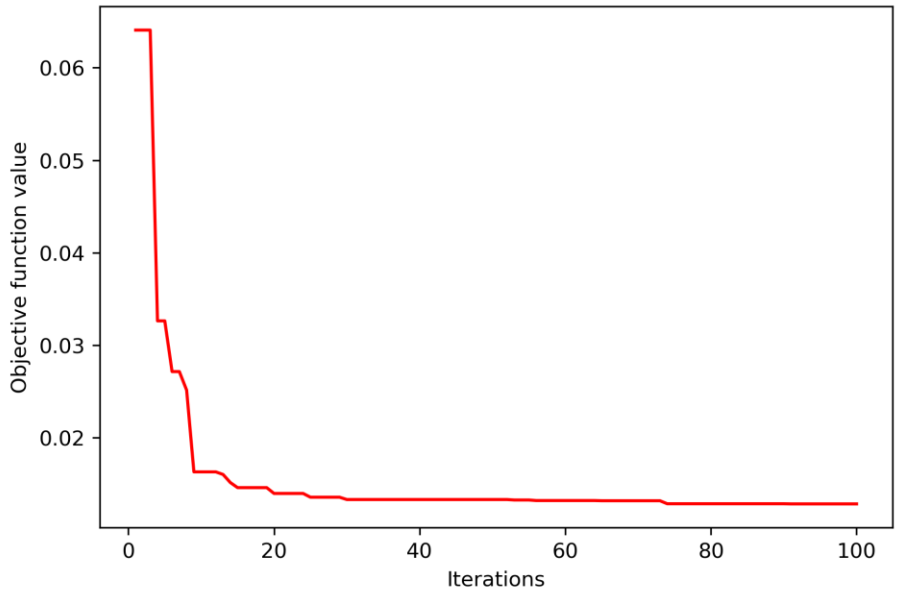
02. Process Module

HACO Algorithm Searching for Optimum Solution



Ackley Test Function $f(\mathbf{x}) = -a\exp\left(-b\sqrt{\frac{1}{d}\sum_{i=1}^{d}x_i^2}\right) - \exp\left(\frac{1}{d}\sum_{i=1}^{d}\cos(cx_i)\right) + a + \exp(1)$

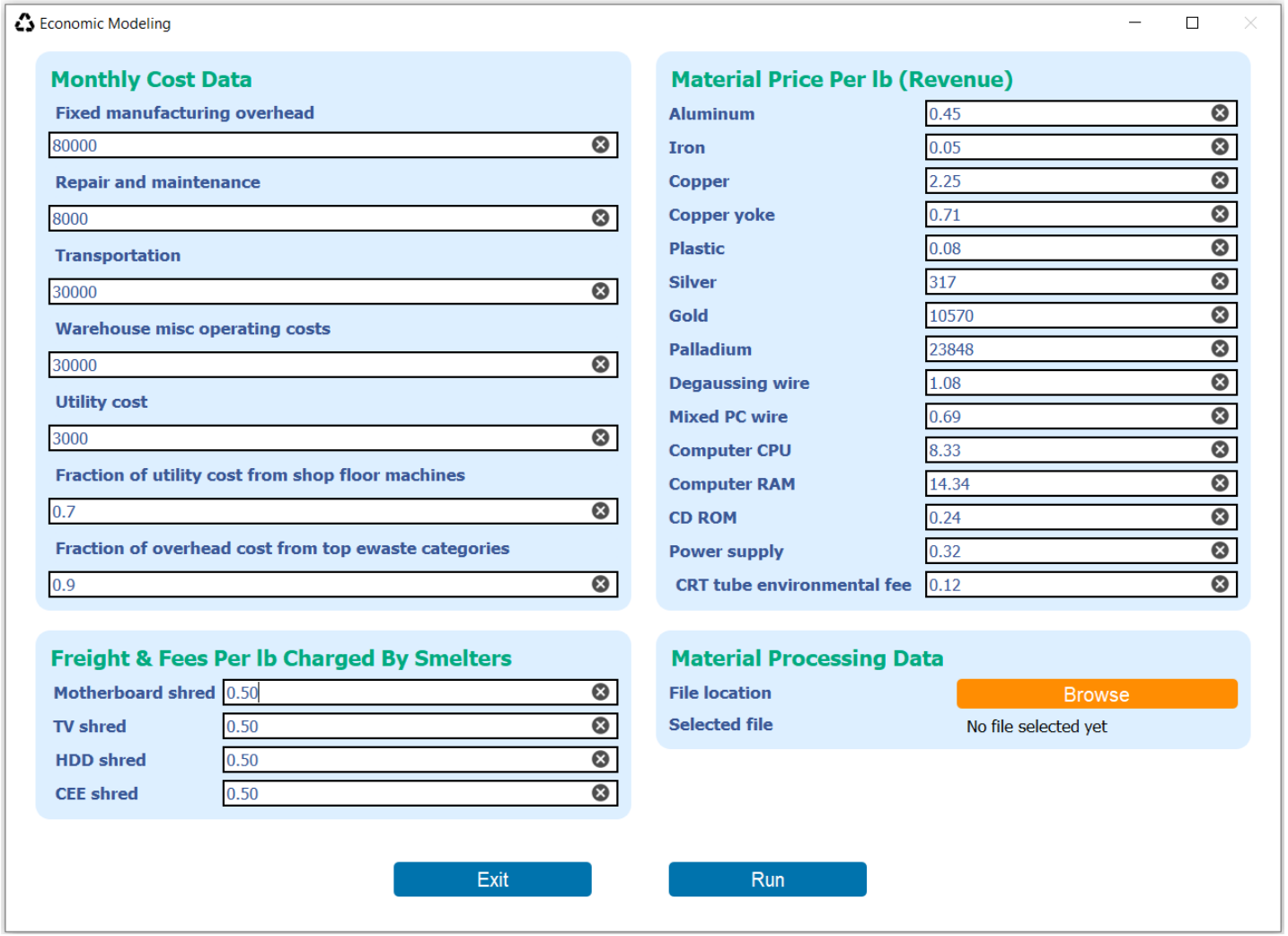
Optimization of Manpower



Optimum Allocation of Manpower

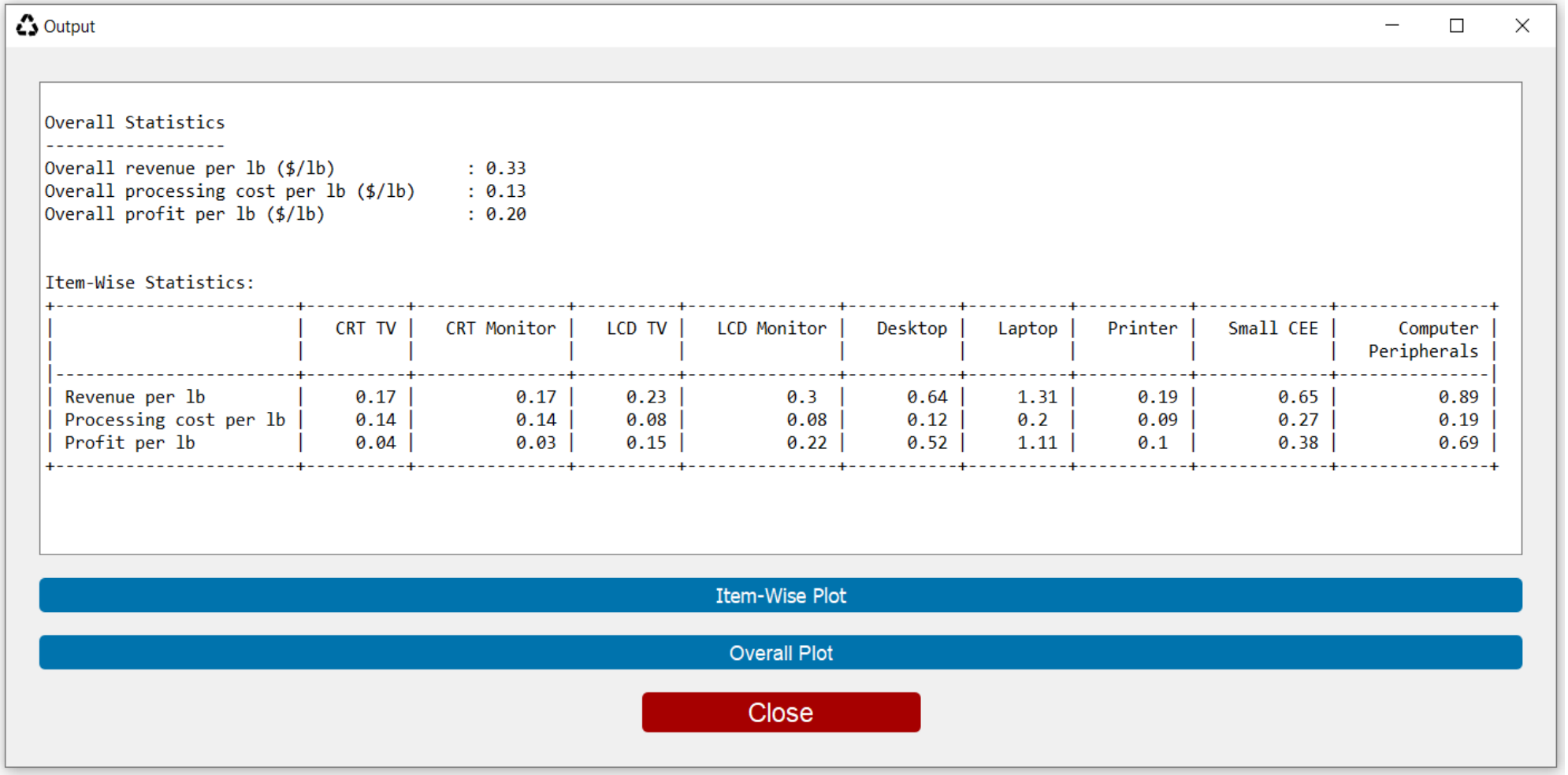
Sorting Station	: 05
Dismantling Station	: 12
Inventory Production	: 11
Shredding Machine	: 02
Optimized processing cost	: 0.013 $/lb

03. Economic Module



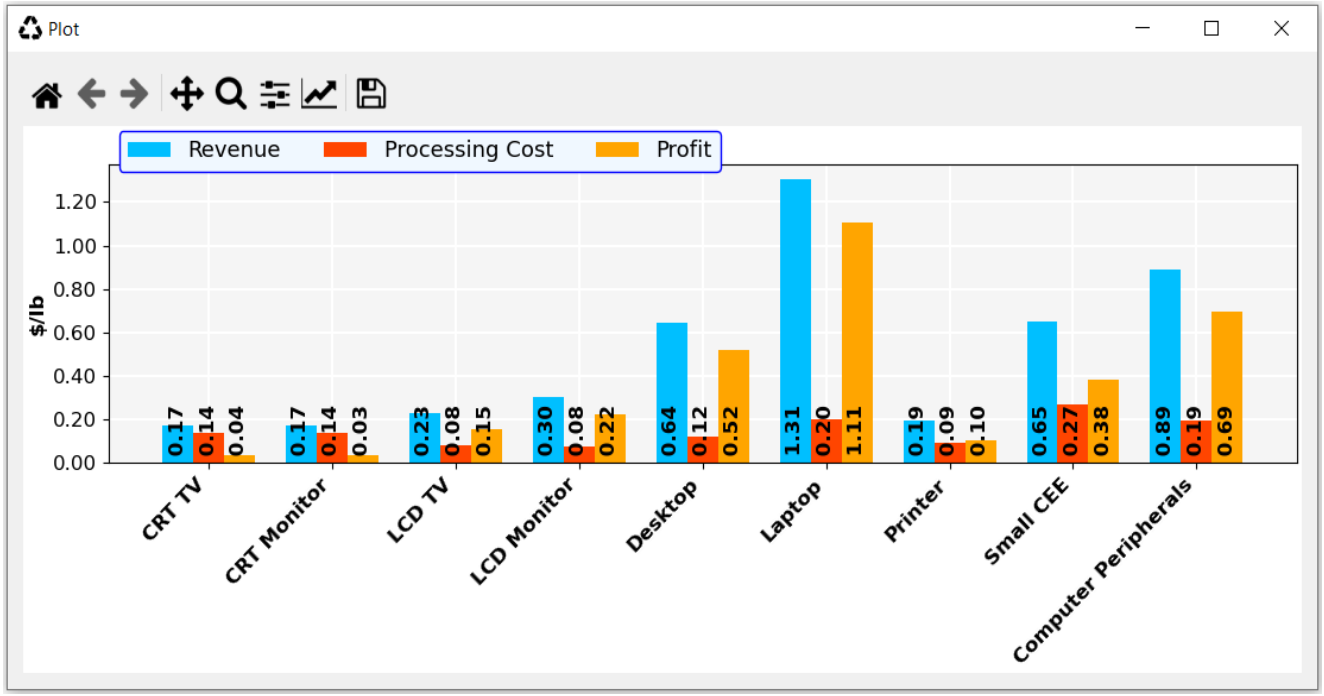
Input Window

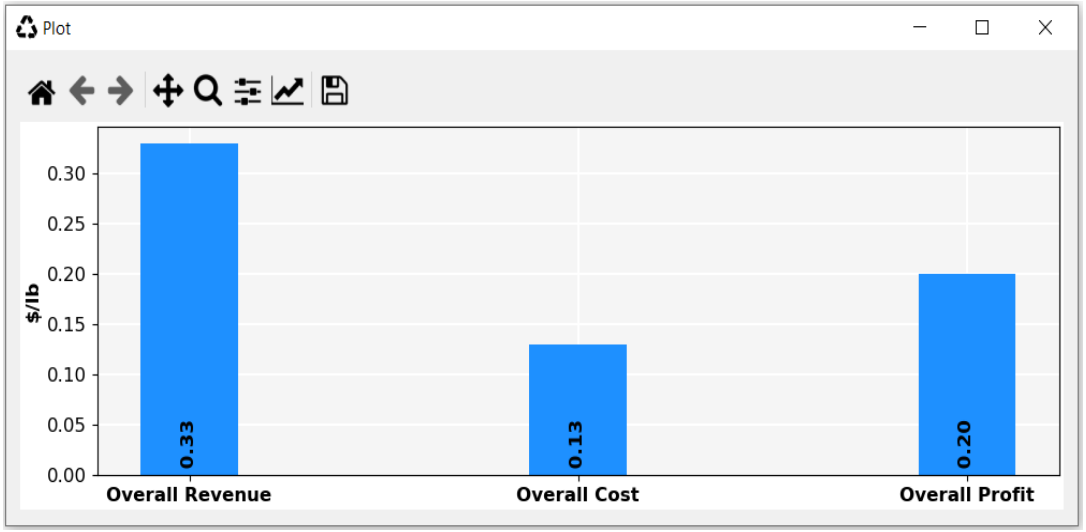
03. Economic Module



	CRT TV	CRT Monitor	LCD TV	LCD Monitor	Desktop	Laptop	Printer	Small CEE	Computer Peripherals
Revenue per lb	0.17	0.17	0.23	0.3	0.64	1.31	0.19	0.65	0.89
Processing cost per lb	0.14	0.14	0.08	0.08	0.12	0.2	0.09	0.27	0.19
Profit per lb	0.04	0.03	0.15	0.22	0.52	1.11	0.1	0.38	0.69

03. Economic Module





Concluding Remarks

- Very easy to use
- Zero simulation/coding experience
- Source code in Python
- Plan to release as open source under Apache License
- Customizable for other industries
- Our other software and scientific offerings at:

  https://dynamicmodel.inl.gov/SitePages/Home.aspx

  https://github.com/IdahoLabResearch/

THANK YOU!

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