Summer Fellowship Report

On

FlowCost : DWSIM Flowsheet Techno-Economic Analysis

Submitted by

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I am also thankful to the entire **FOSSEE team** for providing the resources, platform, and support necessary to carry out this work. The opportunity to contribute to an open-source initiative and work with DWSIM has greatly enhanced my understanding of process simulation, techno-economic analysis, and software development.

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Chapter 1

Abstract

DWSIM is an open-source process simulator widely used for modelling and analysing chemical processes through process flowsheets. While process simulation provides detailed information regarding equipment and material streams, performing a complete techno-economic analysis often requires significant manual effort. Conventional approaches based on the CAPCOST methodology and Turton's equipment-costing correlations require users to manually extract equipment parameters, identify appropriate cost correlations, and perform multiple calculations using different references. This process can be time-consuming and prone to errors, particularly for complex flowsheets.

To address this challenge, **FlowCost** was developed as an open-source software tool for automating the techno-economic analysis of DWSIM flowsheets. The application automatically extracts process and equipment data from DWSIM simulations and estimates equipment purchase costs, capital expenditure (CAPEX), operating expenditure (OPEX), raw-material costs, utility costs, and key economic indicators. By integrating these calculations into a single workflow, FlowCost significantly reduces the effort required for preliminary process economic evaluation.

The developed methodology was validated using **11 DWSIM flowsheets obtained from IIT Bombay FOSSEE**, representing a variety of process configurations and equipment combinations. The resulting cost estimates showed satisfactory agreement with reference values, demonstrating the applicability of the tool for preliminary techno-economic assessment.

FlowCost is freely available as an open-source project on GitHub, providing an accessible alternative for automated process costing and economic analysis. Further validation against commercial techno-economic analysis tools remains an area for future work. GitHub

Chapter 2

Introduction

2.1 Project Overview

FlowCost is an open-source software application developed to automate the techno-economic evaluation of chemical process flowsheets generated using DWSIM. The project aims to bridge the gap between process simulation and economic analysis by providing a unified platform capable of converting process and equipment information into meaningful economic indicators. Rather than requiring users to manually transfer simulation data into separate costing spreadsheets or economic-analysis tools, FlowCost integrates the entire workflow into a single application.

2.2 Architecture

The software is designed around a modular architecture consisting of data extraction, equipment costing, capital cost estimation, operating cost estimation, and economic evaluation modules. Process information exported from DWSIM is automatically parsed and converted into a structured format that can be used for equipment-specific cost calculations. The application supports a wide range of commonly encountered process equipment, including distillation columns, heat exchangers, pumps, compressors, reactors, vertical and horizontal vessels, kettle reboilers, and other generic equipment through fallback costing methods.

2.3 Capital Cost Estimation

For each equipment item, FlowCost estimates purchased-equipment cost and bare-module cost using established cost correlations and correction factors. These equipment-level costs are subsequently aggregated to generate a complete capital-cost assessment. The application calculates key capital-investment metrics including total purchase cost, total bare-module cost, contingency allowance, engineering fees, Inside Battery Limits (ISBL), Outside Battery Limits (OSBL), total fixed capital, startup costs, working capital, and total project cost.

2.4 Operating Cost Estimation

In addition to capital-cost estimation, FlowCost performs operating-cost calculations. The software estimates utility costs, labour costs, maintenance expenses, insurance costs, and overhead expenses to determine the overall operating expenditure (OPEX) of the process. Annualized capital costs and total annual costs are also calculated, allowing users to perform preliminary economic assessments of alternative process configurations.

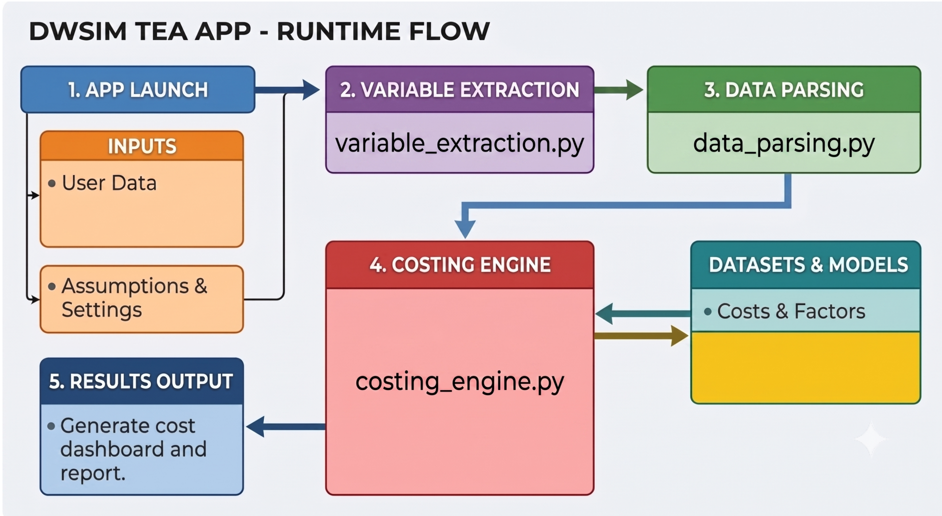


Figure 2.1: Project Flowchart

2.5 Economic Assumptions and User Inputs

A significant feature of FlowCost is its flexibility in handling economic assumptions. Users can specify parameters such as CEPCI values, contingency percentages, engineering costs, startup and working-capital fractions, plant life, discount rate, operating hours, utility prices, electricity costs, location factors, currency-conversion factors, and material-of-construction selections. This allows the same process model to be evaluated under different economic conditions and geographical locations.

2.6 User Interface and Workflow

The complete workflow is implemented through an interactive graphical interface that enables data upload, economic configuration, equipment-level analysis, CAPEX and OPEX evaluation, and result visualization. Consequently, FlowCost provides a comprehensive framework for performing preliminary techno-economic assessments directly from DWSIM process simulations.

Chapter 3

Methodology

3.1 Overall Computational Workflow

FlowCost converts a converged DWSIM process flowsheet into a preliminary techno-economic assessment through a sequential computational workflow. The methodology consists of extracting process and equipment information from DWSIM, mapping the extracted variables to equipment-specific costing parameters, estimating purchased and installed equipment costs, calculating capital and operating expenditure, and finally evaluating the economic performance of the process. The overall framework follows the module-costing methodology of Turton et al., with the numerical correlations and implementation parameters stored in the FlowCost costing database. [?, ?]

The computational sequence can be represented as

$$DWSIMData \rightarrow EquipmentSize \rightarrow C_p^0 \rightarrow C_{BM} \rightarrow CAPEX/OPEX \rightarrow EconomicIndicators. \quad (3.1)$$

3.2 DWSIM Data Extraction and Processing

The first stage is the extraction of process and equipment information from the DWSIM simulation. The extraction framework identifies variables required for equipment sizing and costing, including equipment dimensions, volume, heat-transfer duty, heat-transfer area, power requirement, pressure, temperature, flow rate, number of stages, tray spacing, reflux ratio, and other equipment-specific parameters. The extracted information is written to an intermediate Excel workbook and organized into structured sheets containing objects, material streams, compositions, energy streams, distillation columns, heat exchangers, pumps, compressors, connections, and costing variables. [?, ?]

The parsed data are then converted into a unified equipment inventory. Each physical unit operation is mapped to a corresponding costing category and capacity parameter. For example, pumps and compressors are primarily represented by shaft power, vessels by internal volume, heat exchangers by heat-transfer area, and distillation columns by shell dimensions and stage information. This mapping allows a common costing engine to process different DWSIM unit-operation classes.

3.3 Purchased Equipment Cost Estimation

For equipment covered by the selected Turton correlations, the purchased equipment cost is estimated from a characteristic equipment capacity parameter A using

$$\log_{10}(C_p^0) = K_1 + K_2 \log_{10}(A) + K_3[\log_{10}(A)]^2 \quad (3.2)$$

where C_p^0 is the reference purchased equipment cost and K_1, K_2, and K_3 are equipment-specific empirical regression coefficients. These coefficients are published Turton parameters rather than freely tunable model constants. The applicable minimum and maximum capacity limits are also stored for each equipment subtype. [?, ?]

BARE-MODULE FACTORS AT CARBON STEEL, LOW PRESSURE

EQUIPMENT	B1	B2	F_{BM}	C_{BM} / C_P^0
Heat exchanger	1.63	1.66	**3.29**	3.3×
Pump	1.89	1.35	**3.24** (×F_M 1.6 → 4.05)	3–4×
Vertical vessel / column / reactor	2.25	1.82	**4.07**	4.1×
Horizontal vessel	1.49	1.52	**3.01**	3.0×
Compressor (material lookup)	–	–	**2.8** (CS)	2.8×

Figure 3.1: Bare Module Constants

When the calculated capacity lies outside the valid correlation range, FlowCost evaluates the cost at the nearest boundary and applies a power-law extrapolation:

$$C_p^0(A) = C_p^0(A_{\text{bound}}) \left(\frac{A}{A_{\text{bound}}} \right)^n \tag{3.3}$$

where n is the equipment-specific scaling exponent. The application generates a warning whenever extrapolation is required, allowing the user to identify estimates that lie outside the original fitted range. [?]

3.4 Cost Escalation Using CEPCI

The equipment correlations are expressed on a historical cost basis and must therefore be adjusted to the selected costing year. FlowCost uses the Chemical Engineering Plant Cost Index according to

$$C_{p,\text{current}} = C_p^0 \left(\frac{CEPCI_{\text{target}}}{CEPCI_{2001}} \right). \tag{3.4}$$

The current methodology uses $CEPCI_{2001} = 397$ as the reference basis and $CEPCI_{\text{target}} = 800$ as the default target index. The target CEPCI is treated as a project input and may be changed according to the required costing year. [?]

3.5 Bare-Module Cost Estimation

The purchased equipment cost represents the basic equipment price, whereas the bare-module cost represents the estimated installed cost of the equipment within the process plant. For standard equipment classes, FlowCost calculates the bare-module factor as

$$F_{BM} = B_1 + B_2 F_M F_P \tag{3.5}$$

and the corresponding bare-module cost as

$$C_{BM} = C_{p,\text{current}} F_{BM}. \tag{3.6}$$

Here, B_1 and B_2 are equipment-specific Turton coefficients, F_M is the material factor, and F_P is the pressure factor. The factors account empirically for the additional cost associated with installing and constructing equipment rather than representing installation labour alone. [?, ?]

At carbon-steel, low-pressure conditions, representative bare-module factors are approximately 3.29 for heat exchangers, 3.24 for pumps before additional material correction, 4.07 for vertical vessels, and 3.01 for horizontal vessels. Therefore, a bare-module cost several times the purchased equipment cost is an expected outcome of the selected methodology rather than a separate three-times installation charge. [?]

2.4 CAPEX FACTORS

PARAMETER	DEFAULT	CLASS	MEANING & JUSTIFICATION
contingency_pct	15%	TURTON	Extra capital for unforeseen costs, as % of bare-module cost. 15% is Turton's standard contingency for a defined project.
engineering_pct	10%	TURTON	Detailed engineering and fees, % of bare-module cost. Turton-typical for the legacy roll-up.
startup_pct	5%	DEFAULT	Commissioning and start-up, % of fixed capital. Standard range is 5–10%; the low end is chosen.
working_capital_pct	10%	DEFAULT	Cash for initial inventory and receivables, % of fixed capital. Turton uses 15–20% of grassroots; 10% of FCI is a conservative equivalent.
PARAMETER	DEFAULT	CLASS	MEANING & JUSTIFICATION
osbl_factor	0.10	DEFAULT	Outside-battery-limits site utilities and infrastructure as a fraction of ISBL. **Legacy mode only.**
capex_mode	"Rigorous (System Expansion)"	PROJECT	Which roll-up to use (§3). Rigorous = Turton grassroots with explicit factors; Legacy = simpler percentage stack.

Different equipment classes use different formulations. Compressors and turbines use material-dependent pressure-independent factors, while trays use $F_{BM} = F_M$. These formulations are selected according to the equipment-specific costing method stored in the dataset. [?]

For vessels and columns, the pressure factor is derived from shell thickness and diameter. The implemented relationship is

$$t_s = \frac{(P+1)D}{2[850 - 0.6(P+1)]} \tag{3.7}$$

followed by

$$F_P = \frac{t_s + 0.00315}{0.0063}. \tag{3.8}$$

For pumps and heat exchangers, the pressure factor is calculated using the Turton polynomial

$$\log_{10}(F_P) = C_1 + C_2 \log_{10}(P) + C_3[\log_{10}(P)]^2. \tag{3.9}$$

For pumps and heat exchangers, the pressure factor is calculated using the Turton polynomial

$$\log_{10}(F_P) = C_1 + C_2 \log_{10}(P) + C_3[\log_{10}(P)]^2. \tag{3.10}$$

The material factor F_M adjusts the carbon-steel reference cost for alternative materials of construction. The numerical material and pressure factors are equipment specific. [?, ?]

3.6 Distillation Column and Heat Exchanger Sizing

Distillation columns are divided into the column shell and internal trays. The shell is treated as a vertical vessel, while tray costs are calculated separately. The shell volume is obtained from

$$V = \frac{\pi}{4} D^2 H \tag{3.11}$$

and the tray area from

$$A_t = \frac{\pi}{4} D^2. \tag{3.12}$$

Tray cost is then multiplied by the number of trays and the quantity factor F_q. Condensers and reboilers represented separately in the flowsheet are treated as separate heat-transfer equipment.

For heat exchangers where physical area is not directly available from DWSIM, FlowCost estimates the required area using

$$A = \frac{Q}{U \Delta T_{lm}} \tag{3.13}$$

where Q is heat duty, U is the overall heat-transfer coefficient, and ΔT_{lm} is the logarithmic mean temperature difference. The utility selected for the duty determines the associated U-value and utility cost. [?]

3.7 CAPEX and OPEX Calculation

The equipment-level bare-module costs are aggregated to obtain plant-level capital expenditure. FlowCost supports a rigorous system-expansion mode and a legacy percentage-based mode. In the rigorous mode,

2.5 OPEX FACTORS

PARAMETER	DEFAULT	CLASS	MEANING & JUSTIFICATION
opex_method	"Turton (COMd)"	PROJECT	COM_d is Turton's cost of manufacture (§4.1) — the accepted, non-double-counting way to build OPEX. The alternative, Simple Addition, is a transparent line-by-line sum.
operator_salary	60,000 $/yr	DEFAULT	Fully burdened cost of one operator-position-year. Turton-typical US labour.
shifts_per_position	5.0	TURTON	Operators needed to man one position around the clock: 3 shifts/day × 7 days plus vacation and sick coverage ≈ 4.5–5 people. 5 is the standard staffing multiplier.
maintenance_pct	6%	TURTON	Annual maintenance as % of fixed capital. Turton's 0.06·FCI.
overhead_pct	60%	DEFAULT	Plant overhead as % of labour — **Simple-Addition mode only**. In COM_d mode overhead is already embedded in the 2.73 labour coefficient, so it is not added again.
insurance_pct	3%	TURTON	Insurance plus local taxes, % of fixed capital. Turton's 0.03·FCI.
labour_cost_override	None	PROJECT	Set a $/yr number to bypass the $N^{0.7}$

Figure 3.2: Opex Factors

$$C_{TM} = 1.18 \sum_i C_{BM,i} \tag{3.14}$$

where the 18% allowance is separated into 15% contingency and 3% contractor fee. A grassroots auxiliary-facilities allowance is then added to obtain the fixed capital requirement. [?]

For operating expenditure, the default Turton cost-of-manufacture model is

$$COM_d = 0.18FCI + 2.73C_{OL} + 1.23(C_{UT} + C_{RM}), \tag{3.15}$$

where FCI is fixed capital investment, C_{OL} is operating labour, C_{UT} is utility expenditure, and C_{RM} is raw-material expenditure. Utility expenditure is calculated from process duty, annual operating hours, and utility price. [?]

3.8 Economic Evaluation and Assumptions

The final economic assessment uses fixed capital investment, OPEX, plant lifetime, and discount rate. The capital recovery factor is

$$CRF = \frac{r(1+r)^n}{(1+r)^n - 1} \tag{3.16}$$

and annualized CAPEX is calculated as

$$C_{\text{annualized}} = FCI \times CRF. \tag{3.17}$$

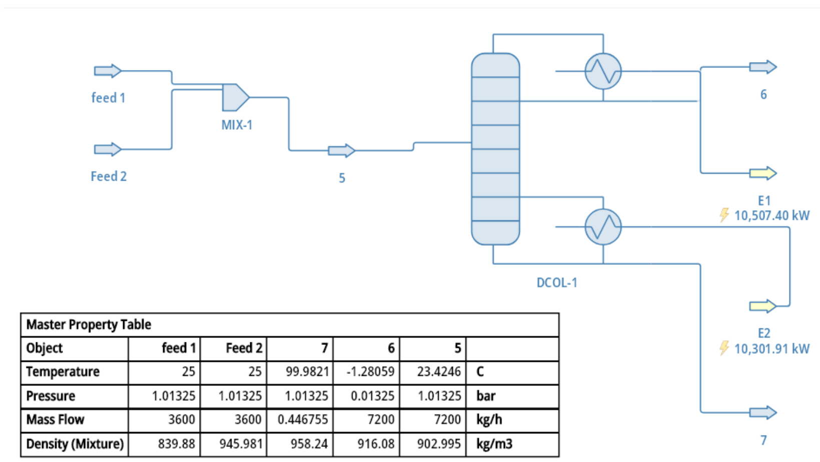
The resulting annualized CAPEX and OPEX are combined to obtain total annual cost, while NPV can be evaluated when the corresponding economic inputs are specified. [?]

For reproducibility, FlowCost distinguishes between three types of parameters: published Turton constants, engineering defaults, and project-specific economic assumptions. Turton coefficients such as K_1, K_2, K_3, B_1, and B_2 are treated as fixed methodological parameters, while values such as heat-transfer coefficients, operating hours, residence times, utility prices, plant life, and discount rate can be modified according to the requirements of the analysis. [?]

Chapter 4

Results and Discussion

4.1 Results for Flowsheet 1- Ethanol and Water Distillation



Master Property Table						
Object	feed 1	Feed 2	7	6	5	
Temperature	25	25	99.9821	-1.28059	23.4246	C
Pressure	1.01325	1.01325	1.01325	0.01325	1.01325	bar
Mass Flow	3600	3600	0.446755	7200	7200	kg/h
Density (Mixture)	839.88	945.981	958.24	916.08	902.995	kg/m3

Figure 4.1: Ethanol and Water Distillation

OPEX SUMMARY (USD/yr)

Item	Value (USD/yr)
Raw Materials	0
Utilities	5,156,755
Labour	1,638,000
Maintenance	217,856
Overhead	1,113,514
Insurance & Tax	108,928
Total OPEX	**8,235,054**
Annualised CAPEX	**590,919**
Total Annual Cost	**8,825,972**

CAPEX SUMMARY (USD)

Item	Value (USD)
Total Purchase Cost	897,123
Total Bare-Module Cost	2,797,334
Contingency	419,600
Engineering Fee	83,920
ISBL (Inside Battery Limits)	3,300,854
OSBL (Outside Battery Limits)	330,085
Total Fixed Capital Investment	**3,630,940**
Startup Cost	181,547
Working Capital	363,094
Total Project Cost	**4,175,581**

UTILITY SUMMARY

Tag	Duty Type	Utility	Duty (kW)	Price ($/GJ)	Annual Cost (USD/yr)
DCOL-1_Condenser	Condenser (cooling)	Refrigeration	10,507.4	0	2,387,618
DCOL-1_Reboiler	Reboiler (heating)	LP Steam	10,301.91	0	1,803,906
DCOL-1_Reflux_Pump	Pump (electricity)	Electricity	2	0	960

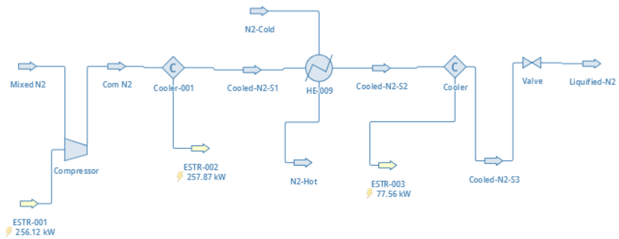
EQUIPMENT COST SUMMARY

Tag	Equipment Type	Size Parameter	Purchase Cost (2001 USD)	Purchase Cost (Current USD)	Bare-Module Cost (USD)
DCOL-1	Distillation Column	D=2.31m, H=8.0m, N=10 trays	66,799	132,142	295,676
DCOL-1_Condenser	Condenser	A=1917.54 m2	149,623	295,982	973,781
DCOL-1_Reboiler	Reboiler	A=198.05 m2	218,228	431,697	1,420,282
DCOL-1_Reflux_Drum	Reflux Drum	V=3.60 m3	6,231	12,326	37,102
DCOL-1_Reflux_Pump	Reflux Pump	P=2.00 kW	2,626	5,194	21,038
MIX-1	Mixer	N/A	10,000	19,782	49,455

Figure 4.2: Summary of equipment-level costing, utility costing, CAPEX, and OPEX results for Flowsheet 1.

For Flowsheet 1, FlowCost estimated a total purchased equipment cost of $897,123 and a bare-module cost of $2.797 million. The total fixed capital was approximately $3.631 million, while the total project cost reached $4.176 million. Annual OPEX was estimated at $8.235 million, with utilities forming the largest operating-cost contribution.

4.2 Results for Flowsheet 2 : Nitrogen Liquefaction Linde Cycle



Nitrogen Liquefaction - Material Stream									
Object	N2-Hot	N2-Cold	Mixed N2	Liquified-N2	Cooled-N2-S3	Cooled-N2-S2	Cooled-N2-S1	Com N2	
Temperature	229.000009	77.354723	300.000000	77.354722	85.000000	185.421934	300.000000	1,131.982017	K
Pressure	1.000000	1.000000	1.000000	1.000000	25.000000	25.000000	25.000000	25.000000	atm
Mass Flow	810.000000	810.000000	1,000.000000	1,000.000000	1,000.000000	1,000.000000	1,000.000000	1,000.000000	kg/h
Molar Flow	28.914114	28.914114	35.696437	35.696437	35.696437	35.696437	35.696437	35.696437	kmol/h
Volumetric Flow	9,039.506245	2,933.487221	14,638.558044	317.457296	21.548744	330.795696	580.618715	2,224.492556	L/min
Molar Enthalpy (Vapor)	-2,026.180673	-6,491.084701	46.205128	-6,491.084717	0.000000	-3,747.282874	-130.711665	25,876.051649	kJ/kmol
Mass Flow (Vapor) / Nitrogen	810.000000	810.000000	1,000.000000	82.385093	0.000000	1,000.000000	1,000.000000	1,000.000000	kg/h
Mass Flow (Liquid 1) / Nitrogen	0.000000	0.000000	0.000000	917.614907	1,000.000000	0.000000	0.000000	0.000000	kg/h

Figure 4.3: Nitrogen Liquefaction Linde Cycle

Item	Value (USD/yr)
Raw Materials	0
Utilities	68,002
Labour	1,638,000
Maintenance	9,937
Overhead	988,762
Insurance & Tax	4,969
Total OPEX	2,709,671
Annualised CAPEX	26,955
Total Annual Cost	2,736,625

Item	Value (USD)
Total Purchase Cost	49,665
Total Bare-Module Cost	127,599
Contingency	19,140
Engineering Fee	3,828
ISBL (Inside Battery Limits)	150,567
OSBL (Outside Battery Limits)	15,057
Total Fixed Capital Investment	165,624
Startup Cost	8,281
Working Capital	16,562
Total Project Cost	190,467

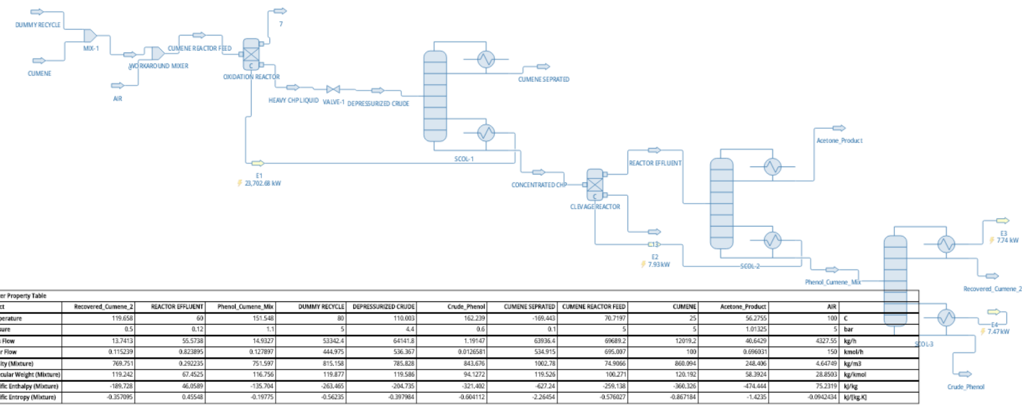
Tag	Duty Type	Utility	Duty (kW)	Price ($/GJ)	Annual Cost (USD/yr)
Cooler	Heat Exchanger	LP Steam	77.56	0	13,581
HE-009	Heat Exchanger	LP Steam	35.86	0	6,279
Cooler-001	Heat Exchanger	Chilled Water	257.87	0	35,426

Tag	Equipment Type	Size Parameter	Purchase Cost (2001 USD)	Purchase Cost (Current USD)	Bare-Module Cost (USD)
Cooler	Heat Exchanger	A=nan m2	881	1,743	6,013
HE-009	Heat Exchanger	A=0.27 m2	1,635	3,234	11,155
Cooler-001	Heat Exchanger	A=nan m2	881	1,743	6,013
Compressor	Compressor	P=10.00 kW	11,709	23,162	64,855
Valve	Valve	N/A	10,000	19,782	39,564

Figure 4.4: CAPEX, and OPEX results for Flowsheet 2.

For Flowsheet 2, FlowCost estimated a total purchase cost of $49,665 and a bare-module cost of $127,599. The total fixed capital investment was $165,624, with a total project cost of $190,467. Annual OPEX was $2,709,671, dominated by labour and overhead, while the total annual cost was $2,736,625.

4.3 Results for Flowsheet 3 : Co-Production of Phenol and Acetone via the Cumene Hydroperoxide (Hock) Process



Master Property Table												
Object	Recovered_Cumene_2	REACTOR EFFLUENT	Phenol_Cumene_Mix	DUMMY RECYCLE	DEPRESSURIZED CRUDE	Crude_Phenol	CUMENE SEPRATED	CUMENE REACTOR FEED	CUMENE	Acetone_Product	AIR	
Temperature	119.658	60	151.548	80	110.003	162.239	-169.443	70.7197	25	56.2755	100	C
Pressure	0.5	0.12	1.1	5	4.4	0.6	0.1	5	5	1.01325	5	bar
Mass Flow	13.7413	55.5738	14.9327	53342.4	64141.8	1.19147	63936.4	69689.2	12019.2	40.6429	4327.55	kg/h
Molar Flow	0.115239	0.823895	0.127897	444.975	536.367	0.0126581	534.915	695.007	100	0.696031	150	kmol/h
Density (Mixture)	769.751	0.292235	751.597	815.158	785.828	843.676	1002.78	74.9066	860.094	248.406	4.64749	kg/m3
Molecular Weight (Mixture)	119.242	67.4525	116.756	119.877	119.586	94.1272	119.526	100.271	120.192	58.3924	28.8503	kg/kmol
Specific Enthalpy (Mixture)	-189.728	46.0589	-135.704	-263.465	-204.735	-321.402	-627.24	-259.138	-360.326	-474.444	75.2319	kJ/kg
Specific Entropy (Mixture)	-0.357095	0.45548	-0.19775	-0.56235	-0.397984	-0.604112	-2.26454	-0.576027	-0.867184	-1.4235	-0.0942434	kJ/[kg.K]

Figure 4.5: Co-Production of Phenol and Acetone via the Cumene Hydroperoxide (Hock) Process

Tag	Equipment Type	Size Parameter	Purchase Cost (2001 USD)	Purchase Cost (Current USD)	Bare-Module Cost (USD)
SCOL-2	Distillation Column	D=0.23m, H=9.0m, I	3,288	6,504	19,441
SCOL-2_Reflux_Drum	Reflux Drum	V=3.00 m3	5,718	11,312	34,048
SCOL-2_Reflux_Pump	Reflux Pump	P=1.50 kW	2,532	5,008	20,283
SCOL-1	Distillation Column	D=3.19m, H=9.0m, I	129,117	255,417	560,377
SCOL-1_Reflux_Drum	Reflux Drum	V=3.00 m3	5,718	11,312	34,048
SCOL-1_Reflux_Pump	Reflux Pump	P=1.50 kW	2,532	5,008	20,283
SCOL-3	Distillation Column	D=0.10m, H=9.0m, I	1,150	2,276	7,503
SCOL-3_Reflux_Drum	Reflux Drum	V=3.00 m3	5,718	11,312	34,048
SCOL-3_Reflux_Pump	Reflux Pump	P=1.50 kW	2,532	5,008	20,283
CLEVAGE REACTOR	Reactor	V=1.00 m3	3,143	6,218	25,308

Item	Value (USD)
Total Purchase Cost	384,939
Total Bare-Module Cost	939,405
Contingency	140,911
Engineering Fee	28,182
ISBL (Inside Battery Limits)	1,108,498
OSBL (Outside Battery Limits)	110,850
Total Fixed Capital Investment	1,219,348
Startup Cost	60,967
Working Capital	121,935
Total Project Cost	1,402,250

Item	Value (USD/yr)
Raw Materials	0
Utilities	2,657
Labour	3,276,000
Maintenance	73,161
Overhead	2,009,497
Insurance & Tax	36,580
Total OPEX	5,397,895
Annualised CAPEX	198,443
Total Annual Cost	5,596,338

Figure 4.6: CAPEX, and OPEX results for Flowsheet 3.

For this flowsheet, FlowCost estimated a total purchase cost of \$384,939 and a bare-module cost of \$939,405. The total fixed capital investment was \$1.219 million, with a total project cost of \$1.402 million. Annual OPEX was estimated at \$5.398 million, resulting in a total annual cost of \$5.596 million.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

The developed **FlowCost** framework provides an automated approach for performing preliminary techno-economic analysis of DWSIM process flowsheets. The developed workflow extracts process and equipment information from DWSIM and automatically performs equipment-level costing, CAPEX estimation, OPEX estimation, and annual economic analysis. The current model is capable of costing **23 equipment units/categories**, allowing the economic evaluation of flowsheets containing different process equipment and configurations.

The use of equipment-specific costing correlations, material and pressure corrections, utility-cost estimation, and project-level capital-cost calculations reduces the requirement for repetitive manual calculations and provides a unified workflow for preliminary process-economic evaluation.

The methodology was evaluated using multiple DWSIM flowsheets, and the results demonstrated that FlowCost can generate complete equipment-level and process-level economic estimates. The analysis also highlighted the importance of appropriately handling equipment-specific edge cases and ensuring that process sizing parameters remain within the valid ranges of the underlying costing correlations.

5.2 Future Work

Future development of FlowCost will focus on improving the accuracy, robustness, and accessibility of the software. **A/B testing of model parameters** will be performed to evaluate their influence on CAPEX and OPEX predictions and to identify more appropriate parameter values for different equipment types and operating conditions.

The costing methodology will also be improved to provide more accurate equipment-level estimates, particularly for edge cases where the current correlations may produce unusually high or uncertain values. In particular, some tested flowsheets have shown unusually high **reboiler-cost estimates**. Further investigation of heat-transfer-area calculations, temperature-driving-force assumptions, and correlation limits will therefore be carried out to improve the treatment of such cases.

Another major development will be the transition from the current DWSIM XML-based workflow to a **web-based application**. Hosting FlowCost online would allow users to perform costing and techno-economic analysis directly through a web interface, making the software easier to access without requiring manual handling of DWSIM XML files or installation of the complete local application environment.

Future versions of FlowCost will therefore aim to provide a **more accurate, better-validated, robust, and user-friendly techno-economic analysis platform** for DWSIM-based process simulations.

Chapter 6

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