CH402 Chemical Engineering Process Design

Class Notes L14

Cost Estimation & Capital Investments

WPR1 Corrections Due Friday 14 Feb 2359
(Bonus, Point value = 40% of cut)

Download and open "Cost and Evaluation Spreadsheet"

L14 Learning Objectives

- 1. Relate the I/O analysis from Lesson 13 to the different cash flows in a process.
- 2. Calculate the different types of cash flow in a chemical process (Figure 6-1).
- 3. Calculate equipment costs using capacity scaling factors.

Definitions:

Working capital, nonmanufacturing and manufacturing fixed costs, direct and indirect costs, total capital investment, gross profit, purchased equipment costs, operating labor costs, utility costs, depreciation, annual total product costs, cumulative cash position, cost capacity scaling factors

Known Vinyl Chloride Routes

5 processes

$$C_2H_2 + HCI \longrightarrow C_2H_3CI \qquad A$$

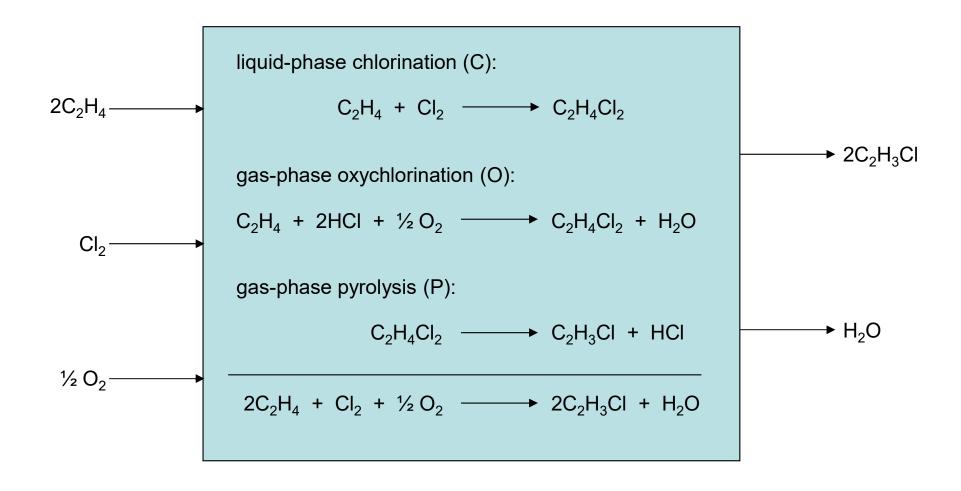
$$C_2H_4 + CI_2 \longrightarrow C_2H_3CI + HCI \qquad C$$

$$C_2H_4 + CI_2 \longrightarrow C_2H_3CI + HCI \qquad C-P$$

$$C_2H_4 + HCI + \frac{1}{2}O_2 \longrightarrow C_2H_3CI + H_2O \qquad O-P$$

$$2C_2H_4 + CI_2 + \frac{1}{2}O_2 \longrightarrow 2C_2H_3CI + H_2O \qquad C-O-P$$

Input/Output Structure - Route 5 – "COP"



The I/O diagram allows us to assessment the overall economics of the process.

Economic Analysis Based on I/O Structure

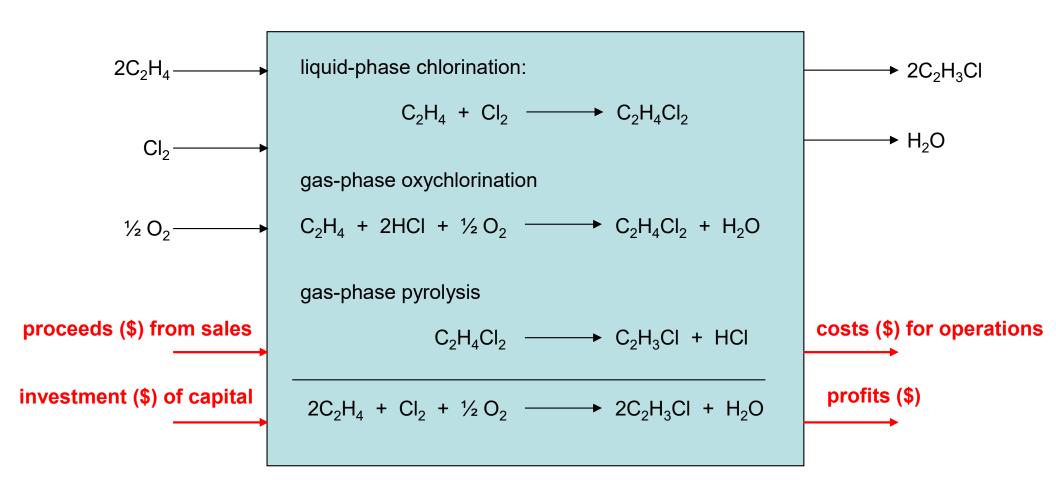
	Α	В	С	D	E	F	G	Н
1	Example 4-	2. Compare prod	luct and raw m	aterial value	s based or	1kg of vin	yl chloride	
2								
3					Reactio	n Path, kg	/kg VC	
4	Species	MW, kg/kgmol	Price, \$/kg	1	2	3	4	5
5	Cl ₂	70.9	0.03		1.13	1.13		0.57
6	HCI	36.5	0.22	0.58	0.58	0.58	0.58	
7	C ₂ H ₂	26.0	1.39	0.42				
8	C ₂ H ₄	28.1	0.45		0.45	0.45	0.45	0.45
9	C_2H_3CI	62.5	0.45	1.00	1.00	1.00	1.00	1.00
10	O ₂	32.0	0.04				0.26	0.13
11								
12	product val	ue		\$0.45	\$0.58	\$0.58	\$0.45	\$0.45
13	reactant co	st		\$0.71	\$0.24	\$0.24	\$0.34	\$0.22
14	excess valu	ie		-\$0.26	\$0.34	\$0.34	\$0.11	\$0.23

I/O diagram for process 5 is shown in slide 6.

The bottom line represents \$ per kg of product. If we know the kg/year, then we know the annual cash flow.

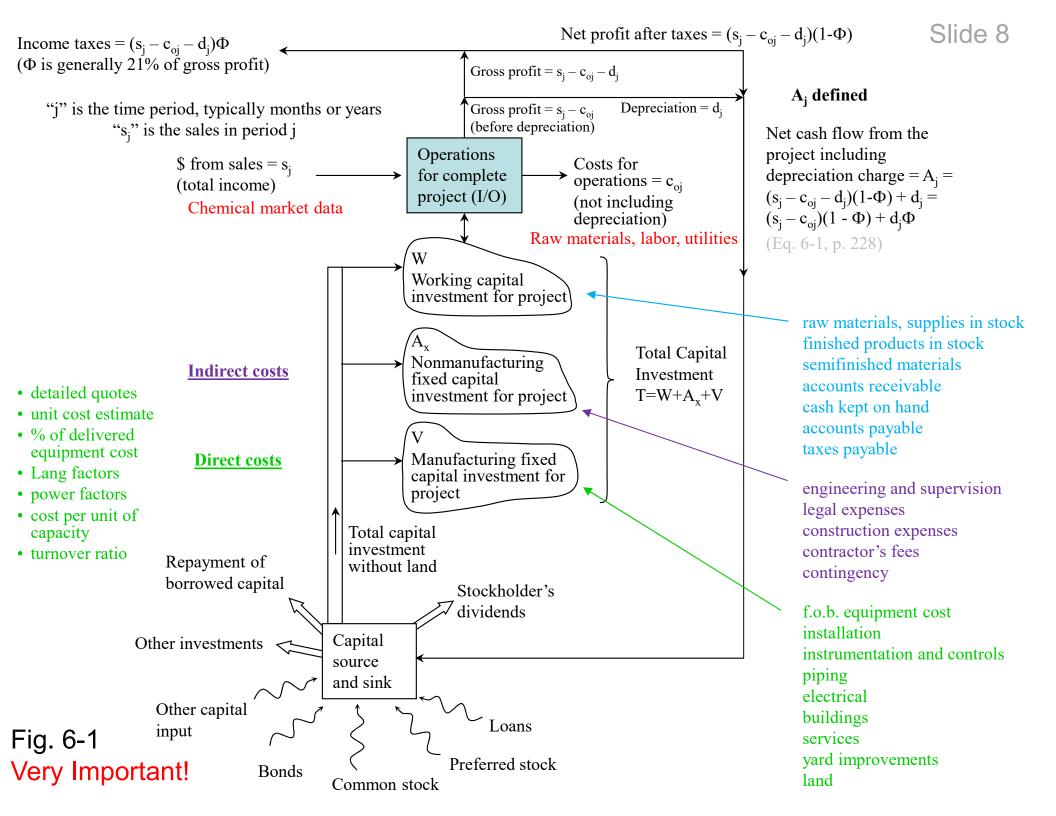
Input/Output Diagram - Route 5 - COP

Decision Makers (company, government, army, etc.) are concerned with cash flows.



Evaluation of Industrial Processes

- Economic depends on cost of process, cost of process flows, and cash flows to and from process.
- Equipment needs to be designed, sized, and costed.
- Preliminary cash flow patterns must be created from future cash flows and analyzed.
- Future cash flows are functionally related to chemical flow rates through market values.
- Future cash flows must account for (1) interest, (2) depreciation, and (3) taxes.







■ Gost and Evaluation Spreadsheet *







🧝 SiriusXM - For You 🐞 Home - Welcome -... 🚱 New Tab 🙀 Astrometry,net 🧱 Personal-Use Math... 🔥 GoogleDrive

CH402 Chemical Engineering Process Design

USMA Chemical Engineering AY23-2 Professor Andrew Biaglow (BH441, x4080) C1R2 & D1S2 hours, BH331

Web site last modified 10 January 2023

USMA CHEMIC

Program Mission Program Objectiv Student Outcome

COURSE ADMIN

Schedule

Welcome Email

Standing Instructions for Students (SIS)

Section Marcher Duties & Rotation

Registrar

SharePoint Directory

Roster C1R2-Hour

Roster D1S2-Hour

Seating Chart C1R2-Hour

Seating Chart D1S2-Hour

FE Reference Handbook v10.2 (2022)

FE Calculator Policy

Cover Sheet

COST INDICES

CE Plant Cost Index

ENR Skilled Labor Index

Nelson-Farrar Refinery Index

Nelson-Farrar Chemical Cost Index

SPREADSHEETS

Cost & Evaluation Spreadsheet

Agitator Design Spreadsheet

Pneumatic Conveyor Design Spreadsheet

CAPSTONE DESIGN PROJECT

Project Handout

Project Grading Rubric

Database Activation

Safety Design Checklist

Assignments and Groups

Guidance for IPR1

Guidance for IPR2

SAFETY AND ENVIRONMENTAL

Chemical Safety & Hazard Investigation Board Registry of Toxic Effects of Chem. Subst.

Nat. Inst. for Occ. Health & Safety

Safety Data Sheets

OTHER USEFUL RESOURCES

Online Unit Converter

Unit Glossary

Unit Dictionary

Nominal Pipe Size Charts

NIST WebBook

USMA Library

Perry's Chemical Engineer's Handbook

ChemExper (Structure and Properties)

CAPSTONE PR

Encyclopedia of Encyclopedia of Encyclopedia of

USMA Research

European Patent

Japanese Patent § US Patent Search

Access Engineeri

Google Scholar

SciFinder

Knovel

USEFUL JOUR

American Chemi

Chemical Engine Chemical Engine

Chemical Process

EngineerLive

USEFUL eBOO

Chemical Process Rules of Thumb Chemical Process

Pipeline Rules of

Troubleshooting

Cost Components of Capital Investments

FEE Reference Handbook, v10.4, pp. 257 (263/502)

ESTIMATION OF CAPITAL INVESTMI	ENT BY PERO	CENTAGE OF	DELIVERED	EQUIPMENT	METHOD		
(See Table 6-9)							
The fractions in the cells below are	e approxima	tions applic	able to typic	cal chemical	processing		
plants. These values may differ de	epending on 1	nany factors	such as locat	tion, process	type, etc.		
Required user input	Default		Subtotal		Result		
Required, from a linked sheet or		anually		Notes & con	nments		
Project Identifier: Illustration 101	Fraction	of delivered	equipment	User: copy	Calculated		
•	Solid-	Solid-fluid	Fluid	from values			
	processing	processing	processing	at left or	million \$		
	plant	plant	plant	insert			
	Direct	Costs					
Purchased equipment, E'					1.000		
Delivery, fraction of E'	0.10	0.10	0.10	0.10	0.100		
Subtotal: delivered equipment					1.100		
Purchased equipment installation	0.45	0.39	0.47	0.47	0.517		
Instrumentation&Controls(installed)	0.18	0.26	0.36	0.36	0.396		
Piping (installed)	0.16	0.31	0.68	0.68	0.748		
Electrical systems (installed)	0.10	0.10	0.11	0.11	0.121		
Buildings (including services)	0.25	0.29	0.18	0.18	0.198		
Yard improvements	0.15	0.12	0.10	0.10	0.110		
Service facilities (installed)	0.40	0.55	0.70	0.70	0.770		
Total direct costs	1.69	2.02	2.60	2.60	3.960		
	ndirect Cos						
Engineering and supervision	0.33	0.32	0.33	0.33	0.363		
Construction expenses	0.39	0.34	0.41	0.41	0.451		
Legal expenses	0.04	0.04	0.04	0.04	0.044		
Contractor's fee	0.17	0.19	0.22	0.22	0.242		
Contingency	0.35	0.37	0.44	0.44	0.484		
Total indirect costs	1.28	1.26	1.44	1.44	1.584		
Fire	d conital i	rootment /F/	~! \		E E A A	Sent to 'Eval u	ation' and
Fixe	d capital inv	esunent (FC	ار)		5.544	'Year-0 \$' , the	ere adjusted as
Working capital (WC)	0.70	0.75	0.89 0.89		0.979	described belo)W
Tota	l capital inv	estment (TC	CI)		6.523		

Sent to 'Annual TPC'

Raw Materials and Labor

ANNUAL RAW MATERIAL COSTS AND PRODUCTS VALUES

r: Illustratio	n 101		
out	Notes & co	mments	
changed			
oproducts	and Bypro	oducts	
Price,	Annual	Annual	e
\$/kg	Amount,	value of	
	million	product,	
	kg/y	million \$/y	
1.60	30.000	48.00	
0.25	12.000	3.00	
		0.00	
		0.00	
		0.00]
		0.00	1
value of pro	ducts =	51.00	Sent
	Price, \$/kg 1.60 0.25	Price, Annual Amount, million kg/y 1.60 30.000	Price, \$/kg Amount, million \$/y 1.60 30.000 48.00 0.25 12.000 3.00 0.00 0.00 0.00

explained	in
slide 13	

exp	lain	ed	in
sl	ide	13	

	Operating I	₋abor	
Number of	Shifts per	Operator	Annual
operators per	day**	rate, \$/h #	operating
shift*		, .	labor cost,
			million \$/y
3.0	3	33.67	0.885

ANNUAL OPERATING LABOR COSTS Process Identifier: Illustration 101

*See Tables 6-13 and Fig. 6-9.

Required user input Default, may be changed

RESULT

**Default = 3 for continuous process.

Enter appropriate value for batch operation.

[#]To obtain current, local value, ente<mark>gratest local</mark>

ENR skilled labor index)/6067

t to 'Evaluation' and 'Year-0 \$'

	Raw Mate	erials								
Name of	Price,	Annual	Annual raw							
Material	\$/kg	Amount,	materials							
		million	cost,							
kg/y million										
1	0.45	20.000	9.00							
2	0.25	12.000	3.00							
3	0.05	13.000	0.65							
			0.00							
			0.00							
0.00										
Total annual co	st of raw ma	aterials =	12.65							

Sent to sheet

'Annual TPC'

Table 6-13 Typical Labor Regizements for Process Equipment

Notes & comments

Tubio o To Typioui Euboi Routomo	1100 101 1 10000	o Equipino		
Type of equipment	Workers/u	nit/shift	# units	
Blowers and Compressors	0.1-0.2	0.15	4	0.6
Centrifugal separator	0.25-0.50	0.37	0	0.0
Crystallizer, mechanical	0.16	0.16	0	0.0
Dryer, rotary	0.5	0.5	0	0.0
Dryer, spray	1.0	1	0	0.0
Dryer tray	0.5	0.5	0	0.0
Evaporator	0.25	0.25	0	0.0
Filter, vacuum	0.125-0.25	0.131	0	0.0
Filter, plate and frame	1.0	1	0	0.0
Filter, rotary and belt	0.1	0.1	0	0.0
Heat exchangers	0.1	0.1	2	0.2
Process vessels, towers	0.2-0.5	0.35	2	0.7
Reactor, batch	1.0	1	1	1.0
Reactor, continuous	0.5	0.5	1_	0.5

Total number of workers per shift =

ENR Skilled Labor Index

Nelson-Farrar Refinery Ind

Nelson-Farrar Chemical Cost Index

ENR Skilled Labor Index

				ENF	R'S SKILLED	LABOR INDI	EX (1990-20)22)				
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ост	NOV	DEC
2023	11337	11360										
2022	11056	11110	11112	11114	11155	11178	11200	11223	11246	11269	11292	11314
2021	10775	10797	10800	10805	10805	10815	10826	10848	10880	10978	11000	11055
2020	10626	10626	10626	10626	10626	10637	10658	10679	10690	10701	10722	10744
2019	10431	10436	10441	10441	10441	10483	10525	10527	10527	10548	10569	10622
2018	10224	10254	10275	10277	10277	10277	10277	10297	10349	10380	10380	10411
2017	1011	10021	10021	10061	10061	10061	10090	10133	10158	10168	10196	10216
2016	9705	9732	9771	9809	9809	9878	9888	9898	9898	9927	9927	10011
2015	9465	9468	9475	9529	9474	9551	9563	9570	9618	9653	9696	9715
2014	9188	9192	9225	9265	9294	9295	9306	9309	9341	9387	9387	9434
2013	9010	9028	9028	9028	9029	9047	9051	9058	9062	9129	9164	9183
2012	8809	8820	8848	8848	8848	8851	8879	8963	8966	8973	8997	9010
2011	8644	8644	8644	8652	8652	8711	8725	8748	8763	8773	8793	8800
2010	8356	8391	8391	8391	8437	8449	8494	8499	8517	8593	8634	8645
2009	8112	8112	8112	8112	8171	8191	8200	8240	8251	8255	8255	8356
2008	7796	7796	7796	7803	7818	7818	7846	7861	7975	8103	8105	8107
2007	7459	7459	7464	7466	7579	7579	7590	7644	7701	7718	7793	7796
2006	7201	7207	7209	7213	7213	7213	7218	7224	7266	7416	7450	7459
2005	6912	6926	6926	6926	6972	6981	6997	7065	7157	7164	7199	7199
2004	6644	6660	6672	6672	6672	6698	6717	6728	6838	6874	6878	6912
2003	6366	6393	6411	6421	6426	6487	6515	6553	6569	6596	6604	6616
2002	6097	6097	6109	6109	6148	6166	6242	6264	6291	6306	633	6338
2001	5874	5874	5874	5892	5906	5948	5978	5984	6052	6065	606	6067
2000	5641	5650	5676	5676	5714	5735	5750	5764	5770	5812	581	5873
1999	5474	5474	5474	5489	5495	5521	5548	5548	5589	5596	5605	5635
1998	5294	5314	5317	5317	5317	5345	5369	5387	5416	5463	5471	5473
1997	5177	5177	5179	5182	5203	5203	5231	5263	5267	5280	5288	5294
1996	5016	5020	5020	5028	5039	5060	5075	5123	5133	5160	5164	5177
1995	4881	4892	4894	4903	4909	4909	4945	4967	4982	4998	5017	5016
1994	4766	4764	4764	4776	4782	4806	4816	4835	4865	4878	4878	4880
1993	4653	4653	4665	4665	4665	4662	4720	4720	4749	4757	4762	4766
1992	4539	4529	4536	4542	4553	4558	4593	4627	4639	4642	4551	4653
1991	4389	4387	4387	4390	4421	4440	4475	4493	4504	4520	4539	4539
1990	4242	4242	4248	4250	4267	4308	4310	4332	4372	4374	4387	4389

Entry for labor index:

 $\frac{11360}{6067} = 1.87$

Notes:

Index value in "Colorful" worksheet is **bold** and hightlighted in yellow

Bold RED values were extrapolated from the data for July through December 2022.

The skilled labor index is found at http://www.enr.com/economics/historical_indices/

Last updated 22 February 2023

Additional Info for Determining Operating Labor (Figure 6-9)

Example: A large automated plant produces 100,000 kg/day with 12 processing steps.

(34 employee hours per day / step) x 12 steps = 408 employee hours per day

408 employee hours per day / (8 hours / day) = 51 employees

51 employees / 3 shifts = 17 employees per shift

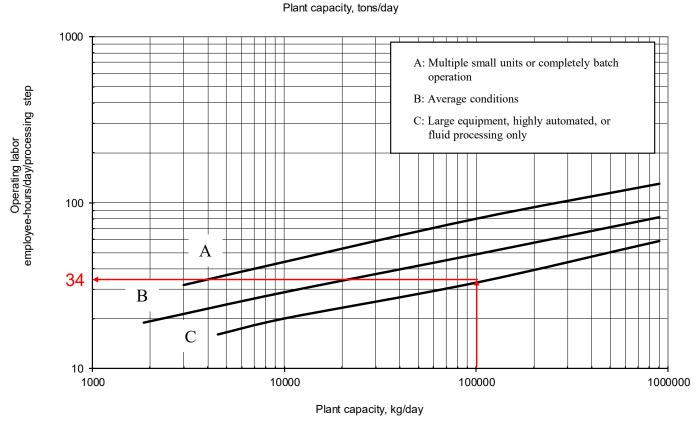


Figure 6-9 Operating Labor in the chemical process industries

Utility Costs

See Table 6-14 and Table B-1 for ranges of utility unit costs and sources of information. Default values are rough averages and may be changed. Utility costs can differ widely with location.

Process Identifier: Illustration 10	Required use	er input	Notes & comments				
		Result	_	Default, may be	changed		
TOTAL UTILITY COST =		2.025	million \$/y		,		
	Sent to	sheet 'Ann	ual TPC'	1			
Utility	Unit	Default cost units	Annual utility requirement, in appropriate units	Default units of utility requirement	Annual utility cost, million \$/y		
Air, compressed							
Process air	0.45	\$/100m ³ #		100 m ^{3*} /y			
Instrument air	0.90	\$/100m ³ #		100 m ^{3*} /y			
Electricity							
Purchased, U.S. average	0.045	\$/kWh	1800000	kWh/y	0.081		
Self-generated	0.05	\$/kWh		kWh/y			
Fuel							
Coal	1.66	\$/GJ		GJ/y			
Fuel oil	3.30	\$/GJ		GJ/y			
Natural gas	3.00	\$/GJ	360000	GJ/y	1.080		
Manufactured gas	12.00			GJ/y			
Refrigeration, to temperature							
15 °C	4.00	\$/GJ		GJ/y			
5 °C	5.00	\$/GJ		GJ/y			
-20 °C	8.00	\$/GJ		GJ/y			
-50 °C	14.00	\$/GJ		GJ/y			
Steam, saturated							
3550 kPa	8.00	\$/1000 kg		1000 kg/y			
790 kPa	6.00	\$/1000 kg	40000	1000 kg/y	0.240		
Exhaust (150 kPa)	2.00	\$/1000 kg		1000 kg/y			
Waste water							
Disposal	0.53	\$/m ³		m³/y			
Treatment	0.53	\$/m ³	400000	m³/y	0.212		
Waste disposal							
Hazardous	145.00	\$/1000 kg		1000 kg/y			
Non-hazardous	36.00	\$/1000 kg		1000 kg/y			
Water							
Cooling	0.08	\$/ m ³	2500000	m³/y	0.200		
Process							
General	0.53	\$/m ³	400000	m³/y	0.212		
Distilled	0.90	\$/m ³		m ³ /y			

Modified Accelerated Cost Recovery System (MACRS)

FEE Reference Handbook, v10.4, pp. 231-232 (257-258/502)

1		934																			
DEPRE	CIATIO	NC																			
Default = 8	5-y MA	CRS.	Defau	lt is in	place ir	n sheet	s 'Eva	luation	and "	Year-0	\$'.										
To use a different recovery period, copy the entire row into the depreciation row of sheets 'Evaluation' and 'Year-0 \$' (add columns to these sheets as needed).																					
										1.5											
User may elect straight-line depreciation and period (d = FCI/period), and																					
substitute the value into the depreciation row on sheets 'Evaluation' and																					
'Year-0 \$'.						- 1/-		III III	1111			1			95						9
							E	entry =	MACR	S depr	eciatio	n as fra	ction/y	of FCI							
Recovery						18					YEAR				-						
period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
3-year	0.333	0.444	0.148	0.074																	
f	0.200	0.320	0.192	0.115	0.115	0.058	524	- 4		2 8	88				35			526	160		3 3
7-year	0.143	0.245	0.175	0.125	0.089	0.089	0.089	0.045			80			3 90	98	8		6			2 83
10-year	0.100	0.180	0.144	0.115	0.092	0.074	0.066	0.066	0.066	0.066	0.033										
15-year	0.050	0.095	0.086	0.077	0.069	0.062	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.030		532			3 3
20-year	0.038	0.072	0.067	0.062	0.057	0.053	0.049	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.022

Annual Total Product Cost

See Figure 6-7 and 6-8		Š.	à		5	
Default, may be changed		Subtotal	Notes & co	omments		
User input		RESULT				
Required, may be calculated here, in	linked work	sheet, or entered n	nanually.			
Project identifier: Illustration 101			3:	2	Q §	
Capacity	30	10 ⁶ kg per year		8	8 - 3	
Fixed Capital Investment, FCI	50.114	million \$		6	9 6	
Item	Default factor, user may change	Basis	Basis cost, million \$/y	Cost, million \$/y		
Raw materials		8	8	12.650	1 3	
Operating labor		,		0.885		
Operating supervision	0.15	of operating labor	0.885	0.133		
Utilities	West .	ALL COMP.		2.025		
Maintenance and repairs	0.06	of FCI	50.114	3.007		
Operating supplies	0.15	of maintenance &	3.007	0.451	i s	
Laboratory charges	0.15	of operating labor	0.885	0.133	8 8	
Royalties (if not on lump-sum basis)	0.01	of co	26.674	0.267	9	
Catalysts and solvents	0	22		0.000	8	
Varia	able cost =	VACABLES IN	all Section 2011	19.550	Sent to 'Eval	uation' and
Taxes (property)	0.02	ofFCI	50.114	1.002		Year-0 \$
Financing (interest)	0	ofFCI	50.114	0.000		
Insurance	0.01	ofFCI	50.114	0.501	0	
Rent	0	ofFCI	50.114	0.000		
Depreciation	Calculate	d separately				
Marian and the state of the sta			Charges =	1.503		
Plant overhead, general	0.6	of labor, supervisi		2.415	20	
8		AD-SS NOV	verhead =	1000000		
		Manufactur			4 8	
Administration	0.2	of labor, supervisi		0.805		
Distribution & selling	0.05	of co	26.674	1.334		
Research & Development	0.04	of co	26.674	1.067	8 6	
	1	General Expen	ise =	3.206		
TOTAL PRODUCT COST WITH	OUT DEP	RECIATION =	c , =	26.674		
			8	Sent to 'Eva and 'Year-0		

Economic Evaluation

			-	and the second		WITTE SAN	and the later	476	20		90 - 2	GC	0 0				10		20	no	3	no :	C-	307 - 000
ECONOMIC EVALUATION			CURRENT, Le. INFLATED, DOLLARS							8 1	8 3	8 8	2 8	8		8 8		E .	8 8			1	18 - 8	
Project identifier: Illustration 101			Construction Inflation rate, fraction/y -				0.02															4.		
Expenditures, entries must be negative		. 8	Product price inflation rate, fraction/y -				0		3	3 3		1 3	- 3		1 1		3 1				3	13 21		
Default values, can be changed	- 1	9	2 6	Deliver of the last	and the second	, fraction	Accessed to the last	-	0.02			3 3	3 3	2 8	8		8 8		8	8 8		18	4	16 - 6
Required, user must supply						ding disci									0.15	,	6 8		0)	6 6		76 5	3	303 173
Required, may be calculated here, in it	nked					ounding		rate, fraci	tion/y = n	rinëmum:	acceptab	le rate of	return, r	and the	0.14									
worksheet, or entered manually			- 8	Income I	tax rate =		0.35			3 9	2 9	Š - S	3	- 8		8		8 3	8			3	10 10	
Comments and notes begin in column	S	2 3	REQUE	- 8			8 3	A STATE OF	- 2		8.——	8 3	9	2 8	- 8		8 8		8 3	8 8		16 1	3	18 9
																		_						4
	3 3		- 3				2 2					2 - 3	3 3		Row		ENTS & NO	The second second		1 2		T .	1	10 1
Year ending at time	-3		-1	-	- 1	2	3	- 4	5	- 6	7	- 8	9	10	Sum		200000000000000000000000000000000000000	of estimate,	time -	2 is the first	inflation.			L.
1. Land, 10 5 (see notes)	8 3	0.00	0.00	0.00		Ü.	8 8	3	- 8		8 1	Q 3		0.06	0.00			default is 0.	93					
2. Fixed Capital Investment, 10°5		-7.32	-17.42	-25.38									_			Time 0 is s								L.
3. Working Capital, 10 5 (see notes)	2 3	8 8	. 3	-8.85		8 3	8 3	3	- 8		8 3	§ 3	8 8	8.85	0.00	_		ime 0, (+) wh	_	covered.				
4. Salvage Value, 10 %														0.00	0.00	Salvage va	ilue is (+) at	time of reco	overy.					
5. Total Capital Investment, 10 5	8	-7.32	-17.42	-34.23		ě i	<u> </u>	2				ĝ :	1 1	. 8	-58.96				- 22					
6. Annual Investment, 10 5					0:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Planned In	vestments (e.g. replace	ments	entered he	re at inflate	d value.		
7. Start-up cost, 10 ⁶ \$	8 8	3 8	8	8	-5.01	1	L west	1 -2	100	750	E-SAS	i mari	1	27715	8		aut is 10%			li .				1
8. Operating rate, fraction of capacity	§ §	3 3	8	- 8	0,50	0.90	1.00	1.00	1.00	1.00	1.00	1,00	1.00	1.00			amp-up of p	production.						
9. Annual sales, 10°\$	5K	2 6		- 10	25.50	45.90	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51,00	479,40									
10. Annual Total Product Cost,					-17.93	-25.76	-29.45	-30.04	-30.64	-31.25	-31.88	-32.51	-33.17	-33.83	-297.45	Operating r	rate affects	only variable	e part o	of TPC.				i i
depreciation not included 10°S																E02.000.00000		200000000000000000000000000000000000000	1000	1000-000				
11. Annual depreciation factor, 1/y	3 6	3 8	- 3	- 8	0.20	0.320	0.192	0.115	0.115	2.89	8	9 9	8 8	- 3	50.11	Depreciatio	in derault is	5-year MAC	MS.					
12. Annual depreciation, 10 S/y	2 3	5 3	2	- 2	10.02	16.04	9.62	5.77	5.77		40.40	40.40	47.00			Official country		2222						
13. Annual Gross Profit, 10 5		· ·			-7.47	3.11	11.93	15.19	14.59	16.86	19.12	18.49	17.83	17.17		Start costs subtracted here.								
14. Annual Net Profit, 10 5	2 - 3	2 3	2	- 8	-7.47	2.02	7.75	9.87	9.48	10.96	12.43	12.02	11.59	11.16		V11-2012/05/4701-107-20129/20120-1011-101-101-101-101-101-101-101-1								
15. Annual operating cash flow, 10 %				2722	2.56	18.06	17.38	15.65	15.25	13.85	12.43	12.02	11.59		129.93	-Annual operating cash flow + Annual investment								
16. Total annual cash flow, 10 \$	0.00	-7.32			2.56	18.06	17.38	15,65	15.25	13.85	12.43	12.02	11.59		70.97	-Annual op	perating cas	n now + Ann	nuai in	vestment				
17. Cumulative cash position, 10 %	0.00	-7.32		-58.96	-56.41	-38.35	-20.98	-5.33	9.92	23.77	36.20	48.22	59.81	70.97		ROI, PBP and Net return do NOT include recovery amounts, by text definition.								
Profitability measures, time value of money NOT included:						8 3	2 3	8 8		- 8	RESOLUTION OF THE PARTY OF THE	A MARK THOUSAND TO THE	Company of the Compan		recovery a	mounts, by	text definiti	on.						
18. Return on investment, ave. %/y	13:5															Compare with ROI = 15.0 %/y								
19. Payback period, y	5.8		3	- 8		Š	9 4	8				8 8		3	- 3	Compare with reference PBP = 3.6 y.								
20. Net return, 10°\$	-0.86	at m _{er} -	15.0	%/y	Si							0.0				Compare w	vith net retu	m = 0,						
		3				9 -	E 3	6 3	- 3			8 3	3	1 - 3	1 8									- 1
Profitability measures including time	e value o	of money	, with Al	NNUALE	ND-OF-	YEAR CB	sh flows	and disc	counting				i	Samuel States	2	NPW and DCFR include recovery amounts, by text definition.								
21. Present worth factor	1.52	1.32	1.15	1.00	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25	8			ent worth fac						- 3
22. Present worth of annual cash	0.00	-9.68	-20.03	-34.23	2.22	13.65	11.42	8.95	7.58	5.99	4.67	3.93	3.30	2.76	0.53	If there is n	nore than o	ne sign chan	ige in t	the annual o	ash flow, cl	heck DCFR	value sepa	rately.
flows 10°S		27 Y 5 Y L	35.00	100000000000000000000000000000000000000	300000	12000	770000	30,000		2723	2000	, S	September 1	S0000	.7656	200000000000000000000000000000000000000	***		-					
23. Net present worth, 10°5 -	0.53	at discou	unt rate-	15.0	%/y		1					n n	1			Compare w	ith net pres	sent worth -	0.					
24. Discounted cash flow rate of		To get D	CER on	to "Tools	and fun	ction "So	luer* Co	t tamet n	ell as SP	541 to b	e made -	O by	6 5			*Mo restue*	esculte fees	n a magazitura	total a	ach flow in i	927			
return, DCFR, %/y =	15.2					be rerun :					- made -	3.01))			"No value" results from a negative total cash flow in R27. Compare with R5.								
Iterated discount rate 0.152		and the same	,,,,		as made	sreits		- Inga with	ij ance		T i	-	2 - 3			Sompare w	rost rost.							
25. Present worth factor	1.53	1.33	1.15	1.00	0.87	0.75	0.65	0.57	0.49	0.43	0.37	0.32	0.28	0.24	- 8									-
26. Present worth of annual cash		"Williams"	Spirit Carrie	100000	Elisa d			45565 CM	S-7,617	50.00	THE PARTY		THEFT		222									
flows 10 ⁶ 5	0.00	-9.71	-20.06	-34.23	2.22	13.61	11.37	8.89	7.52	5.93	4.62	3.88	3.25	2.71	0.00									
	Q 1	8 3		- 33		8	§ 3		- 3		<u> </u>	Q 1	<i>i</i> 3	. 3										
		3 - 3	111 8	1.8		2	1 1	- 3			8	ğ j	3 3	1	1									
Profitability measures including time	e value o	of money	, with C	DUNITHO	OUS casi	n flows a	nd disco	unting	47.00	300,000	8	8	E. Care	1	2	NPW and I	OCFR Includ	de recovery :	amour	ts, by text o	lefinition.			
27. Present worth factor	1.63	1.42	1.23	1.07	0.93	0.81	0.71	0.61	0.53	0.46	0.40	0.35	0.31	0.27	8	Uses 1-year	r present w	vorth factor fr	rom Ta	ble 7-5.				
28. Present worth of annual cash	35555	15.44.85g*	AUCONS:	agolijulia)	19605	14.65	12.25	9.60	8 14	5.42	5.02	4 22	3.54	2.05	0.57	If there is n	nore than o	ne sign chan	ige in t	the annual o	ash flow, cl	heck DCFR	value sepa	rately.
flows 10°S	1000000	- Professional	2000000	CALL VICE	2000	14.00	12.20	2.00	9.15	0.42	2.44	3.55°	0.34	2.20	0,07	-		and the same of						
29. Net present worth, 10 5 -	0.57	at discou	unt rate-	14.0	%/y		2	i. 25				W 7	v 9			Compare w	ith net pres	sent worth -0	0.					1
20 Discounted each four rate of		To col 5	OEP	to Tree!	1 20 f f :-	ction *So	hiori Ca	t tarnet v	all ac EC	EE4 45 5	o made	D by	, ,		-	data control				In 200				
30. Discounted cash flow rate of return, DCFR, %/y =	44.9		TOO INCOME.					DOMESTIC CONTRACTOR		T-12-17	e mage =	u by	9			"No value" results from a negative cash flow in R26.								
	1991	unanging	g cell SC:	549. SON	ret must	be rerun :	anter a ch	ange on a	any snee	100	3 - 7	2	<u>5</u>		8	Compare with R6								
Iterated discount rate = 0.141	454	4.42	1.24	1.07	0.03	0.04	0.70	0.64	0.63	0.45	0.40	0.25	0.20	0.05										4
31. Present worth factor 32. Present worth of annual cash	1.64	1.43	Association in		0.93	0.81	0.70	0.61	0.53	0.46	0.40	0.35	0.30	0.26										-
flows 10 ⁶ S	0.00	-10.43	-21.55	-36.77	2.38	14.62	12.21	9.55	8.08	6.37	4.96	4.17	3.49	2.92	0.00									
mas III 2	3	7			1000000	S. Contraction	1	1	13		S)	3	3				E 8		r -	E s		T .	1	1
	8 8	š 8		- 8		Š i	8 8) 9	- 8		2	8 1	8 8		- 8		3 3		6	8 8			1	
				1																				1
8 1 (2) (2)	W 0	Q 0		1 5	_	00	8 0	72	- 3		3	8 0	0 5		Y 3		20 5		20	20 5		00	V	200

Cumulative Cash Flow Position

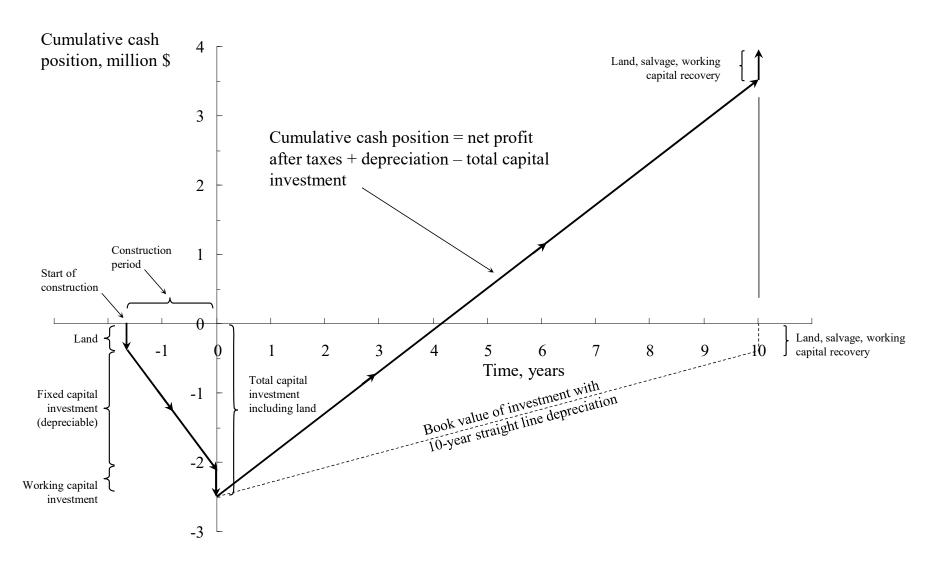


Figure 6.2 Graph of cumulative cash position showing effects of cash flow over full life cycle for a 10-year industrial operation, neglecting the time value of money

Problem 6-1

The purchased cost of a shell-and-tube heat exchanger (floating head and carbon steel tubes) with 10 m² (not 100 m²) of heating surface was \$4200 in 1990. What was the 1990 purchased cost of a similar heat exchanger with 20 m² of heating surface if the purchased cost capacity exponent is 0.60 for surface areas ranging from 10 to 40 m²? If the purchased cost capacity exponent is 0.81 for surface areas ranging from 40 to 200 m², what was the purchased cost of a heat exchanger with 100 m² of heating surface in 2000?

This problem jumps ahead to lesson 15.

Scaling of Equipment Costs

Cost of equipment $a = (Cost of equipment b) \cdot X^{0.6}$

X is the "capacity ratio"

Equipment	Size Range	Exponent
Heat exchanger, shell-and-tube, floating head, (c.s.)	10 - 40 m ²	0.60
Heat exchanger, shell-and-tube, fixed sheet, (c.s.)	10 - 40 m ²	0.44
Pump, centrifugal, horizontal, cast steel (with motor)	4 - 40 (m³/s)·(kPa)	0.33
Reactor, glass-lined, jacketed (without drive)	0.2 - 2.2 m ³	0.54
Tower (c.s.)	500 – 5,000,000 kg	0.62
Tray, sieve	1 - 3 m	0.86

Lesson 15

FEE Reference Handbook, v10.4, pp. 258 (264/502)

Scaling of Equipment Costs

The cost of Unit A at one capacity related to the cost of a similar Unit B with X times the capacity of Unit A is approximately X^n times the cost of Unit B.

Cost of Unit A = Cost of Unit B
$$\left(\frac{\text{Capacity of Unit A}}{\text{Capacity of Unit B}}\right)^n$$

Typical Exponents (n) for Equipment Cost vs. Capacity

Equipment	Size range	Exponent
Dryer, drum, single vacuum	$10 \text{ to } 10^2 \text{ ft}^2$	0.76
Dryer, drum, single atmospheric	$10 \text{ to } 10^2 \text{ ft}^2$	0.40
Fan, centrifugal	10^3 to 10^4 ft ³ /min	0.44
Fan, centrifugal	2×10^4 to 7×10^4 ft ³ /mir	1.17
Heat exchanger, shell and tube, floating head, c.s.	100 to 400 ft ²	0.60
Heat exchanger, shell and tube, fixed sheet, c.s.	100 to 400 ft ²	0.44
Motor, squirrel cage, induction, 440 volts, explosion proof	5 to 20 hp	0.69
Motor, squirrel cage, induction, 440 volts, explosion proof	20 to 200 hp	0.99
Tray, bubble cup, c.s.	3- to 10-ft diameter	1.20
Tray, sieve, c.s.	3- to 10-ft diameter	0.86

average, this table = .76

average, all equipment = .60

Problem 6-2

Plot the 2000 purchased cost of the shell-and-tube heat exchanger outlined in Problem 6-1 as a function of surface area from 10 to 200 m². Note that the purchased cost capacity exponent is not constant over the range of surface areas requested.

This problem also jumps ahead to lesson 15.

Questions?