11 *Developing Project Cash Flows*

After this chapter you will be able to:

1. sort a project's cash flows into operating, investing, and financing elements
2. build a cash flow tableau with one row per element and one column per year
3. read the after-tax cash flow off the bottom row of the tableau, and discount it at the MARR
4. compute the present-worth cost of working capital, $WC\,[1-(P/F,i,N)]$, even when it is fully recovered
5. build the financed view of a project, deducting the loan interest but not the principal repayment
6. build the tableau in actual dollars under inflation, discount at the market rate $i = i' + f + i'f$, and explain why the depreciation tax shield erodes

chapter 10 built the after-tax cash flow of a single operating year: depreciate, tax, add the depreciation back. That was the atom. This chapter assembles the atoms into a whole project. A real proposal is more than a string of identical operating years. Money leaves at the start to buy equipment and to stock the shelves; some of that money comes back at the end; a loan may pay for part of it, with interest and principal on separate tax footings; and every price in the future may drift upward with inflation while the depreciation schedule, fixed at the purchase price, does not. The job of this chapter is to lay all of these flows on one timeline, in the right sign and the right year, and to reduce the whole thing to a single present worth and a single rate of return. The organizing device is the *cash flow tableau*: one row per cash-flow element, one column per year, and one bottom line, the after-tax cash flow, that feeds the decision tools of chapter 5 and chapter 7 unchanged. We ground the chapter in Park's Chapter 10 (project cash-flow analysis), keep the after-tax pipeline of chapter 10, and cross-link the inflation machinery of chapter 4. Nothing about the decision rule changes; what changes is the completeness of the cash flows that go into it.

Cash traps in a financed project.

Q1. A firm invests 30,000 SAR in working capital (spare parts and ore stockpiles) at the start of a project and recovers the full 30,000 SAR at the end of year 5. Since the money comes back in full, does working capital have any effect on the project's present worth?

Q2. A project is part financed by a loan. In the after-tax cash flow, which part of each loan payment is tax-deductible: the interest, the principal, or both?

Q3. Under inflation, a project's revenues and cash costs both rise each year with the price level, but its straight-line depreciation charge stays fixed at the original amount. What happens to the real value of the depreciation tax shield over time?

Answers.

Q1. *Yes.* The 30,000 SAR leaves at year 0 and returns at year 5, but a SAR five years from now is worth less than a SAR today. At a 12% MARR the recovery is worth only $30{,}000\,(P/F, 12\%, 5) = 30{,}000\,(0.5674) = 17{,}022$ SAR in today's money, so the round trip costs about $30{,}000 - 17{,}022 = 12{,}978$ SAR of present worth. Working capital is not free even when it is fully recovered; its cost is the time value of the cash tied up.

Q2. Only the **interest**. Interest on business debt is a deductible operating expense, so it lowers taxable income and earns a $t \times$ interest shield. The principal repayment is the return of borrowed money, not an expense, so it is *not* deductible. Treating the whole loan payment as deductible is a common and expensive error.

Q3. It *erodes*. The shield $t \times D$ is a fixed number of future SAR because D is fixed, but each future SAR buys less as prices rise. So the shield's purchasing power falls year by year. This is why inflation quietly reduces the value of depreciation: the deduction is frozen in nominal terms while everything around it inflates.

Lecture 25. This section is covered by Lecture 25.

Reference. Park, 3rd ed., Sections 10.4–10.5 (pp. 439–448).

Operating cash flows. The cash from running the project: revenues R, cash operating expenses E, deductible interest, and income taxes. The after-tax operating cash flow is net income plus the depreciation add-back.

11.1 *The Elements of a Project Cash Flow*

A project's cash flows fall into three groups, sorted by what they are for. Park calls them operating, investing, and financing activities, and every line of the tableau belongs to exactly one of them.

Operating flows are the ones from chapter 10: revenues R, cash operating expenses E, and income taxes, combined into the after-tax operating cash flow $(R - E - D)(1 - t) + D$. When a project carries a loan, the deductible *interest* also sits here, because interest is an operating expense, not a financing flow, even though it is paid to a lender.

Investing flows are the three that surround the physical asset: the **capital expenditure** at the start, the **net salvage** at the end, and the **working-capital** investment and its recovery. Capital expenditure is capitalized and reaches the tax computation only through depreciation; working capital is also an investment, but it earns no depreciation deduction, and its recovery carries no tax because no income was ever recognized on it.

Financing flows are the loan's own two moves: the borrowed amount comes in at year 0, and the principal is repaid over the loan's life. The interest deliberately does not appear in this group; it lives with the operating flows because it is deductible. Keeping interest and principal in separate groups, with only interest deductible, is the whole art of the financed cash flow.

Capital expenditure (capex). The cost of acquiring the depreciable asset, spent at year 0 (or spread over the construction years). Capitalized, not expensed: it enters the tax computation only through depreciation.

Working capital. Cash tied up in non-depreciable current assets — inventories, spare parts, ore stockpiles, and accounts receivable — needed to run the project. Injected as an investment, and recovered, untaxed, when the project ends.

Net salvage. $S - t(S - BV)$: the cash kept from selling the asset at the end, after the gain is taxed or the loss is credited. The net proceeds of chapter 10, entering the final year.

Financing cash flows. The loan itself: the borrowed amount received at year 0 and the principal repayments. The interest is *not* here — it is deductible and belongs to operations.

> **Insight.** Depreciation is the hinge between the investing group and the operating group. The capital expenditure is an *investing* outflow at year 0, cash that truly leaves. Depreciation then re-enters as a non-cash *operating* deduction, one slice per year, to compute the tax. The two must never be double-counted: you subtract the capex once, at year 0, and you never subtract depreciation as cash. Depreciation's only job in the tableau is to size the tax; that is why it is added back after the tax line.

Reference. Park, 3rd ed., Table 10.1 (the cash-flow statement format).

11.2 *The Cash Flow Tableau*

The tableau is a table with one row per element and one column per year. The rows come in the order a firm computes them: first the income statement (revenues down to net income), then the cash adjustments (add back depreciation, subtract the investing and financing flows). The bottom line is the after-tax cash flow (ATCF) of each year, and that row — and only that row — is discounted.

Example 11.1 — A flotation module, laid out as a tableau

Najd Copper adds a flotation module at its concentrator. The capital expenditure is 120,000 SAR, depreciated straight line over 4 years to a salvage estimate of 20,000 SAR. The module needs 30,000 SAR of working capital (reagent inventory and spares), invested at year 0 and recovered at the end of year 4. It adds revenues of 150,000 SAR per year and cash expenses of 90,000 SAR per year. At the end of year 4 the module is sold for 24,000 SAR. The tax rate is 20% and the MARR is 12%. Build the cash flow tableau and find the present worth.

Solution.

Step 1: depreciation and the operating pipeline.

The straight-line charge is $D = (120{,}000 - 20{,}000)/4 = 25{,}000$ SAR per year, identical across years 1–4. The operating pipeline is then the same every year:

$$TI = 150{,}000 - 90{,}000 - 25{,}000 = 35{,}000, \quad \text{tax} = 0.20\,(35{,}000) = 7{,}000,$$

$$\text{net income} = 28{,}000, \qquad \text{ATCF}_{\text{op}} = 28{,}000 + 25{,}000 = 53{,}000 \text{ SAR.}$$

Step 2: settle the disposal.

After four straight-line years, $BV_4 = 20{,}000$ SAR. The module sells for 24,000 SAR, 4,000 SAR above book value, so the gain is taxed:

$$\text{net salvage} = 24{,}000 - 0.20\,(24{,}000 - 20{,}000) = 24{,}000 - 800 = 23{,}200 \text{ SAR.}$$

Step 3: assemble the tableau.

The working capital of 30,000 SAR leaves at year 0 and returns, untaxed, at year 4.

End of year	0	1	2	3	4
Revenues R		150,000	150,000	150,000	150,000
− Expenses E		90,000	90,000	90,000	90,000
− Depreciation D		25,000	25,000	25,000	25,000
Taxable income		35,000	35,000	35,000	35,000
− Tax (20%)		7,000	7,000	7,000	7,000
Net income		28,000	28,000	28,000	28,000
+ Depreciation		25,000	25,000	25,000	25,000
− Capital expenditure	−120,000				
− Working capital	−30,000				
+ WC recovery					+30,000
+ Net salvage					+23,200
ATCF	−150,000	**53,000**	**53,000**	**53,000**	**106,200**

Table 11.1. The cash flow tableau for the flotation module. The top block is the income statement; the lower block adds back depreciation and lays in the investing flows. Only the bottom row is discounted.

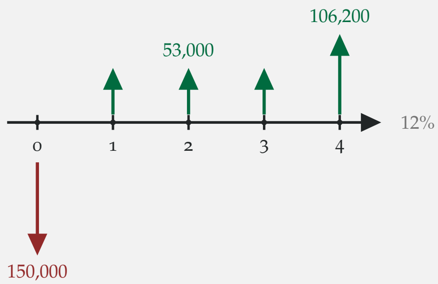

Figure 11.1. The module's after-tax cash flows: the combined capex-plus-working-capital outlay at year 0, three operating ATCFs, and the last year swollen by the working-capital recovery and the net salvage.

Step 4: present worth at the MARR.

With $(P/A, 12\%, 4) = 3.0373$ and $(P/F, 12\%, 4) = 0.6355$:

$$\begin{aligned}\text{PW}(12\%) &= -150{,}000 + 53{,}000\,(3.0373) + 53{,}200\,(0.6355)\\ &= -150{,}000 + 160{,}976.90 + 33{,}809.63 = \boxed{+44{,}786.53 \text{ SAR}} > 0,\end{aligned}$$

where the 53,200 SAR at year 4 is the working-capital recovery plus the net salvage, discounted once. The present worth is positive, so **accept** the module. The internal rate of return of the bottom row is about $\boxed{24.0\%}$, well above the 12% MARR — the same verdict, read a second way.

Insight. Read the tableau top to bottom and the logic is always the same. The income statement decides the tax. The cash adjustments turn accounting profit into cash: add back the non-cash depreciation, then lay in the real cash moves that the income statement never saw — the capital bought, the shelves stocked, the shelves emptied, the asset sold. The bottom line is the only row with a claim to be "cash the project generated," and it is the only row the discount factors ever touch.

Figure 11.2 runs the tableau's year 1 column through as a pipeline; follow depreciation, which is subtracted once and added straight back, and the working-capital branch that never touches a row above it.

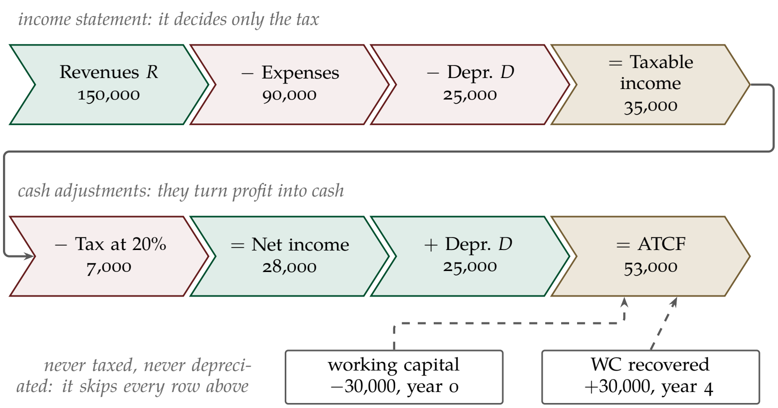

Figure 11.2. The after-tax cash flow pipeline of Example 11.1, one chevron per line of Table 11.1. Depreciation is subtracted once to size the tax and then added straight back, because it never was cash. Working capital is the branch that bypasses the whole income statement: it is neither an expense nor depreciable, so it enters and leaves the bottom line untouched by tax.

Reference. Park, 3rd ed., Section 10.4.2 (investing activities).

11.3 *Working Capital*

Working-capital recovery. The return of the parked working capital when the project ends. It carries no tax, because the recovery is a return of invested cash, not income.

Working capital deserves its own section because it is the element engineers most often forget, and the one whose logic is least like the others. It is not spent and gone, like the capital expenditure; it is *parked*. The firm lays out cash to fill the pipeline — ore ahead of the mill, spares in the store, reagent in the tank, receivables on the books — and that cash sits there for the life of the project, released only when the project winds down and the pipeline drains.

Two rules make working capital behave in the tableau. First, the investment is an outflow (usually at year 0), and it is *not* depreciated: no deduction, no shield. Second, the recovery is an inflow (usually in the final year), and it is *not* taxed, because getting your own parked cash back is not income. The two rules together say the money makes a full round trip in nominal terms — out at the start, back at the end, same number of SAR.

Example 11.2 — The present-worth cost of parked cash

Take the working capital from Example 11.1 in isolation: 30,000 SAR invested at year 0, recovered in full at the end of year 4, with a 12% MARR. It is fully recovered, so a quick reading says it is free. Show that it is not, and find its cost in present worth.

Solution.

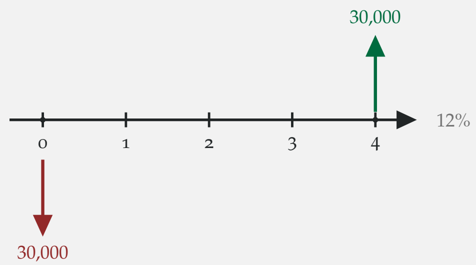

Figure 11.3. Working capital in isolation: out at year 0, back in full at year 4. The arrows are equal in size but not in worth.

The recovery is a single amount four years out:

$$\begin{aligned} \text{PW} &= -30{,}000 + 30{,}000\,(P/F, 12\%, 4) \\ &= -30{,}000 + 30{,}000\,(0.6355) = \boxed{-10{,}935\ \text{SAR}}. \end{aligned}$$

The working capital costs about 10,935 SAR of present worth even though not one SAR is lost. The cost is the time value of the cash held idle for four years: the firm could have earned the MARR on that 30,000 SAR elsewhere, and parking it in inventory forfeits exactly that return. The longer the project and the higher the MARR, the more a given block of working capital costs.

In practice. The size of the working-capital block is set on the plant floor, not in the finance office. A mine that runs a 30-day ore stockpile ahead of the mill ties up thirty days of feed; halving the stockpile to fifteen days, where the geology and haulage allow it, halves that slice of working capital and recovers part of the 10,935 SAR drag of Example 11.2. Inventory policy, supplier lead times, and credit terms are the levers, and they are also why growth eats cash: every scale-up parks more cash in the pipeline before the new sales collect.

Insight. Notice what working capital is *not*. It is not an expense, so it never touches taxable income; it earns no depreciation shield; and its recovery is not a gain. It is pure timing: cash out now, the same cash back later. That is exactly the kind of flow the time value of money was built to price, which is why a fully recovered working-capital block still shows up as a real cost in Example 11.2. When a proposal claims working capital is "free because we get it back," it has confused nominal recovery with present worth.

Lecture 26. This section is covered by Lecture 26.

Reference. Park, 3rd ed., Section 10.5.2 (projects financed with borrowed funds).

11.4 *Financed and Equity Views of the Same Project*

So far every project was paid for entirely from the firm's own cash — the *equity* view. Most real projects borrow part of the money. Adding a loan changes the tableau in three places, and the three must be kept straight:

1. the borrowed amount **comes in** at year 0, reducing the cash the firm itself must put up;
2. the **interest** each year is a deductible operating expense: it lowers taxable income and earns a $t \times$ interest shield;
3. the **principal** repayment each year is a cash outflow but is *not* deductible, because repaying borrowed money is not an expense.

The equity view and the financed view answer different questions. The equity view asks what the whole project earns on the whole capital; the financed view asks what the firm's own money earns after the lender is served. Both are legitimate; you must know which one a number refers to.

Equity view. The project financed entirely from the firm's own funds. The year-0 outflow is the full capex plus working capital; no loan flows appear.

Financed (levered) view. The project part-funded by a loan. The year-0 outflow is reduced by the borrowed amount; interest is deductible, principal is not, and both are subtracted from the equity cash flow.

Example 11.3 — The flotation module, bought partly on credit

Rework the flotation module of Example 11.1, but now *Najd Copper* borrows 60,000 SAR of the 120,000 SAR capital expenditure. The loan is repaid in four equal annual installments at 10% interest. Everything else is unchanged: tax 20%, MARR 12%. Compare the financed present worth with the equity present worth of 44,787 SAR.

Solution.

Step 1: the loan payment and its split.

The equal annual payment is

$$A = 60{,}000\,(A/P, 10\%, 4) = 60{,}000\,(0.31547) = 18{,}928 \text{ SAR}.$$

Each payment splits into interest (on the balance still owed) and principal, and only the interest is deductible:

Year	1	2	3	4
Interest (deductible)	6,000	4,707	3,285	1,721
Principal (not deductible)	12,928	14,221	15,643	17,207
Balance after payment	47,072	32,851	17,208	0

Table 11.2. The loan amortization. Interest falls and principal rises each year; only the interest column earns a tax shield.

Step 2: the levered ATCF.

Now interest joins the deductions, so each year's taxable income is 35,000 − interest, and the principal is subtracted after tax:

$$\text{ATCF}_n = (R - E - D - \text{int}_n)(1-t) + D - \text{prin}_n.$$

End of year	0	1	2	3	4
Operating ATCF (before financing)		53,000	53,000	53,000	53,000
− Interest shield adjustment*		−4,800	−3,766	−2,628	−1,377
− Principal repayment		−12,928	−14,221	−15,643	−17,207
+ WC recovery + net salvage					+53,200
− Capex − WC + loan	−90,000				
Equity ATCF	−90,000	**35,272**	**35,013**	**34,729**	**87,616**

Table 11.3. The financed (equity) cash flow. The year-0 outflow drops to 90,000 SAR because 60,000 SAR is borrowed. *The interest costs $\text{int}_n\,(1-t)$ after its own shield: e.g. year 1 $6{,}000\,(0.80) = 4{,}800$ SAR.

Step 3: present worth of the equity cash flow.

Discount the bottom row at the 12% MARR:

$$\text{PW} = -90{,}000 + \frac{35{,}272}{1.12} + \frac{35{,}013}{1.12^2} + \frac{34{,}729}{1.12^3} + \frac{87{,}616}{1.12^4} = \boxed{+49{,}806 \text{ SAR}}.$$

The financed present worth, 49,806 SAR, *exceeds* the equity present worth of 44,787 SAR by about 5,019 SAR, and the equity IRR climbs to about $\boxed{32.5\%}$

from the unlevered 24.0%. The reason is precise: the firm borrows at 10% while its capital is required to earn 12%. Financing part of the project at a rate below the MARR leaves more value for the owners. Please note the caution from Park: if the firm could borrow far below its MARR, that same cheap borrowing would also pull the MARR itself down, so a large gap between the two views is not something to expect in practice.

Insight. The financed view rewards borrowing only because interest is deductible *and* the loan rate is below the MARR. Strip either condition away and the advantage shrinks. The deduction is the reason the after-tax cost of debt is rate $(1-t)$, not the rate itself: at 10% and a 20% tax rate, the module's debt costs $10\%\,(0.80) = 8\%$ after tax. It is that 8%, compared against the 12% MARR, that creates the 5,019 SAR of extra present worth. Deduct the principal by mistake and the whole comparison collapses — which is exactly the audit in Exercise 11.10.

Reference. Park, 3rd ed., Section 10.6 (effects of inflation on project cash flows); chapter 4 for the rate machinery.

11.5 *Inflation in After-Tax Analysis*

chapter 4 established the rule: value *actual-dollar* cash flows at the *market* rate, or value *constant-dollar* cash flows at the *real* rate, and never cross the pairs. After-tax analysis forces the first choice. Taxes are levied on actual taxable income, in the SAR of the year they fall, so the tax computation must be done in actual dollars. That means the whole tableau is built in actual dollars and discounted at the market rate

$$i = i' + f + i' f,$$

where i' is the real (inflation-free) rate and f is the general inflation rate.

Actual-dollar analysis. Building every cash flow in the inflated SAR of the year it occurs, then discounting at the market rate i. Required for after-tax work, because taxes are computed on actual income.

Here is the subtlety this chapter adds to chapter 4. Under inflation, most cash flows rise with the price level: revenues, cash expenses, and the working-capital requirement all inflate at (roughly) the rate f. But two flows do *not* inflate, because they are fixed in the loan and purchase contracts: the **depreciation** charge, locked to the historical purchase price, and the loan **interest and principal**, locked to the loan agreement. So as prices rise, the depreciation deduction becomes a smaller and smaller share of taxable income, taxable income climbs faster than real activity, and the real value of the depreciation tax shield erodes.

Example 11.4 — Shield erosion at the flotation module

Reconsider the equity-financed flotation module of Example 11.1, now under a general inflation rate of $f = 5\%$ per year. Revenues, cash expenses, and the working-capital recovery all inflate at 5%; the straight-line depreciation of 25,000 SAR per year stays fixed. The real MARR is $i' = 12\%$. Find the present worth in actual dollars, and show what inflation does to the depreciation shield.

Solution.

Step 1: the market rate.

Because taxes are computed on actual income, discount actual-dollar cash flows at the market rate:

$$i = 0.12 + 0.05 + (0.12)(0.05) = \boxed{17.6\%}.$$

Step 2: inflate the operating flows, keep depreciation fixed.

In year n, revenue is $150{,}000\,(1.05)^n$ and expense is $90{,}000\,(1.05)^n$, while $D = 25{,}000$ every year:

End of year	1	2	3	4
Revenues (inflated)	157,500	165,375	173,644	182,326
− Expenses (inflated)	94,500	99,225	104,186	109,396
− Depreciation (fixed)	25,000	25,000	25,000	25,000
Taxable income	38,000	41,150	44,458	47,930
− Tax (20%)	7,600	8,230	8,892	9,586
ATCF (operating)	55,400	57,920	60,566	63,344

Table 11.4. The actual-dollar operating pipeline. Taxable income climbs faster than 5% because the fixed depreciation charge shields a shrinking share of a growing income.

Step 3: present worth in actual dollars.

Add the inflated working-capital recovery and net salvage at year 4 (the salvage estimate inflates too; we keep the earlier 23,200 SAR net figure for comparability and inflate only the operating flows and the 30,000 SAR recovery to $30{,}000\,(1.05)^4 = 36{,}465$ SAR), and discount each year at 17.6%:

$$\mathrm{PW}(17.6\%) \approx \boxed{+37{,}164 \text{ SAR}}.$$

The project still clears the hurdle, but its present worth has fallen from the 44,787 SAR of the no-inflation case.

Step 4: read the shield erosion.

The depreciation shield is $t\,D = 0.20\,(25{,}000) = 5{,}000$ SAR every year — a fixed number of *nominal* SAR. Discounted at the market rate, its present worth is

$$5{,}000\,(P/A, 17.6\%, 4) \approx 13{,}556 \text{ SAR},$$

against $5{,}000\,(P/A, 12\%, 4) = 15{,}187$ SAR with no inflation. Same nominal shield, worth about 1,600 SAR less in present terms, because each fixed future SAR now buys less. That erosion is inflation's quiet tax on depreciation, and it is why an asset's real after-tax value falls when inflation rises even if every operating margin keeps pace with prices.

Insight. Two effects pull in opposite directions under inflation, and the tableau shows both. Revenues and costs inflate together, so the operating margin roughly keeps its real size — the project is not ruined by inflation. But the depreciation deduction is frozen, so the tax bill rises in real terms and the shield's purchasing power shrinks. The net effect is a real loss, concentrated entirely in the tax line. This is the after-tax face of chapter 4: it is not the cash flows that inflation attacks, it is the deductions that cannot inflate with them.

In practice. A plan projecting a plant a decade out often escalates revenues and costs for inflation and stops there, leaving depreciation and the loan schedule to inflate too. That overstates the shields and understates the real tax. The discipline is simple: inflate what the market reprices — sales, wages, reagents, receivables — and freeze what a contract fixed — the depreciation schedule and the loan's interest and principal.

11.6 *Capstone: A Bagging Plant, Both Ways*

Everything in the chapter now meets in one project: capital expenditure, MACRS depreciation, working capital and its recovery, a disposal with a half-year adjustment, a loan with deductible interest, and a present worth and an internal rate of return computed under both the equity and the financed views.

Example 11.5 — The Wadi Lithium bagging plant, equity and financed

Wadi Lithium builds a lithium-carbonate bagging plant. The capital expenditure is 300,000 SAR, 5-year MACRS property (percentages 20, 32, 19.2, 11.52, 11.52, 5.76). It needs 50,000 SAR of working capital, invested at year 0 and recovered at the end of year 5. The plant runs for 5 years, adding revenues of 260,000 SAR per year and cash expenses of 150,000 SAR per year, and is sold at the end of year 5 for 60,000 SAR. The tax rate is 25% and the MARR is 15%. (a) Build the equity-view cash flow and find its PW and IRR. (b) Now finance 150,000 SAR with a 5-year equal-payment loan at 12%, and find the equity PW and IRR of the financed project.

Solution.

Step 1: MACRS schedule with the disposal-year half charge.

The plant is sold at the end of operating year 5, *during* its 6-year recovery period, so the year-5 charge is halved:

$$D_1 = 60{,}000,\ D_2 = 96{,}000,\ D_3 = 57{,}600,\ D_4 = 34{,}560,\ D_5 = \frac{34{,}560}{2} = 17{,}280.$$

The book value at disposal is $BV = 300{,}000 - 265{,}440 = 34{,}560$ SAR. The sale of 60,000 SAR beats it, so the gain is taxed:

$$\text{net salvage} = 60{,}000 - 0.25\,(60{,}000 - 34{,}560) = 60{,}000 - 6{,}360 = 53{,}640\,\text{SAR}.$$

Step 2: (a) the equity-view cash flow.

With $R - E = 110{,}000$ and $t = 0.25$, each operating ATCF is $(110{,}000 - D_n)(0.75) + D_n = 82{,}500 + 0.25\,D_n$:

End of year	0	1	2	3	4	5
D_n		60,000	96,000	57,600	34,560	17,280
Operating ATCF		97,500	106,500	96,900	91,140	86,820
+ WC recovery						+50,000
+ Net salvage						+53,640
− Capex − WC	−350,000					
Equity ATCF	−350,000	**97,500**	**106,500**	**96,900**	**91,140**	**190,460**

Table 11.5. The equity-view tableau for the bagging plant. The MACRS charges front-load the shield, so the early ATCFs are largest before the schedule tapers.

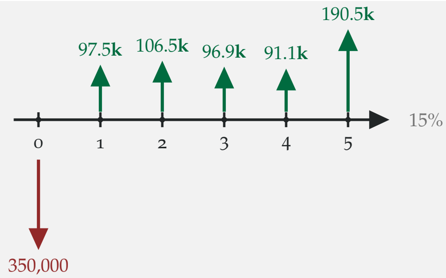

Figure 11.4. The bagging plant, equity view: the combined capex-plus-working-capital outlay, five MACRS-shaped operating ATCFs, and a final year lifted by the working-capital recovery and net salvage.

Discounting the bottom row at 15%:

$$\mathrm{PW}_{\text{equity}}(15\%) = \boxed{+25{,}827 \text{ SAR}}, \qquad \mathrm{IRR}_{\text{equity}} = \boxed{17.8\%}.$$

Positive PW, IRR above the MARR: **accept**.

Step 3: (b) the financed view.

Borrow 150,000 SAR at 12% over 5 years: the payment is $150{,}000\,(A/P, 12\%, 5) = 41{,}611$ SAR. The interest is deductible; the principal is not. The year-0 outflow drops to $350{,}000 - 150{,}000 = 200{,}000$ SAR.

End of year	0	1	2	3	4	5
Interest (deductible)		18,000	15,167	11,993	8,439	4,458
Principal (not deduct.)		23,611	26,445	29,618	33,172	37,153
Equity ATCF	−200,000	**60,389**	**68,680**	**58,287**	**51,638**	**149,963**

Table 11.6. The financed-view tableau: each operating ATCF is reduced by the after-tax interest and the principal; year 5 still carries the WC recovery and net salvage.

Discounting at 15%:

$$\mathrm{PW}_{\text{financed}}(15\%) = \boxed{+46{,}851 \text{ SAR}}, \qquad \mathrm{IRR}_{\text{financed}} = \boxed{23.3\%}.$$

Step 4: read both verdicts.

Both views accept the plant. The financed view shows a larger present worth (46,851 versus 25,827 SAR) and a higher return (23.3% versus 17.8%), because *Wadi Lithium* borrows at 12% while its capital must earn 15%, and the interest is deductible on top. The equity view is the honest measure of the plant as an asset; the financed view is what the owners earn on their own 200,000 SAR after the lender is paid. A complete recommendation reports both and names which is which.

11.7 *Case Study from the Literature*

Published techno-economic assessments build exactly the tableau of this chapter and then solve it backward: instead of fixing a price and reading the present worth, they fix the present worth at zero and solve for the price that makes it so — the *minimum selling price*. Rosentrater (2020) does this for a plant that ferments food waste into ethanol, and the study states the working-capital rule this chapter emphasizes explicitly: working capital is taken as 15% of the fixed capital investment, and the discounted cash flow is run to the internal rate of return the owners require. The study's amounts are in US dollars, the currency of the paper, and we keep them.

Reference. Rosentrater (2020), *Energies* 13(2):436. Open access (CC BY); full reference at the end of the chapter.

Example 11.6 — Case study: working capital in a food-waste ethanol plant

Rosentrater (2020) models a commercial plant processing 2,000 Mg per day of food waste, and evaluates three process scenarios by discounted cash flow to find the minimum ethanol selling price (MESP) that yields a zero present worth at a required internal rate of return of 10%. The financial basis takes working capital as 15% of the fixed capital investment. Using the paper's own rule, show how the working-capital block enters the tableau and why its recovery does not cancel its cost.

Solution.

Step 1: size the working capital from the stated rule.

The paper sets working capital at 15% of fixed capital investment. Writing the fixed capital investment as FCI, the working-capital block is $WC = 0.15\,FCI$, injected as the plant starts up and recovered when it closes. For a plant with, say, $FCI = \$100$ million (a round figure to fix ideas; the paper's own capital scales with the scenario), that is \$15 million parked for the life of the plant.

Step 2: the present-worth cost of that block.

Over a 20-year life at the paper's 10% required return, the recovery is worth

$$15\,(P/F, 10\%, 20) = 15\,(0.1486) = \$2.23 \text{ million},$$

so the round trip costs $15 - 2.23 \approx \$12.8$ million of present worth on a $15 million block — about 85% of the cash tied up, lost to time value, even though every dollar is nominally recovered. This is Example 11.2 at industrial scale: the longer the horizon, the closer the present-worth cost creeps toward the full block.

Step 3: why it matters for the selling price.

Because the tableau must earn the required 10% on *all* the capital it ties up, including the working capital, the minimum selling price has to be high enough to cover that 2.23-versus-15 gap. Drop the working-capital line and the model would understate the capital at work and quote too low a selling price. Rosentrater reports a lowest MESP of $2.41 per gallon ($0.64 per liter) for the enzyme-free, two-column scenario, about 6% below the enzyme scenario — a gap driven by capital and operating cost, of which working capital is one transparent piece.

What did the study conclude? That food-waste fermentation can reach a competitive ethanol price even without added enzymes, with the enzyme-free two-column design giving the lowest minimum selling price of the three scenarios (Rosentrater, 2020). The sensitivity analysis found the selling price most responsive to plant capacity, fixed capital cost, and co-product credit values, which is the sensitivity-analysis theme of chapter 12 seen in a real cost model.

Insight. The case study verifies a point about method, not just arithmetic. Given the paper's stated 15%-of-FCI rule and its 10% required return, the present-worth cost of the working capital follows mechanically, and it is large. What the tableau cannot check from outside are the estimates themselves: the fixed capital cost from the process simulation, the food-waste composition, the co-product prices. The cash-flow structure is exact; its inputs are engineering judgment — the same division of labor as every case study in this book.

11.8 Chapter Summary

- A project's cash flows sort into three groups: **operating** (revenues, expenses, deductible interest, taxes), **investing** (capital expenditure, working capital and its recovery, net salvage), and **financing** (loan received, principal repaid). Interest is *operating*, not financing, because it is deductible.

- The **cash flow tableau** has one row per element and one column per year. The top block is the income statement (down to net income); the lower block adds back depreciation and lays in the investing and financing flows. Only the bottom row, the **ATCF**, is discounted.

- **Capital expenditure** is capitalized, not expensed: it leaves at year 0 and enters the tax computation only through depreciation. Never subtract depreciation as cash; its job is only to size the tax.

- **Working capital** is cash parked in inventories, spares, and receivables. It is invested (no depreciation) and recovered (no tax). Even when fully recovered it costs present worth — the time value of the cash tied up, $WC\,[1-(P/F,i,N)]$.

- The **net salvage** $S - t\,(S - BV)$, not the raw selling price, enters the final year, exactly as in chapter 10.

- With a **loan**, the borrowed amount comes in at year 0, the **interest** is deductible (a $t\times$ shield), and the **principal** is not. Borrowing below the MARR raises the equity present worth; the after-tax cost of debt is rate $(1-t)$.

- The **equity view** funds the whole project from own cash; the **financed view** nets out the loan and measures the return on the owners' money. A complete recommendation reports both.

- Under **inflation**, build the tableau in **actual dollars** and discount at the **market rate** $i = i' + f + i'f$, because taxes are levied on actual income. Revenues, costs, and working capital inflate; **depreciation and the loan schedule do not**, so the depreciation tax shield **erodes** in real terms.

- The decision rule is unchanged from chapter 5 and chapter 7: accept when PW at the MARR is positive, equivalently when the IRR beats the MARR. This chapter only made the cash flows complete.

11.9 Exercises

These problems run from a single tableau row to the full financed, inflation-adjusted project, adding working capital, the depreciation shield, loan interest and principal, and inflation one layer at a time.

Elements and the tableau

Exercise 11.1. A project needs a capital expenditure of 80,000 SAR and working capital of 20,000 SAR, both at year 0. It runs 5 years; the working capital is recovered at the end of year 5. Classify each of the four flows (capex now, working capital now, working-capital recovery, and the annual depreciation charge) as operating, investing, or financing, and state which are taxed or deductible.

Exercise 11.2. A machine costs 100,000 SAR (capex at year 0), is depreciated straight line over 5 years to a 10,000 SAR salvage estimate, and needs 25,000 SAR of working capital recovered at year 5. It earns $R - E = 45{,}000$ SAR per year pre-tax, is sold for 10,000 SAR at year 5, and faces $t = 20\%$, MARR $= 10\%$. Build the ATCF for year 0, a typical operating year, and year 5.

Working capital

Exercise 11.3. A project ties up 40,000 SAR of working capital at year 0 and recovers it in full at the end of year 6. The MARR is 15%. Find the present-worth cost of the working capital, and explain why a fully recovered block is not free.

Exercise 11.4. A firm doubles a project's output. Explain, in terms of the tableau, why this can force a cash outflow *now* even though the extra sales are profitable, and name the tableau line that carries the effect.

Financing and inflation

Exercise 11.5. A project borrows 50,000 SAR, repaid in 4 equal annual payments at 8%. The tax rate is 25%. Find the equal payment, split the year-1 payment into interest and principal, and state which part is deductible and the year-1 interest shield.

Exercise 11.6. A project has revenues of 200,000 SAR and cash expenses of 120,000 SAR in year-0 prices, both inflating at $f = 4\%$, and a fixed straight-line depreciation of 30,000 SAR per year. The tax rate is 25% and the real MARR is $i' = 10\%$. Find the market rate, and compute the year-1 taxable income and after-tax cash flow in actual dollars.

Exam-style problems

The problems below follow the format, length, and point weights of the final exam. Work each part in exam order: lay out the tableau, box each answer with its units, keep interest and principal separate, and close with the decision sentence.

Exercise 11.7. *Najd Copper* installs a concentrate-thickening line. The capital expenditure is 240,000 SAR, 5-year MACRS property (percentages 20, 32, 19.2, 11.52, 11.52, 5.76). It needs 40,000 SAR of working capital, recovered at the end of year 5. The line adds revenues of 180,000 SAR per year and cash expenses of 95,000 SAR per year, is sold for 45,000 SAR at the end of year 5, and faces a tax rate of 20% and a MARR of 12%. (a) (*6 pts*) Build the MACRS schedule (halving the year-5 charge for the disposal), and find the book value at disposal and the net salvage. (b) (*10 pts*) Compute the operating ATCF of each of years 1–5 and lay out the equity-view tableau. (c) (*8 pts*) Find the present worth at the MARR and state the decision. (d) (*6 pts*) State the present-worth cost of the working-capital block alone, and explain in one sentence why it is not zero.

Exercise 11.8. *Wadi Lithium* evaluates a drying line: capital expenditure 160,000 SAR, straight-line depreciation over 4 years to a 16,000 SAR salvage estimate, working capital 30,000 SAR recovered at year 4. It earns $R - E = 70{,}000$ SAR per year, is sold for 16,000 SAR at year 4, and faces $t = 25\%$, MARR $= 10\%$. (a) (*6 pts*) Find the equity-view PW. (b) (*10 pts*) Now finance 80,000 SAR with a 4-year equal-payment loan at 8%. Build the amortization split and the equity ATCF of each year. (c) (*6 pts*) Find the financed-view equity PW and state, with a reason, why it differs from the equity-view PW of part (a).

Assessing outside recommendations

Each problem below quotes a finished analysis produced by someone else. The work looks professional and its arithmetic is internally consistent, but each contains one or two genuine method errors. Decide whether to accept or reject, name each flaw precisely, and produce the corrected number.

Exercise 11.9. An AI assistant prepares the tableau for a *Najd Copper* filtration line: capex 100,000 SAR, straight-line over 5 years to a 10,000 SAR salvage, working capital 25,000 SAR, $R - E = 40{,}000$ SAR per year, sold for 10,000 SAR at year 5, $t = 20\%$, MARR $= 10\%$. Its memo reads:

> "Depreciation: $(100{,}000 - 10{,}000)/5 = 18{,}000$ SAR per year. Operating ATCF: $(40{,}000 - 18{,}000)(0.80) + 18{,}000 = 35{,}600$ SAR per year. Year 0: $-(100{,}000 + 25{,}000) = -125{,}000$ SAR. Year 5: operating 35,600 plus the 10,000 SAR salvage = 45,600 SAR. $\text{PW}(10\%) = -125{,}000 + 35{,}600\,(P/A, 10\%, 5) + 10{,}000\,(P/F, 10\%, 5) = -125{,}000 + 134{,}954 + 6{,}209 = 16{,}163$ SAR. Accept."

Accept or reject the memo? Name each flaw and produce the corrected present worth.

Exercise 11.10. A consultant evaluates a financed *Wadi Lithium* press: the operating after-tax cash flow is 54,000 SAR per year for 5 years, the year-0 equity outlay (after a 100,000 SAR loan) is 120,000 SAR, and the loan is repaid in 5 equal payments of 25,046 SAR at 8% ($t = 25\%$, MARR $= 12\%$). The memo reads:

> "Each year we pay the lender 25,046 SAR, and the whole payment is a deductible business expense, so it shields $0.25\,(25{,}046) = 6{,}261$ SAR of tax. Net financing cost per year: $25{,}046 - 6{,}261 = 18{,}785$ SAR. Equity ATCF: $54{,}000 - 18{,}785 = 35{,}215$ SAR per year. $\text{PW}(12\%) = -120{,}000 + 35{,}215\,(P/A, 12\%, 5) = -120{,}000 + 126{,}945 = +6{,}945$ SAR. Accept."

Accept or reject the memo? Name the flaw and produce the corrected present worth and decision.

References

Park, C. S. (2012). *Fundamentals of Engineering Economics* (3rd ed.). Pearson.

Rosentrater, K. A. (2020). Techno-economic evaluation of food waste fermentation for value-added products. *Energies*, 13(2), 436. Open access (CC BY). https://www.mdpi.com/1996-1073/13/2/436