INTERACTIVE SIMULATION TEACHING HANDBOOK

Supply Chain Finance & Operations Analytics

Instructor Guide with Equations, Worked Examples, and Exercises

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Overview

This handbook accompanies an integrated browser-based simulation dashboard designed for graduate and advanced undergraduate courses in supply chain management, financial operations, enterprise risk management, and applied business analytics. The dashboard consolidates six interactive modules into a single HTML file that runs entirely in the browser with no server infrastructure or software installation required.

Each module is grounded in a formal analytical model. This handbook provides the complete mathematical derivations, defines all notation, walks through worked numerical examples with reference to specific dashboard configurations, and offers structured classroom exercises with discussion prompts.

Module	Topic	Session
1	Cash Conversion Cycle & Working Capital	75–90 min
2	Dynamic Discounting & Reverse Factoring	75–90 min
3	Monte Carlo Profit Risk Simulation	90–120 min
4	Futures, Forwards & Hedging	75–90 min
5	FinTech Platforms & Blockchain in SCF	60–75 min
6	Stochastic Models & Capital Pricing	90–120 min

Contents

1 Cash Conversion Cycle and Working Capital

1.1 Dashboard Overview

The Module 1 interface consists of a left panel with six parameter sliders (Annual Revenue, COGS%, DIO, DSO, DPO, and Cost of Capital) and a right panel rendering two real-time visualizations: the operating cycle timeline and the CCC-versus-financing-cost sensitivity chart. The top stats bar displays the computed CCC, operating cycle length, net working capital, annual financing cost, and the marginal value of a one-day CCC reduction.

Default configuration: Revenue = $80M, COGS = 60%, DIO = 45d, DSO = 50d, DPO = 25d, CoC = 6%. CCC = 70 days, NWC = $13.59M, Financing Cost = $815K/yr.

1.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Compute the CCC from financial statement data and interpret each component (DIO, DSO, DPO) in operational terms
2. Calculate the net working capital requirement and annual financing cost implied by a given CCC
3. Evaluate the financial impact of targeted improvements in any single CCC component
4. Explain why firms such as Amazon and Dell have achieved negative CCC values

1.3 Notation

D	Annual revenue, measured in dollars
$COGS$	Cost of goods sold, annual, measured in dollars
DIO	Days Inventory Outstanding: average number of days inventory is held before sale
DSO	Days Sales Outstanding: average number of days to collect accounts receivable
DPO	Days Payable Outstanding: average number of days the firm defers payment to suppliers
r	Weighted average cost of capital (WACC), expressed as an annual rate
CCC	Cash Conversion Cycle, measured in days
OC	Operating Cycle $= DIO + DSO$, measured in days
NWC	Net Working Capital required, measured in dollars

1.4 Core Equations

The cash conversion cycle is defined as the difference between the operating cycle and the payment deferral period:

$$CCC = DIO + DSO - DPO \tag{1}$$

Each component is derived from the balance sheet and income statement:

$$DIO = \frac{\text{Average Inventory}}{COGS} \times 365, \quad DSO = \frac{\text{Average AR}}{D} \times 365, \quad DPO = \frac{\text{Average AP}}{COGS} \times 365 \tag{2}$$

Net working capital:

$$NWC = \frac{COGS}{365} \times DIO + \frac{D}{365} \times DSO - \frac{COGS}{365} \times DPO \tag{3}$$

The annual financing cost and marginal value of a one-day CCC reduction:

$$\text{Annual Financing Cost} = NWC \times r, \qquad \Delta\text{Cost per Day} = \frac{D}{365} \times r \tag{4}$$

1.5 Reading the Timeline Chart

The timeline chart visualizes the operating cycle as three horizontal bars on a shared time axis measured in days from the date of inventory purchase. The blue bar represents DIO, the orange bar represents DSO (starting at day DIO and extending to day $DIO + DSO$), and the green bar represents DPO. The red dashed bracket beneath identifies the CCC as the gap between the end of DPO and the end of the operating cycle. When DPO exceeds $DIO + DSO$, the CCC turns negative and the annotation changes to indicate float generation.

1.6 Reading the Sensitivity Chart

The sensitivity chart plots annual financing cost on the vertical axis against CCC in days on the horizontal axis. Because financing cost equals daily revenue times the cost of capital times CCC, the relationship is linear. The current operating point is marked with a red dot. The green-shaded region to the left of $CCC = 0$ represents configurations where the firm earns float income rather than paying financing costs. This chart helps students see that each day of CCC reduction saves a fixed dollar amount, regardless of whether the starting CCC is 100 days or 10 days.

1.7 Worked Example

Worked Example: Large Manufacturer (Revenue = \$80M, COGS = 60%)

Step 1: Set Revenue = \$80M, COGS = 60% of revenue = \$48M. Set $DIO = 45$, $DSO = 50$, $DPO = 25$.
Step 2: $CCC = 45 + 50 - 25 = 70$ days. Operating Cycle $= 45 + 50 = 95$ days.
Step 3: Inventory $= (\$32.5\text{M}/365) \times 35 = \$3{,}116{,}438$. AR $= (\$50\text{M}/365) \times 40 = \$5{,}479{,}452$. AP $= (\$32.5\text{M}/365) \times 30 = \$2{,}671{,}233$.
Step 4: $NWC = \$3{,}116{,}438 + \$5{,}479{,}452 - \$2{,}671{,}233 = \$5{,}924{,}657$.
Step 5: At $r = 6\%$: Annual Financing Cost $= \$13{,}589{,}041 \times 0.06 = \$815{,}342$.
Step 6: One-day CCC reduction value: $(\$80\text{M}/365) \times 0.06 = \$13{,}151/\text{year}$.
Step 7: Try adjusting DPO from 25 to 70 in the dashboard. CCC drops from 70 to 25 days, NWC falls by approximately \$5.92M, and financing cost drops by about \$355K. This demonstrates how extending payment terms frees substantial working capital.

1.8 Classroom Exercises

Exercise 1: DSO vs. DPO Levers

A 10-day DSO reduction and a 10-day DPO increase both reduce CCC by 10 days. However, the NWC impact differs because DSO is computed on revenue while DPO is computed on COGS. Using the default parameters (COGS = 65% of revenue), compute the exact dollar difference.
Solution: The DSO reduction frees $\$50\text{M}/365 \times 10 = \$1{,}369{,}863$, while the DPO extension frees $\$32.5\text{M}/365 \times 10 = \$890{,}411$. The DSO lever releases 54% more capital.

Exercise 2: Negative CCC

Set revenue to $100M and DPO to 120 days while keeping $DIO = 35$ and $DSO = 40$. Observe that CCC becomes negative (-45 days). Discuss: Amazon's CCC was approximately -30 days in recent years. What business model features enable this?
Discussion points: Consignment inventory, credit card settlement in 1–2 days, 60–90 day supplier payment terms. Is this sustainable or exploitative?

Exercise 3: Interest Rate Sensitivity

Vary the cost of capital from 2% to 15%. Observe how the sensitivity line steepens. For a high-interest-rate environment (e.g., emerging market at 12%), the same CCC of 45 days costs $739K/year instead of $296K. Discuss: How should a CFO in a high-rate environment prioritize CCC reduction differently from one in a low-rate environment?

2 Dynamic Discounting and Reverse Factoring

2.1 Dashboard Overview

The Module 2 interface contains seven parameter sliders covering the invoice amount, payment terms, early payment day, discount APR, buyer's and supplier's costs of capital, and the bank factoring rate. Below the sliders, three cards compare the Standard, Dynamic Discounting, and Reverse Factoring strategies. The right panel shows the discount curves chart and the net benefit sensitivity chart. The top stats bar indicates whether a credit arbitrage exists.

Default configuration: Invoice = $750K, Terms = 90d, Early = 15d, $r_d = 7\%$*,* $r_b = 4\%$*,* $r_s = 14\%$*,* $r_k = 3.5\%$*. Win-win condition holds:* $4\% < 7\% < 14\%$*, combined surplus = $20.8K.*

2.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Compute the dollar discount and annualized return for a dynamic discounting arrangement
2. Evaluate when dynamic discounting generates a positive net return for the buyer versus when it does not
3. Compare dynamic discounting with bank-intermediated reverse factoring
4. Articulate the win-win condition as a credit arbitrage inequality

2.3 Notation

F	Invoice face value (dollars)
T	Standard payment terms (days from invoice date)
t	Early payment day (days from invoice date), where $t < T$
Δt	Acceleration window $= T - t$ (days of early payment)
r_d	Discount APR: annualized discount rate for early payment
r_b	Buyer's cost of capital (WACC), annualized
r_s	Supplier's cost of capital, annualized
r_k	Bank factoring rate in reverse factoring, annualized
d	Dollar discount on the invoice

2.4 Core Equations

2.4.1 Dynamic Discounting

The discount amount, buyer's opportunity cost, and net benefits:

$$d = F \times \frac{r_d}{365} \times (T - t) \tag{5}$$

$$\text{Buyer Net Benefit} = F \times \frac{r_d - r_b}{365} \times (T - t) \tag{6}$$

$$\text{Supplier Net Benefit} = F \times \frac{r_s - r_d}{365} \times (T - t) \tag{7}$$

2.4.2 Win-Win Condition (Credit Arbitrage)

Both parties benefit simultaneously if and only if:

$$\boxed{r_b \ < \ r_d \ < \ r_s} \tag{8}$$

The total surplus captured when this condition holds:

$$\text{Total Surplus} = F \times \frac{r_s - r_b}{365} \times (T - t) \tag{9}$$

2.4.3 Reverse Factoring

In reverse factoring, a bank pays the supplier early at a rate anchored to the buyer's credit rating:

$$\text{Bank Fee} = F \times \frac{r_k}{365} \times (T - t), \qquad \text{Supplier Net} = F \times \frac{r_s - r_k}{365} \times (T - t), \qquad \text{Buyer Net} = 0 \tag{10}$$

2.5 Reading the Discount Curves Chart

Four lines plot the dollar discount (or cost) as a function of early payment day, each at a different annualized rate: the supplier's CoC (r_s, red), the discount APR (r_d, dark blue), the buyer's CoC (r_b, light blue), and the bank rate (r_k, orange dashed). All lines converge to zero at the payment due date and fan out as the early payment day moves earlier. At any given day, the vertical distance between two lines represents the net benefit or cost differential.

2.6 Reading the Net Benefit Chart

The supplier and buyer net benefit curves are plotted as functions of the early payment day. When $r_b < r_d < r_s$, both curves are positive, visually confirming the win-win condition. The magnitude increases as the early payment day moves earlier (more days of acceleration).

2.7 Worked Example

Worked Example: $750K Invoice, Net 90 (Win-Win Scenario)

Step 1: $F = \$500{,}000$, $T = 60$ days, $t = 10$ days, $\Delta t = 50$ days.
Step 2: $r_d = 7.0\%$, $r_b = 4.0\%$, $r_s = 14.0\%$, $r_k = 3.5\%$.
Step 3: Dynamic discount: $d = \$500{,}000 \times (0.03/365) \times 50 = \$2{,}055$.
Step 4: Buyer opportunity cost $= \$750{,}000 \times (0.04/365) \times 75 = \$6{,}164$. Buyer net $= \$10{,}788 - \$6{,}164 = +\$4{,}624$. The buyer earns a positive return because $r_d\,(7\%) > r_b\,(4\%)$.
Step 5: Supplier financing saved $= \$750{,}000 \times (0.14/365) \times 75 = \$21{,}575$. Supplier net $= \$21{,}575 - \$10{,}788 = \$10{,}788$. The supplier benefits because $r_d\,(7\%) < r_s\,(14\%)$.
Step 6: Win-win check: $r_b\,(4\%) < r_d\,(7\%) < r_s\,(14\%)$. The credit arbitrage condition holds. Total surplus $= \$4{,}624 + \$10{,}788 = \$15{,}411$.
Step 7: Reverse factoring: Bank fee $= \$750{,}000 \times (0.035/365) \times 75 = \$5{,}393$. Supplier net $= \$21{,}575 - \$5{,}393 = \$16{,}182$. Buyer net $= \$0$.
Step 8: Reverse factoring produces higher combined surplus (\$16,182 vs. \$15,411), but dynamic discounting is the only strategy where the buyer also captures value.
Step 9: Set $r_d = 3\%$ (below $r_b = 4\%$). The buyer net flips negative, demonstrating the arbitrage boundary in real time.

2.8 Classroom Exercises

Exercise 1: Finding the Win-Win Zone

Slowly increase the Discount APR slider from 1% to 15%. Observe the exact APR at which the buyer's net benefit transitions from negative to positive (it equals $r_b = 5\%$). Then find the APR at which the supplier's net benefit turns negative (it equals $r_s = 10\%$). The range 5%–10% is the win-win zone.

Exercise 2: Trade Credit vs. Reverse Factoring

A supplier is offered 2/10 net 30 (2% discount for payment on day 10 instead of day 30). Compute the annualized cost:

$$\frac{0.02}{0.98} \times \frac{365}{20} = 37.2\%$$

Compare this with reverse factoring at 4% APR. The trade credit discount is 9× more expensive, illustrating why SCF platforms are displacing traditional trade discounts.

Exercise 3: Cash-Rich Buyer Scenario

Set the buyer's CoC to 2% (cash-rich tech company) and supplier CoC to 15% (small manufacturer). Total surplus at day 10: $F \times (0.15 - 0.02)/365 \times 50 = \$8{,}904$. Discuss: Why might Apple, Google, and Microsoft run large-scale SCF programs?

Discussion: They have excess cash earning near-zero returns and suppliers who borrow at 10–15%.

3 Monte Carlo Profit Risk Simulation

3.1 Dashboard Overview

The Module 3 interface contains six parameter sliders (Mean Demand, Demand StdDev, Unit Cost, Selling Price, Salvage Value, and Order Quantity) plus a re-run button that triggers 10,000 fresh Monte Carlo trials. The right panel displays the profit distribution histogram (with VaR and expected profit annotated) and two smaller charts showing Expected Profit and VaR(5%) as functions of Q. The top stats bar reports $\mathbb{E}[\pi]$, $\sigma(\pi)$, VaR(5%), achieved service level, and the analytically optimal Q^*.

Default configuration: $\mu = 500$, $\sigma = 120$, $c = \$45$, $p = \$90$, $s = \$15$, $Q = 820$. *Results:* $\mathbb{E}[\pi] = \$12.9K$, *VaR(5%)*$= -\$1.8K$, $Q^* = 530$.

3.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Derive the Newsvendor critical ratio and compute Q^* for normally distributed demand
2. Interpret VaR(5%) as a downside risk threshold
3. Analyze the tradeoff between expected profit and tail risk as Q varies
4. Connect inventory risk to the mean-variance frontier concept from portfolio theory
5. Articulate how ML demand forecasting integrates with Monte Carlo simulation

3.3 Notation

p	Selling price per unit (dollars)
c	Unit procurement cost (dollars)
s	Salvage value per unsold unit (dollars), where $s < c$
D	Random demand, $D \sim \mathcal{N}(\mu, \sigma^2)$, truncated at zero
μ	Mean of the demand distribution
σ	Standard deviation of the demand distribution
Q	Order quantity (decision variable)
Q^*	Optimal order quantity maximizing $\mathbb{E}[\pi]$
CR	Critical ratio $= (p - c)/(p - s)$
$\pi(Q, D)$	Profit realization for given Q and demand D
$\Phi(\cdot)$	CDF of the standard normal distribution

3.4 Core Equations

3.4.1 Profit Function

$$\pi(Q, D) = p \cdot \min(Q, D) + s \cdot \max(Q - D, 0) - c \cdot Q \tag{11}$$

When $D \geq Q$: all units sell, $\pi = (p - c) \cdot Q$. When $D < Q$: $\pi = p \cdot D + s \cdot (Q - D) - c \cdot Q = (p - s) \cdot D - (c - s) \cdot Q$.

3.4.2 Optimal Order Quantity

The first-order condition yields the critical ratio, which is the target service level:

$$CR = \frac{p - c}{p - s} \tag{12}$$

$$\boxed{Q^* = \mu + \sigma \cdot \Phi^{-1}(CR)} \tag{13}$$

When $CR > 0.5$, the profit margin exceeds the overage cost, and $Q^* > \mu$. When $CR < 0.5$, $Q^* < \mu$.

3.4.3 Risk Metrics from Simulation

From $N = 10{,}000$ simulated profit realizations $\{\pi_1, \ldots, \pi_N\}$:

$$\mathbb{E}[\pi] = \frac{1}{N}\sum_{i=1}^{N}\pi_i, \qquad \sigma(\pi) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\pi_i - \mathbb{E}[\pi])^2} \tag{14}$$

$$\text{VaR}(5\%) = \text{5th percentile of } \{\pi_1, \ldots, \pi_N\}, \qquad \text{Sharpe-like Ratio} = \frac{\mathbb{E}[\pi]}{\sigma(\pi)} \tag{15}$$

3.5 Reading the Profit Histogram

The horizontal axis measures profit in dollars. Bins to the left of the VaR(5%) line (red dashed) are shaded red, representing the worst 5% of outcomes. The green dashed line marks $\mathbb{E}[\pi]$. With $Q = 820$ well above $Q^* = 530$, the distribution forms a near-perfect bell curve because Q is large enough that almost all demand is satisfied (SL = 99.5%), and profit variation comes mainly from unsold-unit salvage losses. The red-shaded tail shows profits below approximately −\$1,800, meaning there is a 5% chance of actual financial loss.

3.6 Reading the $\mathbb{E}[\pi]$ and VaR Curves

The two smaller charts plot Expected Profit and VaR(5%) as functions of Q. The $\mathbb{E}[\pi]$ curve is concave, peaking at Q^*. The VaR curve initially increases (more stock means more sales in low-demand scenarios) but eventually decreases sharply (extreme overstocking produces large losses). Together, these charts form a visual risk-return frontier: **the Q that maximizes $\mathbb{E}[\pi]$ is not the same Q that maximizes VaR(5%)**.

3.7 Worked Example

Worked Example: Seasonal Product ($\mu = 500$, $p = \$90$, $c = \$45$, $s = \$15$)

Step 1: $\mu = 500$, $\sigma = 120$, $p = \$90$, $c = \$50$, $s = \$15$.
Step 2: $CR = (90 - 50)/(90 - 15) = 40/75 = 0.5333$.
Step 3: $\Phi^{-1}(0.600) \approx 0.253$. $Q^* = 500 + 120 \times 0.253 = 530$ units.
Step 4: At $Q = 820$ (well above Q^*): $\mathbb{E}[\pi] \approx \$12.9\text{K}$, VaR(5%)$\approx -\$1.8\text{K}$, SL$\approx$ 99.5%, Sharpe$\approx$ 1.44. The histogram is a symmetric bell curve.
Step 5: At $Q = Q^* = 530$: $\mathbb{E}[\pi] \approx \$16.8\text{K}$, VaR(5%)$\approx \$6.5\text{K}$, Sharpe$\approx$ 2.9. Higher expected profit *and* positive VaR. Right-skewed histogram.
Step 6: At $Q = 300$ (conservative): $\mathbb{E}[\pi] \approx \$12.5\text{K}$, VaR(5%)$\approx \$11.8\text{K}$, Sharpe$\approx$ 7.2. Nearly all scenarios yield stable profit, but upside is capped.

Three regimes emerge: $Q \ll Q^*$ (safe but low upside), $Q \approx Q^*$ (max expected profit, moderate risk), and $Q \gg Q^*$ (symmetric bell but negative VaR). The choice depends on the manager's risk tolerance.

3.8 Classroom Exercises

Exercise 1: Perishable Goods ($s = 0$)

Set salvage value to \$0 (perishable goods). Observe how the histogram shifts left and VaR(5%) drops substantially. Compute the new Q^*: $CR = (90-45)/(90-0) = 0.500$, so $\Phi^{-1}(0.500) = 0$, and $Q^* = 500$. Compare with the original Q^* of 530. The absence of salvage value makes overstocking more costly and pulls Q^* to the mean.

Exercise 2: High-Margin vs. Thin-Margin Products

Compare two products, both with $\mu = 500$, $\sigma = 120$:

	p	c	s	CR	Risk Profile
Product A	\$200	\$100	\$20	0.556	High margin, high risk
Product B	\$60	\$50	\$40	0.500	Thin margin, low risk

Run the simulation for each. Product A has higher absolute profit but also higher standard deviation and more negative VaR at extreme Q values. Product B has minimal upside but almost no downside. This demonstrates how margin structure shapes the risk profile.

Exercise 3: AI/ML Extension

In practice, μ and σ are estimated from data. A gradient boosted model trained on 3 years of weekly sales data with features (seasonality, promotions, weather, competitor pricing) might produce $\hat{\mu} = 520$ with a 90% prediction interval of [380, 660], implying $\hat{\sigma} \approx 85$ (compared to the historical $\sigma = 120$). Feed these ML-derived parameters into the dashboard and observe that Q^* shifts and VaR improves.
Discussion: Why does a better demand forecast reduce both σ and the gap between $\mathbb{E}[\pi]$ at Q^* versus $Q = \mu$?

4 Futures, Forwards, and Hedging

4.1 Chapter Overview

This module introduces derivative instruments for managing commodity price risk across supply chains. Students learn the mechanics of forward and futures contracts, construct long and short hedges, analyze basis risk, and evaluate option-based strategies including collars.

4.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Distinguish forwards from futures by standardization, counterparty risk, and margining
2. Construct a long hedge (input buyer) and a short hedge (output seller)
3. Compute the optimal hedge ratio for cross-hedging with a correlated contract
4. Evaluate option payoffs and construct a zero-cost collar
5. Explain how maturity mismatches create liquidity risk even when the directional bet is correct

4.3 Notation

S_0	Current spot price of the commodity
S_T	Spot price at time T (random)
F_0	Forward or futures price agreed at time 0
T	Time to maturity (years)
r	Risk-free interest rate (annualized)
y	Convenience yield (annualized)
h^*	Optimal hedge ratio
ρ	Correlation between spot and futures price changes
$\sigma_S,\ \sigma_F$	Standard deviation of spot / futures price changes
K	Strike price of an option
$C,\ P$	Call / put option premium

4.4 Core Equations

4.4.1 Forward Pricing (Cost-of-Carry)

$$F_0 = S_0 \cdot e^{(r-y)\,T} \tag{16}$$

When the convenience yield y exceeds the risk-free rate, the forward price is below spot (backwardation). When $y < r$, the forward trades at a premium (contango).

4.4.2 Hedging Payoffs

For a **long hedge** (buyer locks in purchase price): effective cost $= S_T - (S_T - F_0) = F_0$. For a **short hedge** (seller locks in selling price): effective revenue $= S_T + (F_0 - S_T) = F_0$. In both cases, the effective price is locked at F_0 regardless of where S_T lands.

4.4.3 Optimal Hedge Ratio

When cross-hedging with a correlated but imperfect contract:

$$\boxed{h^* = \rho \cdot \frac{\sigma_S}{\sigma_F}} \tag{17}$$

4.4.4 Option Payoffs

$$\text{Call payoff} = \max(S_T - K,\ 0), \qquad \text{Put payoff} = \max(K - S_T,\ 0) \tag{18}$$

A **collar** combines a purchased call at K_{high} with a sold put at K_{low}:

$$\text{Collar cost} \in [K_{\text{low}},\ K_{\text{high}}] \quad \text{regardless of } S_T \tag{19}$$

4.5 Worked Example

Worked Example: Chocolate Manufacturer Hedging Cocoa

Step 1: A manufacturer needs 100 tons of cocoa in 3 months. $S_0 = \$3{,}200$/ton. Buys cocoa futures at $F_0 = \$3{,}250$/ton.
Step 2 (Price rises to $3,500): Physical cost = 100 × $3,500 = $350,000. Futures gain = 100 × ($3,500 − $3,250) = $25,000. Net cost = $325,000 (effective price $3,250/ton).
Step 3 (Price falls to $3,000): Physical cost = $300,000. Futures loss = −$25,000. Net cost = $325,000 (same effective price).
Step 4 (Cross-hedge): An airline hedges jet fuel ($\sigma_S = 0.035$) with heating oil futures ($\sigma_F = 0.040$). $\rho = 0.92$. $h^* = 0.92 \times (0.035/0.040) = 0.805$. For each gallon of jet fuel exposure, hedge with 0.805 gallons of heating oil futures.
Step 5 (Collar): Buy a call at $80/bbl and sell a put at $60/bbl. If premiums offset, the firm's effective cost is bounded in $[\$60, \$80]$ at zero net premium.

4.6 Classroom Exercises

Exercise 1: Long vs. Short Hedge

A wheat farmer expects to harvest 50,000 bushels in 4 months. Current spot = $6.20/bu, futures = $6.40/bu. (a) Should the farmer take a long or short hedge? (b) Compute the effective revenue if spot falls to $5.80 at harvest. (c) What if spot rises to $7.00?
Solution: Short hedge. Both scenarios yield effective revenue of 50,000 × $6.40 = $320,000.

Exercise 2: Basis Risk

A copper fabricator uses LME copper futures to hedge, but purchases copper scrap whose price correlation with LME is $\rho = 0.85$. $\sigma_S = \$0.08$/lb, $\sigma_F = \$0.10$/lb. Compute h^*. Discuss: why is the hedge imperfect, and what residual risk remains?
Solution: $h^* = 0.85 \times (0.08/0.10) = 0.68$. Residual basis risk: quality and location mismatch.

Exercise 3: Metallgesellschaft Case Discussion

Metallgesellschaft hedged 10-year fixed-price oil contracts with 1-month rolling futures. When oil prices fell, they faced $1.3B in margin calls despite being "right" long-term. Discuss: (a) Why did the maturity mismatch create a liquidity crisis? (b) How should the hedge ratio have been adjusted? (c) What is the role of funding liquidity in hedging strategy?

5 FinTech Platforms and Blockchain in SCF

5.1 Chapter Overview

This module examines how technology is reshaping trade finance. Topics include digital SCF platforms with network effects, blockchain and smart contracts for automated settlement and double-financing prevention, data-driven credit scoring using alternative data, and purchase order finance. The Greensill Capital collapse serves as a cautionary case study.

5.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Compare bank-anchored, multi-bank, ERP-embedded, and peer-to-peer SCF platform models
2. Explain how blockchain addresses the double-financing problem in trade finance
3. Evaluate the limitations of blockchain adoption (scalability, accuracy, regulation)
4. Describe how alternative data sources enable credit scoring for firms without audited financials
5. Distinguish purchase order finance from receivables-based instruments by risk and cost

5.3 Key Concepts

5.3.1 Generations of SCF Technology

Gen	Era / Technology	Impact
1.0	1990s: EDI	Replaced paper POs and invoices between large firms
2.0	2000s: Web platforms	Multi-bank reverse factoring; e-invoicing
3.0	2010s: Cloud + API + Analytics	Real-time ERP integration; dynamic discounting; AI credit scoring
4.0	2020s: Blockchain + IoT + DeFi	Smart contracts; IoT-triggered financing; decentralized experiments

5.3.2 Network Effects in SCF Platforms

SCF platforms exhibit strong network effects: more buyers attract more suppliers (who want early payment), which attracts more financiers (who want low-risk assets), which lowers rates, attracting even more participants. This creates a winner-take-most dynamic.

5.3.3 Blockchain Applications

Four primary applications: (1) invoice tokenization for frictionless transfer; (2) smart contract automation (e.g., "when IoT sensor confirms delivery, release payment"); (3) double-financing prevention via a single source of truth; (4) multi-tier visibility extending financing to Tier-2 and Tier-3 suppliers.

5.3.4 Alternative Data for Credit Scoring

Data Source	Signal	Application
ERP transaction data	Payment history, order patterns	Predict default from relationship quality
Logistics data	Shipping frequency, lead time consistency	Operational reliability as financial proxy
Social/web signals	Employee reviews, news sentiment	Early warning of distress
Open Banking	Real-time cash flow, balances	Cash-flow-based lending for SMEs
IoT sensors	Inventory levels, machine utilization	Real-time collateral monitoring

5.3.5 Purchase Order Finance

PO finance bridges a gap that receivables-based instruments cannot: it provides funding *before* goods are shipped. Typical advance rate: 60–80% of PO value. Cost: 8–15% annualized (vs. 3–8% for receivables finance) because production risk has not yet been resolved.

5.4 Case Study: Greensill Capital (2021)

Greensill pioneered "prospective receivables" financing: lending against invoices not yet issued, based on predicted future revenue. When key clients faced distress, the prospective receivables proved speculative. Credit Suisse liquidated $10B in Greensill-linked funds. **Lesson:** SCF instruments must be backed by real, verifiable commercial transactions. Prospective receivables without confirmed POs are effectively unsecured lending disguised as trade finance.

5.5 Classroom Exercises

Exercise 1: Platform Model Comparison

For each of the following buyer profiles, recommend the most appropriate SCF platform type (bank-anchored, multi-bank, ERP-embedded, or P2P) and justify: (a) A Fortune 100 retailer with 5,000+ suppliers and a single banking relationship. (b) A mid-market manufacturer using SAP wanting seamless procurement integration. (c) A startup buyer seeking the lowest possible financing rate for its suppliers.
Discussion: (a) Bank-anchored (existing relationship, scale). (b) ERP-embedded (Taulia/SAP). (c) Multi-bank or P2P (rate competition).

Exercise 2: Blockchain Limitations

Contour, a blockchain LC platform backed by 8 major banks, went live in 2020 but ceased operations in 2023. Discuss: (a) Why did technological success not translate to commercial viability? (b) What does "garbage in, garbage out" mean for blockchain in trade finance? (c) How does the "last mile" problem (connecting physical goods to digital records) limit adoption?

Exercise 3: Supplier Risk Scoring

A supplier scores 7/10 on payment history, 5/10 on financial health, 8/10 on order consistency, 6/10 on industry stability, and 9/10 on relationship length. Using weights of 30%, 25%, 20%, 15%, and 10%: (a) Compute the composite score. (b) Determine the risk tier. (c) Recommend an SCF instrument.
Solution: Composite $= 7(0.30) + 5(0.25) + 8(0.20) + 6(0.15) + 9(0.10) = 6.65$. Medium risk ($5 \leq 6.65 \leq 7$). Recommend: factoring with recourse at 5–8%.

6 Stochastic Models and Capital Pricing

6.1 Chapter Overview

This module introduces the quantitative foundations of financial decision-making for supply chains: the Capital Asset Pricing Model for determining cost of equity, geometric Brownian motion for modeling commodity prices, the Black-Scholes formula for option pricing with a derivation sketch, and real options for valuing managerial flexibility.

6.2 Learning Objectives

Learning Objectives

After completing this module, students should be able to:

1. Apply CAPM to compute the cost of equity for a supply chain investment
2. Write the GBM stochastic differential equation and solve it via Ito's Lemma
3. Derive the Black-Scholes PDE from a delta-hedged portfolio
4. Price European call and put options using the Black-Scholes formula
5. Compute the Greeks (Δ, Γ, Θ, ν, ρ) and interpret their hedging implications
6. Value real options (defer, expand, abandon) using the Black-Scholes framework

6.3 Notation

$S,\ S_0,\ S_T$	Asset price: current, at time 0, at time T
μ	Drift (expected rate of return)
σ	Volatility (standard deviation of returns)
r	Risk-free interest rate
R_f	Risk-free rate of return
R_m	Market portfolio return
β_i	Sensitivity of asset i to market movements
$W,\ dW$	Wiener process and its increment ($dW \sim \mathcal{N}(0, dt)$)
K	Strike price of an option
T	Time to expiry (years)
V	Option value as a function of S and t
$N(\cdot)$	Standard normal CDF
$d_1,\ d_2$	Black-Scholes parameters
$\Delta,\ \Gamma,\ \Theta,\ \nu,\ \rho$	The Greeks

6.4 Core Equations

6.4.1 Capital Asset Pricing Model

$$\mathbb{E}[R_i] = R_f + \beta_i \left(\mathbb{E}[R_m] - R_f\right) \tag{20}$$

where $\beta_i = \mathrm{Cov}(R_i, R_m)/\mathrm{Var}(R_m)$. Only systematic (non-diversifiable) risk is compensated. The market risk premium $\mathbb{E}[R_m] - R_f$ is historically 5–7% for US equities.

6.4.2 Geometric Brownian Motion

The standard model for asset price dynamics:

$$dS = \mu\, S\, dt + \sigma\, S\, dW \tag{21}$$

Solution via Ito's Lemma. Let $Y = \ln S$. Apply Ito's Lemma to $f(S) = \ln S$:

$$d(\ln S) = \left(\mu - \tfrac{\sigma^2}{2}\right) dt + \sigma\, dW$$

Integrate from 0 to T and exponentiate:

$$\boxed{S_T = S_0 \exp\Big[\Big(\mu - \tfrac{\sigma^2}{2}\Big)\,T + \sigma\sqrt{T}\,Z\Big], \quad Z \sim \mathcal{N}(0,1)} \tag{22}$$

Log-returns are normally distributed: $\ln(S_T/S_0) \sim \mathcal{N}\big((\mu - \sigma^2/2)\,T,\ \sigma^2 T\big)$.

6.4.3 The Black-Scholes PDE

Construct a portfolio $\Pi = V - \Delta\,S$ with $\Delta = \partial V/\partial S$. By Ito's Lemma, dV contains both dt and dW terms. Setting $\Delta = \partial V/\partial S$ eliminates the dW term, making the portfolio locally risk-free. The no-arbitrage condition $d\Pi = r\,\Pi\,dt$ yields:

$$\boxed{\frac{\partial V}{\partial t} + \tfrac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + r\,S\,\frac{\partial V}{\partial S} - r\,V = 0} \tag{23}$$

The drift μ does not appear. Under risk-neutral pricing, we replace μ with r.

6.4.4 The Black-Scholes Formula

With boundary condition $V(S,T) = \max(S-K,0)$ for a European call:

$$C = S_0\,N(d_1) - K\,e^{-rT}\,N(d_2), \qquad P = K\,e^{-rT}\,N(-d_2) - S_0\,N(-d_1) \tag{24}$$

$$d_1 = \frac{\ln(S_0/K) + (r + \sigma^2/2)\,T}{\sigma\sqrt{T}}, \qquad d_2 = d_1 - \sigma\sqrt{T} \tag{25}$$

Put-call parity: $C - P = S_0 - K\,e^{-rT}$.

6.4.5 The Greeks

Greek	**Definition**	**Interpretation**
$\Delta = \partial V/\partial S$	$N(d_1)$ for call	Change per $1 move in underlying
$\Gamma = \partial^2 V/\partial S^2$	$n(d_1)/(S\sigma\sqrt{T})$	Rate of change of delta
$\Theta = \partial V/\partial t$	Time decay	Options lose value approaching expiry
$\nu = \partial V/\partial \sigma$	$S\,n(d_1)\sqrt{T}$	Sensitivity to volatility
$\rho = \partial V/\partial r$	$KT\,e^{-rT}N(d_2)$	Sensitivity to interest rate

6.4.6 Real Options

Real options extend Black-Scholes to physical investment decisions. Map: S_0 = PV of project cash flows, K = investment cost, σ = cash flow volatility, T = decision deadline.

Option Type	**Supply Chain Example**	**Analogue**
Defer	Delay building a DC until demand is clearer	Call
Expand	Design factory with extra floor space	Call
Contract	Flexible labor contracts allowing reduction	Put
Abandon	Lease equipment; return if project fails	Put
Switch	Dual-fuel plant (gas/oil)	Portfolio

6.5 Worked Example

Worked Example: Black-Scholes Pricing + Real Option Valuation

Part A: Option on Copper. $S_0 = \$8{,}500/\text{ton}$, $K = \$9{,}000$, $r = 5\%$, $\sigma = 25\%$, $T = 0.5$ yr.
$d_1 = [\ln(8500/9000) + (0.05 + 0.03125) \times 0.5]/(0.25\sqrt{0.5}) = [-0.0572 + 0.0406]/0.1768 = -0.094$
$d_2 = -0.094 - 0.1768 = -0.271$
$N(d_1) = 0.4625$, $N(d_2) = 0.3932$
$C = 8500 \times 0.4625 - 9000 \times e^{-0.025} \times 0.3932 = 3{,}931 - 3{,}452 = \$479/\text{ton}$.
Greeks: $\Delta = 0.463$, $\Gamma = 0.00047$, $\nu = 1{,}992$.
Part B: Expansion Real Option. PV of expansion cash flows $S_0 = \$2.5\text{M}$, expansion cost $K = \$3\text{M}$, $T = 2$ yr, $\sigma = 40\%$, $r = 5\%$.
$d_1 = [\ln(2.5/3) + (0.05 + 0.08) \times 2]/(0.4\sqrt{2}) = [-0.182 + 0.26]/0.566 = 0.138$
$d_2 = 0.138 - 0.566 = -0.428$
$C = 2.5 \times 0.555 - 3 \times e^{-0.10} \times 0.334 = 1.388 - 0.907 = \$0.48\text{M}$
If the base warehouse NPV is $-\$0.2\text{M}$, the adjusted NPV is $-0.2 + 0.48 = +\$0.28\text{M}$. The project should proceed because the embedded flexibility creates value.

6.6 Classroom Exercises

Exercise 1: CAPM and Supply Chain Investment

A logistics firm ($\beta = 0.85$) considers an automated warehouse. $R_f = 4.5\%$, market risk premium $= 6\%$. (a) Compute the cost of equity. (b) If the warehouse IRR is 8%, should the firm invest? (c) What β would make the firm indifferent?
Solution: (a) $4.5 + 0.85 \times 6 = 9.6\%$. (b) No, IRR $<$ cost of equity. (c) $\beta = (8 - 4.5)/6 = 0.583$.

Exercise 2: GBM Confidence Interval

Crude oil at $S_0 = \$75$, $\mu = 5\%$, $\sigma = 30\%$. Compute the 95% confidence interval for S_T after $T = 0.5$ year.

Solution: $\ln S_T \sim \mathcal{N}(\ln 75 + (0.05 - 0.045) \times 0.5,\ 0.09 \times 0.5)$. Mean $= 4.320$, std $= 0.212$. CI: $[\exp(4.320 - 1.96 \times 0.212),\ \exp(4.320 + 1.96 \times 0.212)] = [\$49.67,\ \$114.71]$. This wide range illustrates why commodity hedging matters.

Exercise 3: Real Options — Defer vs. Invest Now

A firm can invest \$5M now in a new production line (NPV = +\$0.3M) or wait 1 year for demand clarity. The option to defer has $S_0 = \$5.3$M (PV of cash flows), $K = \$5$M, $\sigma = 35\%$, $T = 1$, $r = 5\%$. (a) Price the deferral option using Black-Scholes. (b) Should the firm invest now or wait? (c) Under what volatility level does immediate investment dominate?

Discussion: Higher volatility increases the option value, favoring delay. The crossover occurs when the option value equals the NPV of immediate investment.

7 Curriculum Alignment

7.1 Curriculum Mapping

The six modules directly support multiple program areas in supply chain management, financial operations, and applied business analytics. Module 1 bridges supply chain management and financial management. Module 2 introduces financial instruments at the intersection of SCM and enterprise risk management. Module 3 integrates applied business analytics with operations management via Monte Carlo simulation and financial risk metrics. Module 4 covers derivative instruments for commodity risk management. Module 5 examines technology-driven transformation in trade finance. Module 6 provides the quantitative foundations connecting stochastic calculus to real asset valuation.

Module	Primary Course Area	Secondary	Session
CCC & Working Capital	Financial Management	Supply Chain Mgmt	75–90 min
Dynamic Discounting & RF	Supply Chain Management	Risk Management	75–90 min
Monte Carlo Profit Risk	Business Analytics / AI-ML	Operations Mgmt	90–120 min
Futures & Hedging	Risk Management	Financial Mgmt	75–90 min
FinTech & Blockchain	Supply Chain Management	Information Systems	60–75 min
Stochastic Models & Pricing	Quantitative Finance	Operations Mgmt	90–120 min
Integrated Dashboard	Capstone / Integrative	All of the above	2–3 hours

7.2 AI and Machine Learning Extensions

Each module includes a natural extension point for AI/ML. In Module 1, predictive models can forecast DIO, DSO, and DPO from operational data for proactive working capital management. In Module 2, dynamic pricing algorithms optimize the discount APR in real time based on buyer cash position and supplier urgency. In Module 3, the Monte Carlo framework directly consumes probabilistic demand forecasts from ML models, replacing the assumed normal distribution with empirical distributions that capture nonlinearities, seasonality, and external covariates.

7.3 Technical Notes

The dashboard is a single HTML file (∼40 KB) with embedded CSS and JavaScript. Visualizations use the HTML5 Canvas 2D rendering API. Monte Carlo simulation uses the Box-Muller transform for normal random variates and runs 10,000 trials in under 100 milliseconds. The inverse normal CDF uses the Abramowitz and Stegun rational approximation. All computation is client-side, ensuring data privacy and offline capability.

7.4 Suggested Readings

- Brealey, R. A., Myers, S. C., & Allen, F. (2020). *Principles of Corporate Finance* (13th ed.). McGraw-Hill. Chapters 29–30.
- Cachon, G. P., & Terwiesch, C. (2019). *Matching Supply with Demand* (4th ed.). McGraw-Hill. Chapter 12.
- Hofmann, E., & Belin, O. (2011). *Supply Chain Finance and Financial Supply Chains*. Springer.
- Hull, J. C. (2022). *Options, Futures, and Other Derivatives* (11th ed.). Pearson. Chapters 1–5, 13–15.
- Kouvelis, P., & Zhao, W. (2012). Financing the Newsvendor. *Operations Research*, 60(3), 566–580.
- Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2021). *Designing and Managing the Supply Chain* (4th ed.). McGraw-Hill.
- Trigeorgis, L. (1996). *Real Options: Managerial Flexibility and Strategy in Resource Allocation*. MIT Press.