The Practical Science of Prioritization

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Today’s Topics

• Why establish priorities?
• What is economic prioritization?
• What is Cost of Delay?
• How should we prioritize activities?
• Where else does this apply?
• And few other observations
Why establish priorities?
Why Use a Rational Process to Set Priorities?

• Priorities affect economic outcomes.
• Priorities align group behavior around economic leverage points.
• A rational process for setting priorities will:
  • Intrinsically stabilize priorities;
  • Permit people to understand the economic logic behind the current priorities;
  • Alert you to when you should change your priorities.
What is Economic Prioritization?
When capacity is constrained, the decision to service one job is a decision to delay another.

Delay Cost = Cost of Delay x Duration of Delay
The Economics of Priority Setting

All prioritization decisions are reducible to the comparison of two projects.

\[ COD_A = \text{Cost of Delay for Project A} \]
\[ T_A = \text{Time Resource is Required for Project A} \]
\[ COD_B = \text{Cost of Delay for Project B} \]
\[ T_B = \text{Time Resource is Required for Project B} \]

If \( T_A \cdot COD_B \leq T_B \cdot COD_A \) then Project A gets priority.

Divide both sides by \( T_A T_B \)

If \( \frac{COD_B}{T_B} \leq \frac{COD_A}{T_A} \) then Project A gets priority.
What is Cost of Delay?
Availability Date Affects Total Profit

Life Cycle Profit

Product A

Product B

Profit Loss

Delay

COD A

COD B

Product Availability Date
Time is Money.

\[ t = m \]

\[ \Delta t = \Delta m \]
\[ \Delta t \left( \frac{\partial m}{\partial t} \right) = \Delta m \]

Cost of Delay
Making Economic Decisions

Proxy Variable Space
- Waste
- Cycle Time
- Variability
- Efficiency
- Revenue
- Unit Cost
- Value-Added

Transformations

Economic Space
- Life Cycle
  - Profits

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The Modeling Process

Create Baseline Model

- Model Expense Overrun
- Model Cost Overrun
- Model Value Shortfall
- Model Schedule Delay
- Model Risk Change

Determine Total Profit Impact of Missing a MOP

Calculate Sensitivity Factors

MOP = Measure of Performance
## Baseline Scenario

<table>
<thead>
<tr>
<th>Baseline Scenario</th>
<th>Quarter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assume</strong></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
<td>2,000</td>
<td>4,000</td>
<td>4,000</td>
<td>2,000</td>
<td>1,000</td>
<td>-</td>
<td>14,000</td>
</tr>
<tr>
<td><strong>Unit Sales</strong></td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><strong>Price Erosion Rate</strong></td>
<td>-4% Per Qtr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Sales Price</td>
<td>$3,000</td>
<td>$2,880</td>
<td>$2,765</td>
<td>$2,654</td>
<td>$2,548</td>
<td>$2,446</td>
<td>$2,348</td>
<td>$2,254</td>
<td>$2,164</td>
<td>$35,000,736</td>
<td></td>
</tr>
<tr>
<td><strong>Sales Revenue</strong></td>
<td>$ -</td>
<td>$ -</td>
<td>$2,764,800</td>
<td>$5,308,416</td>
<td>$10,192,159</td>
<td>$9,784,472</td>
<td>$4,696,547</td>
<td>$2,254,342</td>
<td>$ -</td>
<td>$ -</td>
<td>$35,000,736</td>
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<tr>
<td><strong>Cost Improvement</strong></td>
<td>0.5% Per Qtr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit Cost</td>
<td>$900</td>
<td>$896</td>
<td>$891</td>
<td>$887</td>
<td>$882</td>
<td>$878</td>
<td>$873</td>
<td>$869</td>
<td>$865</td>
<td>$12,319,230</td>
<td></td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>$ -</td>
<td>$ -</td>
<td>$891,023</td>
<td>$1,773,125</td>
<td>$3,528,538</td>
<td>$3,510,896</td>
<td>$1,746,671</td>
<td>$868,969</td>
<td>$ -</td>
<td>$12,319,230</td>
<td></td>
</tr>
<tr>
<td>Gross Margin</td>
<td>$ -</td>
<td>$ -</td>
<td>$1,873,778</td>
<td>$3,535,281</td>
<td>$6,663,621</td>
<td>$6,273,577</td>
<td>$2,949,876</td>
<td>$1,385,374</td>
<td>$ -</td>
<td>$22,681,506</td>
<td></td>
</tr>
<tr>
<td>Percent Gross Margin</td>
<td>70%</td>
<td>69%</td>
<td>68%</td>
<td>67%</td>
<td>65%</td>
<td>64%</td>
<td>63%</td>
<td>61%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Op Expenses</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$8,000,000</td>
</tr>
<tr>
<td>Variable Op Expenses</td>
<td>25% of Revenue</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,691,200</td>
<td>$1,327,104</td>
<td>$2,548,040</td>
<td>$2,446,118</td>
<td>$1,174,137</td>
<td>$563,586</td>
<td>$ -</td>
<td>$8,750,184</td>
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<tr>
<td><strong>Total Op Expenses</strong></td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,691,200</td>
<td>$1,327,104</td>
<td>$2,548,040</td>
<td>$2,446,118</td>
<td>$1,174,137</td>
<td>$563,586</td>
<td>$ -</td>
<td>$16,750,184</td>
<td></td>
</tr>
<tr>
<td>Operating Profit</td>
<td>$ (1,000,000)</td>
<td>$ (1,000,000)</td>
<td>$182,578</td>
<td>$1,208,177</td>
<td>$3,115,581</td>
<td>$2,827,459</td>
<td>$775,740</td>
<td>(178,212)</td>
<td>$ -</td>
<td>$ 5,931,322</td>
<td></td>
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<tr>
<td>Cumulative Op Profit</td>
<td>$(1,000,000)</td>
<td>$(2,000,000)</td>
<td>$(1,817,423)</td>
<td>$(609,245)</td>
<td>$2,506,336</td>
<td>$5,333,794</td>
<td>$6,109,534</td>
<td>$5,931,322</td>
<td>$5,931,322</td>
<td>$5,931,322</td>
<td>$5,931,322</td>
</tr>
</tbody>
</table>

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Typical Delay Scenario

Quarterly Sales

Quarter

Delay Scenario

Baseline
Delayed
## Delayed Scenario

<table>
<thead>
<tr>
<th>Delay Scenario</th>
<th>Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Unit Sales</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Price Erosion Rate</strong></td>
<td>-4%</td>
</tr>
<tr>
<td>Average Sales Price</td>
<td>$3,000</td>
</tr>
<tr>
<td>Sales Revenue</td>
<td>$ -</td>
</tr>
<tr>
<td><strong>Cost Improvement</strong></td>
<td>-0.5%</td>
</tr>
<tr>
<td>Unit Cost</td>
<td>$900</td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>$ -</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>$ -</td>
</tr>
<tr>
<td><strong>Percent Gross Margin</strong></td>
<td>70%</td>
</tr>
<tr>
<td>Fixed Op Expenses</td>
<td>$ -</td>
</tr>
<tr>
<td>Variable Op Expenses</td>
<td>$ -</td>
</tr>
<tr>
<td>Total Op Expenses</td>
<td>$ -</td>
</tr>
<tr>
<td>Operating Profit</td>
<td>$ -</td>
</tr>
<tr>
<td>Cumulative Op Profit</td>
<td>$ -</td>
</tr>
</tbody>
</table>

Baseline $5,931,322
Change $3,982,084
Per Month $1,327,361

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The Model Output

<table>
<thead>
<tr>
<th>1 Percent Expense Overrun</th>
<th>1 Percent Product Cost Overrun</th>
<th>1 Percent Value Shortfall</th>
<th>1 Month Delay</th>
<th>1 Percent Increase in Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>-$40,000</td>
<td>-$150,000</td>
<td>-$100,000</td>
<td>-$500,000</td>
<td>-$80,000</td>
</tr>
</tbody>
</table>

Life-Cycle Profit Impact
Any Analysis Beats Intuition

Range of Cost of Delay Estimates

- Quality Analysis: 1.2:1
- Average Analysis: 2:1
- Best Case Intuition: 10:1
- Average Intuition: 50:1
- Poor Intuition: 200:1

Source: Reinertsen & Associates Clients
How should we prioritize?
The Hospital Emergency Room

• Toyota is the best-managed company in the world.
• We want to rigorously imitate their practices.
• All arriving patients will now be processed on a FIFO basis.
Prioritization is Queueing Discipline

Pseudo-Economic/Non-Economic Approaches

• High Profit First (HPF)
• Minimum Slack Time First (MSTF)
• The squeaky wheel gets the grease.

Economic Approaches

• First In First Out (FIFO)
• Shortest Job First (SJF)
• High Cost of Delay First (HDCF)
• Weighted Shortest Job First (WSJF)
Economic Queueing Disciplines

Cost of Delay

Homogeneous

FIFO

SJF

Non-Homogeneous

HDCF

WSJF

Homogeneous Duration

Non-Homogeneous
Use FIFO for Homogeneous Flow

First-In First-Out

Cost of Delay

Last-In First-Out

Cost of Delay

<table>
<thead>
<tr>
<th>Project</th>
<th>Duration</th>
<th>Cost of Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Delay Cost
### Shortest Job First (SJF)

#### Shortest First

<table>
<thead>
<tr>
<th>Project</th>
<th>Duration</th>
<th>Cost of Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

#### Longest First

- **Delay Cost**

**Time**

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High Delay Cost First (HDCF)

<table>
<thead>
<tr>
<th>Project</th>
<th>Duration</th>
<th>Cost of Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

High Delay Cost First

Low Delay Cost First

Total Delay Cost
## Weighted Shortest Job First (WSJF)

### High Weight First

<table>
<thead>
<tr>
<th>Project</th>
<th>Duration</th>
<th>Cost of Delay</th>
<th>Weight = COD/Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Low Weight First

160 → 7
96 Percent Reduction!

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Priorities are Inherently Local

- The highest economic priority at a resource depends on:
  - Cost of Delay is a global property of a project.
  - Remaining time at a resource is a local property at that specific resource.
  - Therefore, priorities are local properties of tasks, not global properties of projects.
A Possible Approach

<table>
<thead>
<tr>
<th>Duration</th>
<th>Low</th>
<th>Medium</th>
<th>Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td>9</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Medium</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Short</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Cost of Delay

High

Medium

Low
Where else does this apply?
It’s Pretty General

• Prioritizing to maximize benefit to cost ratio is broadly applicable in for-profit organizations.
  • At the portfolio level
  • At the feature level
  • For sequencing activities
  • For your to do list
• Ultimately, you want the things you do to be more valuable than the things you don’t.
Optimizing Testing Sequences

• Tests differ in their cost and their effectiveness at generating useful information.
• Powerful and cheap tests should obviously come first.
• But what about powerful and very expensive* tests?

* Note: Using expensive in the sense of total cost which includes includes expenses and Delay Cost.
### Screening Efficiency

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Success Probability</th>
<th>Failure Probability</th>
<th>Cost of Test</th>
<th>Cost per Percent Screened</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>60%</td>
<td>40%</td>
<td>$100,000</td>
<td>$2,500</td>
</tr>
<tr>
<td>Two</td>
<td>50%</td>
<td>50%</td>
<td>$200,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Three</td>
<td>40%</td>
<td>60%</td>
<td>$360,000</td>
<td>$6,000</td>
</tr>
</tbody>
</table>
Effect of a Correct Sequence

Probability of Passing
Test 1 = 60%
Test 2 = 50%
Test 3 = 40%
Overall = 12%

Expected Cost
Test 1 = $100 K
Test 2 = $120 K
Test 3 = $108 K
Overall = $328 K

Probability of Occurrence

Test 1
100%

Test 2
60%

Test 3
30%

Cumulative Cost

$100K
$200K
$360K

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Effect of Poor Sequence

Probability of Occurrence

Probability of Success
Test 1 = 60%
Test 2 = 50%
Test 3 = 40%
Overall = 12%

Cumulative Cost

Test 1 = $20 K
Test 2 = $80 K
Test 3 = $360 K
Overall = $460 K

Expected Cost

Test 3 = $360 K
Test 2 = $80 K
Test 1 = $20 K
Overall = $460 K
Some Other Issues

• What happens when we don’t know duration?
• Should we preempt jobs currently in process?
• How does WSJF change behavior?
• Should we change priorities?
Round Robin Scheduling

- Computer operating systems handle non-repetitive tasks, with diverse priorities, and unpredictable durations.
- A standard strategy for doing this is Round-Robin (RR) Scheduling.
  - Each job gets a fixed quantum of capacity.
  - If it is unfinished it returns to the queue.
  - Most short jobs process in a single quantum.
    - Heuristic is 80 percent clear on first quantum.
- This is easily extended to Weighted Round Robin (WRR).
A and B Arrive at Same Time

Project A
Cost of Delay = $400,000 per month
Time Required = 1 month

Project B
Cost of Delay = $100,000 per month
Time Required = 2 weeks

B First
A Delay Cost = $200,000

A First
B Delay Cost = $100,000
A Arrives When B Is 75% Done

Project A
Cost of Delay = $400,000 per month
Time Required = 1 month

Project B
Cost of Delay = $100,000 per month
Time Required = 0.5 week remaining

B Blocks A
A Delay Cost = $50,000

A Preempts B
B Delay Cost = $100,000

Effort already expended is a “sunk cost.”
Preemption is Dangerous

• We are tempted to preempt to eliminate the residual time of the job being preempted.
• Preemption can cause context switching costs that reduce the capacity of the queued bottleneck.
  • Reducing bottleneck capacity can lead to an even bigger queue.
• Nevertheless, preemption is sometimes justifiable economically.
• However, first consider reducing residual time by decreasing batch size.
Does WSJF Change Behavior?

• How can a project manager increase the priority for their tasks?
  • Claim his Cost of Delay is very large.
  • Claim her task duration is very small.
  • Decompose the task into smaller chunks.
    • This is batch size reduction, which is inherently desirable.

• When there is no cost for lying about facts, manipulation will be widespread.
WSJF in the Wild: CD3 at Maersk

Black Swan Farming using Cost of Delay
Discover, nurture and speed up delivery of value

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Abstract—Improving prioritization has become a tired concept in most IT departments, and yet it has the potential to change the conversation from one of cutting cost, to delivering valuable solutions as quick as the business needs it. This paper examines how Maersk Line applied an economic framework across a $100 million portfolio to quickly discover, nurture and speed up the delivery of value.

model, using the larger, more mature outsourcing vendors like IBM and TCS.

The outsourcing model means that Maersk Line expect to be able to staff their I.T. department with generalists rather than specialists. For example, it is not uncommon to make a career move from Sales to I.T.

Should Priorities Change?

• When economics change, priorities change.
• The longer we delay changing priorities the more we hurt our economics.
• If we always jettison features, shouldn’t we preplan what can be jettisoned?
  • Rather that insisting to lose a single feature will jeopardize 100 percent of revenue.
Some Take-Aways

1. Don’t prioritize on project value, ask how value is affected by delay.
2. Don’t treat priority as a global property of a project.
3. Join the 15 percent of developers who know the Cost of Delay for their projects.
4. Do prioritize on Weighted Shortest Job First (WSJF).
5. Only use FIFO for homogeneous flow.
6. Recognize that queueing discipline can reduce the cost of queues without changing the size of queues.
7. When you don’t know durations use Round Robin.
8. Treat money already spent as a sunk cost.
10. Use WSJF to drive batch size reduction.
Going Further

- **Developing Products in Half the Time**
  - Second Edition
  - Print + Kindle
  - 1991 / 1997

- **Managing the Design Factory**
  - A Product Developer’s Toolkit
  - Print Only
  - 1997

- **The Principles of Product Development**
  - FLOW
  - Second Generation Lean Product Development
  - Print + Kindle
  - 2009