Realized Value Optimization in Product Development Post-certification
Plan

- Problem overview
- Model 1 (mono period)
- Model 2 (multi periods)
- Model 3 (stochastic)
- Research perspectives
P&WC Engineering Planning Cycle Overview

Programs list all desired tasks to be accomplished

Finance performs Consolidation of all tasks

If demand exceeds offer, high management needs to prioritize tasks

Tasks with low priority will be pushed to the following year

Objectives

- Ensure projects demand balances with available resources
- Optimize project budgets for shareholder value
- Allocate available resources to enhance delivered value
- Enable more frequent planning with less effort
Lean approach for determining priority

Engineering task value (input) calculated based on:

- Customer impact
- Criticality of issue
- Work progress
- Impact on business
Definition of engineering tasks

PROJECT EXAMPLE

- Engine
- Nacelle
- Advanced Studies
- Compressor
- Air/Oil Systems
- Controls
- Engine Integration
- Planning Package
- WBS
- Job
- OBS
- \textbullet\, PD Job 1
- \textbullet\, PD Job 2
- Ress1\ldots Ress_i
Mono-Period Model

Sets definition
\[ T : \text{set of tasks} \]
\[ K : \text{set of resource type} \]
\[ J : \text{set of value criteria} \]
\[ H : \text{set of activity type} \]
\[ P : \text{set of projects} \]

Parameters
\[ D_{ik} : \text{Quantity (hours) of resource } k \in K \text{ required to complete task } i \in T \]
\[ V_i : \text{Value of task } i \in T \]
\[ \delta_{ip} : 1 \text{ if task } i \in T \text{ is part of project } p \in P, 0 \text{ otherwise} \]
\[ \delta_{ih} : 1 \text{ if task } i \in T \text{ is an activity of type } h \in H, 0 \text{ otherwise} \]
\[ C_k : \text{Capacity (hours) of resource type } k \in K \]
\[ B_p : \text{Budget (hours) of project } p \in P \]
\[ \alpha_h : \text{Minimum rate of task of activity type } h \in H \text{ to be completed} \]
\[ \beta_p : \text{Maximum rate of project } p \in P \text{ Budget} \]
\[ \gamma_p : \text{Minimum rate of project } p \in P \text{ Budget} \]

Decision variables
\[ O_i : 1 \text{ if we decide to complete task } i \in T, 0 \text{ otherwise} \]
Mono-Period Model

Objective function

\[ \max \left( \sum_{i \in T} O_i \times V_i \right) \]

Maximize the realized value

Constraints

1. Capacity: \( \forall k \in K \)

\[ \sum_{i \in T} O_i \times D_{ik} \leq C_k \]

Limited capacity per resource type

2. Total budget:

\[ \sum_{i \in T} O_i \times D_{ik} \leq \sum_{p \in P} B_p \]

Limited total budget for all projects

3. Project budget: \( \forall p \in P \)

\[ \gamma_p \times B_p \leq \sum_{i \in T} O_i \times \delta_{ip} \times D_{ik} \leq \beta_p \times B_p \]

Limited budget per project with respect to priority

4. Activities types: \( \forall h \in H \)

\[ \sum_{i \in T} \sum_{k \in K} O_i \times \delta_{ih} \times D_{ik} \geq \alpha_h \times \left( \sum_{i \in T} \sum_{k \in K} \delta_{ih} \times D_{ik} \right) \]

Priority given to some activities
Mono-period: results obtained

- **Solver**
  - Solver: Xpress Mosel.

- **1st Data set (planning package level)**
  - 377 tasks, 26 resource types
  - CPU time: 0.7 seconds

- **2nd Data set (job level)**
  - 4000 tasks, 26 resource types
  - CPU time: 11 seconds
Multi-Periods Model

Sets definition
- $T$ : set of tasks
- $K$ : set of resource type
- $H$ : set of activity type
- $P$ : set of projects
- $Q$ : set of periods

Parameters
- $E_{ikq}$ : Estimated hours for task $i \in T$ for resource type $k \in K$ in period $q \in Q$
- $C_{kq}$ : Resource type $k \in K$ capacity (hours) in period $q \in Q$
- $V_i$ : Value of task $i \in T$
- $B_{pq}$ : budget (hours) for project $p \in P$ in period $q \in Q$
- $\delta_{ip}$ : 1 if task $i \in T$ is part of project $p \in P$, 0 otherwise
- $\delta_{ih}$ : 1 if task $i \in T$ is an activity of type $h \in H$, 0 otherwise
- $\alpha_{hq}$ : Minimum rate of tasks of activity type $h \in H$ to be completed in period $q \in Q$
- $\beta_{pq}$ : Maximum rate of project $p \in P$ budget in period $q \in Q$
- $\gamma_{pq}$ : Minimum rate of project $p \in P$ budget in period $q \in Q$
- $P_{iq}$ : Penalty for task $i \in T$ in period $q \in Q$

Decision variables
- $X_{ikq}$ : worked hours for task $i \in T$ for resource type $k \in K$ in period $q \in Q$
- $Y_{ikq}$ : earned value for task $i \in T$, for resource type $k \in K$ in period $q \in Q$
Multi-Periods Model

Objective function

\[ \max \left( \sum_{i \in I} V_i \times \left( \sum_{q \in Q} V_{iq} \right) \right) - \sum_{i \in I} V_i \times P_{iq} \times \left( \sum_{k \in K} X_{iqk} \right) \]

Maximize the realized value

Constraints

1. Capacity constraint: \( \forall (k, q) \in K \times Q \)
   \[ \sum_{i \in I} X_{iqk} \leq C_{iqk} \]
   Limited capacity per resource type per period

2. Minimum (E, X): \( \forall (i, k, q) \in T \times K \times Q \)
   \[ Y_{ikq} \leq E_{ikq} \]
   \[ Y_{ikq} \leq X_{ikq} \]
   Earned value limits

3. Respect estimated hours: \( \forall (i, k) \in T \times K \)
   \[ \sum_{q \in Q} X_{iqk} = \sum_{q \in Q} E_{ikq} \]
   Respect estimated hours

4. Total budget constraint: \( \forall q \in Q \)
   \[ \sum_{i \in I} X_{iqk} \leq \sum_{p \in P} B_{pq} \]
   Budget constraints

5. Project budget constraint: \( \forall (p, q) \in P \times Q \)
   \[ \gamma_{pq} \times B_{pq} \leq \sum_{i \in I} \delta_{ip} \times X_{ikq} \leq \beta_{pq} \times B_{pq} \]

6. Activities types constraints: \( \forall (h, q) \in H \times Q \)
   \[ \sum_{i \in I} \delta_{ih} \times X_{iqk} \geq \alpha_{hq} \times \left( \sum_{k \in K} \delta_{ih} \times E_{iqk} \right) \]
   Priority given to some activities

7. Positivity constraints: \( \forall (i, k, q) \in T \times K \times Q \)
   \[ X_{iqk} \geq 0 \]
   \[ Y_{ikq} \geq 0 \]
Multi-periods: results obtained

- **Data set (job level)**
  - 4000 tasks,
  - 26 resource types
  - 1,664,000 variables
  - CPU time: 34 seconds

- **Solver**
  - Solver: Xpress Mosel.

![Graph showing objective function value against budget]
Stochastic models

1\textsuperscript{st}: Dynamic program model

2\textsuperscript{nd}: Hybrid solution: Genetic/simulation (programmed in Ruby)
   - Genetic algorithm: jobs priority
   - Simulation: evaluation function using a sequential scheduling approach

3\textsuperscript{rd}: Stochastic gradient descent (programmed in Ruby)
   1. generate random priority vector
   2. evaluate the solution
      for each quarter, task and resource
      \[ x = \min (\text{estimate, remaining capacity for resource } k) \]
      \[ x = \min (x, \text{remaining total budget}) \]
      \[ x = \min (x, \text{remaining budget for task } i \text{ project}) \]
      update remaining capacity, budgets
      update cost function
      postpone remaining estimate
   3. update the best known solution if better
   4. switch 2 tasks of the best known solution
   5. go to 2
   6. if after 10 trials we don't improve the best known solution, go to 1
Conclusion

- Workshop objectives
  - Validate the initial model
  - Propose a multi-period model
  - Obtain a feasible solution with real data within a reasonable time period

- Research perspectives:
  - Test the multi-period model at the activity level
  - Expand and test the stochastic models