OPTIMIZE THE CREW POOL/BOARD SIZES

• Problem Definition
  – Find the Optimal sizes for crew boards (regular pools and extraboard) while following the business rules involved in crew-to-train assignment process and maintaining an on-time train performance.
HOW IT’S DONE?
OPTIMIZING THE POOL SIZES WHILE SIMULATING THE BUSINESS PROCESSES

OVERVIEW OF THE CREW PLANNING TOOL
WHY SIMULATION MODEL?
BUSINESS RULES ARE TOO COMPLEX TO MODEL ONLY BY OPTIMIZATION

• Each freight train uses an engineer and a conductor, belonging to a crew pool.
• Each crew pool has a home terminal and up to five away terminals.
  – Excessive crew wait time at away terminal results in a ‘detention’ cost.
• Crew rest rules
  – 10 hours rest at home and away terminal.
  – 48 hours rest after 6 days of service.
  – 3 days rest after 7 days of service.
• Crew operating rules
  – Maximum on-duty time 12 hours, schedule a re-crew if needed after 12 hours.
• Crew pool types:
  – Regular, crews wait in a queue to take the next available train.
  – Carded or Scheduled, crews wait in a queue within a certain time period (call window).
  – Extraboard, a pool of crews who support the regular or carded pools.
MORE COMPLEXITIES MODELED USING SIMULATION

• Complex functionalities modeled:
  – Variation in train departure times and transit times.
  – Variation in crew-availability due to mark-off.
  – Re-crew decisions making process.
    • Schedule a re-crew if crew is on-duty for more than 12 hours and train is not complete.
  – Deadhead decisions making process.
    • Crews can be deadheaded to home or away terminal without operating a train.
  – Detention time decision making process.
  – Pre-defined work-rest calendar for some crew pools.
  – Include limbo time in rest duration if necessary.
TECHNOLOGY USED FOR SIMULATION MODEL

- Discrete Event Simulation
- Home grown
- Java
HIGH LEVEL PROCESS FLOW

Simulation $r$ Replications

KPIs Satisfied?

Yes

Fix Pool Size

Collect and Report Metrics

Stop

No

Determine Pool Sizes

Optimization Module

Simulation r Replications

Output Analyzer
OPTIMAL SIZING PROBLEM IS MODELED AS
MULTI-CRITERIA SINGLE-DISCRETE-VARIABLE

• Problem is how many crews are required in regular pools and the extraboard to achieve a target service level.
  – Service level is defined by multiple KPIs considered together.
• This problem is formulated as a multi-criteria single-discrete-variable optimization model.
• Used implicit complete enumeration approach.
  – This means we used handful of sizing options by excluding those that are definitely sub-optimal.
  – Used greedy heuristic.
HIGH LEVEL PROCESS FLOW

Simulation \( r \) Replications → KPIs Satisfied?

- Yes → Fix Pool Size → Collect and Report Metrics → Stop
- No → Determine Pool Sizes

Optimization Module

Output Analyzer
Problem is to incorporate randomness inside simulation model but report out single value results for metrics and pool sizes.

The output data analyzing process achieves that using following algorithm:

- Find sample mean, median and mode for each metrics from the r simulation runs in the last cycle (with optimal pool sizes).
- Use Bootstrapping to measure variability between sample and population.
- Calculate new Bootstrapping sample mean\_boot, median\_boot and mode\_boot.
- Calculate Standard Error (SE) for each estimator (mean, median and mode).
- Select the estimator minimizing SE.
QUICK RECAP OF THE CREW PLANNING TOOL

Process Flow:

Input → Cycle 1
- RUN 1 (KPIs) Simulation
- RUN 2 (KPIs) Simulation
- ... (Repeat)
- RUN r (KPIs) Simulation

Output Module → Optimization Module

Cycle 2
- RUN 1 (KPIs) Simulation
- RUN 2 (KPIs) Simulation
- ... (Repeat)
- RUN r (KPIs) Simulation

Output Module → Optimization Module

Cycle N
- RUN 1 (KPIs) Simulation
- RUN 2 (KPIs) Simulation
- ... (Repeat)
- RUN r (KPIs) Simulation

Output Analyzer
SAMPLE RESULTS

Suggest optimal number of crews to achieve target KPI, e.g., 24 crews required in crew pool XY to achieve less than 1% train delays and 0 cancellations.
A typical what-if case study to analyze the impact of mark-off rate on crew size to achieve same level of performance.
QUESTIONS?
THE CREW PLANNING TOOL

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