Solving Business Problems with Analytics

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SAS Institute Inc.

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1. Customer Case Study: ATM Replenishment
2. Customer Case Study: Insurance Claim Assignment
3. Sample Consulting Engagements
Outline

1. Customer Case Study: ATM Replenishment

2. Customer Case Study: Insurance Claim Assignment

3. Sample Consulting Engagements
Business Problem

- Given transactional data (withdrawals, deposits, replenishments) for past 3 months
- Forecasting problem: estimate hourly demand for each ATM for the next month
- Optimization problem: determine which hours to replenish each ATM over the next month to avoid cashouts
- “replenish” means fill to capacity
- “cashout” means ATM inventory < next 4 hours of demand
Business Problem

- Four possible objectives to minimize:
  - Cashout hours
  - Cashout events (consecutive cashout hours at same ATM)
  - Lost demand (in dollars)
  - Number of replenishments

- Budget limits total number of replenishments

- Limit on number of simultaneous replenishments varies throughout the day

- Eligible replenishment hours depend on ATM:
  - all day: 4am-noon, 1pm-11pm
  - overnight: 9pm-7am

- Run replenishment scheduling every two weeks for one-month rolling horizon
Workflow

- Forecasting
  - Data Cleansing
  - SAS Forecast Server
  - Base SAS
Workflow

- Optimization
  - SAS/OR (OPTMODEL)

- Forecasting
  - SAS Forecast Server

- Data Cleansing
  - Base SAS
Workflow

User Interface

Flash/Flex, SAS BI

Optimization

SAS/OR (OPTMODEL)

Forecasting

SAS Forecast Server

Data Cleansing

Base SAS
Forecasting: SAS Forecast Studio
PROC OPTMODEL

- Reads forecasted demand for each ATM and period
- Builds mixed integer linear programming (MILP) instance
- Calls MILP solver
- Outputs optimal solution
Initial MILP Formulation

- **Replenish** \( [a, p] = \begin{cases} 
1 & \text{if ATM } a \text{ is replenished in period } p \\
0 & \text{otherwise} 
\end{cases} \)

- **Cashout** \( [a, p] = \begin{cases} 
1 & \text{if ATM } a \text{ cashes out in period } p \\
0 & \text{otherwise} 
\end{cases} \)

- **Inventory** \( [a, p] \leq \text{capacity } [a] \)
  - number of dollars in ATM \( a \) at end of period \( p \)

- Linear constraints among these variables

- Problem is hard to solve
Network-Based MILP Formulation

- For $p < q$,
  \[
  \text{Replenish } [a, p, q] = \begin{cases} 
  1 & \text{if ATM } a \text{ is replenished in periods } p \text{ and } q \text{ but not between} \\
  0 & \text{otherwise}
  \end{cases}
  \]

- Arc cost $c[a, p, q]$ could be number of cashout hours between periods $p$ and $q$, or lost demand, etc.
Network-Based MILP Formulation

- Integer network flow problem with few side constraints
- LP relaxation yields nearly integer solution (fractional in a small percentage of components)
- Typically solves at root node of branch-and-bound tree
- Solves more quickly, allows simpler modeling of objectives
- Complicated side constraints in initial formulation correspond to removal of arcs:
  - maximum number of consecutive cashout hours
  - minimum number of hours between replenishments
Optimization Results and Business Impact

<table>
<thead>
<tr>
<th>Objective</th>
<th>Baseline</th>
<th>Optimized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashout Events</td>
<td>391</td>
<td>15</td>
</tr>
<tr>
<td>Number of Replenishments</td>
<td>11,424</td>
<td>9,828</td>
</tr>
</tbody>
</table>

- 2-hr runtimes well within overnight requirements
- *Significantly increased customer satisfaction* (main goal)
- $1.4 million projected annual savings
- Similar results using historical demands
Possible Enhancements

- Account for interest rates (opportunity cost)
- Consider lost revenue from out-of-network fees
- Incorporate forecast uncertainty in optimization
- Provide truck routing (in addition to scheduling)
- Allow partial replenishments (fill to less than capacity)
- Include cash accepting machines
ATM Replenishment Optimization Demo

- Interface written in Adobe Flash/Flex
- Calls PROC OPTMODEL code as stored process
- Communication via SAS data sets and SAS macro language
1 Customer Case Study: ATM Replenishment
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3 Sample Consulting Engagements
Business Problem

- Given daily insurance claims and availability of adjusters
- Objective:
  - Increase efficiency of claim processing
  - Provide user capability to visualize current state of workload
- Optimization problem: Distribute claims evenly among adjusters while considering eligibility and capacity constraints
Mathematical Model

- **Objective**
  - Minimize workload deviation among adjusters

- **Decision**
  - *Which claims assigned to which adjuster*

- **Assignment eligibility**
  - Skill level
  - Location

- **Capacity requirements based on skill level of adjuster**
  - Limit on total weighted load
  - Limit on number of newly assigned claims
Insurance Claim Assignment Optimization

- Planning horizon: 5 months
- Claims
  - Average number of claims per day: 80
  - Type: auto, home
- Adjusters
  - Number of adjusters: 20
  - Job grade: 1,2,3
- Skills: Construction, auto body, paralegal, software, ...
- Geographical regions in Florida: North, Central, South
Insurance Claim Assignment Optimization

- Interface written in Adobe Flash/Flex
- Calls PROC OPTMODEL code as stored process
- Communication via SAS data sets and SAS macro language

Launch Insurance Claim Assignment Optimization Demo
Outline

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3. Sample Consulting Engagements
Sample Consulting Engagements

Advanced Analytics and Optimization Services
» Part of Advanced Analytics Division in R&D
» Ph.D.-level developers/consultants

Areas of Focus
» Generic Optimization
» Simulation
» Revenue Management
» Inventory Optimization
Sample Consulting Engagements: Generic Optimization

- Investment portfolio optimization
- Optimal ATM replenishment
- Optimal loan assignment
- Chemical mixture optimization
- Stochastic deal optimization
- Optimal binning for credit risk
- Student assignment optimization
- Water management
- Casino floor mix optimization
- Census simulation optimization
Sample Consulting Engagements: Simulation

- Simulation for discovery oncology
- Mortgage loan simulation
- Prison population simulation
Sample Consulting Engagements: Revenue Management (RM) and Pricing

- RM framework for car rental
- RM framework for cruise line
- Show ticket RM
- Pricing and inventory optimization
Sample Consulting Engagements: Inventory Optimization (IO)

- Retail inventory replenishment
- IO for spare parts
- IO for automotive
- IO for construction equipment
Investment Portfolio Optimization

- Customer: Large US Government Agency
- Investment portfolio optimization
  - Portfolio mix: T-Bills, T-Notes, CDs
  - Suggested investment strategy for a (e.g.) 1-month period
  - Discrete: minimum investment requirements
- MILP
- SAS tools:
  - SAS Forecast Studio
  - SAS/OR: OPTMODEL, MILP solver
- Generalized network flow formulation
Census Simulation Optimization Overview

- **Customer:** Large US Government Agency
- **Census simulation optimization for budget planning**
  - Minimize the deviation of the population change over different census categories
  - Census targets such as income, unemployment, health insurance
  - Covers the whole US population

- **LP**

- **SAS tools:**
  - SAS/OR: OPTMODEL, LP solver
Simulation for Discovery Oncology

- Customer: Large Global Pharmaceutical
- Discrete Event Simulation for Oncology Drug Discovery
  - Synthesizing and testing drug compounds is very expensive
  - Goal is to find a candidate for clinical trials:
    - Faster—reduce time to market
    - Cheaper—reduce cost of assay testing
    - More reliably—increase chance of success in trials
  - Major strategies to evaluate via simulation:
    - Which compound to synthesize next?
    - Which compounds to send to which assays?
    - When to stop testing a compound?
    - How to identify a good clinical candidate?

- SAS Simulation Studio
ATM Cash Optimization Overview

- Customer: Large South-East Asian Bank
- ATM cash replenishment optimization
  » Large number of ATMs
  » Discrete cashout constraints
  » Side constraints (budget, etc)
- MILP
- SAS tools:
  » SAS/OR: OPTMODEL, MILP solver
  » SAS Forecast Studio: demand forecasting
- Reformulated for tractability
Retail Inventory Replenishment

- Customer: Large Retail Company
- Retail Inventory Replenishment
  - Large number of SKUs, locations, and vendors
  - Demand forecast
  - Reorder point to satisfy service level
  - Order decisions
- Stochastic optimization at stores
- MILP optimization at depots
- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver
  - SAS Forecast Studio: demand forecasting
- Decomposed for tractability
Optimal Loan Assignment

- Customer: Large US Bank
- Loan Assignment Optimization
  - Goal: assign new loans (foreclosures, short sales, etc)
  - Minimize standard deviation between teams
  - Resource pool: CRMs (Customer Relationship Managers) teams and PS (Process Support) resources
  - Constraints: maximum case loads, limits on case types, etc.
  - Eligibility rules: case type match, geographical (time zone), language, etc.
- Difficult problem (MINLP):
  - Nonlinear objective (standard deviation)
  - Binary variables (assignment)
- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver
  - SAS/DI and SAS/BI for data integration and reporting
Mortgage Loan Simulation

- Customer: Large US Bank
- Mortgage Loan Simulation
- Goal: to study how loans evolve from state to state over time
  - States include current, 30-days delinquent, bankruptcy, etc.
  - At end of each simulated month, compute the number of loans in each state: used for capacity-planning purposes
- Next phase of the model will attempt to determine optimal staffing allocations to address the huge portfolio of loans
- Large-scale model: Simulation Studio resource entity feature is key to making the model efficient
- SAS tools:
  - SAS/OR: SAS Simulation Studio
Mixture Optimization

- Customer: Large US CPG Company
- Optimization of raw material portfolio for manufacturing
  - Minimum cost portfolio problem
  - Nonlinear performance constraints
  - Discrete: assignment constraints

- MINLP

- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver, NLP solver
  - JMP
  - (Future) SAS/Grid Manager: parallel computations

- Completely custom algorithm
Revenue Management for Car Rental

- Customer: Large US Car Rental Company
- Business Analytics Framework development
- Optimizing for growth (market share)
- Automate RM process
- Pricing and reservation system
  - Data integration
  - Segmentation
  - Forecasting: unconstrained demand by segment
  - Optimization: automatic generation of step recommendations
- RMPO with extensions
Show Ticket Revenue Management

- Customer: Large US Resort
- Occupancy forecast
- Show ticket price/availability optimization
- Demand Channel Management
- SAS tools:
  - RMPO with extensions
  - SAS/OR: OPTMODEL, QP solver
Revenue Management for Cruise Line

- Customer: Large US Entertainment Company
- Business Analytics Framework development
- Automate pricing and availability management process
- Account for multiple constraints
- Pricing and revenue management system
  - Data integration
  - Segmentation
  - Forecasting: unconstrained demand by segment
  - Estimation: demand response to changes in pricing strategy
  - Optimization: automatic generation of pricing and availability recommendations

- RMPO with extensions
Stochastic Deal Optimization Overview

- Customer: Large US Airplane Engine Manufacturer
- Pricing service contracts of engines ($50B portfolio)
  - Find minimum yearly price stream to achieve financial metrics
  - Specify price intervals and bounds and maximum number of price changes
  - Replaces current business rule process
- MILP
- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver
  - Embedded in SAS/FM application
  - Potential for Monte-Carlo simulations from SAS/ETS
- Completely custom (replacing homegrown Excel spreadsheets)
Pricing and Inventory Optimization

- Customer: Large US Retailer
- Product promotion optimization
  - Retail pricing and inventory network
  - Non-convex NLP
  - Discrete side constraints
- Multi-objective NLP
- SAS tools:
  - SAS/OR: OPTMODEL, NLP and MILP solvers
- Customized heuristics
Optimal Binning for Credit Scoring

- Customer: Enterprise Miner (SAS Internal)
- Rigorous binning with constraints
  - Monotonicity constraints
  - Nonlinear measures of risk
  - Discrete binning requirements
- MINLP
- SAS tools
  - SAS/OR: OPTMODEL, MILP solver, OPTNET
  - SAS Enterprise Miner
- Reformulation or DP heuristic
Student Assignment Optimization

- Customer: Wake County Public Schools
- Yearly assignment of Elementary, Middle, and High School students to schools
  - > 100,000 students, 159 schools
  - Optimize: 3-year assignment planning period
  - Minimize overcrowding, travel distance, demographic imbalances, reassignments
  - Required “what-if” analysis capability

- MINLP

- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver
  - SAS Grid Manager
  - JMP

- Completely custom solution
Spare Parts Inventory Optimization

- Customer: Injection Molding Systems
- Inventory Replenishment
  - Large number of SKUs
  - Three Warehouses in America, Europe, and Asia
  - Demand forecast
  - Reorder point to satisfy service level
  - Order decisions
- Stochastic optimization at warehouses
- Inventory balancing across warehouses
- SAS tools:
  - PROC MIRP
  - SAS Forecast Studio: demand forecasting
- Decomposed for tractability
Manufacturing Inventory Planning

- Customer: Large Automaker

- Manufacturing Inventory Planning
  - Large supply chain networks with plants, warehouses, and dealers
  - Close to one thousand packages (cars with options)
  - More than ten thousand service parts
  - A few hundred outsourcing parts for manufacturing
  - Inventory decisions for finished goods, service parts, and manufacturing parts

- SAS tools:
  - SAS Inventory Replenishment Planning
  - SAS/OR: OPTMODEL, MILP solver
  - SAS Forecast Server: demand forecasting
Manufacturing Inventory Planning

- Customer: Large Construction Equipment Manufacturer
- Manufacturing Inventory Planning
  - Supply chain networks with plants, and warehouses
  - Dozens of product lines
  - Hundreds of critical components
  - Long order-to-delivery (OTD) time
  - Inventory decisions for components to meet OTD constraints

- SAS tools:
  - SAS Inventory Replenishment Planning
Customer: State Legislative Agency

Prison Planning and Scenario Analysis
- Mandated projections to plan for prison capacity
- Numbers highly dependent on legislative policy
- Must consider current population and future entries
- Need to account for revocations

SAS tools:
- SAS/OR: Simulation Studio
Water Management

- **Customer**: National Utilities Agency
- **Water flow scheduling and routing**
  - Demand forecast for public water
  - Network of reservoirs and pumping stations
  - Business rules for reserve capacity and flow
  - Multi-objective problem
- **SAS tools**:
  - SAS/OR: OPTMODEL, MILP solver
  - SAS Forecast Server
Casino Floor Mix Optimization

- Customer: Canadian Casino
- Slot Machine Floor Mix Optimization
  - Machine categorization
  - Forecasting Revenue and Utilization
  - Optimizing Revenue to determine slot machine mix on the floor (hard and soft constraints)

- MILP
- SAS tools:
  - SAS/OR: OPTMODEL, MILP solver
  - SAS Forecast Studio
  - SAS Enterprise Miner