HVAC Sales Forecasting

Metin Çakanyıldırım

Melek C. Aksoy, Andrew J. Royal, Anthony Dsouza, John Beckett, Divakar Rajamani
Typical HVAC Products

- Important products:
  - Furnace (FR) → Air Conditioner (AC); Coil Blower (CB) → Heat Pumps (HP)
  - Less important products: Evaporator Coils, Single Package Units
A Typical HVAC Manufacturer named HC-Man

- Make-to-stock process
- Sells directly to the dealers with limited contact with builders
- SC network has about 5-10 regions
  - each with a central warehouse
  - distance from a central warehouse to its dealers usually 1 day
  - aims a SC Network redesign-improvement
- Required level of responsiveness at the manufacturing level
  - 5 days for mix adjustment among the product types (see next page)
  - 4 weeks for volume adjustment
  - workforce is the bottleneck at HC-Man
- Subject to low Brand loyalty
  - Consumers do not know the brand of their ACs.
  - High degree of brand switching to be expected
Air Conditioners at HC-Man

- **Types:**
  - XC21 – highest cost
  - XC16
  - XC15
  - AC13
  - XC13
  - 13ACX
  - 13ACD – the most sold model

- **Sizes (in tons):**
  - 1.5
  - 2
  - 2.5
  - 3
  - 3.5
  - 4
  - 5

A SKU is Type x Size.
Customer Types

- **Replacement**, 60% of the revenue dropping
  - Impromptu customers
  - More difficult to forecast

- **RNC**, 40% of the revenue increasing
  - Consist of builders
    - Rates negotiated with builders; actual demand dictated by dealer network
  - Penalty for being wrong is very high
  - Our current focus is the RNC segment

- Goodman Global reports 70% replacement and 30% RNC in 2006.
Demand Seasonality for RNC + Replacement

Cooling picks up from May through July; It drops in August when heating increase

Sept to Dec – high heating months
Residential New Customer (RNC)

- Schedule of furnace/AC installation known.
  - But not provided by the builders
  - 98% of the sales orders are from customers who expect same day delivery. But the problem is that there are dealers between HC-Man and the end customers. Sometimes HC-Man cannot supply the requested products
  - Builders provide none of the following: Starting date, progress, estimated completion date, phases of a housing project, the sizes of the houses.

```
New House Timeline

Ground breaking 1 month 3-4 months 1 month
Sale

Furnace
From the same company
A/C
```

From the same company
Dealers Stock Inventory

**Push**

- Plant
- North American Distributor

**Pull**

- Regional Distributor
- Warehouse
- Dealer (Hold new home inventory)
- Dealer (Hold no inventory)
- Dealer (Hold both types of inventory)
- Builder
- Residential New Customer
- Replacement Customer

30% of dealers stock
Dealer’s Behavior

- If a dealer sells more, it can become a preferred dealer. Preferred dealers buy products from HC-Man at a low price (computed by dealer specific multipliers).
- To become a preferred dealer for a certain manufacturer, dealers may push the products of that manufacturer.
- Some dealers have warranty/maintenance contracts with the consumers, so they prefer to sell/install durable products to minimize after-the-sale service.
Purchasing Behavior of Builders

- Builders are offered a menu of manufacturer rebates at the time of starting their projects. (0301)
- The menu specifies the quantities at which the builder becomes eligible for certain discount price. (0301)
- Builders make no quantity commitments to this menu. However, they specify the type of the AC to be used in their project. (0301)
- Builders stage their orders. (0201)
  - They allow for 1 day of delivery time after they request the delivery of the type of products specified earlier-right after the announcement of the manufacturer rebate. (0222)
- The competition among HVAC manufacturers happens mostly when the builders place their actual orders. (0301)
  - Since the builders do not specify their purchase quantity at the time the manufacturer rebate is announced, there is little competition then.
- At the end of a project, a builder reports the number of ACs purchased and asks for the rebate check.
- It is extremely unlikely for a builder to use different brands of heaters and coolers in the same residential project.
Some Facts

- Regulatory issues by region
- Utility rebates are an important factor for demand
- Rates are market driven
- Heat wave is a factor for the replacement demand
- Seasonality is an important factor for demand
  - Demand during peak season is greater than capacity: Capacity smoothing, Seasonal Inventory
- HC-Man is guessing a lag effect between sales and macroeconomics factors up to three to four months
- The average life of an air conditioner is around 10 to 15 years and a furnace is up to 20 years.
A Forecasting Tool

- **A forecast for Sales to Dealers**
  1. Air Conditioners
  2. Heat Pumps
  3. Furnace
  4. Coil Blower

- **Significant indicators of the demand**
  - Indicators can be products themselves:
    - e.g., Furnace $\rightarrow$ AC
  - But there are many other indicators, more on this later

- **Improve forecast accuracy**
  - More proactive planning as opposed to revising the targets based on sales and inventory
Inputs

- Sales
- Housing Starts
- Building Permits
- Temperatures
- Average Sales Price
Input: Sales Data

- Sales to Dealers for months over Jan01-Feb07
  - Months are columns
- Sales are by
  - District
    - U453 for Dallas
  - Product Hierarchy
    - C1C12A4T7J and C1C12A4T7Y
    - Both belong to Hierarchy Description HP29 3PH, which is an Air Conditioner
- Rows are indexed by (District) X (Product Hierarchy)
  - 30080 Rows
Aggregating Sales Data

- By location:
  - Aggregate Districts into Regions, Call them RDNs
    - Florida', 'Great Lakes', 'North Central', 'Northeast', 'South Central', 'Southwest', 'Eastern Canada', 'Western Canada'

- By product grouping:
  - Aggregate Product Hierarchies into
    - AC: Air Conditioners, FR: Furnaces
    - HP: Heat Pumps, CB: Coil Blowers
CB and HP Sales
Input: Publicly Available Housing Starts

- By Regions
  - Northeast, Midwest, South, West
- By Months

Issues:
- These regions are larger than desired.
  - South covers several RDNs Florida, South Central, Southwest
- Housing starts themselves are estimates.
- The time from housing start until purchasing Furnace and Air Conditioner varies.
Input: Available Building Permit Data

- By RDNs
  - 'Florida', 'Great Lakes', 'North Central', 'Northeast', 'South Central', 'Southwest', 'Eastern Canada', 'Western Canada'
- By Months

Issue: There is a significant lag between building permit issuance and the housing start. This lag becomes longer when housing market slows down.
Input: Temperatures

- By Cities
  - Toronto, Orlando, Detroit, Chicago, New York, Dallas, Los Angeles, Calgary

- By Day

- Issue: Multiple cities in a single region.
  - Toronto and Montreal are both in Eastern Canada, which city to use?
Input: Average Sales Price

- By Product
  - AC, FR, HP, CB

- By Cities
  - Toronto, Orlando, Detroit, Chicago, New York, Dallas, Los Angeles, Calgary, many more

- By Month

- Issue: Prices are very variable.
  - They change with the product mix.
AC Prices in Dallas
Over Jan 01 – May 07
AC Prices in Orlando
Over Jan 01 – May 07

Graph showing data points with x-axis labeled 'Index' and y-axis labeled 'ac.avesellprice[2]'. The data points range from around 400 to 1600.
Forecasting: Preprocessing

- Preprocessing:
  - Additive and Multiplicative models (log-based)
  - Compute heating and cooling degree days
    - CDD(month) = Average \( \max\{0, \text{temp(day)} - 65\} \) over days
    - HDD(month) = Average \( \max\{0, 65 - \text{temp(day)}\} \) over days
Forecasting: Models

- From simple to complex
  - Trend and Seasonality
  - Add terms to capture correlation between AC - FR.
  - Add Cooling Degree Days.
  - Add Housing Starts.
  - Add unemployment in Michigan to explain sales.
  - Replace Housing Starts with Building Permits.
  - Add Average Selling Price

- Show the results in *Summary.xls*
Forecasting: Suggestions

- Primary Factors
  - Seasonality
  - Trend

- Secondary Factors
  - Correlation between products
  - Cooling degree days
  - Housing starts

- Tertiary Factors
  - Average sales prices

- 3 levels of factors call for 3 models
Forecasting: Software

- 3 Forecasting Models are in Predictions3.R
- Show the code *Predictions3.R*
- Run to obtain the predictions for the coming months for 3 models
- The code runs in (Open Source) R environment
- Because of the difficulty of importing/exporting data in/out of SAP, we did not attempt to use SAP modules. Moreover, SAP is unlikely to have forecasting modules that can deal with the very specifics of the forecasting requirements.
- Because of our limited knowledge about Excel, we did not attempt to use Excel. Moreover, Excel is not a statistics software and hence is unlikely to have the vector regression capability exploited in Predictions.R.
Software Architecture

HC-Man
- sales_phd.csv
- product_phd.csv
- RDN.csv
- AvePriceData.xls
- InputPrices.xls

Intermediate Files
- sales_csv
- AvePriceData.xls
- InputPrices.xls

Census Bureau
- Housing.csv

Temperature Archive
- sccccccc.txt

Memory
- chddcalculator.r
- tcccccc.avecdd

Output File
- forecaster.r
- predictionfromR.csv
Forecasting: Comparison with Existing

- Out of 24 accuracy measures in Summary.xls existing method beats us slightly 3 times
  - 1 month-out for AC in last 3 years and last year.
  - 1 month-out for Coil Blower in last 3 years
- We are confident with 10-15% forecast accuracy of our models.
- Inaccuracy in input data hinders our efforts to increase the accuracy.
- We believe that there still is some institutional knowledge/expertise that we have not captured.
Benefits of Our Method

- No requirement of institutional expertise/knowledge
- Streamlined
- Objective

- Provides distribution of the future sales rather than just a forecast
  - This is important when weighing in whether to produce exactly at the forecast, or slightly more, or much more.
  - The likelihood of slightly more sales versus much more sales than forecast can be obtained.
Uncertainty of Sales via Distributions

- **Furnaces**
  - Density
  - $N = 29$, Bandwidth = 0.04103

- **Air Conditioners**
  - Density
  - $N = 29$, Bandwidth = 0.07131

- **Coll Blowers**
  - Density
  - $N = 29$, Bandwidth = 0.05675

- **Heat Pumps**
  - Density
  - $N = 29$, Bandwidth = 0.0518
Near Future

- We shall update the input data files to make forecasts from the end of August 2007
Recommendations

- Gather data separately for RNC and Replacement market
  - Identify the idiosyncrasies of RNC and Replacement
    - Hypothesis: RNC driven by Housing starts
    - Hypothesis: Replacement driven by Heat wave
- More accurate input data helps
  - But comes at a cost
- Personal opinion: 10-15% accuracy is good. Next issue is to optimally plan