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Demand Forecasting Automation

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Problem Statement

Understanding the business need

"We have no way of managing the backorder process or the purchasing of parts. We have stock for some parts that will cover two years worth of demand and we are still getting back orders."

Stocking the incorrect parts

"Our distribution centers are at capacity we need more warehousing space to service our customers."

Wrong idea what the problem is

"It's always a knee-jerk reaction to fulfill our customer's orders. Buyers are always too busy putting out fires. They can't manage vendors or pipeline."

Closer to the 'real' problem

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Problem Statement

Framing as an analytical problem

The client want to ***maximize*** the ***fulfillment*** of their customers demand whilst ***optimizing*** the ***cost*** of holding the relevant inventory in their part distribution centers. This speaks to maintaining correct amount of inventory whilst minimizing the following situations:

- Holding cost, when inventory exceeds demand
- Opportunity Cost, when there is not enough inventory to meet demand, there is cost associated with lost revenue if the order gets cancelled
- Back Order Cost, the additional cost incurred for the fulfillment of a back order.

The big idea is to improve ***sustainable growth*** rate by reducing and controlling operating capital.

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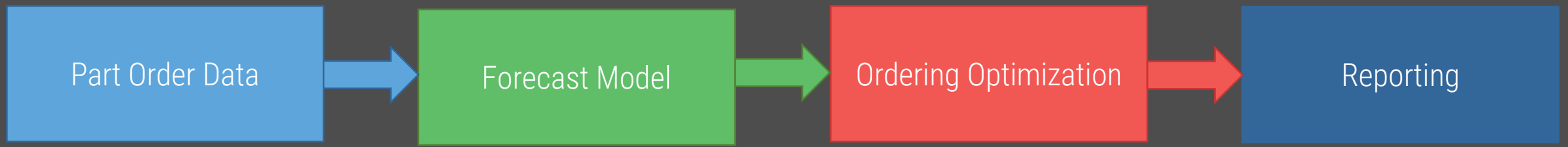
High-level approach



- Supersessions
- Cancelled Orders
- Customer Preferred PDC
- Customer Shipping address PDC

- Seasonality
- Trend Effect
- Confidence Intervals

- Holding cost
- Back Order Cost
- Interest Rate
- Simulations
- Varying Order Cycles
- Pipeline Management

- Dashboard
  Filter/Slice by:
  Buyer
  Supplier
  Part
  PDC
- Detailed Summary Information
- Accuracy Measurement

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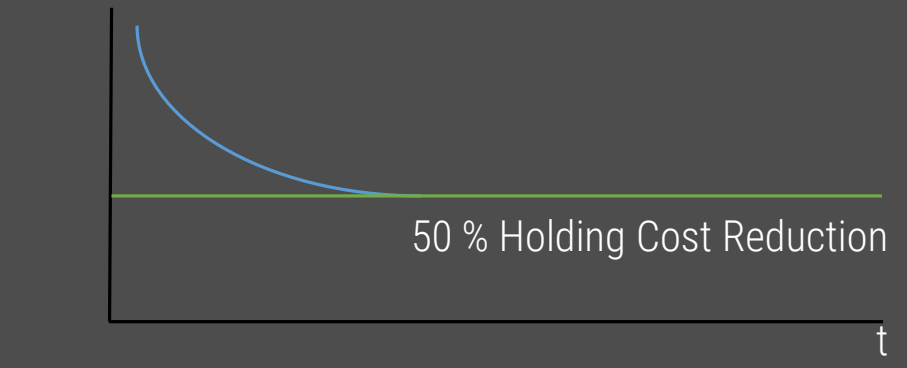
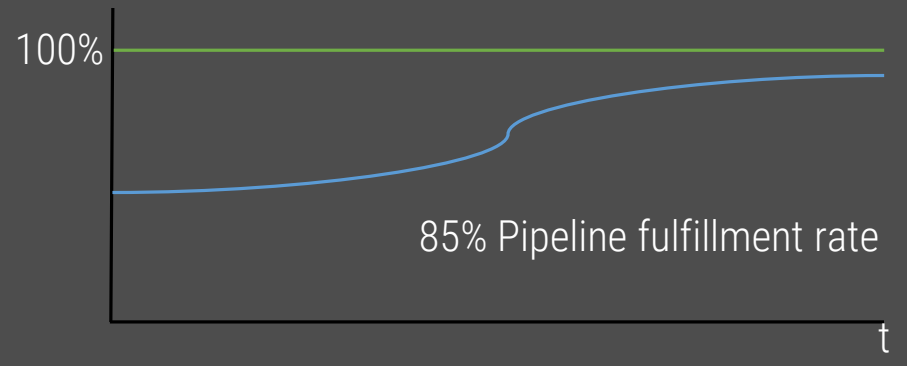
Model Performance Testing

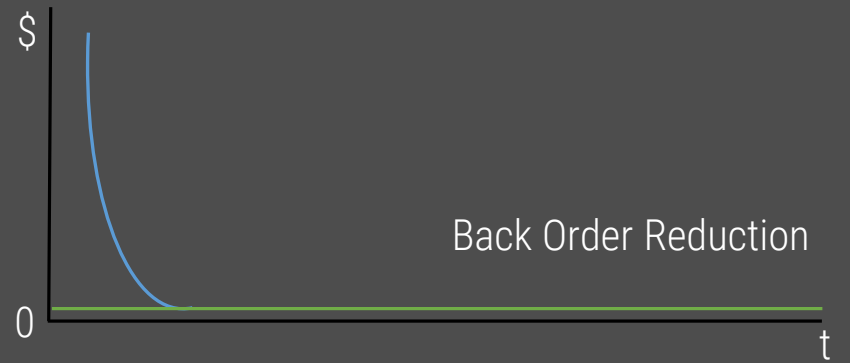
Top 10 Analysis

Part	Actual (2016)		Demand Forecasting (2016)	
	Times in Back Order	Back Order Quantity	Times in Back Order	Back Order Quantity
Part1-001	67	110	0	0
Part2	87	167	0	0
Part3-001	28	49	0	0
Part4-001	16	17	2	17
Part5-001	163	468	0	0
Part6-2	93	111	0	0
Part7-001	35	44	0	0
Part8-001	78	149	0	0
Part9-001	110	139	0	0
Part10-001	88	208	0	0
Total	**765**	**1462**	**2**	**17**

* excl. Direct & Drop Ship







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Forecast Approaches

Historical Demand Safety Stock Legacy Inventory	Seasonality Time Series Trend Effect Seasonal Effect Gaussian Error	No Demand Safety Stock Risk Likelihood of failure Qty. Utilized in production
New Demand Probabilistic Model 95% Confidence Level	Erratic Demand Replenish Stock Max Demand During Lead Time	Random Demand Probabilistic Model 95% Confidence Level

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DevOps and Coding Standards

For each distribution center process in parallel

1. Load libraries, source code, initialize custom functions, set parameters:

```
source("config/Config.Libaries.R")
source("config/Config.Parameters.R")
source("config/Config.PartConfig.R")
source("services/Services.ModelBuild.R")
source("services/Services.InventoryThreshold.R")
source("services/Services.SuggestedOrders.R")
…

LoadLibraries()
SetParameters()
LoadPartDetail()
```

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Data Import and Structure

2. Import inventory, sales and part metadata from shared data hub.
3. Clean and structure data, determine seasonality

```
dbcon2 <<- odbcConnect('SDHProd', uid='<username>', pwd='*****')

PartDetails <<- sqlQuery(dbcon2, paste(readLines("./scripts/MDSPartConfiguration.sql"),
collapse = " "))

partdemand = ts(Orders,
       frequency=12,
       start = c(year(StartDate), month(StartDate)),
       end = c(year(EndDate), month(EndDate)))

#Determine significant seasonal pattern
is.null(tbats(partdemand)$seasonal.periods)
```

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Model Selection

Using either an Exponential Smoothing, Seasonal Models, Naïve methods, Auto Forecast features, Averages and Linear equations

4. Apply business rules to determine which models to fit
5. Apply models and calculate mean absolute scaled error
6. Forecast 12 month order demand from model
7. Calculate 24 month trend

$$MASE = n^{-1} \sum \frac{|yt - ft|}{q}$$

```
#Cost function Scaled difference between fitted and actual
residual[i] = sum(((data.frame(forecastlist[[i]][[2]]$fitted)
                - data.frame(partdemand))^2) / q)

linear = tslm(latest_demand ~ 1 + trend)
```

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Inventory Control and Management

Determine KPI levels for buyer management and inventory control

8. Calculate Lower Control limits, Target and Upper control limits based off lead time

```
#LCL = Lower Control Level(Business Safety Level)
#Target = Demand During Lead Time (CDLT)
#UCL = Upper Control Level(Demand during lead time and order cycle)

LCL = pmax(0, SafetyStock)
Target = if(model != 'Safety'){
                sum(forecasted$PointForecast[i:(i+LT),])
          } else {
                rollapply(partdemand, LT, sum))
          }
UCL = sum(forecasted$PointForecast[i:(i+LT+OC),])
```

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Automated Ordering

Pipeline & Warehouse management

9. Calculate suggested ordering for the forecast

```
#Code simplified due to limitations

OrderQty = Target[LT]
           + sum(Demand[1:LT])
           - OpenOrders
           - EndingInventory
```

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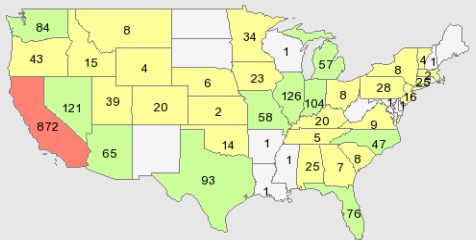
Reporting
Actionable Insights

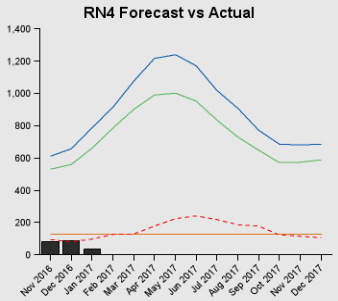
Demand Forecast Detail
Feb 2, 2017

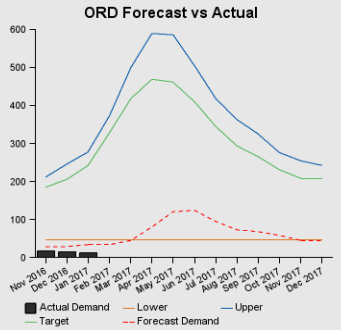
Overall	RN4	ORD	MDT	RN4	ORD	MDT	ERROR RATE
QOH: 1,272 QOO: 1,233 Target: 1,495 DELTA: 1,010	QOH: 478 QOO: 1,048 Target: 900 DELTA: 626	QOH: 466 QOO: 185 Target: 418 DELTA: 233	QOH: 328 QOO: 0 Target: 177 DELTA: 336	↗	↗	↗	31%

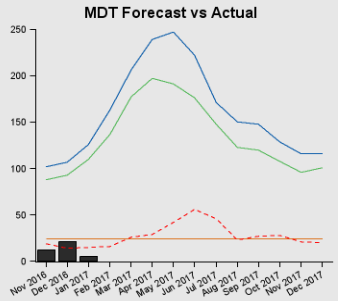
QOH less than lower limit | QOH between lower limit & target | QOH between target and upper limit | QOH greater than upper limit

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	35	79	91	161	305	216	220	116	150	98	51	67
2014	79	60	85	220	314	281	238	156	237	72	89	43
2015	63	102	138	240	369	379	224	223	139	127	69	44
2016	62	161	187	260	372	390	350	218	174	108	112	124
2017	52											
Average	58	100	125	220	340	316	258	178	175	101	80	70









Buyer	Vendor	PartNumber	Part Description	Code	Model	Trend	Month	Month Forecast	Lower	Target	Upper	Quantity Available	Quantity Open Orders	Delta	Category	MOQ	Total Lead Time	Suggested Order	Total Free Stock
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	2
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	1	0	1	Blue	6	119	0	2
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	0	0	1	0	1	Blue	6	119	0	2
MK	ETI			MDT	Seasonal	Stable	Feb 2017	2	0	7	9	4	10	7	Yellow	6	119	0	6
MK	ETI			ORD	Safety	Stable	Feb 2017	0	2	7	9	9	0	2	Green	6	119	0	6
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	2	2	6	0	4	Blue	6	119	0	6
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	0	119	0	5
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	5	0	5	Blue	0	119	0	5
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	0	119	0	5
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			RN4	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			MDT	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0
MK	ETI			ORD	Safety	Stable	Feb 2017	0	0	0	0	0	0	0	Green	6	119	0	0

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