Demand Variability Pooling and Risk Pooling Factor
Executive Summary

Business Scenario
• Often time a single stocking node will supply multiple downstream customer facing nodes. Holding a single inventory allow for risk pooling of the variability of the demand and reduce the total inventory.

Recommendation
• EIS calculates reduced safety stock requirements while considering risk pooling.
Agenda

Demand variability pooling concept

Simple static demand example

Customer example

Advanced considerations

Correlated Demand Streams – Risk Pooling Factor
Demand Variability Pooling

Demand uncertainty is propagated upstream from each stocking node starting at CF nodes

- Expected order quantity (MRP logic)
- Demand standard deviation (EIS demand propagation)

Demand variability pooling occurs when a stocking point replenishes multiple demand streams downstream

- Demand variability from each demand stream is assumed to be independent with no correlation
- Net demand variance* is not the sum of the individual demand variances
- As individual demand is aggregated, it becomes more likely that high demand from one stream will be offset by low demand from another
- Typically, the higher the CV of the individual demands, the greater is the benefit from variability pooling

* Variance is the square of standard deviation
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Static Demand Example

EIS demand propagation logic

Demand variability pooling logic

Expected order @ DC = 100 + 100 + 100 = 300
Demand variance @ DC = 50^2 + 50^2 + 50^2 = 7500
Demand stdev @ DC = sqrt(7500) = 87
Demand CV @ DC = 87/300 = 0.29

Net demand

Customer demand

Propagated demand

Net demand
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Correlated Demand Streams – Risk Pooling Factor
Real Life Customer Example

1. Forecast mean is based on MRP logic (LT, Q, net requirements, etc)
2. Demand Std Dev for IN is based on EIS propagation
3. Average CV is ratio of avg. std dev and avg. forecast over horizon
Forecast Demand Mean at IN

Due to batch sizes, net replenishment quantities may be 0 in certain time periods for each demand stream (batch size can cover multiple periods)

Demand mean at IN on 10/4 is 2,772 due to two batch sizes of 1,386 requested by CF3 for 10/18 and no replenishment to CF1, CF2

Demand mean at IN on 10/11 is 0 due to no replenishment requests

Demand mean at IN on 10/18 is 57 due to one batch size of 57 requested by CF1 for 10/25 and no replenishment to CF2, CF3

Demand mean at IN on 10/25 is 198 due to one batch size of 198 requested by CF2 for 11/15 and no replenishment to CF1, CF3
Forecast Demand Mean at IN

Demand standard deviation values at IN in periods 10/4 – 10/25 will be explained in advanced considerations section (later in the presentation)

The advanced consideration in these periods is that exposure demand (forward looking) is decreasing at CF3

Since all PBR=1, demand standard deviation at IN on 11/1 (and 11/8) is based on demand standard deviation at downstream nodes 1 week prior, i.e. 10/25 (and 11/1)

In these two periods, downstream exposure demand is increasing

On 11/1 at IN, demand stdev = sqrt(11^2 + 22.5^2 + 142^2) = 144

On 11/8 at IN, demand stdev = sqrt(11^2 + 22.5^2 + 178^2) = 179

On both these dates, the demand stdev is much smaller than the sum of the individuation stdevs. (176 and 211, respectively) due to variability pooling benefit
Average Forecast CV in Static Output Report is Informational Only

Avg. forecast CV at CF nodes is calculated by Demand Intelligence Module
At CF1, CV = 6.7/8.8 = 0.77; At CF2, CV = 18/25 = 0.72; At CF3, CV = 1375.6/1160 = 1.19

Avg. forecast CV at internal nodes is calculated by MIPO as a ratio of average standard deviation to average forecast
Demand mean is based on MRP logic, while demand standard deviation is based on EIS demand uncertainty propagation logic
When demand is time-varying, calculating CV in every period and then taking an average is statistically incorrect

Avg. Forecast at IN = 756.75, Avg. Stdev at IN = 666, Avg CV = 0.88 (over 4 weeks)
Note: The static output report provides these values over entire data horizon
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Exposure Demand is Decreasing

As mentioned earlier, exposure demand (forward looking) at CF3 is decreasing in periods 10/4 – 10/18 relative to the previous period.

The intuition that the demand variance at IN is the sum of the variances of the three downstream demand variances is true under independence assumption and if the exposure demand in the following period is not decreasing.

If the exposure demand in the following period is decreasing, then this further reduces the demand variance from that downstream node.

This advanced concept is utilized by EIS algorithms and results in more accurate inventory targets.

The explanation is in EIS advanced training material on demand propagation logic.

Demand stdev. at IN on 10/11 is 898 which is less than \(\sqrt{7^2 + 18^2 + 1376^2} = 1376\).
• Consider a stocking node that replenished external and dependent demand with differentiated service levels
• Internally, the algorithms assign the demand streams to service classes based on the target service levels
• Variability pooling effect is observed across demand streams in the same class
• Under DIVIDE inventory allocation policy, there is no variability pooling between the service classes
• Under PRIORITY inventory allocation policy, there is some variability pooling (but not complete as in FCFS) between the service classes
• This topic is considered in further detail in EIS training material on service level differentiated demand streams
• For reporting purposes, the completely pooled variability across classes is reported as the stocking node output
Agenda

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Correlated Demand Streams – Risk Pooling Factor
Correlated Demand Streams – Risk Pooling Factor

Default assumption is that demand streams are independent, this is not always the case.

Risk Pooling Factor

Used to make an adjustment to demand standard deviations (by multiplying the demand standard deviation with the pooling factor) to accommodate the correlation of demand across downstream stocking points.

Recall Single Stage SS calculations formula…

Safety Stock = \( z \times \sigma \times \sqrt{LT + PBR} \)

Safety Stock = \( z \times \sigma \times RPF \times \sqrt{LT + PBR} \)

This basic formula adjustment illustrates the impact of a RPF but in a multi-stage optimization this formula is in-exact as there are multiple sources of variation.
Risk Pooling Factor (RPF) can be used at any Stocking Node in MIPO or at the model level in DIM.

The risk pooling factor can take any value $\geq 0$.

- Using $<1$ reduces the impact of demand standard deviation. (Negative correlation)
- Using $=1$ does not have any impact. (default setting – no correlation)
- Using $>1$ increases the impact of demand standard deviation. (Positive correlation)

RPF $>1$ should be set on CF node in this example.

Cookie demand at Walmart is typically high at the same time as groceries.
MIPO (Risk) Pooling Factor – Upstream Example

Upstream nodes can also accept risk pooling factors if separate demand streams share upstream input materials.

Cookie demand on 3 pack cookies typically decreases when consumers buy more than average 6 pack cookies.

RPF < 1 should be set on IN node in this example.
DIM Risk Pooling Factor

Within DIM there is an opportunity for lost variation due to forecast transformation. Risk pooling factor can help fix the aggregation impact.

April CV = 0

April CV > 0

To account for this, we may insert a RPF in DIM settings to account for weekly variability not considered in monthly forecasts.

Mathematically, \( \text{RPF} = \sqrt{\text{weeks in month}} \). Approximation is \( \sqrt{4} = 2 \). More precise value is \( \sqrt{\frac{365}{12}/7} = 2.085 \)
Impact of Batch Size on Risk Pooling Factor

The Risk Pooling Factor, also known as the Correlation Factor (the MIPO stocking point static input "Pooling Factor") is used to adjust the demand standard deviation used in calculating safety stock.

The definition from the 6.7.2 MIPO User's Guide: "A heuristic adjustment made to the safety stock computation based on the perceived correlation of demand across customer-facing nodes."

When you introduce batch size, the relationship between risk pooling factor and safety stock is not linear.

When the batch size is greater than zero, an increase impacts cycle stock so the safety stock requirements do not double.

The risk pooling factor affects the demand variability in the calculation of safety stock.
Impact of Minimum Batch sizes and Risk Pooling Factors

Note four combinations of 0 and 200 batch sizes with RPF’s of 1 and 2
Impact of Batch Size and Risk Pooling Factor on Safety Stock

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Batch Size | RPF
---|---
Item 1 | 0 | 1
Item 2 | 0 | 2
Item 3 | 200 | 1
Item 4 | 200 | 2

Customer service is measured using non-stockout probability
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