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And Productivity

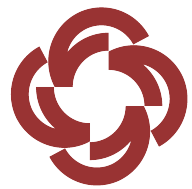
30 Years of Engineering the Real World

Master Production Schedule Stability Under Conditions of Finite Capacity

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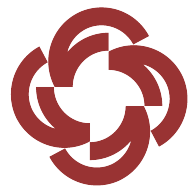
INFORMATION

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WHAT I WILL DISCUSS TODAY

I. Bias adjusted safety stock

II. Master production scheduling

- MODS (Modified Dixon Silver Heuristic)

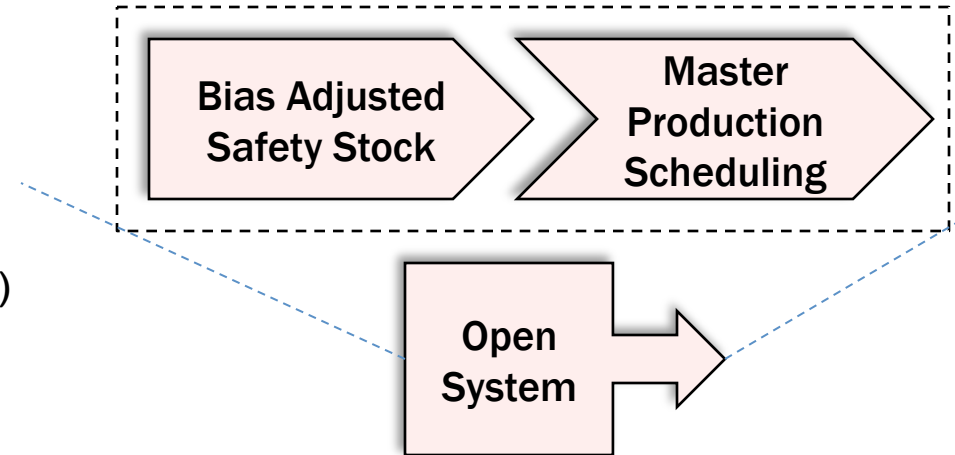
III. Open system

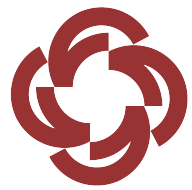
- Way of layering and delivering models using Internet

IV. Simulation

- Performance measure - Stability

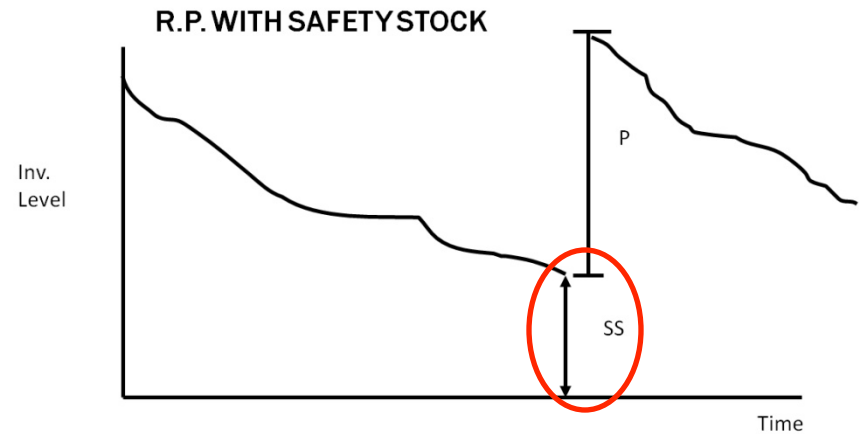
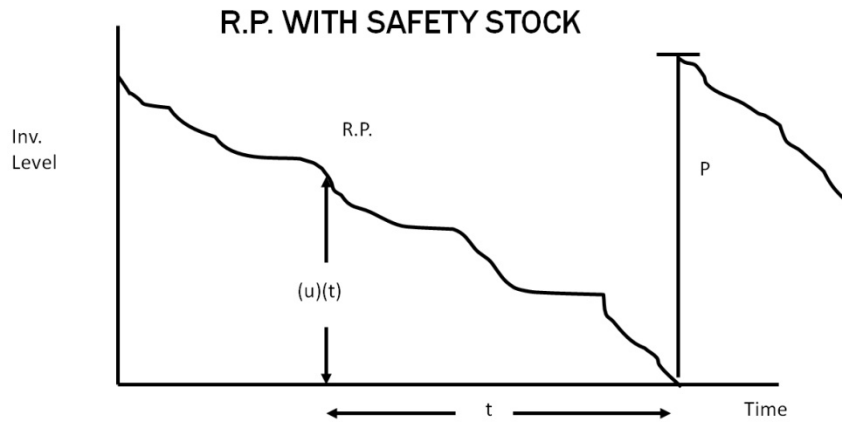
V. Conclusion





SAFETY STOCK

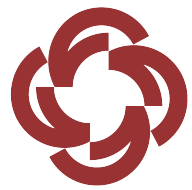
Why would you ever need to carry safety stock?



- Are backorders acceptable to you?

- JIT(Just-In-Time) production vs. make-to-stock type production





MASTER PRODUCTION SCHEDULING

Forecasts of Demand

Aggregate Plan

Master Production Schedule
Schedule of Production Quantities by production and time period

Materials Requirements Planning System
Explore master production schedule to obtain requirements for components

Detailed Job Shop Schedule
To meet specification of production quantities from the MRP system





(OPEN SYSTEM) MASTER PRODUCTION SCHEDULING

- **Master Scheduling Model along with Open Systems**

- Open source versus open systems
- Powerful trend in the computer industry: Salesforce.com, Netsuite

- **M Language (since 2003) and other web standards**

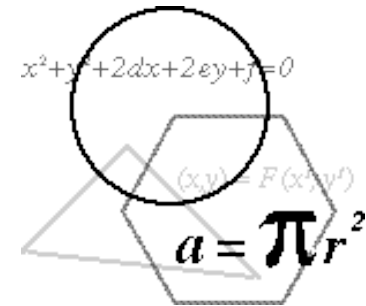
- Semantic connections for models and data via the Internet
- <http://mlanguage.mit.edu>

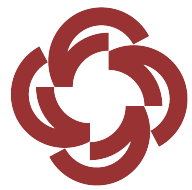
- **Software as a Service**

- Access a sophisticated scheduling model on a remote server using an Excel spreadsheet interface that can reside on any microcomputer with Internet link
- Match a specific model to a specific problem
- Create a world-wide standard for a specific MPS problem
- Provide a way of “layering” models

- **No implementation of model on local system, access is immediate**

- No storage of data on the server





ARCHETYPAL MPS

- Do not integrate statistical safety stock planning into algorithms or heuristics
- Make no provision for type 1 or type 2 customer service levels (ability to meet demand Vs total percentage of cases shipped)
- Do not account for forecast bias
- Assume independent demand is “deterministic”
- **Accept forecast at face value**
- Can not find optimal solutions for sequencing and lot sizing problems under situations with dynamic safety stock





CLASSIC STATISTICAL THEORY AS APPLIED TO SAFETY STOCK

- Typically, the amount of safety stock is incorporated in replenishment planning process as a fixed reserved quantity, which would be:

$$\text{Safety Stock} = k(MAD)\sqrt{LT}^*$$

where

k = multiplier based on desired service level

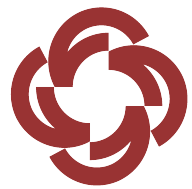
MAD = Mean Absolute Deviation between forecast and actual demand

LT = lead time

- **Major Flaw**
 - It is not appropriate in “lumpy demand” situation OR where “forecast bias” is likely to occur all the time
 - Kakorous et al., 2002, Measure, then manage, APICS – The Performance Advantage, 12(10)

* Krupp, 1997, Safety Stock Management, Prod. Inv. Mgt. 38(3)





BIASED ADJUSTED SAFETY STOCK MODEL ENHANCED FROM KRUPP(1997)

- A mechanism to apply the safety stock to future demand in a dynamic manner based on forecast bias

$$\text{Adjusted Safety Stock}_n = k(1 - FETS_n)(TICF_n)(LT)u_n$$

where

k = multiplier based on desired service level

u_n = future forecasted demand per week

$TICF$ = Time Increment Contingency Factor, a measure of variability applied to the real forecast u_n

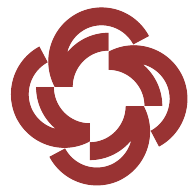
$$TICF_n = \sum_{i=1}^n |1 - x_i/u_i|/n \quad (\%)$$

$FETS$ = Forecast Error Tracking Signal, a measure of forecast bias

$$FETS_n = \frac{\sum_{i=1}^n (1 - x_i/u_i)/n}{TICF_n}$$

LT = lead time



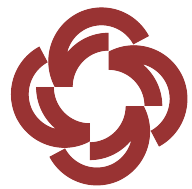


SOLUTION METHODS FOR MPS

Attribute	Math Prog.	Simulation	Heuristic
Hold Time		X	X
Queue Time		X	X
Customer Service		X	
Forecast Bias		X	
Set-up Cost	X		X
Holding Cost	X		X
Overtime Cost	X		X
Capacity	X		X
Production Lot-Size	X		X
Production Sequence	X		X
Customer Due Date	X	X	X
Family Structure	X		

X : Functional





THE MODIFIED DIXON SILVER HEURISTIC

- **Circumstances**
 - A make-to-stock manufacturing environment with no stock-outs or backorders permitted.
 - Multi-item, single level, dedicated production lines with finite capacity
 - Setup times and cost are nonzero and sequence independent
 - Sequencing of multiple items to be produced within a specific time period is not considered
 - Safety stocks (buffers) are determined “**outside**” of the scheduling system.



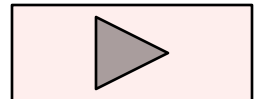


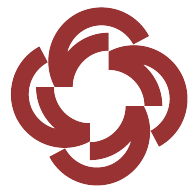
THE MODIFIED DIXON SILVER HEURISTIC (CON.)

- **Heuristic**
 - FC (finite capacity) version of Silver-Meal Heuristic
 - Obtain initial feasible solution dividing marginal cost by available capacity
 - Improve the solution by shifting
- **Result**
 - MIP solver could't get feasible solution from 6 out of 16 test problems, while MODS solved every problems less than ten seconds
 - Worst-case cost penalty for MODS was 12% but the majority were under 5% (DOE).
 - Came up with feasible solutions where MIP would not converge.

References

- Silver, E. A., Meal, H. (1973), Dixon, P. S., Silver, E. A. (1981), Maes, J., Van Wassenhove, I. N. (1986)





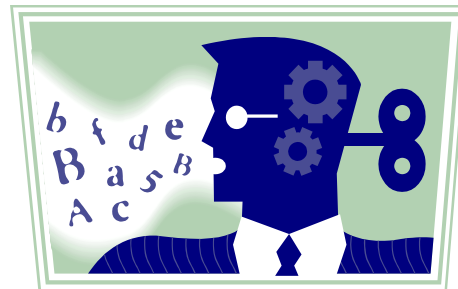
SEMANTIC MODELING

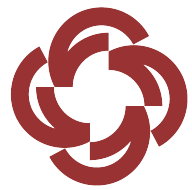
Take the output of one model and use as the input of another model.

-M Language provides semantic input/output that is machine understandable

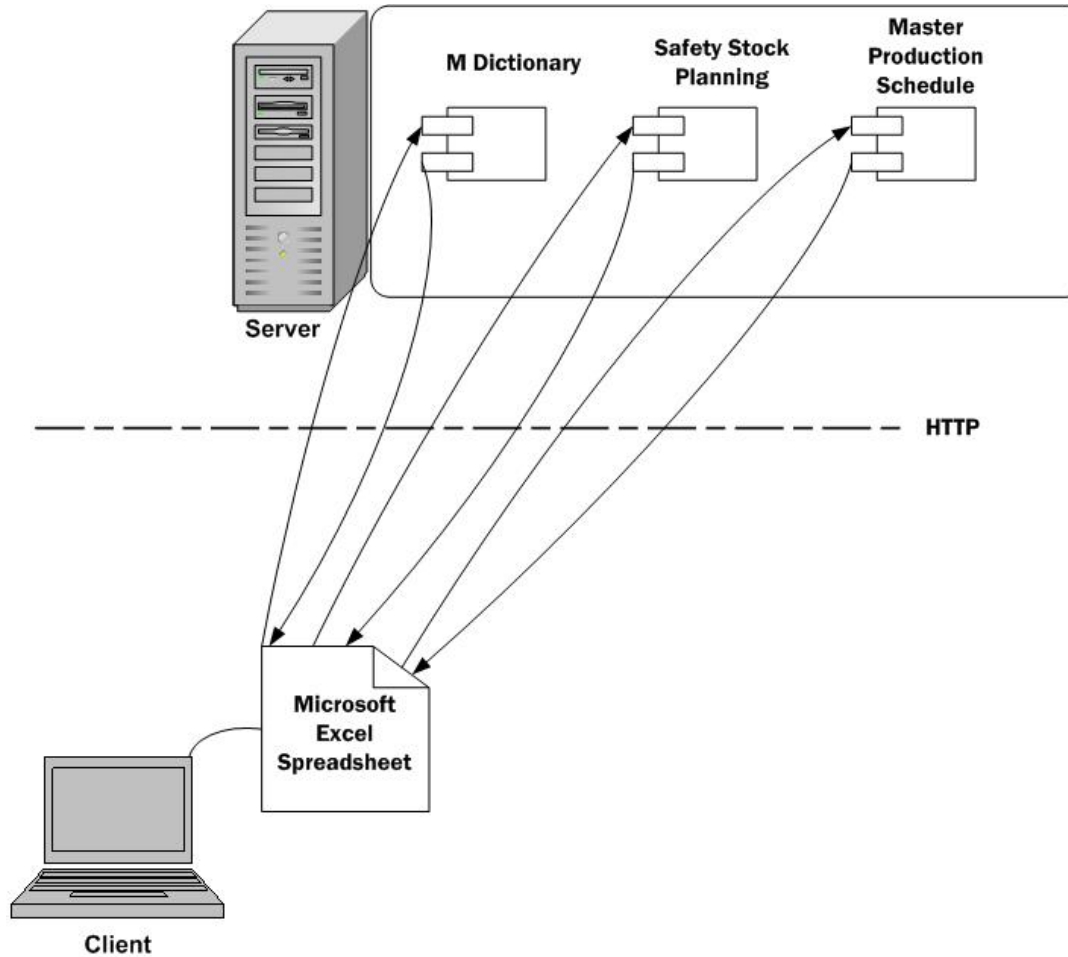
Find the models that need to be linked together.

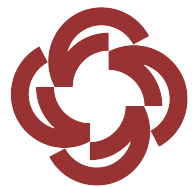
Bias adjusted safety stock model + Finite production planning Model





THE OVERALL ARCHITECTURE

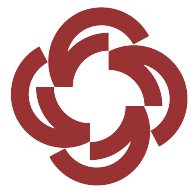




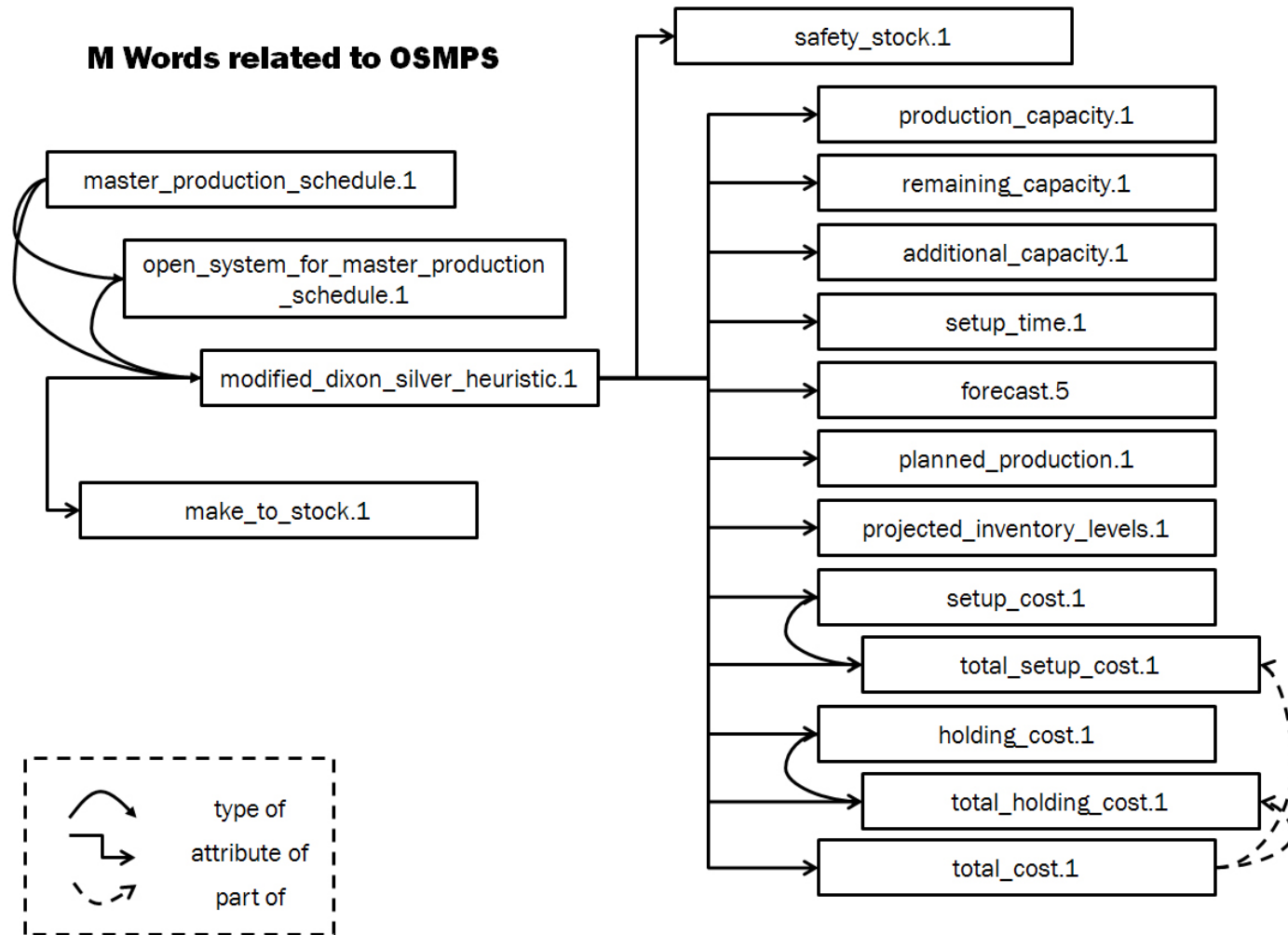
EXCEL SPREADSHEET INTERFACE FOR MASTER PRODUCTION SCHEDULING PART

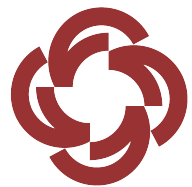
	A	B	C	D	E	F	G	H	I	J	K	L	M
13	Steps:												
14		1.	Enter data in yellow fields including production_capacity.1 , forecast.5 , capacity_absorbed.1 , hold										
15		2.	(optional) Check the meaning of the words by clicking on a word; re-click to close definition box.										
16		3.	Please make sure that macros are enabled. The spreadsheet will automatically interact with the MIT serve										
17		4.	Click on Run OSMPS.										
18		5.	Check the results (model outputs) by looking at planned_production.1 , projected_inventory_levels .										
19													
20			<u>Note:</u> Forecast.5 is netted for beginning inventory. This version DOES NOT contain safety stock.										
21													
22													
23	total_holding_cost.1		\$65,316	Run OSMPS!!									
24	total_setup_cost.1		\$274,200										
25	total_cost.1		\$339,516										
26			<p>- Definition: The capability of a system to perform its expected function. 2) The capability of a worker, machine, work center, plant, or organization to produce output per time period. Capacity required represents the system capability needed to make a given product mix (assuming technology, product specification, etc.). As a planning function, both capacity available and capacity required can be measured in the short term (capacity requirements plan), intermediate term (rough-cut capacity plan), and long term (resource requirements plan). Capacity control is the execution through the I/O control report of the short-term plan. Capacity can be classified as budgeted, dedicated, demonstrated, productive, protective, rated, safety, standing, or theoretical.</p> <p>- Attribute of: modified_dixon_silver_heuristic.1</p>										
27													
28													
29	production_capacity.1												
30	remaining_capacity.1			100	100	100	100						
31	additional_capacity.1			2	0	0	24						
32				0	0	0	0						
33			Period #										
34		ITEM #	1	2	3	4	5	6	7	8	9	10	11
35	forecast.5	154	0	0	0	6.3	6.3	6.8775	6.8775	6.8775	6.8775	8.841	8.841
36		155	0	5.88	5.88	5.88	5.88	6.4575	6.4575	6.4575	6.4575	8.82	8.82
37		156	17.052	4.5675	4.5675	4.5675	4.5675	4.9875	4.9875	4.9875	4.9875	4.557	4.557
38		157	35.28	9.555	9.555	9.555	9.555	10.21125	10.21125	10.21125	10.21125	6.678	6.678





THE OSMPS RELATED ONTOLOGY





AN EXAMPLE FROM THE M DICTIONARY

http://mlanguage.mit.edu/website/ - Windows Internet Explorer

http://mlanguage.mit.edu/website/

File Edit View Favorites Tools Help

http://mlanguage.mit.edu/website/



The Data Center
An MIT Research Program

prototype

[home](#) [m language](#) [web machines](#) [applications](#) [about](#) [feedback](#)

[the dictionary](#) [the web services](#) [the specification](#) [create w...](#)

Search Results:

Noun:

forecast.1, prognosis.2 -- A prediction about how something (as the weather) will develop.

forecast.5 -- An estimate of future demand. A forecast can be constructed using quantitative methods, qualitative methods, or a combination of methods extrinsic (external) or intrinsic (internal) factors. Various forecasting techniques attempt to predict one or more of the four components of demand: cyclic trend. Example of forecasting techniques include Box-Jenkins model, exponential smoothing forecast, extrinsic forecasting method, intrinsic forecasting method, qualitative forecasting method, quantitative forecasting method.

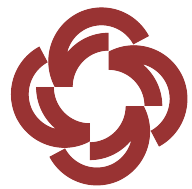
Verb:

forecast.2, calculate.2, estimate.7, reckon.4, count_on.1, figure.16 -- Judge to be probable.

forecast.3, bode.1, portend.1, auspicate.2, prognosticate.1, omen.2, presage.3, betoken.1, foreshadow.1, augur.2, foretell.1, prefigure.1, predict.1 -- Inc bode bad news.

forecast.4, calculate.5 -- Predict in advance.





STABILITY TEST FOR PROPOSED METHOD

- MPS stability – frequency of changes in timing and quantity over time for end-items appearing in the MPS

$$\text{Stability} = k \times \sum_{i=1}^n \sum_{t=1}^H W_t \times |Q_{i,t}^{p2} - Q_{i,t}^{p1}| / B$$

* Sridharan, et. al., 1988, Measuring Master Production Schedule Stability Under Rolling Planning Horizons, "Decision Sciences, 19(1).

where:

$i = 1 \dots n$, Item number

$t = 1 \dots H$, Time period, weeks

n = Total number of products, $n = 22$

H = Planning horizon length, $H = 52$

$Q_{i,t}^{p2}$ = Scheduled production for item i , period t , during planning cycle 2

$Q_{i,t}^{p1}$ = Scheduled production for item i , period t during planning cycle 1

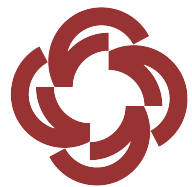
B = Total production for planning cycle 2

k = Multiple factor used to amplify the result, for calculations in this paper $k = 100$

W_t = Weighting factor, $\text{Exp}(1/t-1)$

Schedule changes (instability) in early periods are amplified





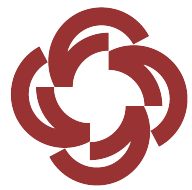
APPENDIX E – EXPERIMENTAL DATA

The following is experimental data used to run a 2^5 full factorial design to determine how the factors affect the MPS stability measure:



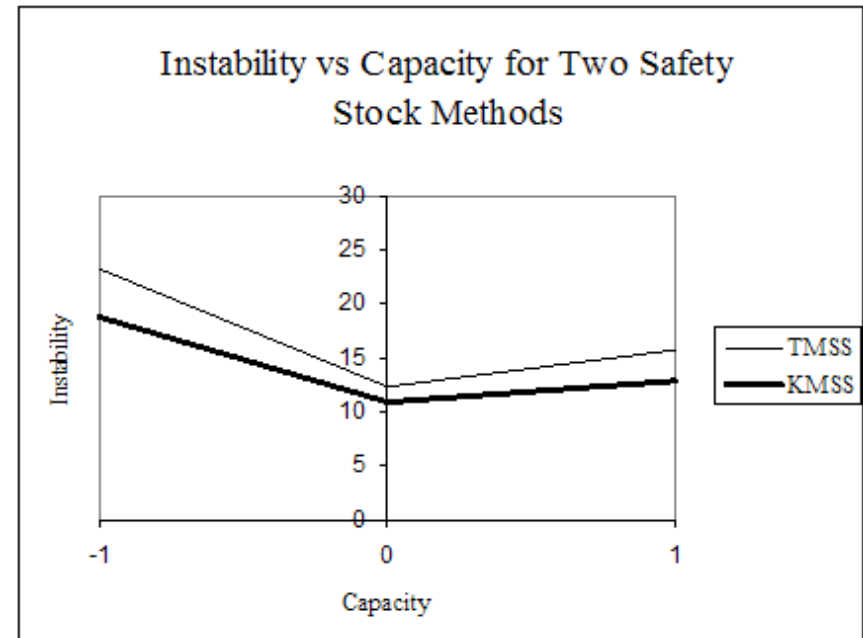
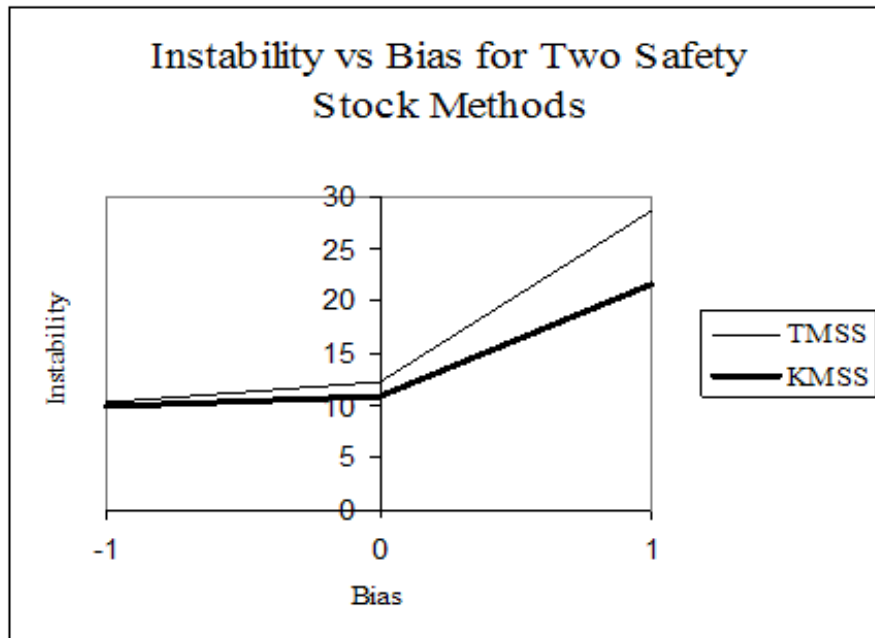
Experiment Number	Bias	Capacity	Demand Variation	Service Level	SS Method	Instability Measure
1	.05	.90	.15	.75	1	11.81
2	.05	.90	.15	.995	-1	12.98
3	.05	.90	.50	.75	-1	14.37
4	.05	.90	.50	.995	1	14.58
5	.05	1.10	.15	.75	-1	5.79
6	.05	1.10	.15	.995	1	4.62
7	.05	1.10	.50	.75	1	8.73
8	.05	1.10	.50	.995	-1	8.95
9	.60	.90	.15	.75	-1	37.55
10	.60	.90	.15	.995	1	26.99
11	.60	.90	.50	.75	1	23.94
12	.60	.90	.50	.995	-1	37.98
13	.60	1.10	.15	.75	1	20.48





STABILITY TEST FOR PROPOSED METHOD (CON.)

- Forecast bias, capacity, and safety stock rendered significant from 2^5 full factorial design
- Sensitivity analyses



TMSS : Traditional model for safety stock

KMSS : Enhanced model of Krupp for safety stock





PREDICTIVE EQUATION

$$\text{Stability} = 17.29 + 7.44 (\text{Bias}) - 3.33 (\text{Capacity}) \\ - 1.77 (\text{SS Method}) - 1.63 (\text{Bias} \times \text{SS Method})$$

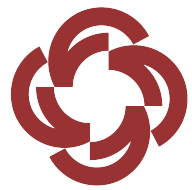




CONCLUSION

- **Bias adjusted safety stock + Real-time master production scheduling**
 - mitigates negative effects of forecast bias
 - improves MPS stability without freezing a portion of the planning horizon
- **A comprehensive solution to the MTS scheduling problem**
 - ongoing recalculation of bias obtained from rolling forward through a finite time horizon
 - controls production and the level of end-item inventory while adjusting forecast bias
- **Open system approach**
 - powerful trend in the context of software-as-a-service
 - M language incorporates semantic disambiguation and syntactic conversion facilitating search and layering mathematical models





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Thank you!





REFERENCE ON MIP

- Dzielinski, B.C., and R.E. Gomory, “Optimal Programming of Lot Sizes, Inventory and Labor Allocations,” *Management Science*, **11**, no.9(1965):874-890.
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- Tempelmeier, H., and M. Derstroff, “A Lagrangean-based Heuristic for Dynamic Multilevel Multi-item Constrained Lot-Sizing with Setup Times,” *Management Science* **42**, no. **5**(1996): **739-757**.





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- Dixon, P.S., and E.A. Silver. “A Heuristic Solution Procedure for the Multi-Item, Single-Level, Limited Capacity, Lot-Sizing Problem,” *Journal of Operations Management* 2, no. 1 (1981): 23-39.
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