Fundamentals of Materials Management and Lot Sizing

Juha Sipilä

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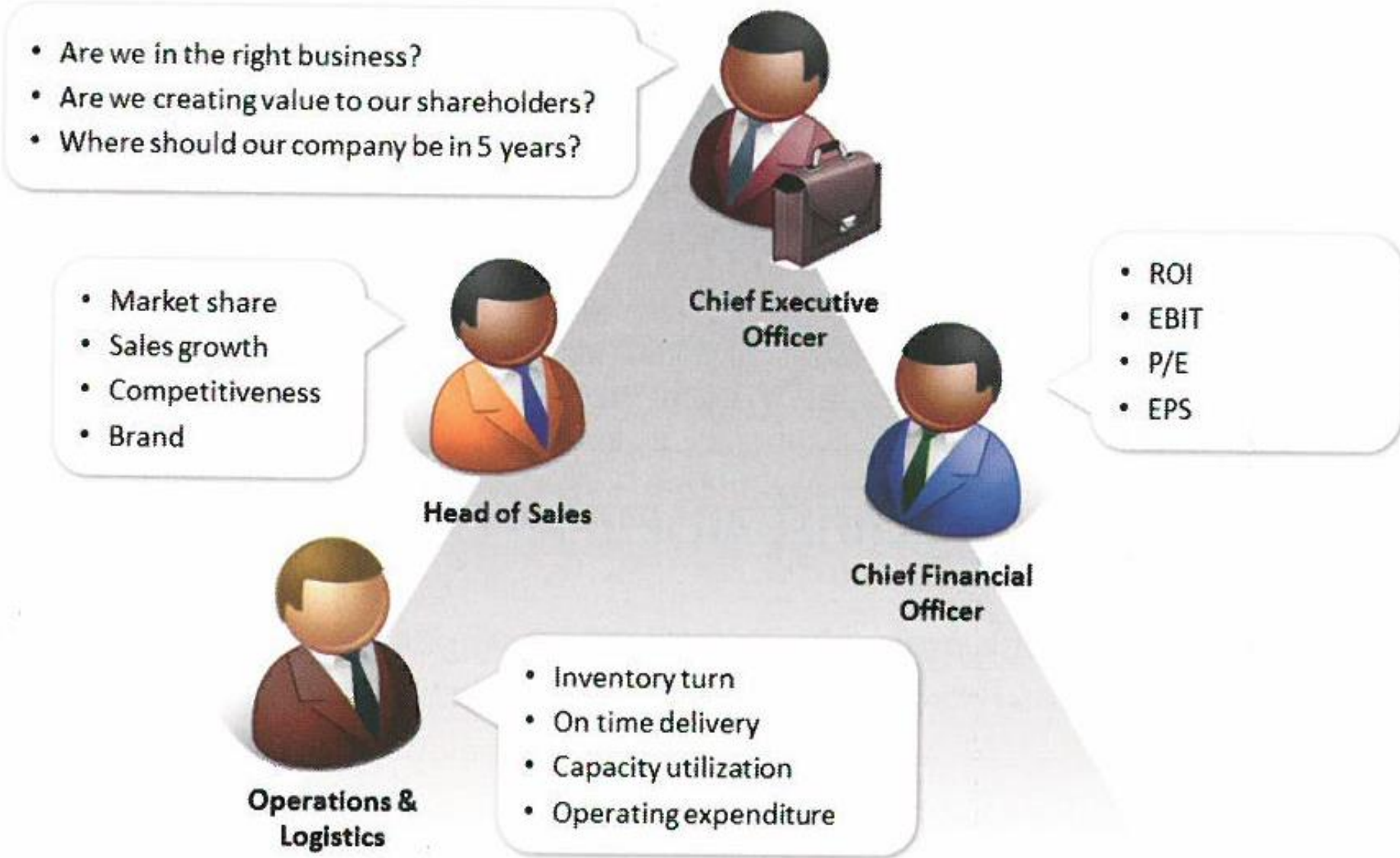
What's on top managements agenda?



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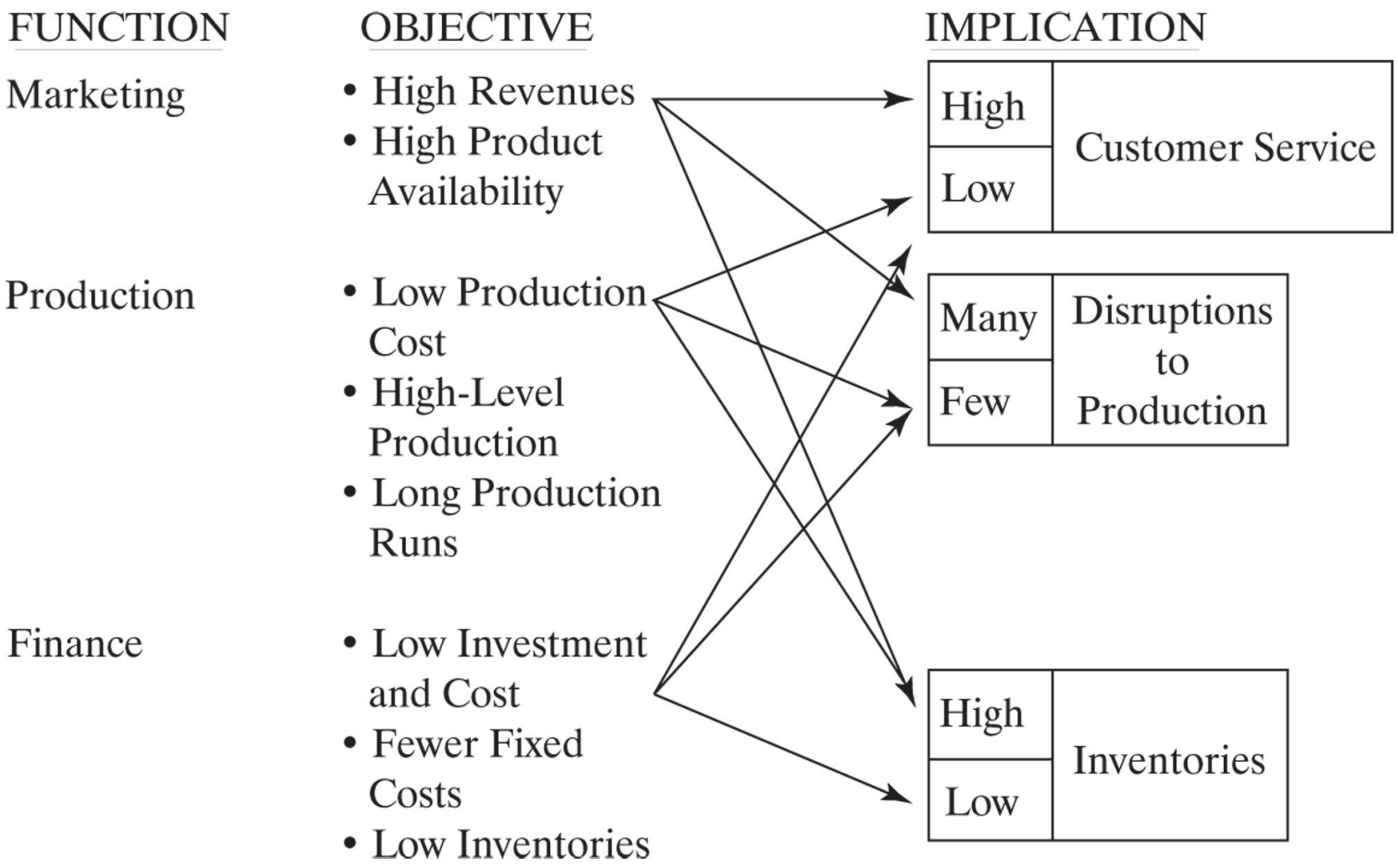
The “natural” conflict of management in production companies



Chapman *et al.*

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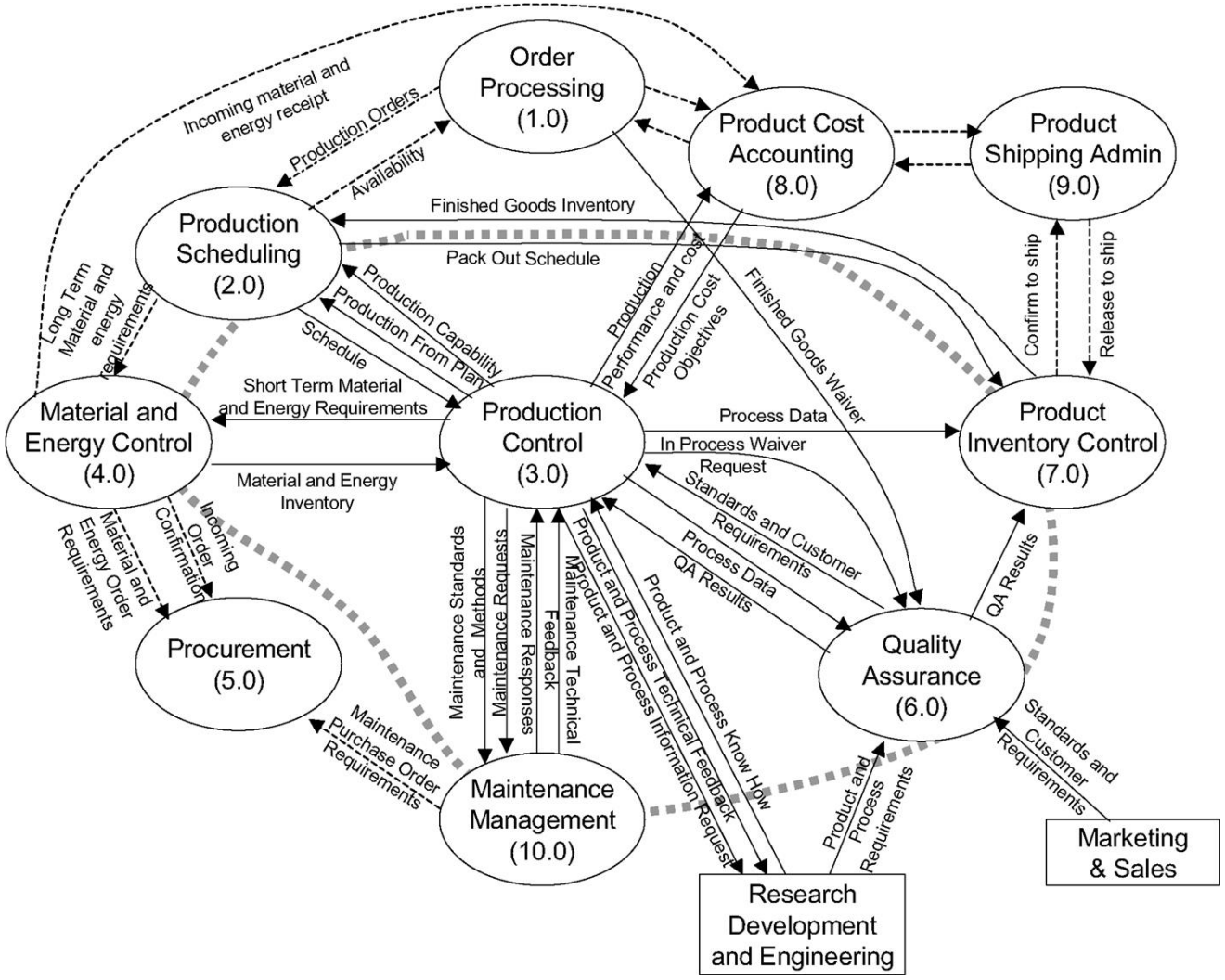
ISA-95



Front. Energy Res., 21 October 2014 | https://doi.org/10.3389/fenrg.2014.00044

http://www.productionsoftware.fi/MES/isa_95.htm

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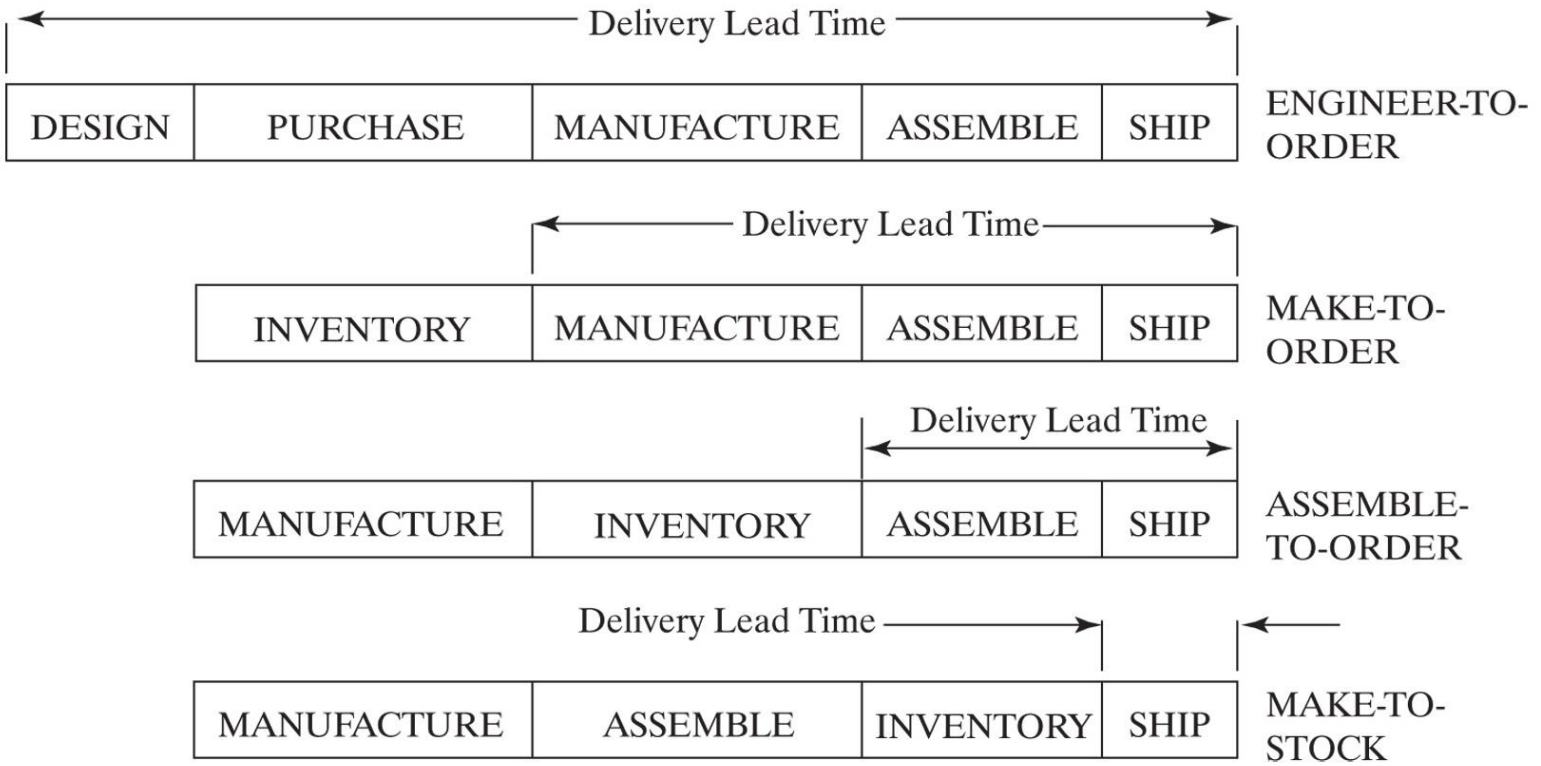
About production strategies…



Some terms

Lead Time: how long it takes from order to delivery

Throughput Time (TH): how long it takes to complete product from start to stock or shipment

Cycle Time or Takt Time (CT): how long are work phases in production (should be balanced)

WIP = Work in Process

Little's Law: *WIP = TH x CT*

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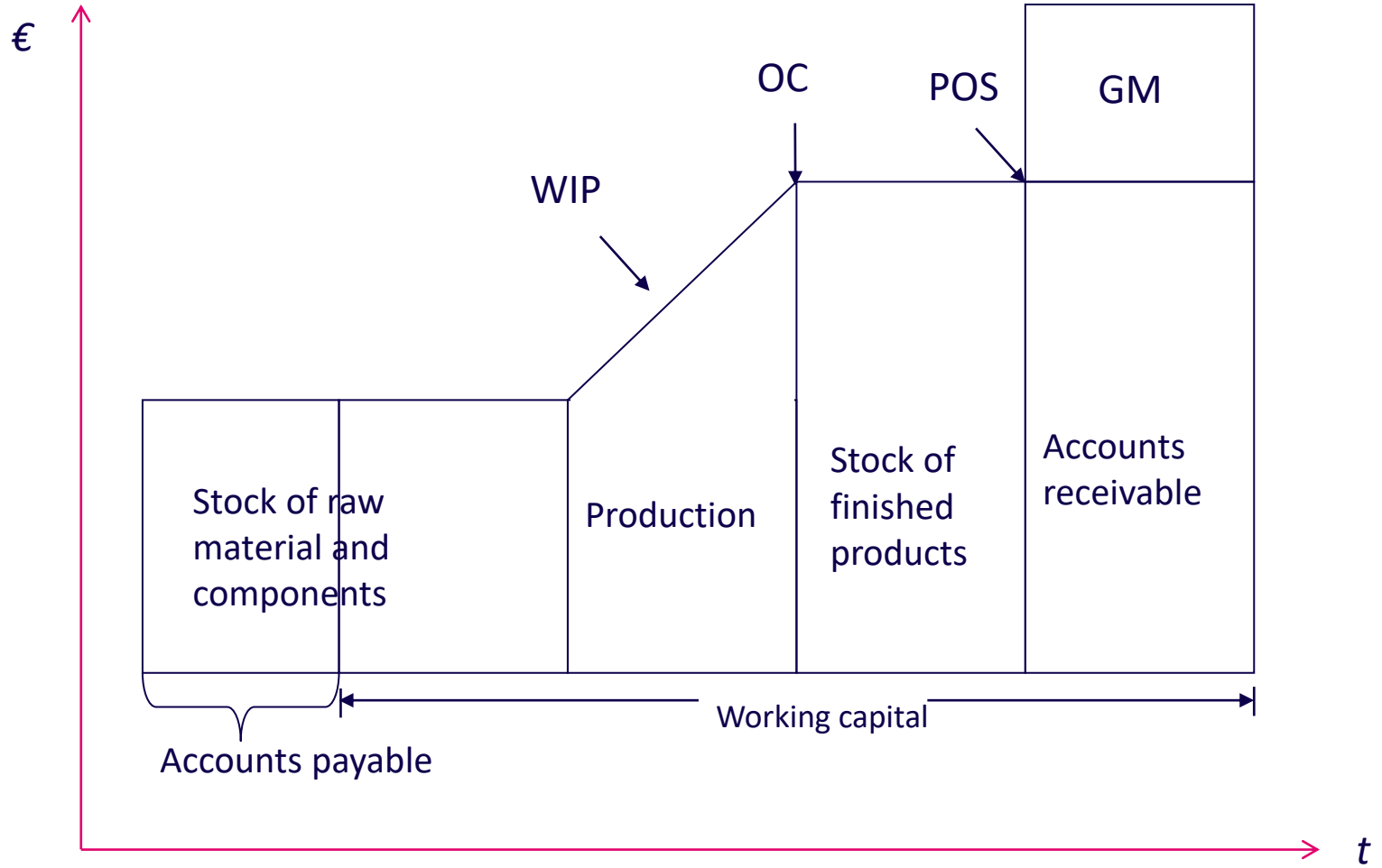
Schematic chart of Working Capital and WIP



GM = gross margin
POS = Point of Sales
OC = Own Cost of product(s)

Uusi-Rauva ym. (modified)

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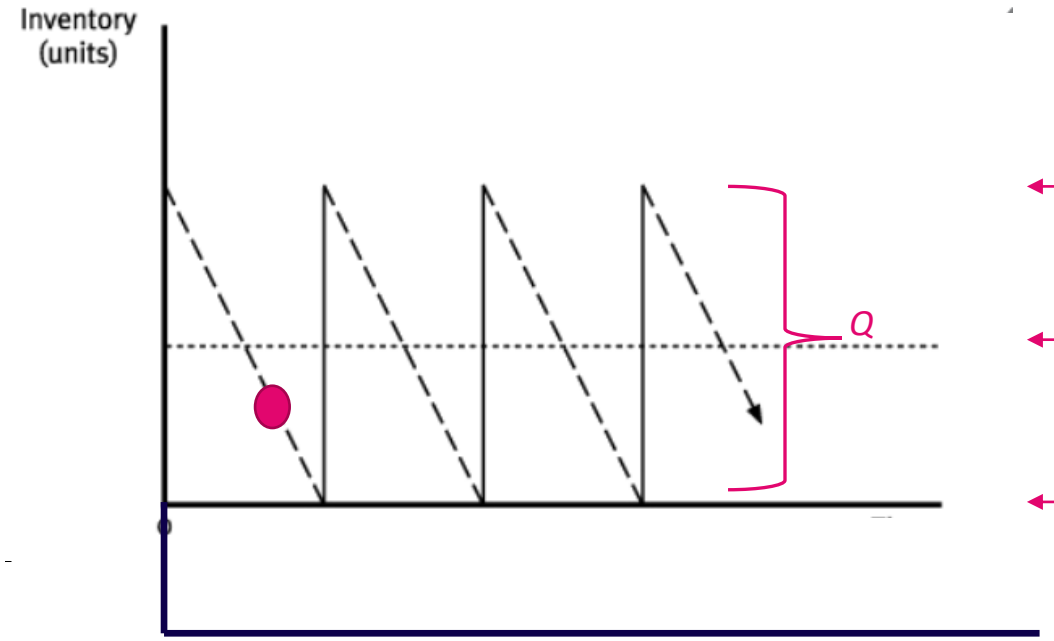
Background for lot sizing

- **Why do we have SKUs (Stock Keeping Unit)?**



Q = Lot Size

Max inventory = *Q + SS*

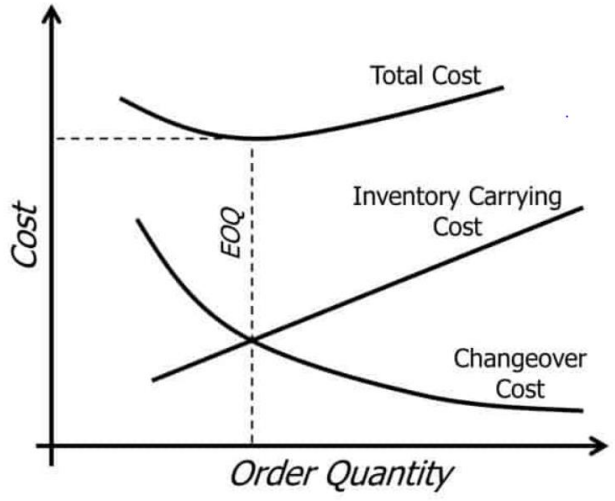
Avg inventory = *Q/2 + SS*

Safety Stock *SS (see e.g., Talluri)*

= Reorder Point (ROP) typically $\overline{D}_L$

Background for lot sizing

- **What is lot sizing?**
- The eldest known approach is *EOQ* (Economic Order Quantity) and it's "sister" formula *EPL* (Economic Production Lot)
- First introduced 1913 by Harris.
- Widely studied method, Andriolo *et al*.



$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}$$

where
D = annual demand (units)
S = cost per order (or ordering costs)
I = holding cost %
H = holding costs (€) = *I x C*

Assumptions (Basic EOQ)

- Demand is known and independent
- Lead time is known and constant
- Receipt of inventory is instantaneous and complete
- Quantity discounts are not considered
- Only variable costs are setup/ordering and holding
- No stockouts

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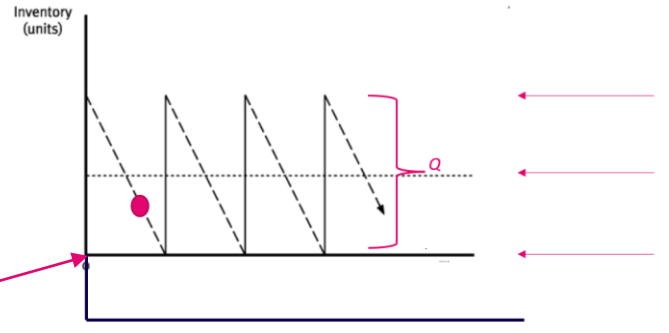
About safety stock (*SS*)

Demand \ Lead-Time	Constant	Variable
Constant	**Case I**	**Case II**
Variable	**Case III** Current Model	**Case IV** Proposed Model

Demand \ Lead-Time	Constant	Variable
Constant	No Safety Stock	$R_L = RL$ $\sigma_L = \sqrt{R^2 s_L^2}$ $SS = F_s^{-1}(CSL)\sigma_L$
Variable	$R_L = RL$ $\sigma_L = \sqrt{\sigma_R^2 L}$ $SS = F_s^{-1}(CSL)\sigma_L$	$R_L = RL$ $\sigma_L = \sqrt{\sigma_R^2 L + R^2 s_L^2}$ $SS = F_s^{-1}(CSL)\sigma_L$



Q = Lot Size

Max inventory = *Q + SS*

Avg inventory = *Q/2 + SS*

Safety Stock *SS (see e.g., Talluri)*

= Reorder Point (ROP) typically $\bar{D}_L$

Notations vary to some extend, depending on source

Talluri *et al*.

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About safety stock (*SS*)… *cont.*

NORMS.INV.(cell)

Service level	*Factor*
80,00 %	0,841621
90,00 %	1,281552
95,00 %	1,644854
98,00 %	2,053749
99,00 %	2,326348
99,50 %	2,575829
99,99 %	3,719016

A typical table of the standard normal function $\Phi(z)$ is provided in Figure 13.22.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

z	1.282	1.645	1.960	2.326	2.576	3.090	3.291	3.891	4.417
$\Phi(z)$	.90	.95	.975	.99	.995	.999	.9995	.999 95	.999 995
$2[1 - \Phi(z)]$	.20	.10	.05	.02	.01	.002	.001	.0001	.000 01

About our papers

- *We have written 5 papers and published 3 papers of Lot Sizing (still to come: one submitted and one accepted waiting in queue – really long thruput time…)*

- *In all our papers we utilize Multiobjective Optimization*
- *Professor Kaisa Miettinen, JYU supervisor*
- *Her doctoral students Adhe Kania (4 papers) and Risto Heikkinen (1 paper) are the main authors*
  - *Real-life data from a production company*
  - *Supply Chain Manager acted as the DM – Decision Making Support worked in a beautiful way*
  - *We had several DM sessions – Learning Curve could be noticed*
  - *My role merely practical point of view based on industrial experience and defining Objective Functions and Constraints*
- *We have several conflicting Objective Functions (depending on the Model):*
  - *Inventory Turnover (ITO)*
  - *Cycle Service Level (CSL)*
  - *Costs (Holding Costs, Ordering Costs and Purchasing Cost)*
  - *Probability of Product Availability (PPA)*
  - *Minimum Order Quantity (MOQ)*
- *Constraints:*
  - *Fill Rate (FR)*
  - *Order Policy with MOQ and rounding value there*
  - *Lower Bound for Decision Variables (depending on the Model)*
    - *Safety Order Time (SOT)*
    - *Safety Stock (SS)*
    - *Safety Lead Time (SLT)*

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Our papers

2021

Interactive Multiobjective Optimization in Lot Sizing with Safety Stock and Safety Lead Time

Adhe Kania[1,3(✉)], Juha Sipilä[2], Bekir Afsar[1], and Kaisa Miettinen[1]

[1] University of Jyvaskyla, Faculty of Information Technology, P.O. Box 35 (Agora), 40014 University of Jyvaskyla, Finland
adhe.a.kania@student.jyu.fi
[2] JAMK University of Applied Sciences, School of Technology, Jyvaskyla, Finland
[3] Institut Teknologi Bandung, Faculty of Mathematics and Natural Sciences, Jl Ganesha 10, Bandung 40132, Indonesia

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Integration of lot sizing and safety strategy placement using interactive multiobjective optimization

Adhe Kania[a,c,*], Juha Sipilä[b], Giovanni Misitano[a], Kaisa Miettinen[a], Jussi Lehtimäki[b]

[a] University of Jyvaskyla, Faculty of Information Technology, P.O. Box 35 (Agora), FI-40014 University of Jyvaskyla, Finland
[b] JAMK University of Applied Sciences, School of Technology, Jyväskylä, Finland
[c] Institut Teknologi Bandung, Faculty of Mathematics and Natural Sciences, Jl Ganesha 10, Bandung 40132, Indonesia

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DESMILS: a decision support approach for multi-item lot sizing using interactive multiobjective optimization

Adhe Kania[1,3] · Bekir Afsar[1] · Kaisa Miettinen[1] · Juha Sipilä[2]

[1] University of Jyvaskyla, Faculty of Information Technology, P.O. Box 35 (Agora), FI-40014 University of Jyvaskyla, Finland
[2] JAMK University of Applied Sciences, School of Technology, Jyväskylä, Finland
[3] Institut Teknologi Bandung, Faculty of Mathematics and Natural Sciences, Jl Ganesha 10, Bandung 40132, Indonesia

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