Excel建模与分析的供应链决策

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2020/6/17

中国供应链与运营管理人俱乐部

我 们 助 您 创 未 来！

China Supply Chain & Operations Manager Club

互动问题

- 1. 你所在的职位，对Excel表的使用，主要用于在哪些方面?
- 2. 公司在做供应链决策时，一般的流程和做法是怎么样的?
- 3. 你所面临的通过数字驱动供应链决策有哪些?
- 4. 你所在的公司是否广泛应用Excel表格作为分析数据工具?
- 5. 你所接触到的Excel表格分析模块有哪些?
- 6. 做一个供应链决策，你所在的职位，一般会考量哪些数据？你是如何收集这些数据的?

议程纲领

案例内容和学习目的

1. 引用5个实操案例，通过Excel工具，展示相关联的数据、方程及运算过程

1） 如何用Excel检验预测数据的精确性
学习目的：使用 Mean Error, MAD, RMSE, MAPE作为衡量预测数据的标准，解释它们的字母代表及定义。通过计算检验预测精确性。计算调整后的预测数据，减小预测与需求差异，从而减少库存风险。

2） EOQ 订单量和供应商提供采购折扣量之间的选择和运算
学习目的：了解什么是EOQ及其计算方式；与订单相关联的成本种类和计算公式； 基于EOQ, MOQ, Fixed Lot-size 或供应商采购折扣量条件下，求得最优订单量 (Optimal Q)的计算。作为采购不只关注需求满足（demand fulfilment), 还需关注与订单相关联的成本。

3）两个或多个供应商的选择决策
学习目的：在两个或多个供应商（Dual-sourcing or Multi-sourcing）情况下，如何选择最优供应商？计算主要是基于成本和库存因素；通过学习，掌握和订单相关联的成本计算公式 : total landed cost (TLC- 总着陆成本), procurement cost（采购成本）, transportation cost（运输成本）, inventory holding cost（库存成本）; 掌握和了解常规库存种类与其计算方式: base stock（基数库存）, cycle stock（周期库存）, safety stock（安全库存）, pipeline stock (渠道库存或中转库存)。

4 ）直邮和越库（或称交叉停靠）的模式及其区别，安全库存影响和成本计算
学习目的：直邮和越库（Direct ship vs. Cross docking）定义及区别；现有的国际供应链中，无论是电子商务还是生产制作的供应链，运输产品都可能存在从中心仓库到区域仓库的库存周转。通过实操案例，对比两种模式的安全库存及关联成本，盈利点计算，从而决定哪种模式更为经济，产生更多盈利。

5 ）生产制造中，将库存保存在不同产生阶段的效益和利润对比
学习目的：在生产制造中，有分单一的生产流程和多分流向的生产流程。本次分享内容主要是集中在单一的生产流程模式上，库存持有在不同生产阶段的效益对比：即，所有阶段都持有库存；部分阶段都持有库存；只某一阶段持有库存。

讲师介绍

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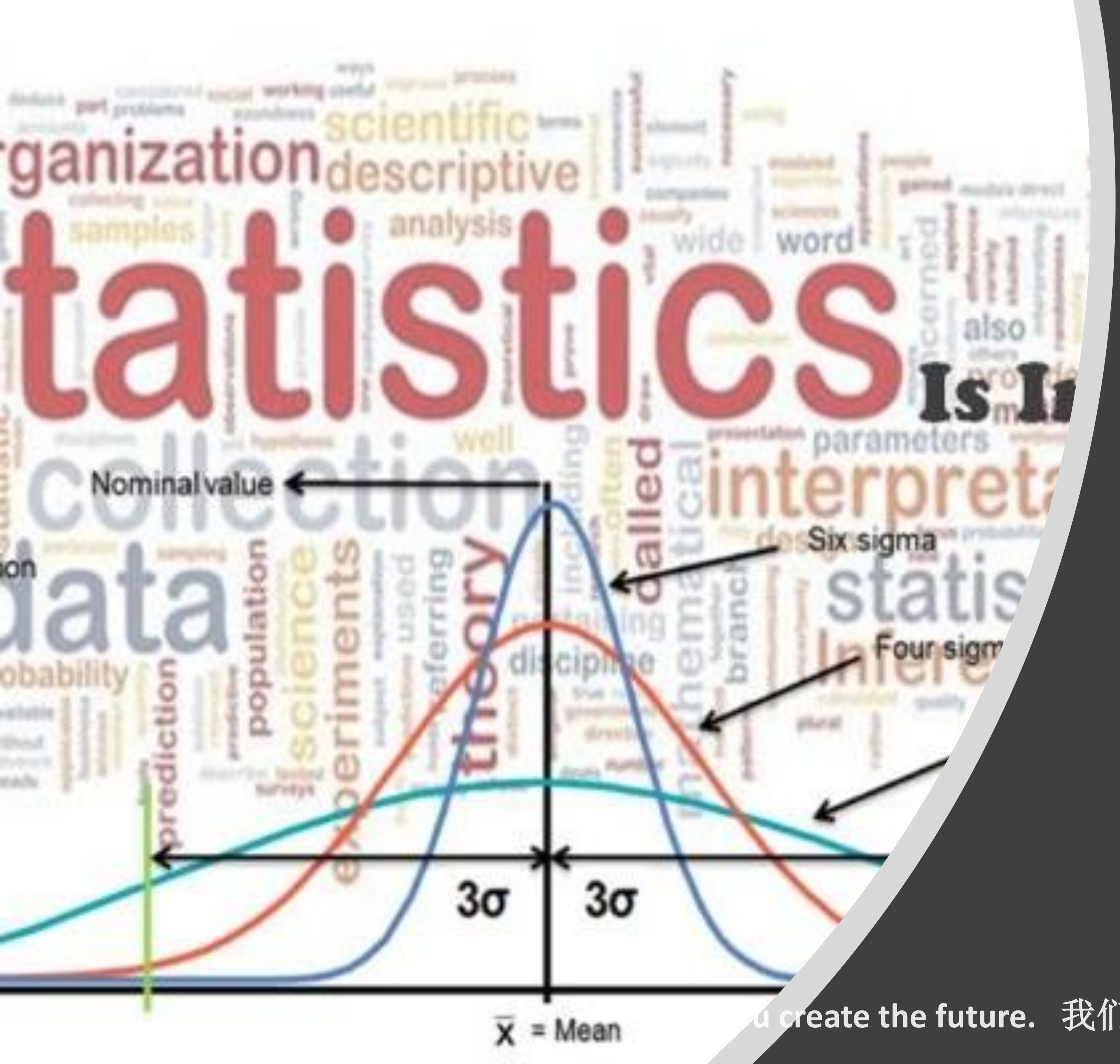
Jenny He，美国南加州大学国际供应链硕士；麻省理工学院制造运营学研究生专业；六西格玛（绿带）认证；APICS-CSCP认证；麻省理工学院SAS、SQL供应链分析认证。

拥有10余年中美海外产品运营及国际供应链管理经验。早期，在中国知名高科技企业担任海外产品经理，于2013年移民美国，在美国企业从事国际供应链工作至今。曾入职苹果(Apple)、面书 (Facebook)、雷蛇 (Razer) 担任新成品项目供应链管理工作，负责全球供应商、亚洲ODM制造协作、新产品周期管理包括：产品设计、寻源、物料采购、生产管理、预测、及全球仓储及物流管理。专长：新产品国际供应链管理、供应链建模和分析。实战经验：国际寻源、采购、订单管理、需求预测分析、多层面、多渠道的国际库存管理实践。



供应链需掌握的统计学基础

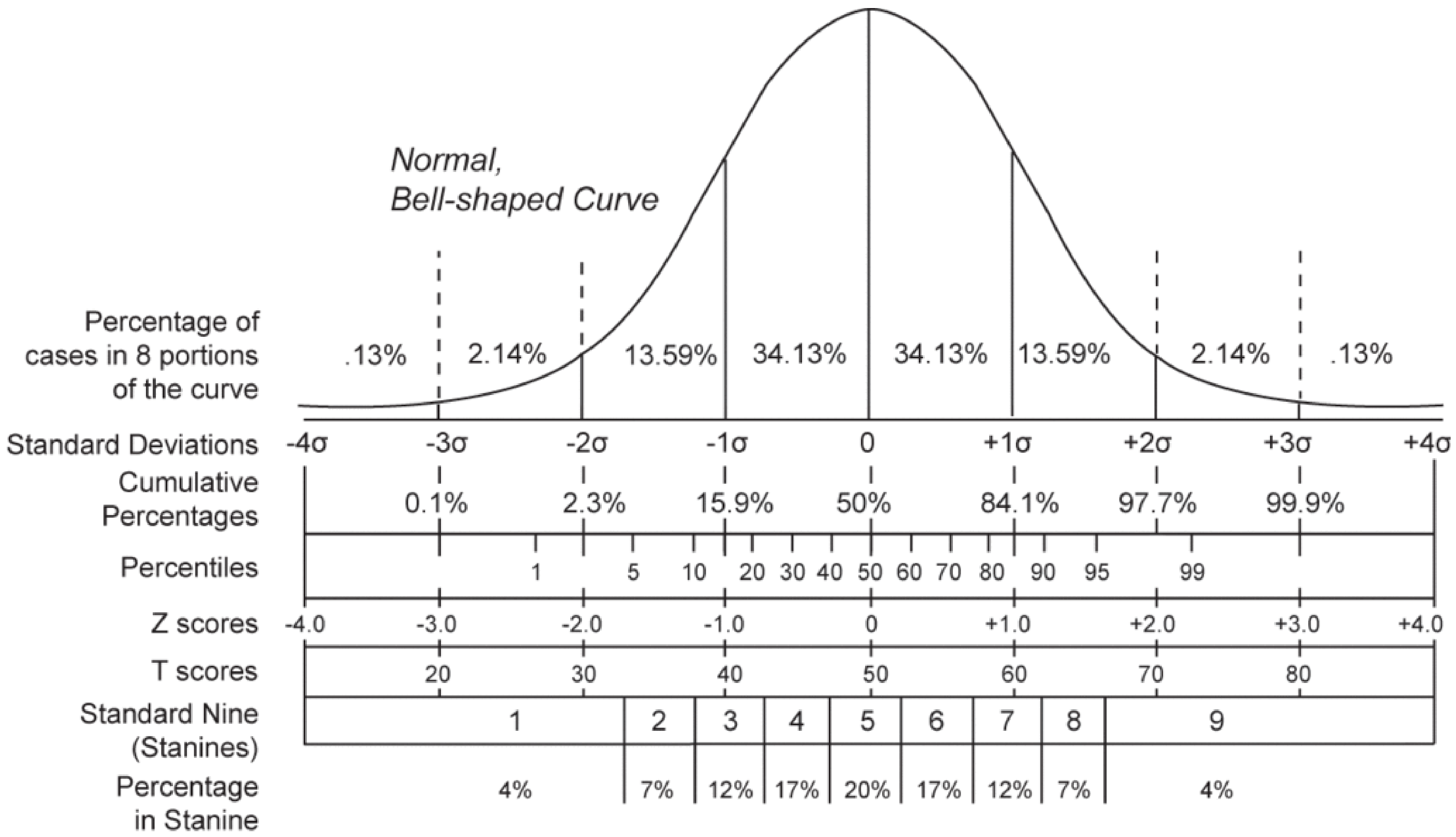
供应链中的基础统计数值 Excel 算法

练习 1： 平均值 μ、平均差(或称标准方差) σ 、方差 v

Excel 1

	A	B	C	D	E	F	G
1	周期	需求历史数据					
2	0	120					
3	1	81					
4	2	96					
5	3	102		计算方式			字母缩写
6	4	78		Mean	90.4074	=AVERAGE(B2:B28	μ
7	5	78		Std.v Population	20.4763	=STDEV.P(B2:B28)	σ
8	6	48		Std.v Sample	20.8663	=STDEV.S(B2:B28)	σ
9	7	83		Variance Population	419.278	=VAR.P(B2:B28)	v
10	8	86		Variance Sample	435.405	=VAR.S(B2:B28)	v
11	9	114		Variance = σ^2			
12	10	97		σ = sqrt (V)			
13	11	121					
14	12	123					
15	13	72					
16	14	115					
17	15	85					
18	16	92					
19	17	103					
20	18	62					
21	19	95					
22	20	72					
23	21	74					
24	22	74					
25	23	122					
26	24	88					
27	25	54					
28	26	106					

六西格玛



Normal,
Bell-shaped Curve
Percentage of cases in 8 portions of the curve
.13%
2.14%
13.59%
34.13%
34.13%
13.59%
2.14%
.13%
Standard Deviations
-4σ -3σ -2σ -1σ 0 +1σ +2σ +3σ +4σ
Cumulative Percentages
0.1% 2.3% 15.9% 50% 84.1% 97.7% 99.9%
Percentiles
1 5 10 20 30 40 50 60 70 80 90 95 99
Z scores
-4.0 -3.0 -2.0 -1.0 0 +1.0 +2.0 +3.0 +4.0
T scores
20 30 40 50 60 70 80
Standard Nine (Stanines)
1 2 3 4 5 6 7 8 9
Percentage in Stanine
4% 7% 12% 17% 20% 17% 12% 7% 4%

Excel 2：以下是10天的产品销量纪录及概率分布。求出平均需求，需求标准差和方差。产品卖出少于和等于6个的几率是多少？卖出大于3个的几率是多少？

	A	B	C	D	E
1	Demand	Pro	Mean	Variance	Std. v
2	0	0.05	0	1.13288	
3	1	0.1	0.1	1.41376	
4	2	0.1	0.2	0.76176	
5	3	0.15	0.45	0.46464	
6	4	0.05	0.2	0.02888	
7	5	0.1	0.5	0.00576	
8	6	0.05	0.3	0.07688	
9	7	0.3	2.1	1.50528	
10	8	0.02	0.16	0.209952	
11	9	0.05	0.45	0.89888	
12	10	0.03	0.3	0.823728	
13			4.76	7.3224	2.7060
14			=SUM(C2:C12)	=SUM(D2:D12)	=SQRT(D13)

	A	B	C	D	E
1	Demand	Pro	Mean	Variance	Std. v
2	0	0.05	0	1.13288	
3	1	0.1	0.1	1.41376	
4	2	0.1	0.2	0.76176	
5	3	0.15	0.45	0.46464	
6	4	0.05	0.2	0.02888	
7	5	0.1	0.5	0.00576	
8	6	0.05	0.3	0.07688	
9	7	0.3	2.1	1.50528	
10	8	0.02	0.16	0.209952	
11	9	0.05	0.45	0.89888	
12	10	0.03	0.3	0.823728	
13			4.76	7.3224	2.7060
14			=SUM(C2:C12)	=SUM(D2:D12)	=SQRT(D13)

Explanation

1. $E(X) = x_1p_1 + x_2p_2 + \ldots + x_{10}p_{10} = 4.76 = \mu$
2. $V(X) = E\left((X-\mu)^2\right) = (x_1-\mu)^2p_1 + (x_2-\mu)^2p_2 + \ldots + (x_{10}-\mu)^2p_{10} = 7.3224 = \sigma^2$
3. The standard deviation of the discrete distribution is the square root of the variance. $\sigma = \sqrt{V(X)} = 2.7060$
4. $P(X \le 6) = P(0) + P(1) + P(2) + \ldots + P(6) = 0.05 + 0.1 + 0.1 + 0.15 + 0.05 + 0.1 + 0.05 = 0.6$
5. $P(X > 3) = 1 - P(X \le 3) = 1 - (P(0) + P(1) + P(2) + P(3)) = 1 - (0.05 + 0.1 + 0.1 + 0.015) = 0.6$

APICS Premier Channel Partner

供应链中常见的库存种类与计算公式

常见库存概念和种类
国际标准

基数库存 Base stock is the order up to point for an inventory policy.
Base stock = demand of mu*(r+L) + z*sigma * sqrt (r+L)

安全库存 Safety stock usually refers to the expected inventory on hand when a replenishment order is received. It is how much extra inventory we have on hand on average so as to provide some high level of service.
Safety stock = z*sigma* sqrt (r+L)

周期库存 Cycle stock is the amount of inventory that is planned to be used during a given period. The period is often defined as the time between orders (for raw materials), or the time between production cycles (for work in process and finished goods) Cycle stock= demand of mu*r/2

渠道库存或中转库存 Pipeline stock also is called pipeline inventory or transit stock, refers to the units which are in transit between locations. Pipeline stock = demand of mu*L

重起订量 Reorder point is the level of inventory which triggers an action to replenish that particular inventory stock.
Reorder point = demand of mu*L + z*sigma*sqrt (L)

预计库存 Expected Inventory is the sum of Cycle stock + Safety stock. E(I)= Q/2+ z* sigma *sqrt (L)

常见库存公式

假设，我们周期性进行库存检查，库存计算如下：

1) 基数库存 Base stock = demand of mu*(r+L) + z*sigma * sqrt (r+L)
2) 周期库存 Cycle stock= demand of mu*r/2
3) 安全库存 Safety stock = z*sigma* sqrt (r+L)
4) 渠道库存或中转库存 Pipeline stock = demand of mu*L
5) 重起订量 Reorder point = demand of mu*L + z*sigma*sqrt (L)
5) 预计库存 E(I)= Q/2+ z* sigma *sqrt (L)

读法和写法
μ = mean = mu
σ = sigma = std.v

字母表达含义：
Demand of Mu(μ): 在一个时间段里的需求平均值
Demand of Sigma(σ):在一个时间段里的需求标准差
r: 库存周期性观测时间（一般为天数）
L: 总周期 (包括物料采购和筹备周期+生产周期+ 运输周期)
Z-value: 又称关键分值。这个分值是和我们提供给客户的服务水平相挂钩。
比如, CSL (Customer Service Level) = 98%, z value = 2.053748911 = 2.05

如何用Excel计算 z-Value (Excel 3)

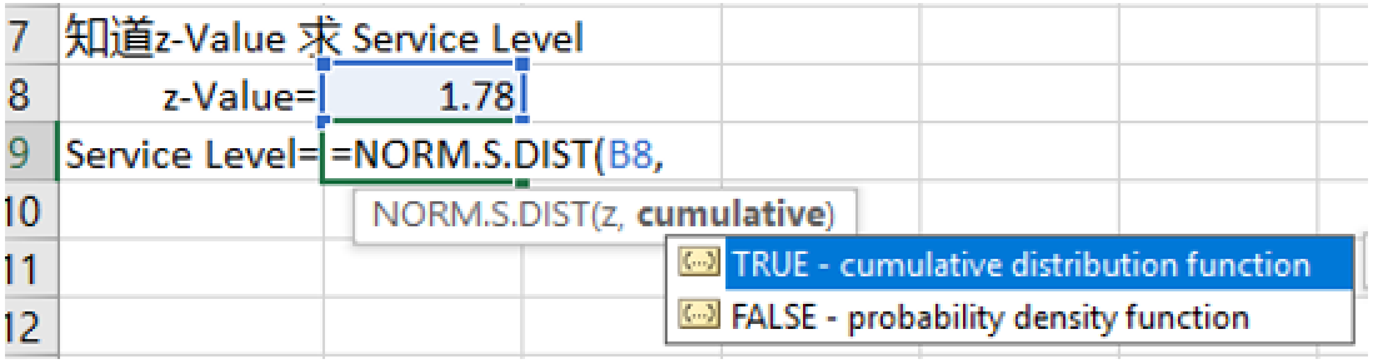
	A	B	C
1	Service Level	0.98	
2	z-Value=	=NORM.S.INV(	
3			

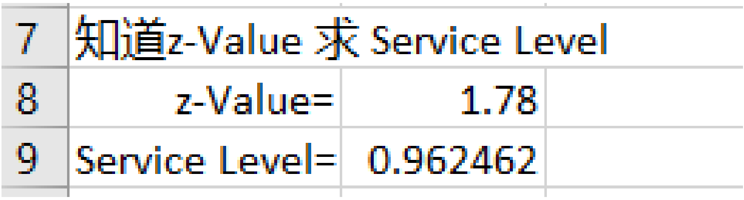
	A	B	C	D
1	Service Level	0.98		
2	z-Value=	=NORM.S.INV(B1		
3		NORM.S.INV(**probability**)		
4				

	A	B
1	Service Level	0.98
2	z-Value=	2.053749
3		

为什么要计算"z-Value"?
回顾第7页库存公式。

如何用Excel计算 CSL (Excel 3)





Excel 4：美国一家 A 零售店从一家中国厂家进大量电动玩具。公司想确保有足够库存，每两个月下单（r=2), 每次下的订单足够支撑5个月需求；如果库存仅支撑1.5个月，公司就会下3.5个库存的订单。假设，每个电动玩具进货价为11元美金，卖30元美金。从中国工厂到美国A零售店仓库，运输周期(L)为2个月；月平均销售需求为140个， 标准方差为85个，库存成本是每个产品的10%。

1. 求每次订购平均量(Average Q)？
2. 求安全库存量(SS)？
3. 求在下批货到来之前的缺货几率？
4. 如果公司想少于1%的缺货，那么最小基数库存(B) 应该是多少？
5. 如果公司想维持安全系数值(z=1.7)， 就会少于5%的缺货几率。这样的情况，公司的库存成本是多少？
6. 如果公司的安全系数值(z=1.7)， 那么达交率(Fill Rate)应该是多少？ （**Partial Loss function的excel 算法**)

Partial Loss Function in excel: = NORM.DIST(z,0,1,FALSE)-z*(1-NORM.DIST(z,0,1,TRUE))

公式换算见右
解题和计算步骤请见Excel 4

Safety stock = z*sigma* sqrt (r+L)
Base stock = demand of mu*(r+L) + z*sigma * sqrt (r+L)
Safety stock = Base stock - demand of mu*(r+L)

Safety stock = z*sigma* sqrt (r+L)
z= Safety stock / sigma* sqrt (r+L)
stockout probability = 1-CSL
CSL=99% z=2.33   E(I)=Q/2+ z* sigma *sqrt (L)

Q1 Explanation

He orders once every two months; so his average order should correspond to two months of demand, or 280 units.

Q2 $safetystock = (order - up - to) - \mu * (r + L) = 700 - 140 * (2 + 2) = 140$

Q3 $z = (700 - 140 * (2 + 2)) / (85 * \sqrt{4}) = 0.82$

The probability that the demand over the lead-time and review period does not exceed 700 (the order-up-to point) is F(z), the cumulative distribution function of the normal distribution:

F(z=0.82) = 0.794; thus, the probability of stocking out is 1 – 0.794 = 0.206.

Q4 Achieving less than 1% probability of stocking out is the same as achieving more than 99% probability of not stocking out. To achieve that, we need find z such that F(z)=0.99. From normal tables, we get z=2.33. We should then set the base stock (B) as:

$$B = (order - up - topoint) = \mu * (r + L) + z * \sigma\sqrt{r + L}$$
$$= 140 * (2 + 2) + 2.33 * 85\sqrt{4} = 560 + 396 = 956$$

Q5 We can calculate the safety stock of Genzo's new policy, which has a safety factor z = 1.7.

$$safetystock = z\sigma\sqrt{r + L} = 1.7 * 85 * 2 = 289$$

The average inventory is:

$$averageinventory = \frac{\mu r}{2} + safetystock = 140 + 289 = 429$$

The holding cost of each unit is $\$11 * 0.1 = \$1.1$ each, so the total annual holding cost is $\$1.1 * 429 = \$471.9$.

Q6 Using the partial loss function,

fill rate = $\frac{1}{\mu r}\left(\mu r - \int_{x=B}^{\infty} (x - B)\, f(x|r + L)\, dx\right) = 1 - \frac{1}{\mu r}\sigma\sqrt{r + L}\int_{x=z}^{\infty} (x - z)\, \phi(x)\, dx$

Partial Loss function = $\int_{x=z}^{\infty} (x - z)\, \phi(x)\, dx = \phi(z) - z\,(1 - \Phi(z))$

Using Excel/LibreOffice/spreadsheet to calculate, we get $0.018288 \approx 0.0183$

Therefore,

fill rate = $1 - \frac{1}{\mu r}\sigma\sqrt{r + L}\int_{x=z}^{\infty} (x - z)\, \phi(x)\, dx = 1 - \frac{1}{280} * 85 * \sqrt{4} * 0.018288 = 0.988897 \approx 0.989$

Excel 4


ANALYSIS
PRODUCT
MANAGEMENT
LOGISTIC
SUPPLY CHAIN
MANAGEMENT
PROFIT
DISTRIBUTION
PROCUREMENT
PLAN

5个供应链实操案例

实操一: 如何用Excel检验预测数据的精确性

两个常规预测模型 Excel 5

a. 移动平均值模型(Moving Average Model)
b. 指数平滑法模式(Exponential Smoothing Model)

$$MAD = \frac{1}{N}\sum_{j=1}^{N}|delta_j|$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(f_i - y_i)^2$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{j=1}^{N}|delta_j|^2}$$

五个预测精确性衡量值

a. Mean Error (ME)预:测差绝对值/数据#(n)

b. Mean Average Demand(MAD)： 预测差绝对值/数据#(n)

所以，某种程度上来说，Mean Error = MAD 是同一个概念，使用ME可以作为Adjusted Forecast的基准

c. Mean-Squared Error(MSE): 预测差^2/数据#(n)

d. Root-Mean-Squared Error (RMSE): SQRT(预测差^2/数据#(n))

e. Mean Absolute Percentage Error(MAPE): Average(预测差的绝对值/实际销售数据)*100%

需求预测的主要模型(Moving Average)

4个月的平均值预测模式

	A	B	C	D	E	F	G	H
1	a. 4-month moving average							
2	Month	Contribution	A(t)	F(t)	Error	Abs. Error	Sq. Error	% Error
3	1	1,074,844	#N/A					
4	2	780,433	#N/A					
5	3	1,082,218	#N/A					
6	4	1,009,653	986,787					
7	5	1,066,739	984,761	986,787	79,952	79,952	6,392,322,304	7.5%
8	6	1,297,010	1,113,905	984,761	312,249	312,249	97,499,594,126	24.1%
9	7	978,685	1,088,022	1,113,905	(135,220)	135,220	18,284,448,400	13.8%
10	8	1,108,218	1,112,663	1,088,022	20,196	20,196	407,888,514	1.8%
11	9	1,019,778	1,100,923	1,112,663	(92,885)	92,885	8,627,623,225	9.1%
12	10	999,380	1,026,515	1,100,923	(101,543)	101,543	10,310,930,078	10.2%
13	11	1,041,070	1,042,112	1,026,515	14,555	14,555	211,840,748	1.4%
14	12	821,189	970,354	1,042,112	(220,923)	220,923	48,806,751,006	26.9%
15	13			970,354		MAD	MSE	MAPE
16						90,020	13,673,006,714	9.9%

=Contribution – F(t)

=ABS(Error/Contribution)

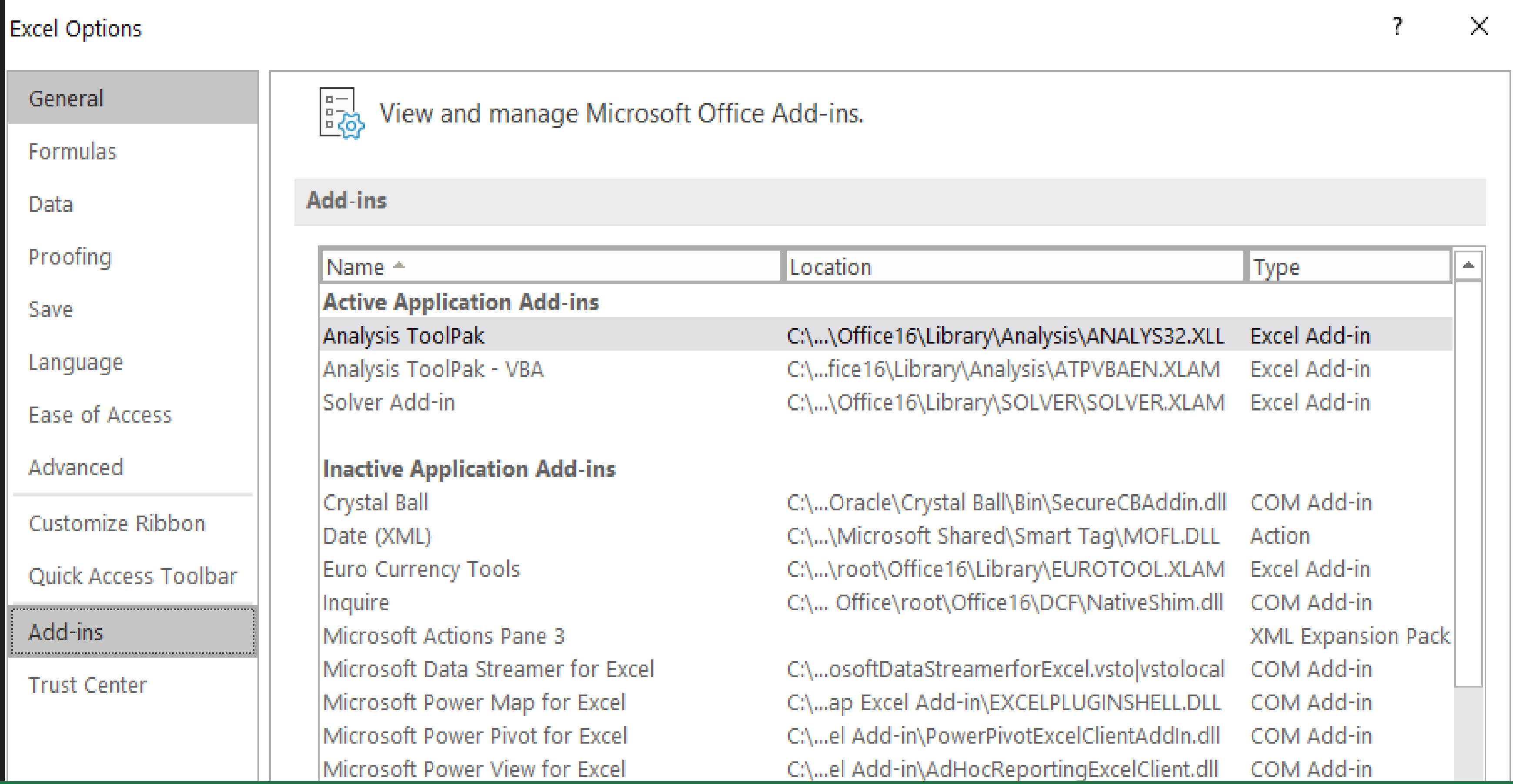
=ABS(Error)

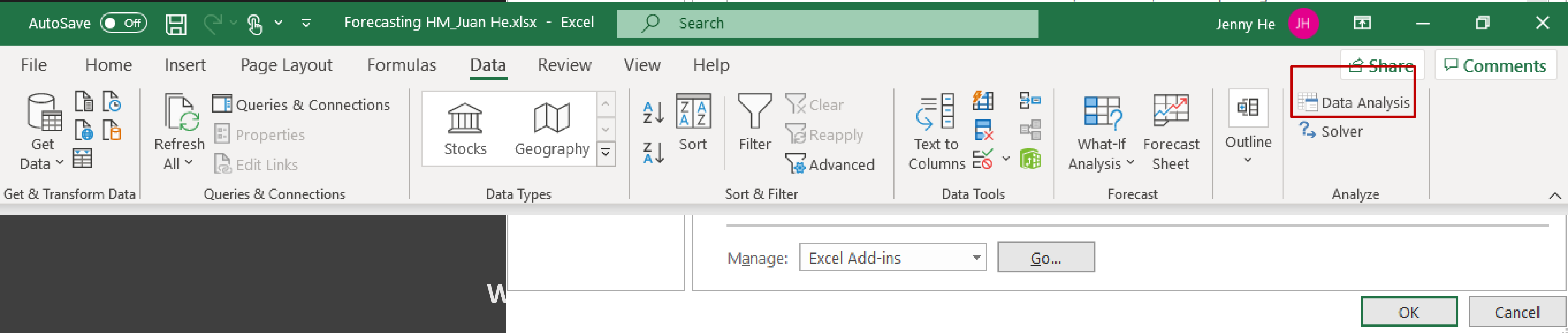
=ABS(Error^2)

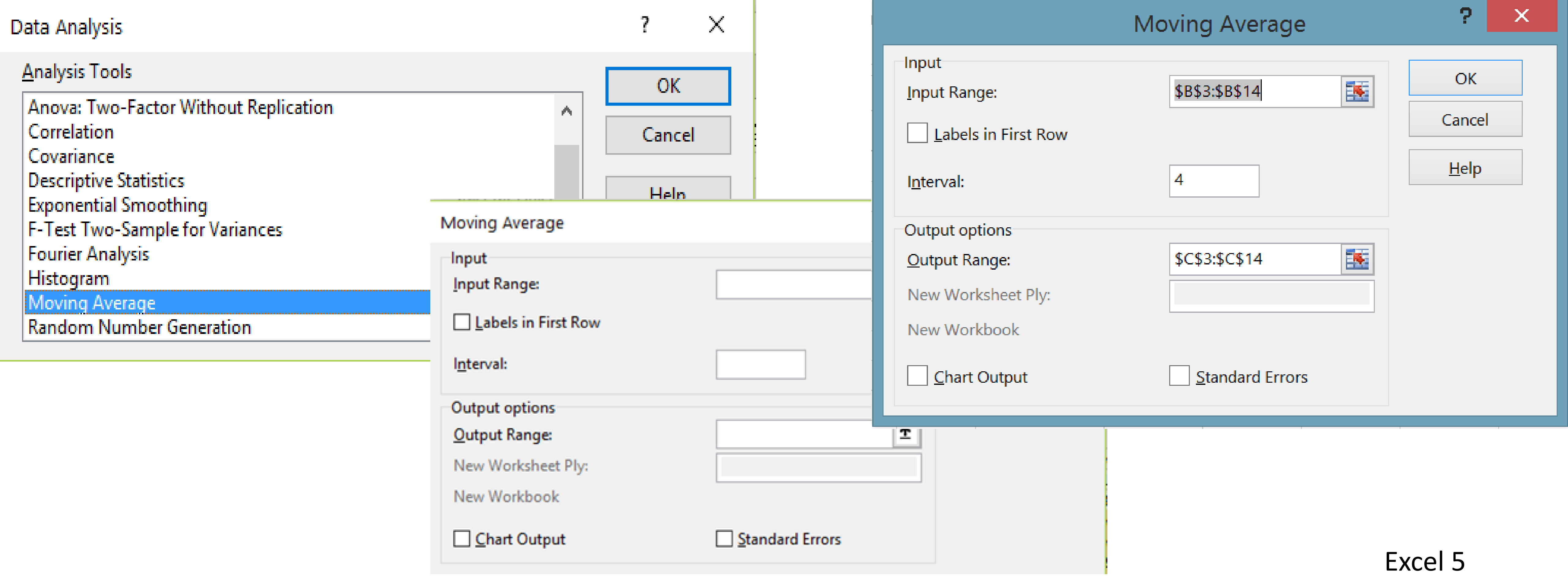
学会使用Excel Data Analysis Tool

如何在Excel表里添加Data Analysis tool？

File ->Options -> Add-ins -> Analysis ToolPack -> Manage -> Go -> Ok.







Excel 5

使用Excel Data Analysis Tool 设置 Moving Average Model

	b. 5-month moving average							
22	Month	Contribution	A(t)	F(t)	Error	Abs. Error	Sq. Error	% Error
23	1	1,074,844	#N/A					
24	2	780,433	#N/A					
25	3	1,082,218	#N/A					
26	4	1,009,653	#N/A					
27	5	1,066,739	1,002,777					
28	6	1,297,010	1,047,211	1,002,777	294,233	294,233	86,572,822,902.76	22.7%
29	7	978,685	1,086,861	1,047,211	(68,526)	68,526	4,695,757,855.36	7.0%
30	8	1,108,218	1,092,061	1,086,861	21,357	21,357	456,121,449.00	1.9%
31	9	1,019,778	1,094,086	1,092,061	(72,283)	72,283	5,224,832,089.00	7.1%
32	10	999,380	1,080,614	1,094,086	(94,706)	94,706	8,969,226,436.00	9.5%
33	11	1,041,070	1,029,426	1,080,614	(39,544)	39,544	1,563,743,753.64	3.8%
34	12	821,189	997,927	1,029,426	(208,237)	208,237	43,362,731,463.84	25.4%
35				997,927		MAD	MSE	MAPE
36						87,225	11,915,331,038	9.5%

7-month moving average							
Month	Contribution	A(t)	F(t)	Error	Abs. Error	Sq. Error	% Error
1	1,074,844	#N/A					
2	780,433	#N/A					
3	1,082,218	#N/A					
4	1,009,653	#N/A					
5	1,066,739	#N/A					
6	1,297,010	#N/A					
7	978,685	1,041,369					
8	1,108,218	1,046,137	1,041,369	66,849	66,849	4,468,807,900.73	6.0%
9	1,019,778	1,080,329	1,046,137	(26,359)	26,359	694,774,287.76	2.6%
10	999,380	1,068,495	1,080,329	(80,949)	80,949	6,552,694,344.51	8.1%
11	1,041,070	1,072,983	1,068,495	(27,425)	27,425	752,114,953.65	2.6%
12	821,189	1,037,904	1,072,983	(251,794)	251,794	63,400,146,494.88	30.7%
			1,037,904		MAD	MSE	MAPE
					90,675	15,173,707,596	10.0%

4个月的预测模式error: 9.9%
5个月的预测模式error: 9.5%
7个月的预测模式error: 10%

对比4-month, 5-month 和 7-month 移动平均值预测，诊断预测准确性(error越低，预测越准确)。因此，可以看出该产品的预测最佳时间周期为5个月。

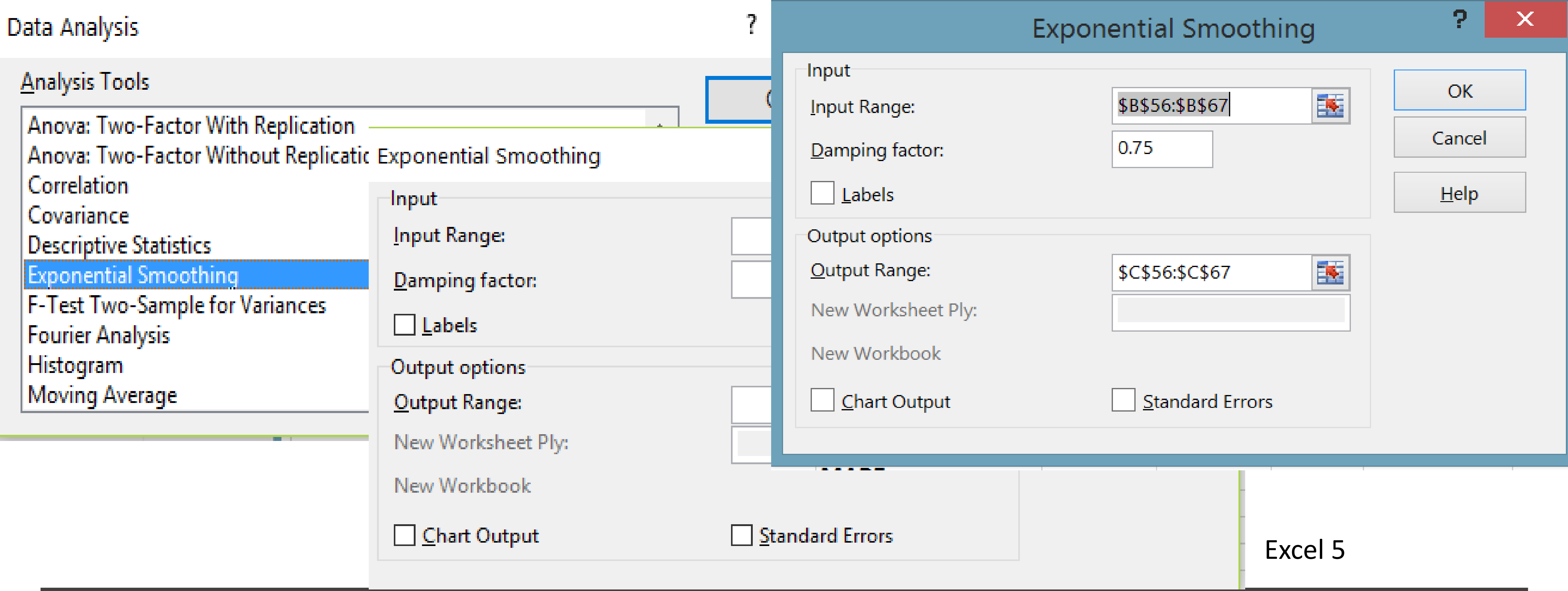
Excel 5

需求预测的主要模型(Exponential Smoothing)

手算： 公式 Ft+1=a*A(t)+(1-a)Ft

54	c. Using exponential smoothing with a=0.25						
55	Month	Contribution	F(t)	Error	Abs. Error	Sq. Error	% Error
56	1	1,074,844	#N/A				
57	2	780,433	1,074,844	(294,411)	294,411	86,677,836,921	37.7%
58	3	1,082,218	1,001,241	80,977	80,977	6,557,234,041	7.5%
59	4	1,009,653	1,021,485	(11,832)	11,832	140,006,577	1.2%
60	5	1,066,739	1,018,527	48,212	48,212	2,324,365,305	4.5%
61	6	1,297,010	1,030,580	266,430	266,430	70,984,813,767	20.5%
62	7	978,685	1,097,188	(118,503)	118,503	14,042,886,250	12.1%
63	8	1,108,218	1,067,562	40,656	40,656	1,652,909,244	3.7%
64	9	1,019,778	1,077,726	(57,948)	57,948	3,357,971,871	5.7%
65	10	999,380	1,063,239	(63,859)	63,859	4,077,972,846	6.4%
66	11	1,041,070	1,047,274	(6,204)	6,204	38,492,788	0.6%
67	12	821,189	1,045,723	(224,534)	224,534	50,415,603,264	27.3%
68			989,590		MAD	MSE	MAPE
69					78,640	11,908,590,003	8.7%

Excel 5



Excel 5

使用Excel Data Analysis Tool
设置 Exponential Smoothing Model

如何用Excel检验预测数据的精确性 *Mean Error, MAD, MSE, RMSE, MAPE*。
案例实操：A公司开发一项产品，对该产品有三种不同的预测数据，都基于过去20个星期。
1. 求预测1、2、3数据的MAD。
2. 求预测1、2、3数据的RMSE。
3. 三组预测中,哪一组最不精准?
4. 基于第三组预测,求出调整后的预测数据, 及其MAD。

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2							Difference			Error Absolute=MAD			Error^2=MSE		
3		Week	Demand	Forecast 1	Forecast 2	Forecast 3	Forecast 1	Forecast 2	Forecast 3	Forecast 1	Forecast 2	Forecast 3	Forecast 1	Forecast 2	Forecast 3
4		1	202	201	217	181	-1	15	-21	1	15	21	1	225	441
5		2	198	203	219	180	5	21	-18	5	21	18	25	441	324
6		3	201	205	220	179	4	19	-22	4	19	22	16	361	484
7		4	196	207	219	182	11	23	-14	11	23	14	121	529	196
8		5	200	209	221	183	9	21	-17	9	21	17	81	441	289
9		6	203	211	219	181	8	16	-22	8	16	22	64	256	484
10		7	210	213	218	186	3	8	-24	3	8	24	9	64	576
11		8	220	215	220	188	-5	0	-32	5	0	32	25	0	1024
12		9	226	217	219	198	-9	-7	-28	9	7	28	81	49	784
13		10	234	219	220	213	-15	-14	-21	15	14	21	225	196	441
14		11	231	221	222	219	-10	-9	-12	10	9	12	100	81	144
15		12	237	223	223	218	-14	-14	-19	14	14	19	196	196	361
16		13	238	225	224	216	-13	-14	-22	13	14	22	169	196	484
17		14	233	227	220	218	-6	-13	-15	6	13	15	36	169	225
18		15	235	229	221	217	-6	-14	-18	6	14	18	36	196	324
19		16	228	231	219	215	3	-9	-13	3	9	13	9	81	169
20		17	223	233	219	214	10	-4	-9	10	4	9	100	16	81
21		18	230	235	223	214	5	-7	-16	5	7	16	25	49	256
22		19	233	237	222	210	4	-11	-23	4	11	23	16	121	529
23		20	226	239	220	212	13	-6	-14	13	6	14	169	36	196
24										Forecast 1	Forecast 2	Forecast 3			
25							Mean Absolute Deviation(MAD)			7.7	12.25	19.0			
26							Mean-Squared Error(MSE)			75.2	185.2	390.6			
27							Root-Mean-Squared Error (RMSE)			8.67	13.61	19.76			
28															
29															

Excel 6

Adjusted Forecast example based on F3

Demand	Forecast 3	MAD	plus/minus	Adjusted F3	Error	ABS Error	S Error^2=MSE
202	181	19	19	200	2	2	4
198	180	19	19	199	-1	1	1
201	179	19	19	198	3	3	9
196	182	19	19	201	-5	5	25
200	183	19	19	202	-2	2	4
203	181	19	19	200	3	3	9
210	186	19	19	205	5	5	25
220	188	19	19	207	13	13	169
226	198	19	19	217	9	9	81
234	213	19	19	232	2	2	4
231	219	19	19	238	-7	7	49
237	218	19	19	237	0	0	0
238	216	19	19	235	3	3	9
233	218	19	19	237	-4	4	16
235	217	19	19	236	-1	1	1
228	215	19	19	234	-6	6	36
223	214	19	19	233	-10	10	100
230	214	19	19	233	-3	3	9
233	210	19	19	229	4	4	16
226	212	19	19	231	-5	5	25
						4.4	29.6

Excel 6

Adjusted Forecast example based on F3

	F3	Error	ABS Error	ABS Error^2=MSE
	21	2	2	4
	18	-1	1	1
	22	3	3	9
	14	-5	5	25
	17	-2	2	4
	22	3	3	9
	24	5	5	25
	32	13	13	169
	28	9	9	81
	21	2	2	4
	12	-7	7	49
	19	0	0	0
	22	3	3	9
	15	-4	4	16
	18	-1	1	1
	13	-6	6	36
	9	-10	10	100
	16	-3	3	9
	23	4	4	16
	14	-5	5	25
Mean Error (ME)	19			
New Adjusted Forecast(MAD)			4.40	
New Adjusted Mean-Squared Error(MSE)			29.60	
New Adjusted Forecast(RMSE)			5.44	

学习目的:
如何计算预测的精确性，那些测量值作为测量。

如何使用MAD/ME来进行Adjusted Forecast。

如何使用What If功能，锁定原有预测数量和ME的关系，加或减。

求得新预测数量，再用测量值检测。

Adjusted Forecast example based on F2

Demand	Forecast 2	MAD	plus/minus	Adjusted F2	Error	ABS Error	Error^2=MSE
202	217	12.3	-12.25	204.75	-2.75	2.75	7.5625
198	219	12.3	-12.25	206.75	-8.75	8.75	76.563
201	220	12.3	-12.25	207.75	-6.75	6.75	45.563
196	219	12.3	-12.25	206.75	-10.75	10.75	115.56
200	221	12.3	-12.25	208.75	-8.75	8.75	76.563
203	219	12.3	-12.25	206.75	-3.75	3.75	14.063
210	218	12.3	-12.25	205.75	4.25	4.25	18.063
220	220	12.3	-12.25	207.75	12.25	12.25	150.06
226	219	12.3	12.25	231.25	-5.25	5.25	27.563
234	220	12.3	12.25	232.25	1.75	1.75	3.0625
231	222	12.3	12.25	234.25	-3.25	3.25	10.563
237	223	12.3	12.25	235.25	1.75	1.75	3.0625
238	224	12.3	12.25	236.25	1.75	1.75	3.0625
233	220	12.3	12.25	232.25	0.75	0.75	0.5625
235	221	12.3	12.25	233.25	1.75	1.75	3.0625
228	219	12.3	12.25	231.25	-3.25	3.25	10.563
223	219	12.3	12.25	231.25	-8.25	8.25	68.063
230	223	12.3	12.25	235.25	-5.25	5.25	27.563
233	222	12.3	12.25	234.25	-1.25	1.25	1.5625
226	220	12.3	12.25	232.25	-6.25	6.25	39.063
						4.925	35.088

Excel 6

实操二: EOQ 订单量和供应商提供采购折扣量之间的选择和运算。

2) EOQ 订单量和供应商提供采购折扣量之间的选择和运算。 Excel 7

计算EOQ与订单相关的成本及公式：

Total purchase cost = $c\mu$

$$Q* = \sqrt{\frac{2K\mu}{h}}$$

Average inventory in an EOQ model is $\frac{Q}{2}$

Total holding cost = holding cost * average inventory = $h\frac{Q}{2}$

ordering cost $\frac{\mu K}{Q}$

$\Pi(Q)$ is the sum of the ordering cost $\frac{\mu K}{Q}$, purchase cost $c\mu$, and holding cost $\frac{hQ}{2}$.

c为采购成本。
μ为平均需求量。
Q为常规订单量；Q*为最佳订单量。如，Q= μ*L； scientific Q*=SQRT((2*K* μ)/h)
h为库存成本：一般是以每个产品计量成本，如: $0.2/per unit/month; 或按时间计量，如：%10库存年成本。
K为订单成本：一般是指每次下订单的固定成本。

案例实操：假设A公司要采购一个模组用于他们的产品上。模组成本每个是$500。公司使用EOQ模式决定采购量。他们观测到年平均销售量是4000台产品，固定订单操作的单一成本是$10,000；平均每个模组的年库存成本是$80。

1. 求Q*？ 1000
2. 基于Q*, 求年采购成本、年订单操作成本、年库存成本？PC= $2,000,000; OC=$40,000; H=$40,000
3. 假设工厂提供采购量达到2000个有5%折，如果公司选择折扣优惠，那么，他们的年采购成本、年订单操作成本、年库存成本又会是多少？ PC= $1,900,000; OC=$20,000; H=$80,000
4. 基于在Q*和折扣Q的数量，哪一个对于企业是最好的？折扣Q是最好的，因为可以节省$80,000一年。

Q1 Explanation

$$EOQ = \sqrt{\frac{2\mu K}{h}} = \sqrt{\frac{2*4000*10000}{80}} = \sqrt{1,000,000} = 1,000$$

Q2 Explanation

Annual Purchase cost = unit cost * demand = $c\mu$ = $500/unit * 4000 units = $2,000,000

Annual Ordering cost = ordering cost * demand / order quantity = $\frac{K\mu}{Q} = \frac{(\$10,000/order)*(4,000units)}{1000units/order} = \$40,000$

Annual Holding Cost = holding cost * average inventory = $h\frac{Q}{2}$ = $80/unit-year * 500 units = $\$40,000$

Q3 Using the same formulas:

Annual Purchase cost = $c\mu$ = ($500/unit*0.95) * 4000 units = $475 * 4000 = $1,900,000

Annual Ordering cost = $\frac{K\mu}{Q}$ = $10,000/order * (4,000 units) / (2000 units/order) = $20,000

Annual Holding Cost = holding cost * average inventory = $h\frac{Q}{2}$ = $80/unit/year * 1000 units * = $80,000/year

Excel 7

实操三: 两个或多个供应商的选择决策

3) 两个或多个供应商的选择决策。 Excel 8

在面对多个供应商的时候，我们通常会考虑交货周期(Deliver Lead-time), 成本(Cost), 质量(Quality)，那么如何把这些信息综合起来进行计算和对比呢？首先，我们来看看将涉及到的公式:

We can express the total land cost (TLC) as the following equation:

$$TLC = c + c_t + hL$$

c: 采购成本
Ct: 运输成本
h:一般指的pipeline inventory产生的成本。
Total Landed Cost (TLC)： 总到岸成本
TLC=purchase cost + transportation cost + pipeline holding cost (if have duty/tax need to add)

到岸成本(Landed cost)是指一批貨物或機器設備由國外進口過程中所發生的所有成本，除了貨物或機器設備本身的成本，還要加上倉儲、運輸、保險、關稅和文件處理等所有費用。

Total Expected Cost (TEC) 公式

Expected total cost = $\mu * TLC + h * (\frac{\mu r}{2} + z\sigma\sqrt{r+L})$

Therefore we only need to add the inventory holding cost for cycle stock and safety stock. Cycle stock is $\frac{\mu r}{2}$, and safety stock is $z\sigma\sqrt{r+L}$.

案例实操：我们有两种资源对一个产品的采购，一个是当地的供应商；另一种是外海的供应商。
以下是关键数据：

	Local supplier	Distant supplier
Cost per unit, c	$1.25	$1.00
Lead time, L, week	2	12
Transportation cost per unit, ct	$0.12	$0.15
Demand of mu, week	100	
Demand of sigma,week	40	
Holding cost, h,week	$0.02	

求：
1. 两个供应商的TLC?
2. 假如，我们每两周清点库存（r=2)，安全系数值为2 (z=2)，周期(L)不同，求基数库存。
3. 计算总成本 Expected Total Cost (ETC)
4. 对比哪一个方案最佳？

Excel 8

Excel 8

Q1 Explanation

We can express the total land cost (TLC) as the following equation:

$TLC = c + c_t + hL$

Therefore, given the values in the table, the two suppliers would have the following total landed costs:

$TLC_{local} = 1.25 + 0.12 + 0.02 * 2 = 1.41$

$TLC_{distant} = 1.00 + 0.15 + 0.02 * 12 = 1.39$

Q2 Explanation

Recall the formula from periodic review:

$B = \mu(r + L) + z\sigma\sqrt{r + L}$

Therefore,

$B_{local} = 100 * (2 + 2) + 2 * 40 * \sqrt{2 + 2} = 400 + 160 = 560$

$B_{distant} = 100 * (2 + 12) + 2 * 40 * \sqrt{2 + 12} \approx 1400 + 300 = 1700$

Q3

Explanation

The total landed cost (TLC) accounts for the procurement cost, transportation cost, and inventory holding cost for the pipeline inventory for a single unit of the product.

Therefore we only need to add the inventory holding cost for cycle stock and safety stock.

Cycle stock is $\frac{\mu r}{2}$, and safety stock is $z\sigma\sqrt{r + L}$.

Therefore, the expected total cost can be calculated as:

Expected total cost = $\mu * TLC + h * (\frac{\mu r}{2} + z\sigma\sqrt{r + L})$

Plugging in the given values,

Local =

$\mu * TLC_{local} + h * (\frac{\mu r}{2} + z\sigma\sqrt{r + L_{local}}) = \backslash(1.41 * 100 + 0.02 * (\frac{100*2}{2} + 2 * 40 * \sqrt{2 + 2} = 141 + 0.02\,(100 + 160) = 146.2)$

Distant =

$\mu * TLC_{distant} + h * (\frac{\mu r}{2} + z\sigma\sqrt{r + L_{distant}}) = \backslash(1.39 * 100 + 0.02 * (\frac{100*2}{2} + 2 * 40 * \sqrt{2 + 12} = 139 + 0.02\,(100 + 300) = 147)$

总结：通过计算，我们预测了基数库存，通过基数库，基数库存的结果不同，主要是建立在两个供应商供货的周期不同。很显然，海外的供应商，距离长，时间久，所以库存需要大才能周转。

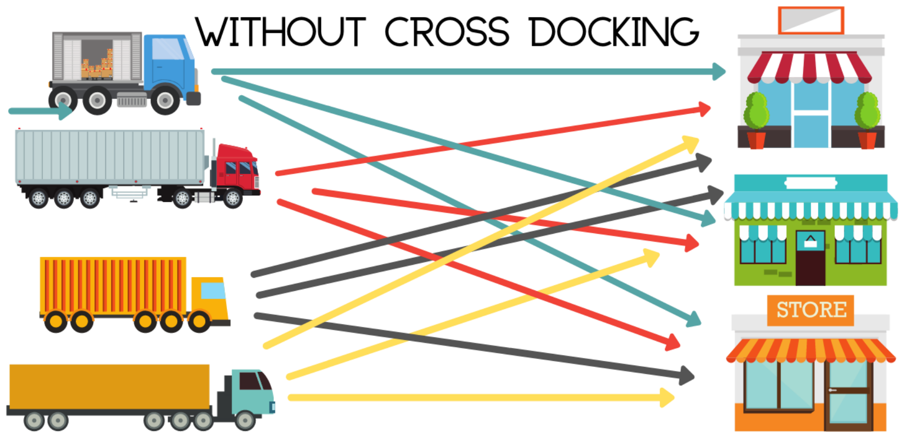
再看总成本价格，两个供应商价格相似，本土供应商为146.2；海外供应商为147。

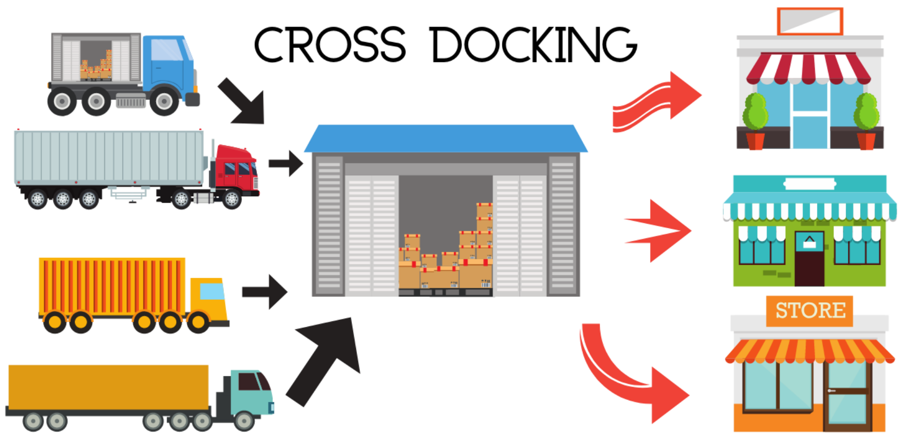
所以，分析此案例，从成本来看都是差不多的。就看公司是希望持有一定库存来应对紧急需求，还是希望J-I-T。

实操四: 直邮和越库模式区别及安全库存设置

4) 直邮和越库 (或称交叉停靠) 的模式及其区别，安全库存影响和成本计算。

- 中国已经成为世界工厂，在供给货物给海外客户的时候，这些海外客户是怎么来衡量和设计运输路线、仓库地理位置设定？该方法还可适用于以个公司层面对渠道、分销商、零售店等的货物物流运输路线及仓管地理位置设计。
- 首先，我们来看看什么是直邮和越库邮寄？解决此方案将涉及到的公式。





Cross-docking model

L1: 从工厂到物流中心

L2: 从物流中心到经销商或客户

由于货物在两个层面流动，运输周期(L)的不同，库房里涉及到的安全库存计算方式也会不同。

案例实操：假设一个电器的制造流程需要9周(L=9 wk)。电器最终供货给三个市场：北美、欧洲、亚太。该产品制造模式为Make-to-Stock，库存管理模式为周期性检测（每周检测）r=1 wk，采用基础库存方式管理运营。需求数据是正态分布，三个市场的平均需求及标准方差数如下。

关键数据表：

Excel 9

L,week	9	
z	2	
r	1	
Region	Mean/week	Std.v/week
NA	100	30
EU	80	24
APAC	150	45

直邮方式的安全库存计算公式：

$$\text{Safety Stock} = z\sigma\sqrt{r+L}$$

交叉停靠邮寄方式的安全库存计算公式：

$$\text{Safety Stock} = z\sigma\sqrt{r+\frac{L_1}{N}+L_2}$$

z: 安全系数(z=2,要实现98%的服务水平）
σ: 需求标准方差
r: 库存检测周期
L: 产品交货周期
- L1: 从工厂到物流中心
- L2: 从物流中心到经销商或客户

N: 可理解为渠道，市场，配发仓库（点）。
Cross-docking 公式里为什么要L1/N ?

求：
1. 算出三个区域的安全库存？（直邮情况下）
2. 假如使用交叉停靠方式，周期变为L1=6和L2=3，总安全库存会减少多少？
3. 假如使用交叉停靠方式，产品制作流程可以缩短为8周(L1=8), L2为1周(L2=1)，安全库存会减少多少？

Q1 Explanation

Safety Stock = $z\sigma\sqrt{r+L}$

North America = $z\sigma_{NA}\sqrt{r+L} = 2*30\sqrt{1+9} = 189.74 \approx 190$
Europe = $z\sigma_{Europe}\sqrt{r+L} = 2*24\sqrt{1+9} = 151.79 \approx 152$
Asia = $z\sigma_{Asia}\sqrt{r+L} = 2*45\sqrt{1+9} = 284.60 \approx 285$

Now that the customization can be delayed for 6 weeks, this can be modeled as a cross dock model of three, sharing a lead time of 6 weeks.
Therefore the safety stock for each product is:
Safety Stock = $z\sigma\sqrt{r+\frac{L_1}{N}+L_2}$, where
$L_1 = 6, L_2 = 3, N = 3$.

Q2 The new safety stock for three product groups are:

NA = $z\sigma_{NA}\sqrt{r+\frac{L_1}{N}+L_2} = 2*30\sqrt{1+\frac{6}{3}+3} = 60\sqrt{6} = 146.97 \approx 147$
Europe = $z\sigma_{Europe}\sqrt{r+\frac{L_1}{N}+L_2} = 2*24\sqrt{1+\frac{6}{3}+3} = 48\sqrt{6} = 117.58 \approx 118$
Asia = $z\sigma_{Asia}\sqrt{r+\frac{L_1}{N}+L_2} = 2*45\sqrt{1+\frac{6}{3}+3} = 90\sqrt{6} = 220.45 \approx 220$
Sum = $147+118+220 = 485$

The sum of safety stocks when the customization could not be delayed was $190+152+285 = 627$
Therefore, the reduced amount of safety stock is $627-485 = 142$.
If you did not round them, you can get 141.

Excel 9

Q3 **Explanation**

Now this can be modeled as a cross dock model of three, sharing a lead time of 8 weeks.

The safety stock for each product is:

Safety Stock = $z\sigma\sqrt{r + \frac{L_1}{N} + L_2}$, where

$L_1 = 8, L_2 = 1, N = 3.$

The new safety stock for three product groups are:

NA = $z\sigma_{NA}\sqrt{r + \frac{L_1}{N} + L_2} = 2 * 30\sqrt{1 + \frac{8}{3} + 1} = 60\sqrt{\frac{14}{3}} = 129.61 \approx 130$

Europe = $z\sigma_{Europe}\sqrt{r + \frac{L_1}{N} + L_2} = 2 * 24\sqrt{1 + \frac{8}{3} + 1} = 48\sqrt{\frac{14}{3}} = 103.69 \approx 104$

Asia = $z\sigma_{Asia}\sqrt{r + \frac{L_1}{N} + L_2} = 2 * 45\sqrt{1 + \frac{8}{3} + 1} = 90\sqrt{\frac{14}{3}} = 194.42 \approx 194$

Sum = $130 + 104 + 194 = 428$

The sum of safety stocks of the 6-week delayed customization was 485.

Therefore, the reduced amount of safety stock is $485 - 428 = 57$.

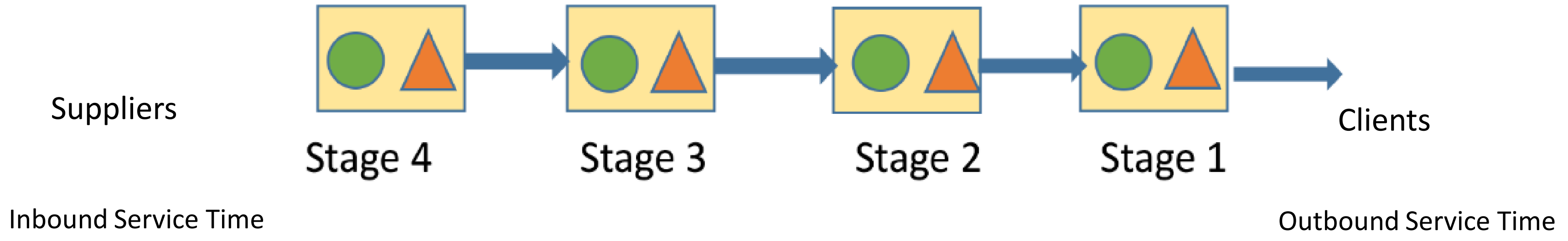
Excel 9

实操五: 生产制造中，将库存保存在不同产生阶段的效益和利润对比

5) 生产制造中，将库存保存在不同产生阶段的效益和利润对比。

- **Net Replenishment L/T (Tau) = SI + L – S**
- **上阶段服务时间 = SI: Inbound Service Time**
- **本阶段的运作时间=L: Stage Process Time**
- **提供服务给下一个阶段的时间 =S: Outbound Service Time**

- **在直线型生产流程中，通过上阶段outbound service time = 下阶段的 inbound service time.**
- **比如：**



首先，我们来看看将涉及到的公式:

Tau 4= S5+L-S4

Tau 3= S4+L-S3

Tau 2=S3+L-S2

Tau 1=S2+L-S1

Excel 10

案例实操：
假设，一个公司生产一个产品，需要四个工序。每个工序都需要储存一定库存，每个库存都存在不同的库存成本。假设，Stage1是供给对外客户(Stage 1 outbound service time =0)。假设，Stage 4收到供应商服务的时间为0, (Stage 4 inbound service time =0)。$D(s)=\mu*s + z* \sigma*sqrt(s)$，生产平均数为 $\mu=100$ per week, $\sigma = 30$ per week, $z = 2$. 假设库存管理成本是10%每年。

方案一：只在Stage 1设置库存，其他Stages无库存。
方案二：全部Stage都搁放库存。
方案三：只在首尾Stage 1 & Stage 4设置库存。

Excel 10

练习如下：
只在Stage 1设置库存，其他Stages无库存：
1) 求安全库存量? 268.33
2) 求全年库存成本（基于安全库存量上）？ $2683

Hold stock at last stage				hold stock
Stage	**4**	**3**	**2**	**1**
L/T,wk	10	5	3	2
Cost added ($/unit)	20	30	20	30
Cumulative Cost ($/unit)	20	50	70	100
S				0
SI/S	10	15	18	0
Net Replen L/T (Tau)	0	0	0	20
SS=E(I)	0	0	0	268.33
Holding cost 10%				
Annual holding cost				$2,683

S 1=	0	S(outbound service)
SI 4=	0	SI (inbound service)
Tau 4= S5+L-S4		
Tau 3= S4+L-S3		
Tau 2=S3+L-S2		
Tau 1=S2+L-S1		

Excel 10

练习如下：
方案二：全部Stage都搁放库存。
1）求在Stage 1上的安全库存是多少？84.85
2）求整个安全库存的库存成本是多少？$2626

New strategy - hold stock	hold stock	hold stock	hold stock	hold stock
Stage	**4**	**3**	**2**	**1**
L/T,wk	10	5	3	2
Cost added ($/unit)	$20	$30	$20	$30
Cumulative Cost ($/unit)	$20	$50	$70	$100
SI	0	0	0	0
Net Replen L/T (Tau)	10	5	3	2
SS	189.74	134.16	103.92	84.85
Holding cost/unit	$2	$5	$7	$10
Annual holding cost	$379	$671	$727	$849
Total annual holding cost				$2,626

When hold stage at all stage, we can assume service time=0, Tau=L+S(outbound service)

Excel 10

练习如下：
方案三：只在首尾Stage 1 & Stage 4设置库存。
1）求在Stage 1 & Stage 4 上的安全库存是多少？Stage 1= 189.74; Stage 2= 189.74
2）求整个安全库存的库存成本是多少？$2277

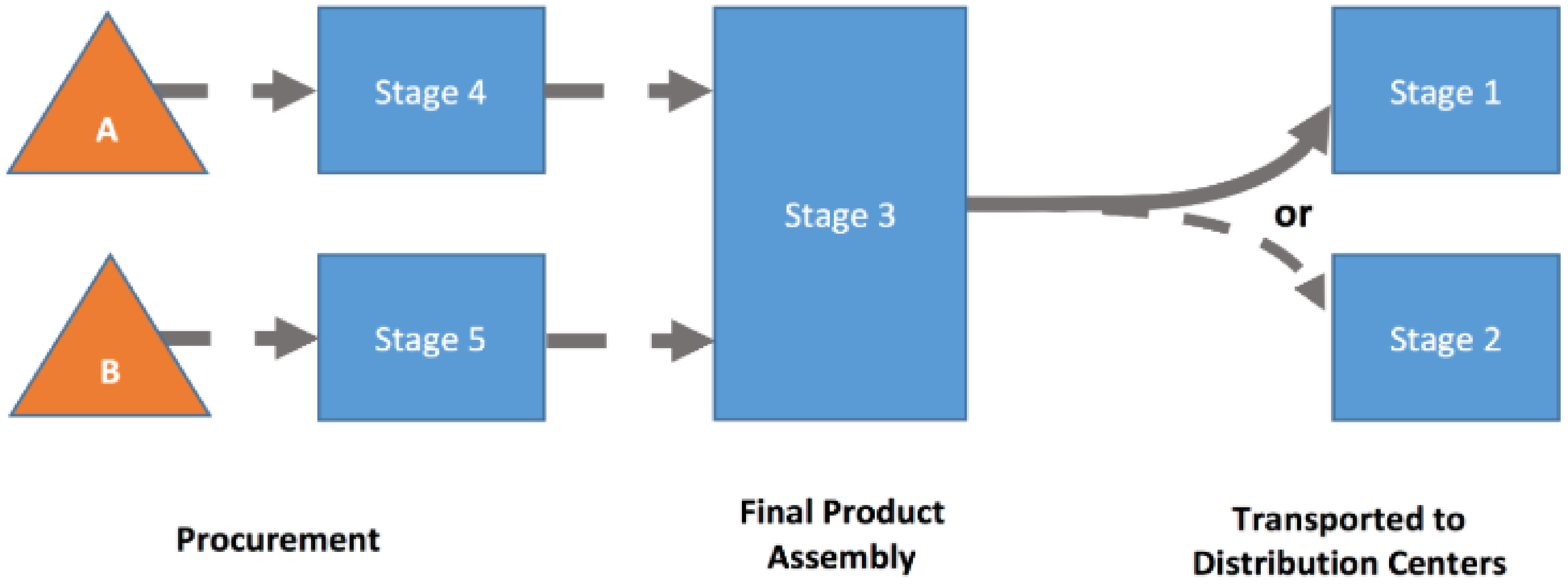
Only hold stock at stage 1 and 4	hold stock			hold stock	
Stage	**4**	**3**	**2**	**1**	
L/T,wk	10	5	3	2	
Cost added ($/unit)	$20	$30	$20	$30	
Cumulative Cost ($/unit)	$20	$50	$70	$100	
SI	0	5	8	0	
Net Replen L/T(Tau)	10	0	0	10	bc stage 4 and stage 1 hold inventory the inbound service time is assumed 0
SS	189.74	0.00	0.00	189.74	
Holding cost 10%	$379.47	$0.00	$0.00	$1,897.37	
Annual holding cost				$2,277	

Tau 3=3=SI3+L3+S3=0+5-0=5
Tau 2=0=SL2+L-S2=5+3-8=0
Tau 1=SI1+L1-S1=8+2-0=10

Excel 10

学习目的：学会Tea时间的计算。学会安全不可计算的公式以及库存在制造流程中，将累积成本作为库存成本计算参数的计算。用该方法，做出最佳库存储货的决策。

备选案例：多分流型系统的库存节省法



System Network Representation

详细计算见Excel 11

多分流型系统案例实操：
假设生产一个产品有五个阶段。两个元件阶段：Stage 4 采购元件A；Stage 5采购元件B；Stage 3是利用Stage 4和Stage 5的元件进行产品的组装。最后将产品输送到Stage 1或Stage 2进行对外打包运输, Stage 1代表的去欧洲的配发中心 Stage 2代表的去北美的配发中心。所以，可以理解为Stage 1和 Stage 2 外延供给对象就是客户。

采集的库存成本和每个阶段的运作时间(L) 关键数据如下：

Stage	5	4	3	2	1
Name	Component A	Component B	Assembly	N. America DC	Europe DC
Lead Time (weeks)	20	10	5	3	7
Cost Added ($/unit)	30	20	10	5	10

假设，Stage 1 和 Stage 2 库存的需求公式为
D(s)= μ *s + z*σ*sqrt (Tau)

采集的库存的需求数据为下：
z = 2
μ1 = 10
σ 1= 3
μ 2 = 20
σ 2= 4

详细计算见Excel 11

1）求Stage 3 的库存需求平均量和标准方差？

Explanation

Stage 3's demand would be the sum of two normally distributed random variables, Stage 1 with demand $X_1\ N(10, 3^2)$ and Stage 2 with demand $X_2\ N(20, 4^2)$.

Therefore, Stage 3's demand would also be normally distributed with parameters
$X_3\ N(10+20, 3^2+4^2) = N(30, 5^2)$

The safety factor z = 2 would remain constant.

					Assume demand bound: D(s)=μj *s+z*σj*sqr(s) , j=1,2	
				Stage1	z=	2
					mu1=	10
Stage3/4/5	mu3=	30			sigma1=	3
	sigma3=	5				
	z=	2		Stage2	mu2=	20
					sigma2=	4

详细计算见Excel 11

2）假设将所有Stages都设置库存，总库存成本将会是多少？

详细计计算见Excel 11

Explanation

Since we are having safety stock at each stage, each stage would have an outbound service time of 0.

Since the inbound service time of stage 4 is also 0, the net replenishment time for each stage is just the lead time of each stage.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
lead time	20	10	5	3	7
service time	0	0	0	0	0
net replen. time	20	10	5	3	7

Safety stock can be calculated as $z\sigma\sqrt{\tau}$. Now Stages 1 and 2 have different demand random variable, so the standard deviation of the demand, σ, is also different for each stage. We need to account for these different demand random variable parameters to calculate the correct amount of safety stock.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
net replen. time	20	10	5	3	7
demand mu	30	30	30	20	10
demand sigma	5	5	5	4	3

The value of the inventory at each stage is also different. Components A and B would have the added values, $30 and $20, but Stage 3 would have the two component values plus the added value of $10, total $60. Stage 4 and 5 would have $5 and $10 added to the value of Stage 3. The unit inventory value for each stage is shown in the table below:

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
cost added ($)	30	20	10	5	10
inven. value ($)	30	20	60	65	70

Therefore, the value of the entire safety stock in the system with the strategy of holding inventory at each stage is:

$$44.72*30+31.62*20+22.36*60+13.86*65+15.87*70=5237.4\approx 5327$$

3）假设将Stage 1, 2 和 Stage 3 设有库存，将会带动多少库存成本？

提示： S4=L4,S5=L5

详细计算见Excel 11

Explanation

Since we are having safety stock only at stages 1, 2, and 3, these three stages would have an outbound service time of 0.

On the other hand, stages 4 and 5 would have a net replenishment time of 0, since they would not be holding any inventory. Stage 3 assembles the two components from Stage 4 and 5, so the inbound service time for Stage 3 would be the maximum of the two outgoing service times of Stage 4 and 5, which is 20.

Therefore, the net replenishment time for Stage 3 is:

$$\tau_3 = max\,(SI_4, SI_5) + L_3 - S_3 = 20 + 5 - 0 = 25$$

The rest of the replenishment times are just the lead times of that stage.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
lead time	20	10	5	3	7
service time	20	10	0	0	0
net replen. time	0	0	25	3	7

Safety stock can be calculated as $z\sigma\sqrt{\tau}$. Now Stages 1 and 2 have different demand random variable, so the standard deviation of the demand, σ, is also different for each stage. We need to account for these different demand random variable parameters to calculate the correct amount of safety stock.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
net replen. time	0	0	25	3	7
demand mu	30	30	30	20	10
demand sigma	5	5	5	4	3
safety stock	0	0	50	13.86	15.87

The value of the inventory at each stage is also different. Components A and B would have the added values, $30 and $20, but Stage 3 would have the two component values plus the added value of $10, total $60. Stage 4 and 5 would have $5 and $10 added to the value of Stage 3. The unit inventory value for each stage is shown in the table below:

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
cost added ($)	30	20	10	5	10
inven. value ($)	30	20	60	65	70

Therefore, the value of the entire safety stock in the system with the strategy of holding inventory at each stage is:

$$0 + 0 + 50 * 60 + 13.86 * 65 + 15.87 * 70 = 5011.8 \approx 5012$$

We he

4）假设将所有Stages都放有库存，除了Stage 3置放库存，那么，总库存成本将会是多少？

详细计算见Excel 11

结果：通过对比，第三种情况 -- 所有Stage都搁置库存（除了Stage 3）不搁置库存为最优方案。

战略一：库存成本为$ 5328
战略二：库存成本为$ 5012
战略三：库存成本为$ 4900

Explanation

Since we are having safety stock at stages 1, 2, 4, and 5, these three stages would have an outbound service time of 0.

On the other hand, Stage 3 would have a net replenishment time of 0, since we would not have any inventory in the assembly stage. The outgoing service time of Stage 3 is:

$$\tau_3 = SI_3 + L_3 - S_3 = 0$$
$$S_3 = SI_3 + L_3 = 0 + L_3 = 5$$

This outgoing service time would be the incoming service time for Stage 1 and 2. The net replenishment times for all the stages are shown in the table below.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
lead time	20	10	5	3	7
service time	0	0	5	0	0
net replen. time	20	10	0	8	12

Safety stock can be calculated as $z\sigma\sqrt{\tau}$. Now Stages 1 and 2 have different demand random variable, so the standard deviation of the demand, σ, is also different for each stage. We need to account for these different demand random variable parameters to calculate the correct amount of safety stock.

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
net replen. time	20	10	0	8	12
demand mu	30	30	30	20	10
demand sigma	5	5	5	4	3
safety stock	44.72	31.62	0	22.63	20.78

The value of the inventory at each stage is also different. Components A and B would have the added values, $30 and $20, but Stage 3 would have the two component values plus the added value of $10, total $60. Stage 4 and 5 would have $5 and $10 added to the value of Stage 3. The unit inventory value for each stage is shown in the table below:

stage	5	4	3	2	1
name	comp. A	comp. B	Assembly	NA DC	Europe DC
cost added ($)	30	20	10	5	10
inven. value ($)	30	20	60	65	70

Therefore, the value of the entire safety stock in the system with the strategy of holding inventory at each stage is:

$$44.72 * 30 + 31.62 * 20 + 0 + 22.63 * 65 + 20.78 * 70 = 4899.55 \approx 4900$$

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