Maintenance Enterprise Resource Planning: Information Value among Supply Chain Elements

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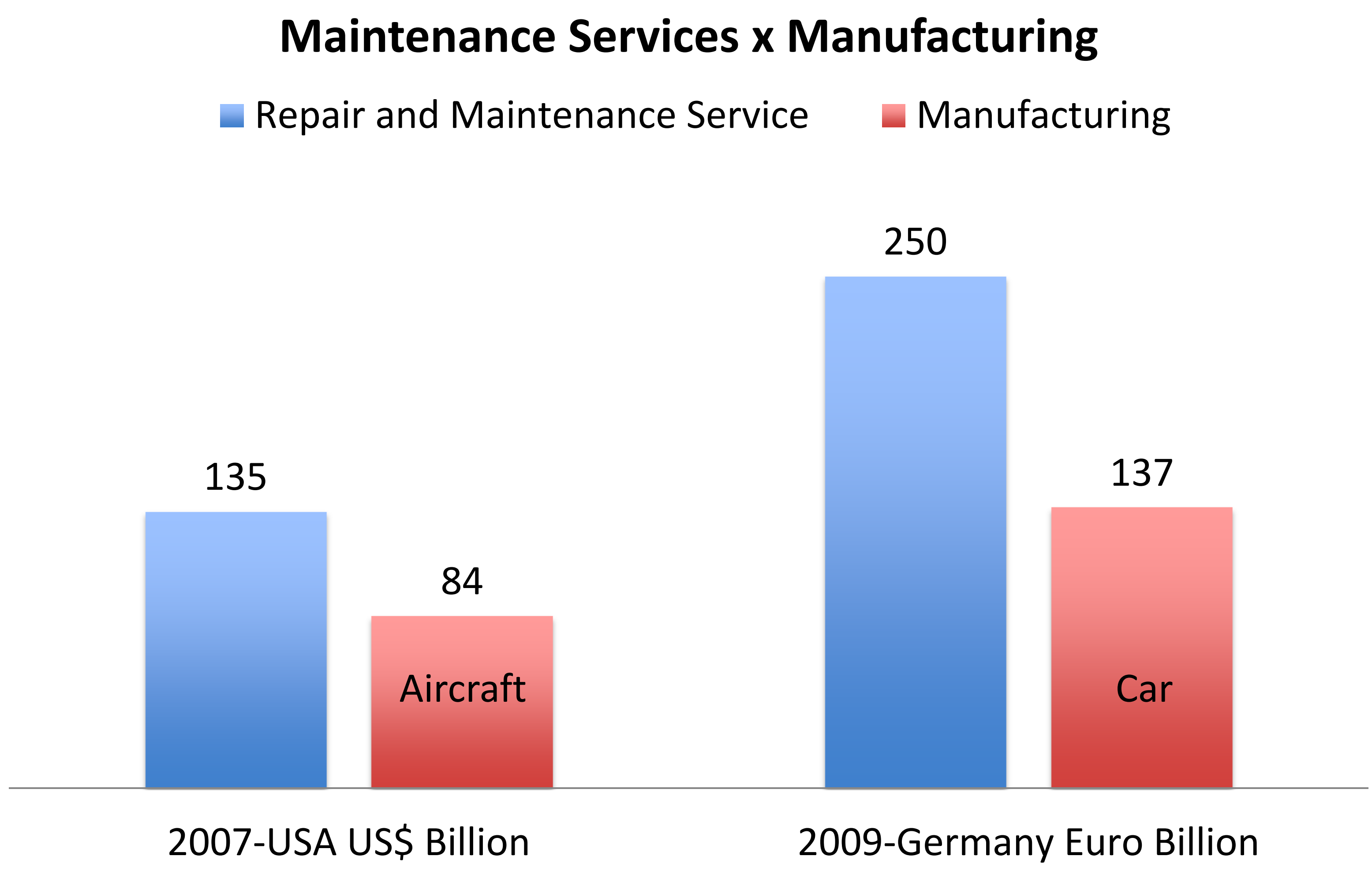
AGENDA

- Problem
- Foundation
- Model
- Experiment
- Result

Importance of Maintenance Area



(United States Census 2007)

(Fabry & Schimitz-Urban, 2010))

S
y
s
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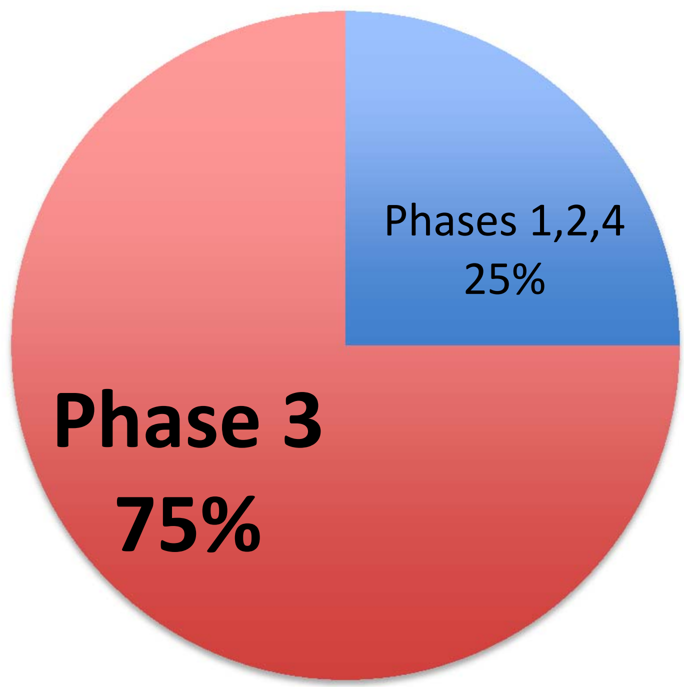
Identified need

Design and development
Production and/or construction
Operational usage and maintenance support
Retirement and material disposal

Life-Cycle Cost



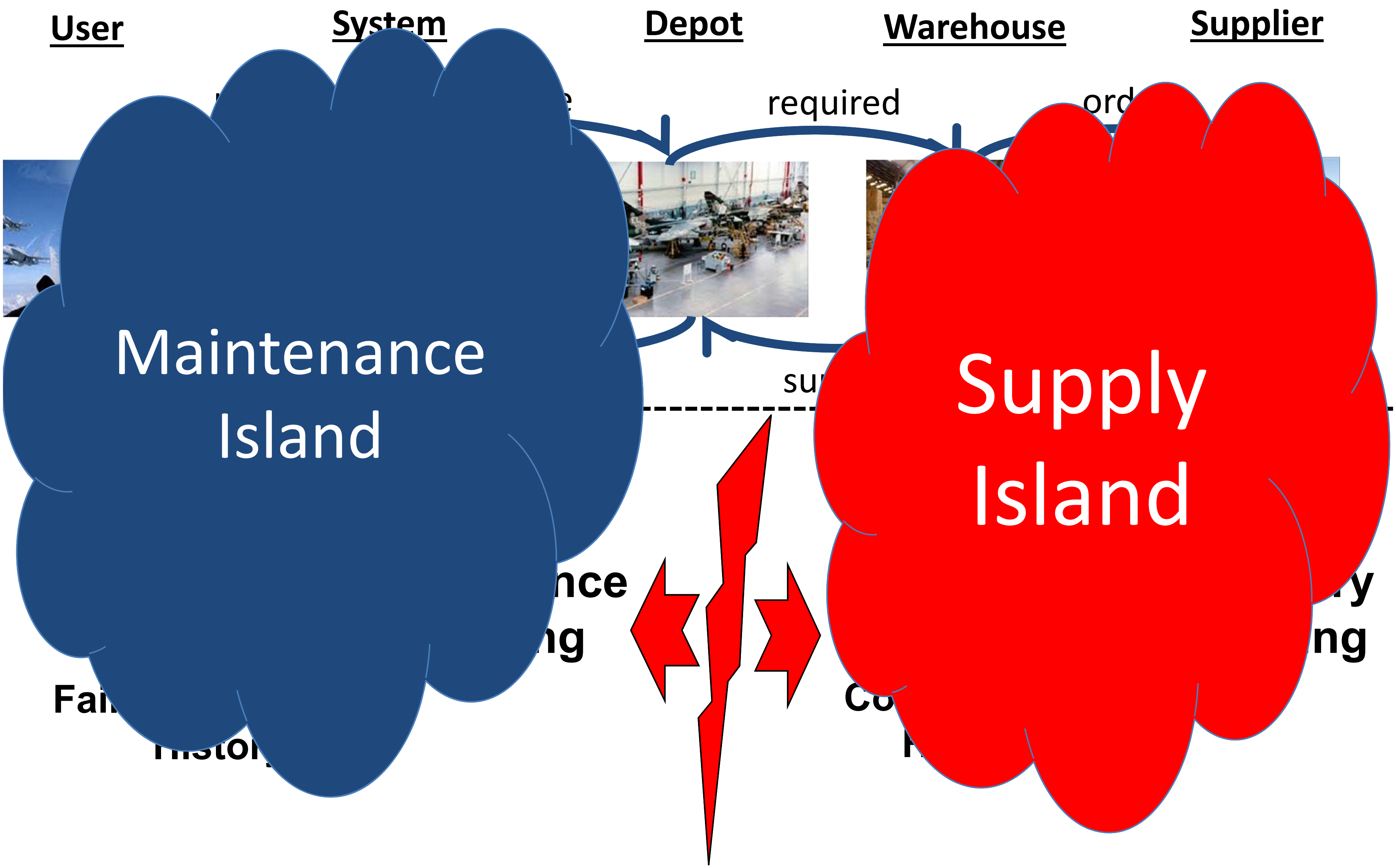
Blanchard (2004), pg 25

Maintenance Supply Chain

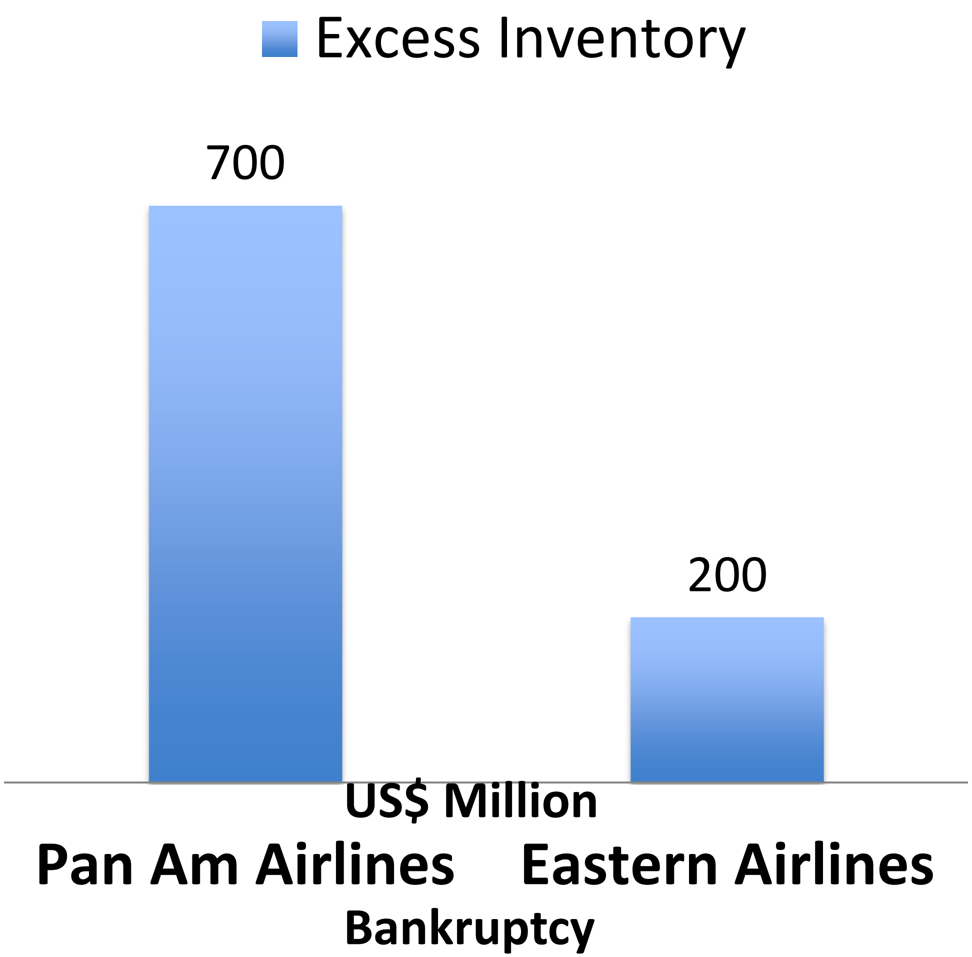
- Stochastic failure;
- Different types of failure to be repaired;
- Large number of spare parts for repair;
- Long lead-time to repair or to purchase spare parts;

Uncertainty

Maintenance Flow



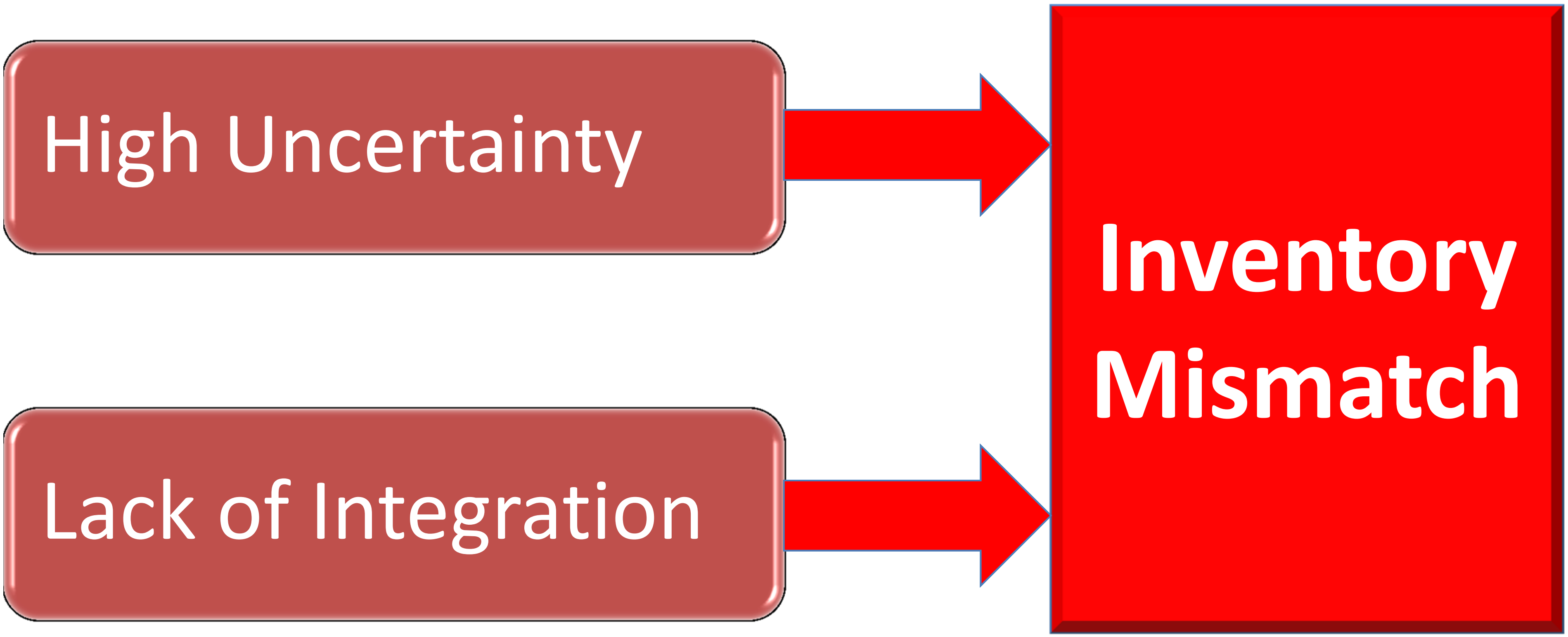
Excess Inventory



Ghobbar & Friend (2007)

Supply System Inventory Report, DoD (2009)

Research Problem



Success Organization

+ Uncertainty

March & Simon, 1993

Tushan & Nadler , 1978

Information Processing

Information Processing Theory (IPT) (Galbraith)

Lower Process Capability

- Lack of Integration
- Technology Limitation

- Buffers
- Self-Contained Tasks

EOQ/ROP

High Capability of Process

- Network Integration
- Fast Processing power

- Integrated Lateral and Vertical information

MERP

Related Studied

- Levitt et al (1999, 2007, 2012)
  - Extend IPT to internal organization dynamic's ;
- Posey & Bari (2009), Flynn & Flynn(1999), Swanson (2003), Bolon (1998), Oosterhuis, Vaart, & Molleman (2011)
  - Relation among the elements of Supply Chain focused on organization design and decision-make
- Need to extend Galbraith Theory with focus on information integration in Supply Chain elements

EOQ and MRP

- EOQ/ROP
  - Independent Demand
  - High Safety Stock
  - Static Plan
- MRP
  - Independent/Dependent Demand
  - Low Safety Stock
  - Dynamic Plan

Related Studied

- Ghobbar & Friend (2007)
  - Airlines companies were not satisfied with inventory control system
- Newman (1985)
  - proposed that M= Preventive Maintenance to MRP .
- Molinder (1997)
  - Used simulation to study uncertainty in MRP systems
- Cohen, Agrawal, & Agrawal, 2006
  - ERP software without customization deliver poor service(Cohen, Agrawal, & Agrawal, 2006).
- Need to deliver a theoretical model of Maintenance Supply Chain.

Research Objective

Proposal

- To test a new information integration model for maintenance supply chain elements to match inventory with maintenance requirements.

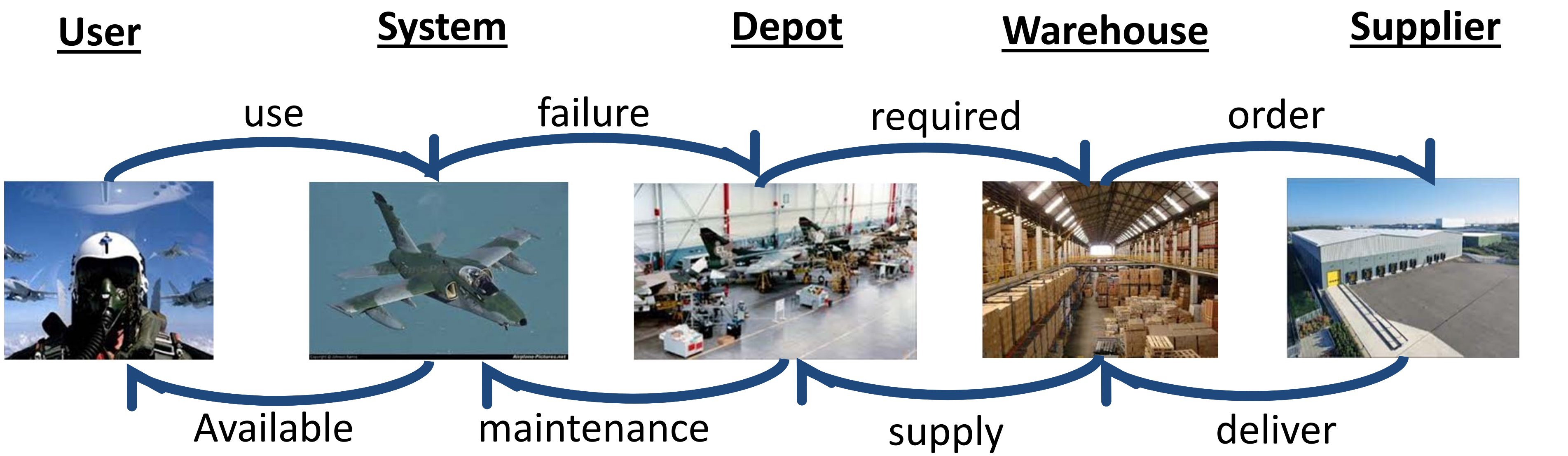
Hypothesis

- Information integration in Maintenance Supply Chain lowers inventory costs compared to Traditional Inventory Models

Factorial Design 2x6

Independent Variable	Models	
# Maintenance Events	**MERP**	**EOQ/ROP**
High	Inventory Cost	Inventory Cost
Medium-High	Inventory Cost	Inventory Cost
Medium	Inventory Cost	Inventory Cost
Low-Medium	Inventory Cost	Inventory Cost
Low	Inventory Cost	Inventory Cost
Very low	Inventory Cost	Inventory Cost

Maintenance Flow



Maintenance Planning

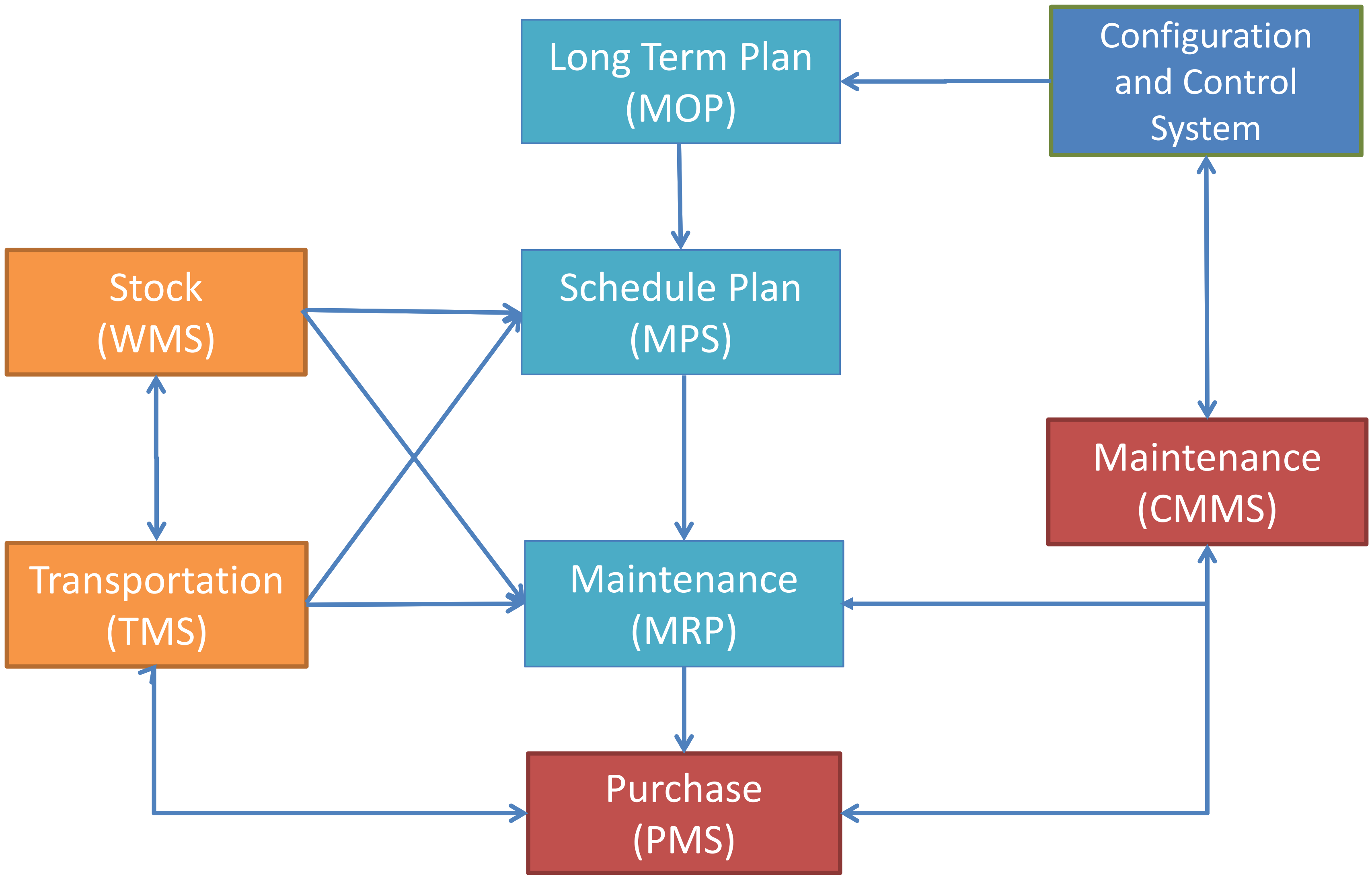
Projection of usage, Failure Rate

Information Integration

Inventory Planning

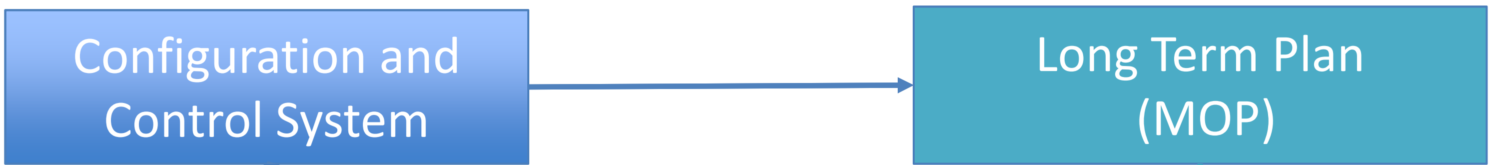
Based in Maintenance Planning and Maintenance Material

MERP Model



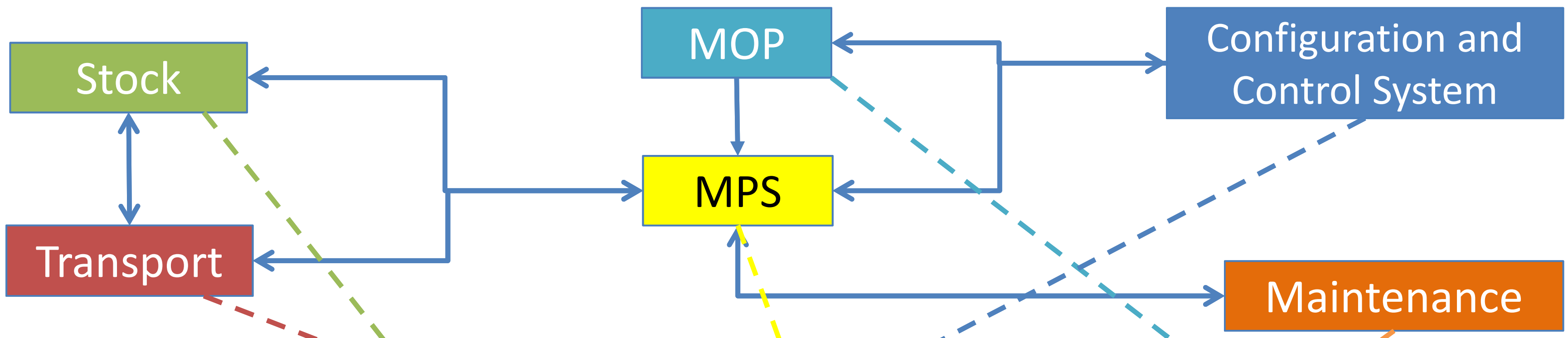
Long Term Plan (MOP)
Configuration and Control System
Stock (WMS)
Schedule Plan (MPS)
Maintenance (CMMS)
Transportation (TMS)
Maintenance (MRP)
Purchase (PMS)

Maintenance Quantity Forecast



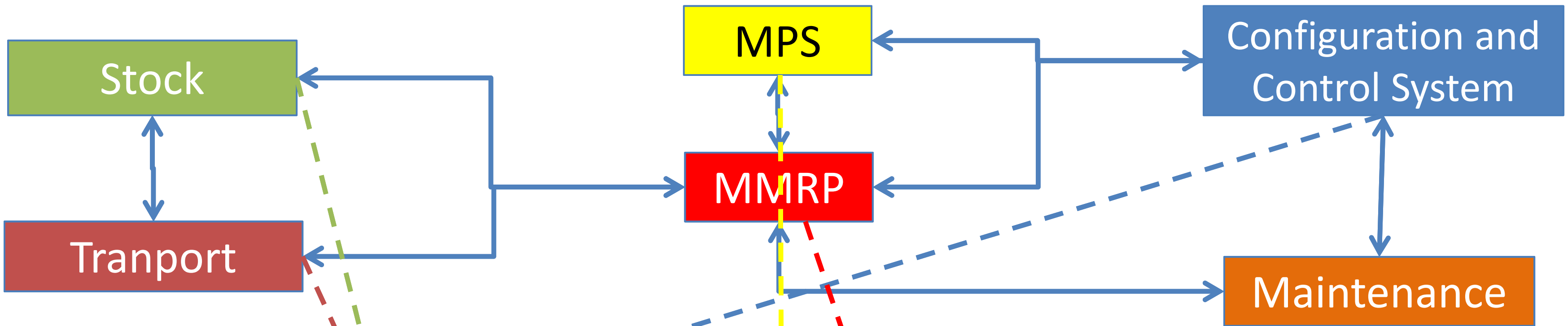
Generator	QPA	# of aircraft	Utilization per Month	MTBUR	TBO	duration	Average Corr	Average Prev	Protection level	Qty MNT Corr	Qty MNT Prev	Cost Man Corr	Cost Man Prev	Total
				1000	3000				0.9			2000	5000	
	X	y	k	λ	z	t	$\mu = x y k \lambda t$	$\mu = x y k z t$						
2014	2	40	35	0.001	0.000333333	12	33.6	11.2	0.9	41	12	82000	60000	142000
2015	2	40	40	0.001	0.000333333	12	38.4	12.8	0.9	46	13	92000	65000	157000
2016	2	40	**45**	0.001	0.000333333	**12**	43.2	14.4	0.9	52	15	104000	75000	179000

Maintenance Schedule



2014	Generator	Period	Dec-13	1	2	3	4	5	6	7	8	9	10	11	12	Total
		Maintenance		5	5	5	5	5	4	4	4	4	4	4	4	53
Maintenance Time	1	Exp'd Service Order Completion		3												
Lot Size	1	Stock Before		4	2	1	1	1	1	1	1	1	1	1	1	
Safety Stock	1	Stock After	4	2	1	1	1	1	1	1	1	1	1	1	1	
		Rec. Ord		0	4	5	5	5	4	4	4	4	4	4	4	
Proportion		Service Order		4	5	5	5	4	4	4	4	4	4	4	4	51
11.54717	0.226415	Prev Serv Order		1	1	1	1	1	1	1	1	1	1	1	1	12
39.45283	0.773585	Corr Serv Order		3	4	4	4	3	3	3	3	3	3	3	3	39

Maintenance Material Requirement Planning



2014	Part A	Period	Dec	1	2	3	4	5	6	7	8	9	10	11	12
QPA	**Probability**														
12	0.8	Engine. Unscheduled Maintenance		15	12	12	12	12	12	12	12	12	12	12	12
10	0.6	Gen. Preventive Maintenance		6	6	6	6	6	6	6	6	6	6	6	6
5	0.5	Gen. Corrective Maintenance		7.5	10	10	10	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
		Demand Total		28.5	28	28	28	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
Lead Time	6	Pred Rec Material		40	30	20	20	20							
Lot Size	12	Stock Before		15	26.5	28.5	20.5	12.5	7	-18.5	16	14.5	13	23.5	22
Safety Stock	6	Stock After	15	26.5	28.5	20.5	12.5	7	-18.5	16	14.5	13	11.5	10	8.5
		Rec. Ord		0	0	0	0	0	0	60	24	24	24	24	24
		Purchase Order		60	24	24	24	24	24	0	0	0	0	0	0

Simulation Experiment

- Simulate equipment use, maintenance and consumption of material with uncertainty
- Calculates 50 samples for each quadrant of the factory design

- EOQ/ROP

$$EOQ = \sqrt{\frac{2KD}{H}}$$

$$ROP = Lt * \bar{D} + z * STD * \sqrt{Lt}$$

SL=90%, Z=1.29

- MERP
  - Lot Size:

$$EOQ = \sqrt{\frac{2K\bar{D}}{H}}$$

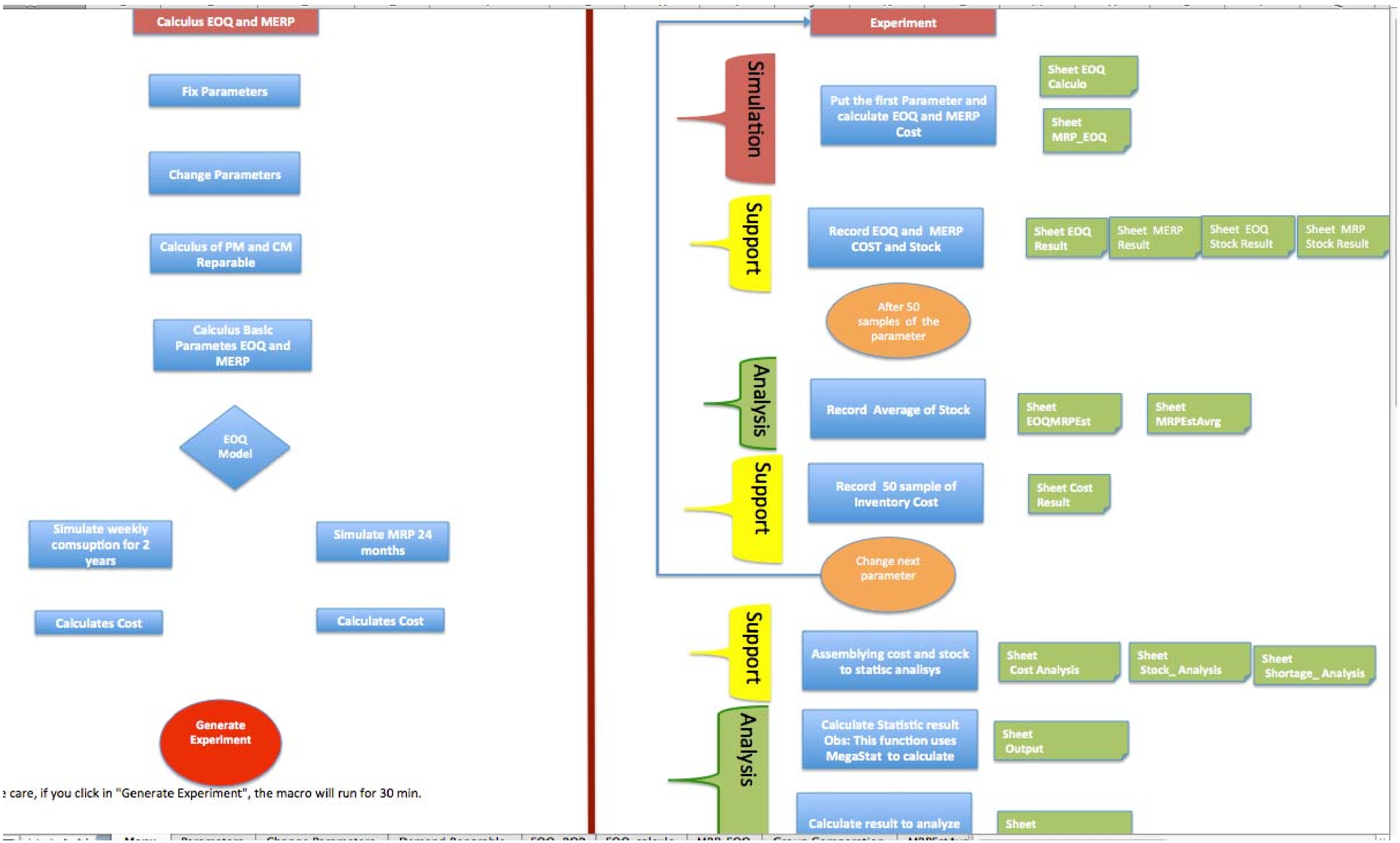
- Maintenance Event

Range
High
Medium High
Medium
Low Medium
Low
Very Low

Simulation

Calculus

Simulation and Analysis



Calculate qty of Preventive and Corrective Maintenance

? | Menu | ?

Calculus of Qtd of Corrective and Preventive Maintenance

Generator	QPA	# of aircraft	Utilization per Month	MTBUR	TBO	duration	Average Corr	Average Prev	Protection level	Qtdt MNT Corr	Qtt MNT Prev
									0.9	$p(k;\lambda)=\frac{\lambda^k}{k!}e^{-\lambda}$	
	X	**y**	**k**	**λ**	**z**	**t**	**μ = x y k λ t**	**μ = x y k z t**			
y-2	2.00	300	125.00	0.00020	0.00033	12	180.00	300.00	0.90	197.000	300.000
y-1	2.00	300	125.00	0.00020	0.00033	12	180.00	300.00	0.90	197.000	300.000
y	2.00	300	125.00	0.00020	0.00033	12	180.00	300.00	0.90	197.000	300.000
y+1	2.00	300	125.00	0.00020	0.00033	12	180.00	300.00	0.90	197.000	300.000
										197.1938185	

Proportion Calculation		?	Proportion	
Weekly	**Mnt Corr Weekly**	**MNT Prev Weekly**	**Corrective**	**Preventive**
y-2	3.79	5.77	0.40	0.60
y-1	3.79	5.77	0.40	0.60
y	3.79	5.77	0.40	0.60
y+1	3.79	5.77	0.40	0.60

Simulate Maintenance and Consumption with Uncertainty

oisson Distribution of Maintenance		Calculus of Spare parts			Calculus Parameters EOQ					
Preventive Maintenace-PM	Corretive Maintenance-CM	Spart Parts		D Real	Average Den	STDeviation	Safety Stock	ROP	EOQ	Uncertanty Demand
5.77	3.79									
5.77	3.79									
5.77	3.79	PN A								
5.77	3.79	Demand PM	Demand CM							
5.77	3	57.69	24	81.6923077	81.69					92.69
5.77	4	57.69	32	89.6923077	81.69					83.69
5.77	4	57.69	32	89.6923077	85.69					87.69
5.77	5	57.69	40	97.6923077	87.03					98.69
5.77	1	57.69	8	65.6923077	89.69					67.69
5.77	4	57.69	32	89.6923077	85.69					85.69
5.77	5	57.69	40	97.6923077	85.69					108.69
5.77	0	57.69	0	57.6923077	87.69					57.69
5.77	5	57.69	40	97.6923077	77.69					93.69
5.77	2	57.69	16	73.6923077	85.69					77.69
5.77	3	57.69	24	81.6923077	81.69					83.69
5.77	3	57.69	24	81.6923077	77.69					84.69
5.77	3	57.69	24	81.6923077	83.69					82.69
5.77	2	57.69	16	73.6923077	79.69					75.69
5.77	7	57.69	56	113.692308	79.69					111.69
5.77	3	57.69	24	81.6923077	87.69					75.69
5.77	3	57.69	24	81.6923077	87.69					89.69
5.77	5	57.69	40	97.6923077	87.69					97.69
5.77	1	57.69	8	65.6923077	93.69					61.69
5.77	2	57.69	16	73.6923077	81.69					71.69
5.77	2	57.69	16	73.6923077	79.69					74.69
5.77	1	57.69	8	65.6923077	77.69					63.69
5.77	3	57.69	24	81.6923077	69.69					89.69
5.77	3	57.69	24	81.6923077	73.69					74.69
5.77	5	57.69	40	97.6923077	75.69	7.66	19.63	322.40	310.82	94.69
5.77	4	57.69	32	89.6923077	81.69	13.06	33.48	360.25	322.91	93.69
5.77	5	57.69	40	97.6923077	87.69	7.66	19.63	370.40	334.56	95.69

Simulation

EOQ/ROP

RR	PR	transito	
0	371	0	
0	0	371	0
0	0	371	0
0	0	371	0
371	331	0	0
0	0	331	0
0	0	331	0
0	361	331	361
331	0	361	
0	0	361	
0	0	361	
361	0	0	
0	0	0	
0	319	0	
0	0	319	
0	0	319	
0	323	319	
319	0	323	
0	0	323	
0	354	323	
323	0	354	
0	0	354	
0	0	354	
354	0	0	
0	327	0	
0	0	327	
0	0	327	
0	0	327	
327	307	0	
0	0	307	
0	0	307	
0	0	307	
307	335	0	
0	0	335	
0	0	335	
0	0	335	
335	315	0	
0	0	315	
0	0	315	
0	0	315	
315	323	0	
0	0	323	

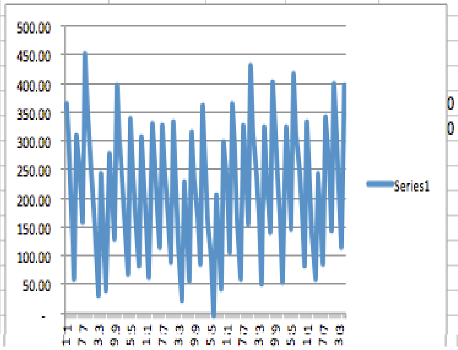
Cost Replacemen	K	54
	K/v	0
Price	v	20
rate	r	0.004
Ht=r*v	H	0.08
Shortage	S	20

EOQ Cost

Sum of Stock Positive Value	Sum of Stock negative Value	Qtd Order	Factor EOQ	Quant Total	Average Stock	Qtd of shortage	Qtd Order
21,899.00	-4.00	27.00					
Total Cost	Shortage Cost	Order Cost	Holding Cost	Quant Total	Average Stock	Qtd of shortage	Qtd Order
3,390.99	80.00	1458.00	1852.99	9048.00	210.57	4.00	27.00

MERP Cost
2,890.96

Menu

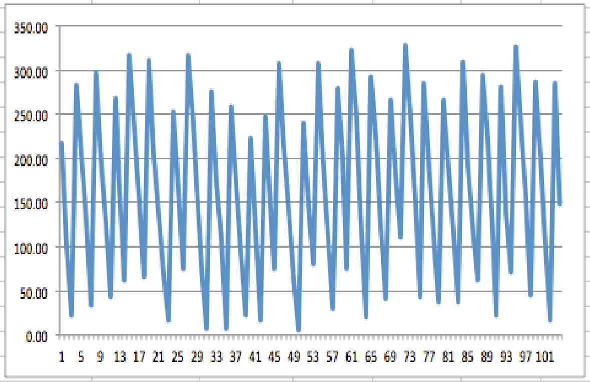


MERP

EI	RR	PR	
0.00			
274.00	330	0	1
195.00	0	0	1
83.00	0	0	1
318.00	330	330	1
216.00	0	0	1
99.00	0	0	1
22.00	0	0	1
283.00	330	330	1
206.00	0	0	1
130.00	0	0	1
34.00	0	0	1
296.00	330	330	1
198.00	0	0	1
128.00	0	0	1
43.00	0	330	1
268.00	330	0	1
168.00	0	0	1
62.00	0	0	1
316.00	330	330	
237.00	0	0	
156.00	0	0	
67.00	0	0	
311.00	330	0	
203.00	0	330	
138.00	0	0	
69.00	0	0	
17.00	0	330	
253.00	330	0	
166.00	0	0	
75.00	0	0	
317.00	330	0	
243.00	0	330	
169.00	0	0	
77.00	0	0	
7.00	0	0	
274.00	330	330	
174.00	0	0	
110.00	0	0	
7.00	0	0	
257.00	330	330	
173.00	0	0	

Cost Replaceme	K	54
	K/v	0
Price	v	20
rate	r	0.004
Ht=r*v	H	0.08
Shortage	S	20.00

	Sum of Stock Positive Value	Sum of Stock negative Value	Qtd Order	Factor EOQ	Quant Total	Average Stoc
	16,935.00	0.00	27.00		9,105.96	
	Total Cost	Shortage Cost	Order Cost	Holding Cost	Quant Total	Average Stoc
MERP Cost	2,890.96	0.00	1,458.00	1,432.96	8,720.00	162.8
EOQ Cost	3,390.99					



Simulation

Manipulate the variables

Utilization

	?
High	205
Medium High	165
Medium	125
Low Medium	85
Low	45
very low	5

	Utilization per Month	MTBUR	TBO	QPA	# Aircraft
	k	λ	z	x	y
201x-2	125	5000	3000	2	300
201x-1	125	5000	3000	2	300
201x	125	5000	3000	2	300
201x+1	125	5000	3000	2	300

	Cost	Qtt
EOQ	3,390.99	9,048.00
MRP	2,890.96	8,720.00

Menu

		?
Cost Replacem	K	54
Price	v	20.00
rate	r a.a	0.22
	r a.w	0.00423077
H=r*v	H -annual	4.40
	H-weekly	0.08
Shortage	S	20.00

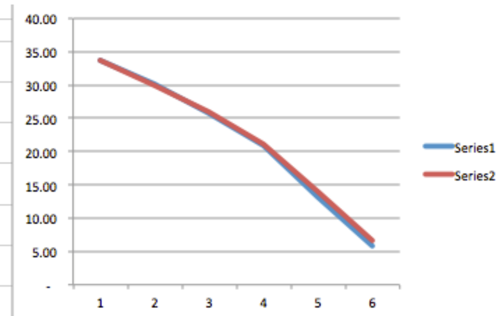
Generate Experiment

Annual rate	0.22
A.m	0.01833333
A.w	0.00423077

Simulation

Independent Variable	Material Replace Models	
Quantity Maintenance	EOQ	MERP
High	Inventory Cost	Inventory Cost
Medium-High	Inventory Cost	Inventory Cost
Medium	Inventory Cost	Inventory Cost
Low-Medium	Inventory Cost	Inventory Cost
Low	Inventory Cost	Inventory Cost

Independent Variable	Material Replace Models	
Quantity Maintenance	EOQ	MERP
High	33.66	33.76
Medium-High	30.16	29.98
Medium	25.80	25.90
Low-Medium	20.92	21.10
Low	13.24	13.88
Very Low	5.83	6.57



Inventory Cost

Independent Variable	Material Replace Models		
Quantity Maintenance	EOQ	MERP	
High	5,604.73	3,845.59	46%
Medium-High	5,250.52	3,451.92	52%
Medium	4,371.84	2,996.56	46%
Low-Medium	3,711.36	2,489.34	49%
Low	2,686.83	1,833.45	47%
Very Low	1,265.09	685.99	84%

Avarege Stock

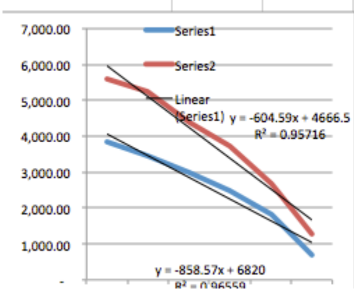
Independent Variable	Material Replace Models		
Quantity Maintenance	EOQ	MERP	
High	262.77	214.21	23%
Medium-High	232.27	190.30	22%
Medium	204.40	167.44	22%
Low-Medium	170.20	137.78	24%
Low	127.50	100.44	27%
Very Low	55.08	34.88	58%

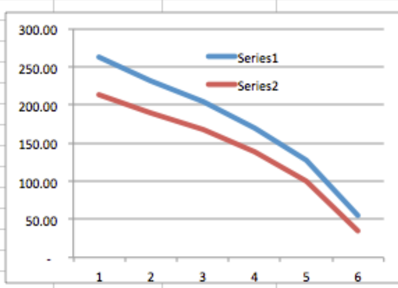
Shortage

Independent Variable	Material Replace Models		
Quantity Maintenance	EOQ	MERP	
High	70.98	3.96	-99.9727%
Medium-High	75.44	4.84	-99.9583%
Medium	55.54	2.66	-99.9696%
Low-Medium	49.12	1.96	-99.9679%
Low	33.80	1.74	-99.9463%
Very Low	23.36	1.08	-99.7713%

Qtt

Independent Variable	Material Replace Models		
Quantity Maintenance	EOQ	MERP	
High	14,903.14	14,504.36	2.7%
Medium-High	12,150.20	11,600.80	4.7%
Medium	9,120.24	8,760.68	4.1%
Low-Medium	6,402.34	6,104.28	4.9%
Low	3,417.64	3,242.82	5.4%
Very Low	492.72	472.24	4.3%
	46,486.28	44,685.18	4.0%





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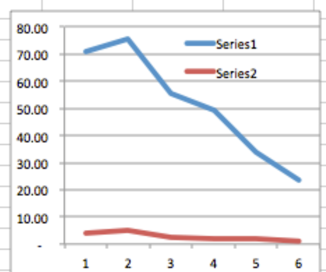

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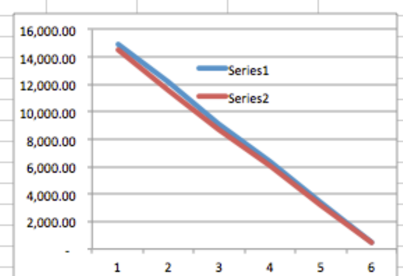
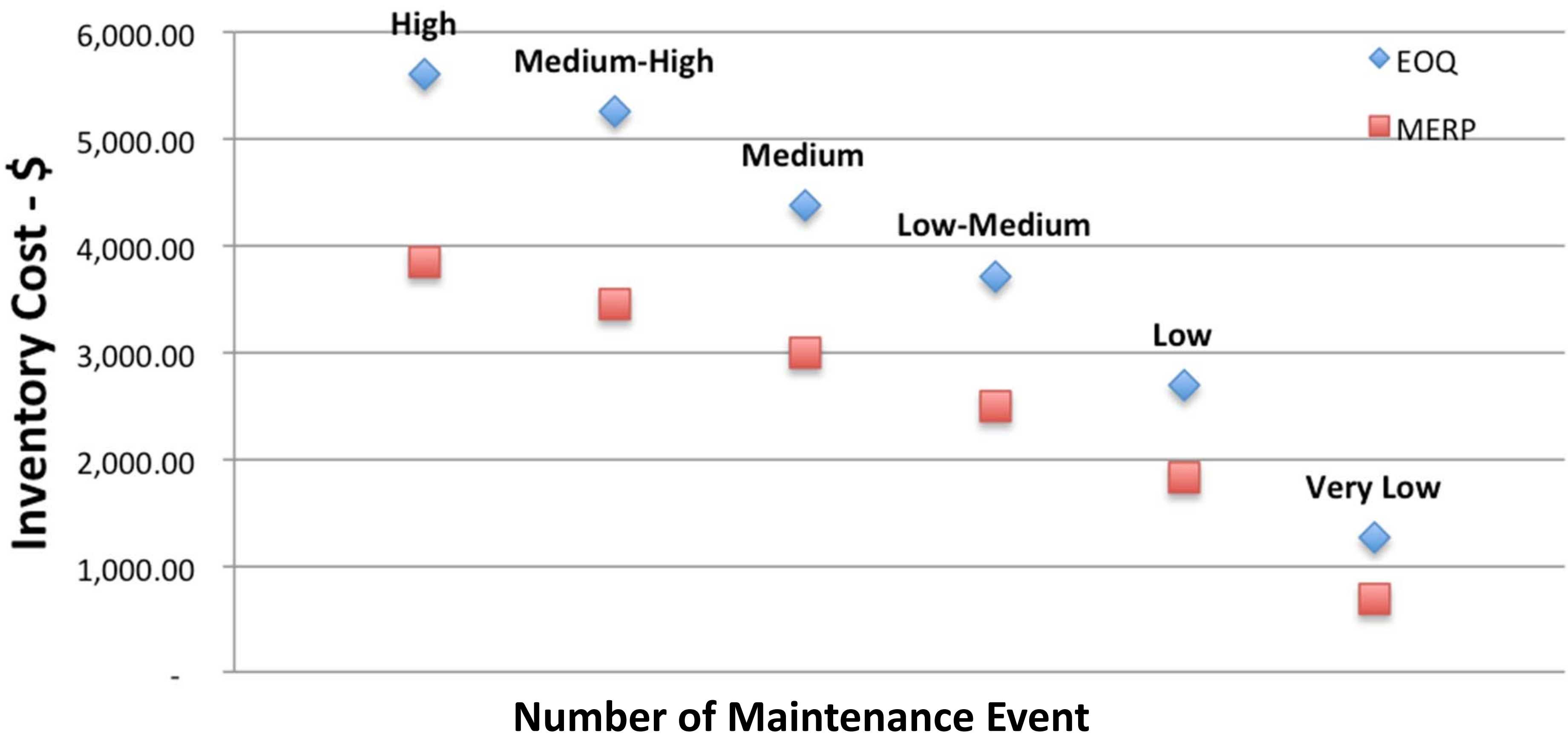


Analysis



6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
-
Inventory Cost - $
High
Medium-High
Medium
Low-Medium
Low
Very Low
EOQ
MERP
Number of Maintenance Event

Hypotheses

- *H-1: There is significant cost difference between inventory models (MERP - EOQ/ROP) for all number of maintenance events.* Confirmed

Source	F	p-value
Models	470.26	9.32E-203
Qty Maintenance	579.94	1.11E-89
Interaction	14.30	3.18E-13

ANOVA Test

- *H-2 to H-7 (to each level of maintenance): Inventory cost is lower using MERP than the EOQ/ROP model for all number of maintenance events.* Confirmed

Maintenance Qty	p-value (one-tailed, lower)
High	1.11E-15
Medium-High	1.37E-13
Medium	8.59E-14
Low-Medium	7.62E-15
Low	7.67E-15
Very Low	1.23E-09

Depend t-test

Theoretical Contribution

- Extend Information processing theory by integrating information process in the supply chain;
- Framework for a new management dimension to maintenance supply chain;
- Lower uncertainty by integrating maintenance elements.

Impact

- Predict specific and customized service to the client;

- Technology as M2M can help to predict usage, failures, maintenance to support different level of service;

- New framework to ERP Software.

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