Optimal Cost Avoidance Investment and Pricing Strategies for Performance-Based Post-Production Service Contracts

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Agenda

- What is PBL
- Motivation
- Business Challenges
- Research Questions
- Model Development
- Illustrative Example
- Future Research
- Acknowledgements
- References

What are Performance-Based, Post-Production Service Contracts

- Performance Based
  - Metrics
  - Delivery of Value Propositions instead of Products
- Post-Production
  - Sustainment
  - Maintenance, Repair and Overhaul (MRO)
  - Support
- Service
  - Trend towards Servicization
- Traditional vs. Performance-Based Post-Production Support
  - Shift in underlying business paradigm
  - Transactional (return on sales) vs. Performance (return on investment)

Motivation:
Cost of Post-Production Support

Joint Strike Fighter (JSF)

Photo: *AP*

JSF has a development and production cost of a staggering $350 billion (GAO, 2008)

The predicted cost to sustain the JSF: in excess of $600 billion (GAO, 2008)

Motivation:
Cost of Post-Production Support

U.S. Airline Industry

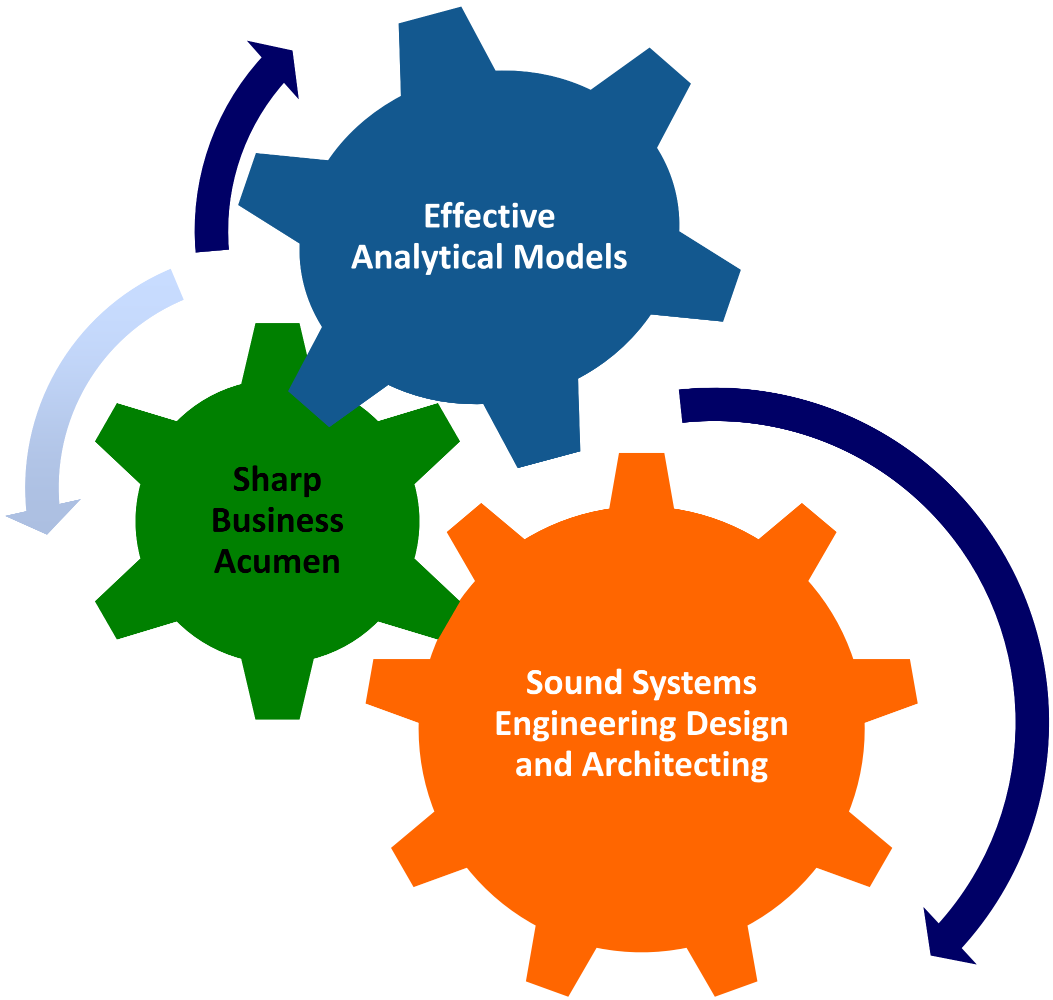
Photo: www.aviationexplorer.com

In the U.S., the Airline Industry spent $45 billion in 2008 on maintenance repair and overhaul (MRO), this is against a calculated $185 billion in revenue (Flint 2007; A.T.A. 2008).

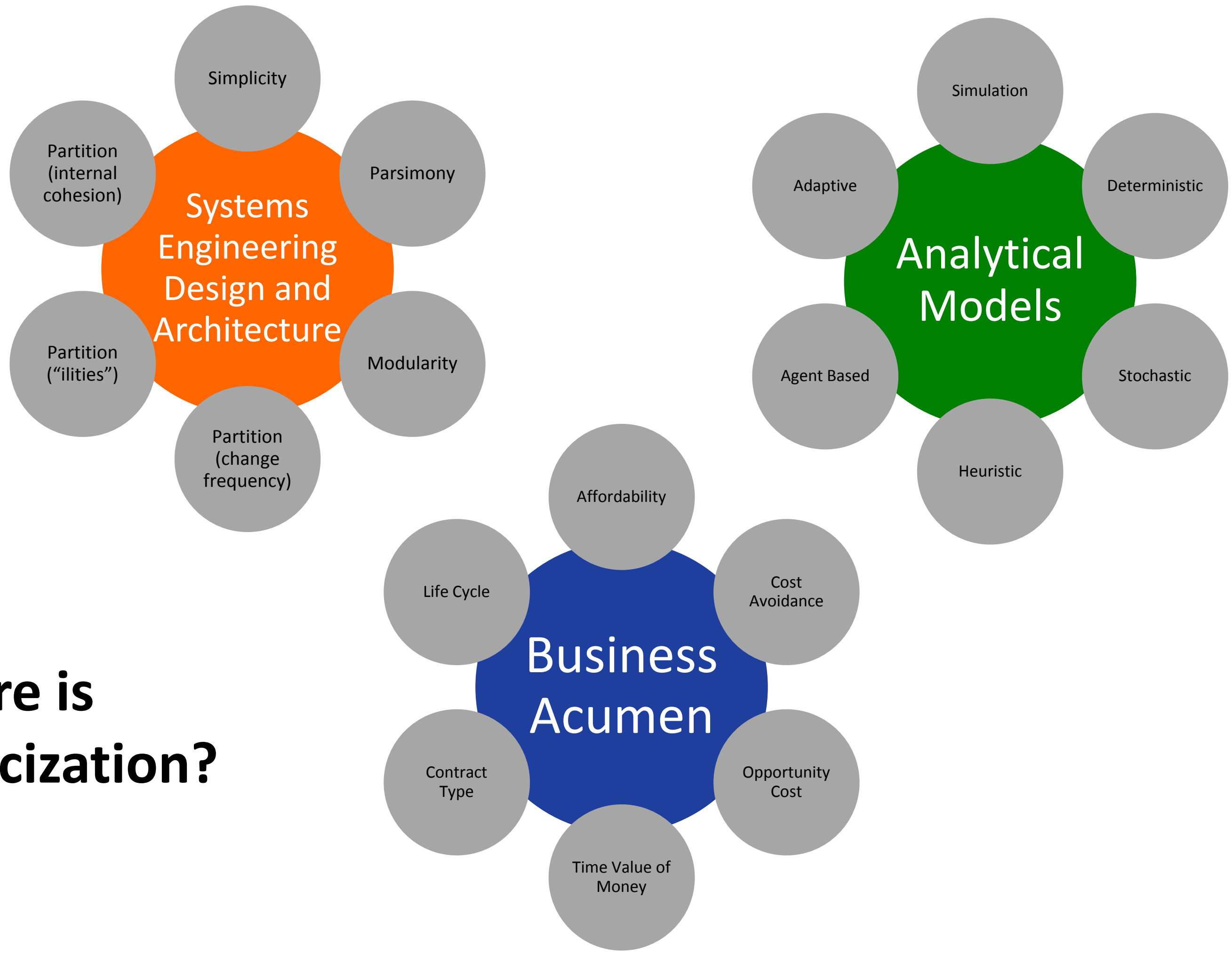
Research Questions

- What are the key characteristics and metrics that define a successful PBC?
- What characteristics make a program a candidate for switching from a traditional logistics contract to a PBC contract?
- What is the optimal price and length of a PBC contract?
- What is the optimal investment strategy in system design and supply chain improvements?

Uncovering Key Characteristics: Nexus of Systems Engineering, Global Supply Chains; Sustainment; and Logistics:



Research Considerations:
Systems Engineering, Global Supply Chains; Sustainment; and Logistics:



Where is Servicization?

Elements

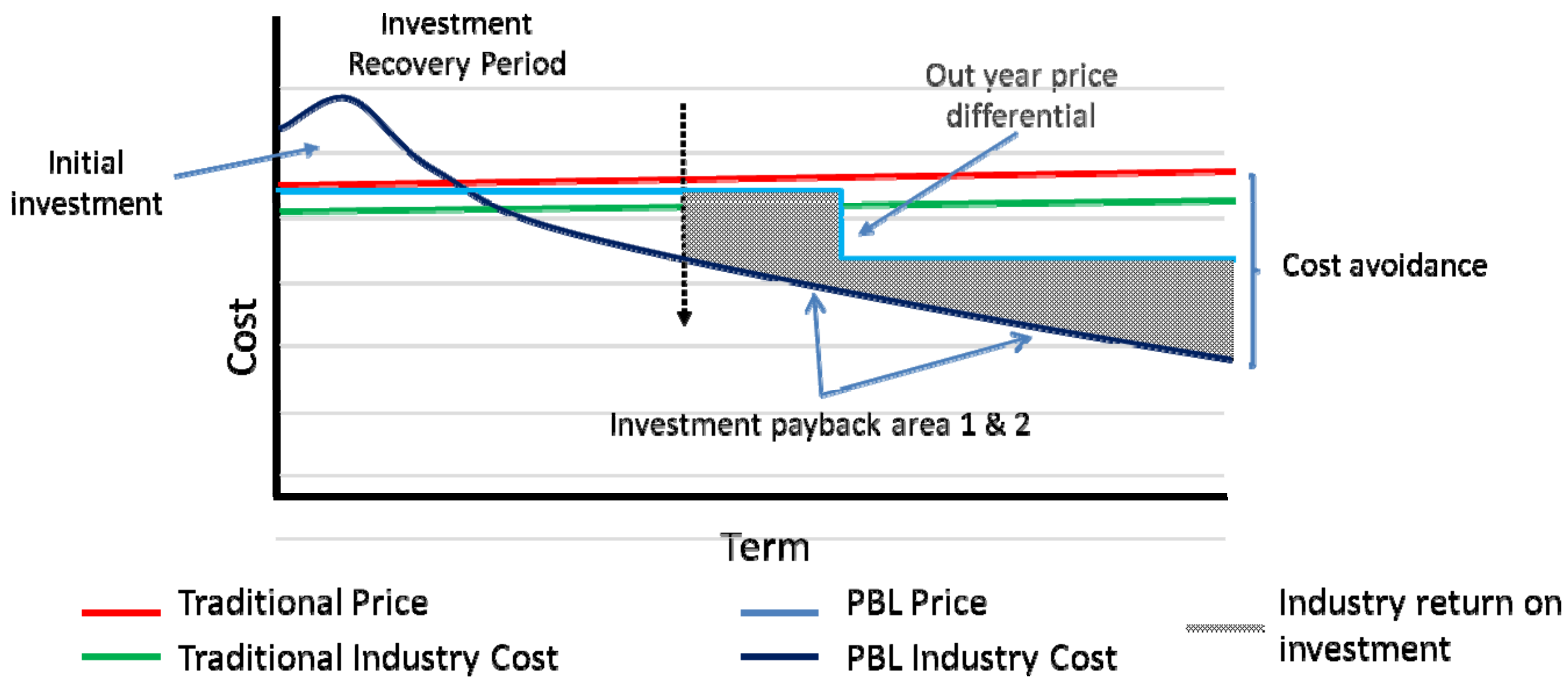
SoS Research Objectives:

Global Supply Chains; Sustainment; and Logistics:

- Understand how adopting SoS perspective changes investment decisions
- Extend current thinking to be more inclusive of opportunities that may be uncovered by examining sustainment from a multi-year, multi-objective, multi-constraint, multi-resource, and multi-system perspective.
- Leverage interactions between technical, material, procedural and engineering innovations that result in decreased cost and improved performance.
- Understand the true cost associated with unreliability
- Emerging research suggests more aggregate management drives earlier initiation of reliability improvement investment.

Research Objectives:

Outcome-Based Price Optimization



Notation

M	are the number of potential customers.
k	is the length of a contact.
m	is the number of missions in a single time period of a contract of length k.
$\mathbf{r_0}$	is the initial reliability of the system for the mission time $\mathbf{t}_m$.
r(x)	is the reliability of the system for a cost avoidance investment of **x**.
$\boldsymbol{\gamma}$	is the marginal investment parameter.
f(r(x))	is the total cost of all system failures for a single period, given that the system has a reliability **r(x)**.
$\boldsymbol{\mu}_c$	is the average cost per failure.
$\boldsymbol{\sigma}_c$	is the standard deviation of the cost per failure.
p	is the periodic contract fee.
i	is the interest rate.
d	is the discount per period expected by customers.
$\boldsymbol{\lambda}$	is the maximal fee that customers are willing to pay for the single-period contract if **r(x)** = 1.
$\mathbf{w}_{r(x),k}$	is the probability density function of customers reservation fees.
$\mathbf{W}_{r(x),k}(\mathbf{p})$	is the fraction of customers that will engage in the **k**-period contract with the periodic fee equal to **p** and the reliability of the system is **r(x)**.
$\Pi(\mathbf{x,p,k})$	is the total profit to the supplier when investing capital **x** into the system reliability design for a **k**-period post-production contract with periodic fee **p**.

Assumptions

The system reliability r depends on cost avoidance investment x in the following way:

$$r(x) = r_o + (1 - r_o)\left(1 - \frac{1}{x/\gamma + 1}\right) = \frac{x + r_o\gamma}{x + \gamma}, \quad (3)$$

where $\gamma > 0$ is a marginal investment parameter, defined as the marginal investment required to achieve an incremental improvement of system reliability. The function $r(x)$ satisfies the assumption regarding the initial reliability of the equipment ($r(0) = r_0$). The signoid shape of the curve $r(x)$ describes the relationship between system reliability and investment observed in reality fairly well (Levesque, 2000).

(A2) The cost per failure is a normally distributed random variable with the mean μ_c and variance σ_c^2.

(A3) The expected cost of all system failures per period decreases with reliability improvements is $f(r(x)) = cm(1 - r(x))$, where m is the number of missions in a single time period.

(A4) The customers' reservation fees follow the triangular distribution:

$$w_{r(x),k}(v) = \begin{cases} \dfrac{(\lambda(1-d(k-1))r - p)^2}{(\lambda(1-d(k-1))r)^2}, & 0 \le p \le \lambda(1-d(k-1))r \\ 0, & o.w. \end{cases}, \quad (4)$$

where λ is a maximal fee that customers are willing to pay for the contract if reliability of the equipment will be improved to $r(x) = 1$ and d is a discount per period expected by customers if they buy a multi-period contract. The use of a triangular distribution to represent reservation fees is consistent with the current state of the pricing literature (Kirman, Schulz, Hardle, & Werwatz, 2005).

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Optimization Model

The goal of the supplier is to identify an optimal investment $\mathbf{x^*}$, optimal periodic contract fee $\mathbf{p^*}$ and optimal contract length $\mathbf{k^*}$ that maximize the supplier's expected profit $\mathbf{E}[\Pi(\mathbf{x,p,k})]$ from a $\mathbf{k}$-period contract ($\mathbf{k} = 1,\ldots,\mathbf{n}$) :

$$E\left[\Pi(x^*,p^*,k^*)\right] = \max_{k=1,\ldots,n} E\left[\Pi(x^*,p^*,k)\right], \quad (5)$$

where,

$$E\left[\Pi(x^*,p^*,k^*)\right] = \max_{\{x,p\}\in F_{x,p}} E\left[\Pi(x,p,k)\right], \quad (6)$$

with a set of feasible solutions:

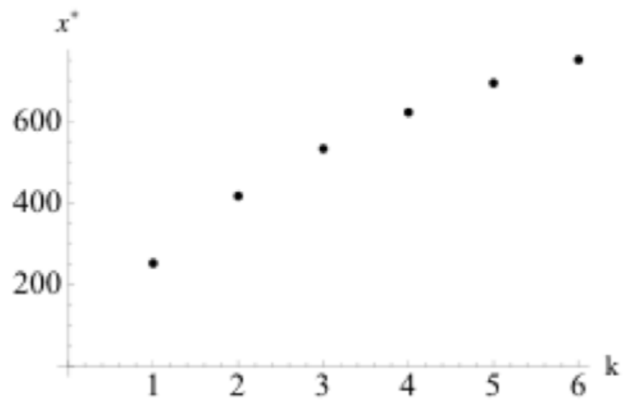
$$F_{x,p} = \left\{\{x,p\} \mid x > 0, 0 \le p \le \lambda)1 - d(k-1))r\right\}. \quad (7)$$

where the upper bound for the price follows from triangularly distributed customers reservation prices. Under the assumptions (A1)-(A4), an expected profit is given by

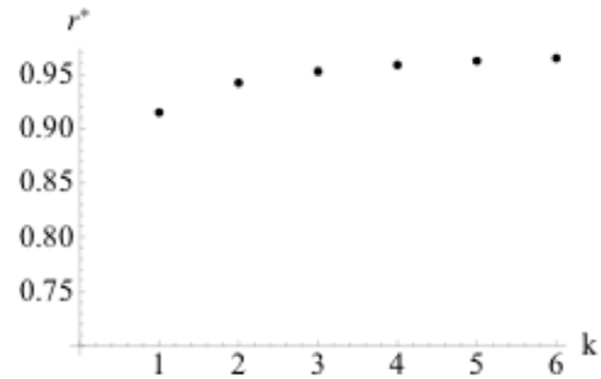
$$E\left[\Pi(x,p,k)\right] = \begin{cases} \dfrac{MI_k(p(x+\gamma) - \mu_c m(1-r_o)\gamma)(p(x+\gamma) - \lambda D_k(x + r_o\gamma))^2}{\lambda^2 D_k^2 (x + r_o\gamma)^2 (x+\gamma)} - x, & 0 \le p \le \lambda D_k r(x) \\ 0, & o.w. \end{cases} \quad (8)$$

where $\mathbf{D_k} = (1 - \mathbf{d}(\mathbf{k} - 1))$ and $\mathbf{I_k} = (1 + \mathbf{i} - (1 + \mathbf{i})^{-\mathbf{k}})/\mathbf{i}$.

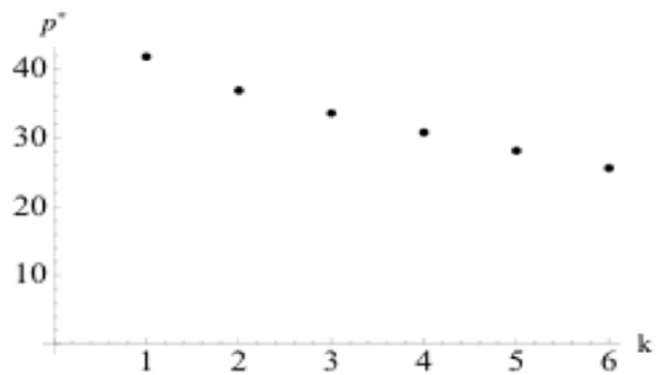
Theoretical Results



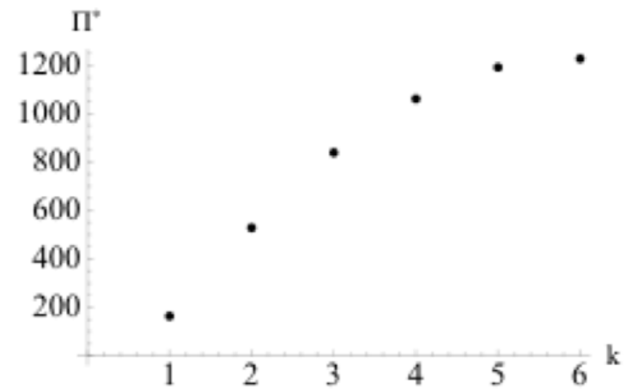
(a) Optimal investment (x) vs contract length (k)



(b) Reliability r(x) vs contract length (k)



(c) Optimal contract fee (p) vs contract length (k)



(d) Profit (π) vs contract length (k)

Figure 1: Optimal investment, reliability, periodic contract fee and profit as functions of a length of a contract

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Theoretical Results

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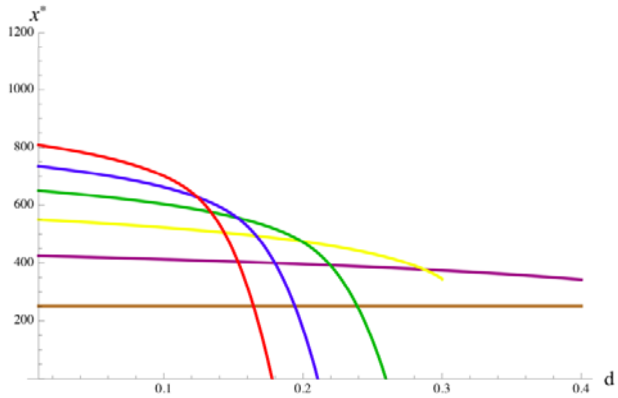
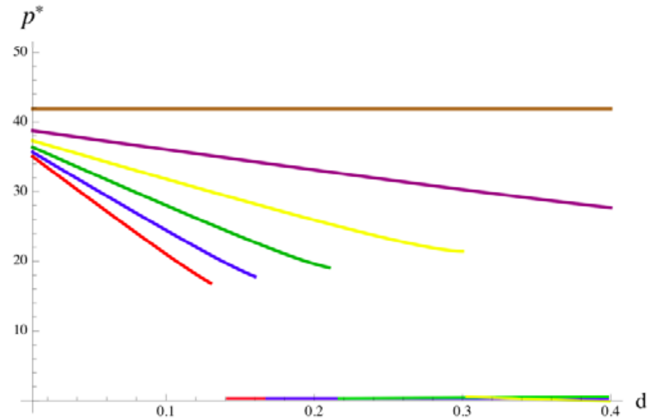
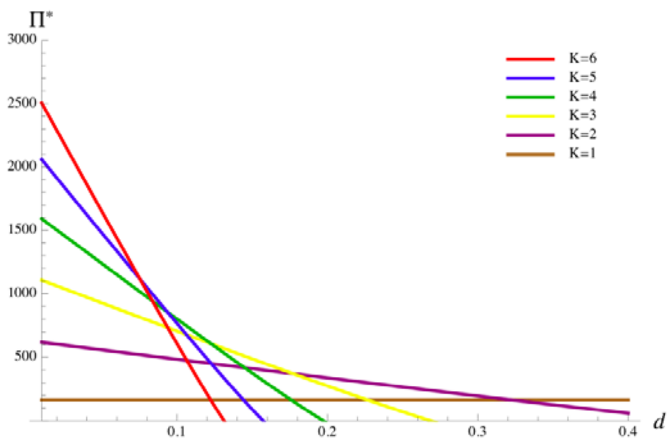


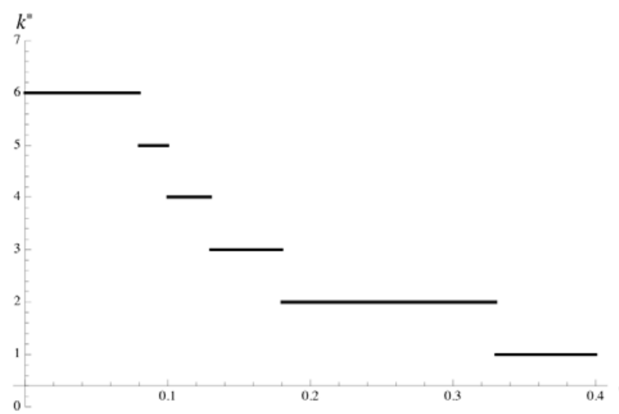
(a) Optimal investment



(b) Optimal periodic contract fee



(c) Profit



(d) Optimal contract's length

Research Objectives:

System Design and Enabling Infrastructure Decisions

$$\max \quad Profit(\mathbf{x},\mathbf{s}) = Rev(\mathbf{x},\mathbf{s}) - Cost(\mathbf{x},\mathbf{s})$$

$s.t.$

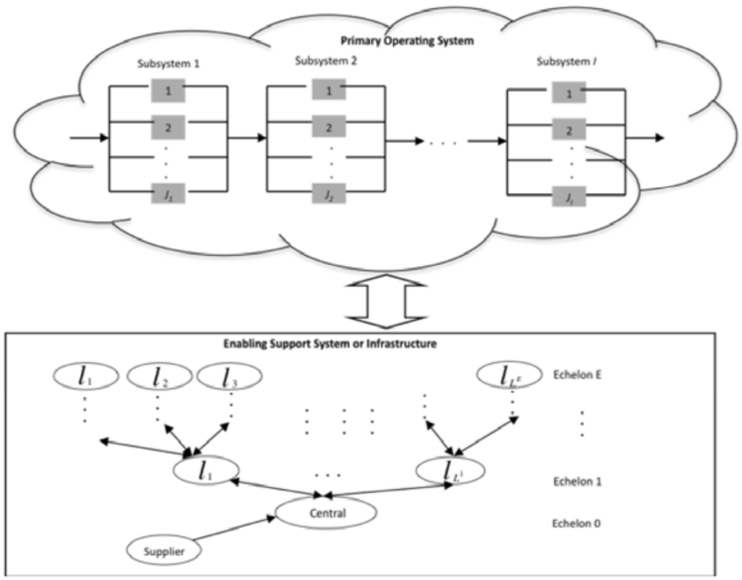
$$MTBF(\mathbf{x}) \geq MTBF'$$

$$LF(\mathbf{x},\mathbf{s}) \leq LF'$$

$$x_{ij} \in \{0,1\} \ \forall i \in I, j \in J$$

$$s_l^e \geq 0$$

$$s_l^e = Integer$$



Future Research:

Examining Key characteristics

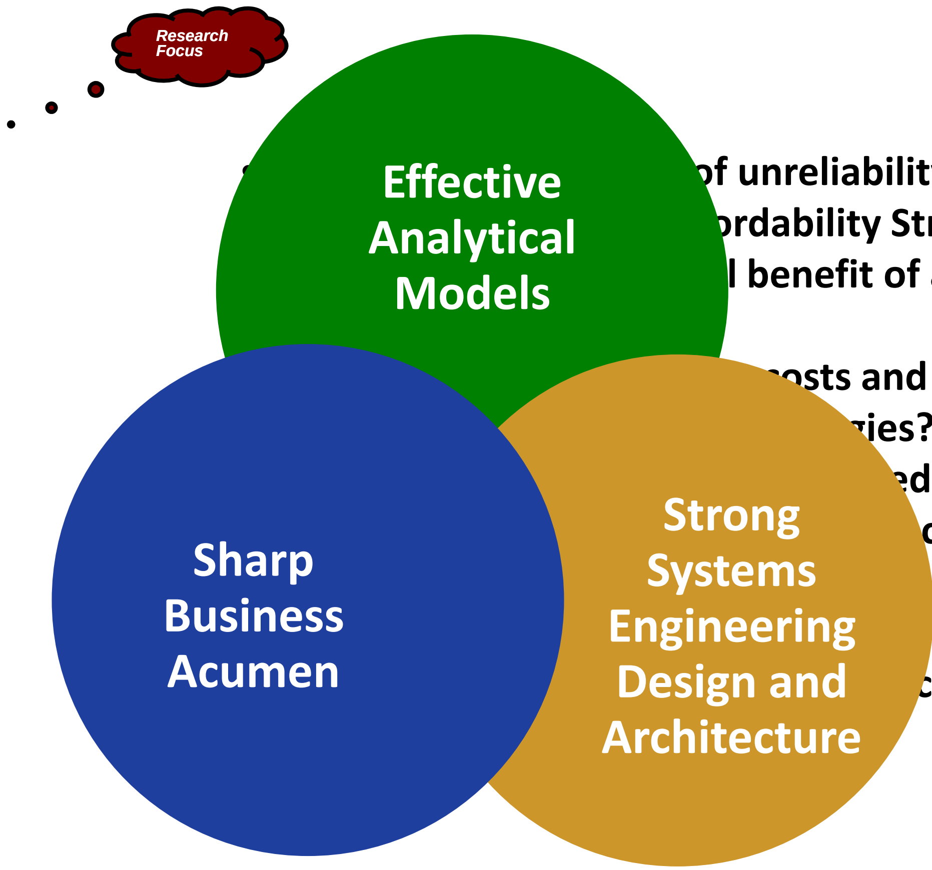
- How does acquisition strategy influence spending over the life cycle? Trade-offs among investment, cost, price, and contract term.
- Does a government population view investment recovery and risk differently from the commercial sector?
- Can a survey approach develop robust and statistically valid data more quickly than standard empirical methods?

Final Measurement Scale

Label	Dimension/Items
	Investment Climate
IC1	Leadership welcomes new ideas.
IC2	People are empowered to make decisions.
IC3	People act entrepreneurial.
	Relational Exchange
RE1	Industry and government trust.
RE2	People know how their work impacts the end customer.
RE3	Communication between industry and government is effective.
	PBL Leadership
L1	Leadership has a long-term focus on affordability and performance.
L2	Leaders align activities to achieve warfighter goals.
L3	Leadership accepts risk taking.
	PBL Effectiveness
PBL1	System performance is improved.
PBL2	The project team has a shared vision of its purpose.
PBL3	There are clear sustainment objectives.
PBL4	There is significant innovation.
PBL5	Cost is avoided.
PBL6	Incentivizes investment in reliability.
PBL7	This strategy is likely to find money to avoid costs.
PBL8	Uses knowledge and skill to improve performance and affordability.

Research Questions:

Systems Engineering, Global Supply Chains; Sustainment; and Logistics:



of unreliability?
rdability Strategies?
l benefit of an improvement in an “ility” to the
osts and relationships need to be considered in
ies?
ed for a PBL?
contract?
contract?
differ from those of industry?
ce and Technology Insertion Strategy

Multi-Year Research Stream

Research In Progress

- Nowicki, David, A Framework for Performance Based Strategy, targeted for *Management Science*
- Randall, Wesley S., David Nowicki, & Jose Ramirez-Marquez "A Design Decision in the Presence of PBL: Redundancy and Spares Allocation Considering Multiple System Effectiveness Criteria," targeted for submission to *Management Science.*
- Wesley Randall & David Nowicki, "Role of Incentive Structure in Performance Strategy," Abstract presented at POMs 2009, targeted for submission to *Journal of Production and Operations Management.*
- Nowicki, David, & Wesley Randall "The Real Cost of (un)Reliability," targeted for submission to *Management Science.*
- Randall, Wesley S. Performance Based Strategy: A Survey of the Literature, targeted for *International Journal of Physical Distribution and Logistics Management*
- Randall, Wesley S., and Steve Geary, "Service Based Logistics, a View from the Top," targeted for submission to *Harvard Business Review.*

Research Under Review

- Randall, Wesley S., Steve Brady, and David Nowicki, "Business Case Analysis in the Face of Investment and Innovation Based Post-Product Support," revise and resubmit at the *Transportation Journal.*
- Nowicki, David A., Jose Ramirez-Marquez & Wesley Randall, **"**Improving the Computational Efficiency of Metric-Based Spares Algorithms," revise and resubmit at the *European Journal of Operational Research*.
- Randall, Wesley S., David Nowicki, and Timothy G Hawkins, "Explaining the Effectiveness of Performance Based Logistics: A Quantitative Examination" under review at the I*nternational Journal of Physical Distribution and Logistics Management.*
- Nowicki, David A., Wesley Randall, & Jose Ramirez-Marquez, "Optimal Cost Avoidance Investment and Pricing Strategies for Performance Base Post-Production Service Contract," Under review at the *European Journal of Operational Research.*
- Hawkins Timothy, Wesley Randall, and Adam V. Coyne, "Sustainable Integrity in an Unethical Context: How Electronic Reverse Auctions Counter the Negative Effect of *Wasta*," Under review at the *Journal of Business Logistics*.
- Haynie, Jeffrey A., Wesley S. Randall, Achilles A. Armenakis, Steve Geary, David Nowicki, and Timoth G. Hawkins, "Team Innovation and Learning: A Qualitative Inquiry into an Evolutionary Change Initiative," under review at the *International Journal of Physical Distribution and Logistics Management.*
- Randall, Wesley S., Michael Gravier, & Victor Prybutok, "The Role of Connectedness in Customer Relationships," under review at *The Journal of Marketing, Theory, and Practice.*

Multi-Year Research Stream

Selected Completed Research

- Randall, Wesley S., Terry L. Pohlen, and Joe B. Hanna, (2010) "Evolving a Theory of Performance Based Logistics Using Insights from Service Dominant Logic," *Journal of Business Logistics* Vol. 31, No. 2, pages 35-62.
- Defee, C. Clifford, Brent D. Williams, Wesley Randall and Rodney Thomas, (2010) "An Inventory of Theories in Logistic and Supply Chain Management Research," the *International Journal of Logistics Management,* Vol 21, No. 3.
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Selected Completed Research

- Randall, Wesley S., Michael J. Gravier, and Vicktor Prybutok, (Forthcoming), "Connection, Trust, and Commitment: Dimensions of Co-Creation?," *The Journal of Strategic Marketing.*
- Hawkins, Timothy, Wesley Randall, and C. Michael Wittmann, (2009) "An Empirical Examination of Reverse Auction Appropriateness," *Journal of Supply Chain Management.* Vol 45, Issue 4, pp. 55-71.
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