Systems Engineering Advancement Research Initiative

Massachusetts Institute of Technology

Managing Uncertainty in Socio-Technical Enterprises using a Real Options Framework

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Committee: Prof. Daniel E. Hastings, chair; Prof. Deborah J. Nightingale; Dr. Donna H. Rhodes

Biography

Tsoline Mikaelian is a doctoral candidate in the Department of Aeronautics and Astronautics at MIT. As a member of MIT's Systems Engineering Advancement Research Initiative (SEAri), her current research focuses on uncertainty management for complex systems and enterprises, supported by Singapore's Defense Science and Technology Agency. Ms. Mikaelian has a Master of Science degree in Aeronautics and Astronautics from MIT, and a Bachelor of Science degree in Space and Communication Sciences from York University, Canada.

Related Publications

Mikaelian, T., Rhodes, D.H., Nightingale, D.J. and Hastings, D.E., "Managing Uncertainty in Socio-Technical Enterprises using a Real Options Framework." *Proc. 6th Conference on System Engineering Research*, Los Angeles, CA, April 2008.

Mikaelian, T., Bartolomei, J. and Hastings, D., "Managing Operational Uncertainty with Real Options." *Proc. 5th Conference on System Engineering Research*, Hoboken, NJ, March 2007.

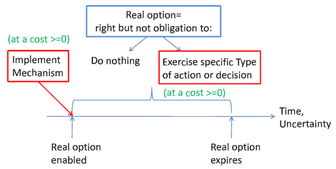
Objective and Challenges

How can real options be used for holistic decision making and architecting of socio-technical enterprises under uncertainty?

1. Although real options analysis has been applied to different domains relevant to an enterprise, such as strategic investments and product design, there is no integrated framework that enables systematic exploration of what type of flexibility is desirable, how to enable flexibility and where to implement flexibility in an enterprise.
2. Enterprises exhibit the emergence of silos that become isolated over time as complexity grows. This constitutes a barrier to effectively communicating information across the silos, which may lead to suboptimal decisions within the isolated silos.

Real option: defined as right, but not the obligation, to take an action at a later time

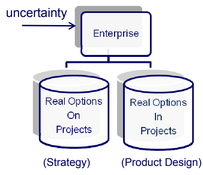
Real Options Characterization



Real Option Mechanism: Actions/decisions that enable a real option

Real Option Type: Actions/decisions that may be exercised by the owner of the real option

Explore interactions between "real option silos"

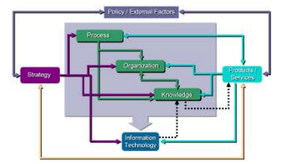


Real Option Mechanism \ Real Option Type	In Design	In Strategy
In Design	MAV design enables a reuse option in future design	MAV design enables future market expansion
In Strategy	MAV development partnership enables option to use new type of technology in design	Investment in MAV project enables option to expand development to swarm in future

MAV = Mini Air Vehicle

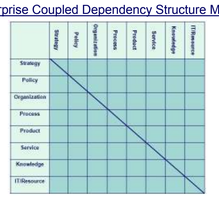
Method

Enterprise Views (Nightingale and Rhodes, 2007)

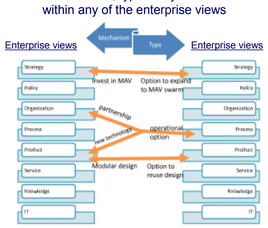


1. Model enterprise views as coupled dependency structure matrix
2. Model uncertainties
3. Explore potential mechanisms and types of options that encompass enterprise views
4. Use real options valuation toolbox

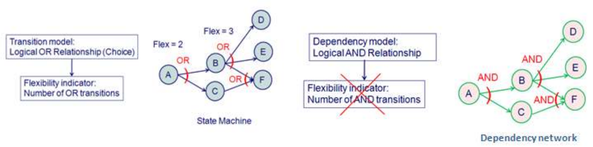
Enterprise Coupled Dependency Structure Matrix



Mechanisms, types may exist within any of the enterprise views



Flexibility Metric for a Dependency Model



C-DSM models dependencies
- To enable semantics compatible with options modeling, augment C-DSM with logical dependency structure modeling

Flexibility metric in dependency network
- Need to isolate OR's to identify options
- Metric defined as number of terms in disjunctive normal form of the logical dependency structure

Example:

[(Insert Battery 1) AND (Insert Battery 2)]

OR

[(Insert Battery 1) AND (remove Battery 2)]

Formula F is in DNF iff

$$F = (\bigvee_{i=1}^{n} (\bigwedge_{j=1}^{m_i} L_{i,j}))$$

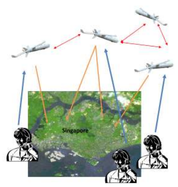
term

Flex metric = number of terms in disjunctive normal form

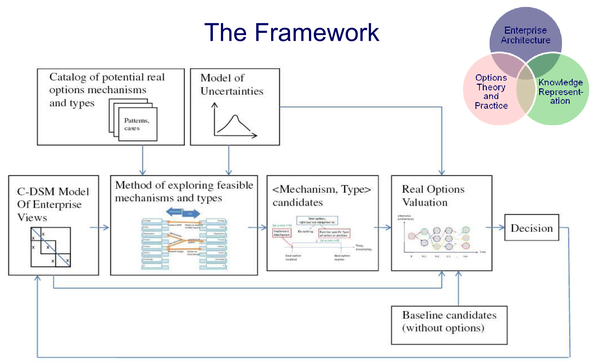
Case Study

Singapore Defense Science and Technology Agency and Defense Science Organization study focused on the UAV enterprise. The framework will be demonstrated through examples ranging from UAV operations to organizational structure and investment decisions.

Challenge	Examples of uncertainties	Examples of real options (mechanism → type) across enterprise views
Dealing with operational uncertainties	- Future mission demands - System failures	Design mechanism: flexible payload bay *(Product View)* → Operational option to add extra battery *(Process View)*
		Train more operators *(Process View)* → Deployment of larger swarm *(Strategy View)*
Investments in research and new technologies	- Future customer demands - Uncertain outcome of the investment	Investment in autonomy *(Strategy, Organization, Knowledge, Product Views)*→ Potential for patents *(Knowledge View)*, competitive advantage *(Strategy, Product Views)*, Deployment of larger swarm *(Process View)*, hiring less operators *(Organization View)*, abandoning the investment if low prospects *(Strategy View)*
		Deferral of decision to invest *(Strategy View)* → Option to invest later *(Strategy View)*
Technology make-buy decisions	- Technology demands for future products - Future availability and performance of COTS components	Develop own components *(Strategy, Organization, Knowledge, Product Views)* → Flexibility to modify, customize components *(Product View)*, may leverage organizational expertise later *(Knowledge View)*
Organizational structure	- Organizational competencies - Types of future projects	Development partnership *(Strategy, Organization Views)* → Option to expand/abandon collaboration in future *(Strategy, Organization Views)*, option to leverage organization's competencies/resources *(Strategy, Organization, Knowledge Views)*



The Framework



"A framework for systematic exploration and valuation of mechanisms and types of real options that deal with enterprise uncertainties supports enterprise architecting and decision making efforts, and is enabled through holistic modeling of enterprise views and their dependencies."

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