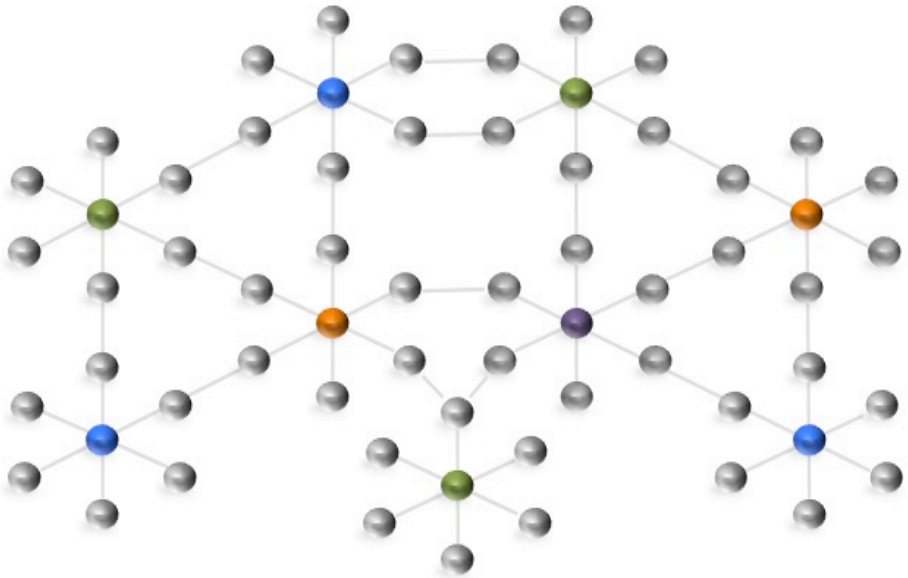
Acquisition in a World of Joint Capabilities

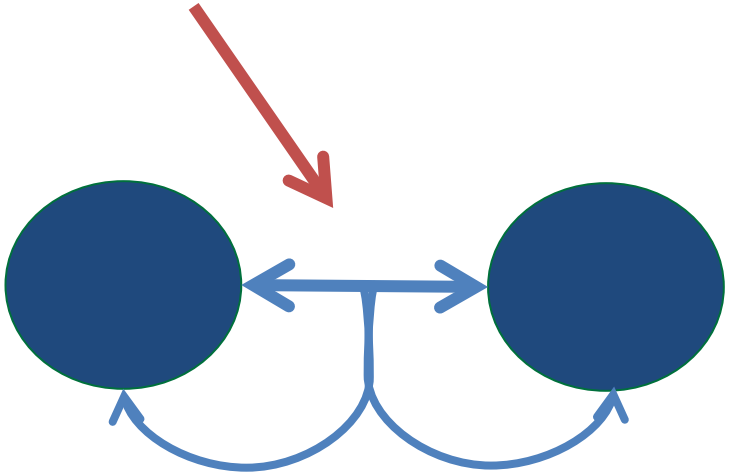


Defining Acquisition as a Complex System

A Complex System…

- A relational property among three or more interdependent entities
- That demands adaptation and adjustment when state changes occur in any one of the entities
- Complexity is in the relations

Interrelations & Complexity



Program Networks

- Inescapable – Technological Superiority
- Take many forms ranging from simple supply chains to more complex joint activities (JSF versus JTRS)
- Form (business model) determines cost and risk
- Often includes contractors
- Based on an Interdependency

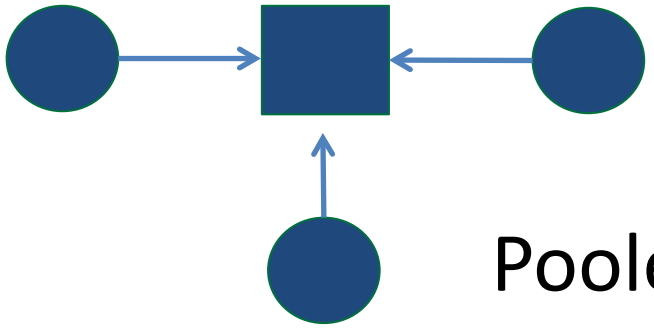
Program Interdependency

Interdependency is defined as dependence on an external source for:

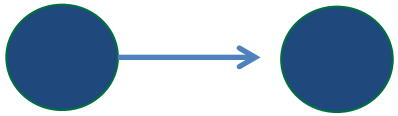
- data,
- money,
- staff,
- facilities, or
- requirements

beyond the normal acquisition workflow

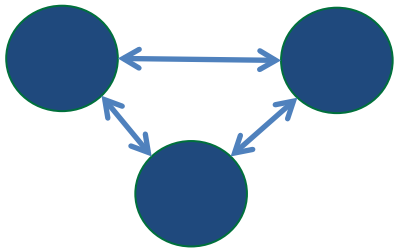
Basic Network Configurations



Pooled



Sequential



Reciprocal

Business Models:

JSF

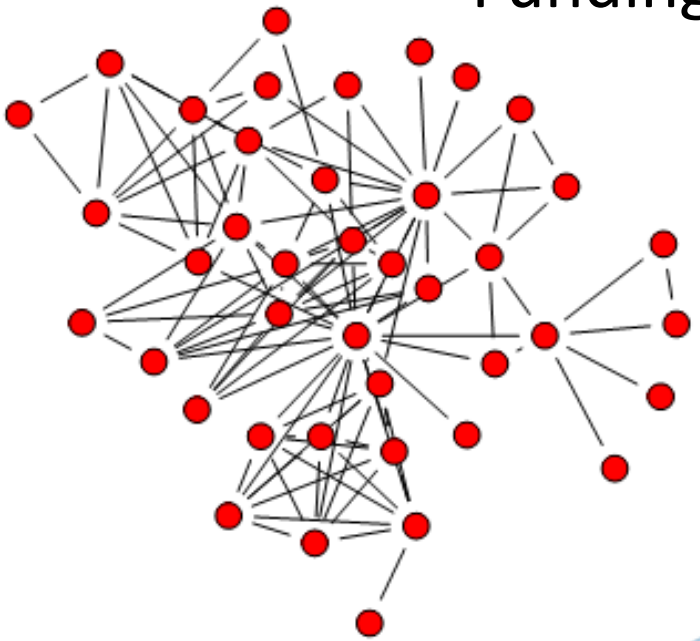
JTRS

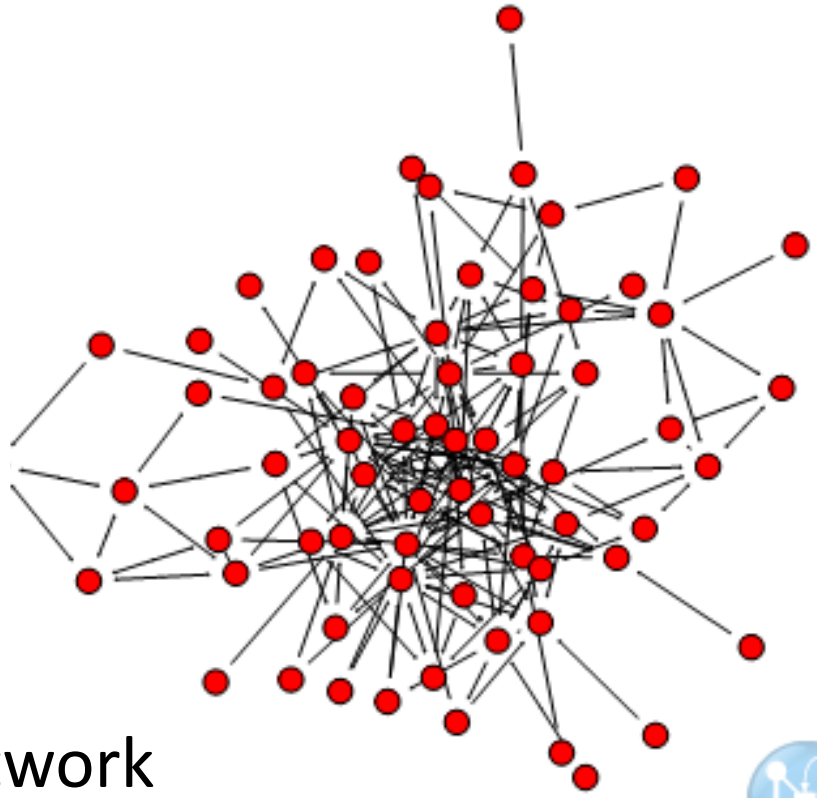
JLTV

Even Within a Program

DoD Networks

Funding Network 2012





Data Network

Does the Program Manager Matter? (Eckerd and Snider)

Interdependency Research is Fragmented & Contradicting

lead to cost and schedule growth due to adaptation requirements

Complex Behavior

- Nonlinear
- Emergent
- Self-organization
- Adaptive Capacity
- Collective Behavior
- Contagion

Better Buying Power

Focus Areas that Program Networks Influence

- Achieve Affordable Programs
- Control Costs Throughout the Product Lifecycle
- Eliminate Unproductive Processes and Bureaucracy

Current Study

longitudinal study testing:

- Multilevel Modeling,
- State Transition Modeling,
- Structural Equation Modeling,
- Contagion Modeling, and
- Exponential Random Graph Modeling

Methods

1. Examined performance over the 2009-2014 time period
   - Funding network connections vary over time

2. Measures
   - PAUC cost growth
   - Cost Variance
   - Number of Connections
   - Exposure rates

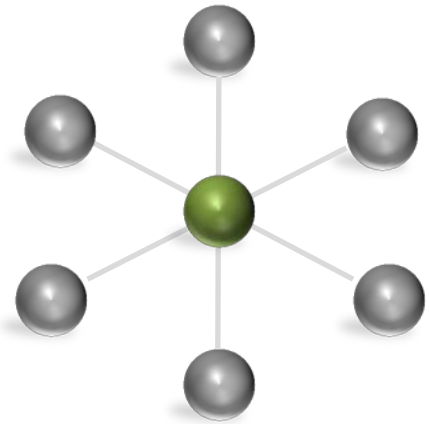
3. Unit of Analyses
   - Network Level
   - MDAP level

Shared Funding Sources

Funding Networks were established through the track-to-budget field of the SAR.

Any given program element (R Doc) funds multiple MDAPS

Funding Networks



Method of Analysis

Hierarchical or Mixed-Effects Model

- Random intercept model
- Random effect is the network cluster or network community

Basic formulas

Model 1: $y_i=\alpha_{ji} + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_5 X_{i5} + \delta_k X_k + \varepsilon_i$

$$\alpha_j = \mu_\alpha + \eta_j$$

Variables in the model of MDAP Total Cost Variance (y_j)			
X_1	Number of network partners	X_2	Diversity of network partners rank abundance curve
X_3	Percent of partners that are considered joint	X_4	Percent of network partners in production
X_5	Total Cost Variance of all network partners	X_k	Vector of fixed effects for years 2009-2014
α_{ij}	Intercept that is a function of the mean of network communities and their variance		

Basic formulas (cont.)

– Model 2: $y_i=\alpha_{ji} + \beta_1 X_{i1}+ \beta_2 X_{i2}+ \beta_3 X_{i3}+ \beta_4 X_{i4}+ \mathbf{\beta_6 X_{i6}}+ \mathbf{\beta_7 X_{i7}}+ \mathbf{\beta_7 X_{i7}}+ \mathbf{\beta_7 X_{i7}} + \delta_k X_k +\varepsilon_i$

$$\alpha_j = \mu_\alpha + \eta_j$$

Variables in the model of MDAP Total Cost Variance (y_j)			
X_1	Number of network partners	X_2	Diversity of network partners rank abundance curve
X_3	Percent of partners that are considered joint	X_4	Percent of network partners in production
X_5	*Total Cost Variance - Not in this model*	$\mathbf{X_6}$	**Schedule cost variance of network partners**
$\mathbf{X_7}$	**Estimation cost variance of network partners**	$\mathbf{X_8}$	**Economic cost variance of network partners**
$\mathbf{X_9}$	**Engineering cost variance of network partners**	$\mathbf{X_k}$	**Vector of fixed effects for years 2009-2014**
α_{ij}	Intercept that is a function of the mean of network communities and their variance		

Method of Analysis (cont.)

- Basic models were leptekurtotic
- Transformed the y_i by the cube root
  - Model 1: $y_i^{1/3} = \alpha_{ji} + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_5 X_{i5} + \delta_k X_k + \varepsilon_i$

    $\alpha_j = \mu_\alpha + \eta_j$
  - Model 2: $y_i^{1/3} = \alpha_{ji} + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_6 X_{i6} + \beta_7 X_{i7} + \beta_7 X_{i7} + \beta_7 X_{i7} + \delta_k X_k + \varepsilon_i$

    $\alpha_j = \mu_\alpha + \eta_j$

Findings

Model 1: Total Cost Variance of Network Partners Effect on Program Cost Variance

Parameter	Est.	Std. Error	Sig.
Number of network partners	0.0714	0.0394	0.071
Diversity of network partner services	**5.9373**	**3.0053**	**0.049**
Network partner total cost variance	0.1847	0.1615	0.253
Network community (variance est.)	0.2734	0.3881	0.481
-2loglik	1723.35		
BIC	1734.95		

Findings

Model 2: Component Cost Variance of Network Partners Effect on Program Cost Variance

Parameter	Est.	Std. Error	Sig.
Number of network partners	**0.1134**	**0.0449**	**0.015**
Diversity of network partner services	**6.3388**	**3.0339**	**0.038**
Network partner estimation cost variance	0.0003	0.0002	0.09
Network community (variance est.)	0.076	0.189	0.688
-2loglik	1766.17		
BIC	1777.75		

Findings

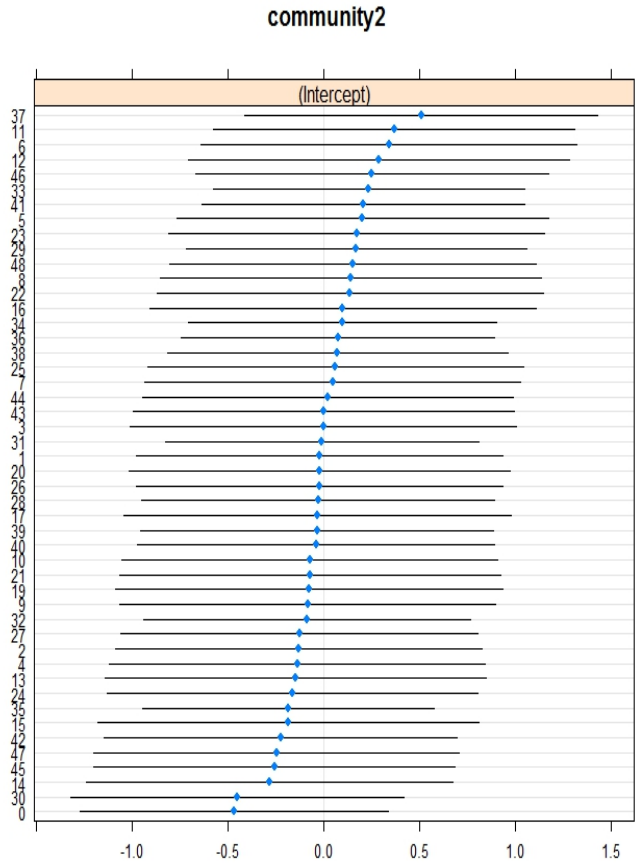
- Diversity and Complexity vs. Cost Variances
  - Importance of diversity and complexity of network partners
  - Relative unimportance of network partner cost variances

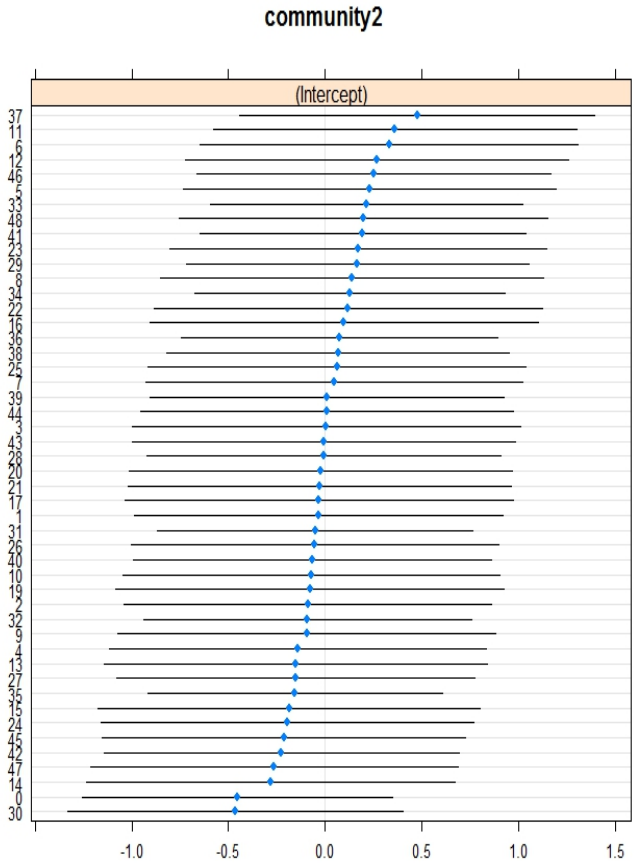
- Network Community is not significant in the model
  - New approach that is theoretically warranted
  - May be viable in other models or research contexts

Thank You!

Addendum

- Random Effects Plot – Total CV (right) and Component (left)





Complex Contagion Research Goals

1. Identify the extent to which exposure to upstream program performance affects downstream programs

1. Identify the extent to which interdependent activities experience turbulence over time

1. Identify hazard and survival rates relating to Program Performance

Better Understanding of Costs of Interdependencies

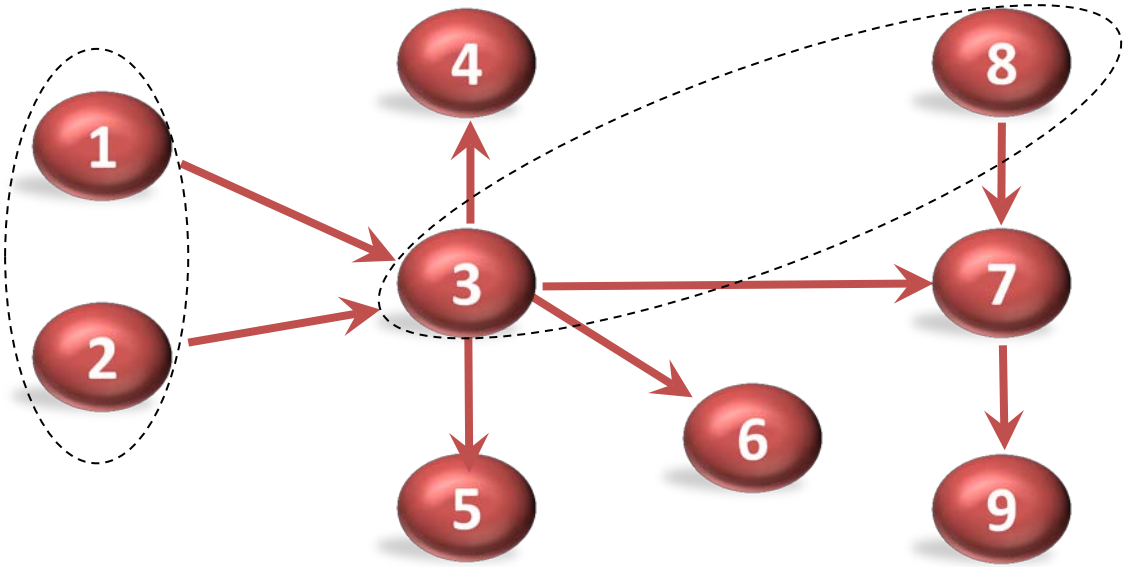
Improved Cost, Schedule, Performance Estimates

Defining Contagion - Refers to the phenomenon in networks where multiple sources of exposure affect a change in state.

Defining Complex Contagion – Examines influence of network exposure on program performance

Exposure Rates
Susceptibility Rates
Mean time in Growth

Thresholds
Survival Rates
Mean Time to Growth



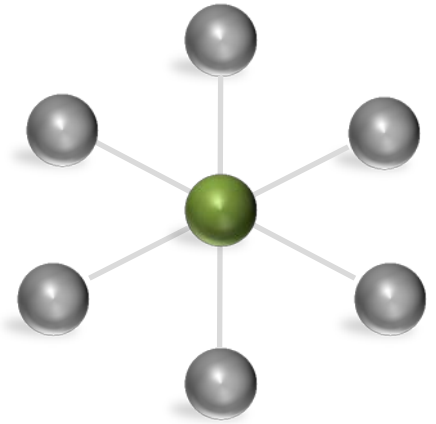
Methods

Examined 2 MDAP Networks

Shared Funding Sources

Funding Networks were established through the track-to-budget field of the SAR. Any given program element (R Doc) funds multiple MDAPS

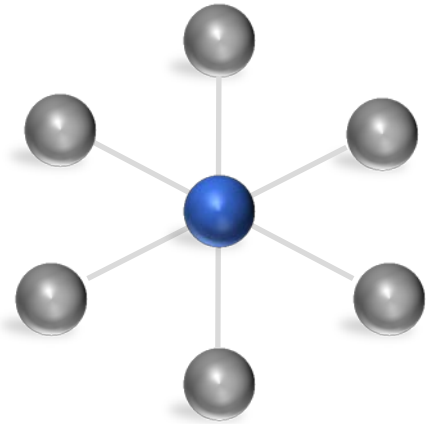
Funding Networks



Data Networks

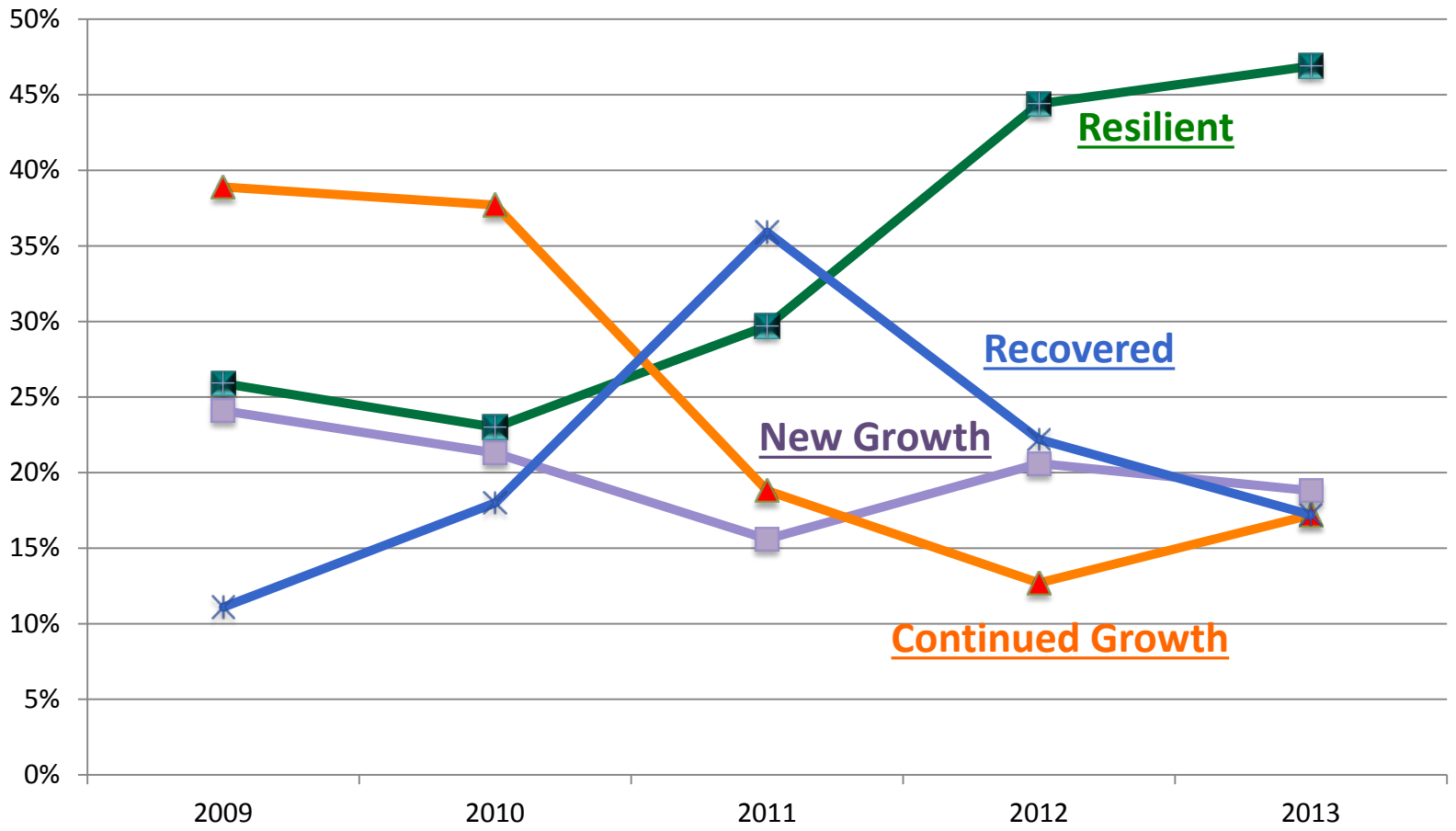
established through a 2009 call to program managers to identify their critical interdependencies.

Data Networks



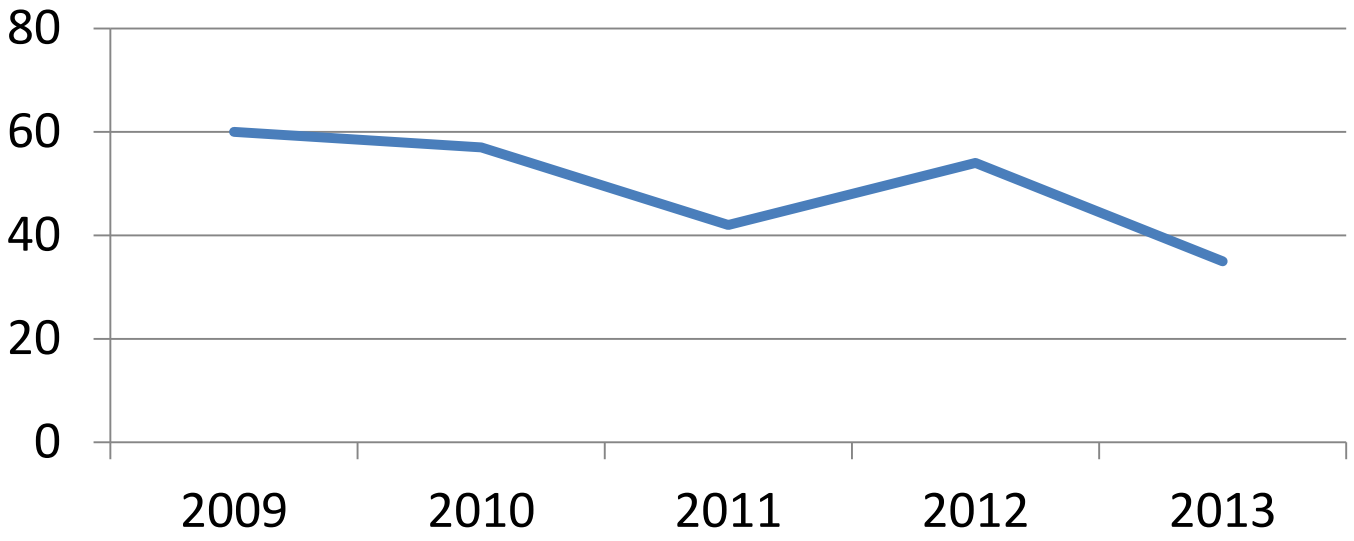
General Descriptives

Average Percent of programs in growth at any point in time = 40%



General Descriptives

- Average Annual PAUC Growth Rate = 8%
- Average Recovery Rate = 2.4 years
- Funding Network average number of partners = 4
- Data Network average number of partners = 5.6



Average Exposure Rate for Both Networks (Pct Partners Growth):

Snapshot Findings

Contagion Results

(Generalized Linear Models Maximum Likelihood Estimation)

Funding Network:

- Exposure did not provide predictive capabilities
- Number of Partners did

Data Network:

- Contagion was apparent and statistically significant

- Technological superiority

Snapshot Findings

Significant Network Level Findings

(Exponential Random Graph Modeling)

Funding Network:

- Increasing complexity over the years
  - Preferential attachment
- Preference for forming cohesive, interlocking relationships

Data Network:

- Preferential Attachment
- Is ***four times more likely to exchange data*** with partners than would normally be expected of a network of this size
  - A preference for tight closed relationships