N2C2M2 Experimentation and Validation

Understanding Its C2 Approaches and Implications

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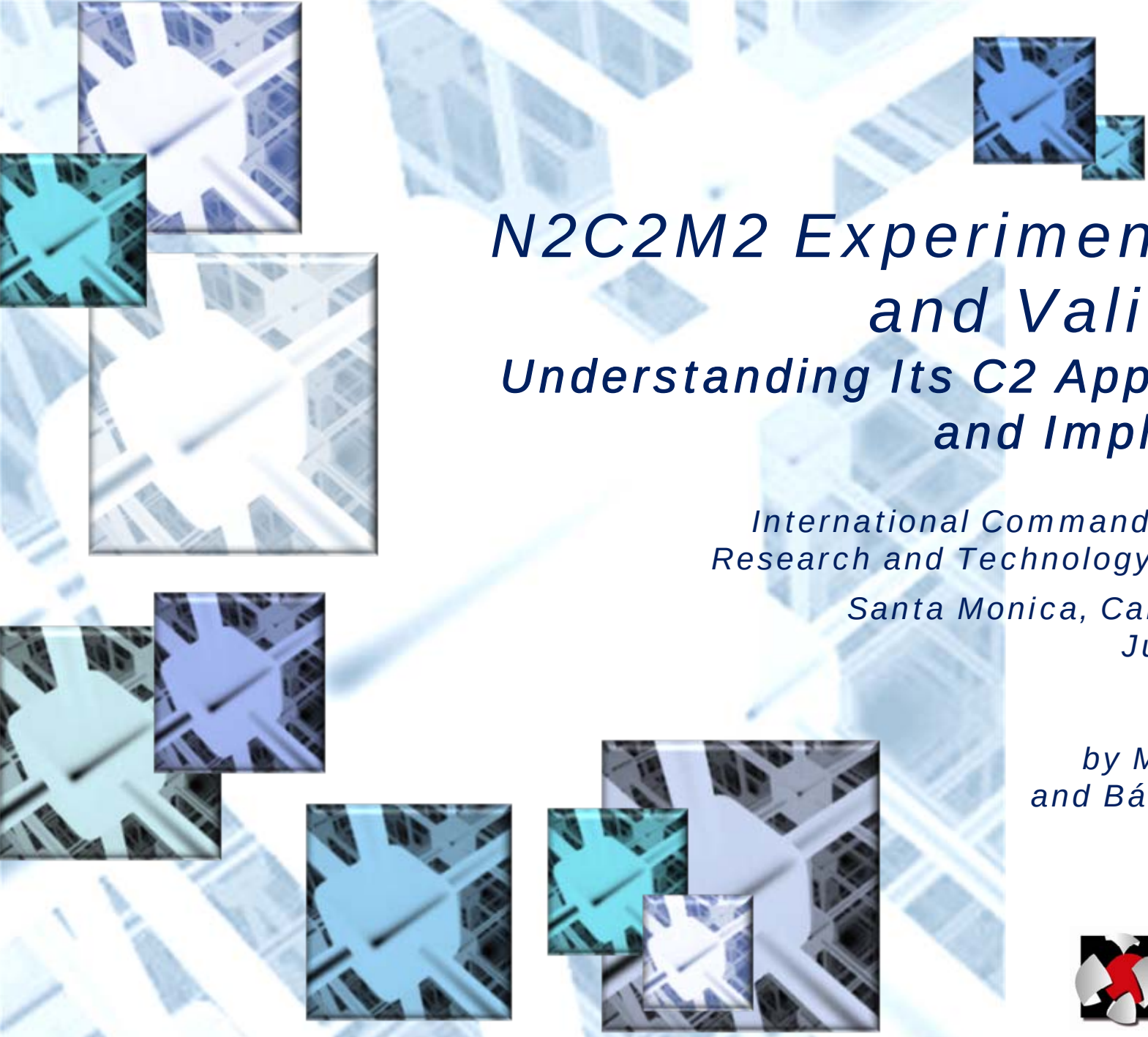


Outline

- **Background**
  - N2C2M2 and theory of NCW
  - ELICIT
- **Experimentation**
  - Early Expectations
  - Model and Key-variables
  - Experiment Design
  - Analysis
- **Conclusions**

Background

N2C2M2 Experimentation

ELICIT Platform

Paper 011
N2C2M2 Experimentation and Validation:
Understanding its C2 Approaches and Implications

Paper 010
Know The Network, Knit The Network:
Applying SNA to N2C2 Maturity Model Experiments

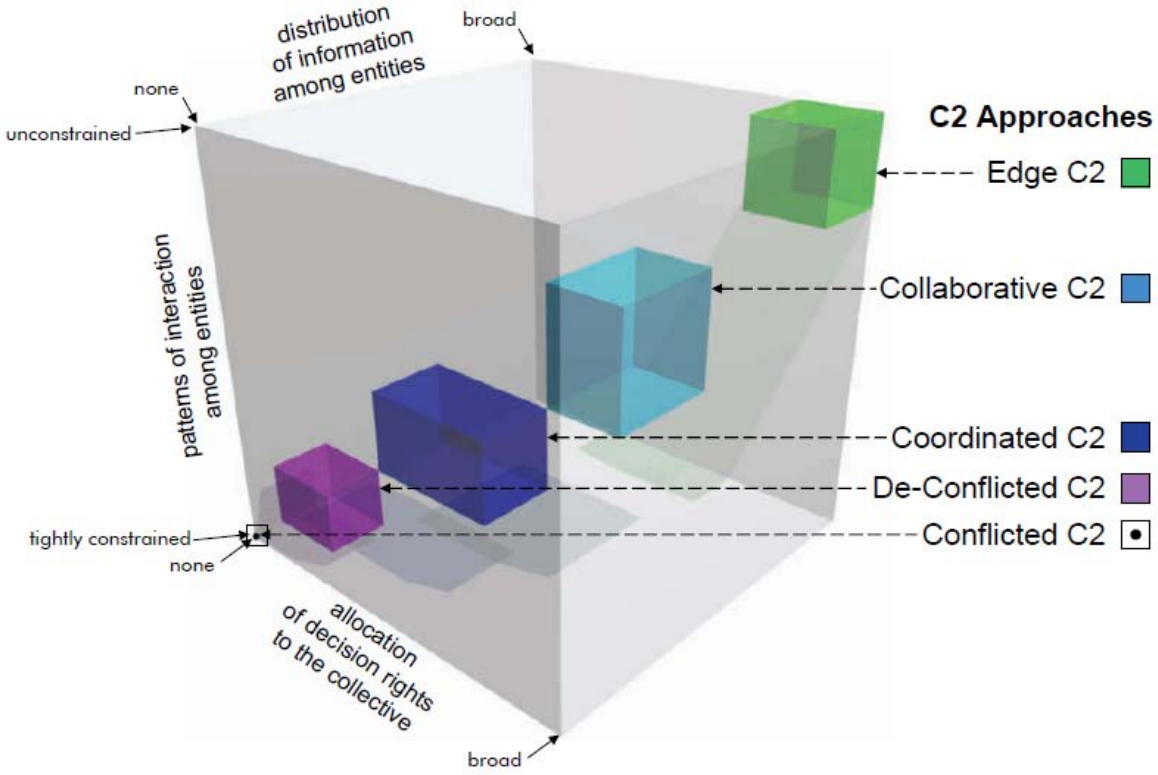
Background

- C2 in the Information Age:
  - Theory of NCW, including *NCW tenets*, *NCW Value Chain* and *C2 Approach Space* (CCRP, Alberts and Hayes)
  - C2 models: C2 CRM (SAS-050)
  - NATO NEC C2 Maturity Model (SAS-065) [1], recently developed and benefiting from multiple validation methods, including experimentation

[1] NATO SAS-065. *NATO NEC C2 Maturity Model*. CCRP Publication Series, 2010.

Background: N2C2M2

- NATO NEC C2 Maturity Model
  - Defines 5 levels of NATO NEC operational capability: levels 1 (less mature) to level 5 (more mature).
  - Defines 5 approaches to C2 associated with each level.



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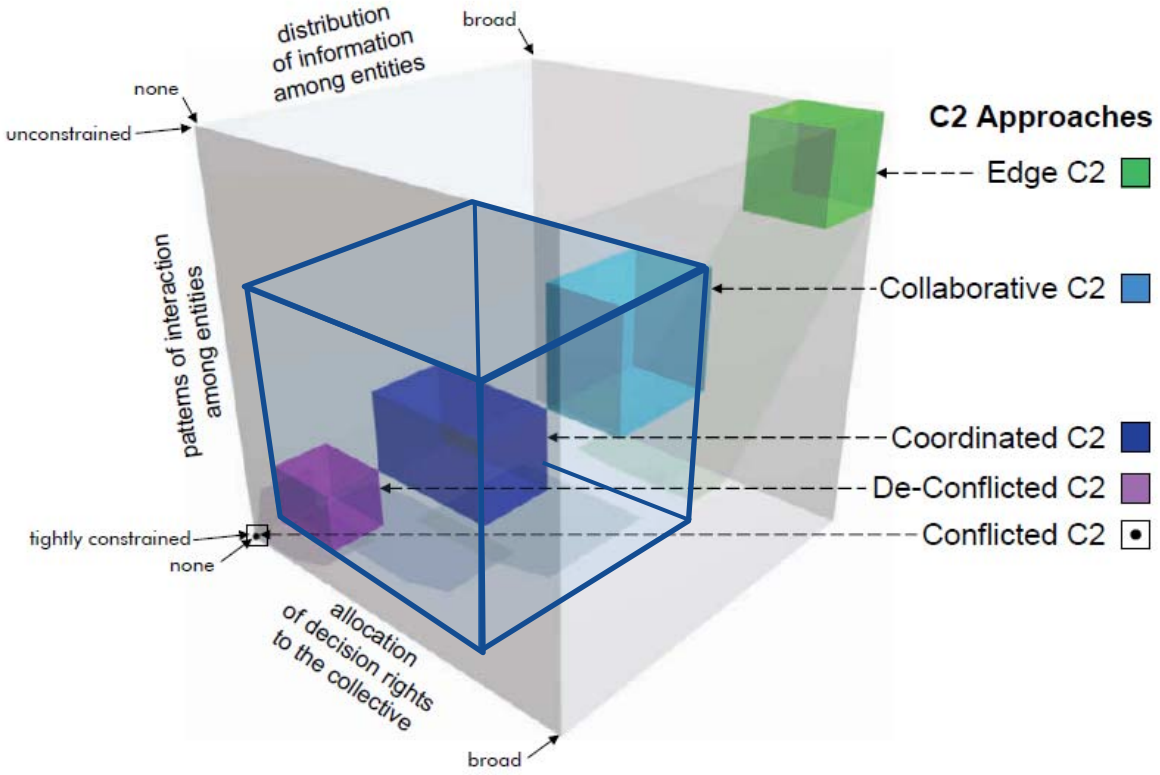


Level 4 Example

Background: N2C2M2

- NATO NEC C2 Maturity Model (2):
  - More maturity delivers:
    - More effectiveness
    - More efficiency
    - More agility
    - Positive impact in intermediate NCW value-chain variables, such as, *Quality of Individual and Shared Information, Quality of Individual and Shared Awareness and Understanding* and *Self-Synchronization**

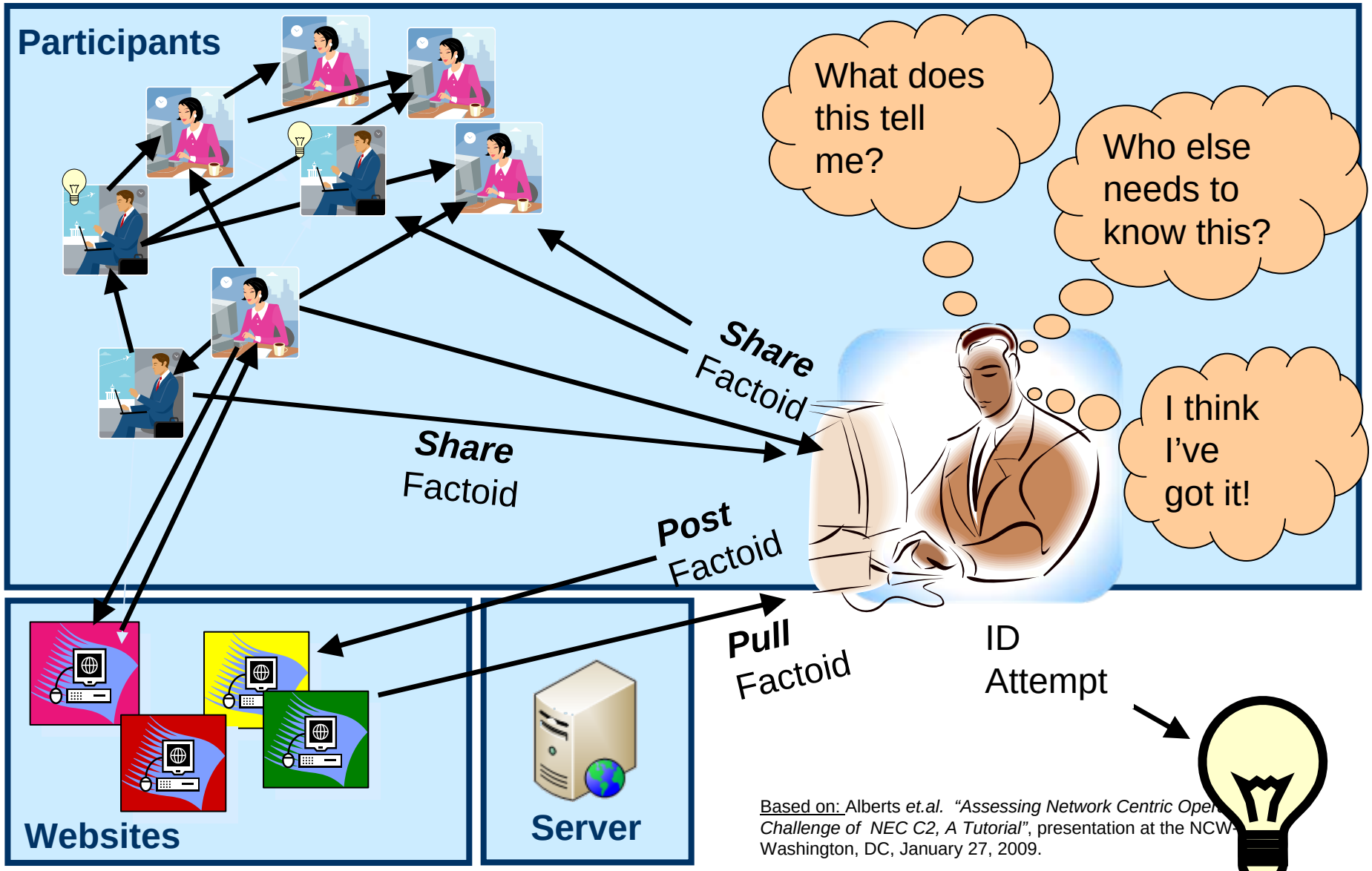
* *For detailed mapping between C2 CRM variables and ELICIT refer to:*
MANSO, Marco, and Paulo NUNES. *ELICIT and the Future C2: Theoretical Foundations for the Analysis of ELICIT Experiments*. Paper presented at the 13th ICCRTS, Seattle, USA, 2008

Background: ELICIT

- ELICIT: **E**xperimental **L**aboratory for the **I**nvestigation of **C**ollaboration, **I**nformation-sharing, and **T**rust.
  - An experimentation environment supported by software tools and instructions/procedures
  - Provides a simple (albeit rich) and collaborative network-centric environment for participating individuals
- Sponsor
  - U.S. DoD Command and Control Research Program (www.dodccrp.org)

Source: Alberts *et.al.* *"Assessing Network Centric Operations The Challenge of NEC C2, A Tutorial"*, presentation at the NCW-2009, Washington, DC, January 27, 2009.

Background: ELICIT



Based on: Alberts *et.al.* *"Assessing Network Centric Oper… Challenge of NEC C2, A Tutorial"*, presentation at the NCW… Washington, DC, January 27, 2009.

Experimentation: Early Expectations

Main hypotheses for validation:

- [1] For a complex endeavor , higher collective C2 maturity approaches are **more effective**.
- [2] For a given level of effectiveness, higher collective C2 maturity approaches are **more efficient**.
- [3] Higher collective C2 maturity approaches are **more agile**.

Experimentation: Early Expectations

Additional hypotheses:

- Higher collective C2 maturity approaches exhibit increased/better levels of:

  [4] Quality of Individual and Shared Information;

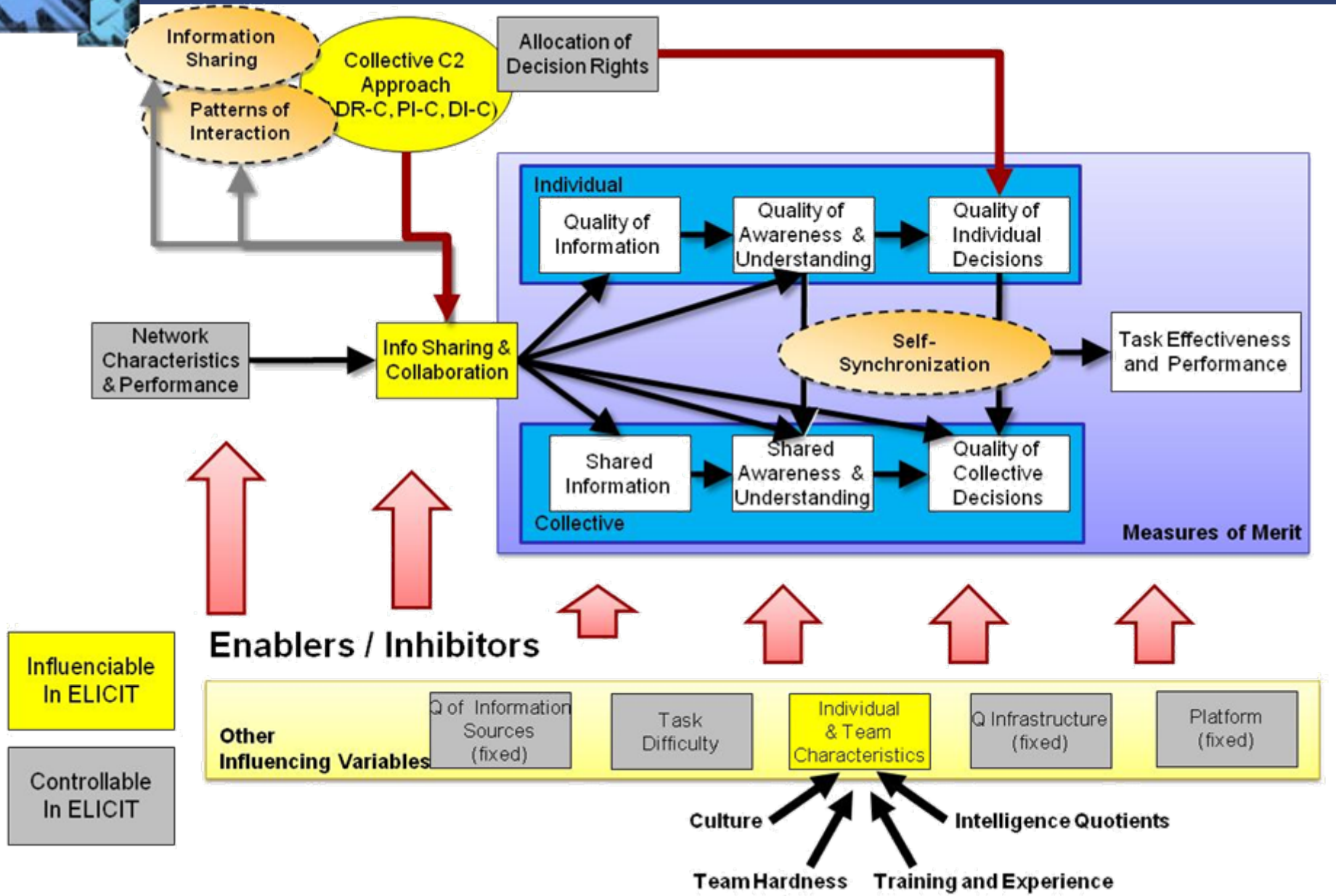
  [5] Quality of Individual and Shared Awareness and Understanding;

  [6] Self-Synchronization (at cognitive level);

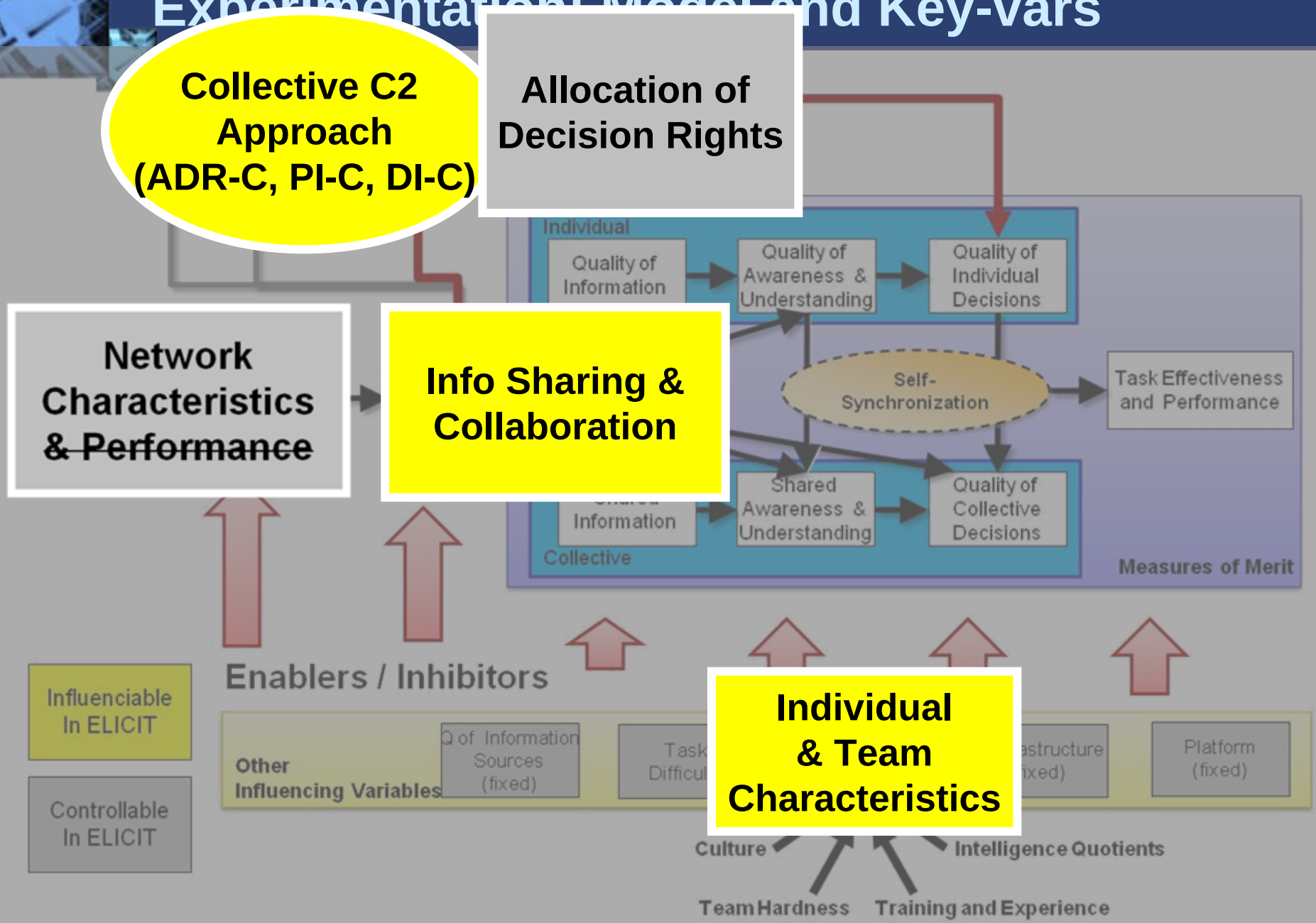
  Than: lower collective C2 maturity approaches.

- [7] Organizations require a minimum level of maturity to be effective in ELICIT.
- [8] Increasing the degree of difficulty in ELICIT require organizations to increase their level of maturity to maintain effectiveness in ELICIT.

Experimentation: Model and Key-vars



Experimentation: Model and Key-vars



Experimentation: Manipulations

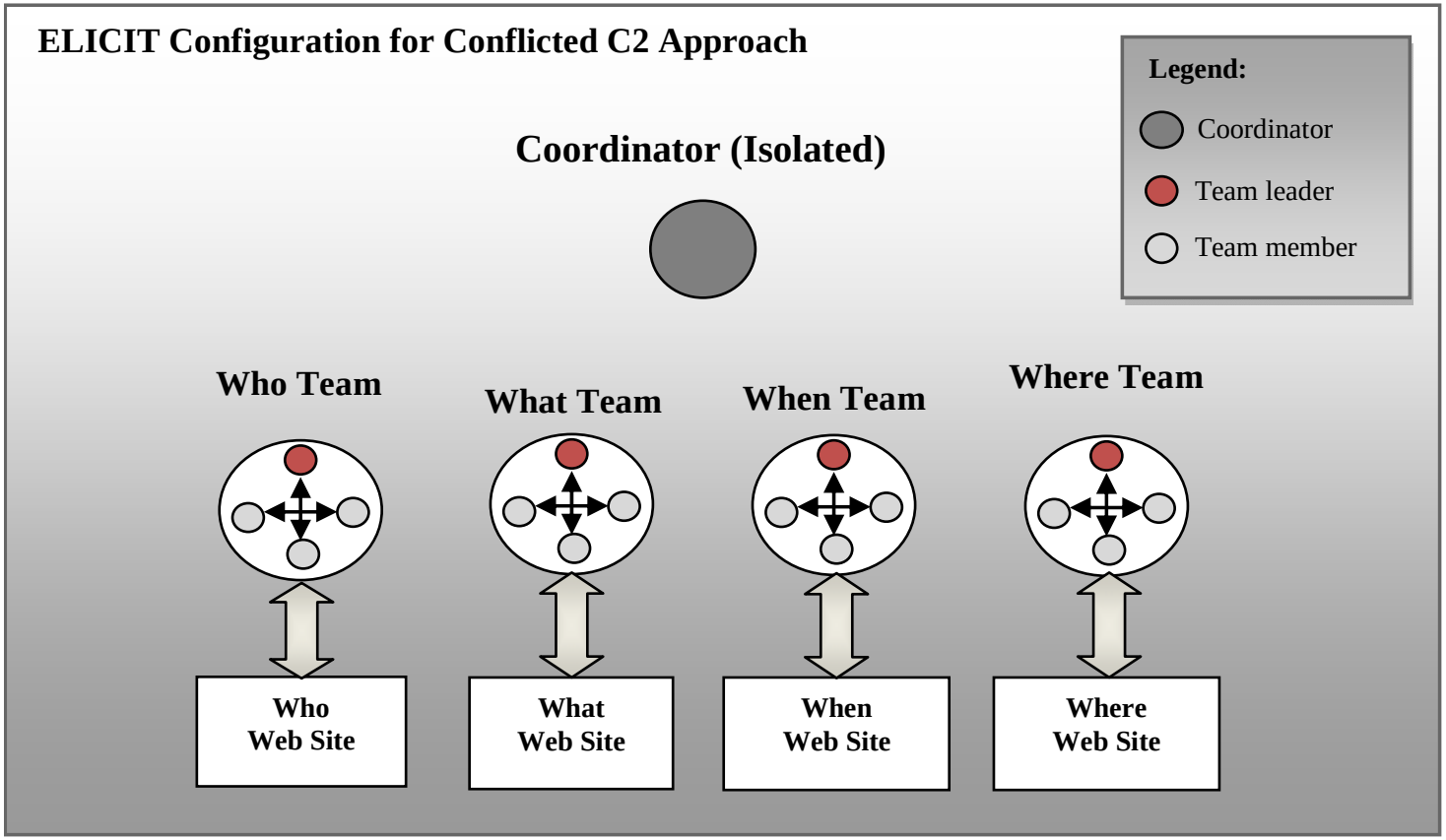
Name	Description
Network Characteristics and Performance	Allow or restrict interactions between: - subjects and teams. - subjects and websites. **This variable affects PI-C and DI-C**.
Information Sharing and (incentives for) Collaboration	Control: predefined server distributions of all factoids to subjects (in three waves). Influence: distribution of information as a result of human sharing and posting (human *will*) We will attempt to induce / influence collaborative behavior by: - defining collective or isolated goals - set individual and collective decision rights (see **ADR**) See paper for further notes on *Individual and Team Characteristics*. **This variable affects PI-C and DI-C**.
Allocation of Decision Rights	Decision rights will be allocated according to the C2 Approach to implement: - Distributed for higher maturity approaches; - None / (de)centralized for lower maturity approaches. **This variable is a C2 dimension**.

Experimentation: Design

Common aspects for all approaches:

- **Entities**: 4 TEAMS and 1 SINGLE ENTITY, except EDGE with 17 ENTITIES
- **Context**: complex endeavor with two or more force elements (entities) present with overlapping intents; operating in the same 'space' and time; and, an entity actions may conflict with those taken by another entities." (Alberts and Hayes 2007).
- **Scenario**: future terrorist attack
- **Task**: identify the "who", "what", "where" and "when" of the attack within a specific timeframe.
- **Information Sharing Capabilities**: *share*, *post* and *pull* actions. High maturity approaches will be enriched with more options (see next).
- **Collaborative Capabilities**: ability to provide "assessment" of importance (relevance) and/or trustworthiness of a factoid.
- **Resource Contention**: subject hoarding of relevant information is considered as a conflict. Cognitive efforts are required.

Experimentation: CONFLICTED model

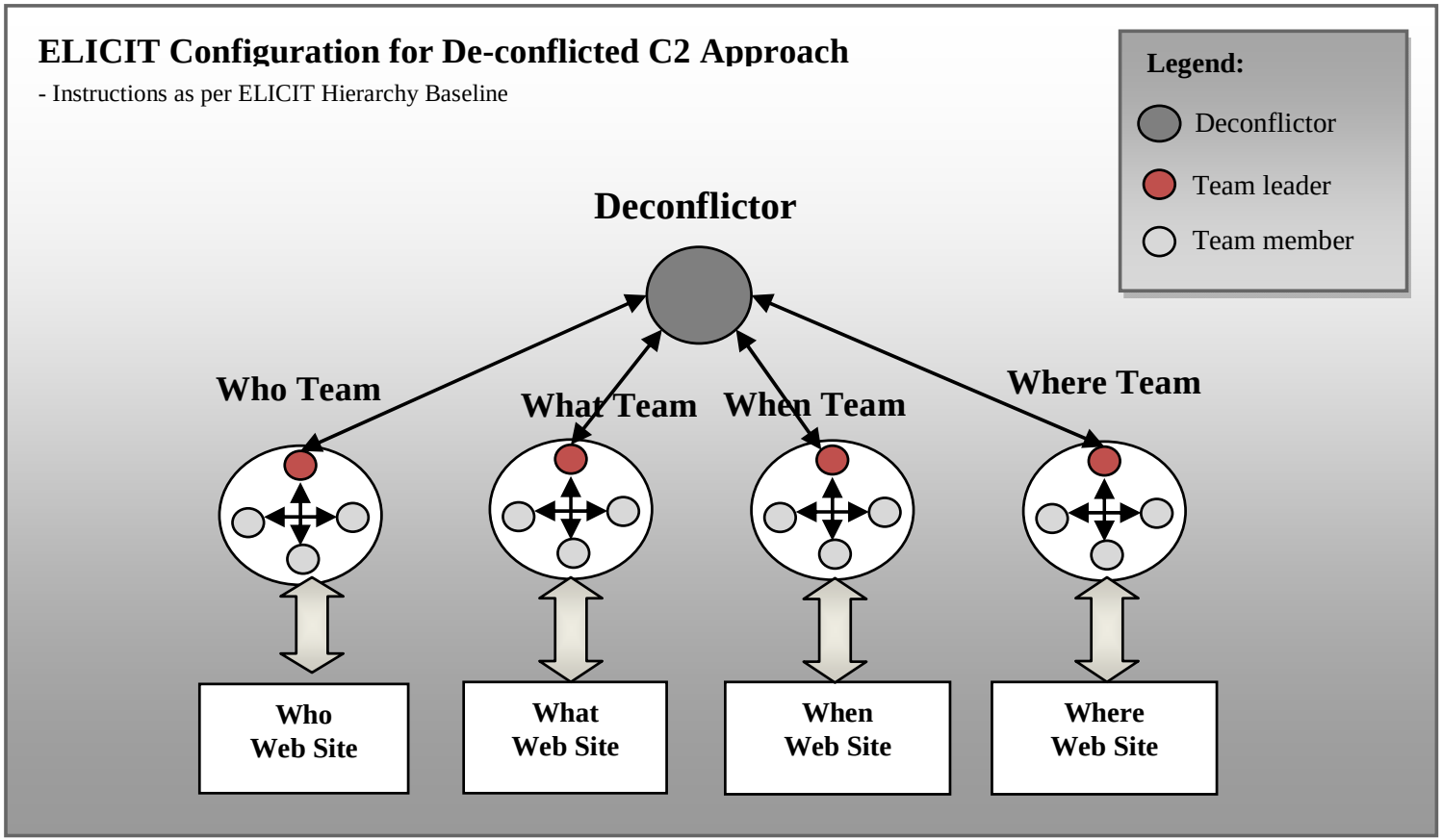


SUCESS CRITERION

Each Team pursues independent goals.

Success occurs if each Team leader finds the correct solution to his problem space.

Experimentation: DE-CONFLICTED model

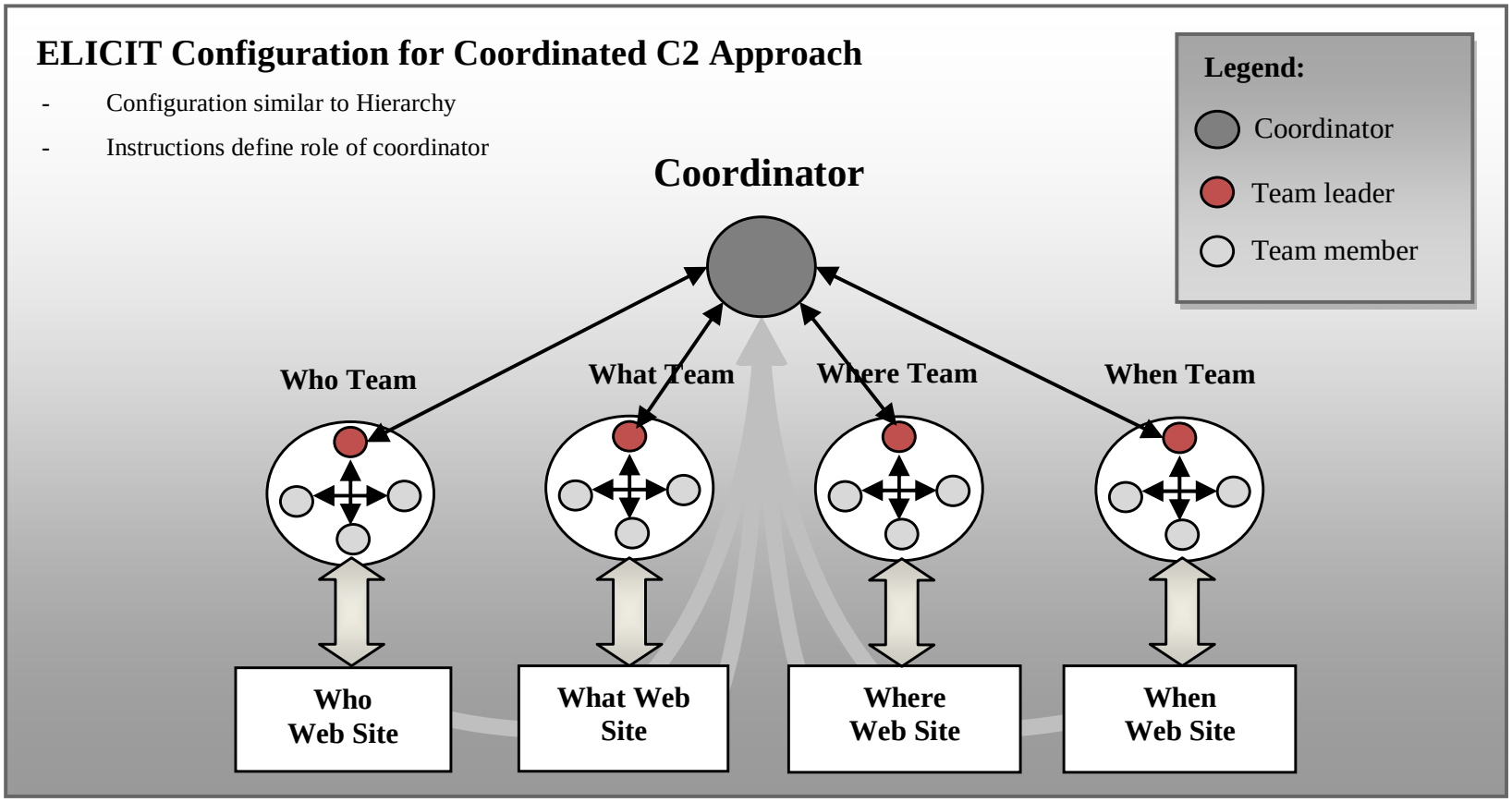


SUCESS CRITERION

Each Team pursues independent goals.

Success occurs if each Team leader finds the correct solution to his problem space.

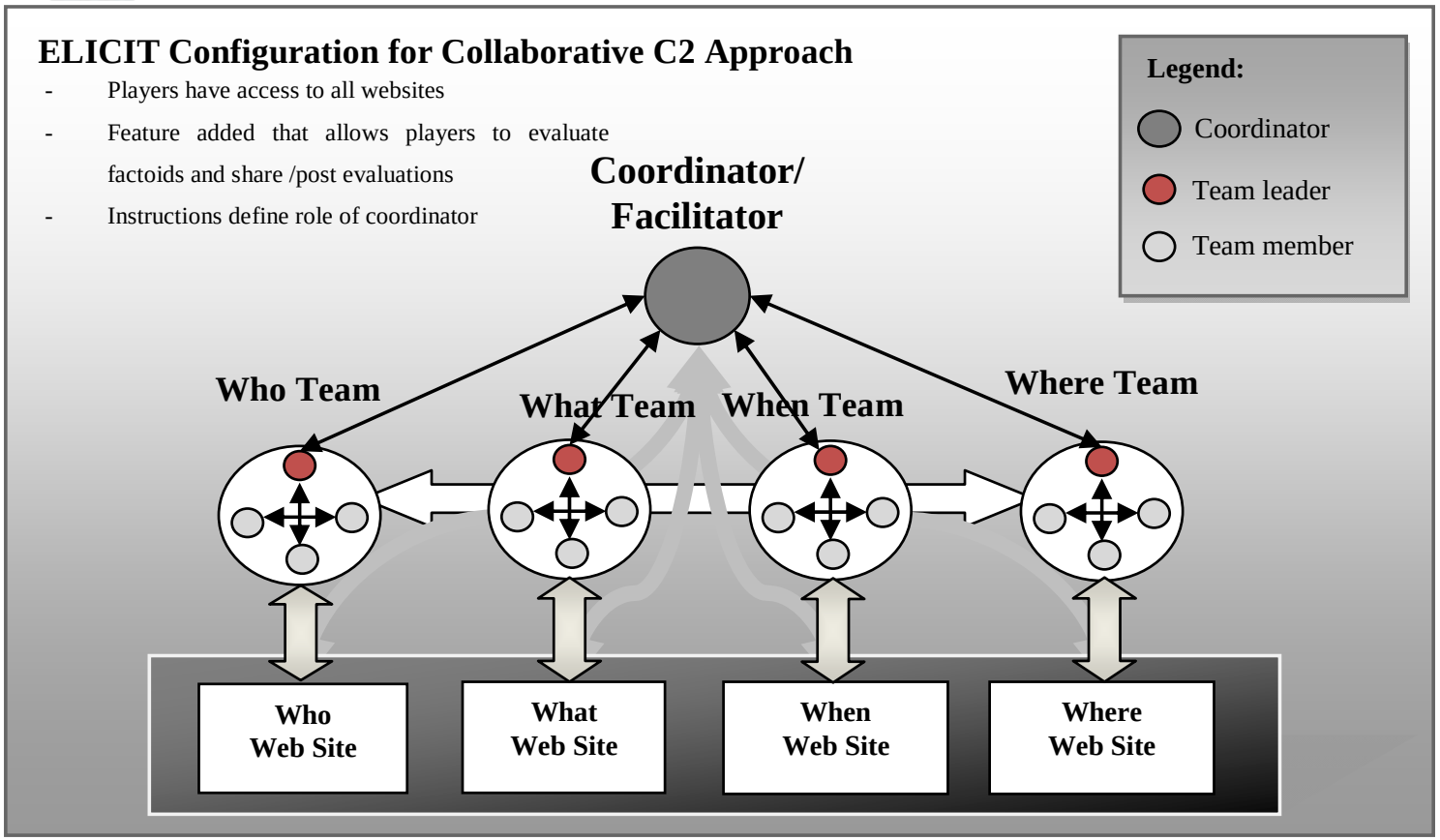
Experimentation: COORDINATED model



SUCESS CRITERION

Organization success depends on the Coordinator finding the correct solution.

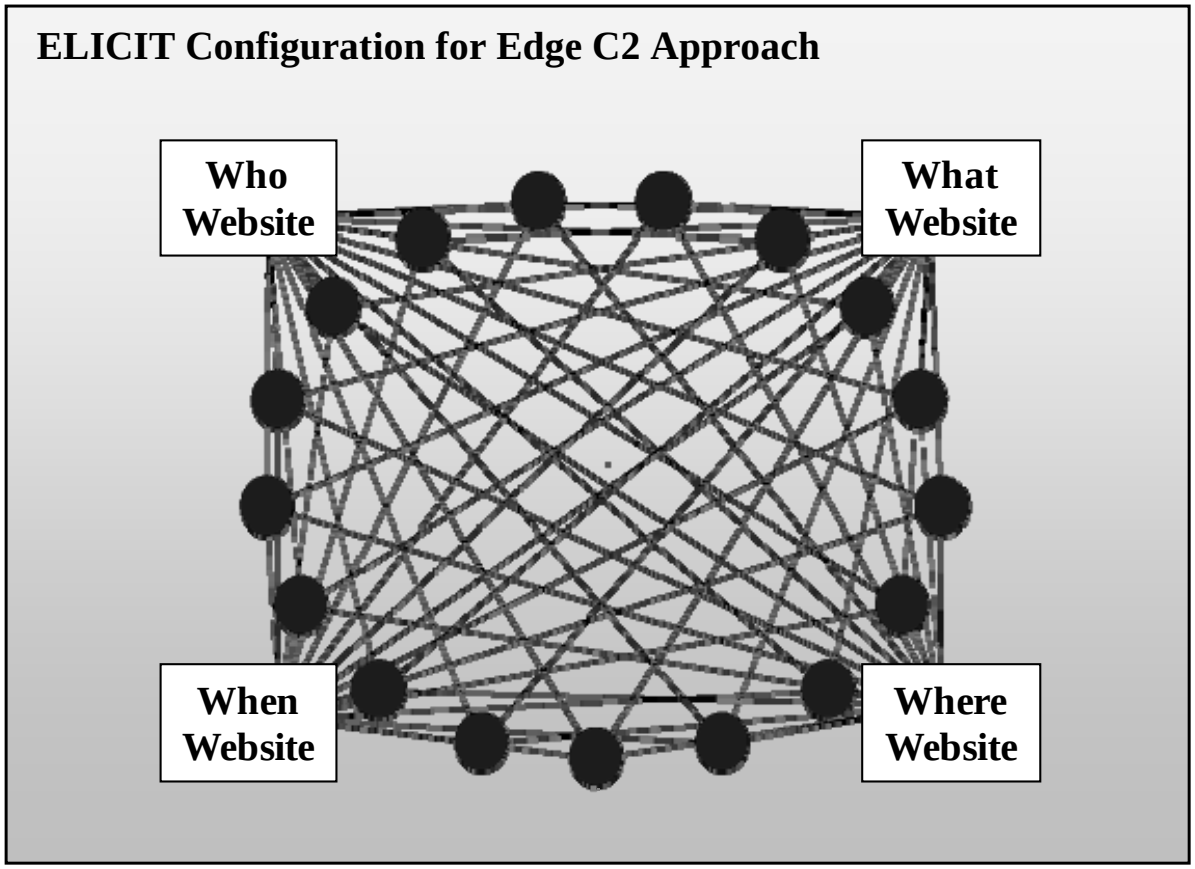
Experimentation: COLLABORATIVE model



SUCESS CRITERION

Coordinator finding the correct solution to all problem spaces OR Team leaders finding the correct solution to their problem space.

Experimentation: EDGE model



SUCESS CRITERION

Organization success depends on the individuals' IDs plurality being correct in each problem space.

Analysis: Experiments Baseline

18 valid runs performed with human subjects:

- 3 runs for CONFLICTED
- 4 runs for DE-CONFLICTED
- 4 runs for COORDINATED
- 4 runs for COLLABORATIVE
- 3 runs for EDGE

Usually, a group of 17 subjects was used to perform two runs. A *test* run (15 to 30 min) was always conducted prior to first *real* run.

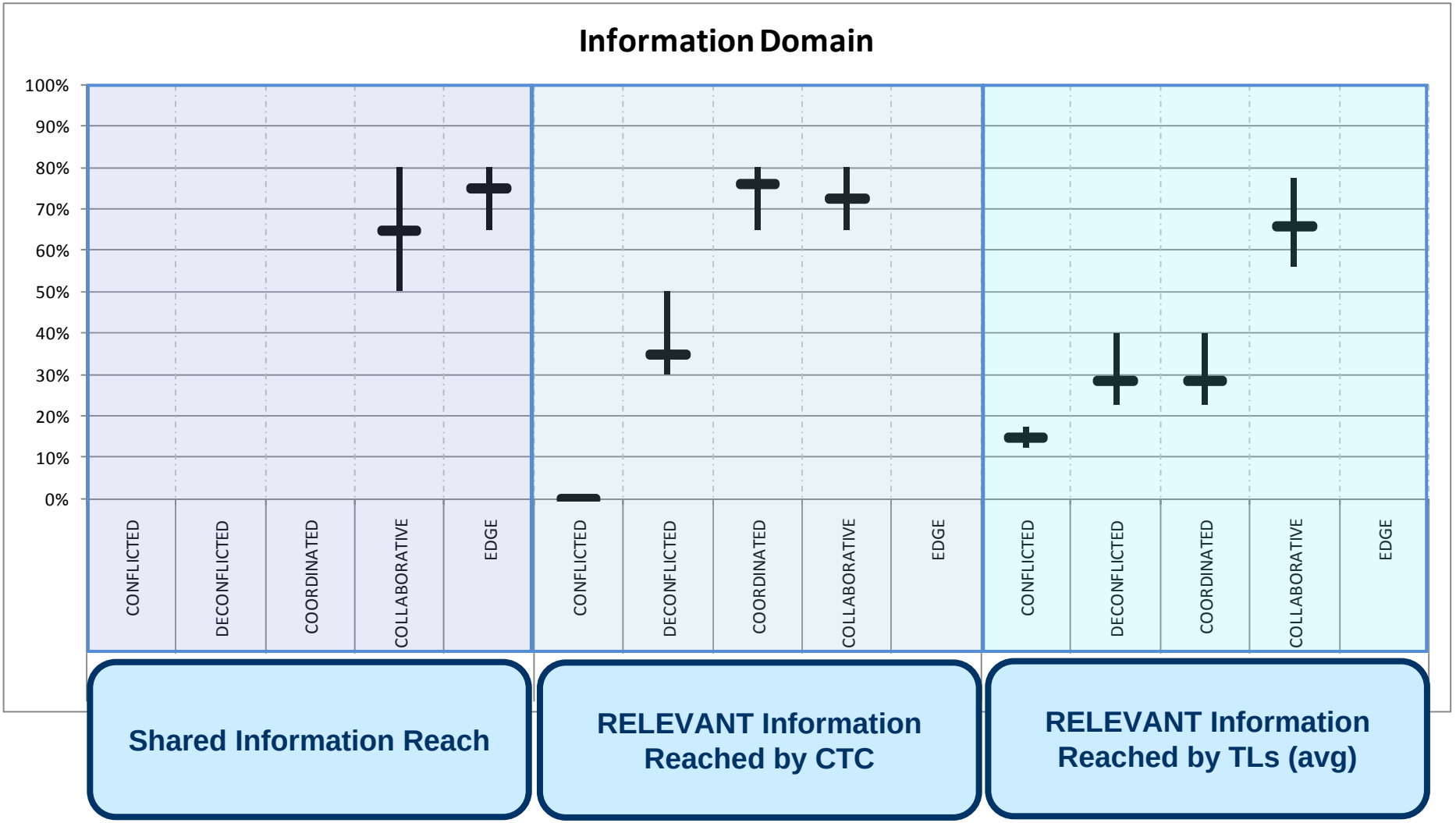
This means:

- About 150 military cadets participated in ELICIT runs.
- About 10 hours of data to analyze
- 9 979 actions, comprising:
  2 290 shares, 1 880 posts, 4 979 pulls and 712 IDs
- Software Analysis Tool: more than 50K SLOC

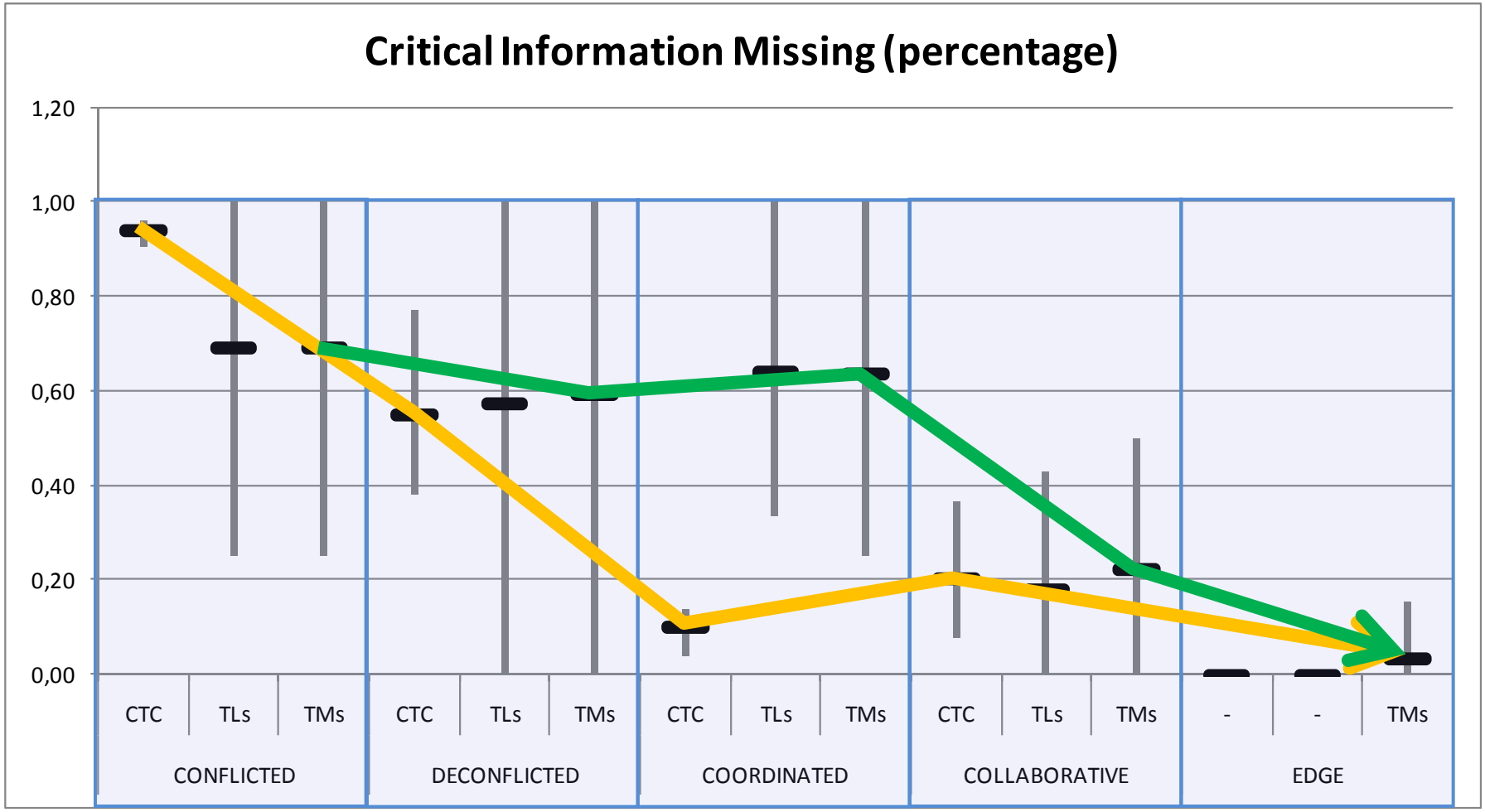
Analysis: Overview

- Information Domain
- Interactions and Social Domain
- Cognitive Domain
- Measures of Merit

Analysis: Information Domain



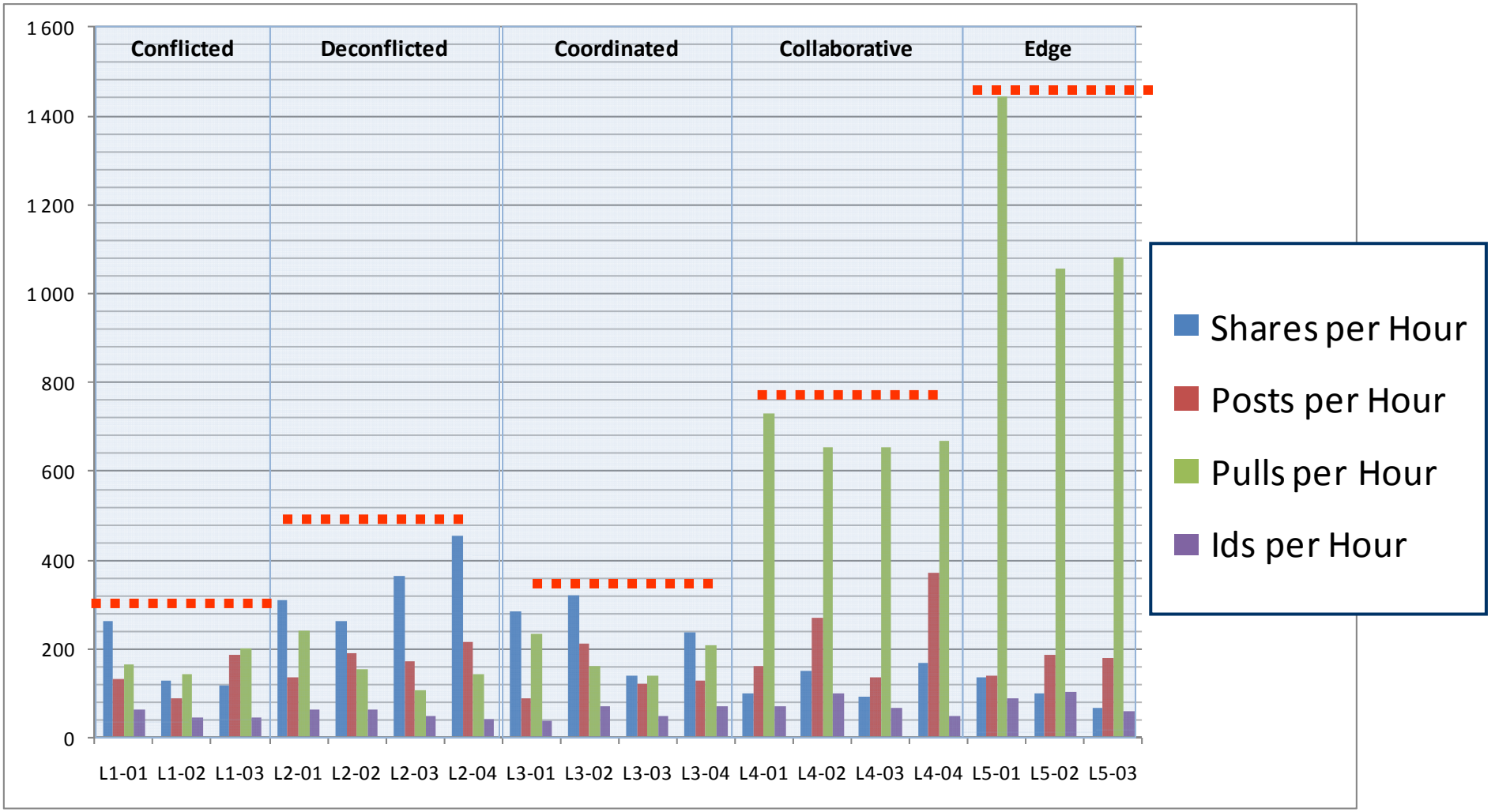
Analysis: Information Domain



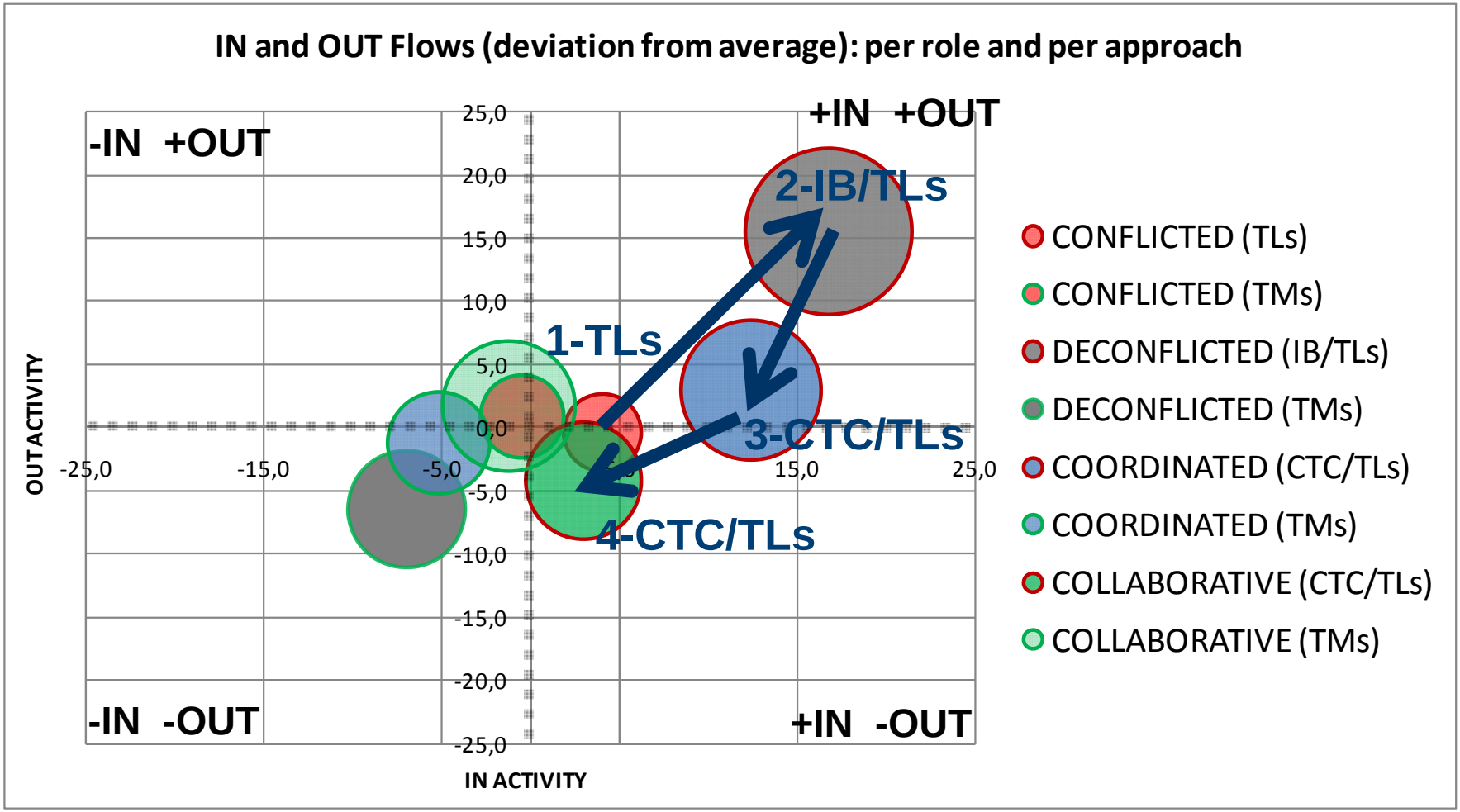
CTC TMs

Analysis: Interactions and Social Domain

Nature and quantity of Interactions:



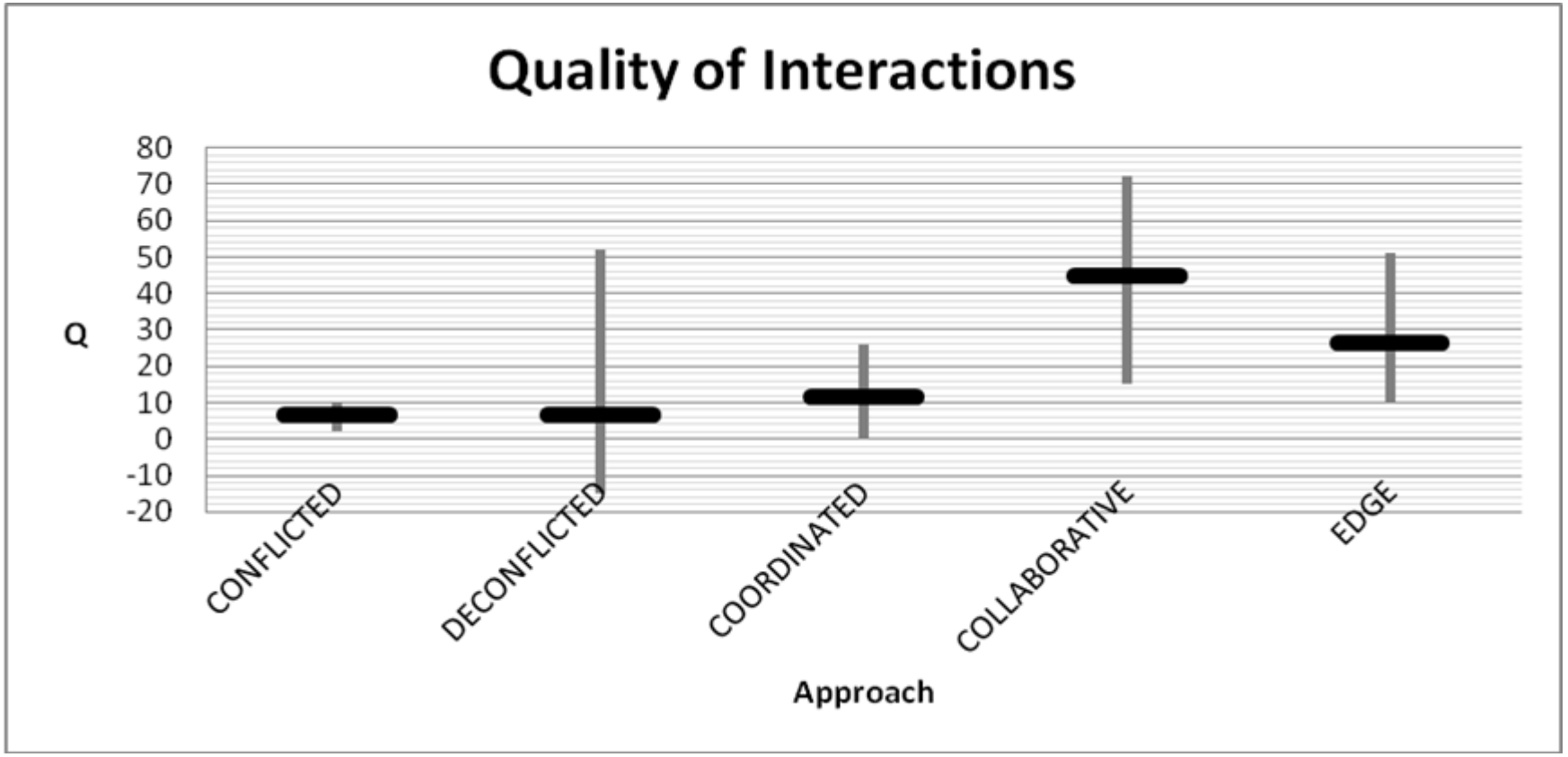
Analysis: Interactions and Social Domain



$$IN\_DEV_{S_i} = (nbr\_shares\_received_{S_i} + nbr\_pulls_{S_i}) - (Average\_nbr\_shares\_received + Average\_nbr\_pulls)$$

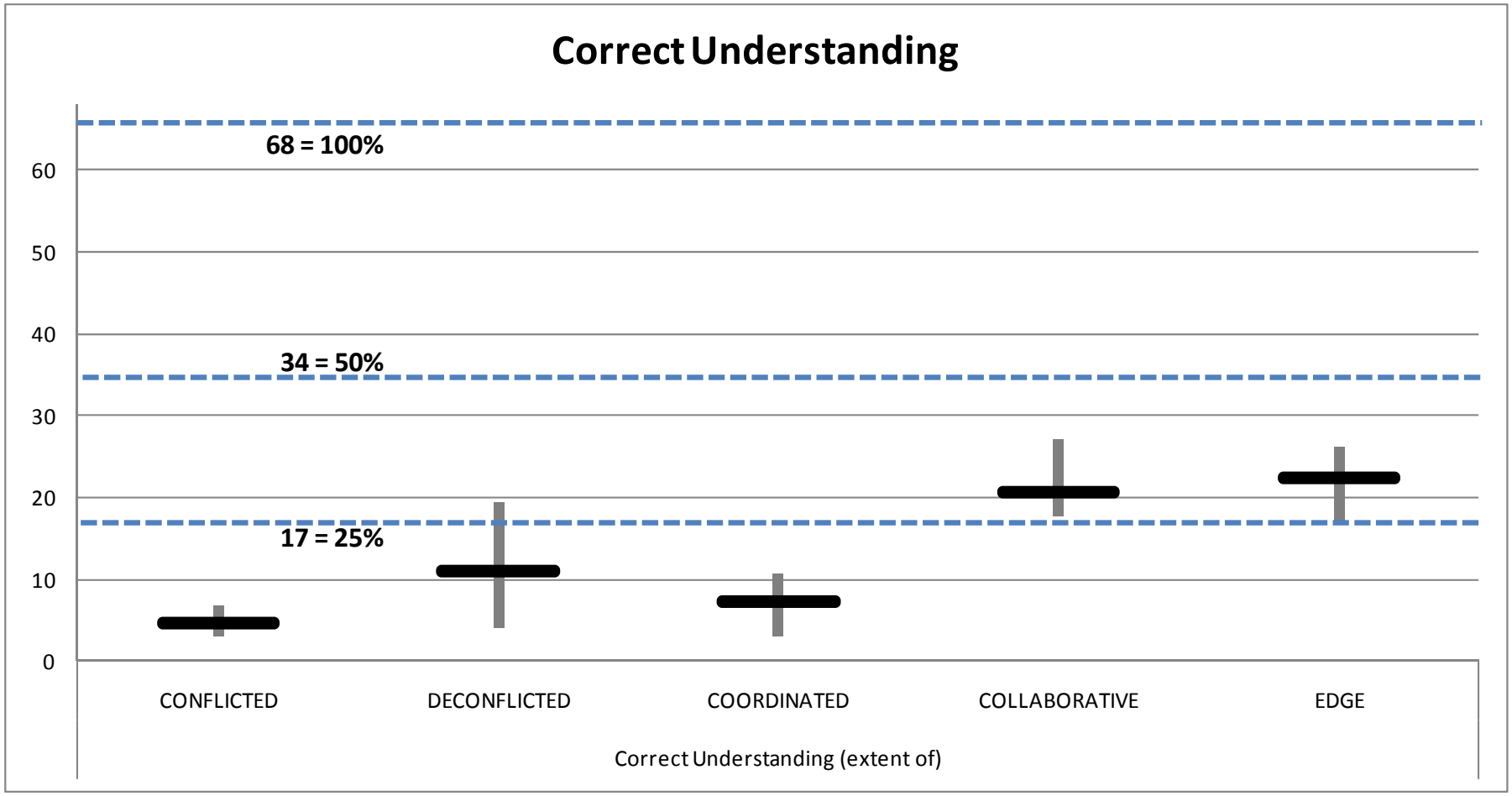
$$OUT\_DEV_{S_i} = (nbr\_shares\_sent_{S_i} + nbr\_posts_{S_i}) - (Average\_nbr\_shares\_sent + Average\_nbr\_posts)$$

Analysis: Interactions and Social Domain

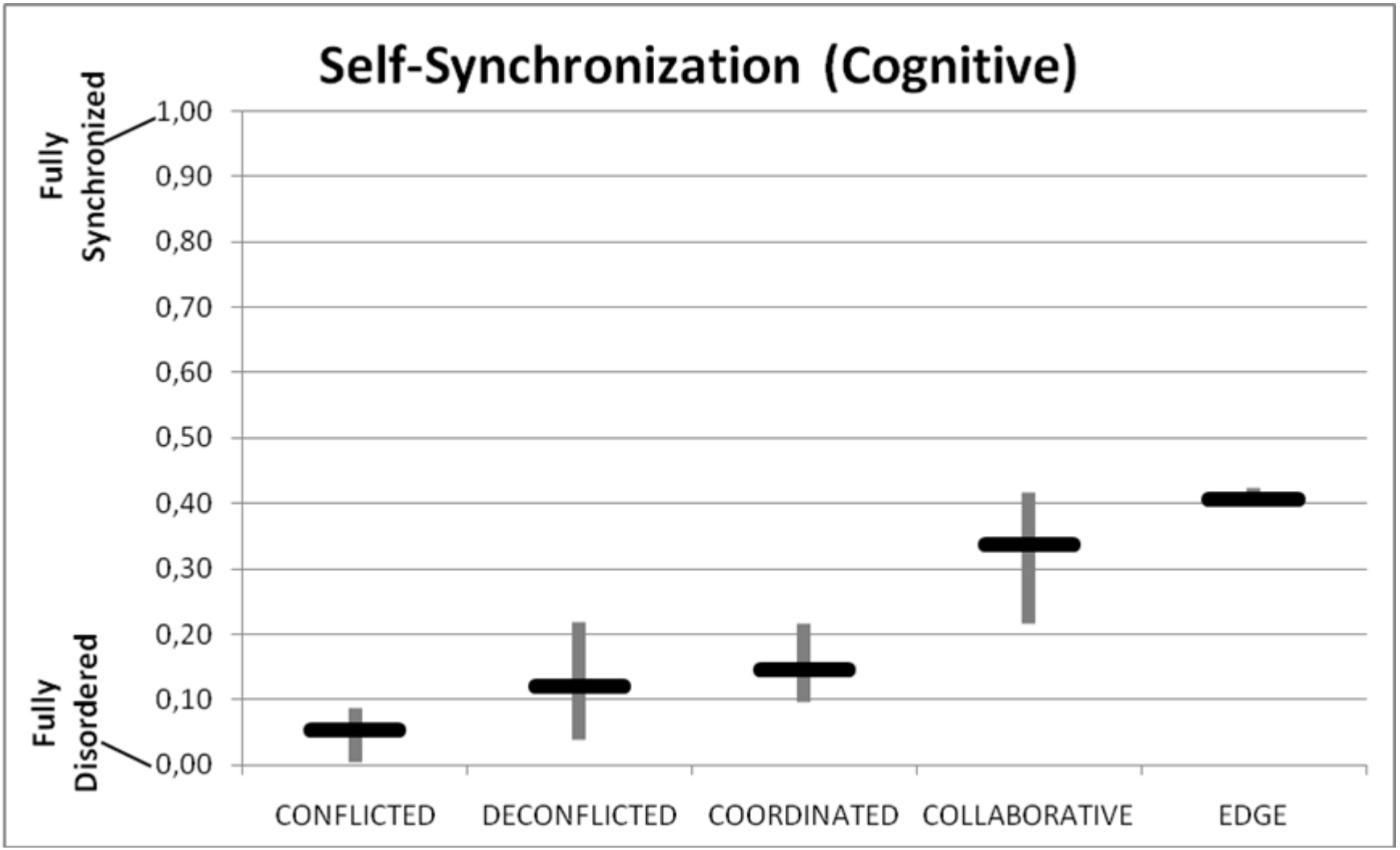


$$Q_{Interactions} = \sum R\_factoids_{shared\_and\_posted} - \sum N\_factoids_{shared\_and\_posted}$$

Analysis: Cognitive Domain

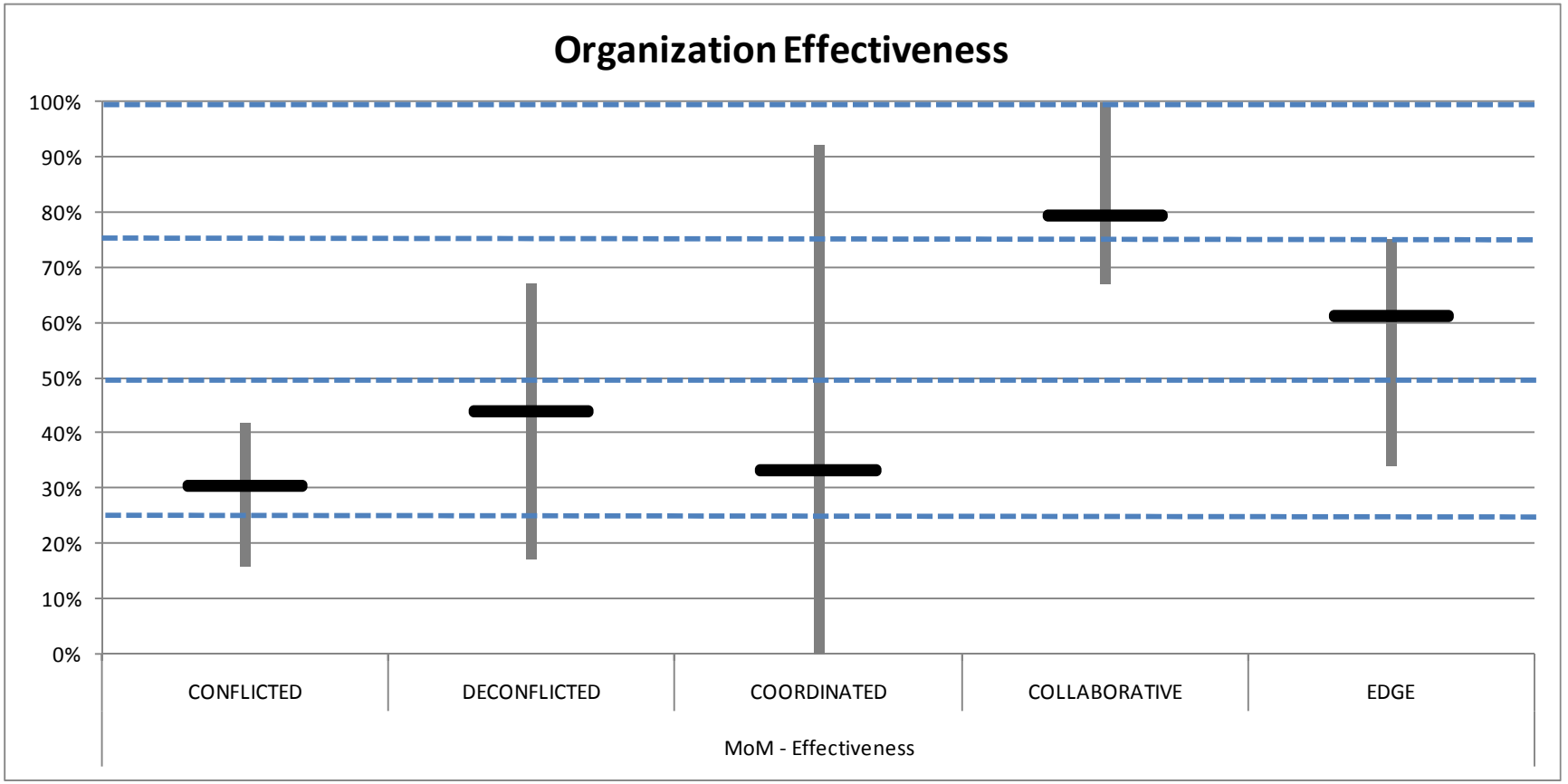


Analysis: Cognitive Domain



$$\text{CSSync}_{problemSpace} = 1 - \sum_{i=1}^{N} P(S_i) * \ln(P(S_i)) / Max\_Disorder_{problemSpace}$$

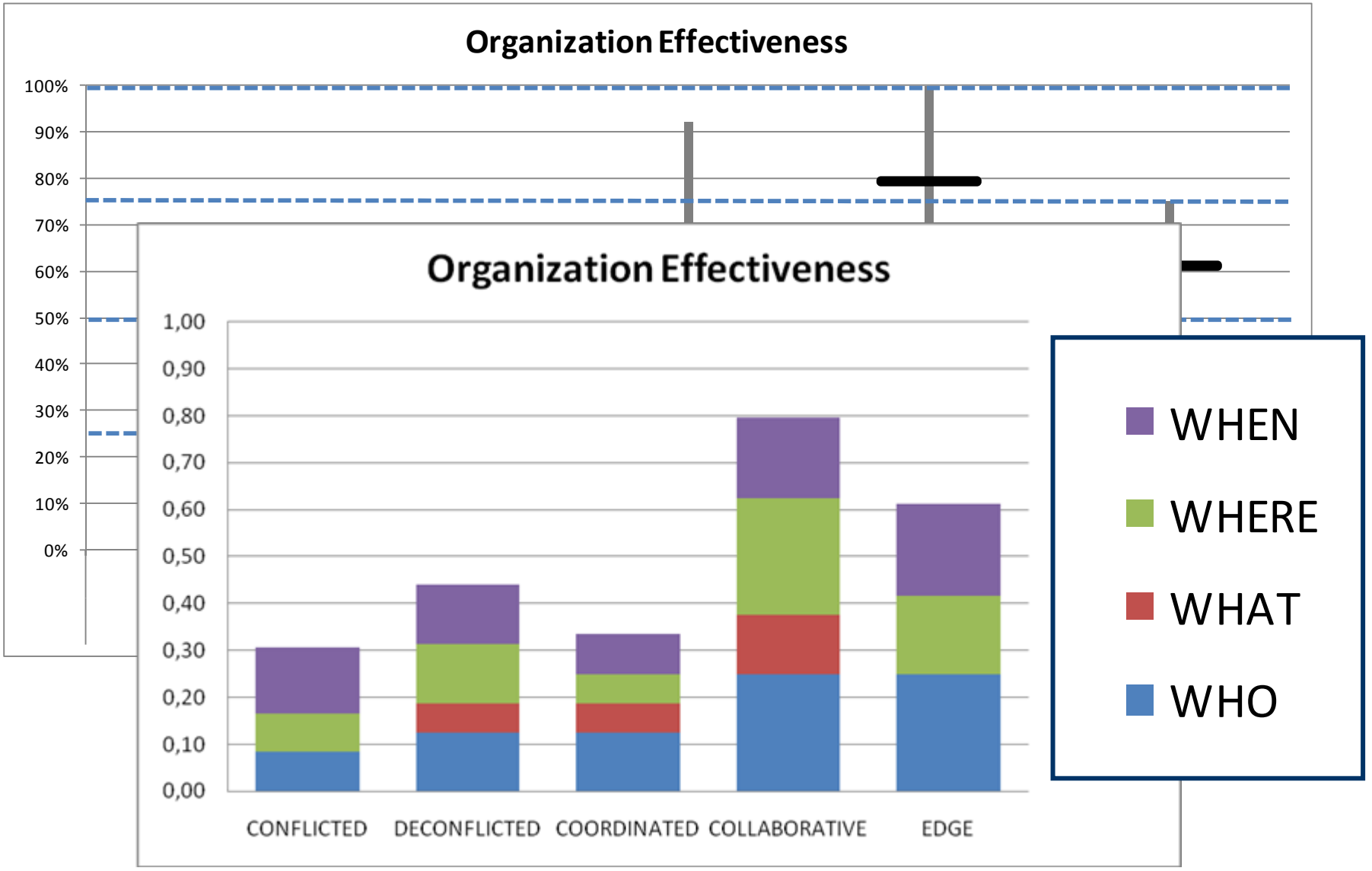
Analysis: MoM



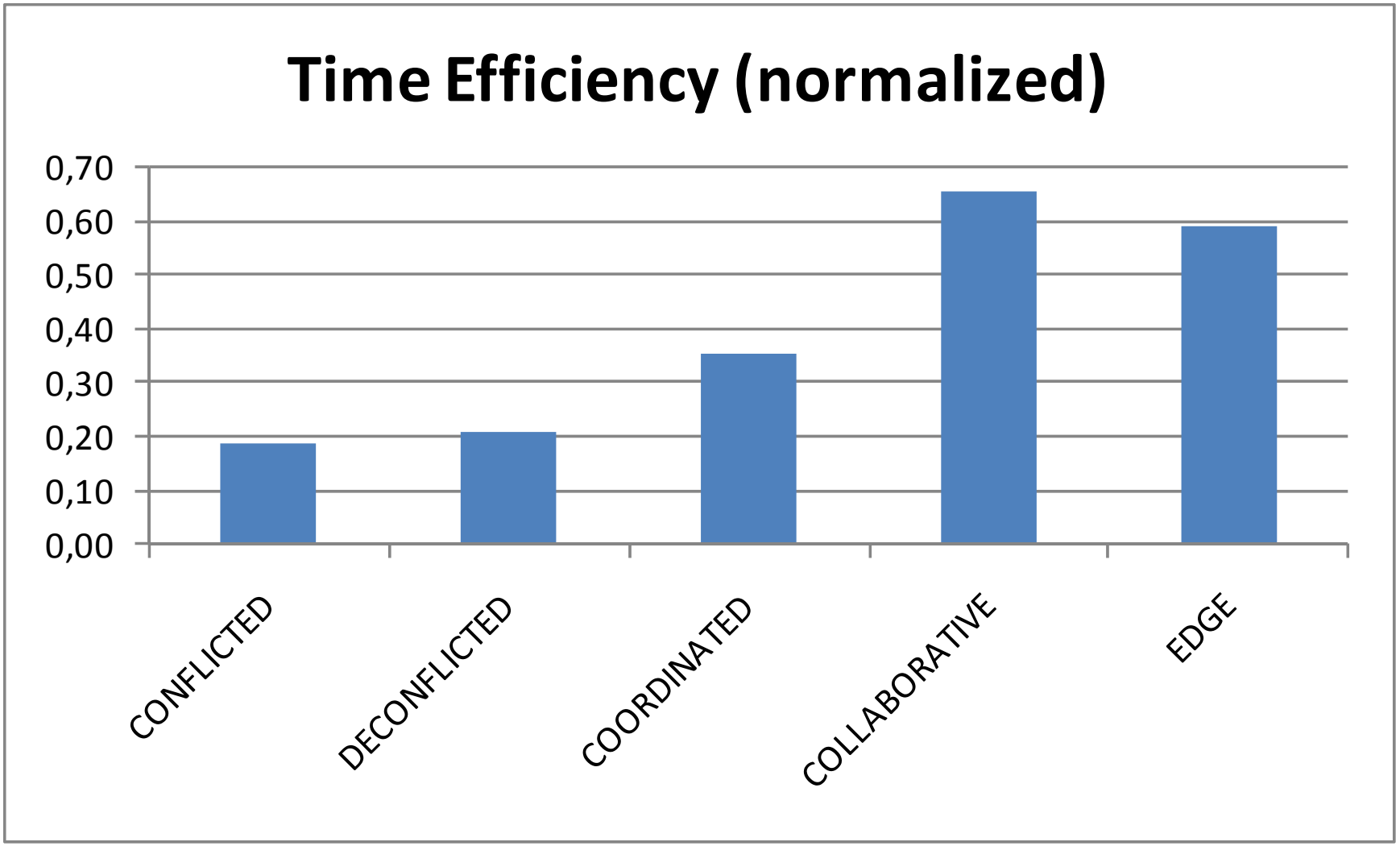
$$Effectiveness = \sum_{i} 0.25 * Correct\_ans_i$$

$Correct\_ans_i$ is 1.0 if correct answer is provided and 0.0 otherwise

Analysis: MoM

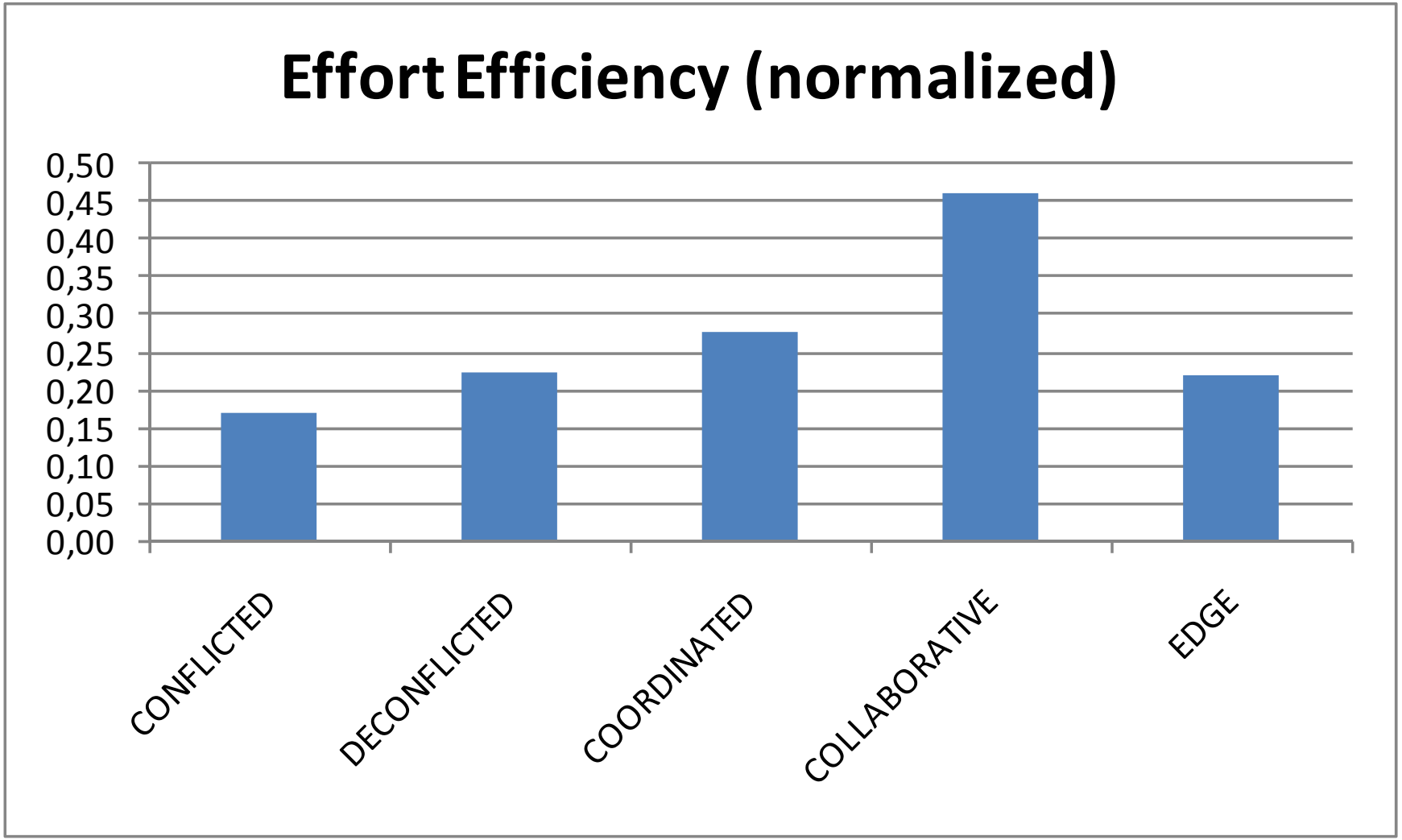


Analysis: MoM



$$Efficiency_{time} = Effectiveness\_score^2 * \log_{10}(1 + 1/time\_last\_ID)$$

Analysis: MoM



$$Efficiency_{effort} = Effectiveness\_score^2 * \log_{10}(1 + {}^{1}\!/_{effort\_spent})$$

Conclusions

Domain / Variable Assessed \ C2 Approach		CONFLICTED	DECONFLICTED	COORDINATED	COLLABORATIVE	EDGE
Information Domain	Shared Information Reach	5	4	3	2	1
	Critical Information Accessible	5	4	3	2	1
Interactions	Quality of Interactions	5	4	3	1	2
Cognitive Domain	Extent of Correct Understanding	5	3	4	2	1
	Cognitive Self-Synchronization	5	4	3	2	1
MoM	Organization Effectiveness	5	3	4	1	2
	Time-Efficiency	5	4	3	1	2
	Effort-Efficiency	5	3	2	1	3

Conclusions

Results are consistent with model expectations (in overall):

[4] *Higher collective C2 maturity approaches exhibit increased/better levels of **Quality of Individual and Shared Information** than lower collective C2 maturity approaches.*

- **OK**

[5] *Higher collective C2 maturity approaches exhibit increased/better levels of **Quality of Individual and Shared Awareness and Understanding** than lower collective C2 maturity approaches.*

- **OK – except for Coordinated**

[6] *Higher collective C2 maturity approaches exhibit increased/better levels of **Self-Synchronization (at cognitive level)** than lower collective C2 maturity approaches.*

- **OK**

Conclusions

Results are consistent with model expectations (in overall):

[1] *For a complex endeavor, higher collective C2 maturity approaches are more effective.*

- **OK – except for EDGE**

[2] *For a given level of effectiveness, higher collective C2 maturity approaches are more efficient.*

- **OK – except for EDGE (with a high-deviation)**

[3] *Higher collective C2 maturity approaches are more agile.*

NOT Covered

Agile C2 is a novel concept under the analysis of SAS-085. This hypothesis will be considered in future research work.

Conclusions

Results are consistent with model expectations (in overall):

[7] *Organizations require a minimum level of maturity to be effective in ELICIT.*

Considering current dataset, requisite maturity in ELICIT is COLLABORATIVE or COORDINATED (having a proper CTC).

[8] *Increasing the degree of difficulty in ELICIT require organizations to increase their level of maturity to maintain effectiveness in ELICIT.*

NOT Covered

There is no sufficient data (factoid set 2 trials) to test this hypothesis.

..:: Thank You for Your Attention ::..

Questions?