National Defence / Défense nationale

ASSISTANT DEPUTY MINISTER (DEFENCE RESEARCH AND DEVELOPMENT CANADA)

DG R&D Science and Engineering

CANADIAN ARMED FORCES / FORCES ARMÉES CANADIENNES

DRDC RDDC

Investigating the Impact of Project Dependencies on Capital Investment Decisions in Defence

Carolyn Chen and Kendall Wheaton

Centre for Operational Research and Analysis

Defense Research and Development Canada

17th NATO Operations Research and Analysis (OR&A) Conference

Laurel, MD

31 October 2023

Canada

Introduction

https://www.canada.ca/en/department-national-defence/services/procurement/integrated-soldier-system-project.html

https://www.canada.ca/en/department-national-defence/services/procurement/ch-147f-chinook.html

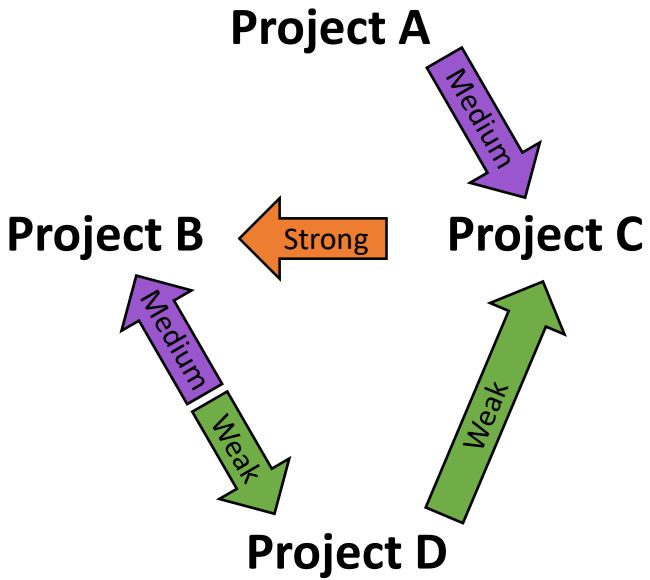
- Long-term strategic planning in defence aims to tackle the challenging problem of selecting the best portfolio of capital investments for equipping future forces
- Often, projects rely on each other to provide functional capabilities to the forces (ex. aircraft need runways)
- Relationships need to be considered in the planning process to avoid future difficulties in capability delivery
  - Mutually exclusive (select A **OR** B)
  - **Dependent** (select A **AND** B)
  - **Synergistic** (select A ↑ B)

https://www.canada.ca/en/department-national-defence/services/procurement/medium-support-vehicle-system-project.html

https://www.canada.ca/en/department-national-defence/services/procurement/arctic-offshore-patrol-ships.html

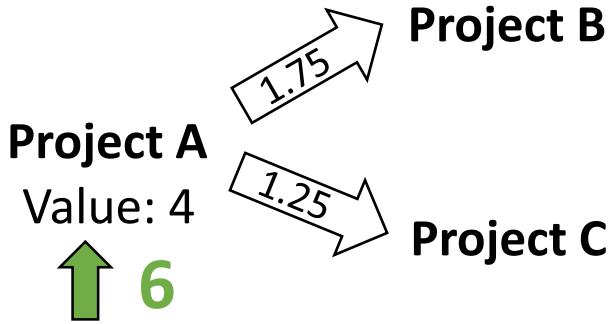
Introduction

- **Dependency** = projects that need to be **selected together**
- Dependencies are defined using 1-way relationships (Two 1-way relationships = 2-way relationship)
- Dependencies are assigned a strength (Weak, Medium, Strong)
- Alternative portfolios are created by making/breaking dependencies based on their strength



Introduction

- **Synergy** = **increases project value** if projects are selected together
- Currently, a synergistic relationship requires the existence of a dependency relationship
- Synergy is applied as a multiplier on the value of the primary project, when selected with the secondary project
- Synergistic effects are averaged if multiple are present



Introduction

- The Canadian Department of National Defence has developed software to support capital investment decision making
  - VIPOR (Visual Investment Planning Optimization & Revision)
  - SPARC (Strategic Portfolio Analyzer with Reconfigurable Components)
- SPARC is capable of visualizing dependencies and includes them in its portfolio optimization algorithm (binary knapsack)
- Analysts can use SPARC to better inform decision makers on the interdependency effects of their decisions

Data Collection

- Data on major capital projects (>$15M) collected for the Capital Investment Program Plan Review (CIPPR) Process
- Collected using Microsoft InfoPath questionnaires filled in by project sponsors
- Project relationships determined using 5 options
  - Cost benefit, Scheduling benefit, Qualitative benefit, Quantitative benefit, Cannot succeed
- Total cost was also collected and used as a resource constraint
- Total project value was determined by subject matter experts using questionnaire data and includes a risk factor
- Natural language processing is being explored as a method for determining project relationships from other project descriptions, reports, and documentation

Data Collection

- A total of 215 major capital projects were analyzed in the preliminary analysis
- Relationship data was processed and cleaned to remove any relationships between projects outside of the list of submitted projects

	0 synergistic relationships	**1 synergistic relationship**	**>1 synergistic relationship**
Dependent relationship	36	0	3
No dependent relationship	83 (projects)	336	5

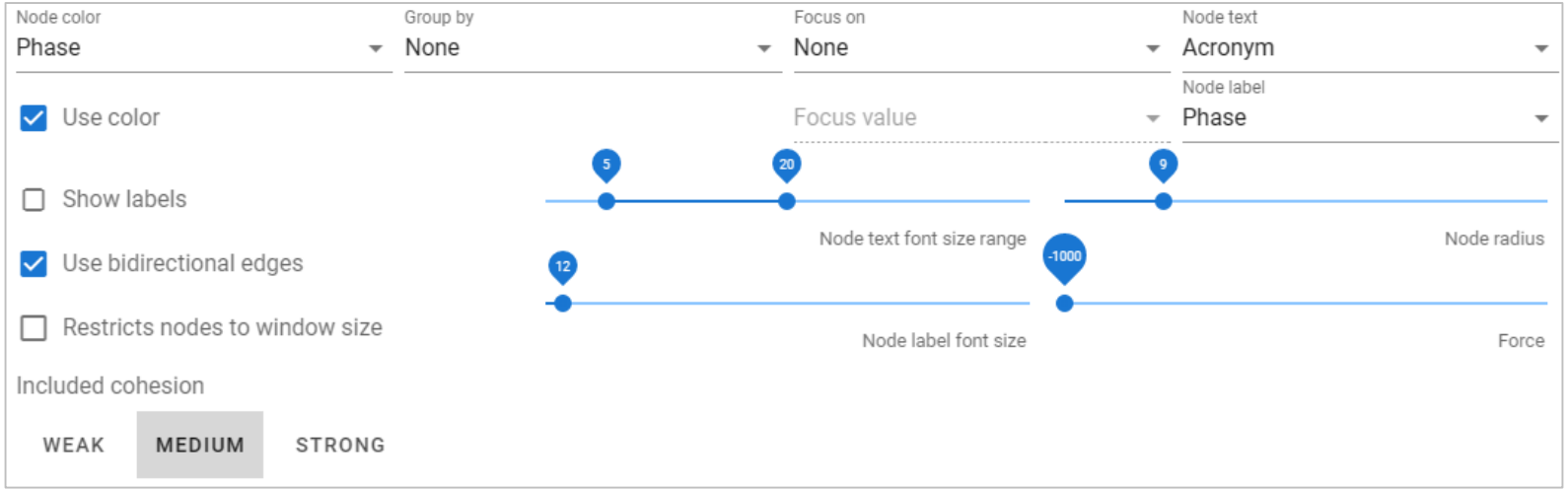
Data Processing

- Relationships were converted into dependency strengths and synergy multipliers

Dependency strength	“Cannot succeed” = Strong More than 1 synergistic relationship = Medium 1 synergistic relationship = Weak
Synergy	Default value is 1. 0.25 is added for each identified synergistic relationship, for a maximum multiplier of 2.

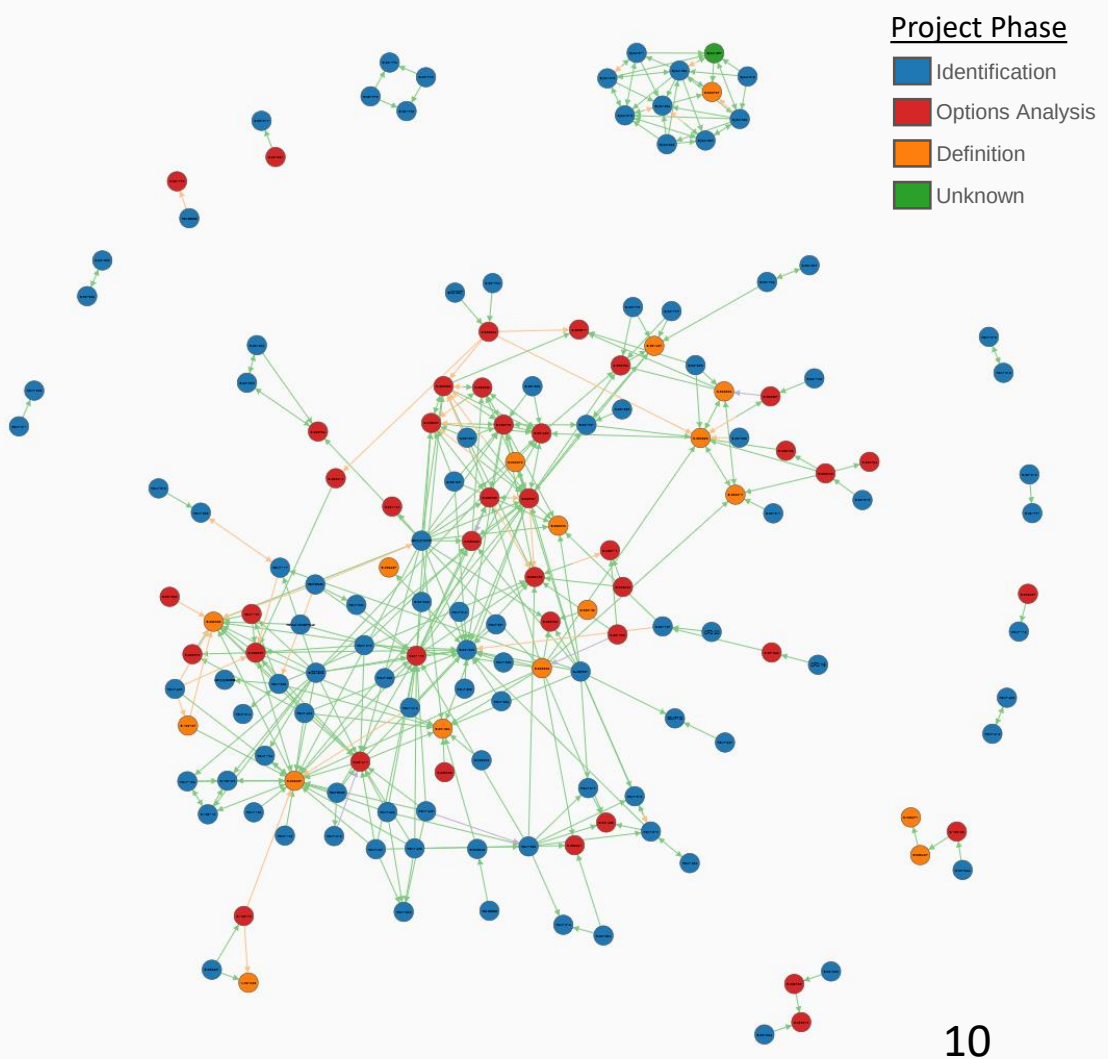
Visualizing Dependencies

- SPARC includes interactive network graphs to provide a better method for visualizing dependencies
- Different display options allow analysts and decision makers to explore the data



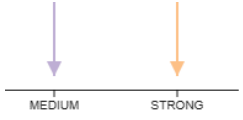
Visualizing Dependencies

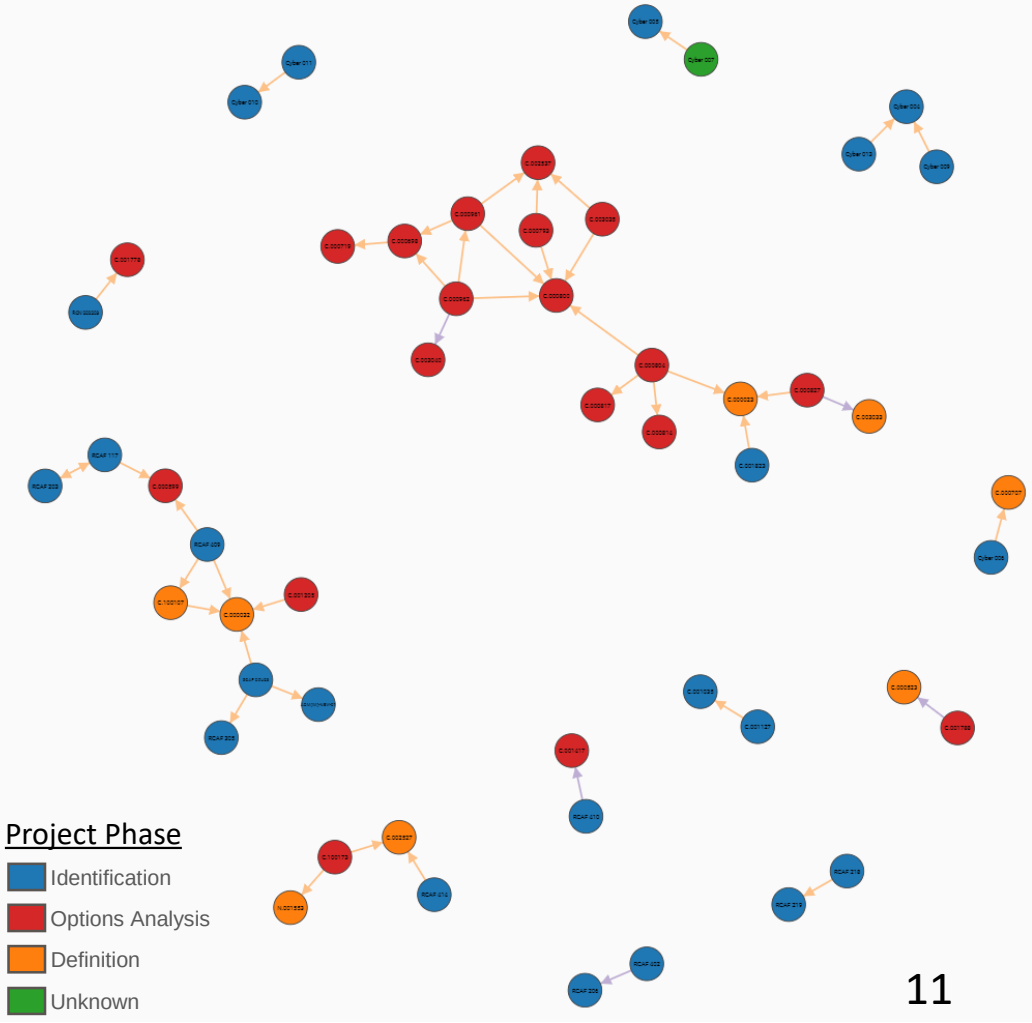
- Visual representation makes it easier to:
  - Determine clusters of dependencies
  - View the higher order dependency chains
  - validate the dependency data



Visualizing Dependencies

- Interactive user features can help analysts and decision makers focus on different aspects of the network
  - Remove dependencies by strength
  - Hover focus on first order dependencies around a project
  - Colour or cluster projects using categorical information





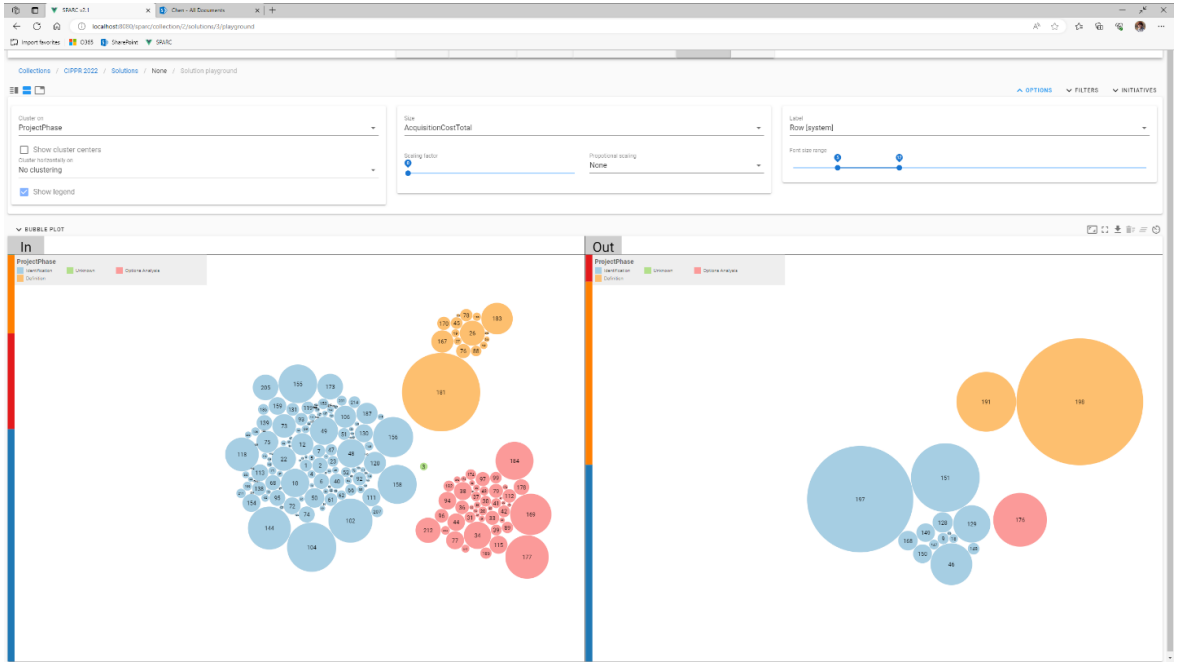
Portfolio Results

- Portfolios were optimized using a binary knapsack algorithm with different levels of dependency strength

	No Dependencies	Strong Dependencies	Medium & Strong Dependencies	All Dependencies
Number of Projects Selected	199	195	192	134
Relative Total Value (%)	-	-4.37	-2.59	-23.2
Relative Total Cost (%)	-	0.003	-19.5	-0.373

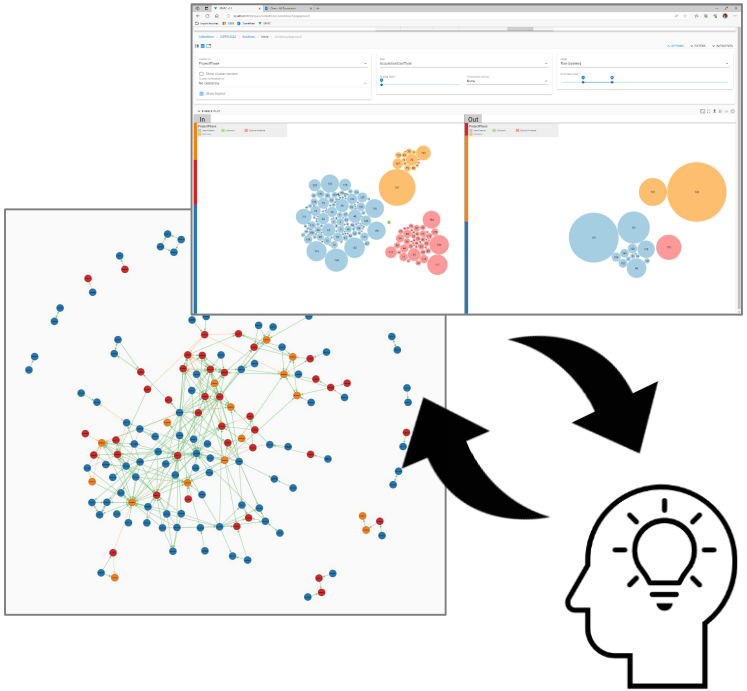
Portfolio Results

- SPARC provides interactive visualizations for reviewing portfolio results
- The bubble plot displays results for each project, and can be used to gain insight into other portfolio features, like cost and project phase
- Portfolio decisions can be reviewed, modified and re-optimized by decision makers



Discussion

- Network graphs can be used in an interactive environment to explore dependency data
- Dependency strengths can be used to create alternative portfolios for decision makers to review
- Synergistic effects can help to reduce the effects of having to include dependent project groupings
- More dependencies are not always better as over-dependent portfolios create large “boulders” that are difficult to include in a portfolio



Conclusions

- Strategic planning becomes more complex when considering interdependency information
- Interactive visualizations can be used to improve the understanding of the dependency data
- Different levels of dependencies can be used to generate alternative portfolios for decision makers
- Synergies can be applied to account for improvements in delivered value when projects are selected together
- NLP is being investigated to improve relationship data quality and labour-intensive data validation methods by extracting information from documentation

Thank you!

Contacts:
Carolyn.Chen@forces.gc.ca

Kendall.Wheaton@forces.gc.ca