

Modeling and Reasoning with Changing Intentions: An Experiment

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Overview

Problem:

We investigate the effectiveness and usability of

- Evolving Intentions,
- Simulation over Evolving Intentions, and
- GrowingLeaf

Practitioners:

- Improves decision making in early-RE
- Consider short-term and long-term impacts of alternatives

Motivating Scenario

A City is evaluating waste management options for its Citizens.

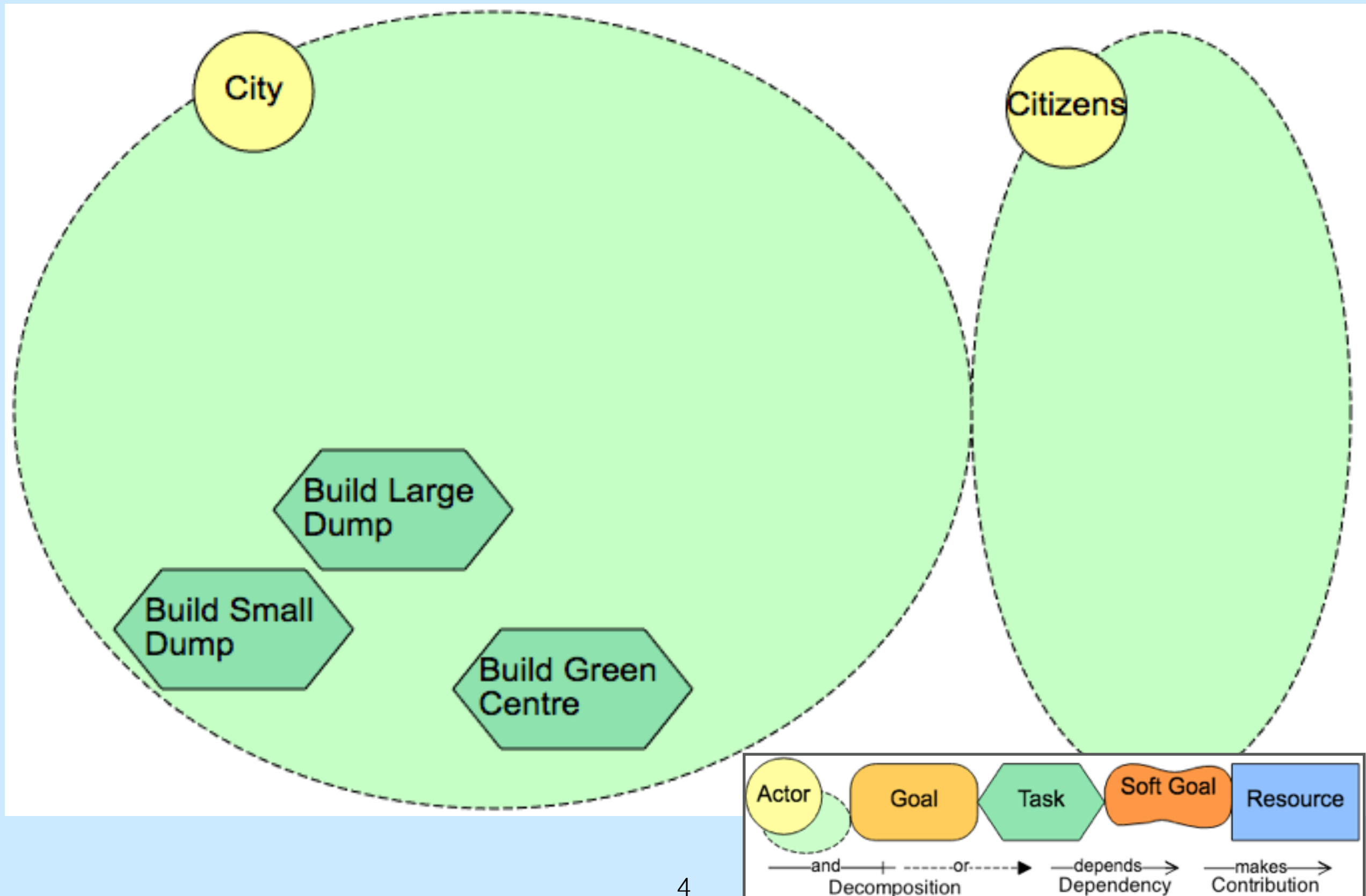
Options: Build Green Centre
Build Landfill / Dump (large, small)



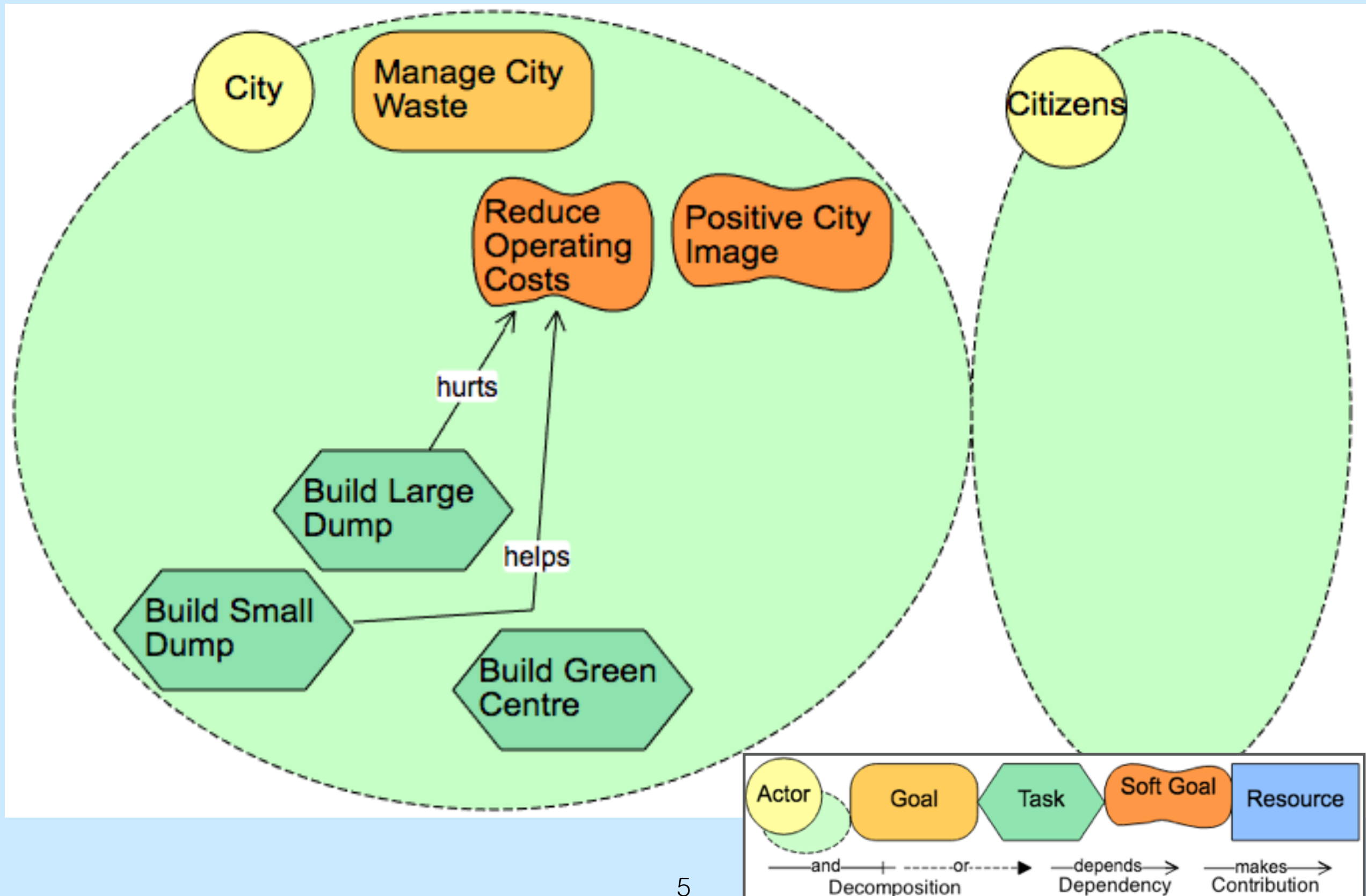
Choose the best alternative(s) using goal modeling.



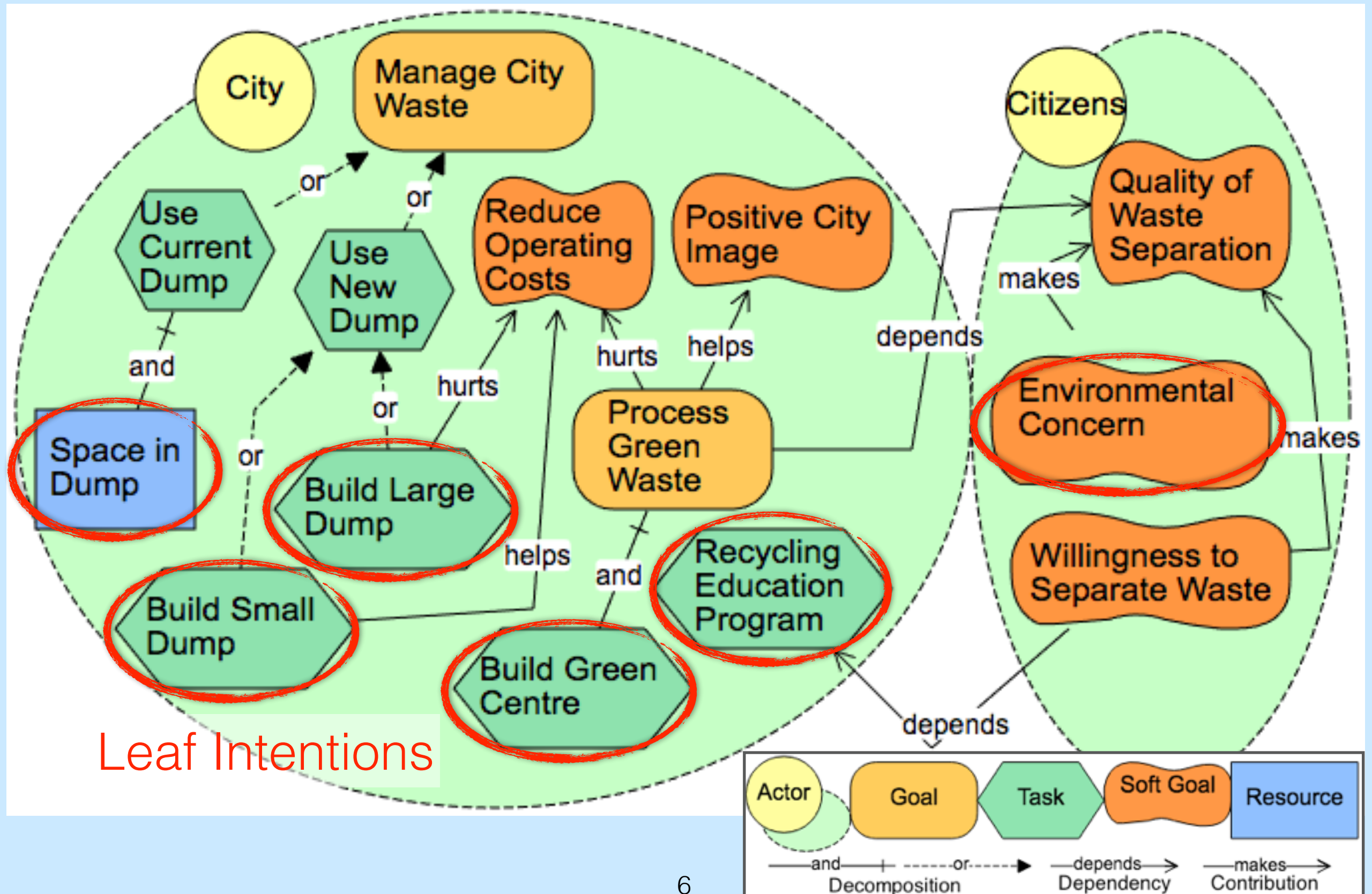
Waste Management Example



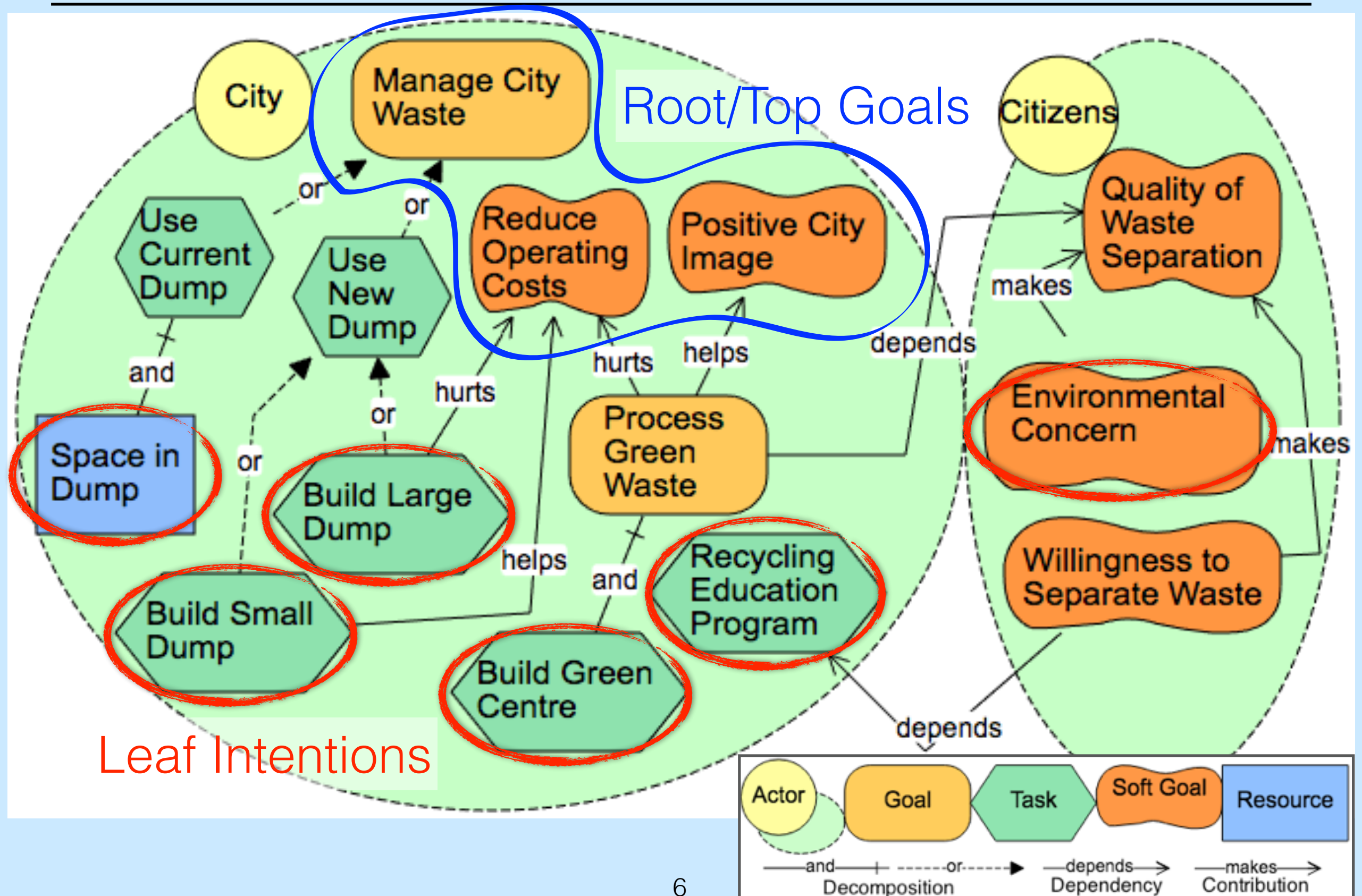
Waste Management Example



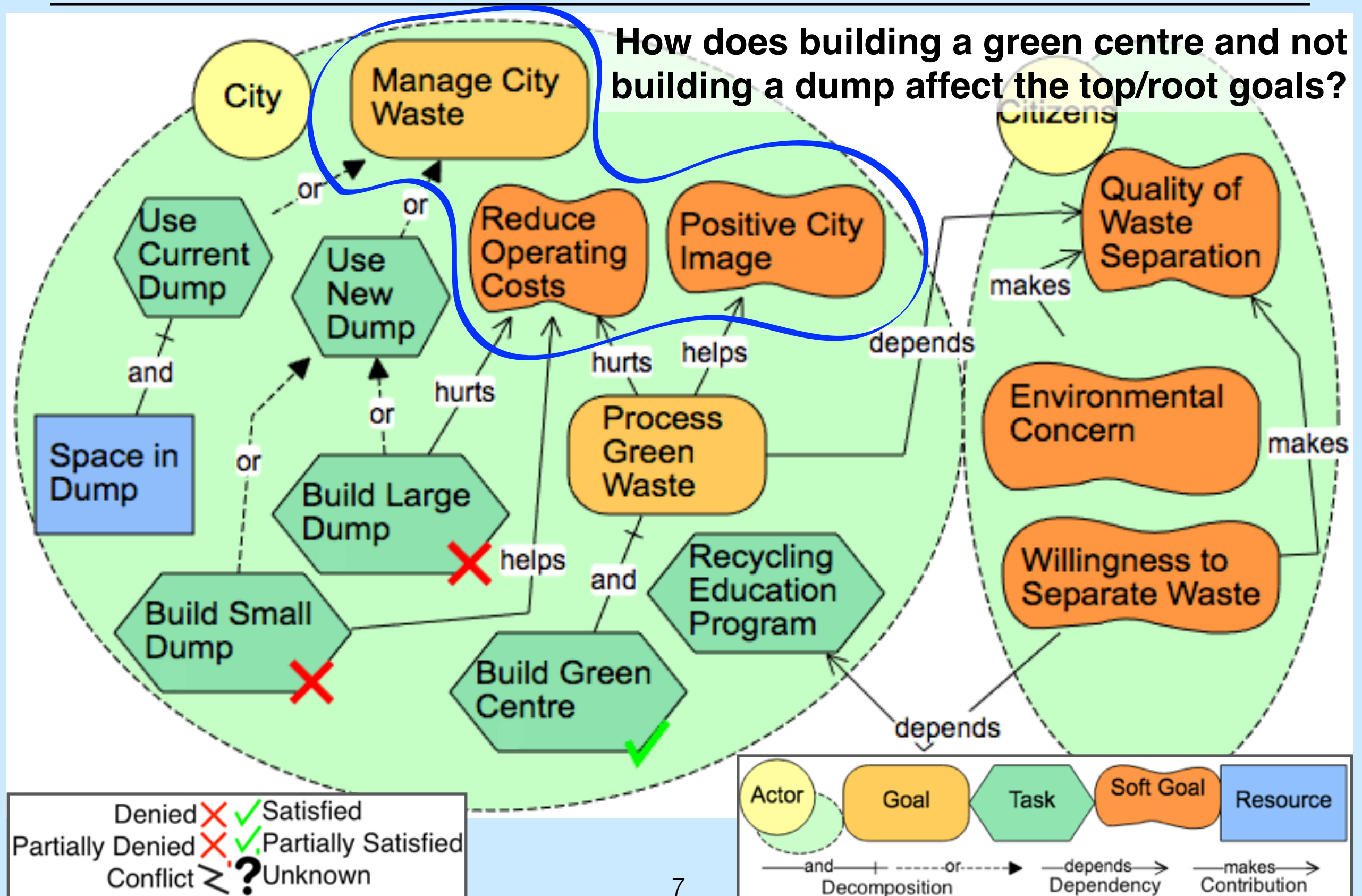
Waste Management Example



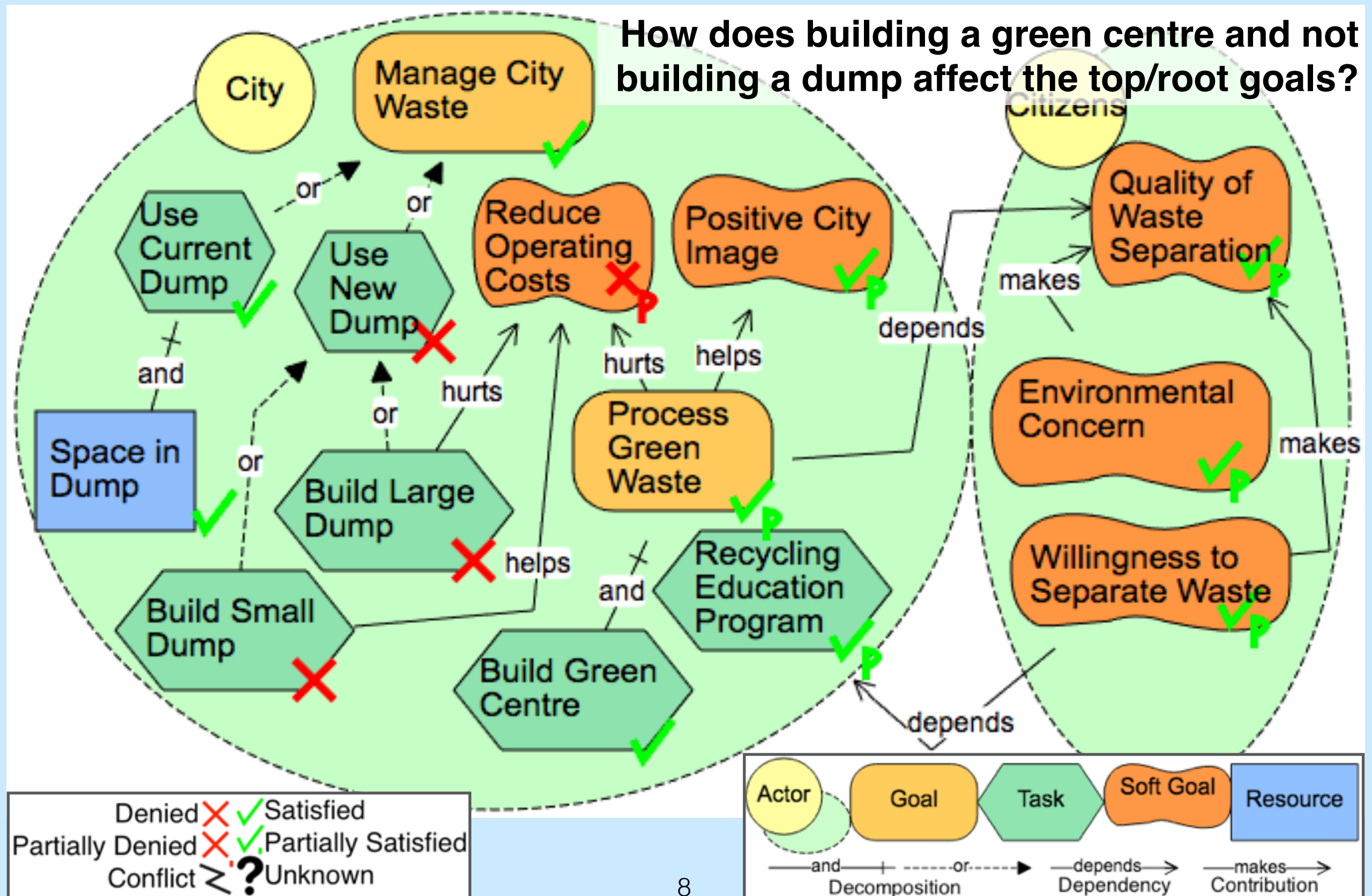
Waste Management Example



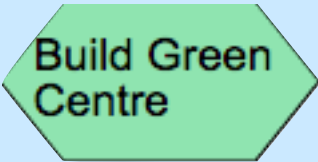
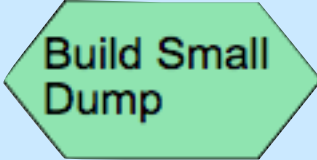
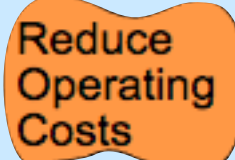
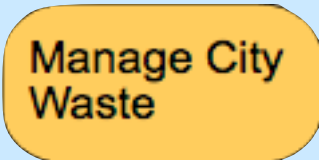
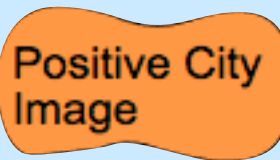
Waste Management Example

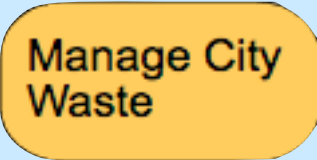
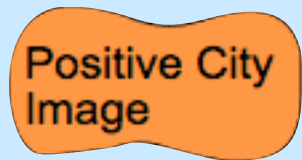
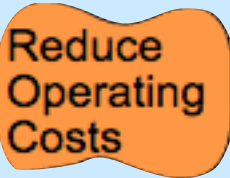


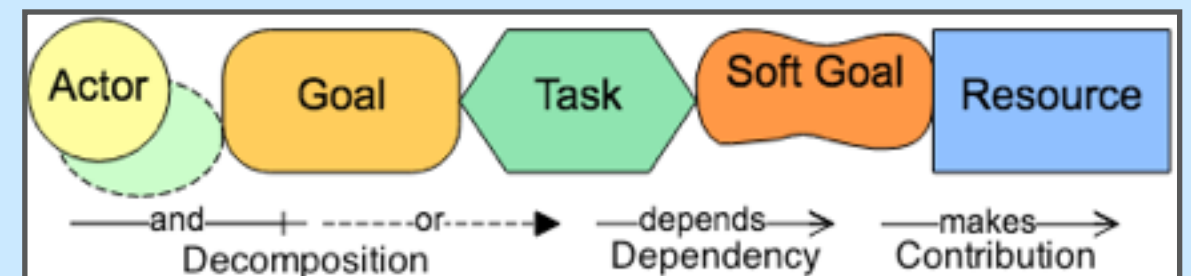
Waste Management Example



Waste Management Example

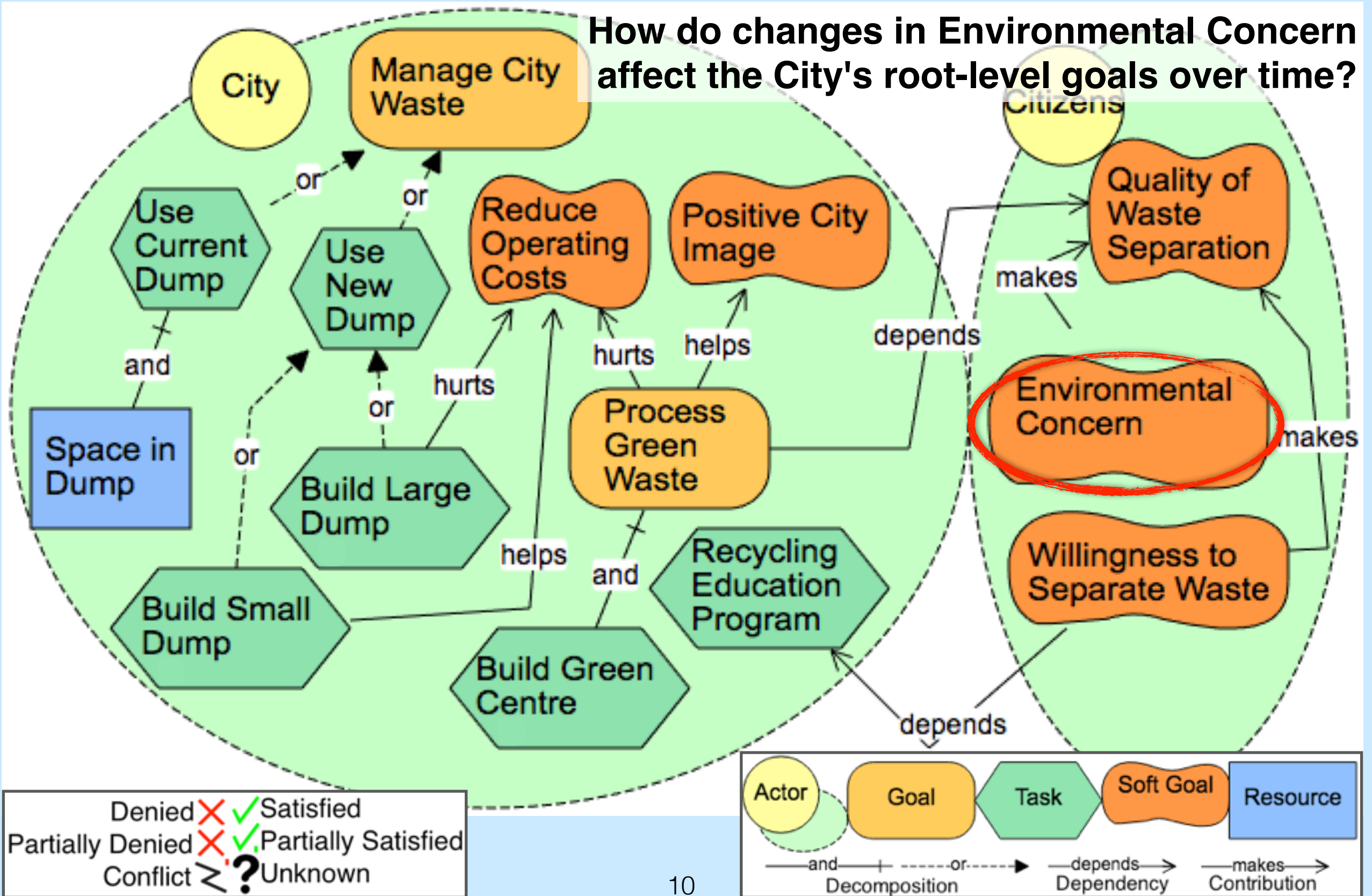
Question: How does satisfying  Build Green Centre
and not satisfying (deny)  Build Small Dump &  Build Large Dump
affect the top/root goals?  Reduce Operating Costs  Manage City Waste  Positive City Image

Answer: It satisfies  Manage City Waste partially satisfies  Positive City Image
but partially denies  Reduce Operating Costs



Waste Management Example

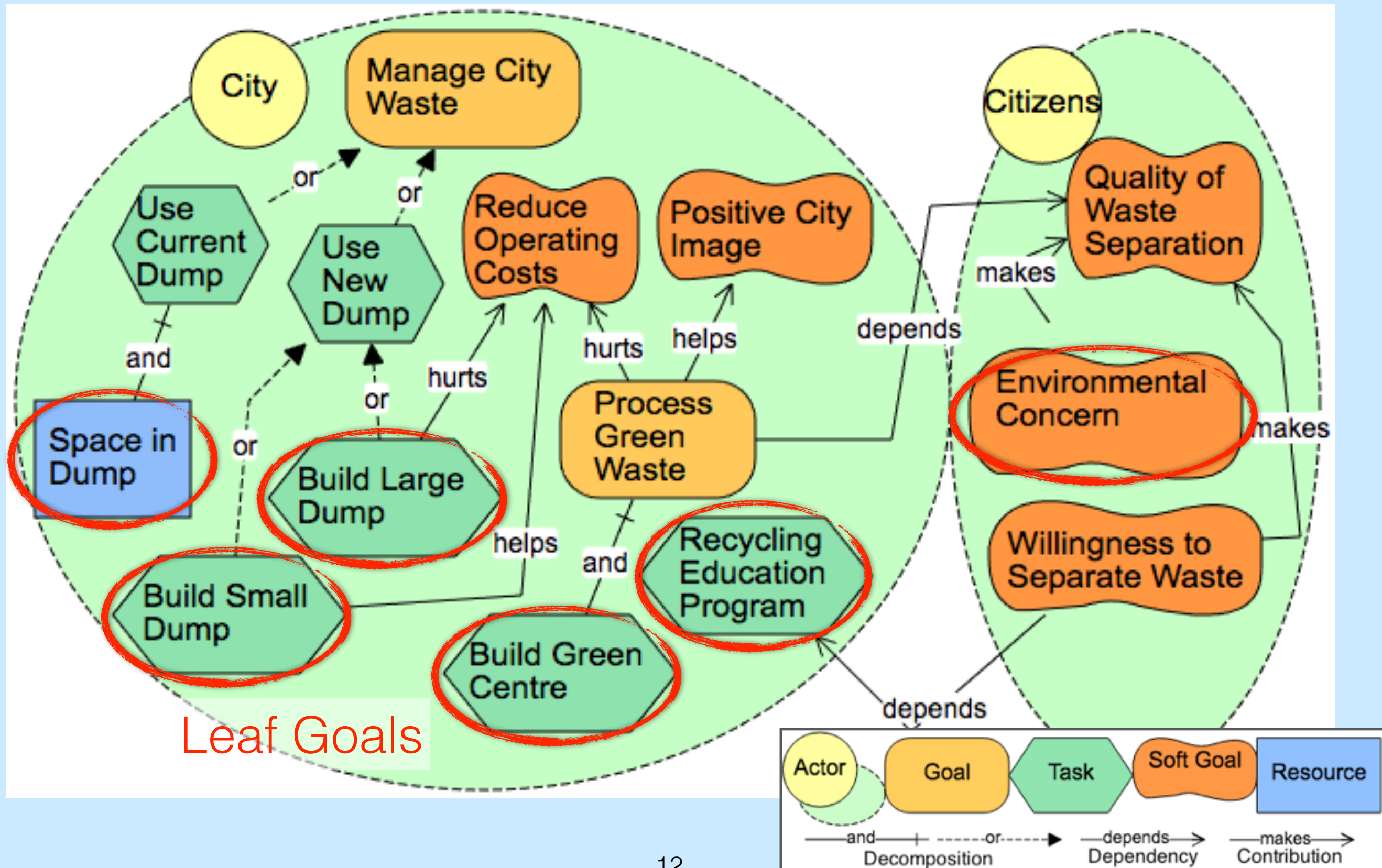
How do changes in Environmental Concern affect the City's root-level goals over time?



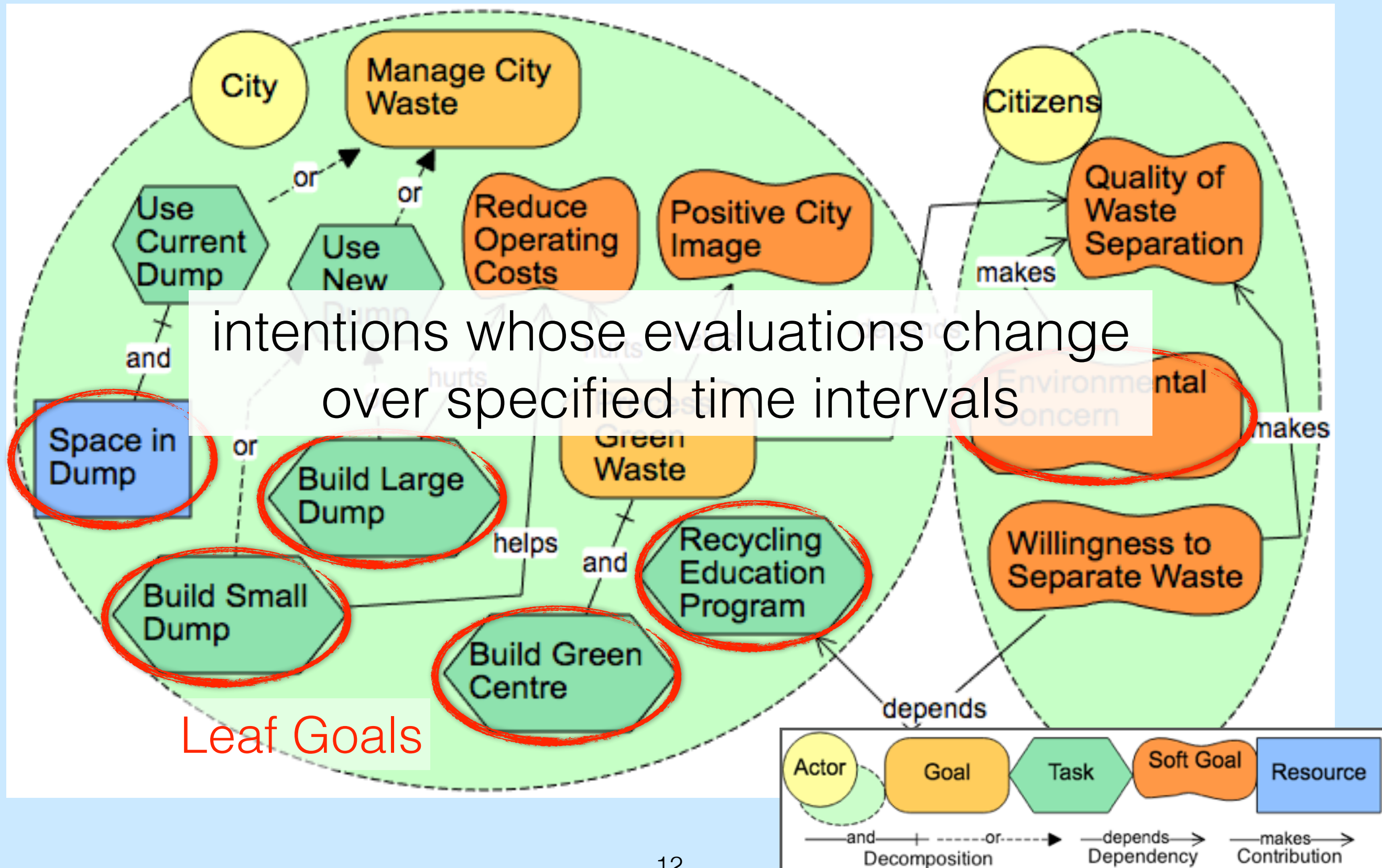
Previous Work

- “Looking into the Crystal Ball:
Requirements Evolution over Time.” [RE’16]
- *Allow* goal model *intentions to change* over time
[Evolving Intentions (EIs)]
 - *Understand the impacts* of dynamically changing
intentions *on decision making*
[Simulation over Evolving Intentions (EI-Sim)]
 - *Tooling* for modeling and analyzing intentions that
change over time. [GrowingLeaf]

Evolving Intentions



Evolving Intentions



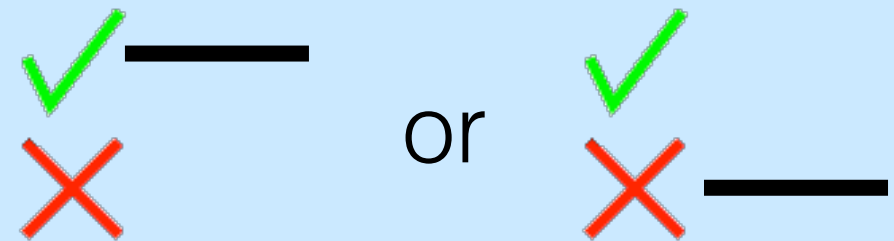
Evolving Intentions

Elementary Functions

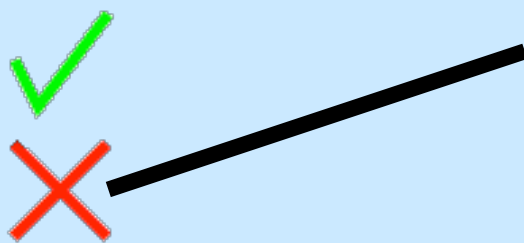
Stochastic (R):



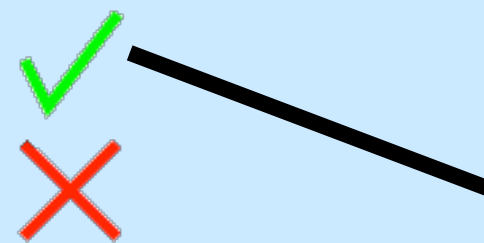
Constant (C):



Increase (I):



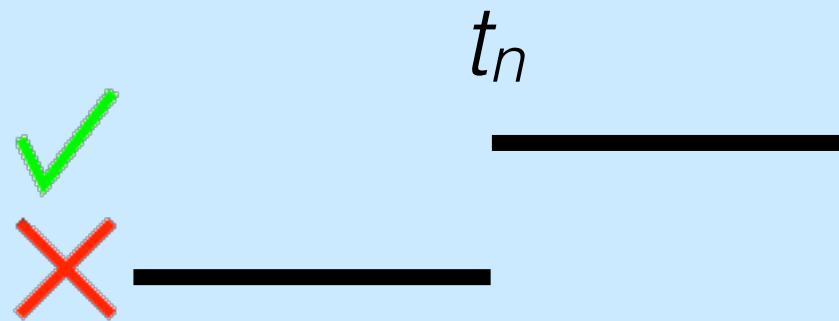
Decrease (D):



Evolving Intentions

Denied-Satisfied (DS)

Patterns:



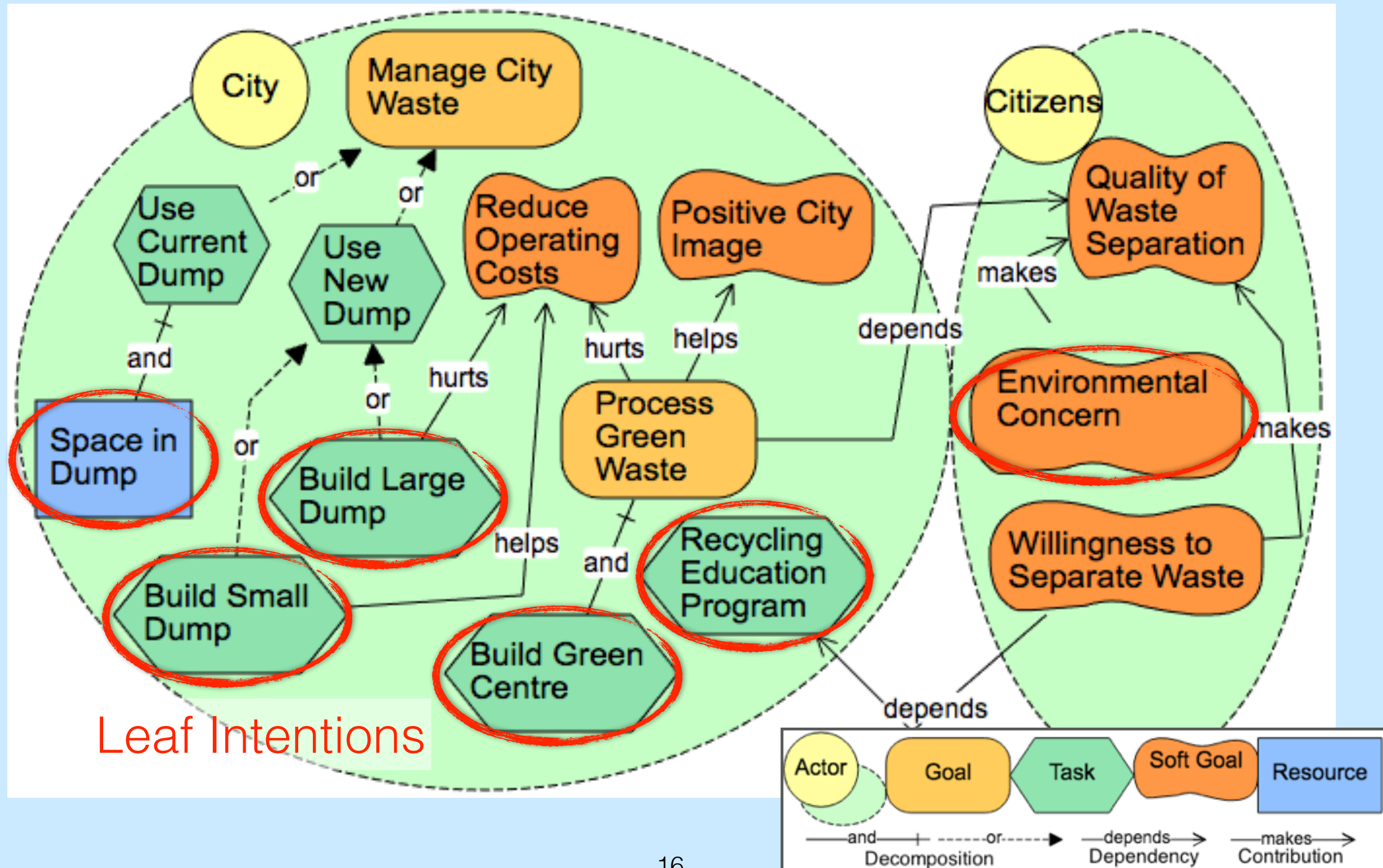
Examples:



Evolving Intentions

Satisfied-Denied (SD)	the satisfaction evaluation remains <i>Satisfied</i> until t_i and then remains <i>Denied</i>
Denied-Satisfied (DS)	the satisfaction evaluation remains <i>Denied</i> until t_i and then remains <i>Satisfied</i>
Stochastic-Constant (RC)	changes in satisfaction evaluation are stochastic or random until t_i and then remains constant at <i>constantValue</i>
Constant-Stochastic (CR)	the satisfaction evaluation remains constant at <i>constantValue</i> until t_i and then changes in evaluation are stochastic or random
Monotonic Positive (MP)	changes in satisfaction evaluation become “more true” to a <i>maxValue</i> at t_i and then remains constant at <i>constantValue</i>
Monotonic Negative (MN)	changes in satisfaction evaluation become “less true” to a <i>maxValue</i> at t_i and then remains constant at <i>constantValue</i>

Simulation over Evolving Intentions

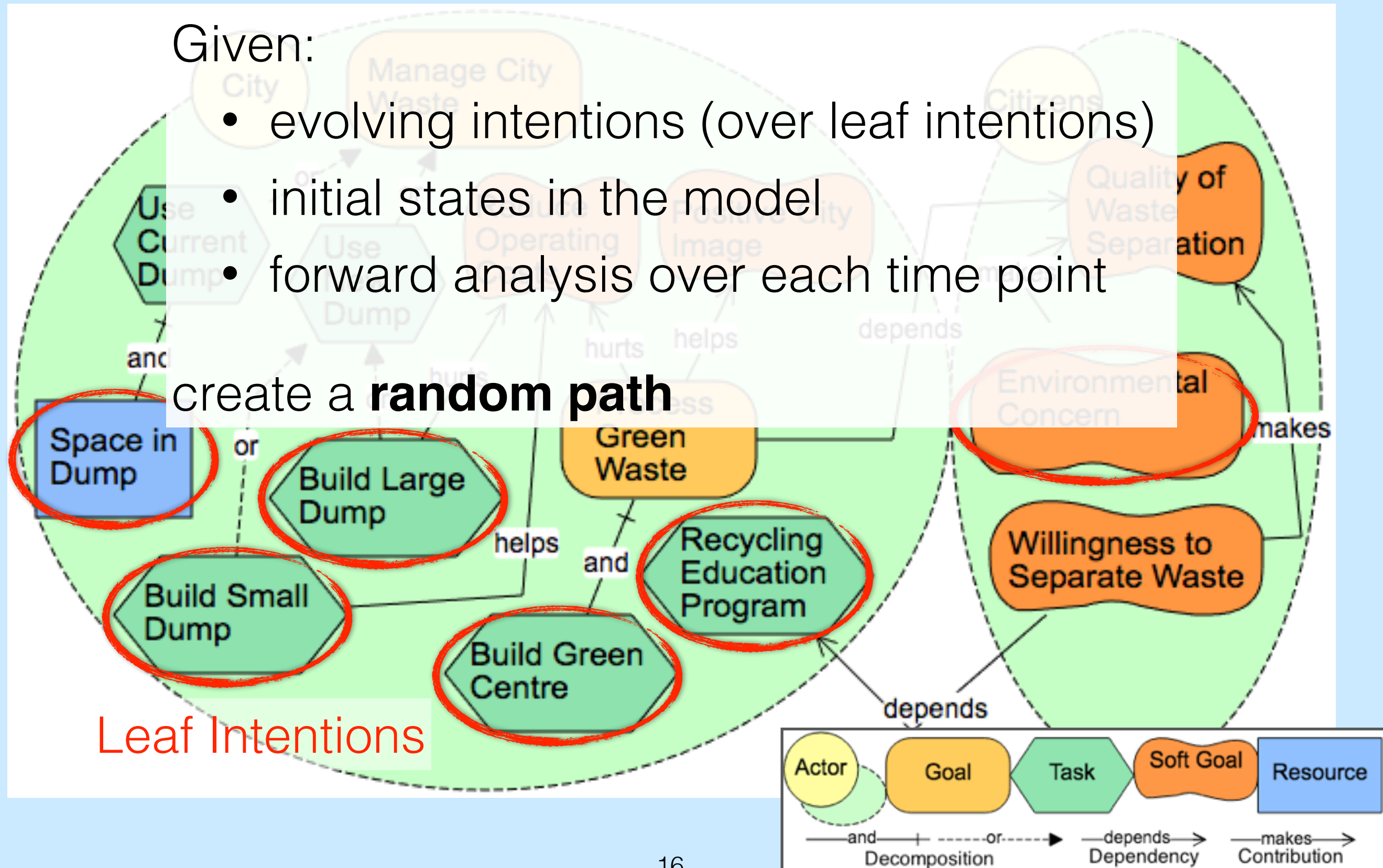


Simulation over Evolving Intentions

Given:

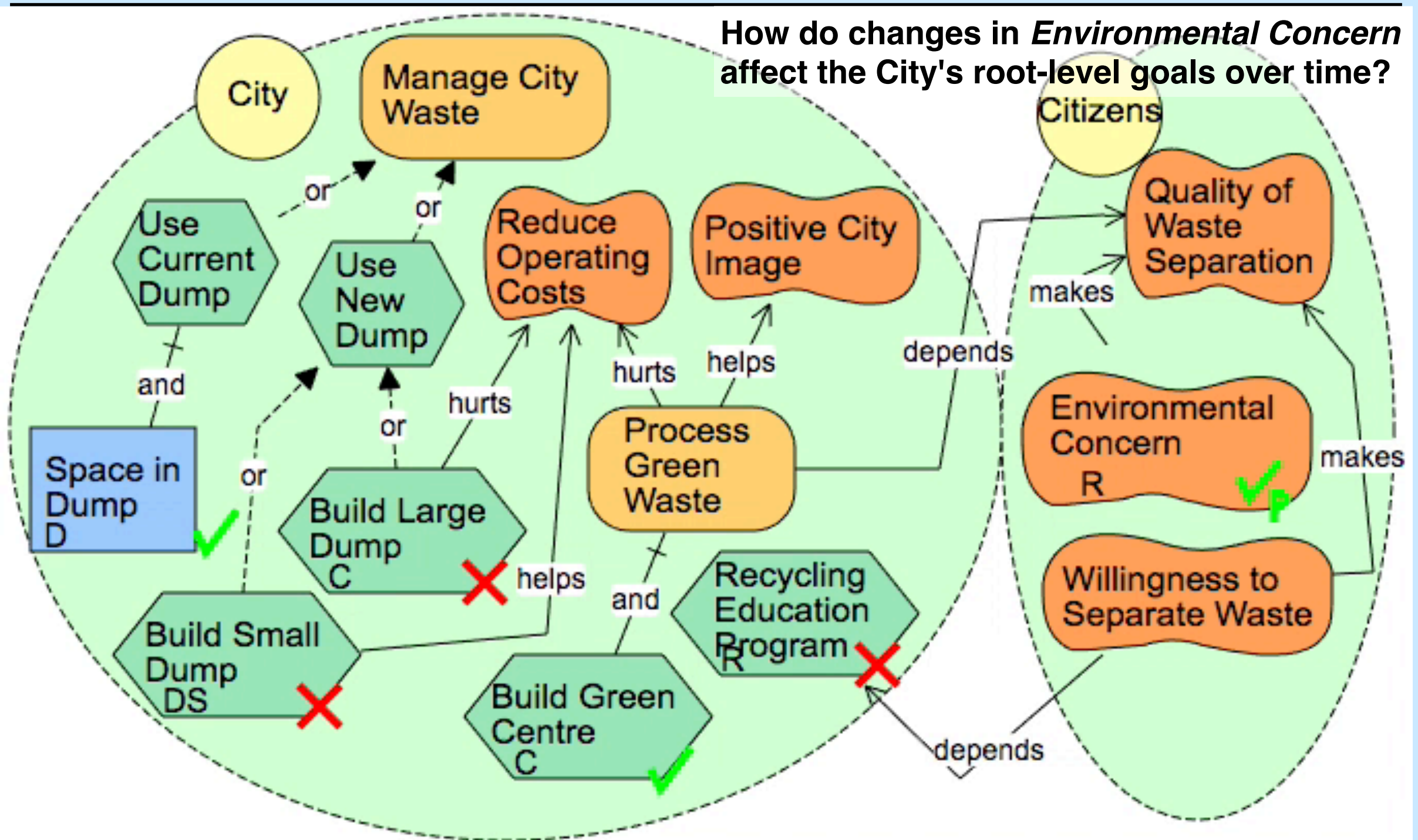
- evolving intentions (over leaf intentions)
- initial states in the model
- forward analysis over each time point

create a **random path**



Simulation over Evolving Intentions


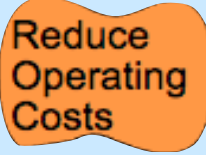
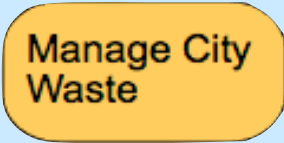
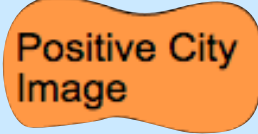
How do changes in *Environmental Concern* affect the City's root-level goals over time?





R:Stochastic, C:Constant,
D: Decrease, DS:Denied-Satisfied

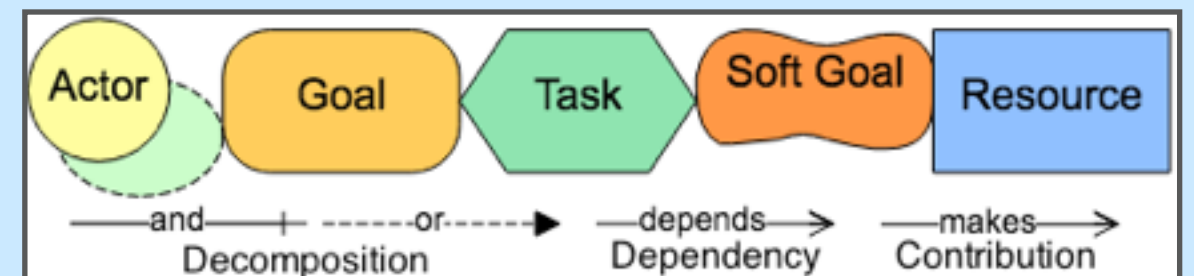
Denied X Satisfied
Partially Denied X Partially Satisfied
Conflict > ? Unknown

Waste Management Example

Question: How do changes in  affect the city's root-level goals    over time?

Answer: Affects  

Satisfying  mitigates the effect of denied 



GrowingLeaf

GrowingLeaf Undo Redo Clear Save Load Zoom In Zoom Out Open as SVG Export .leaf Font Size Help **Model Constraints** Analysis

Stencil

- Goal
- Task
- Soft Goal
- Resource
- Actor

Modelling Relationships

Node name: Build Green

Initial Satisfaction Value: Satisfied

Function Type: Constant

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Powered by: Copyright 2014-2016, client IO. All rights reserved. JointJS: an HTML 5 diagramming component. <http://jointjs.com>

<http://www.cs.toronto.edu/~amgrubb/growing-leaf>

Research Questions

- (RQ1) How do Evolving Intentions (EIs) affect modelers' ability to capture model elements that change over time?
Control: Stochastically Evolving Intentions (SEIs)
- (RQ2) How does Simulation over Evolving Intentions (EI-Sim) affect modelers' understanding and ability to reason about a goal model with time?
*Control: Repeated Forward Analysis (Rep-FA),
Simulation over Stochastically Evolving Intentions (SEI-Sim)*
- (RQ3) How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?

Research Questions

- (RQ0) Do modelers perform similarly on basic cognition tests, given a consistent training protocol?
- (RQ1) How do Evolving Intentions (EIs) affect modelers' ability to capture model elements that change over time?
Control: Stochastically Evolving Intentions (SEIs)
- (RQ2) How does Simulation over Evolving Intentions (EI-Sim) affect modelers' understanding and ability to reason about a goal model with time?
*Control: Repeated Forward Analysis (Rep-FA),
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- (RQ3) How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?

Outline

- Motivating Example & Background
 - Evolving Intentions (EIs)
 - Simulation over Evolving Intentions (EI-Sim)
 - Tooling: GrowingLeaf
- **Study Design**
- Results
- Implication, Threat to Validity, & Reflections

Tools & Videos

Tools

Name	Rationale
GrowingLeaf-EI-Sim (Tool-EI)	Learning of EIs and EI-Sim
GrowingLeaf-SEI-Sim (Tool-SEI)	Control for SEI-Sim, prevents learning effect of EIs
GrowingLeaf-Forward Analysis (Tool-FA)	Intro version without EIs or SEIs, prevents learning effect of EIs or SEIs

Legend	
EI	Evolving Intentions
SEI	Stochastically Evolving Intentions
EI-Sim	Simulation over Evolving Intentions
SEI-Sim	Simulation over Stochastically Evolving Intentions
Rep-FA	Repeated Forward Analysis

Tools & Videos

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Tools & Videos

Videos

	Name	Description
RQ0	Video 0A	Reviewed goal modeling concepts/notations & introduced Tool-FA.
	Video 0B	Introduced forward analysis with Tool-FA.
RQ1	Video IEI	Introduced EIs.
	Video ISEI	Introduced SEIs.
RQ2	Video IIEI	Introduced EI-Sim with Tool-EI.
	Video IISEI	Introduced SEI-Sim with Tool-SEI.
	Video IIAFA	Introduced Rep-FA with Tool-FA.

Legend

EI	Evolving Intentions
SEI	Stochastically Evolving Intentions
EI-Sim	Simulation over Evolving Intentions
SEI-Sim	Simulation over Stochastically Evolving Intentions
Rep-FA	Repeated Forward Analysis

Tools

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Study Protocol

Legend: section topic, video watched, tool used

Recorded
Answers &
Completion
Times

	Subject Groups			
	Group A (n = 5)	Group B (n = 5)	Group CA (n = 3)	Group CB (n = 2)
RQ0	iStar & GrowingLeaf, Video 0A, Tool-FA Forward Analysis, Video 0B, Tool-FA			
RQ1	EIs, Video IEI, Tool-EI	SEIs, Video ISEI, Tool-SEI		
RQ2	EI-Sim, Video IIEI, Tool-EI	SEI-Sim, Video IISEI, Tool-SEI	Rep-FA, Video IIAFA, Tool-FA	
RQ1			EIs, Video IEI, Tool-EI	SEI, Video ISEI, Tool-SEI
RQ3	Tool Evaluation, n/a, n/a			



The image shows a research workstation in an office. It features a light-colored wooden desk with two desktop monitors, a laptop, and a printer. The left monitor is an Apple iMac, and the right monitor is a Dell. Both monitors display a complex network diagram with various colored nodes and connecting lines. A black keyboard and mouse are positioned in front of the iMac, while a white keyboard and mouse are in front of the Dell monitor. A black laptop is open in the center of the desk, displaying a web-based interface with a blue header and several lines of text. A white printer is located to the right of the Dell monitor. A green office chair is visible on the left side of the desk, and another green office chair is partially visible on the right. The floor is covered with a grey carpet. The overall setup suggests a collaborative research environment.

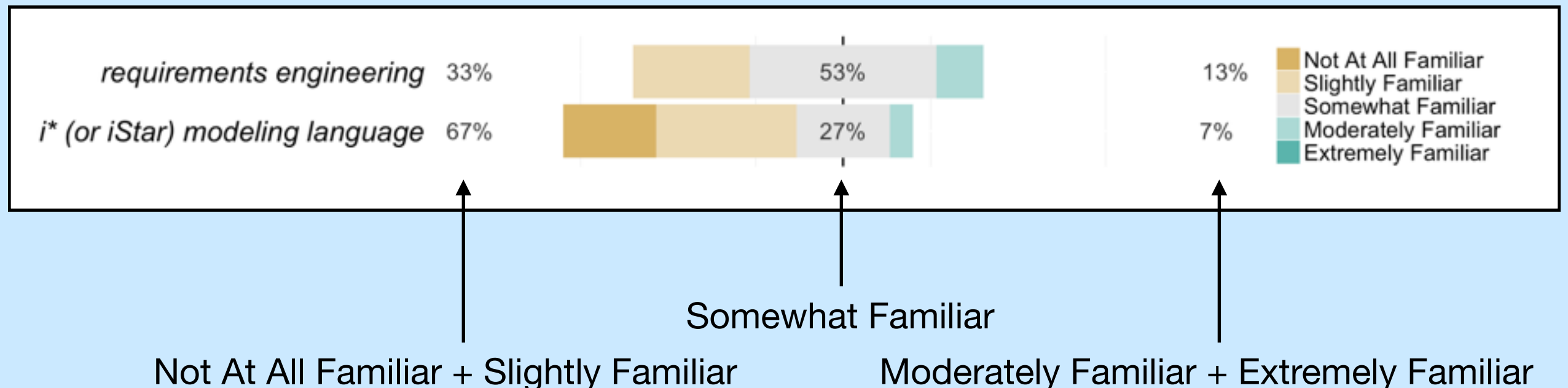
Subject

Researcher

Subjects

- graduate students (9 Masters, 6 PhD)
- basic understanding of RE & proficient in English
- recruited through mailing list and intro course

Subject self-reported familiarity rating:



Outline

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- **Results**
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RQ0: Baseline Test Between-Subject

Research Question:

Do modelers perform similarly on basic cognition tests, given a consistent training protocol?

Findings:

- Subjects *performed similarly* on basic cognition tests
- *Enables comparison* between groups in RQ1-RQ3

RQ1: Evolving Intentions

Research Question:

How do Evolving Intentions (EIs) affect modelers' ability to capture model elements that change over time?

Findings:

- Subjects *understood EIs and SEIs*
- Subjects *evaluated intentions* with EIs and SEIs
- *EIs* were found to be *intuitive*

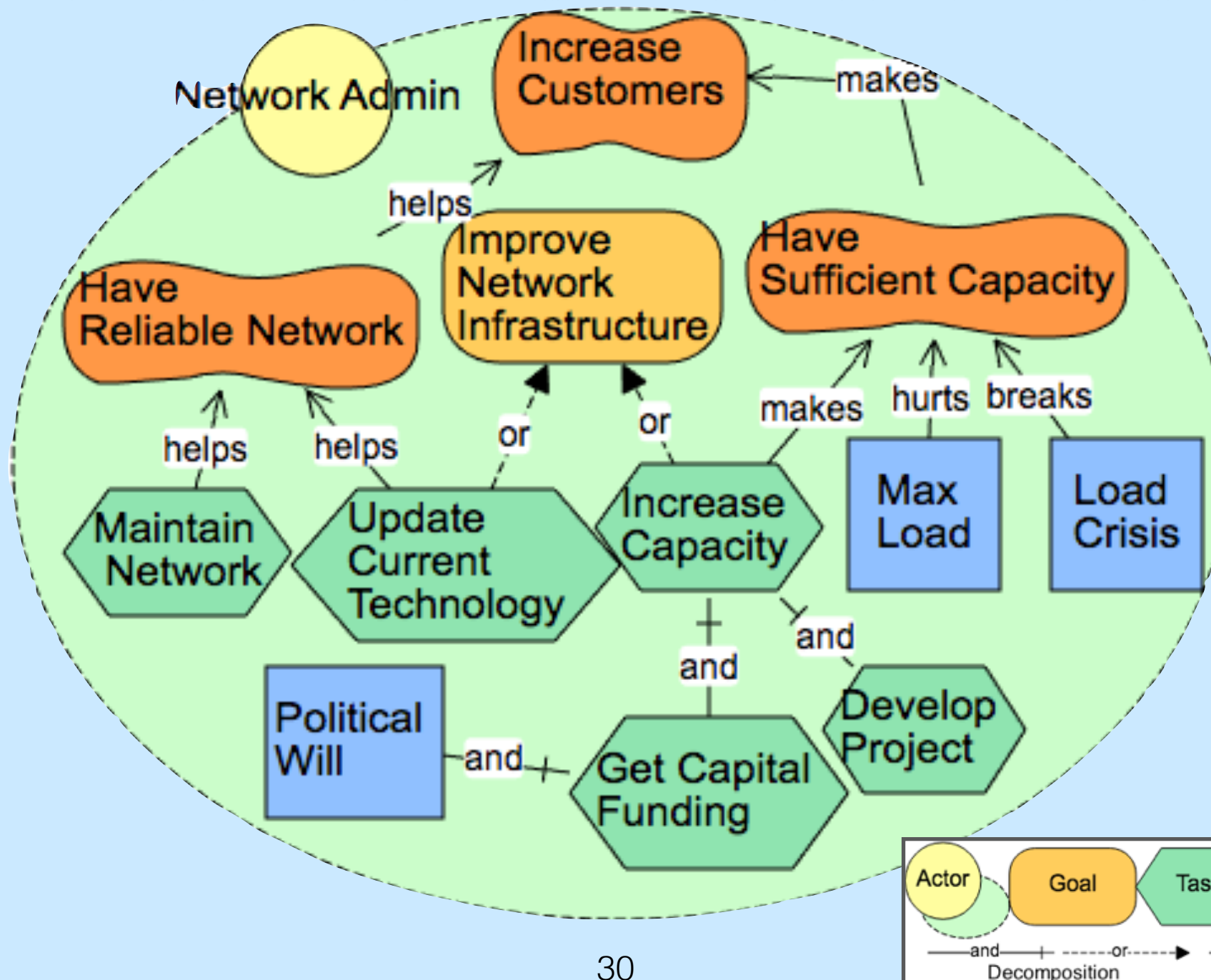
Legend:

EI: Evolving Intention

SEI: Stochastically Evolving Intention

RQ1: Evolving Intentions

Identify which elements in this model change over time?



RQ1: Evolving Intentions

Identify which elements in this model change over time?

Elements	LR	A1	A2	A3	A4	A5	CA	CA	CA	B1	B2	B3	B4	B5	CB	CB
Max Load	L	?	I	P	R	P	C			DS	F	R	R	R	I	R
Load Crisis	L	?	R	R	R	P	R			SD	F	R	R	R	R	R
Political Will	L		R	C	R	R	R			R	R	R	R	R	R	
Update Current Technology	L	MP	MP	P	R	I			I		F	P	DS	R		SD
Maintain Network	L	C	MP	C	R	C					F	C	C	R		
Get Capital Funding	N	?	MP	R	I	P		R	SD					R		
Develop Project	L		MP	MP	MP	P			MP			C	C	I		
Increase Capacity	N			R	MP	I		D					UD	R		DS
Have Reliable Network	N	C		R	R	A	?							R		
Improve Network	R			R	?	A		I						R		
Have Sufficient Capacity	N			R	R	A		MP						R		
Increase Customers	R			R	R	A		R						R		

Position: **L**eamf, **R**oot, **N**either

- Group A identified two additional functions.

RQ1: Evolving Intentions

Identify which elements in this model change over time?

Elements	LR	A1	A2	A3	A4	A5	CA	CA	CA	B1	B2	B3	B4	B5	CB	CB
Max Load	L	?	I	P	R	P	C			DS	F	R	R	R	I	R
Load Crisis	L	?	R	R	R	P	R			SD	F	R	R	R	R	R
Political Will	L		R	C	R	R	R			R	R	R	R	R	R	
Update Current Technology	L	MP	MP	P	R	I			I		F	P	DS	R		SD
Maintain Network	L	C	MP	C	R	C					F	C	C	R		
Get Capital Funding	N	?	MP	R	I	P		R	SD					R		
Develop Project	L		MP	MP	MP	P			MP			C	C	I		
Increase Capacity	N			R	MP	I		D					UD	P		
Have Reliable Network	N	C		R	R	A	?									
Improve Network	R															
Have Sufficient Capacity	N														R	
Increase Customers	R														R	

- Primarily Leaf Nodes Identified
- Root and Intermediate Nodes also identified

Position: **L**eamf, **R**oot, **N**either

- Group A identified two additional functions.

RQ1: Evolving Intentions

Identify which elements in this model change over time?

Elements	LR	A1	A2	A3	A4	A5	CA	CA	CA						
Max Load	L	?	I	P	R	P	C								
Load Crisis	L	?	R	R	R	P	R								
Political Will	L		R	C	R	R	R								
Update Current Technology	L	MP	MP	P	R	I			I			F	P	DS	R
Maintain Network	L	C	MP	C	R	C						F	C	C	R
Get Capital Funding	N	?	MP	R	I	P		R	SD						R
Develop Project	L		MP	MP	MP	P			MP			C	C	I	
Increase Capacity	N			R	MP	I		D					UD	R	DS
Have Reliable Network	N	C		R	R	A	?								R
Improve Network	R			R	?	A		I							R
Have Sufficient Capacity	N			R	R	A		MP							R
Increase Customers	R			R	R	A		R							R

• Group A identified Evolving Intention Functions by Name

Position: **L**eamf, **R**oot, **N**either

- Group A identified two additional functions.

RQ1: Evolving Intentions

Identify which elements in this model change over time?

Elements	LR	A1	A2	A3	A4	A5	CA	CA	CA	B1	B2	B3	B4	B5	CB	CB
Max Load	L	?	I	P	R	P	C			DS	F	R	R	R	I	R
Load Crisis	L	?	R	R	R	P	R			SD	F	R	R	R	R	R
Political Will	L		R	C	R	R	R			R	R	R	R	R	R	
Update Current Technology	L	MP	MP	P	P						F	P	DS	R		SD
Maintain Network											F	C	C	R		
Get Capital Funding														R		
Develop Project												C	C	I		
Increase Capacity				R	MP	I		D					UD	R		DS
Have Reliable Network	N	C		R	R	A	?							R		
Improve Network	R			R	?	A		I						R		
Have Sufficient Capacity	N			R	R	A		MP						R		
Increase Customers	R			R	R	A		R						R		

- Group B refinement of stochastic functions mirror the evolving functions

Position: **L**eam, **R**oot, **N**either

- Group A identified two additional functions.

RQ2: Simulation over Evolving Intentions

Research Question:

How does Simulation over Evolving Intentions (EI-Sim) affect modelers' understanding and ability to reason about a goal model with time?

Findings:

- EI-Sim and SEI-Sim improved understanding of *model structure*
- EI-Sim improved *reasoning* about goal models *over time* (significant slower)
- Rep-FA proved difficult for time-focused questions

Legend:

EI-Sim: Simulation over Evolving Intention

SEI-Sim: Simulation over Stochastically Evolving Intentions

Rep-FA: Repeated Forward Analysis

RQ2: Simulation over Evolving Intentions

Assume you can sequentially complete both “Build Green Centre” and “Build Small Dump”. Which order is best for the top goals (use simulation/forward analysis to evaluate the alternatives)? Why?

Group A (EI-Sim):

- subjects that used EI-Sim and obtained meaningful results
 - 2 subjects used only the Constant (C) function

Group B (SEI-Sim):

- subjects chose the correct answer looking at the structure of the model

Group C (Rep-FA):

- subjects chose the best alternative and ignored ordering

RQ2: Simulation over Evolving Intentions

Evaluate RQ2 Completion Times

Kruskal-Wallis Rank Sum Test

- *Null Hypothesis*: No difference between groups
($p = 0.054$) arguably significant

Dunn's Post-Hoc Pair-wise Comparison Test

- *Group A took significantly longer* (avg. 6 minutes)
Group B ($p = 0.0098$) & Group C ($p = 0.045$)
- no significant difference between Group B & C

RQ3: GrowingLeaf Tool

*Research
Question:*

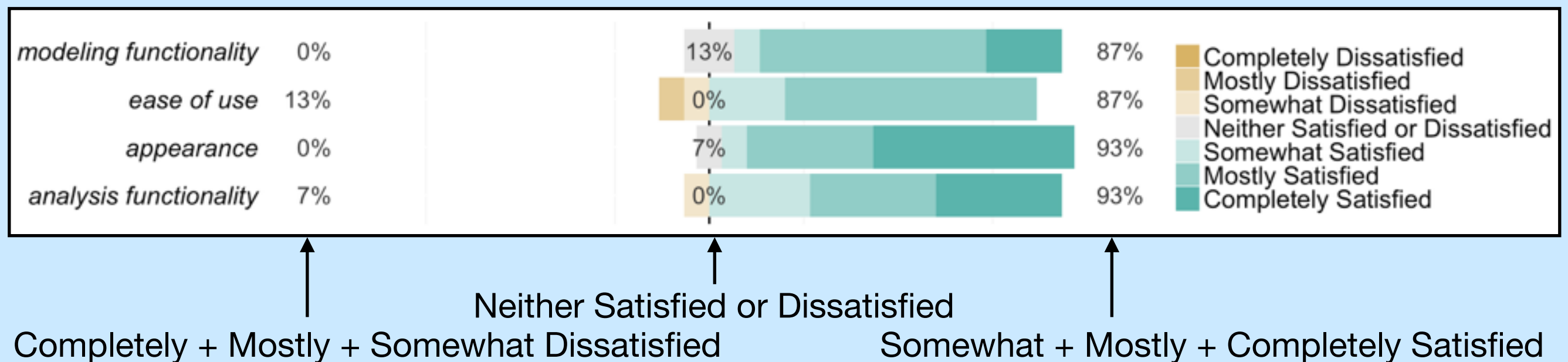
How do modelers evaluate GrowingLeaf after completing modeling and analysis tasks?

Findings:

- Subjects *rated GrowingLeaf highly* and found it usable

RQ3: GrowingLeaf Tool

Rate your level of satisfaction with the tools:



no significant difference between tool version

RQ3: GrowingLeaf Tool

What suggestions or changes would you recommend to the developers of this goal modeling tool?

- Clear all intention evaluation and function labels
- Highlight and unhighlight leaf and root intentions
- Syntax checking

See paper for additional recommendations...

Summary of Results

- Els were suitable to the task of identifying and representing intentions over time
- EI-Sim improved the subjects' ability to reason about goal models over time
- GrowingLeaf was found to be effective and usable

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 - Evolving Intentions (EIs)
 - Simulation over Evolving Intentions (EI-Sim)
 - Tooling: GrowingLeaf
- Study Design
- Results
- **Implication, Threat to Validity, & Reflections**

Implications for Research

- understand why not all Group A subjects used EI-Sim effectively
- subjects paid closer attention to the content of some models but not others



Implications for Education



- subjects had difficulty with the Depends link
- SEI-Sim can be used in teaching to help subjects understand
 - the structure of the model
 - forward propagation rules



Threats to Validity

Conclusion Validity

- low sample size \Rightarrow low statistical power 

Internal Validity

- self-reported understanding of RE and iStar

Construct Validity

- evaluation apprehension 

External Validity

- not generalizable to other populations / domains
- model size not representative

Reflections

Problem: How to effectively study learning?

Ideal: Controlled experiment within a course (with Grades)

Our Approach:

- Control for level of past experience 🤔
- Apply Learning Theory
 - Bloom's Taxonomy: remember, understand, apply, analyze, evaluate, and create 😊
- Run multiple pilots to expose tacit learning 😇

Reflections

Problem: Inherent bias studying your own tool/technique

Ideal: Get independent researcher to run study

Our Approach:

- Use third person instead of “my/our” tool/technique



Reflections

Problem: Inherent bias studying your own tool/technique

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How would you recommend I improve my tool?

VS.

What suggestions or changes would you recommend to the developers of this goal modeling tool?

Reflections

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- Use formal experiment protocol:
 - Handouts 😊
 - Videos (with non-researcher’s voice over) 😇

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Our Approach:

- Use third person instead of “my/our” tool/technique 😊
- Use formal experiment protocol:
 - Handouts 😊
 - Videos (with non-researcher’s voice over) 😊
- Use formal data analysis protocol:
 - Understand data analysis procedure before study 🤔
 - Analyze data after collection is complete 👧👧
 - Use non-parametric statistics (unknown distribution) 😊

Supplemental Information

Supplementary Information for “Modeling and Reasoning with Changing Intentions: An Experiment”

In this paper, we report on a between-subjects experiment we conducted with fifteen graduate students familiar with requirements engineering. The experiment investigates the effectiveness and usability of Evolving Intentions, Simulation over Evolving Intentions, and GrowingLeaf.

A. M. Grubb and M. Chechik. [Modeling and Reasoning with Changing Intentions: An Experiment](#). 2017 IEEE 25th International Requirements Engineering Conference (RE), 2017. © IEEE 2017.

This page discusses supplemental material. It is recommended that you read the paper prior to continuing here.

Materials

Here are the study materials.

Study Protocol:

- [Consent Form](#).
- [Study Questions](#).
- [Prize Draw Form](#).
- [Study Follow-up Form](#).

Models:

- Trusted Computing Model: [.png](#) [.json](#)
- Network Administrator Model: [.png](#) [.json](#)
- Waste Management Model: [.png](#) [.json](#)

Videos and Handouts:

- [Video 0A, iStar Handout](#).
- [Video 0B, Forward Analysis Handout](#).
- [Video IEL, Evolving Intentions Handout](#).
- [Video ISEL, Stochastically Evolving Intentions Handout](#).
- [Video IIEI](#).
- [Video IISEI](#).
- [Video IIAFA](#).

Tool Versions:

- [GrowingLeaf-El-Sim \(Tool-El\)](#).
- [GrowingLeaf-SEI-Sim \(Tool-SEI\)](#).
- [GrowingLeaf-Forward Analysis \(Tool-FA\)](#).

R Files:

- [.R File](#)

Subject Recruitment:

- [Study advertisement email](#).
- [Graduate class Message Board advertisement](#).
- [Emails to schedule experiment](#).

<http://www.cs.toronto.edu/~amgrubb/archive/RE17-Supplement>

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*Useful for other tool
or modeling studies*

Summary

Results:

- Evolving Intentions were intuitive
- EI-Sim increased the subjects' understanding and produced meaningful results
- GrowingLeaf was found to be usable

Future work will improve this study:

- larger sample size and larger models
- different populations and domains

Study methodology and materials available for reuse

Questions?

Modeling and Reasoning with Changing Intentions: An Experiment

Study methodology and materials:

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Tool:

<http://www.cs.toronto.edu/~amgrubb/growing-leaf/>