

# The Role of Cartographic Interface Complexity on Decision Making: A Preliminary Hazardous Waste Trade Case Study

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July 4<sup>th</sup>, 2017 #ICC2017DC

# Outline

- Introduction
- Research Questions
- Methods
- Results
- Conclusions
- Design Recommendations

# Introduction

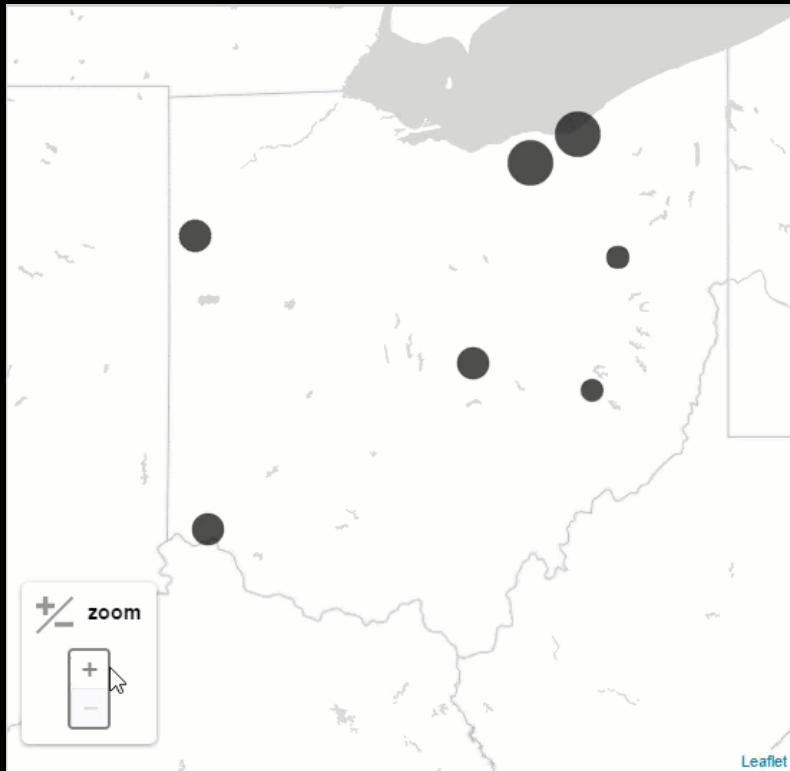
- Social, environmental, and economic problems = visual
- Increasingly interactive (Muehlenhaus 2013)
- Few empirically-derived guidelines exist for designing interactive maps to support decision making (MacEachren 2015)
- **Goal: Improve decision making with interactive maps**
- **How?: Map-based survey with 122 participants**

# Research Questions

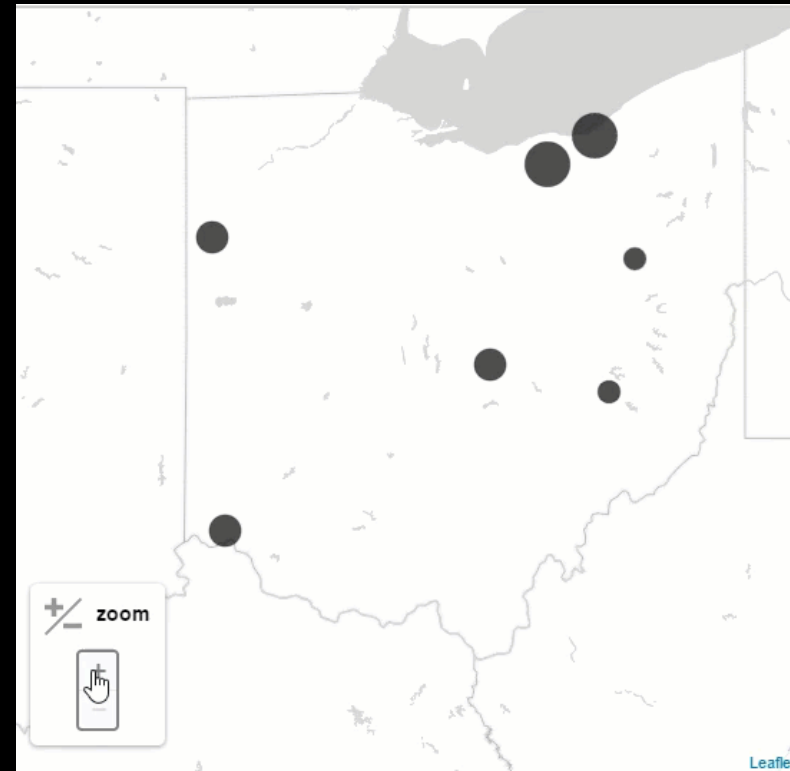
1. **Does cartographic interface complexity influence the success of spatial decision making?**

# Interface Complexity (RQ1)

Scope: the number of interactive operators within the map



Freedom: the precision that each operator can be interactively adjusted

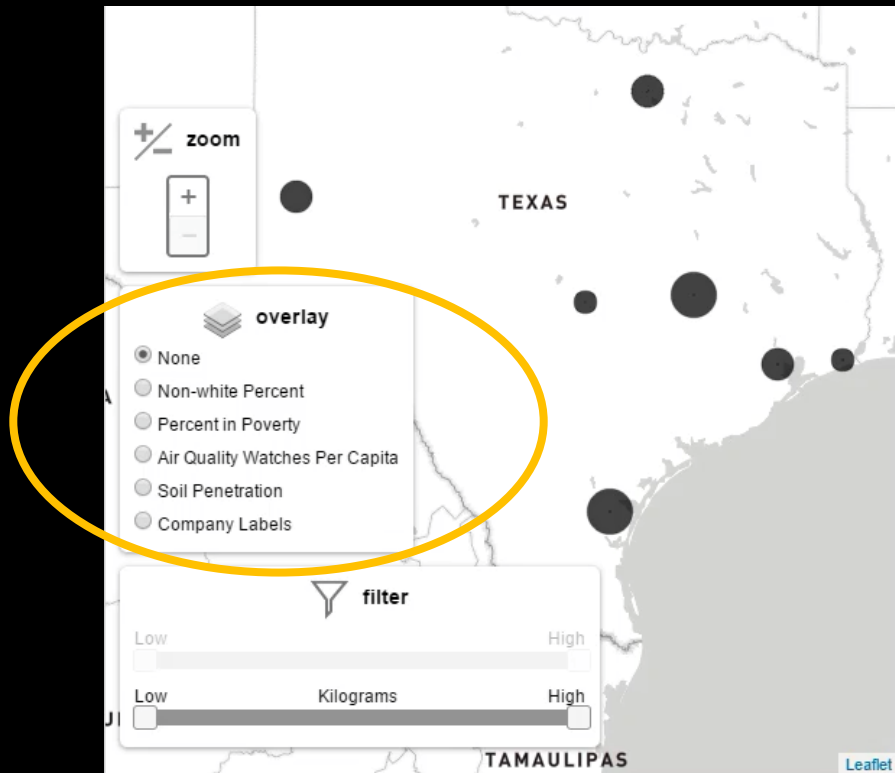


# Research Questions

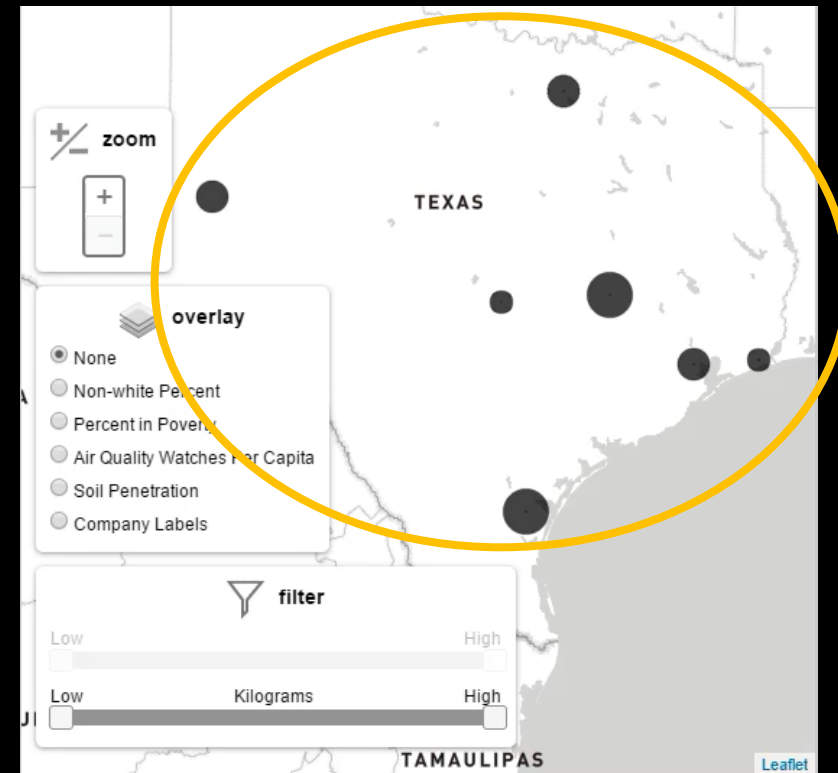
1. Does cartographic interface complexity influence the success of spatial decision making?
2. Does geographic decision complexity influence the success of decision making when using an interactive map?

# Decision Complexity (RQ2)

Criteria: The factors that go into making a decision



Outcomes: Potential decision choices (i.e., sites)



# Research Questions

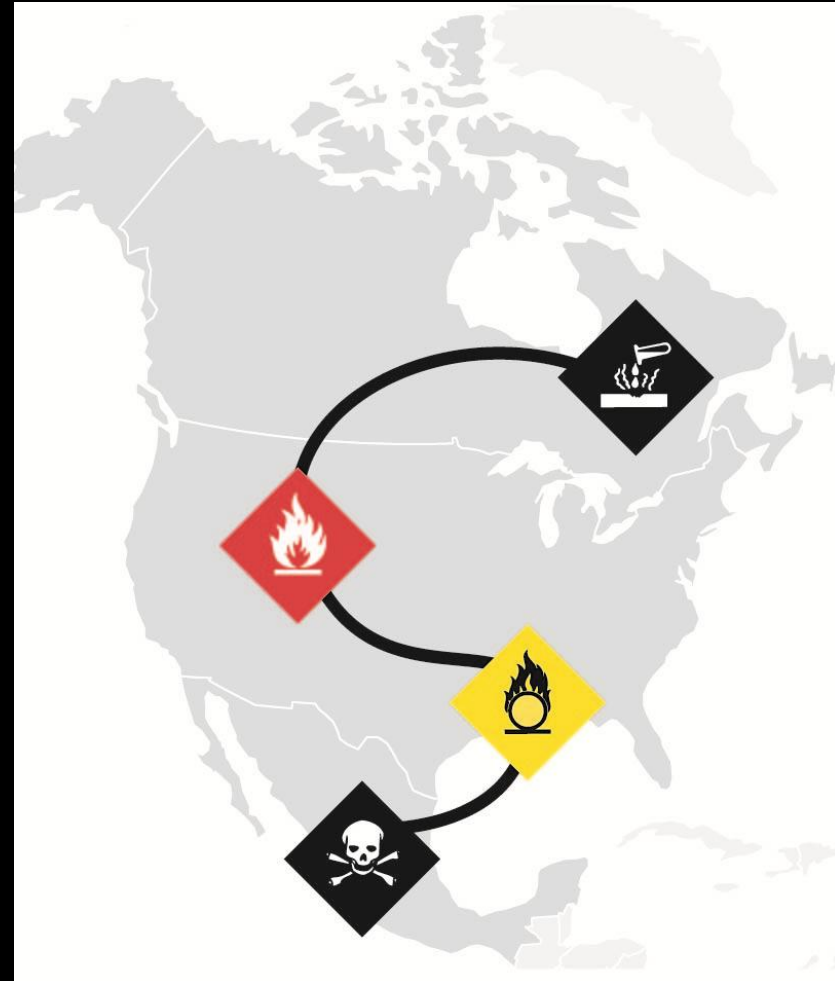
1. Does cartographic interface complexity influence the success of spatial decision making?
2. Does geographic decision complexity influence the success of decision making when using an interactive map?
3. **Is the influence of cartographic interface complexity and geographic decision complexity dependent upon the expertise of the decision maker?**



# Methods: Case Study

- North American hazardous waste trade
- Hazardous materials between Canada, Mexico, and the U.S.
- Ignitable, corrosive, reactive, and/or toxic
- Manufacturing by-products
- Batteries
- Acetone
- Paint

[geography.wisc.edu/hazardouswaste](http://geography.wisc.edu/hazardouswaste)



# Methods: Materials

- 2x2 factorial design
- Interface complexity (*simple, complex*)
- Decision complexity (*simple, complex*)
- Texas and Ohio
- 2 decision scenarios
  - Manager of a hazardous waste facility
    - Rank preference for doing business with
  - Regulator at the EPA
    - Rank urgency for site visits

# Methods: Materials

	<i>Simple</i>	<i>Complex</i>
<b>Interface Complexity (Factor 1)</b>	Basic slippy map <ul style="list-style-type: none"><li>•Pan</li><li>•Zoom</li><li>•Retrieve</li></ul>	Shneiderman's Mantra <ul style="list-style-type: none"><li>•Pan</li><li>•Zoom</li><li>•Retrieve</li><li>•Overlay</li><li>•Filter</li></ul>
<b>Decision Complexity (Factor 2)</b>	3 Criteria <ul style="list-style-type: none"><li>•Kilograms imported</li><li>•Percent non-white population</li><li>•Air quality watches per capita</li></ul>	5 Criteria <ul style="list-style-type: none"><li>•Kilograms imported</li><li>•Percent non-white population</li><li>•Air quality watches per capita</li><li>•Percent in poverty</li><li>•Soil permeability</li></ul>

# Methods: Map Survey

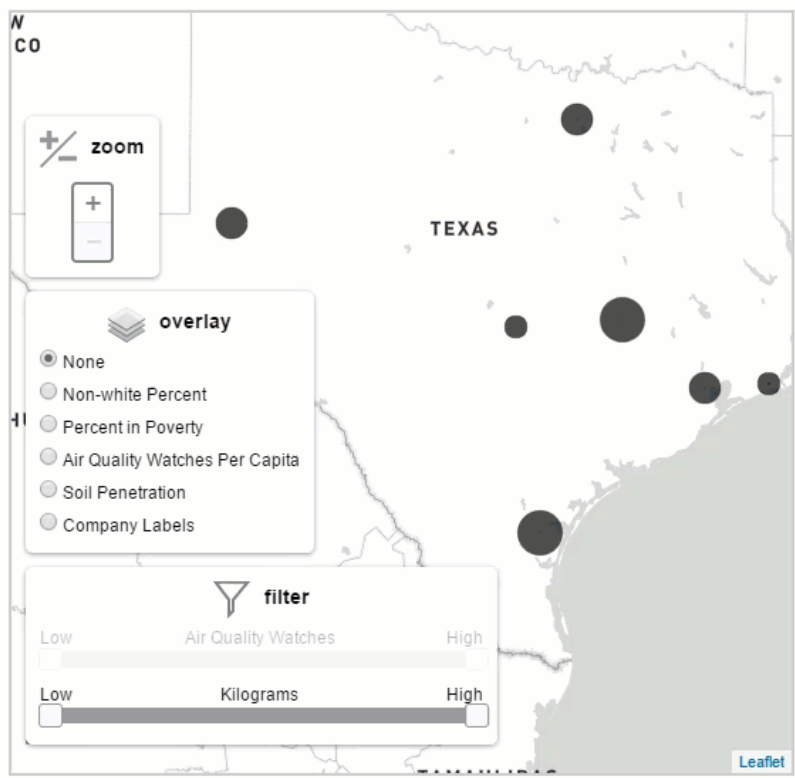
MapStudy: [github.com/uwcart/mapstudy](https://github.com/uwcart/mapstudy)

122 Participants

110 Non-experts

12 Experts

Interactive Maps and Decision Making: A Case Study in the North American Hazardous Waste Trade Time elapsed: 01:29:24



The screenshot shows a map of Texas with several black circles of varying sizes representing hazardous waste facilities. The interface includes a zoom control, an overlay menu with options like 'None', 'Non-white Percent', 'Percent in Poverty', 'Air Quality Watches Per Capita', 'Soil Penetration', and 'Company Labels', and a filter menu with sliders for 'Air Quality Watches' and 'Kilograms'. The map is set to a light gray background with a white border.

### Map Task

\* You are a regulator at the EPA responsible for ensuring that hazardous waste imported from Mexico is processed at facilities in Texas following government regulations. New information suggests that the volume of imported hazardous waste has changed, and that you will need to plan site visits to review the processing facilities. Your job is to examine recent reports to assess each company's potential for negative environmental impacts. Further, community members have come forward with concerns they are at risk of exposure to hazardous waste, and this risk disproportionately impacts marginalized populations.

Given these needs and concerns, use the interactive map to **rank the urgency you need to follow-up with site visits** to each facility (**1=most urgent, 7=least urgent**). Again, drag the company names (seen below) above and below each other to rank the urgency.

The factors that you will be analyzing to come to your decision are (in all cases, **low = good and high = bad**):

- 1. Waste in Kilograms:** An increased volume of hazardous waste at a processing site generally increases the potential risk to the local community and environment, all other things considered.
- 2. Percent non-white population:** Environmental justice research shows that non-white communities may be more more burdened by hazardous waste facilities than white communities.
- 3. Percent in poverty:** Environmental justice research shows that poor communities may be more more burdened by hazardous waste facilities than wealthy communities.
- 4. Air quality watches:** Processing hazardous waste releases emissions that can negatively impact air quality. An air quality watch is issued whenever air quality

This Project is Sponsored by the University of Wisconsin-Madison and the National Science Foundation.

# Results: Overall Decision Performance

- **56.6%** of decisions were statistically correct
- Difficulty: **2.3 / 5**
  - 5 is very difficult
- Confidence: **4.1 / 5**
  - 5 is very confident
- **99.6%** interacted
- **5,900** total interactions!
- Interaction strategies emerged

**Location** was not a factor (Texas vs. Ohio)

**Order** was not a factor (1st vs. 2nd)

# Results: Interface Complexity

## Simple

- **68.4%** of decisions were statistically correct\*
- Difficulty: **2.1 / 5\***
- Confidence: **4.2 / 5\***

## Complex

- **41.7%** of decisions were statistically correct\*
- Difficulty: **2.5 / 5\***
- Confidence: **3.9 / 5\***

**With *simple* map, participants were:**

- **More correct**
- **Thought decision was easier**
- **More confident**

# Interactions: Interface Complexity

**Interface Complexity**

*Simple*

*Complex*

Operator	Sample Size	Extensiveness		Frequency		
Descriptive		Total	Percentage	Total	Avg per Decision	Standard Deviation
Retrieve	136	136 / 136	100	1,984	14.59	104.81
Pan	136	95 / 136	69.9	494	3.63	55.62
Zoom	136	36 / 136	26.5	127	0.93	11.03
Overall	136	136 / 136	100	2,605	19.15	218.72
Retrieve	108	87 / 108	80.6	1,172	10.85	24.54
Pan	108	94 / 108	87.0	918	8.50	89.76
Overlay*	108	89 / 108	82.4	664	6.15	55.25
Zoom	108	42 / 108	38.9	207	1.92	29.34
Filter*	108	35 / 108	32.4	334	3.09	39.09
Overall	108	107 / 108	99.1	3,295	30.51	103.20
Total	244	243/244	99.6%	5,900	24.18	155.45

# Interactions: Interface Complexity

- Retrieve frequency different between *simple* and *complex*
- 2 interaction strategies
  - *Simple*: retrieve-based (more successful)
    - All criteria, 1 outcome
  - *Complex*: overlay-based
    - 1 criteria, all outcomes
- \*Interface complexity had significant impact on decision making



# Results: Decision Complexity

## Simple

- **54.1%** of decisions were statistically correct
- Difficulty: **2.3 / 5**
- Confidence: **4.0 / 5**

## Complex

- **59.0%** of decisions were statistically correct
- Difficulty: **2.2 / 5**
- Confidence: **4.1 / 5**

## **No difference in:**

- **Correctness**
- **Difficulty**
- **Confidence**

**\*Interface complexity = important!**

# Interactions: Decision Complexity

**Decision Complexity**

*Simple*

*Complex*

Operator	Sample Size	Extensiveness		Frequency		
Descriptive		Total	Percentage	Total	Avg per Decision	Standard Deviation
Retrieve	122	112 / 122	91.8	1,613	13.22	144.82
Pan	122	93 / 122	76.2	605	4.96	72.05
Overlay*	54	43 / 54	79.6	254	4.70	33.94
Zoom	122	37 / 122	30.3	134	1.10	13.63
Filter*	54	14 / 54	25.9	152	2.81	45.25
Overall	122	122 / 122	100	2,758	22.61	162.70
Retrieve	122	111 / 122	91.0	1,543	12.65	133.73
Pan	122	96 / 122	78.7	807	6.61	108.40
Overlay*	54	46 / 54	85.2	410	7.59	43.84
Zoom	122	41 / 122	33.6	200	1.64	29.70
Filter*	54	21 / 54	38.9	182	3.37	48.08
Overall	122	121 / 122	99.2	3,142	25.75	152.19
Total	244	243/244	99.6%	5,900	24.18	155.45

# Interactions: Decision Complexity

- No differences between *simple* and *complex*

\*Decision complexity had no significant impact on decision making

# Results: Expertise

## Experts

- **58.3%** of decisions were statistically correct
- Difficulty: **2.4 / 5**
- Confidence: **3.6 / 5\***

## Non-Experts

- **56.4%** of decisions were statistically correct
- Difficulty: **2.3 / 5**
- Confidence: **4.1 / 5\***

*Non-experts were:*

- **More confident**

# Interactions: Expertise

## Hazardous Waste Expertise

### *Experts*

Operator	Sample Size	Extensiveness		Frequency		
Descriptive		Total	Percentage	Total	Avg per Decision	Standard Deviation
Retrieve	24	20 / 24	83.3	346	14.42	23.51
Pan	24	20 / 24	83.3	174	7.25	15.27
Overlay*	12	12 / 12	100	114	9.50	13.10
Zoom	24	9 / 24	37.5	34	1.42	4.06
Filter*	12	5 / 12	41.7	41	3.42	8.96
Overall	24	24 / 24	100	709	29.54	20.65
Retrieve	220	203 / 220	92.3	2,810	12.77	106.26
Pan	220	169 / 220	76.8	1,238	5.63	75.77
Overlay*	96	77 / 96	80.2	550	5.73	47.19
Zoom	220	69 / 220	31.4	300	1.36	19.52
Filter*	96	30 / 96	31.3	293	3.05	31.12
Overall	220	219 / 220	99.5	5,191	23.60	136.35
Total	244	243/244	99.6%	5,900	24.18	155.45

### *Non-Experts*

# Interactions: Expertise

## Extensiveness and Frequency

- Very different!
- *Experts*: overlay
- *Non-experts*: retrieve
- Resembles interaction strategies

\**Experts* not significantly worse, but interacted differently, so expertise matters!

# Conclusions

- Interface complexity affected decision making
  - *Simple* = better
  - More functionality not always better
- Decision complexity did not affect decision making
  - *Simple vs. complex* = no difference
  - Additional information may clarify
- User expertise did not affect decision making
  - Experts less confident, less likely to act
  - Interact differently

# Design Recommendations

- Simple, easy to use interface is best
- Include retrieve!
- Provide data for multiple criteria for each outcome (site)
- Increased interactivity alright for experts



# Thank You!

- This project was supported in part by:
  - NSF Award #1539712
  - NSF Award #1555267
  - UW-Madison Geography Department Trewartha Research Grant
  - AAG Cartography Specialty Group Master's Thesis Research Grant
  - Wisconsin Alumni Research Foundation

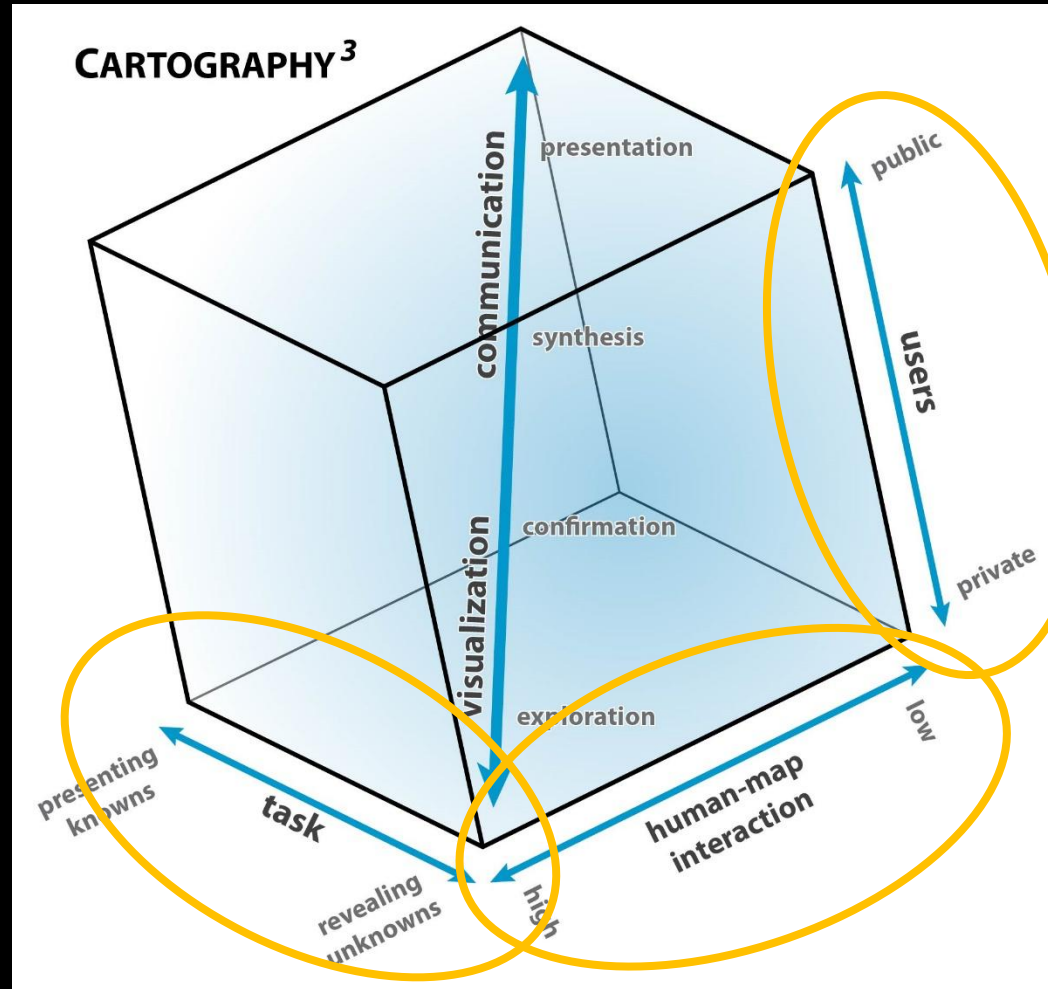
# User Expertise (RQ3)

- **Education:** amount of formal education with the subject
- **Experience:** amount of time with the subject
- **Familiarity:** self-proclaimed knowledge of the subject

Expertise can be with the:

- **Tool** (interactive map)
- **Domain** (decision topic)
- **Computers** (device user is working with)

# Related Work



RQ2:  
Decision making

RQ3:  
Expert vs. Non-Expert

RQ1:  
Interface Complexity

# Decision Making Stages

<b>Information Seeking</b> (Identifying the Need)	<b>Sensemaking</b> (Determining Problem Context and Alternatives)	<b>Action</b> (Identify Best Route, Given Obtained Information)
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# Related Work

- Slippy map
  - Pan, zoom, retrieve
- Shneiderman's Visual Information Seeking Mantra (Shneiderman 1996)
  - Overview first, zoom and filter, details on demand
- Roth (2013) work operator primitives

# Methods: Preparatory Research

## 1. FOIA requests to EPA

Need Consent Form

Please print or type. (Form designed for use of 10/16 (12/16) typewriter.) DL3790028 SC PFW 3/3/2011 Form Approved OMB No. 2050-0039

**UNIFORM HAZARDOUS WASTE MANIFEST** 1. Generator ID Number: 55988 A00674 3152 2. Page 1 of 3 3. Emergency Response Phone: (800) 483-3719 4. Manifest Tracking Number: 003895230 FLE

5. Generator's Name and Mailing Address: Clean Harbors Canada Inc, 7842 Progress Way, Delta, BC V4G 1A4. Exporter name and address. 6. Manifest Tracking Number: 003895230 FLE. Manifest number.

6. Transporter 1 Company Name: Achenafat Transport Inc (USA). 7. Transporter 2 Company Name: Clean Harbors Environmental Services. Importer EPA ID: ARD089748192.

8. Designated Facility Name and Site Address: Clean Harbors El Dorado LLC, 309 American Circle, El Dorado, AR 71730. Importer name and address.

9. U.S. DOT Description (including Proper Shipping Name, Hazard Class, ID Number, and Packing Group (if any)): UN1291, WASTE ALKALI METAL DISPERSIONS, 4.3, PG I. # of containers: 001. Container type: 0099 P. EPA waste code: D001 D003.

UN	U.S. DOT Description (including Proper Shipping Name, Hazard Class, ID Number, and Packing Group (if any))	Containers		Waste Codes	
		Type	Quantity	11. Code	12. Code
UN1291	WASTE ALKALI METAL DISPERSIONS, 4.3, PG I	001	0099 P	D001	D003
UN1291	WASTE ALKALI METAL DISPERSIONS, 4.3, PG I	005	0208 P	D001	D003

14. Special Handling Instructions and Additional Information: 1. E1 - CE487251 ERG#138 1X55; 2. E1 - CE487251 ERG#138 5X85.

15. GENERATOR/SHIPPER'S CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I certify that the waste minimization statement identified in 40 CFR 262.27(a) (if I am a large quantity generator) or (b) (if I am a small quantity generator) is true. Year: 09/26/11.

16. International Shipments:  Import to U.S.  Export from U.S. Port of entry: BLAIN, WA. Port of entry.

17. Transporter Acknowledgment of Receipt of Materials: Transporter 1 Printed/Typed Name: [Signature] Date: 09/26/11. Transporter 2 Printed/Typed Name: [Signature] Date: 09/27/11.

18. Discrepancy: 18a. Discrepancy Indication Space:  Quantity  Type  Residue  Partial Rejection  Full Rejection.

19. Hazardous Waste: Expected management method: H040.

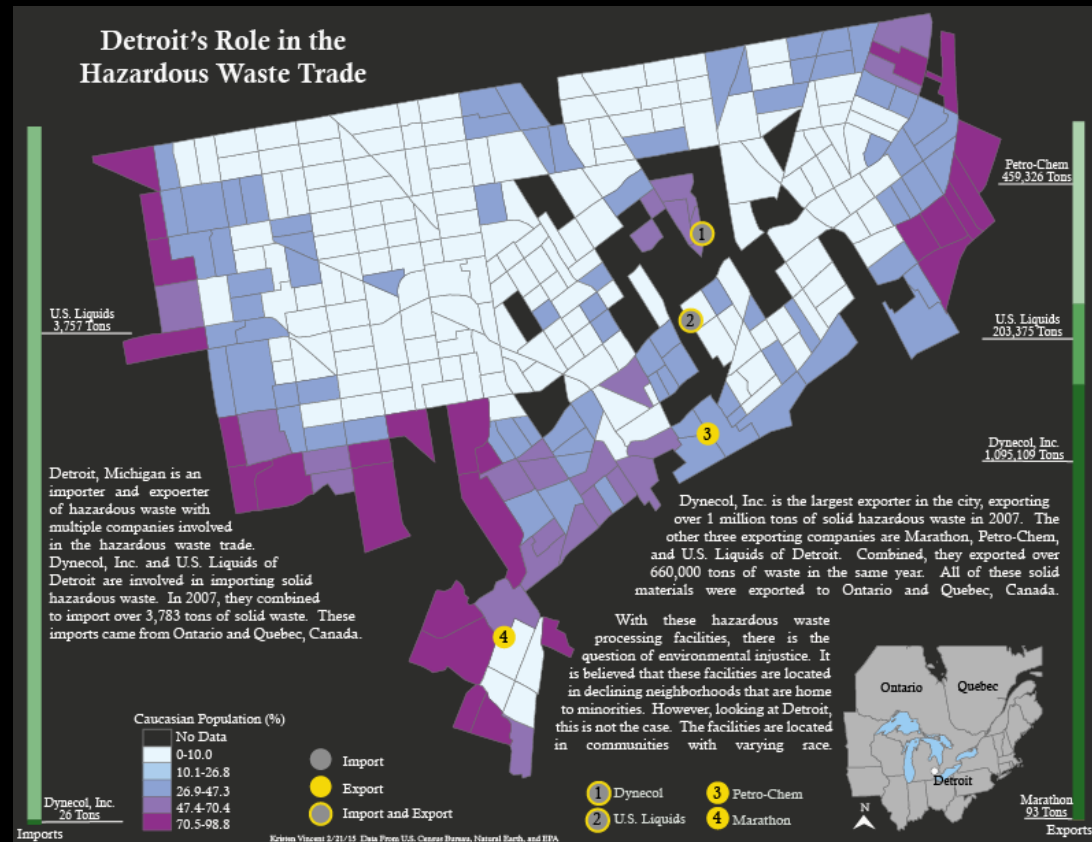
20. Designated Facility Owner or Operator: Certification of receipt of hazardous materials covered by the manifest except as noted in Item 18a. Signature: [Signature] Date: 11/7/11.

EPA Form 8700-22 (Rev. 3-05) Previous editions are obsolete. DESIGNATED FACILITY TO GENERATOR

Clean Harbors has the appropriate permits for and will accept the waste the generator is shipping.

# Methods: Preparatory Research

1. FOIA requests to EPA
2. Design Challenge 2015
3. Semi-structured interviews with domain experts (n=3)
4. Pilot study with UW-Madison Cartography Lab students (n=8)

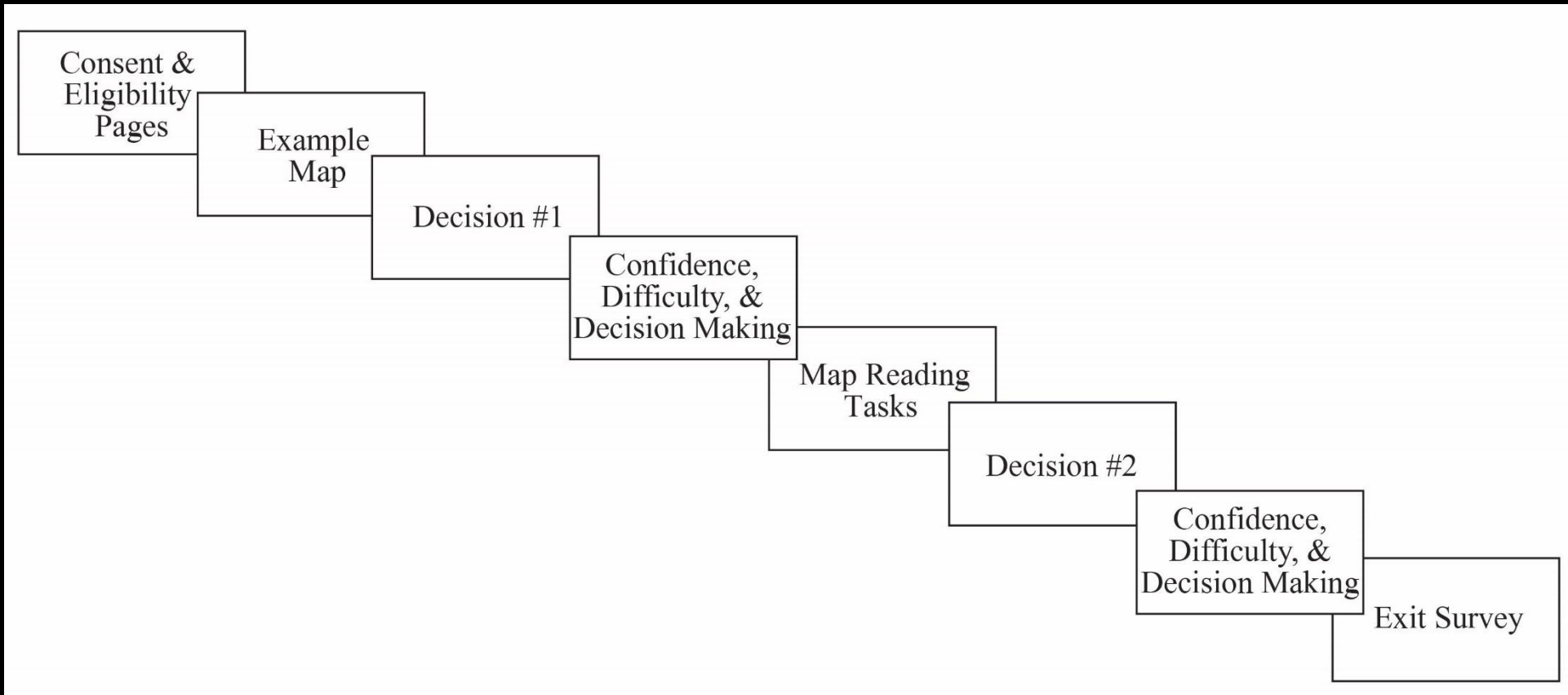


# Methods: Participants

- 122 Participants
  - 110 Non-experts (Amazon Mechanical Turk)
  - 12 Experts (n=3 from the EPA/state government and n=9 from Design Challenge 2015)
- English as 1st language
- Currently living in the United States (but not Texas or Ohio)
- 18 years or older
- Non-mobile devices



# Methods: Procedure



# Methods Procedure

- Amazon Mechanical Turk for *non-experts*
- Email for *experts*
- Random group and order assignments
- Interface complexity varied between groups
- Decision complexity varied within groups
- Recorded survey answers AND interaction logs

# Methods: Measures and Analysis

- Correctness
  - Kendall Rank Correlation Coefficient  
(Crossland et al. 1995, Mennecke et al. 2000, Kiker et al. 2005)
- Confidence
  - z-test
  - t-test
- Difficulty
  - z-test
  - t-test
- Interaction Logs
  - Frequency (t-test)
  - Extensiveness (t-test)

# Conclusions-Interactions

- Interface complexity: 2 interaction strategies
  - *Simple*: retrieve-based (more successful)
    - All criteria, 1 outcome
  - *Complex*: overlay-based
    - 1 criteria, all outcomes
- Decision complexity: no difference
  - Additional information may clarify
- *Experts and Non-Experts*: Differences
  - *Experts*: overlay
- *Non-experts*: retrieve