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

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Outline

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

Introduction

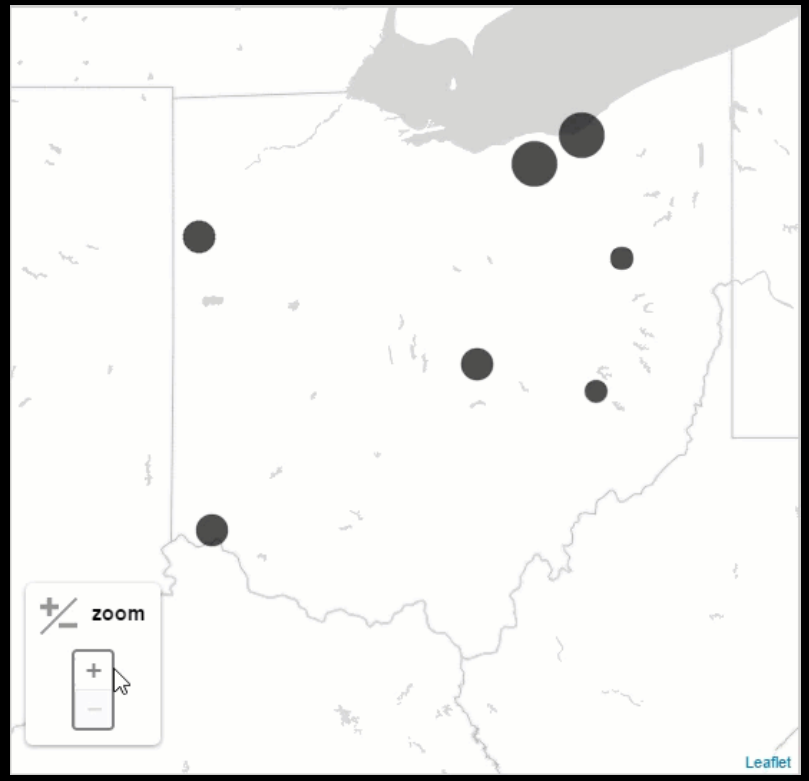
- Social, environmental, and economic problems = visual
- Increasingly interactive (Muehlenhaus 2013)
- Few empirically-derived guidelines exist for designing interactive maps to support decision making (MacEachren 2015)
- **Goal: Improve decision making with interactive maps**
- **How?: Map-based survey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

Research Questions

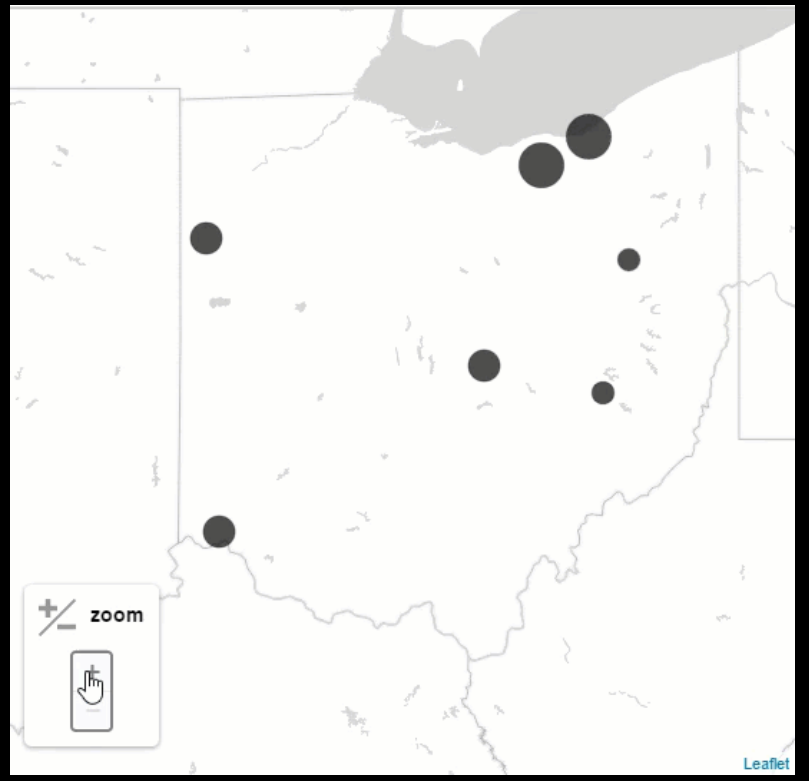
1. **Does cartographic interface complexity influence the success of spatial decision making?**

Interface Complexity (RQ1)

Scope: the number of interactive operators within the map



Freedom: the precision that each operator can be interactively adjusted



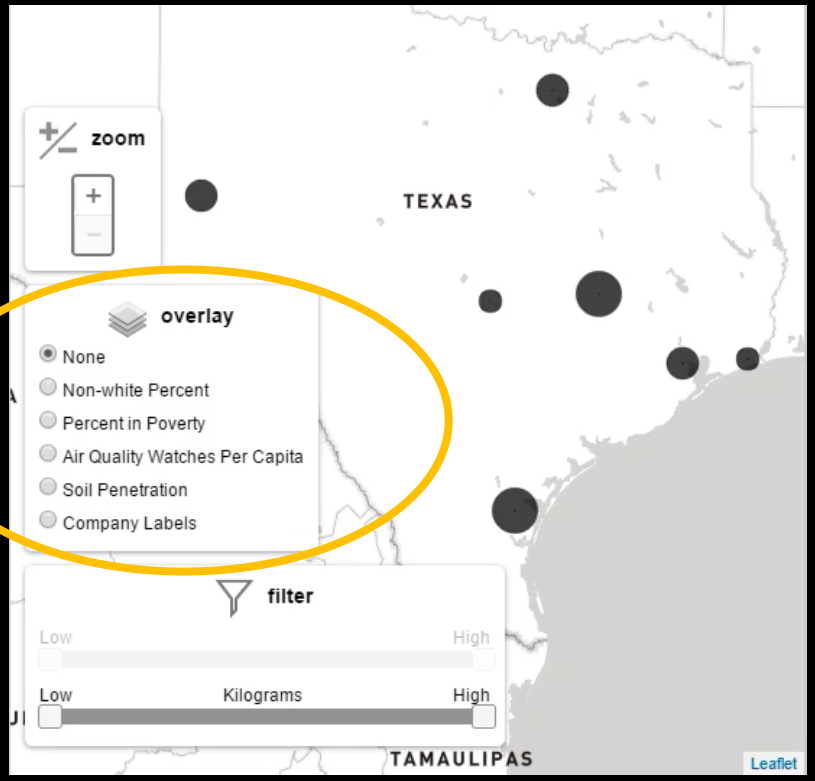
Harrower & Sheesley 2005, Cooper et al. 2007

Research Questions

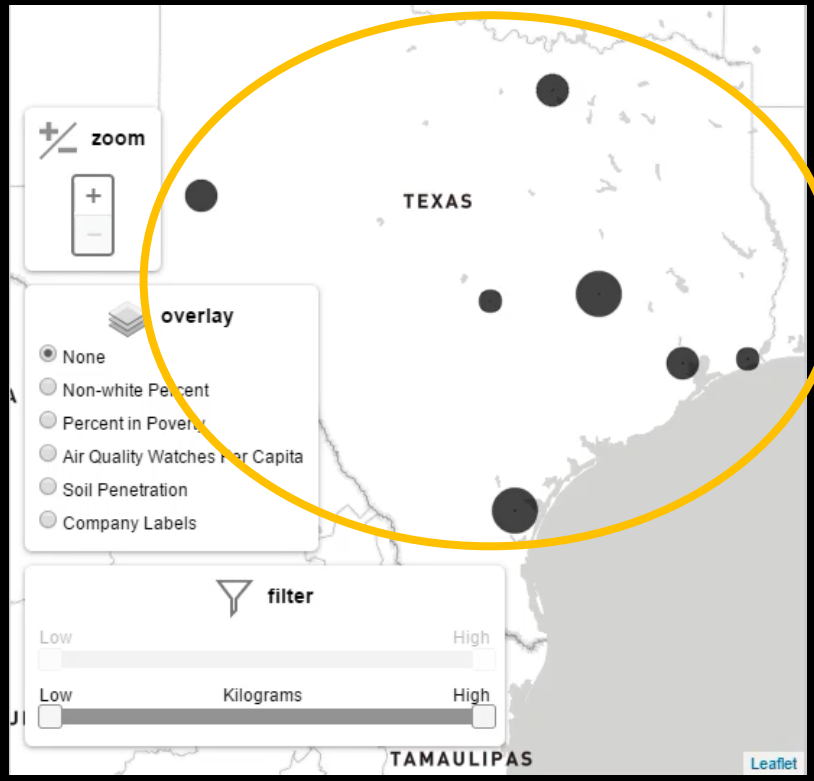
1. **Does cartographic interface complexity influence the success of spatial decision making?**
2. **Does geographic decision complexity influence the success of decision making when using an interactive map?**

Decision Complexity (RQ2)

Criteria: The factors that go into making a decision



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



Crossland et al. 1995, Jelokhani-Niaraki & Malczewski 2015

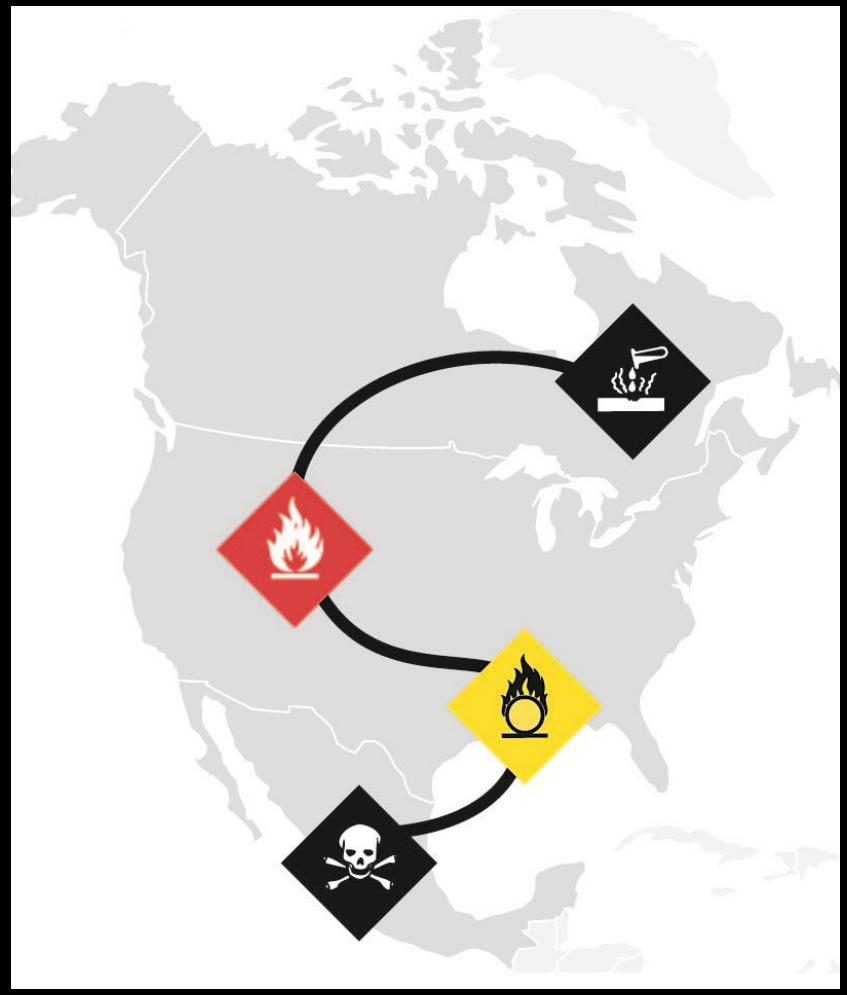
Research Questions

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



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

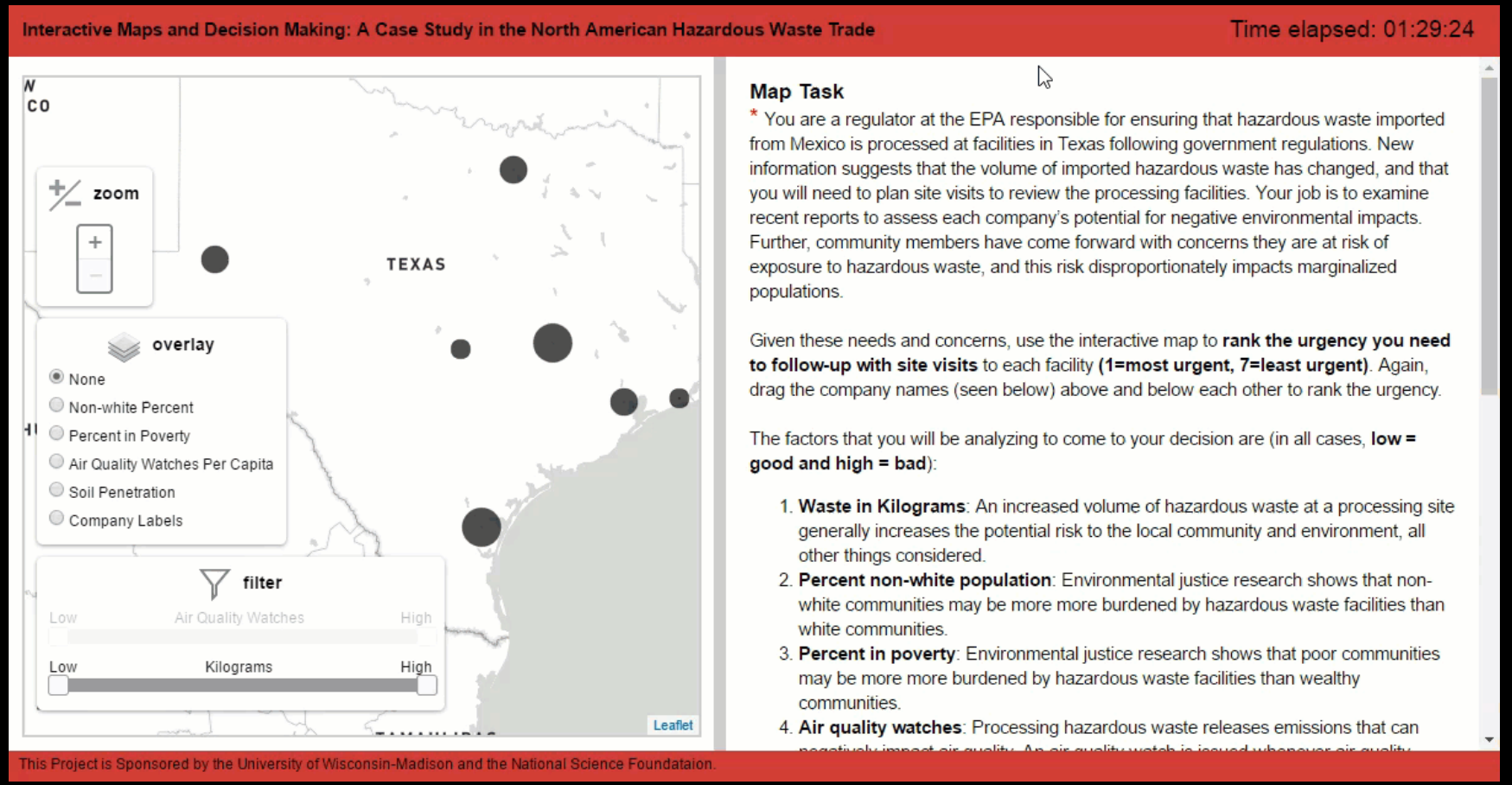
	Simple	***Complex***
Interface Complexity (Factor 1)	Basic slippy map •Pan •Zoom •Retrieve	Shneiderman's Mantra •Pan •Zoom •Retrieve •Overlay •Filter

Decision Complexity (Factor 2)	3 Criteria •Kilograms imported •Percent non-white population •Air quality watches per capita	5 Criteria •Kilograms imported •Percent non-white population •Air quality watches per capita •Percent in poverty •Soil permeability

Methods: Map Survey

MapStudy: github.com/uwcart/mapstudy

122 Participants
110 Non-experts
12 Experts



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

Non-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

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!

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  - Wisconsin Alumni Research Foundation

User Expertise (RQ3)

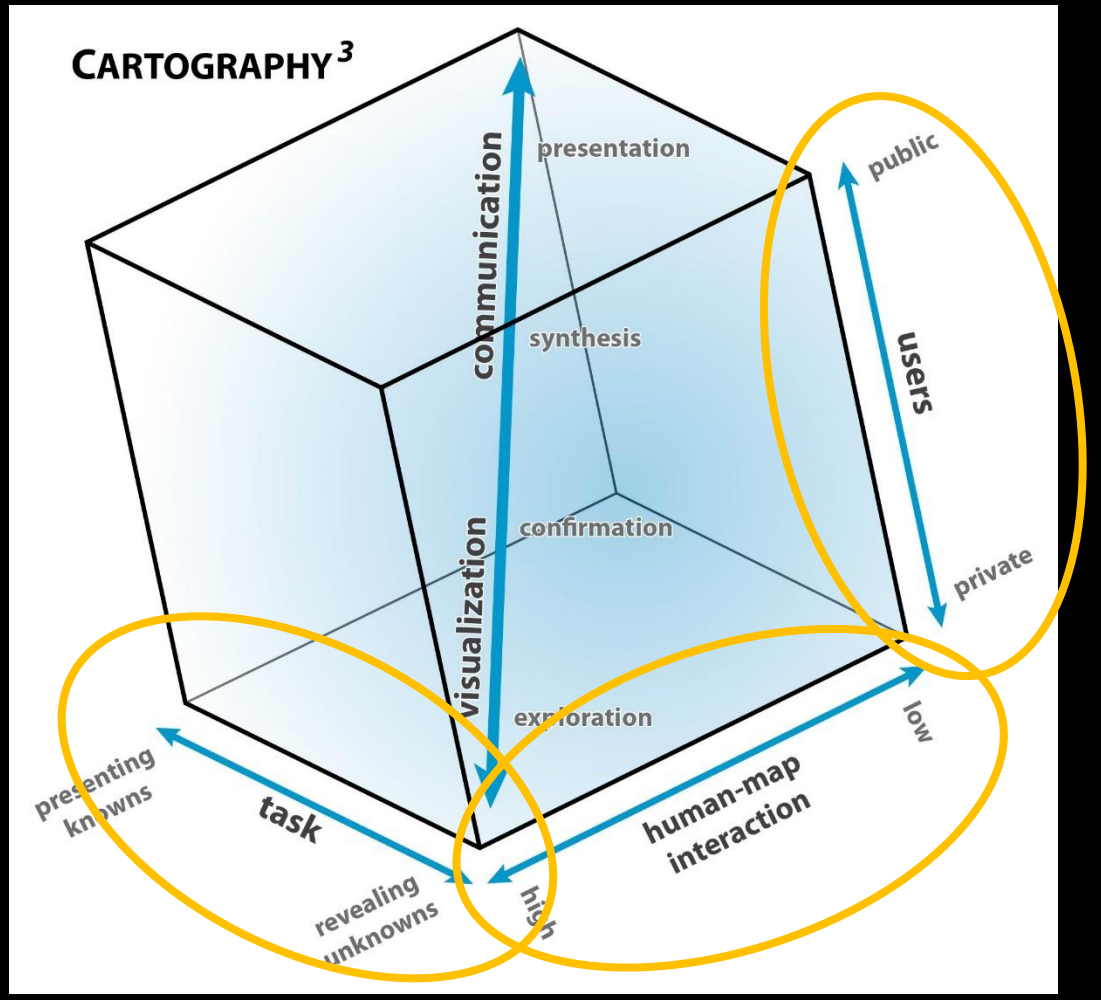
- **Education**: amount of formal education with the subject
- **Experience**: amount of time with the subject
- **Familiarity**: self-proclaimed knowledge of the subject

Expertise can be with the:

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

Roth 2009

Related Work



RQ3:
Expert vs. Non-Expert

RQ2:
Decision making

RQ1:
Interface Complexity

MacEachren 1994

Decision Making Stages

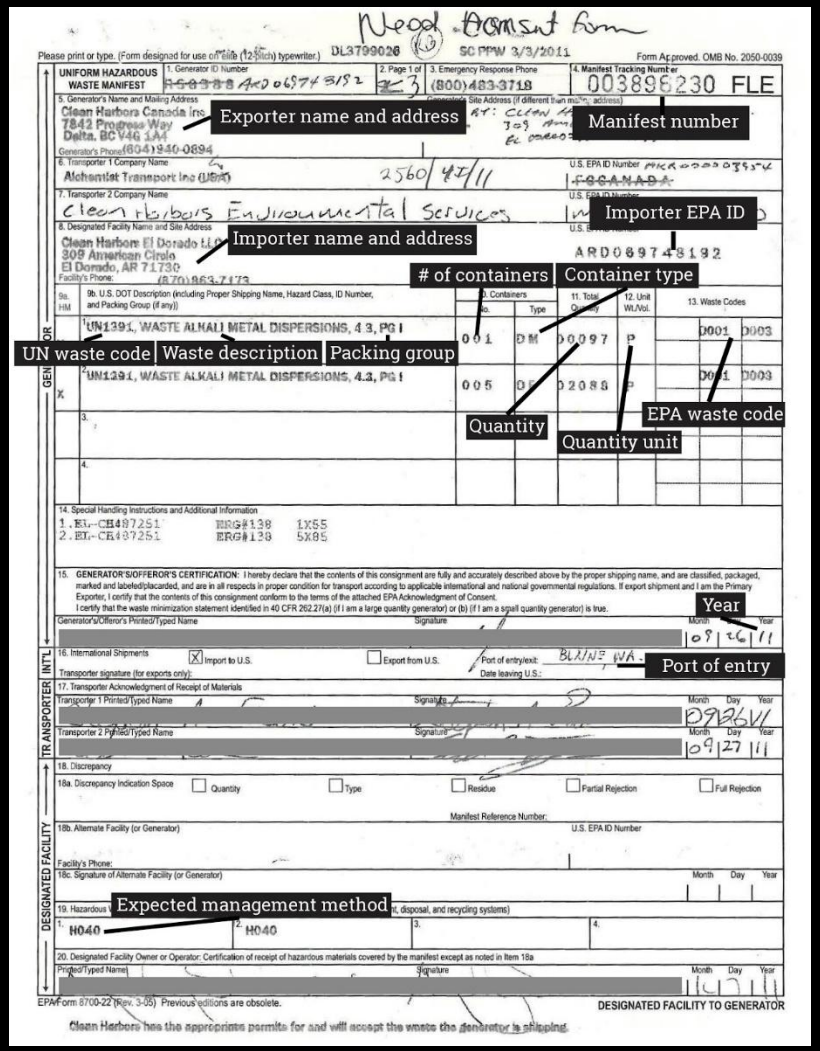
Information Seeking (Identifying the Need)	**Sensemaking** (Determining Problem Context and Alternatives)	**Action** (Identify Best Route, Given Obtained Information)

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

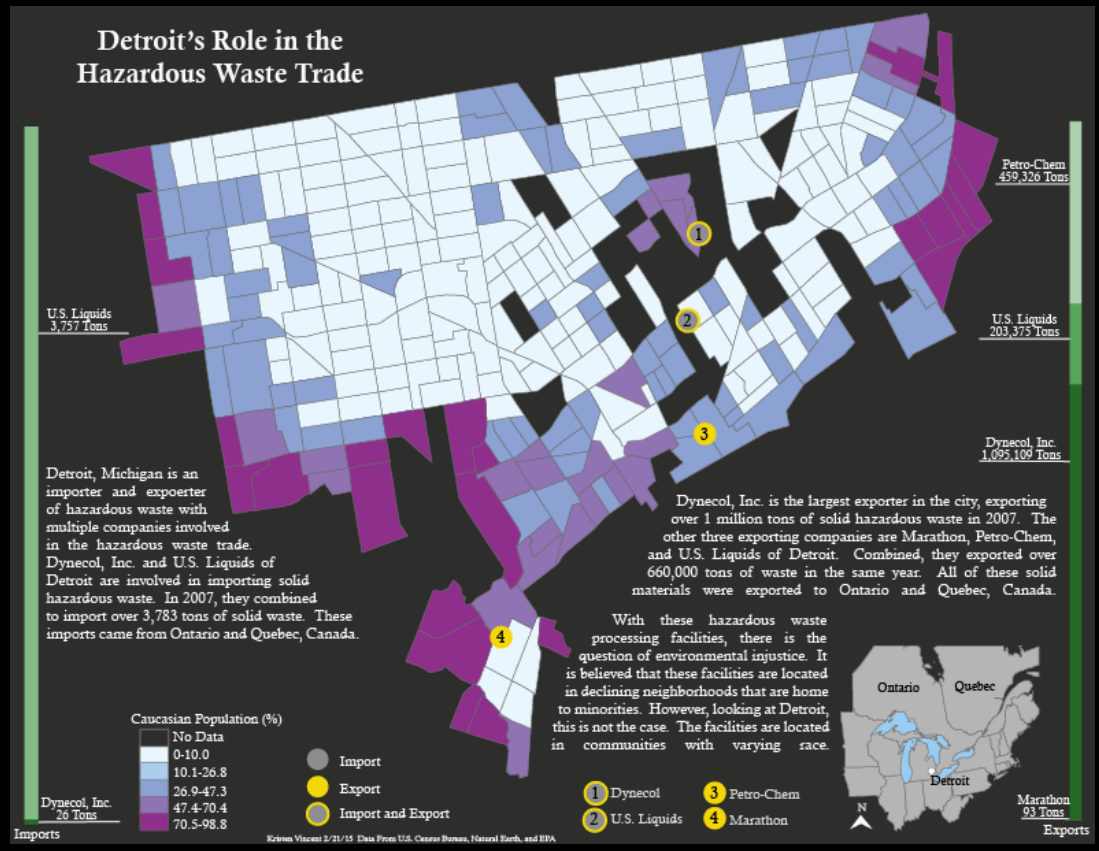
Methods: Preparatory Research

1. FOIA requests to EPA



Methods: Preparatory Research

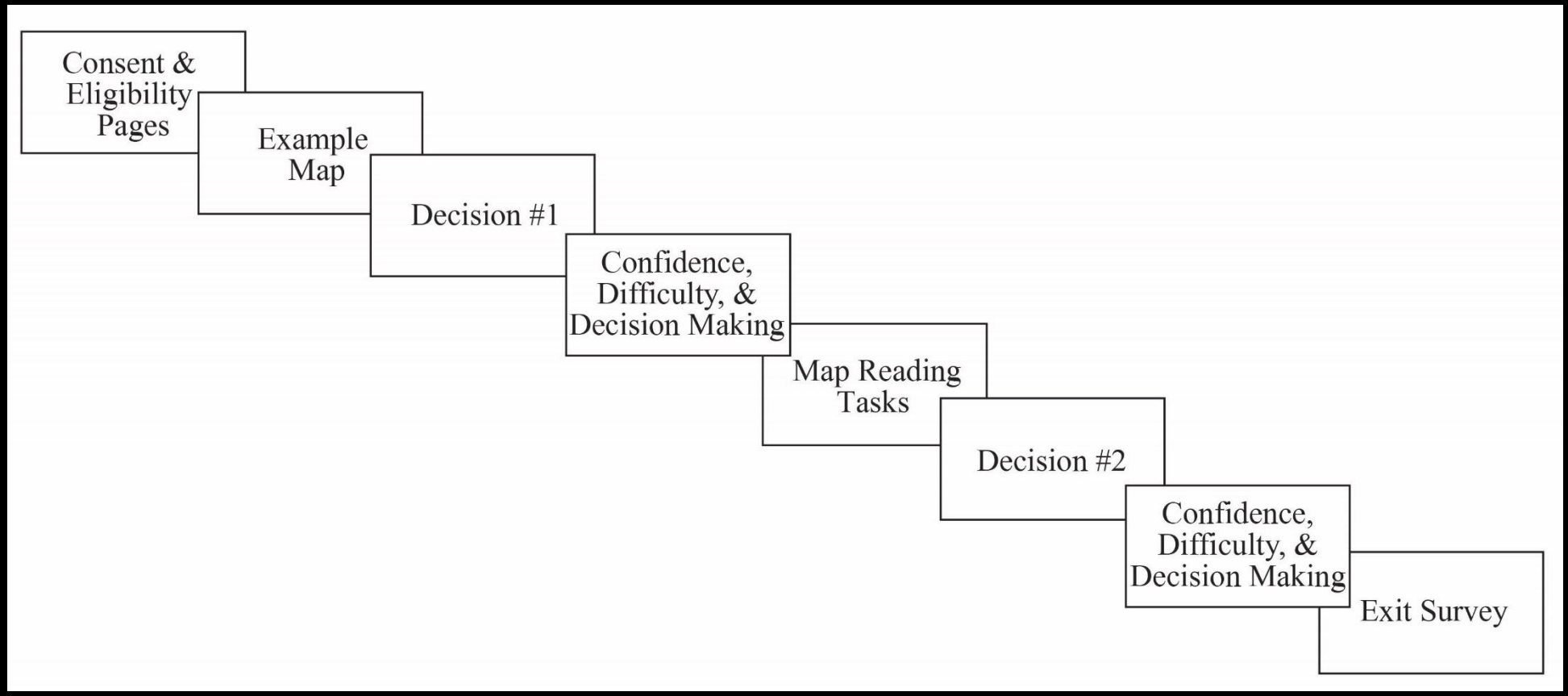
1. FOIA requests to EPA
2. Design Challenge 2015
3. Semi-structured interviews with domain experts (n=3)
4. Pilot study with UW-Madison Cartography Lab students (n=8)



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**