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Analyzing Chemical Substitution Decisions Among Chemical and Product Manufacturers

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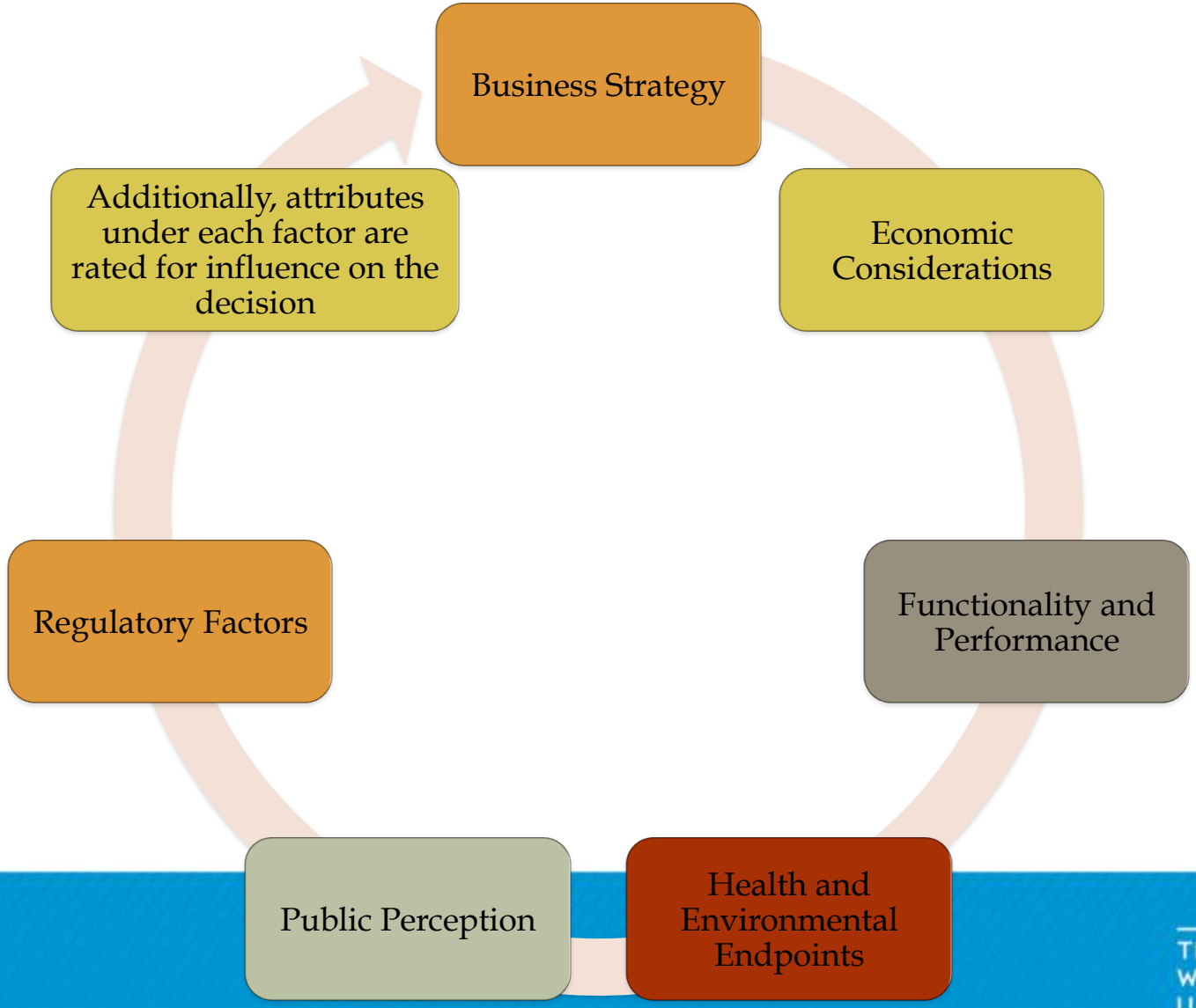
Introduction

- Recently there has been a big trend towards encouraging replacement of hazardous chemicals with greener, safer alternatives
- Literature studying chemical substitution decision making is relatively sparse.
- We seek to analyze decision making among chemical and product manufacturers who have faced a recent substitution decision
- The purpose is to understand tradeoffs taken in decision making by eliciting factors (six in total) and their respective attributes (33 in total) that contribute towards decision making.
  - We gathered data by using an online survey distributed to manufacturers

6 Decision factors



Decision factors

1. **Business Strategy**: issues associated with internal business decisions, including culture, corporate priorities, and approach to sustainability.
2. **Economic Considerations**: issues associated with the economics of product design, including costs and revenue impacts
3. **Functionality and Performance**: issues associated with product performance and design.
4. **Health and Environmental Endpoints**: hazard, exposure, and uncertainty for human health and environmental endpoints.
5. **Public Perception**: issues associated with public risk awareness and brand perception.
6. **Regulatory Factors**: issues associated with meeting mandatory and voluntary regulations and standards.

Our study, continued

- Examples of attributes include:
- Internal Management Culture (Business)
- Product Price, Market Share (Econ.)
- Ease of Product Design, Performance (Func.)
- Consumer Health Hazard, Environmental Hazard (Health and Env.)
- Company reputation, product brand reputation (Public Percep.)
- Meets regulatory standards (Regulatory factor)

Survey Methodology

- The survey is conducted online using Survey Monkey
  - Developed and revised with the help of government, academic, non-profit, and industry professionals through the HESI Sustainable Chemical Alternatives Committee
  - Sent to product and chemical manufacturers
  - Demographic information collected, such as company size and type of industry
  - Survey questions ask for a recent substitution decision and provide rankings (numerical, 1-10) for six decision factors and categorical rankings for 33 attributes
  - 33 complete responses obtained

Hypothesis #1

We wish to test the following hypothesis:

- Chemical/Product design and re-design decision factor tradeoff weights will differ based on company size, time of decision, whether formal AA procedures were used, and whether it is a product or chemical

*Tradeoff weights refer to those used in a Multi-Attribute Decision Model:

$$U(x\downarrow 1 \ldots x\downarrow n\downarrow f\ ) = \sum i=1 \uparrow n\downarrow f\ k\downarrow i\ u\downarrow i\,(x\downarrow i\,)$$

Survey Analysis

We chose a Bayesian inference model to study the tradeoff weights – this allows us to use a model to simulate weights based on the survey results, and use towards describing credible intervals for each tradeoff weight.

This will allow us to compare each tradeoff weight against equal weighting (1/6, or 0.167, since there are six weights).

The model is based on Bayes rule,

$p(\theta|y)=p(\theta)p(y|\theta)/p(y)$

Where $p(\theta)$ is the prior, $p(y|\theta)$ the likelihood, and $p(\theta|y)$ as the posterior

We model the prior and likelihood using the survey results as parameters, and sample to get the posterior results.

General Results – Respondents

Response Option	Number of Respondents
Product or Chemical?	
Chemical	20
Product	13
Design or Redesign?	
New Product	20
Redesign of an Existing Product	13
Timeline	
Less than 1 Year	6
One to Three Years	10
More than Three Years	17

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General Results – Simulated Weights

Pooled Tradeoff Weights						
Overall (n=33)	**BS**	**EC**	**FP**	**HEE**	**PP**	**RF**
Median	0.161	0.168	0.169	**0.187**	**0.148**	0.165
90% CI	(0.146, 0.176)	(0.154, 0.184)	(0.154, 0.187)	**(0.172, 0.203)**	**(0.133, 0.164)**	(0.150, 0.181)
95% CI	(0.144, 0.178)	(0.151, 0.188)	(0.152, 0.190)	**(0.169, 0.207)**	(0.130, 0.168)	(0.147, 0.184)

HEE significant from equal weighting at 0.05 LOS

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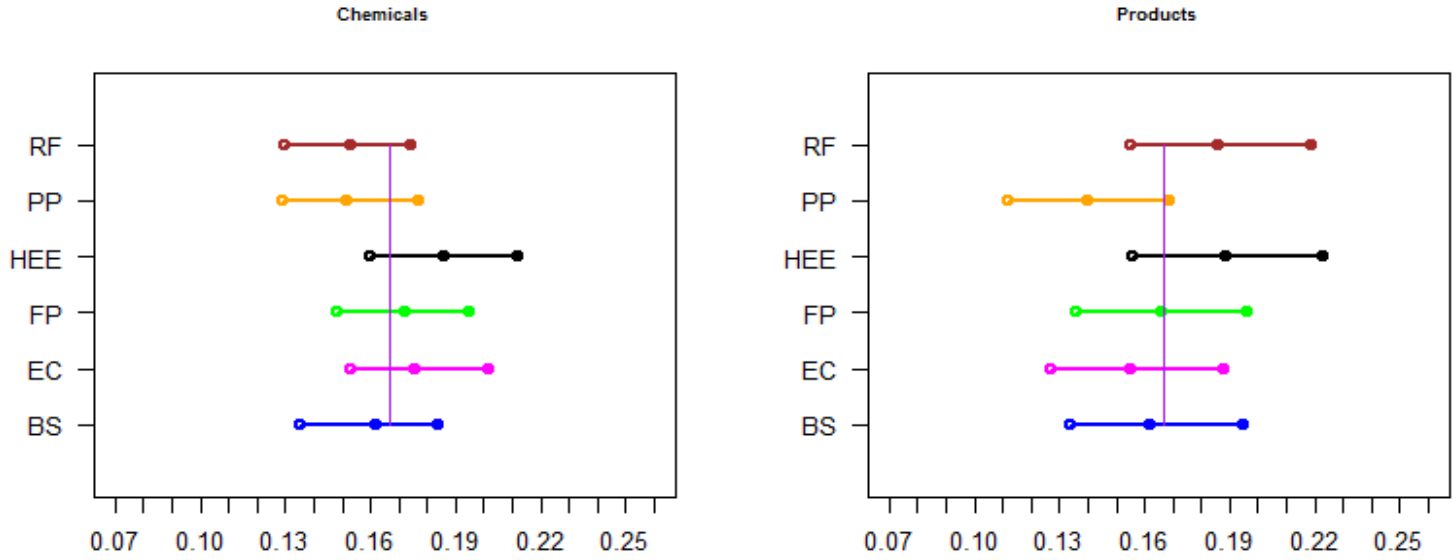
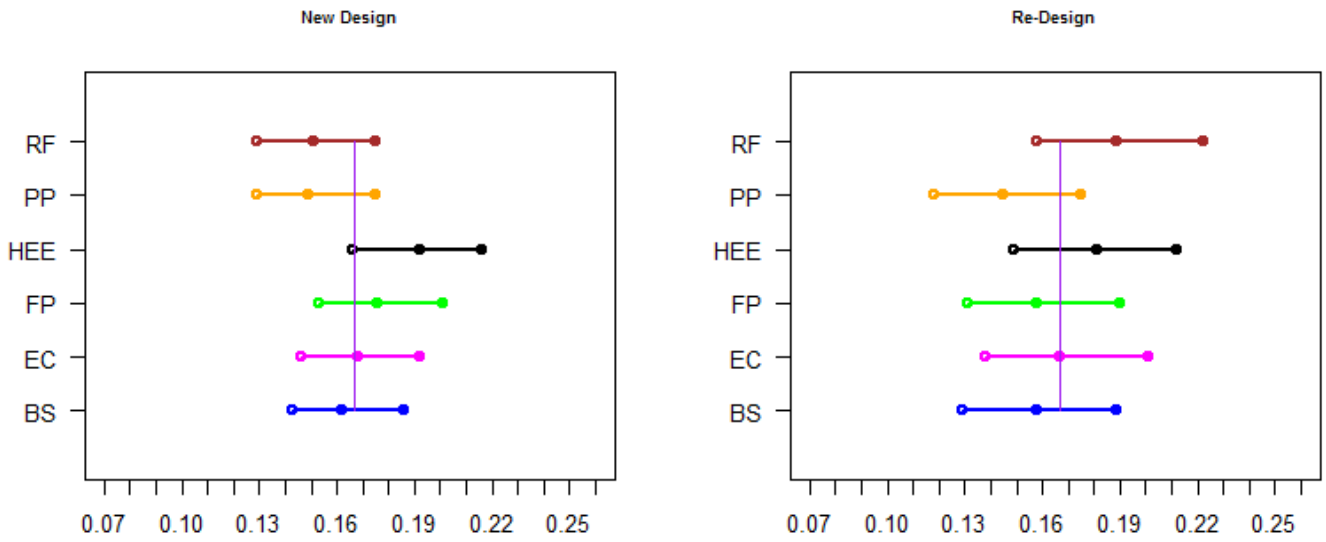
Results – Credible intervals for weights, Chemicals vs Products



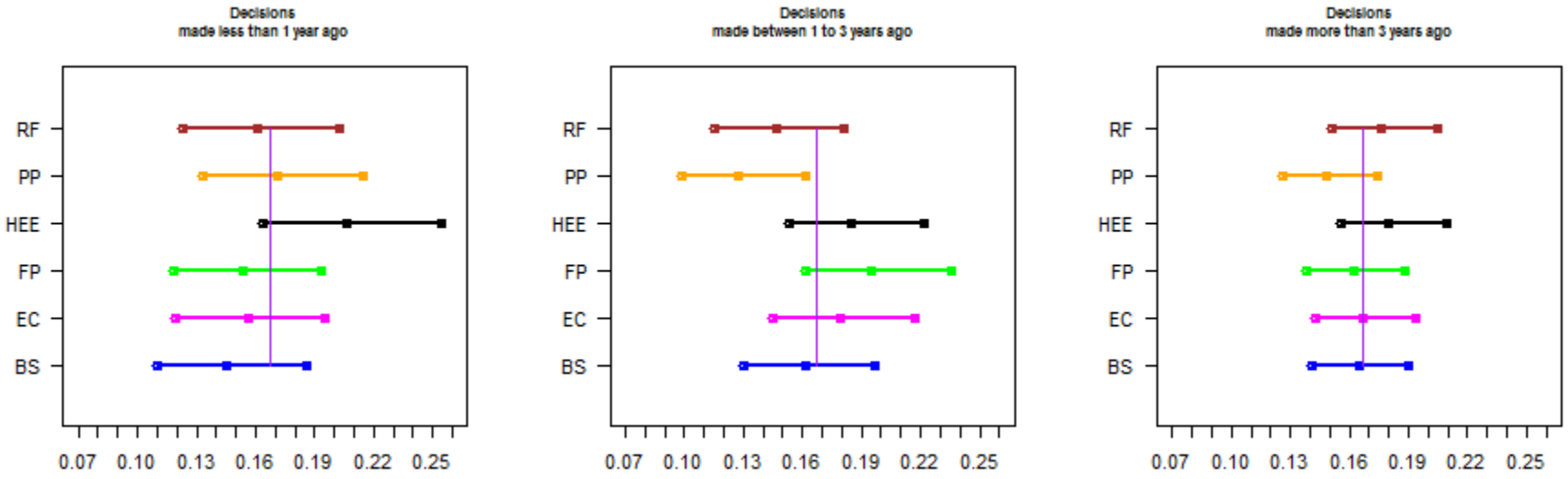
Observations: Two options are not significantly different from each other, PP for product sig. lower

Results – Credible intervals for weights, New Design vs Re-Design



Observations: Two options not significantly different from each other, HEE for New Design is sig. higher!

Results – Credible intervals for weights, Time of Decision



Observations: Three options are not significantly different from each other.

Hypothesis #2

- The influences of the 33 attributes on substitution decisions reflect shared perspectives among product or chemical manufacturers.

- Addressed using Principal Component Analysis on the survey results for Attributes

Conclusions

- Generally, companies are concerned with all factors in regards to making decisions about chemical substitution, however, HEE stands out

- 64% of respondents said they conduct a formal AA. Most use in house tools, a few use standard tools
- Those who don't use AA:
  - Barriers include: Time, Cost, Limited Internal Experience, Resistance to Change

- Suggestions for future AA guidance/policy: concentrate on HEE as key factor, rather than Business Strategy, Econ., or other factors.

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- Japanese Chemical Industry Association
- Toxics Use Reduction Institute