Use of Bayesian Networks to Make More Sustainable Food Packaging Choices That Prevent Food Waste

Summer 2023: by Dr. Claire Sand -
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Key Takeaways

Packaging has **far-reaching implications beyond shelf life**

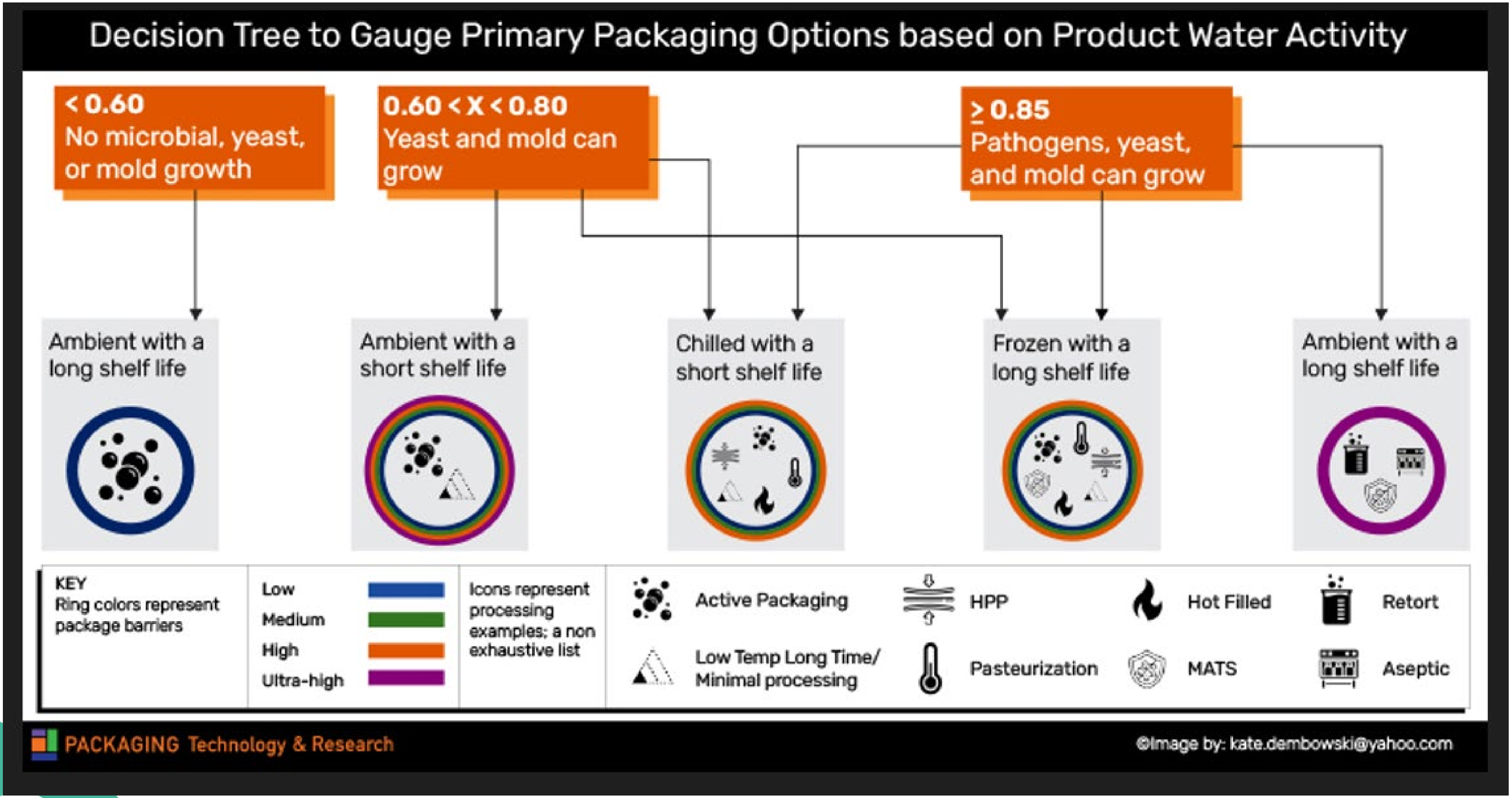
Bayesian Models **link industry and research**

Bayesian Models **identify critical aspects and unintended** consequences to enable implementation of this and other use cases

Use case results **can be seen in Bayesian Models**

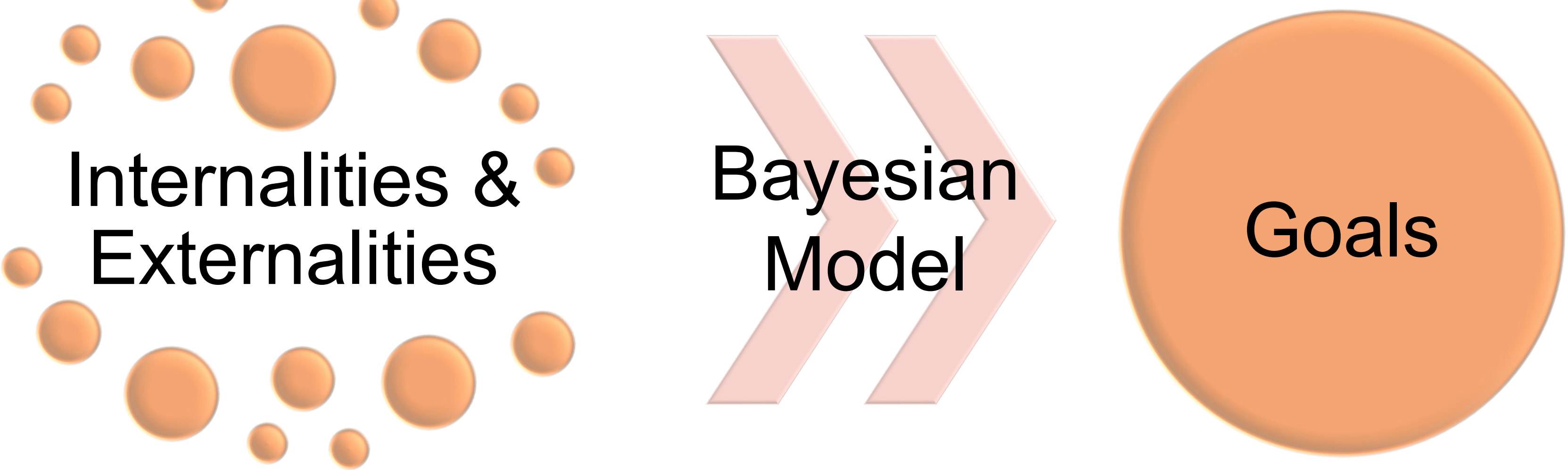
Making Decision I

Decision Trees: A Simplified Example



Decision Making I

Bayesian models show the future and implications and what is needed



Internalities

- Space external to retail
- Planogram issues
- Labor
- OOS
- Unmet consumer needs for size and product
- Shifts in value chain drivers

- **Externalities**
  - Natural disasters (drought, fires, flood, typhoon, hurricane, tornado)
  - Human struggles (virus, famine, political upheaval)
  - Power reliability (outages, internet, production)
  - Variable sustainability pressures (bans, taxes, policies)

- More sustainable food system
- Less food waste
- Greater Resilience
- Optimized costs

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Decision Making I

Bayesian model history and theory

- Bayesian belief network (BBN) - also Bayesian network, is a type of probabilistic reasoning graphical network based on Bayesian theorem
- The method was first proposed by Judea Pearl in 1986
- Bayesian formula application into the network problem can significantly simplify the problem, hence, can be applied to solve real-world complex problems
- Early BBNs only used knowledge from experts in specific fields. Now, data diversification can turn continuous data streams into characterizing the problems node relationships
- BBN supports fault diagnosis and reliability analysis

Decision Making I

Bayesian model history and theory

Bayesian networks are probabilistic graphical models representing system variables, and their conditional dependencies in a Directed Acrylic Graph and are composed of three elements:

1. A set of nodes representing management system variables
2. A set of links showing causal relationships between these nodes
3. A set of probabilities assigned to each node characterizing a belief that a node will be in a specific state as per the the state of the "parent" nodes

Then, conditional Probability Tables (CPT) are constructed.

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Decision Making I

Bayesian models translate industry needs into parameters

Much of academic research is not applicable to industry needs

Bio-derived films that compete against bPE and bPET are an example

Using Bayesian models, parameters that need to be achieved, these films are better able to find a niche

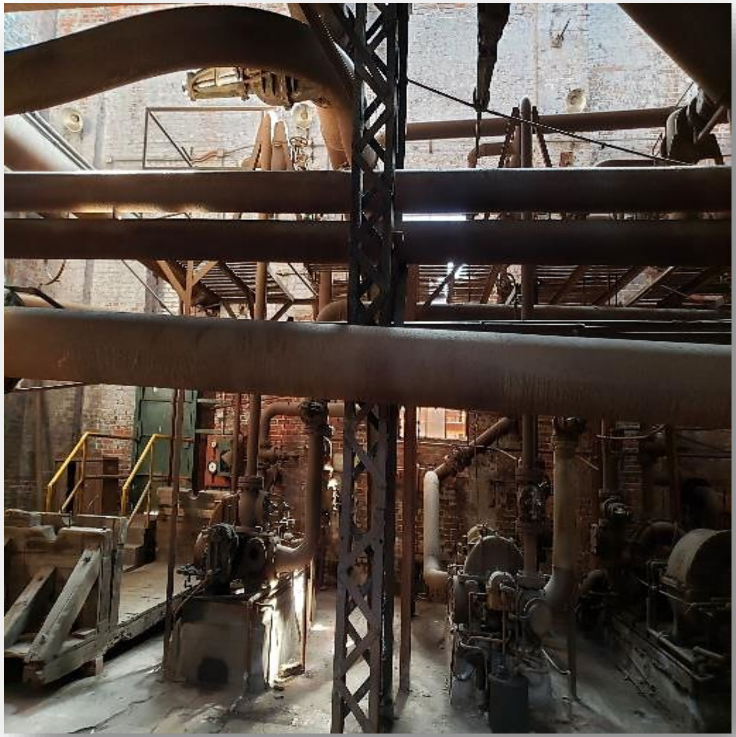
Examples

- Edible barrier for raw pet food company
- Intelligent packaging for frozen vegetable supplier to QSRs
- Active packaging example with bread

Method I

Use case scenario

- This use case addresses what is considered when switching to a better barrier
- Bakery considering converting to metalized film from OPP
- Lower cost due to high oil prices and excess metalized capacity
- Shelf life models show this will increase shelf life from 60 to 370 days



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Method I

Defined Parent – Child relationships

PM Production Run Length		Prod Pkg volume					
PM Alternate structure		moisture transfer from and within product	flavor transfer from and within product	Shelf life	Unsaturated fats	Xray metal detector	Pkg material
PM # of current suppliers		Prod Pkg volume	Food safety risk	Pkg material			
PM # of potential suppliers		Food safety risk	Pkg material				
PM distance to production		Number of current suppliers	PM Production run length				
PM inventory management		Prod Pkg volume	PM Production run length				
Pkg thickness		X-Ray metal detector	Prod Pkg # times SKU packed				
PM batch quality		PM Production run length					
Pkg WV barrrier		Food safety risk	moisture transfer from and within	flavor transfer from and within product	Unsaturated fats	Tertiary Pkg Options	Pkg material
Pkg O2 barrier			flavor transfer from and within product	Food safety risk	Unsaturated fats	Tertiary Pkg Options	Pkg material
Additional converting step		Unsaturated fats	flavor transfer from and within product	moisture transfer from and within			
Pkg material	CF						
Pkg Tensile Strength		Pkg Material					
Pkg Size		Plannogram location	Shelf life	Price-pack architecture			
Pkg Cost		Food Waste					

Prod Pkg volume	low	high			
PM Production Run Length	0.5	0.5			
low	0.5	0.5			
high					
Pkg material	low	low	low	low	low
Xray metal detector	low	low	low	low	low
Unsaturated fats	low	low	low	low	low
Shelf life	low	low	low	low	high
flavor transfer from and within proc	low	low	high	high	low
moisture transfer from and within p	low	high	low	high	low
PM Alternate structure					
yes	0.5	0.5	0.5	0.5	
no	0.5	0.5	0.5	0.5	
Pkg material	low	low	low	low	high
Food safety risk	low	low	high	high	low
Prod Pkg volume	low	high	low	high	low
PM # of current suppliers					
low	0.5	0.5	0.5	0.5	
high	0.5	0.5	0.5	0.5	
Pkg material	low	low	high	high	
Food safety risk	low	high	low	high	
PM # of potential suppliers					
low	0.5	0.5	0.5	0.5	
high	0.5	0.5	0.5	0.5	
PM Production run length	low	low	high	high	
Number of current suppliers	low	high	low	high	
PM distance to production					
low	0.5	0.5	0.5	0.5	
high	0.5	0.5	0.5	0.5	
PM Production run length	low	low	high	high	

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Method I

Use case scenario – Defined Parent – Child relationships

- Quality Assurance
- Environment
- Post Consumer Package Handling
- Food Waste
- Risk
- Innovation
- Food Safety
- Marketing Distribution
- Retailer
- Packaging Converters
- Ingredient supplier
- Package properties
- Production
- Capital Investment

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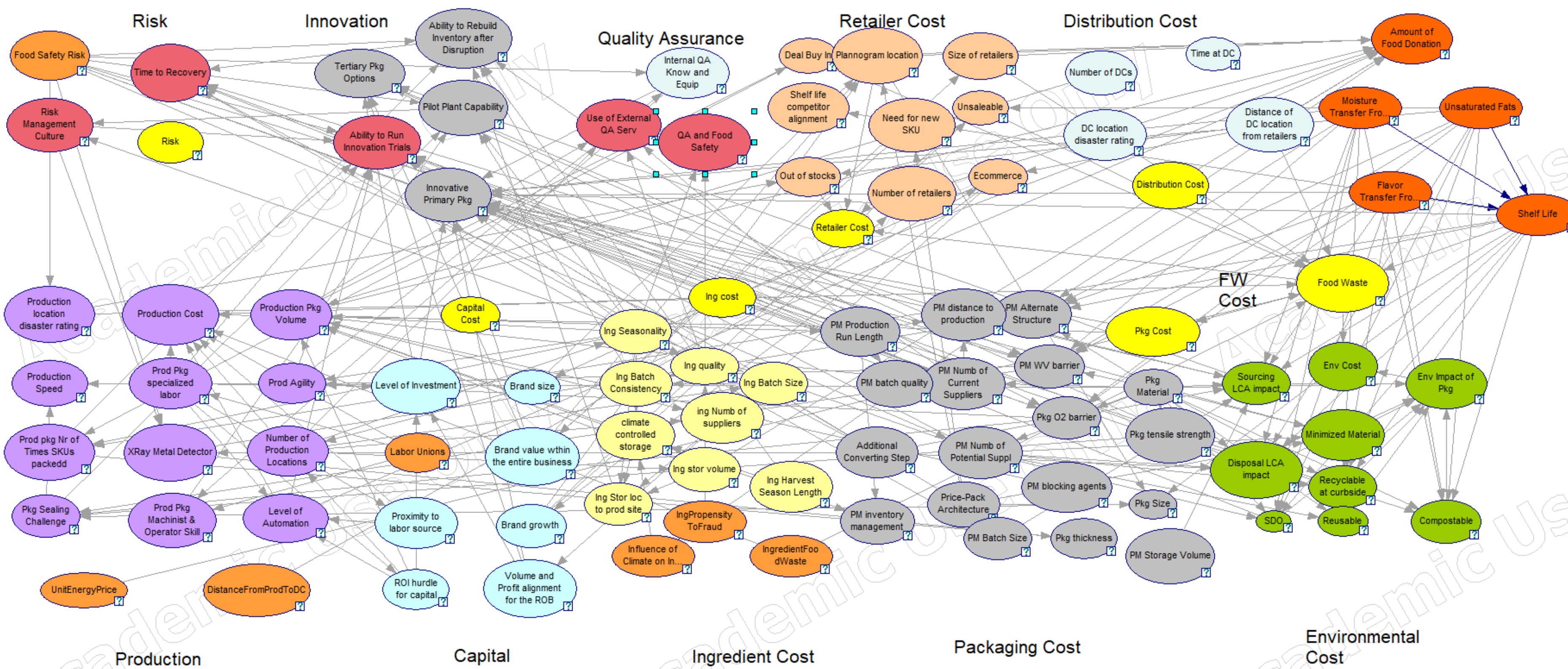
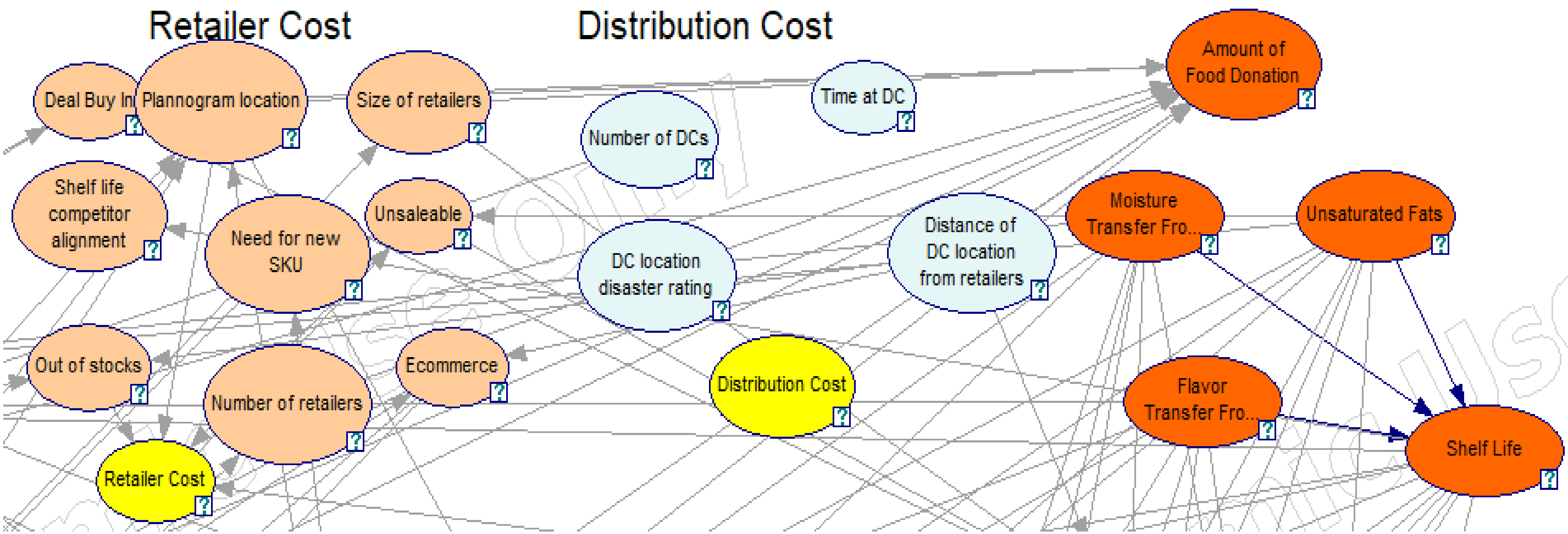
Results I

Implications



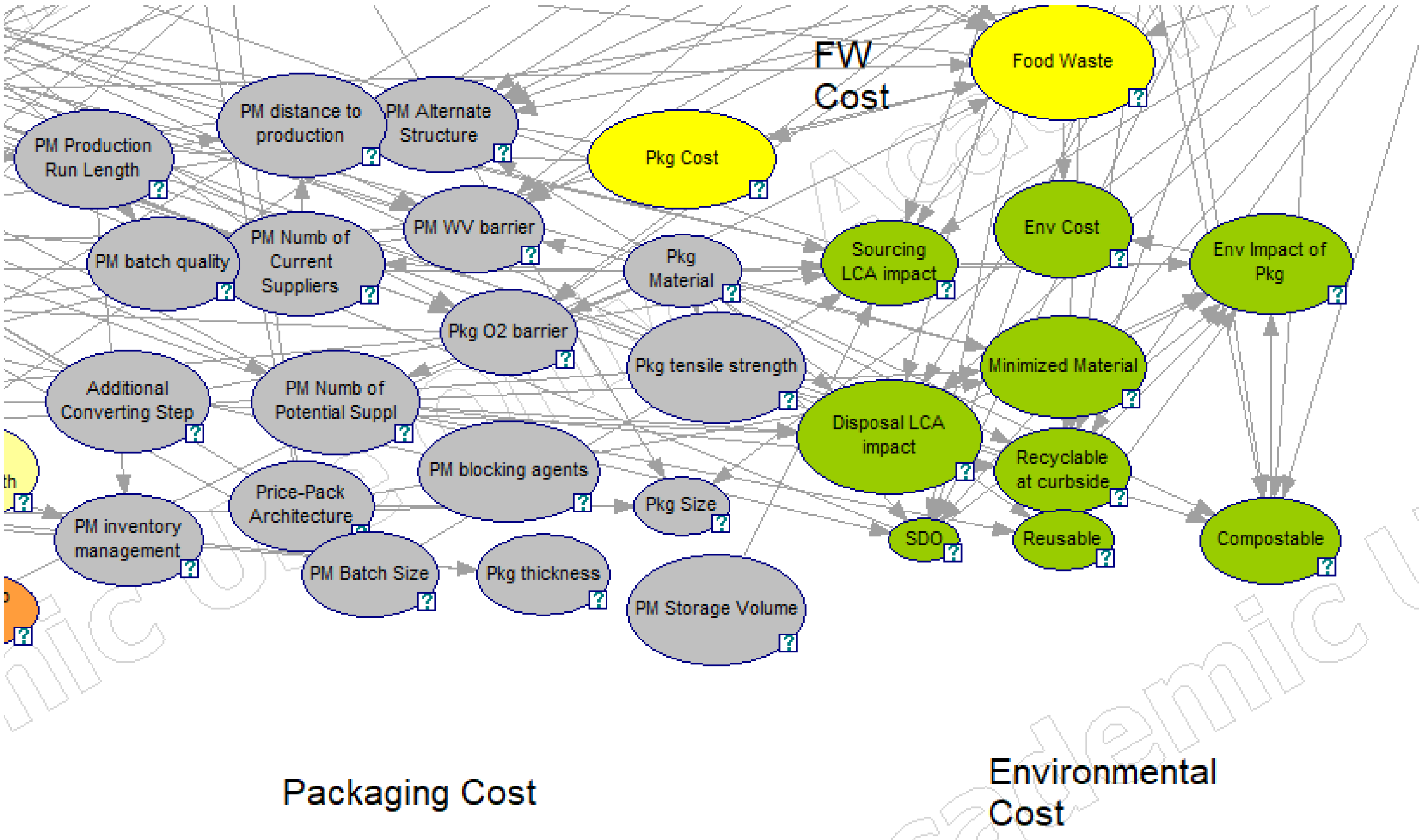
Results I

Implications



Results I

Implications



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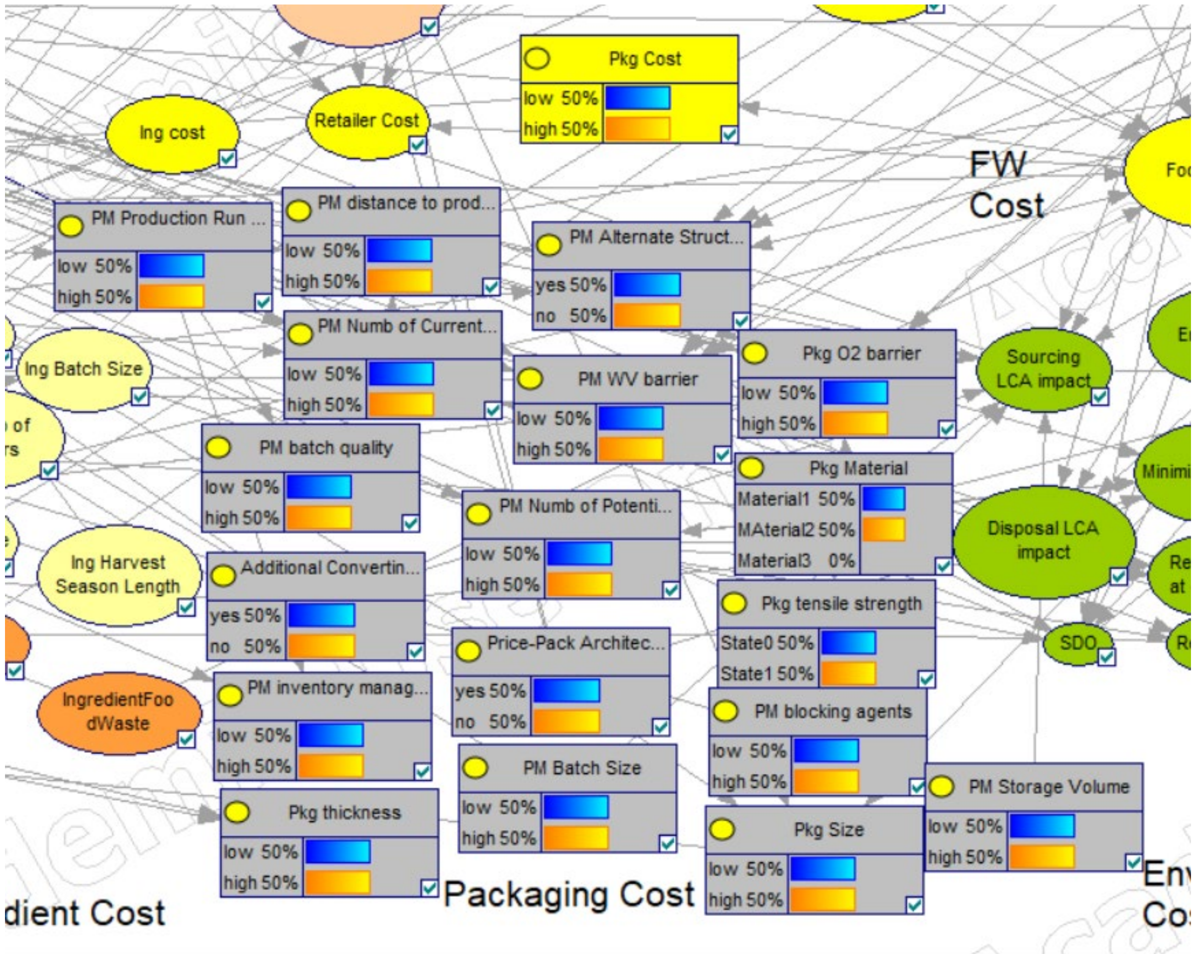
Results I

Bayesian modeling showed implications



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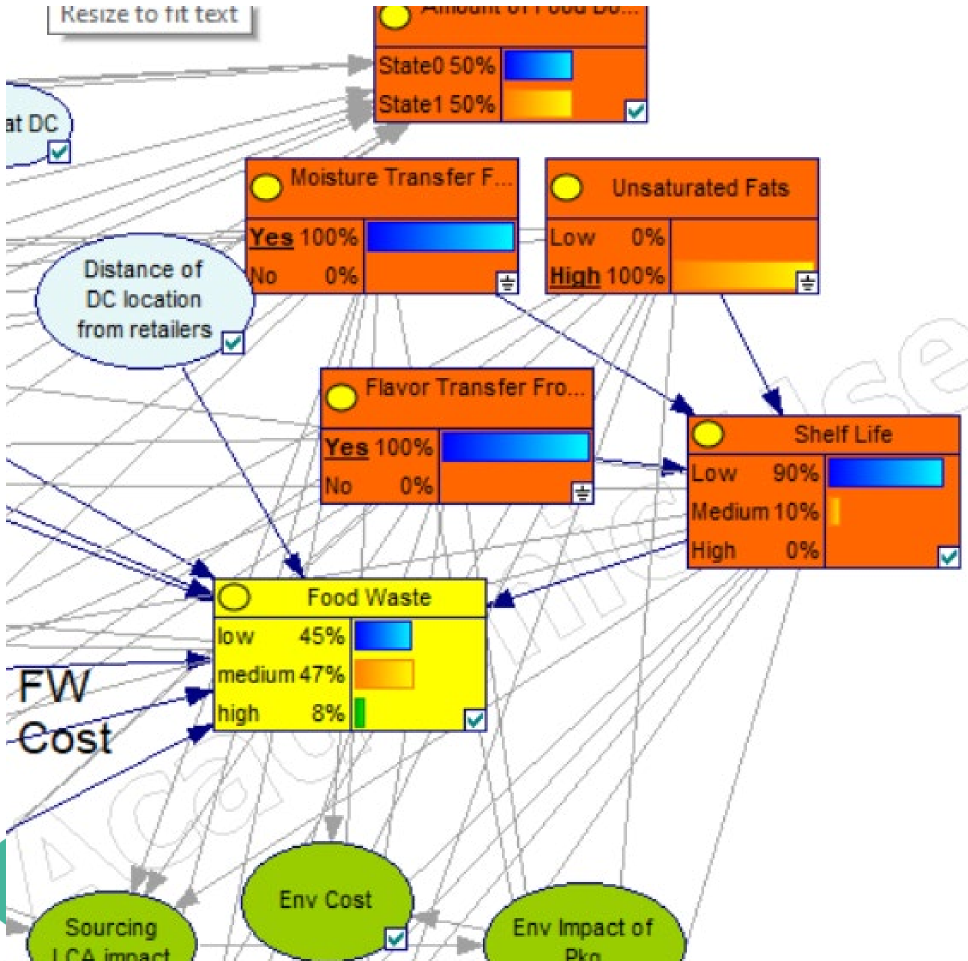
Results I

Implications



Parents

Ingredient food waste	Low	High
Number of retailers	Low	High
Size of retailers	Low	High
Deal buy in	Yes	No
DC location disaster rating	Low	High
Distance from production locatio	Near	Far
Production energy cost	Low	High
Production agility	Low	High
Production location disaster ratin	Low	High
Ing climate influence		
Production energy cost	Low	High
Shelf-life competitor alignment	Low	High
Unsaleable	Low	High
Shelf life	Low	High

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Thank You

Reach out to connect for a virtual coffee

Dr. Claire Sand

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