



Enhancing Supply Chain Resilience: Infant Formula Milk

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Outline



Supply Chain Resilience



Framework for Enhancing Supply Chain Resilience



Infant Formula Milk Supply Chain



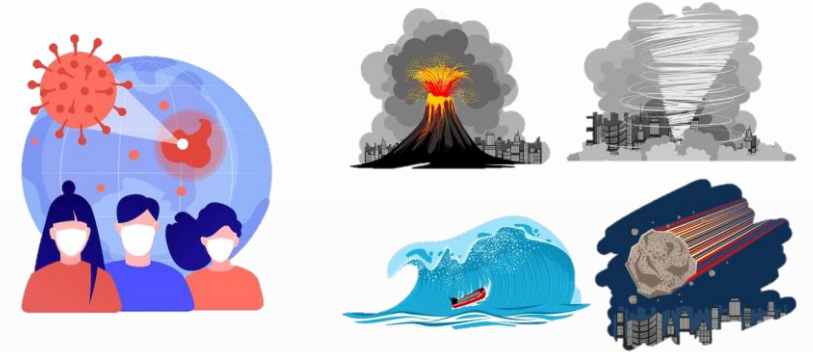
Building a Resilient Infant Formula Milk Supply Chain



Conclusion and Future Work

Disruptions and Risks

World is full of **Uncertainties** and **Risks**.



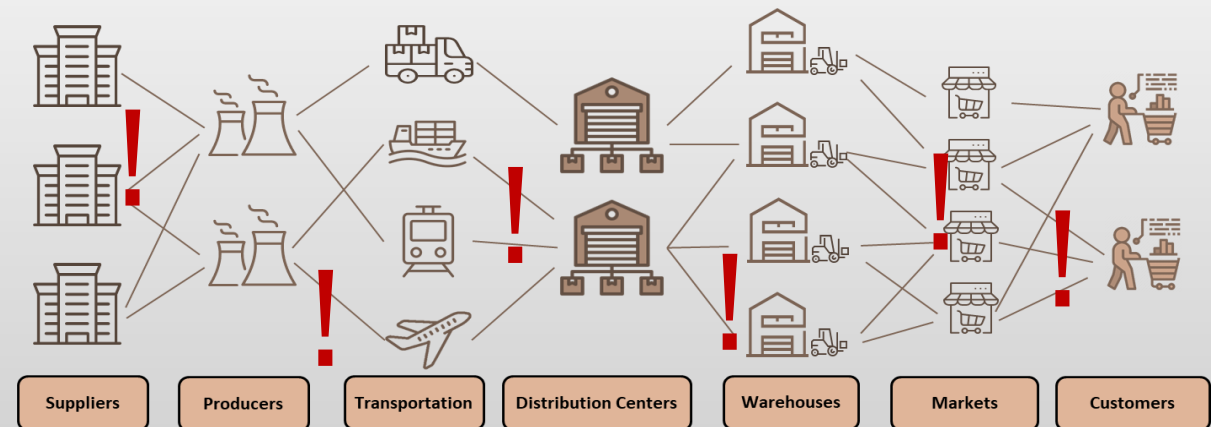
• Uncertainties complicate planning and lead to:

✓ **Delays**

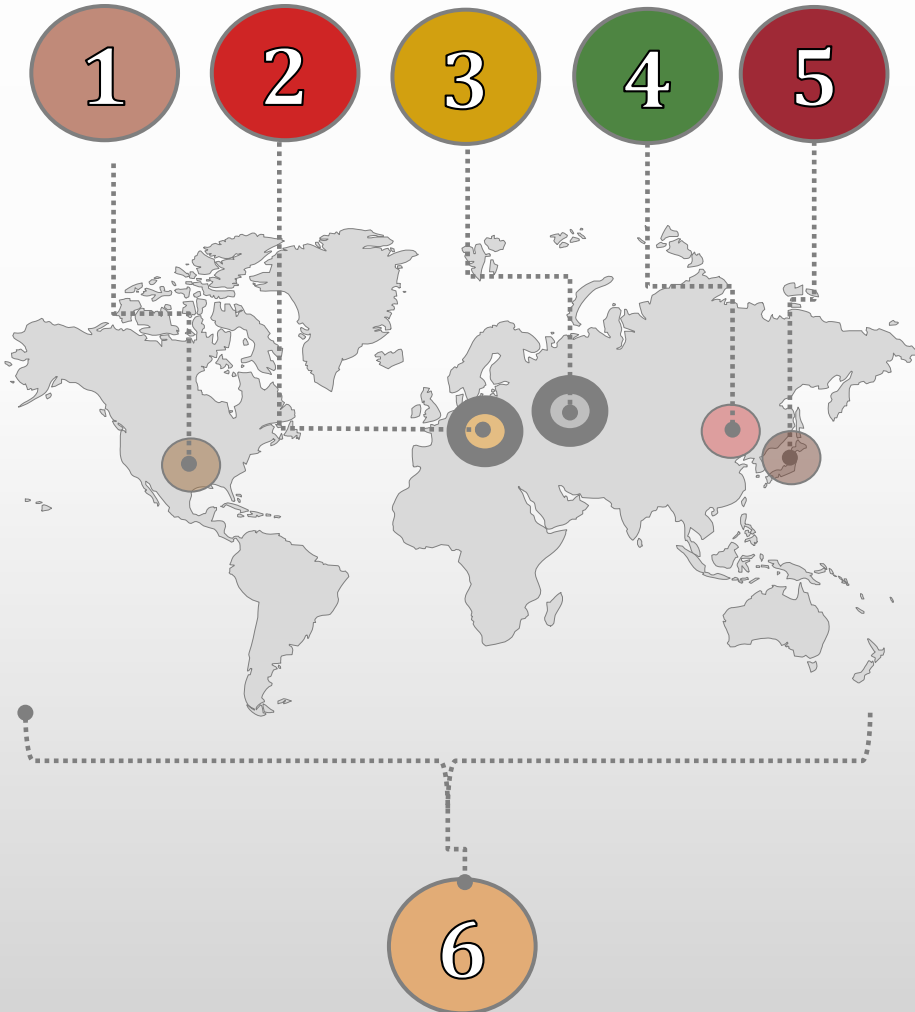
✓ **Shortages**

✓ **Chaos**

✓ **Lack of Visibility**



Disruptions and Risks



1 Terrorism

September 11 in USA, 2001

Five Ford plants have been closed for a long time.

2 Man-made Disasters

Explosion at BASF plant in Ludwigshafen, 2016

15% of raw materials were missing for the entire supply chain
Production of some products at BASF has been stopped for many weeks.

3 War

Russian - Ukrainian War 2022

Natural gas prices rose by around 120-130% in the 6 months, coal prices rose by 95-97%.

4 Strikes

Strikes at Hyundai plants, 2016

Production of 130,000 cars has been affected.

5 Natural Disasters

Earthquake and tsunami in Japan, 2011

Massive collapses in global automotive and electronics supply chains; Toyota lost its market leadership position.

6 Pandemic

Covid-19, 2020

The COVID-19 pandemic led to a sharp drop of 29.2% in global air cargo demand.

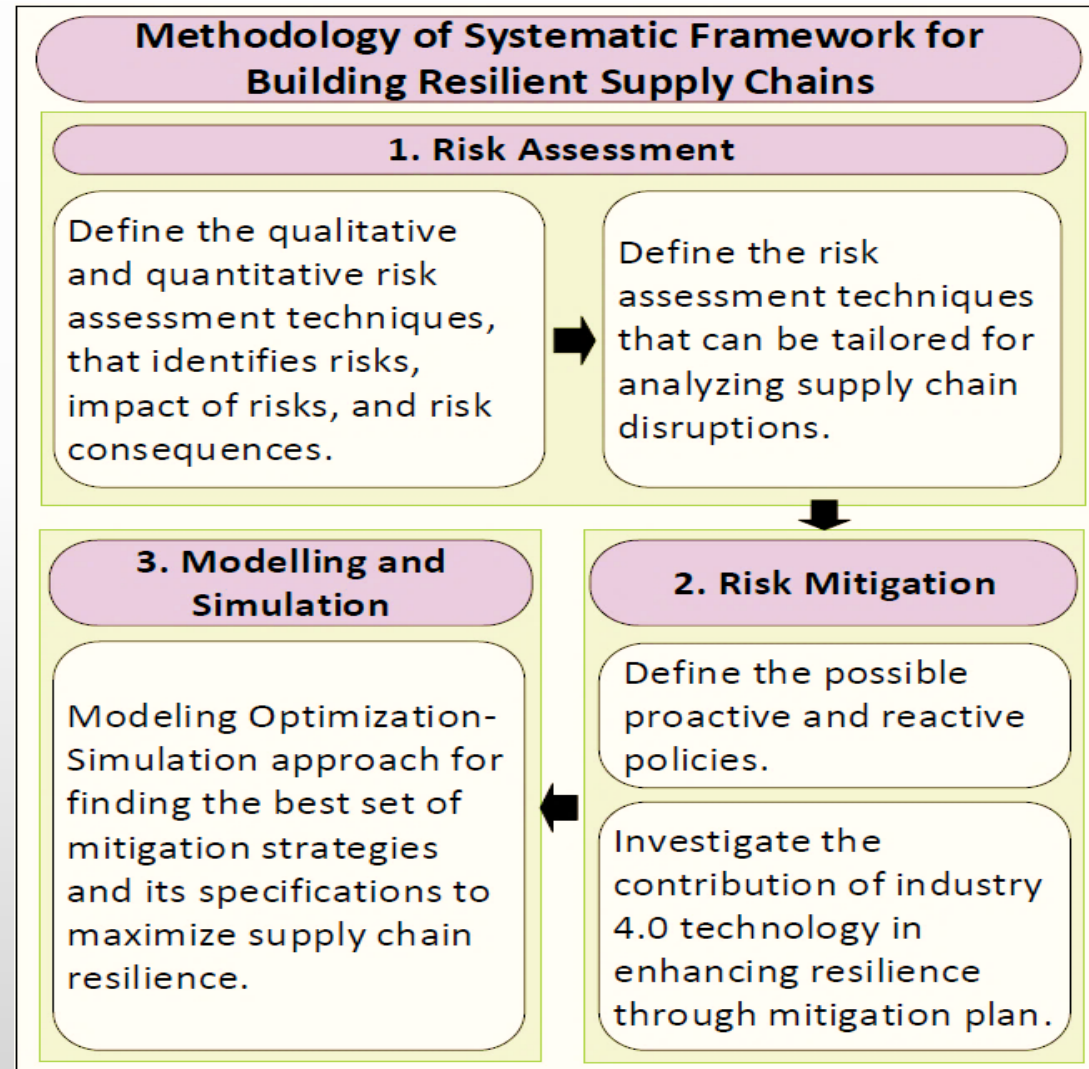
Supply Chain Resilience

Supply Chain Resilience

The ability of a supply chain to maintain, execute, and recover the planned execution along with the achievement of the planned performance during unexpected events or disruptions through proactive and reactive measures.



Supply Chain Resilience Framework



Infant Formula Milk

The first two years of the human's life are fundamental to ensure good health.

- Infants' health goes through rapid physical and brain development.
- The only source of nutrition for infants is milk.
- Infant formula milk (IFM), the sole source of nutrition for infants deprived of mother's milk in their first two years of life



Importance of Infant Formula Milk for Infants.

- In the USA, **67%** of infants by the age of **3 months** which is equal to **2.7 million babies** relying on infant formula milk (IFM) as a part of their daily nutrition.
- In 2019, **only 44%** of infants under the age of six months were exclusively breastfed.



Infant Formula Milk (IFM)



Major shortage in 2022 of IFM resulted from Abbot's shutdown due to contamination.

(shortage rate spiked over 80% in different USA states)



In 2023, Reckitt, a leading **UK-based** production company, **recalled nearly 150,000 tins** of its widely used baby formula due to **possible Cronobacter contamination**



In 2017, a total of **35 infants presented salmonella symptoms in France** after being fed infant formula milk produced by Lactalis Group



In 2008 in **China** where approximately 300,000 children fell victim to contaminated infant Formula milk with melamine **(Death of at least 6 babies)**



The Moroccan Consumer Rights Association reported consecutive increases in **IFM prices since 2020, ranging from 7% increase to 28%** in some brands in **Morocco.**



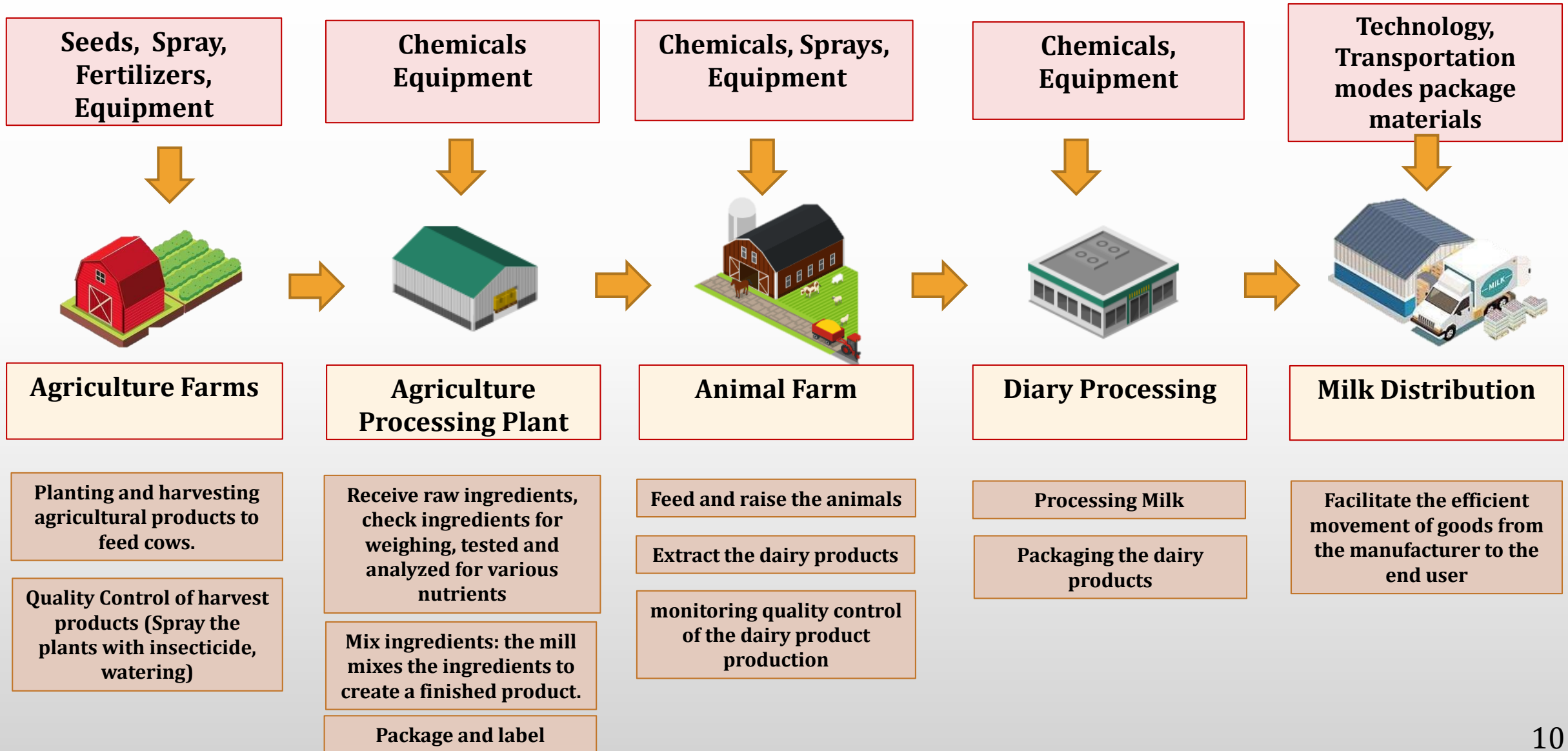
During the beginning of the pandemic in 2020, **access to infant formula was limited**, with panic buying the infant formula experiencing high demand like many other products.



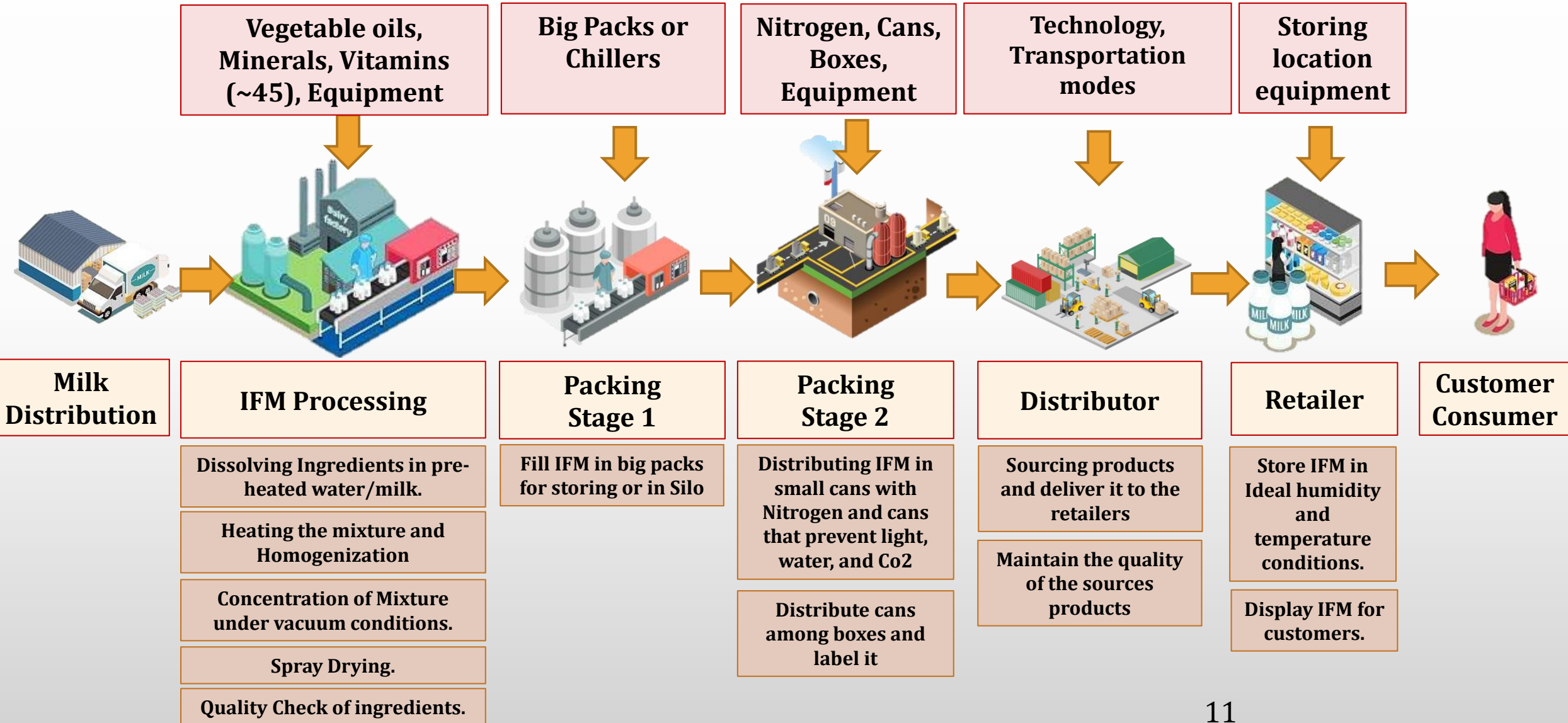
TAILORING THE FRAMEWORK TO IFM SUPPLY CHAIN



IFM Supply Chain



IFM Supply Chain



IFM Supply Chain Inventory

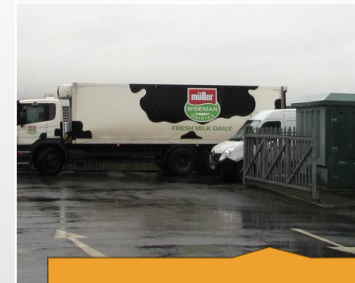
- Purpose of the Inventory:
 - Keeping the ideal conditions to contain and save the products from damage
 - Temperature
 - Pressure
 - Hygiene measures
 - Keeping the products till it is distributed



Silo



Chiller



Transportation



Warehouse

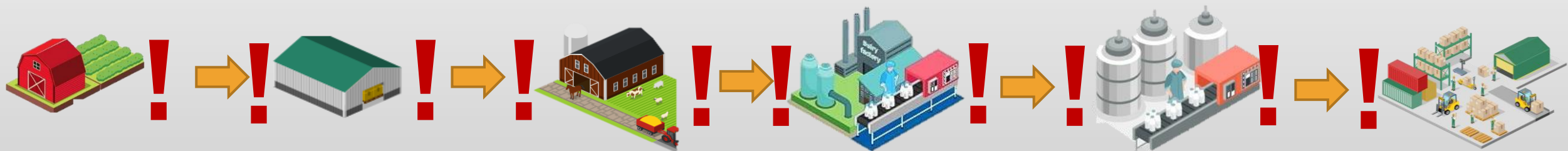
IFM Supply Chain Transportation

Provides the movement of products from one process to another

Can be used as storage in case of filled inventory

Follows multiple criteria

- On-time delivery as IFM is a **perishable product**
- Should follow **temperature, pressure, and hygiene standards**



IFM Supply Chain Stakeholders

Suppliers of Raw material

Fertilizers

Equipment

Sprays

Nitrogen

Boxes, cans, labels

Vegetable oils

Minerals, and vitamins

Manufacturers

Agriculture farms

Animal farms

Infant formula milk plant

Dairy product plants

Agriculture plants

Retailers

Hospitals

Pharmacies

Supermarkets

Online shops

Consumers

Doctors/Nurses

Mothers

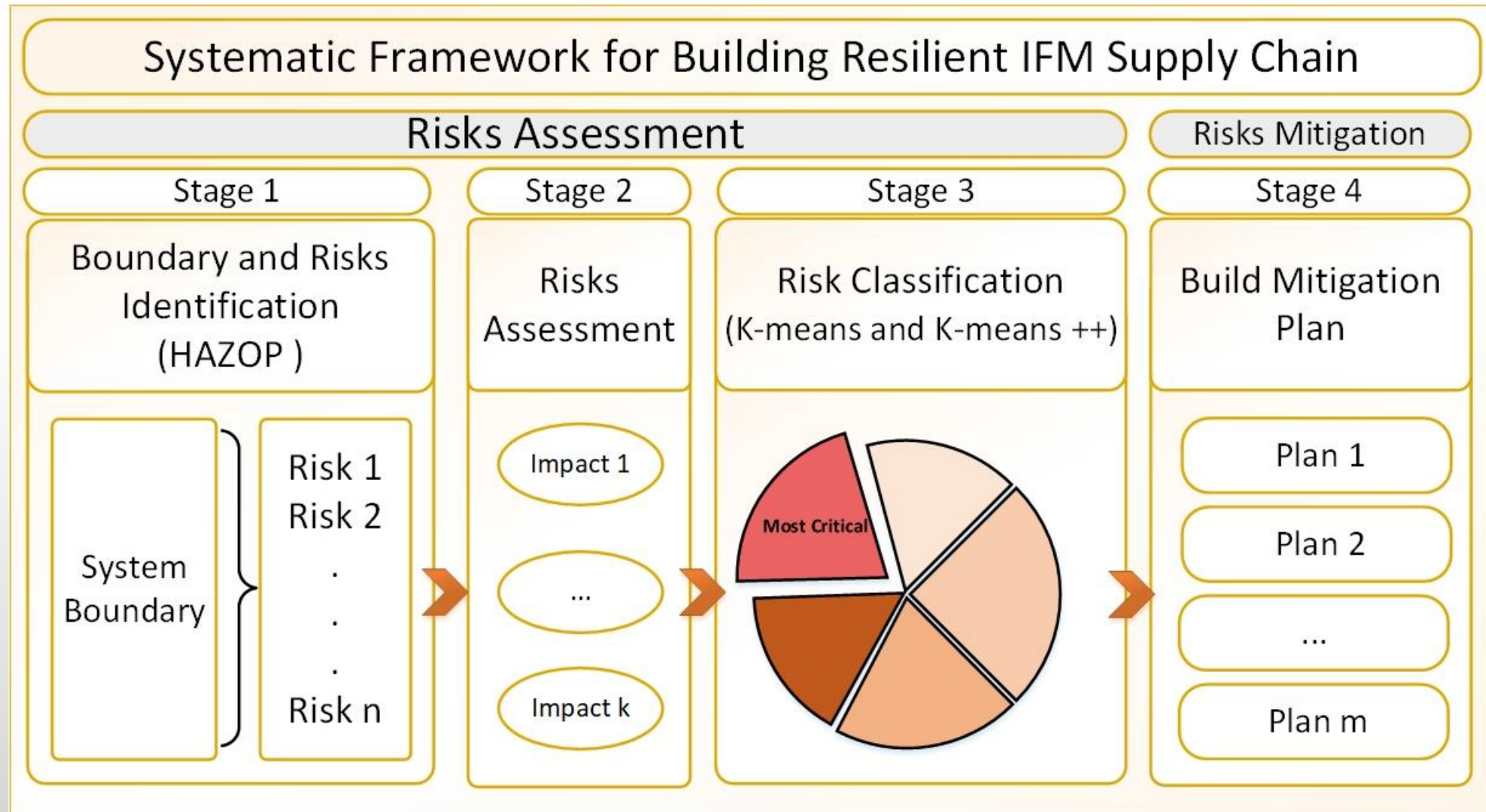
Government agencies

Regulatory Authorities

Product quality control

Labeling control

Supply Chain Resilience Framework



Framework of Resilient IFM Supply Chain

Methodology of Systematic Framework for Building Resilient Supply Chains

Define the supply chain boundaries



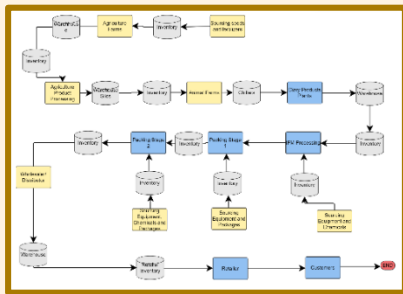
Apply risk assessment techniques that is tailored for analyzing supply chain disruptions



Identify Catastrophic Risks



Build Mitigation Plan



Hazard and Operability Study (HAZOP)



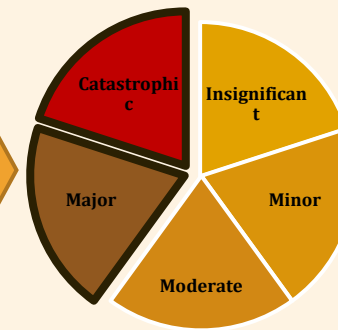
R1
R2
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.
.
R91



Cost
Availability
Lead Times
Health
Probability
Risk Velocity
Detectability
Risk
Persistence



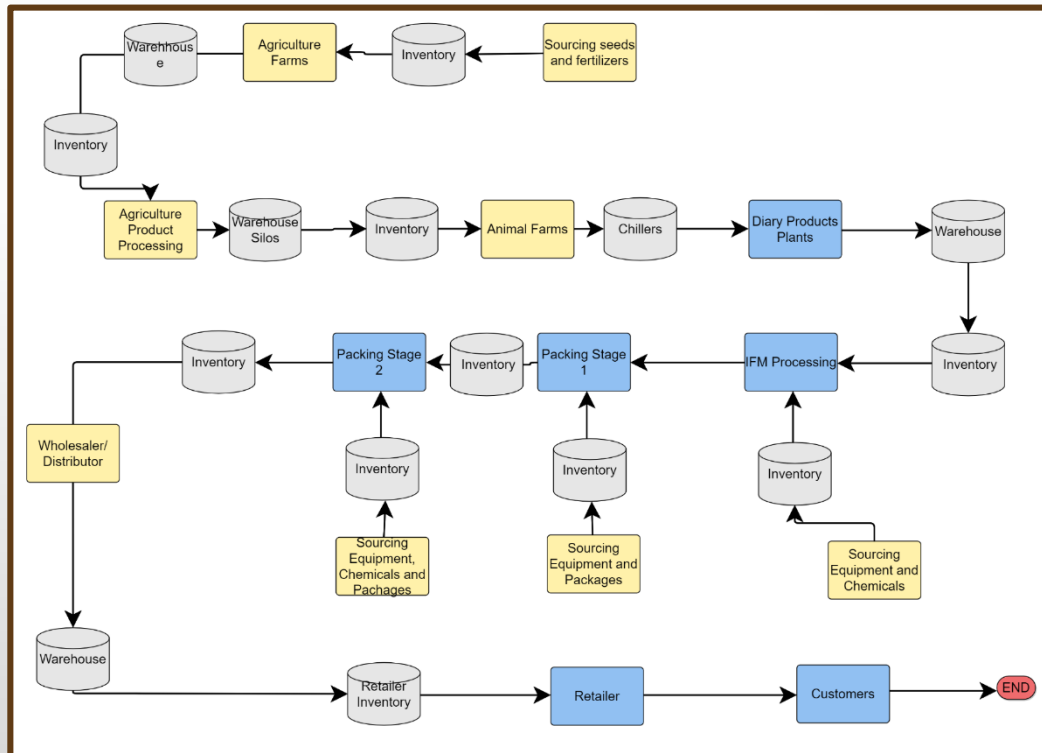
K means ++ & K-Clustering



Mitigation Plan

Resilient IFM Supply Chain

1. Boundary and Risk Identification IFM Supply Chain Boundary



List of Risk
(91 Risks)

Agriculture Phase) — AR(No)

Dairy Product Phase — DR(No)

IFM Phase — IR(No)

Distributor and Retailer Phase — RR(No)

General Supply Chain Risks — (GR(No))

Resilient IFM Supply Chain

1. Boundary and Risk Identification HAZOP



Study Node	Process Parameter	Guide Word	Deviation	Possible Causes	Possible Consequences	Action Required	Responsible	Target Date	Completed Date
1	2	3	4	5	6	7	8	9	10

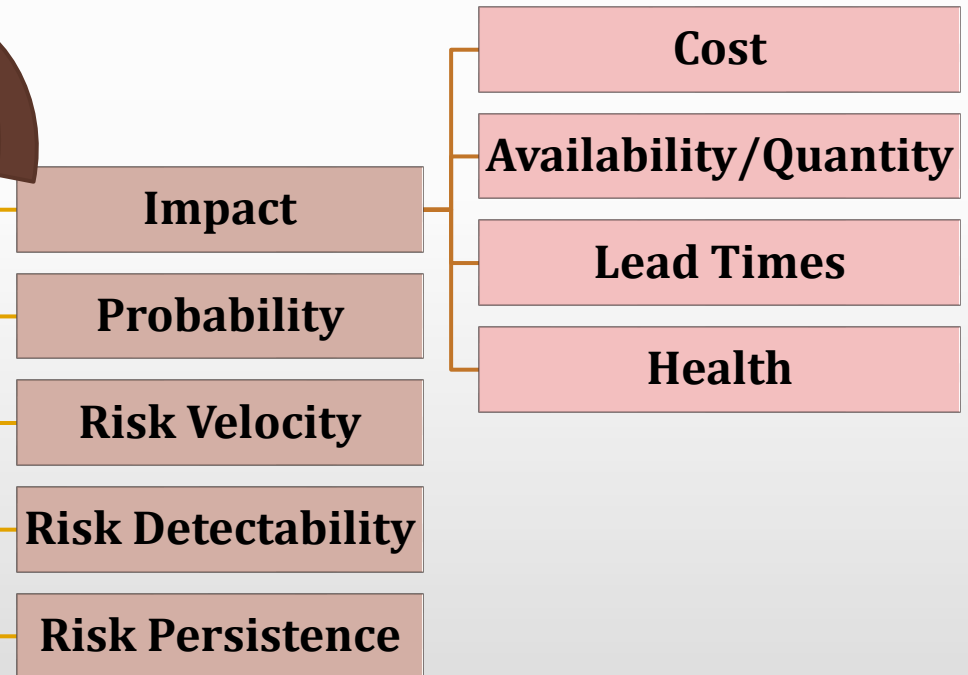
No.	Code	Risk
46	DR16	Filled Inventory that can't accommodate additional arrival of raw dairy products
47	DR17	Improper saving conditions of raw dairy products
48	DR18	Empty Inventory of raw dairy products
49	DR19	Damaged Inventory location of raw dairy products
50	DR20	Producing not enough dairy products
51	DR21	Producing damaged dairy products (wrong processing)
52	DR22	Contamination of dairy products
53	DR23	Machinery damage that processes dairy products
54	DR24	Improper savings of the dairy products
55	DR25	Damaged warehouse location of dairy products
56	DR26	Filled Inventory that can't accommodate additional arrival of dairy products
57	DR27	Improper saving conditions of dairy products
58	DR28	Empty Inventory of dairy products
59	DR29	Damaged Inventory location of dairy products
60	IR1	Filled Inventory that can't accommodate additional arrival of milk and vegetable oils, minerals, and Vitamins and machinery to produce IFM
61	IR2	Improper keeping of the pre-IFM ingredients causes contamination
62	IR3	Damaged Inventory location of Pre-IFM
63	IR4	Not processing the IFM ingredients within the required instructions (not enough heating, not enough mixing, wrong temperature, wrong pressure usage)
64	IR5	IFM processing Equipment breakdown
65	IR6	Dissolving wrong proportions of IFM ingredients

Resilient IFM Supply Chain

2. Risk Assessment Attributes Definition

No.	Code	Risk	Category	Impact						Risk Det
				Cost	Availability/Quantity	Quality	Lead Time	Probability	Risk Velocity	
46	DR16	Filled Inventory that can't accommodate additional arrival of raw dairy products	Economic Losses							
47	DR17	Improper saving conditions of raw dairy products	Health Hazard							
48	DR18	Empty Inventory of raw dairy products	Product Shortage							
49	DR19	Damaged Inventory location of raw dairy products	Product Shortage							
50	DR20	Producing not enough dairy products	Product Shortage							
51	DR21	Producing damaged dairy products (wrong processing)	Health Hazard							
52	DR22	Contamination of dairy products	Health Hazard							
53	DR23	Machinery damage that processes dairy products	Product Shortage							
54	DR24	Improper savings of the dairy products	Health Hazard							
55	DR25	Damaged warehouse location of dairy products	Product Shortage							
56	DR26	Filled Inventory that can't accommodate additional arrival of dairy products	Economic Losses							
57	DR27	Improper saving conditions of dairy products	Health Hazard							
58	DR28	Empty Inventory of dairy products	Product Shortage							
59	DR29	Damaged Inventory location of dairy products	Product Shortage							
60	IR1	Filled Inventory that can't accommodate additional arrival of milk and vegetable oils, minerals, and Vitamins and machinery to produce IFM	Economic Losses							
61	IR2	Improper keeping of the pre-IFM ingredients causes contamination	Health Hazard							
62	IR3	Damaged Inventory location of Pre-IFM	Product Shortage							
63	IR4	Not processing the IFM ingredients within the required instructions (not enough heating, not enough mixing, wrong temperature, wrong pressure usage)	Insufficient Quality							
64	IR5	IFM processing Equipment breakdown	Product Shortage							
65	IR6	Dissolving wrong proportions of IFM ingredients	Insufficient							

Attributes



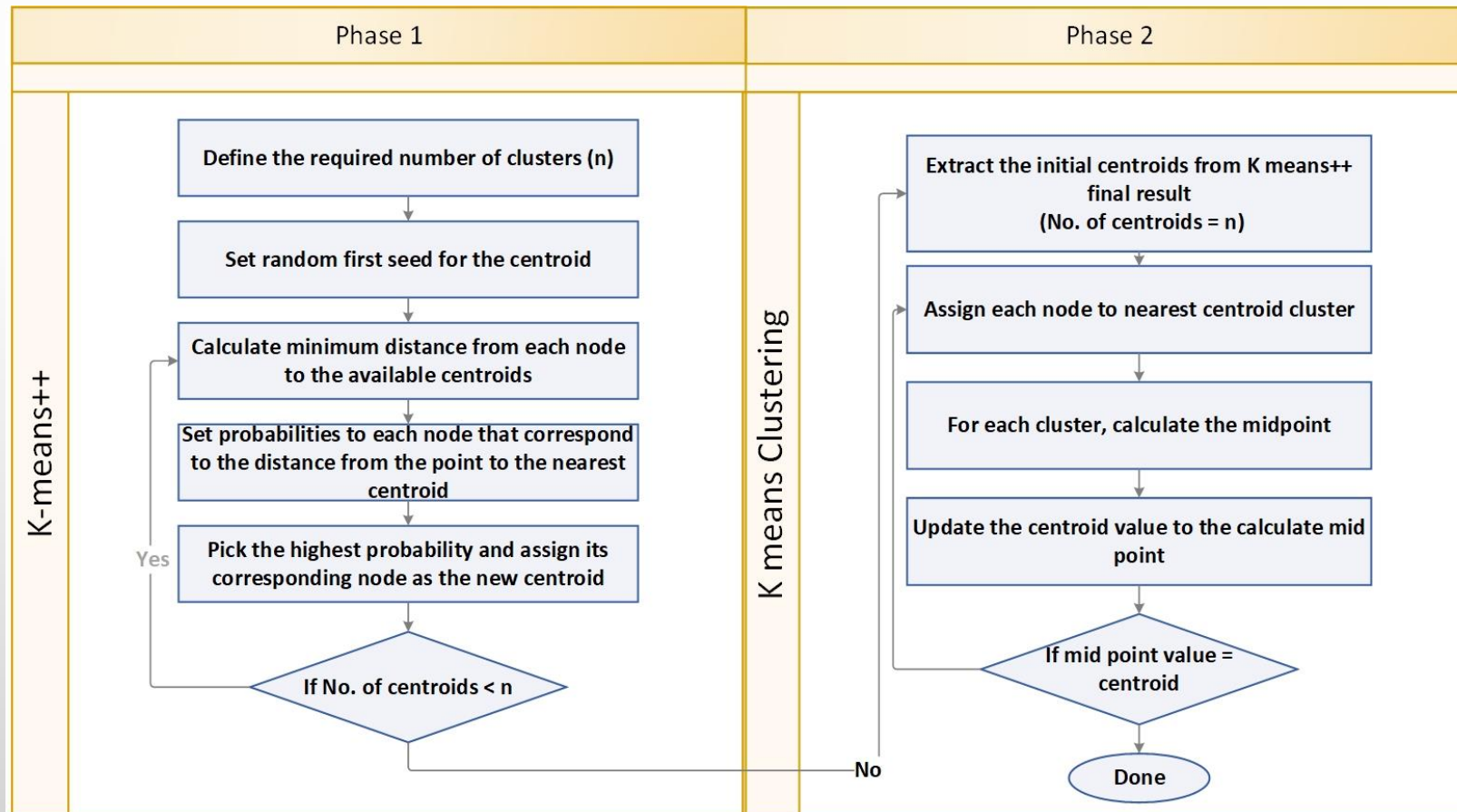
Resilient IFM Supply Chain

2. Risk Assessment Attributes Definition

Cost	<ul style="list-style-type: none">• A financial measure that represent how a disturbance impact the overall cost of the supply chain.
Availability	<ul style="list-style-type: none">• A measurement of the effect of disruption on the quantity of available amount of products in the market
Lead Times	<ul style="list-style-type: none">• A measurement of the effect of disruption on the time it takes till the product reaches the market (Time Delay)
Health	<ul style="list-style-type: none">• The effect of the risk on the health of the customer (consumer).
Probability	<ul style="list-style-type: none">• The probability that this risk will occur taking into consideration that no measures are being implemented to prevent or control it.
Risk Velocity	<ul style="list-style-type: none">• The speed at which a risk can materialize and escalate
Risk Detectability	<ul style="list-style-type: none">• The easiness or difficulty of identifying and detecting a risk event before it occurs or causes significant damage
Risk Persistence	<ul style="list-style-type: none">• The duration or the lasting impact of a risk event

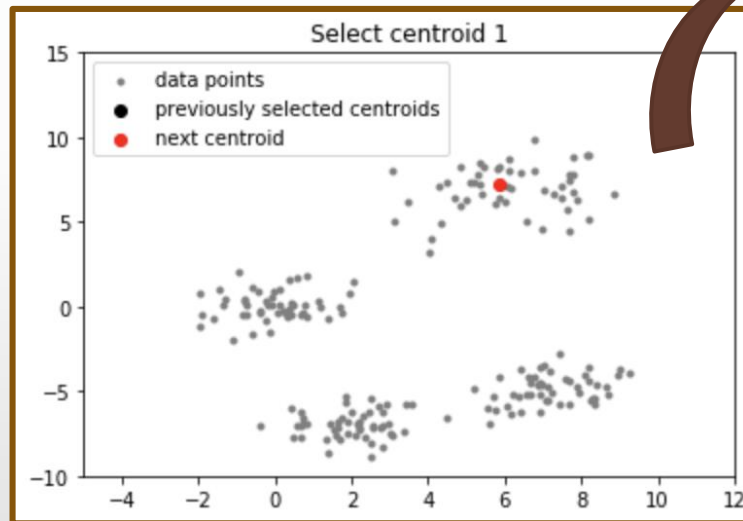
Resilient IFM Supply Chain

2. Risk Assessment K means and K means ++

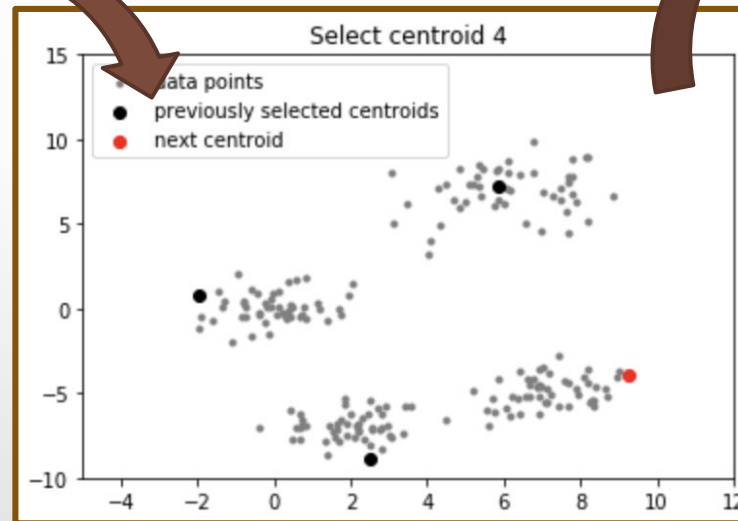


Resilient IFM Supply Chain

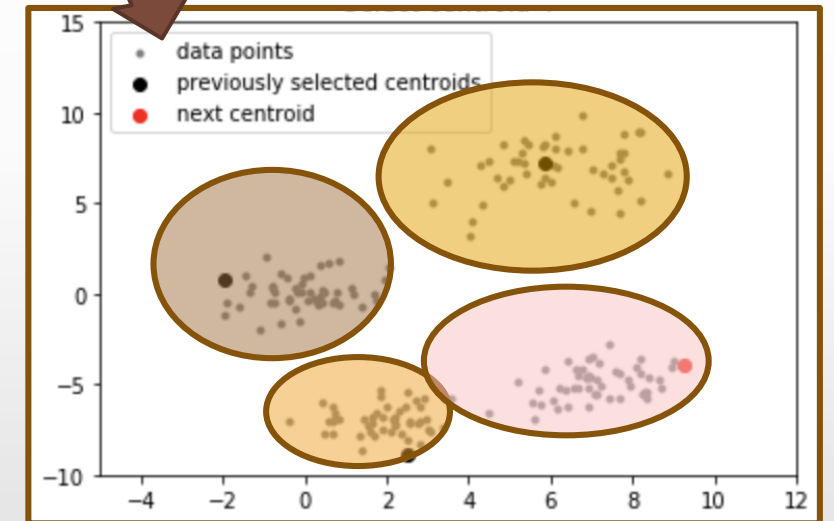
2. Risk Assessment K means and K means ++



choosing the initial cluster centers for more accurate results

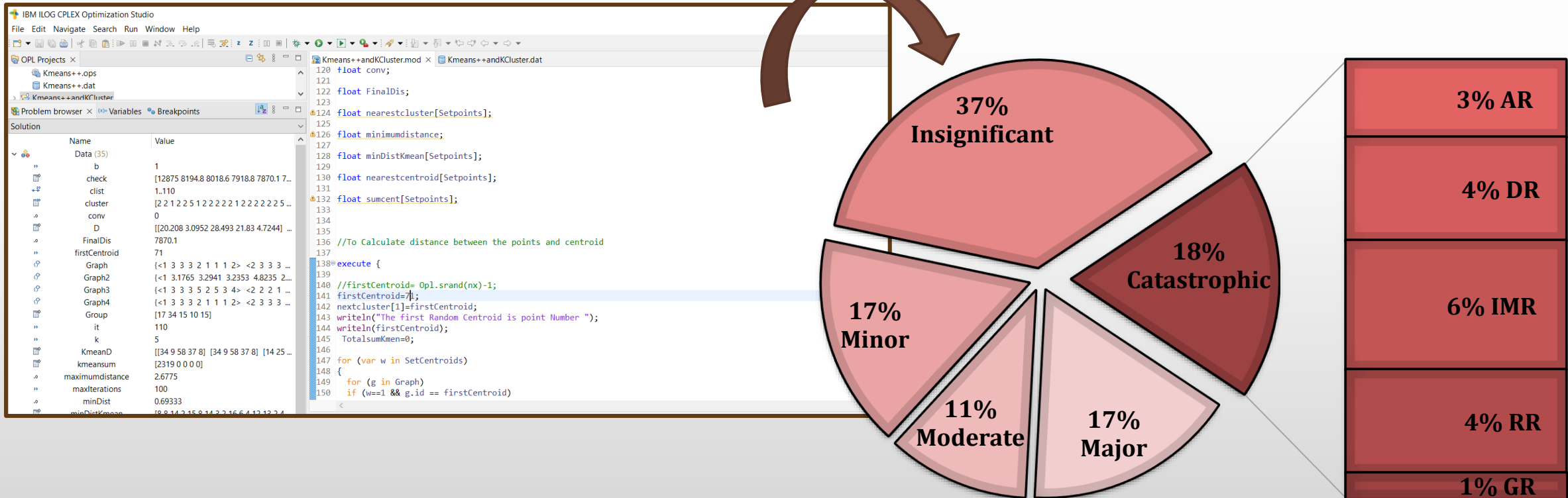


Group data into clusters



Resilient IFM Supply Chain

2. Risk Assessment Catastrophic Risks Identifications



Resilient IFM Supply Chain

2. Risk Assessment

Catastrophic Risks Identifications

17 Risks (Out of 91) ≈ 20% of the risks are considered catastrophic

- **Have serious impact on infants health.**
- **Highly affect availability, cost and lead times**

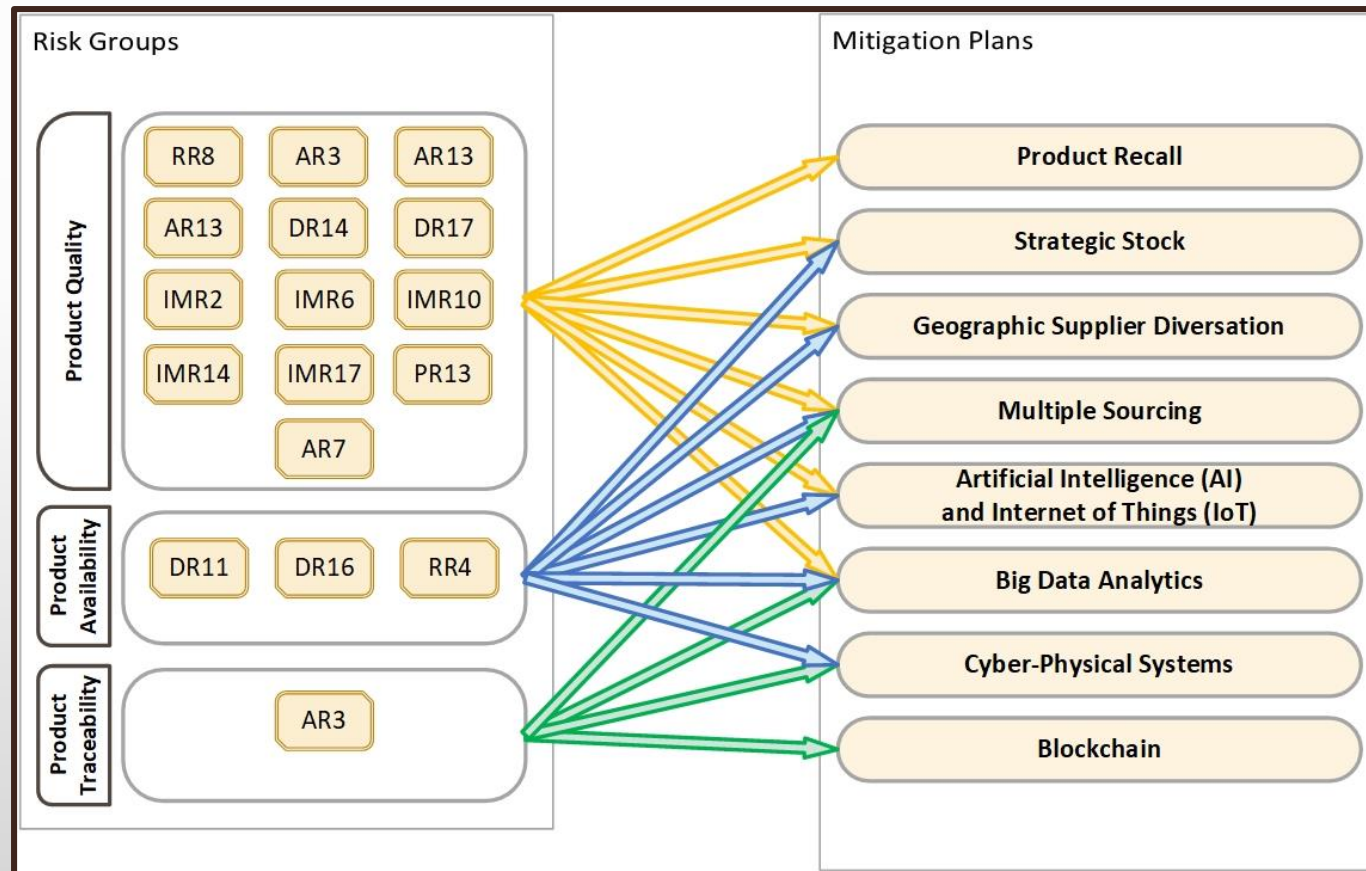
The main negative effect of catastrophic risks is serious negative impact on infants' health

- **Health is an invaluable asset, incapable of being reversed.**
- **No sum of money or any other factor can equate to the loss of infant lives.**
- **Even a minor adverse effect on health can swiftly remove a particular product from the Infant Formula Milk (IFM) market.**



Resilient IFM Supply Chain

4. Build Mitigation Plan



FUTURE WORK

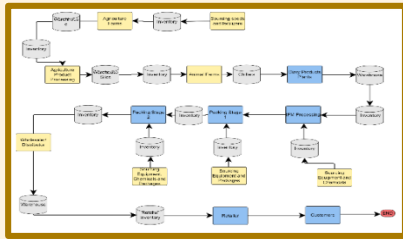
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Apply risk assessment techniques that is tailored for analyzing **supply chain disruptions**

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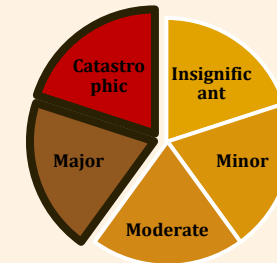


Hazard and Operability Study (HAZOP)

R1
R2
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R91

Define the critical attributes!

K means ++ & K-Clustering



Mitigation Plan

Build a simulation-optimization to the defined chemical supply chain:

- Identify the best set of mitigation strategies, and at which level it should be implemented. (Case Study)



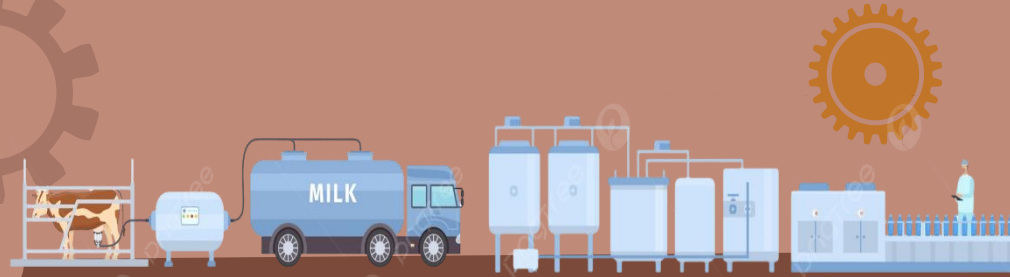
Local production

VS



Outsourcing





Thank You

THANK YOU!