Optimization for Customization

The Future of Food Manufacturing

This report is the outcome of a research project developed by the Institute of Design, Illinois Institute of Technology (ID IIT), and sponsored by the Design Lab at Hitachi America R & D.
The project ran for twenty weeks, from October 2019 to March 2020.

This report envisions the future of food manufacturing through speculative scenarios and related trends.

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Introduction

The objective of this project–understanding optimization for customization in food manufacturing—is to illustrate a new vision of the future of food manufacturing. Through narratives and speculative scenarios, this report outlines noteworthy patterns that reflect the economic, social, and technological shifts that are redefining the food industry. Customers want products that reflect their values—the pursuit of health and wellness and growing concerns about environmental sustainability and society at large. These global issues are shaping customer demand for food products, from the generic to the personalized, and affecting agriculture, food manufacturing, service, and regulations, from mass to customized production.

Customization in manufacturing does not mean ignoring optimization. Technological developments such as sensors, artificial intelligence (AI), blockchain, robotic/automation, and the Internet of things (IoT) will enable optimization for customization—and support health, well-being, and social and environmental sustainability.

Why the Food Industry?

Food manufacturing is highly sensitive to passing time and unpredictable conditions. Its ecosystem is both complex and adaptive, with multiple agents continually interacting and coevolving. The industry requires human-made materials, and also relies on natural resources that are sensitive to environmental conditions.

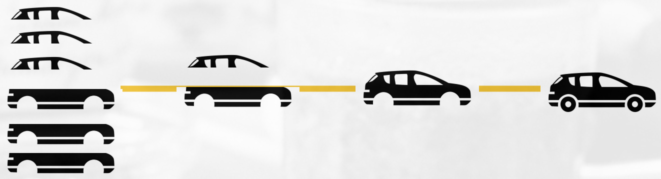
The food industry is inseparable from daily life. Only a small fraction of the world's people do not rely on food manufacturing. Although the industry's processes might appear linear, each operation involves nonlinear interactions among multiple stakeholders. Massive in scope and influence, the food industry encompasses agriculture, manufacturing of machinery and agrichemicals, food processing, wholesale and retailing, regulations, R & D, and financial services.

Why the Food Industry?

Every step in food manufacturing needs to be monitored to enable in-time decisions. Unlike discrete manufacturing, which centers on assembly, with process manufacturing, production is progressive. Raw materials are blended to become a new material, and once mixed, materials cannot be returned to their former state. Each manufactured batch has certain requirements. Therefore, monitoring each step and each batch within process manufacturing leads to better control and enables on-site decision-making and actions to ensure both efficiency of production and quality of product.

Food manufacturing differs from other process manufacturing in its deep connection to humanity. Unlike the production of paint and other chemical products, food requires high safety standards at every moment in its production and delivery and must reflect its attention to human well-being on a daily basis. An essential part of daily human ritual, food not only serves physical survival but also social existence. The food industry thus operates on a paradigm that is both social and economic.

Discrete Manufacturing_Assembly

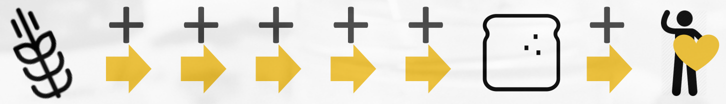


Process Manufacturing_Continuous Operation

Why the Food Industry?

Food manufacturing moves in concert with economic and social realities. Tensions and forces within both the economy and society make food manufacturing a complex endeavor that must adapt and evolve. Sustaining the environment and supporting human well-being have become major forces and initiated the United Nations Global Goals. As a consumer product, food is highly influenced by customer demand, which today reflects an intense review culture and the escalation of highly personal preferences. Goals in manufacturing are thus moving quickly from mass production to mass-customized production.

New technology supports optimization for customization—the future of food manufacturing. Sensors, the Internet of Things (IoT), big data, cloud computing, algorithms, and artificial intelligence (AI), enable real-time monitoring for quality enhancement and endorse customization across food manufacturing.



New technology supports the future of food manufacturing: optimization for customization

Global Goals
for the Future of Food Manufacturing

The pursuit of sustainability is driving industries and other institutions to shape their visions and strategies for the good of humankind and the environment. In the global context, the United Nations launched Sustainable Development Goals (SDGs) in 2015 as a call to action, with the aim of meeting seventeen specific objectives by 2030. These SDGs not only present challenges but also open up opportunities for all industries, including food manufacturing. A wide range of interdependent domains such as agricultural practices, farming and aquaculture techniques, disease control, waste management, the agro-chemical industry, food production and manufacturing, and public health will all be involved and affected. In this context, the future of food is related not only to the "Zero Hunger" SDG, but also to many other goals.

As part of the food industry, food manufacturing potentially endorses five SDGs:

03	Good Health and Well-Being
08	Decent Work and Economic Growth
09	Sustainable Cities and Communities
11	Industry, Innovation, and Infrastructure
12	Responsible Consumption and Production

These five Global Goals frame the future of food manufacturing as a new era—present conditions and trends will drive innovation across the entire food value chain.

03 Good Health and Well-Being

Concerns among the producers and consumers within the food industry are supporting a new culture of customer reviews, consumer trust in food safety, and customizations related to the urgency of food traceability.

Increasing incidences of obesity, noncommunicable diseases, and medical conditions caused by food have become major challenges, raising health awareness, changing behaviors, and modifying diets. Broadening the context of food manufacturing from good health to the importance of overall well-being provides the industry with new considerations, including lifestyle, culture, and religious expression.

08 Decent Work and Economic Growth

Work-life balance, decent work, and worker well-being have become important aspects of economic growth.

Changes in diet, in addition to the goal of economic growth, can generate considerable growth for agricultural production, improving technology on large-scale farms and smallholder farms, establishing more efficient irrigation techniques and aquaculture technology, and producing a circular economy supported by appliances and machinery.

09 Industry, Innovation, and Infrastructure

Investments in infrastructure and new technologies enhance efforts to promote inclusive and sustainable industrialization and foster innovation.

Resilient infrastructures that focus on affordable and equitable access for all support not only economic development but also human well-being. New technologies change manufacturing by increasing productivity and efficiency and also enable connectivity through every stage of food manufacturing.

11 Sustainable Cities and Communities

One major trend related to sustainable cities and communities is improving the scale and efficiency of growing food in urban environments.

Initiatives to increase food production in cities include community gardens, implementation of urban and vertical farming technologies, building energy efficiency, and expanding the use of renewable energy.

12 Responsible Consumption and Production

The food industry is plagued by waste.

Every year 20 to 30 percent of food is wasted along the value chain, and 35 percent of food is wasted at the consumption level, including one-third of all the fruits and vegetables produced. Plastic packaging has become an additional challenge, with the loss of 95 percent of its economic value. Improving waste management is increasingly a collaborative effort between producer and customer, as they share responsibly in the holistic food value chain–supported by data transparency and the incorporation of new technology.

The Future Customer

The notion of safety is expanding. Specialty food consumption is increasing.

As one of the most fundamental needs that humans experience, food not only sustains life, it also carries deep cultural and social significance.

Existing food systems are vast, and they sustain livelihoods of approximately one billion people. What we eat has an environmental impact, which accumulates at each step of food’s journey, from farming to disposal.

Consumer concerns and preferences about food evolve over time based on social, technological, economic, environmental, and political changes. Thus, consumers’ changing expectations shape demand.

Food offerings and company practices are adapting to meet these shifts in demand. Traditionally, the definition of food safety focused on avoiding short-term risks that could be caused by harmful elements in food products, but today the term covers all the practices that serve to keep food safe.[1] A 2015 consumer survey found that the notion of safety is expanding to include clear and accurate information, less processing and fewer ingredients, and nutritional content.[2]

Specialty food consumption is increasing. While there are various motivations for making decisions about consuming specialty food, religious requirements, dietary restrictions, and a sustainability-oriented mindset have the most influence.[3]

Sixty percent of US adults say they adhere to some type of special diet to avoid allergens, limit sodium or fat intake, or avoid food intolerances such as gluten.[4] Moreover, the number of consumers who aim to avoid gluten doubled in the last decade.[5] This increase indicates that improving access to highly specialized food products will become the new normal to meet consumer demand.

60%

of US adults say they adhere to some type of special diet.

1. “What Is Food Safety?” *What Is Food Safety? (EUFIC)*, www.eufic.org/en/food-safety/article/what-is-food-safety
2. Jack Ringquist et al., *Capitalizing on the Shifting Consumer Food Value Equation*. Deloitte, https://www2.deloitte.com/us/en/pages/consumer-business/articles/us-food-industry-consumer-trends-report.html..
3. Elizabeth A. Minton et al., “Religiosity and Special Food Consumption: The Explanatory Effects of Moral Priorities,” *Journal of Business Research* 95 (Feb. 2019): 442–54. doi:10.1016/j.jbusres.2018.07.041.
4. “Gluten Avoidance Is Outpacing Diagnosed Sensitivities,” *The Harris Poll*, Nov. 24, 2014, https://theharrispoll.com/new-york-n-y-november-24-2014-recently-its-become-nearly-impossible-to-walk-through-a-grocery-store-or-look-at-a-restaurant-menu-without-seeing-the-words-gluten-free-emblazoned-on-every-other/.
5. Annalisa Capannolo et al., “Non-Celiac Gluten Sensitivity among Patients Perceiving Gluten-Related Symptoms,” *Digestion* 92, no. 1 (2015): 8–13. *DOI.org (Crossref)*, doi:10.1159/000430090.

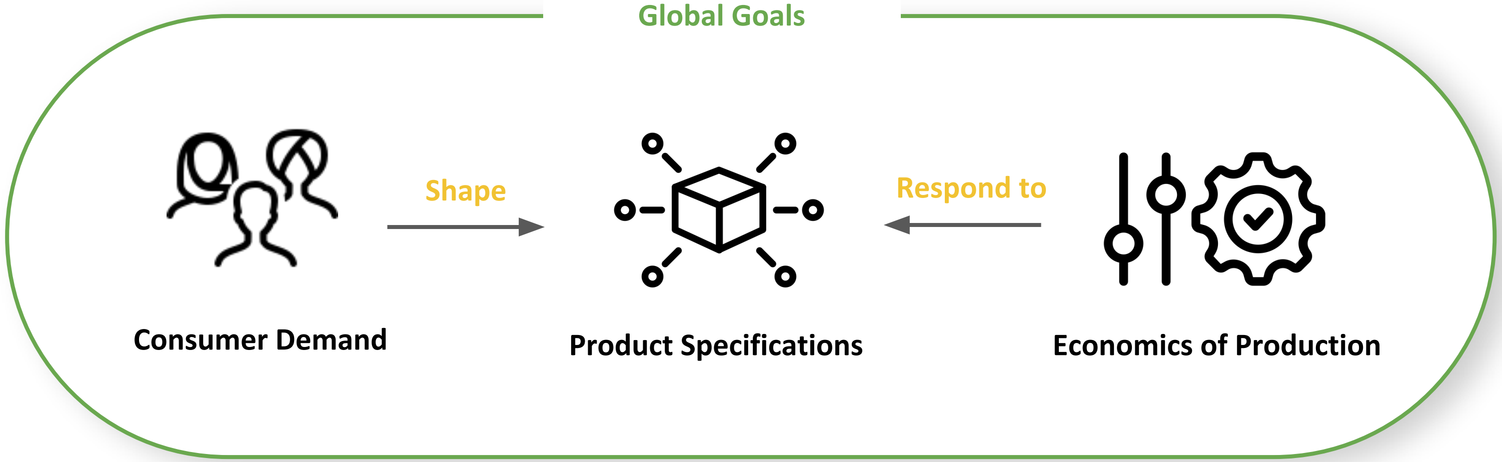
Customer Demand Drivers

As consumers become increasingly aware of the power of food, they are making new demands in three important areas the industry must address: health and wellness, social impact, and environmental impact.

Health and Wellness	Food safety
	Nutrition
Social Impact	Lifestyle, culture, religious expression
	Worker well-being
	Community empowerment
Environmental Impact	Energy efficiency
	Waste management

The Shift
from Optimization for Mass Production
to Optimization for Customization

Increasing attention to health and well-being and awareness of the social and environmental impacts of food are shaping consumer demand and transforming systems of production. Optimization in economic production aims for mass production and mass consumption, making it possible for food suppliers to provide new offerings that reflect desires for healthy food, sustainability, and the UN Global Goals. Customization and optimization are not polar opposites; their unique synergy will enable new business models while delivering higher value for stakeholders in the food manufacturing ecosystem.



Optimization for Customization

New technology supports the future of food manufacturing—optimization for customization—by enabling information flows through add-on solutions that ensure end-to-end multilevel connectivity, transparency, and traceability across the supply chain. Information flows convey data regarding food safety and nutrition, customer lifestyle, cultural and religious expressions, worker well-being, community involvement, energy use and efficiency, resources, and waste management.

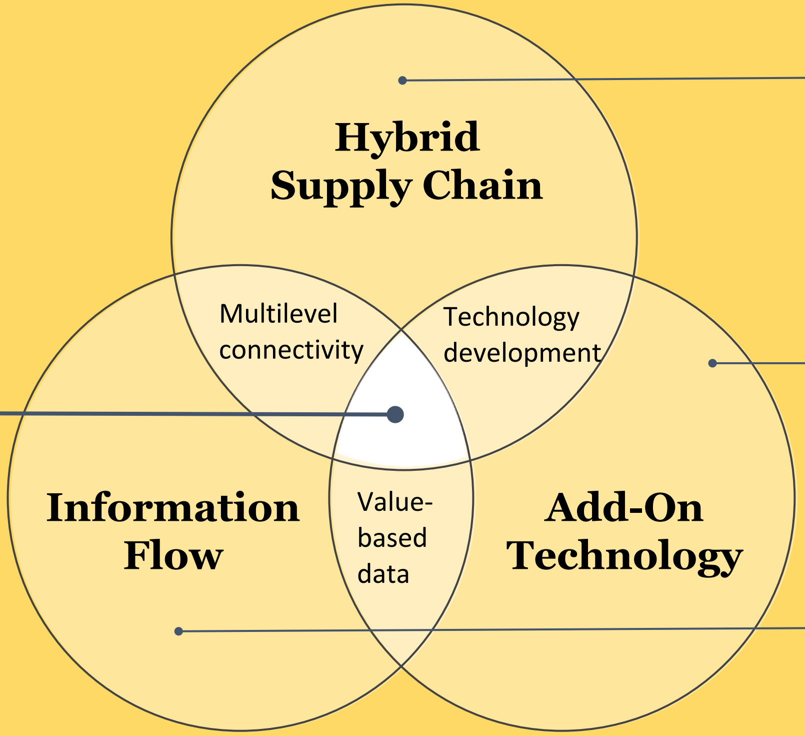
Multilevel connectivity enables planning and operation for the supply chain based on early risk identification, and in-time information will assist with time-sensitive decisions. Transparency and traceability in information flows from producers to consumers make the customer an active participant in decisions so optimization and customization reflect values of health, wellness, social impact, and environmental Impact.

The development of technology also supports innovations in food production and delivery such as vertical farming, advanced techniques in aquaculture, meat making, and home energy. These new practices will raise the complexity of the food supply chain and establish a hybrid supply chain in the spectrum of global to hyperlocal, agile to lean, and low-tech to high-tech.

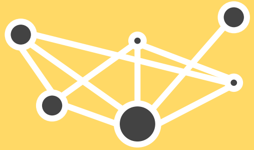
Add-ons of new technology apply to existing equipment such as a meat cutting device that delivers precision and an information system that allows food delivery service for in-time capture of weather and location conditions—all to enhance the quality of production and services that will support health and wellness and address social and environmental impacts of food manufacturing and empower the customer in decision-making.

Optimization for Customization

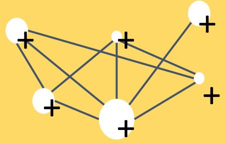
Optimization for customization is the space that should be created for future economic production in food manufacturing. There are three enablers of customization and optimization: a hybrid supply chain, the flow of information, and the add-on technology that is integrated with the information flows among stakeholders. Each enabler has specific attributes—a wide-spectrum hybrid supply chain, end-to-end and in-time information flow, and add-on technology across the supply-chain. Information flow supports a hybrid supply chain for multilevel connectivity. Add-on technology supports information flow to convey value-based data. Add-on technology across the hybrid supply chain requires technology development that supports innovation.



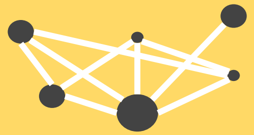
Wide spectrum
Low tech to high tech
Agile to lean
Global to hyperlocal



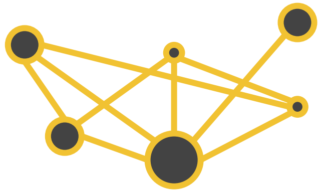
Across the supply chain
Information gathering
Enhancing production quality



End-to-end and in-time
Connectivity
Transparency
Traceability



Hybrid Supply Chain



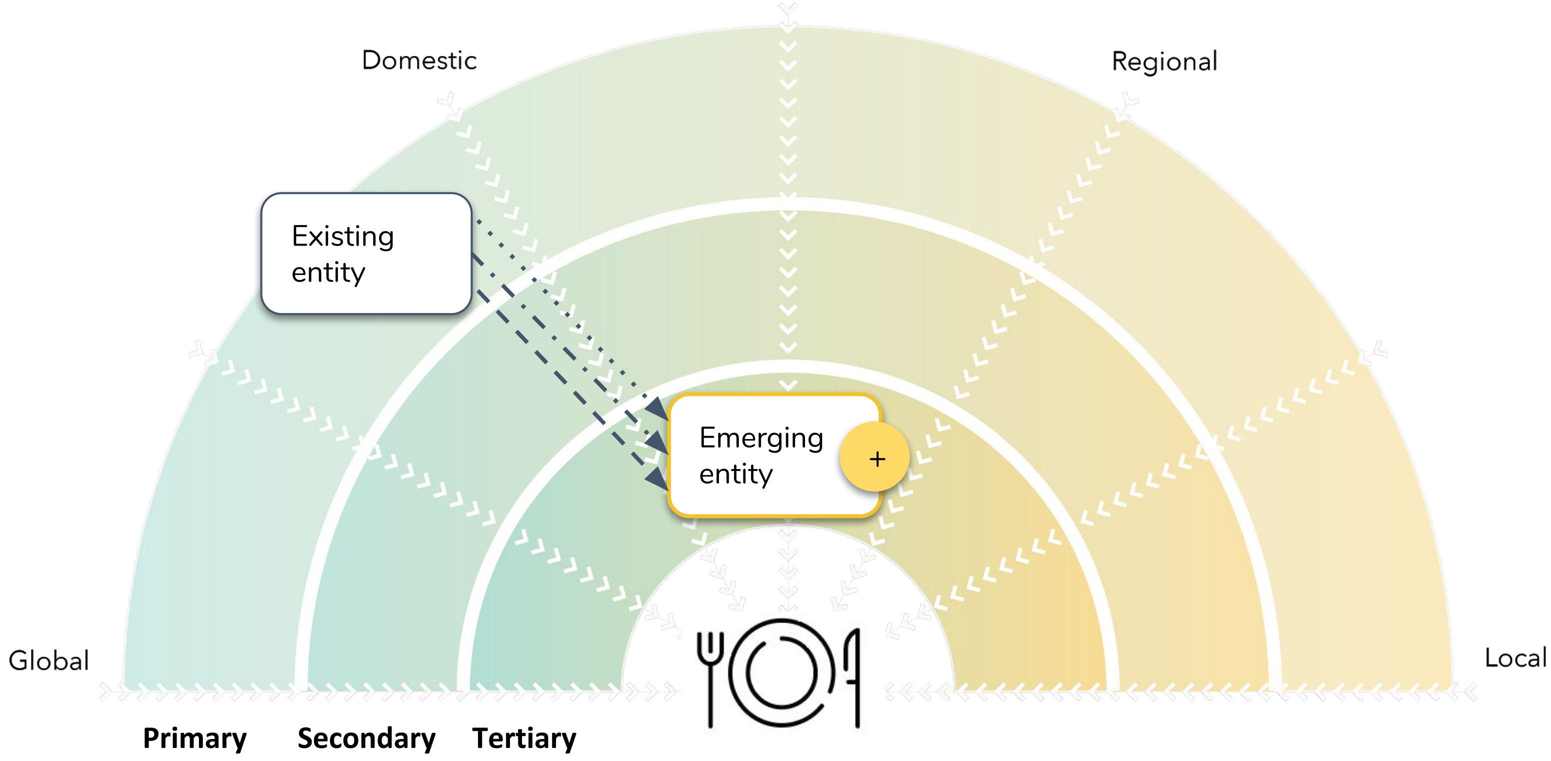
A supply chain is a complex and dynamic system that comprises organizations, people, resources, and information that move offerings from suppliers to their customers. Supply chains involve interdependent heterogeneous entities.

A hybrid supply chain provides a variety of sources—from geographically specific, low-technology production, as in a supply of tropical fruit, to the high technology of controlled environments, such as indoor farming and agile lab-grown meat production, and sources of lean manufacturing such as local cheeses—all on a wide spectrum from **global** to **hyperlocal** in **primary, secondary, and tertiary production**.

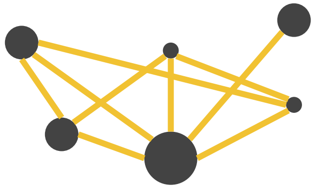
Primary: production of crops and animals from agriculture, both farms and fisheries

Secondary: food processing, from individual ingredients to final food products

Tertiary: service industry, including kitchens and delivery

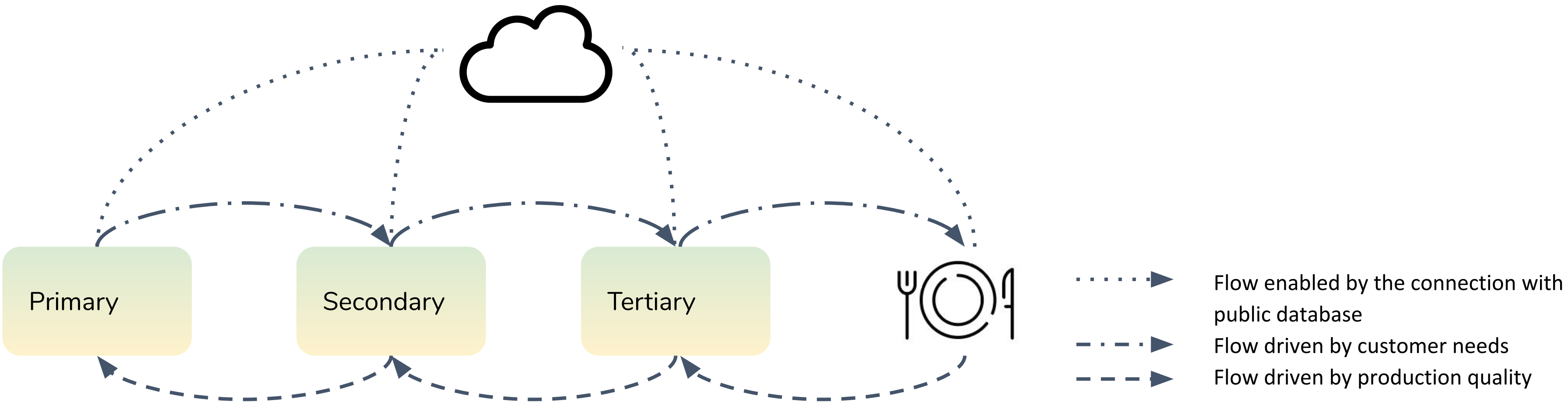


Information Flow



Information and data flow throughout the value chain. The infrastructure in primary, secondary, and tertiary production also connects all stakeholders and uses cloud-based data to ensure end-to-end, multilevel connectivity, transparency, and traceability across the supply chain. Personal data use becomes part of the information flow to enable high customization in production while taking privacy, security, and legal implications into consideration.

Every stakeholder in food manufacturing relies on the flow of information. Producers, suppliers, and consumers alike become a source of streaming data. Big data provides outside intelligence and harvests data from the IoT and other connected devices such as wearables, industrial equipment, and medical devices, as well as public data such as consumer profiles, weather forecasts, and government policy.



Add-On Technology

New technology add-ons will be critical to optimization for customization. A varied supply chain will serve a wide range of requirements for meeting specific optimization in production, making add-on technology with modularity and flexibility features essential.

Add-on technology will strengthen information gathering to support information flows and enhance the quality of the production process, thus serving health and wellness aspirations, as well as social and environmental concerns.

Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety	+	+
	Nutrition		
Social Impact	Lifestyle, culture, religious expression		
	Worker well-being		
	Community empowerment		
Environmental Impact	Energy efficiency		
	Waste management		

Speculative Scenarios

Speculative scenarios illustrate evocative, aspirational visions of the future of food manufacturing. They serve as a design method that captures the complexities of the challenges and opportunities generated by social, economic, political, and technological changes.

The Five Future Trends and speculative scenarios shared in this report address a wide range of contexts and goals entangled with both technological progress and social transformation. The context of concern encompasses cultural, physical, policy, and service as representations of the human aspect–both humans working with humans and humans interacting with machines—that can be gleaned from the UN Global Goals.

The goal of each case described in this report is to elaborate on cultural diversity, diet and healing, policy compliance, customer satisfaction, and freedom of choice as they relate to customer concerns. Relevant technology trends include cellular agriculture, DNA-based diet, urban farming, Robotics as a Service (RaaS), and wearable devices. Cultural trends include the dominance of review culture, hyper-customized service, adaptive learning, in-person customer service, and interest in new materials. The speculative case scenarios attest to the various trends in technology and culture and the complex nature of the future of food manufacturing.

The Future: Relevant Trends

Trends: Tech

- Data-driven prescriptive planting
- Edible packaging
- Urban and vertical farming
- “Meat making” technology
- Autonomous transportation
- Self-managing robot system
- Robotics as a Service (RaaS)
- Performance monitoring
- Wearable devices
- Health data tracker
- Telemedicine
- DNA-based diet
- Alternative energy source
- Energy home storage

Trends: Culture

- Review culture
- Brand-less
- Using imperfect food
- Hyper-customized service
- In-person customer service
- New materials
- Personal data sharing
- Adaptive learning

Trends: Networks

- Connected infrastructure
- Personal data trading and use
- Supply-chain transparency
- Cloud-based data

Optimization for Customization

Five speculative cases reveal a wide range of customization and optimization opportunities.

01 Flight

Customer demand in cultural diversity requires product specifications that reflect cultural preferences –with cellular agriculture as a response.

02 Hospital

Customer demand in diet and healing requires product specifications that reflect hyper-customized service, such as a DNA-based diet.

03 School

Customer demand in policy compliance requires product specifications to support policy, such as urban farming that supports sourcing local food.

04 Fast Food

Customer demand in customer satisfaction requires product specifications that reflect in-person service, such as using Robotics as a Service (RaaS).

05 Vending Machine

Customer demand in new materials requires product specifications that reflect freedom of choice, such as using wearable devices as customer preferences sensors.

Scenario 01
Flight_Cultural Diversity

Lifestyle, culture, and religion all influence meal preferences among passengers. Three variations of burger patties can address passenger needs:

- Halal meat
- Plant-based products
- Products with high “worker well-being” scores

All burgers are served with vegetables that come from airport indoor vertical farming, with options for adding local cheese and various plant-based seasonings and sauces.

Trends considered:
DNA-based diet
Hyper-customized service

Hybrid Supply Chain

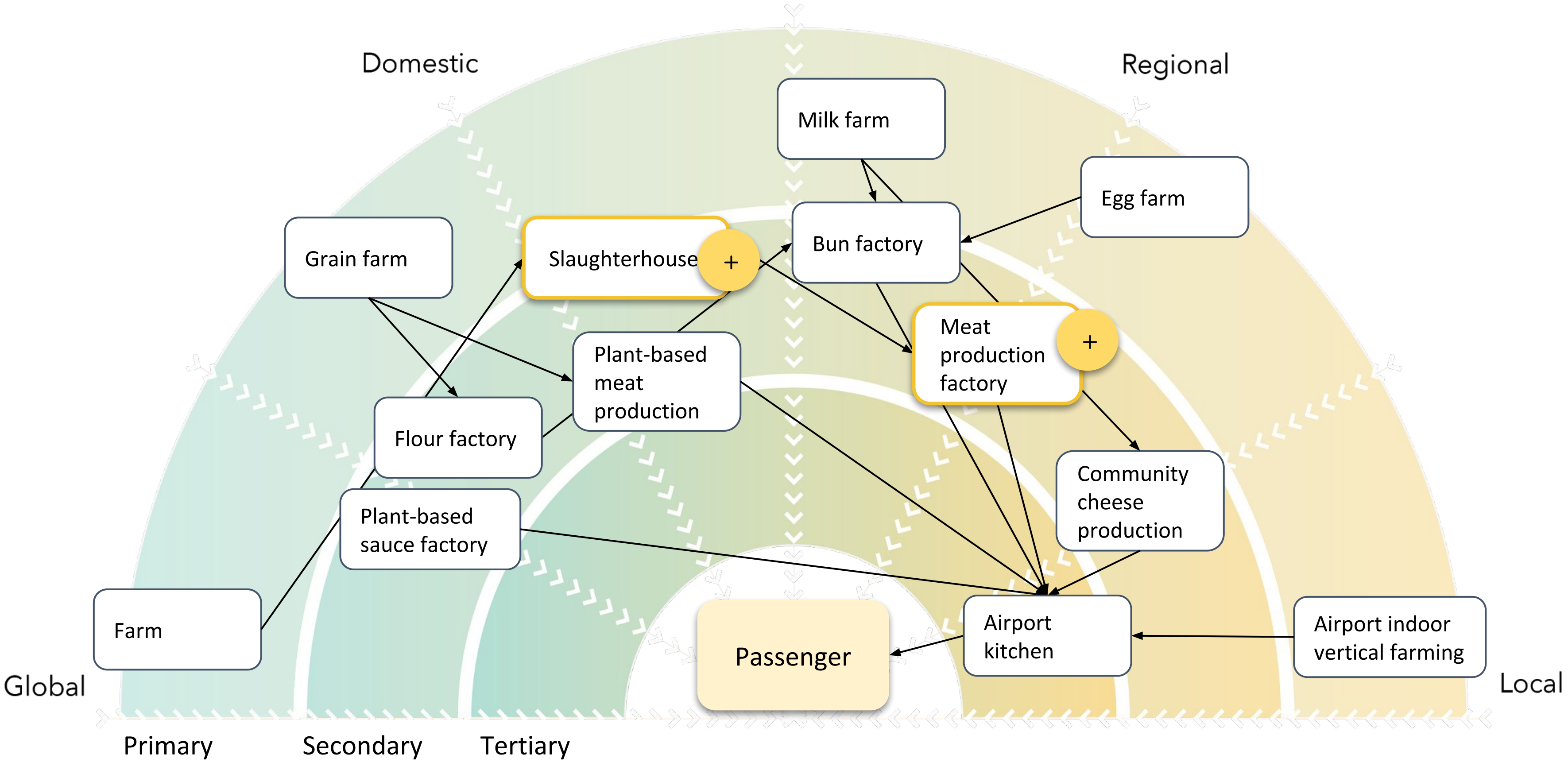
Scenario 01
Flight_Cultural Diversity

Embracing cultural diversity means supporting the expression of identity in every aspect of life, including food preferences.

This scenario—serving three different kinds of burgers—shows a hybrid supply chain that provides a variety of sources for a wide range of products, from imported meat to local food sourcing through vertical farming.

The different burgers are produced from varied sourcing, whether mature manufacturing and meat sourced from animals, or the emerging production of a plant-based burger.

A hybrid supply chain serves the entire spectrum of personal expression: lifestyle, culture, and religion.

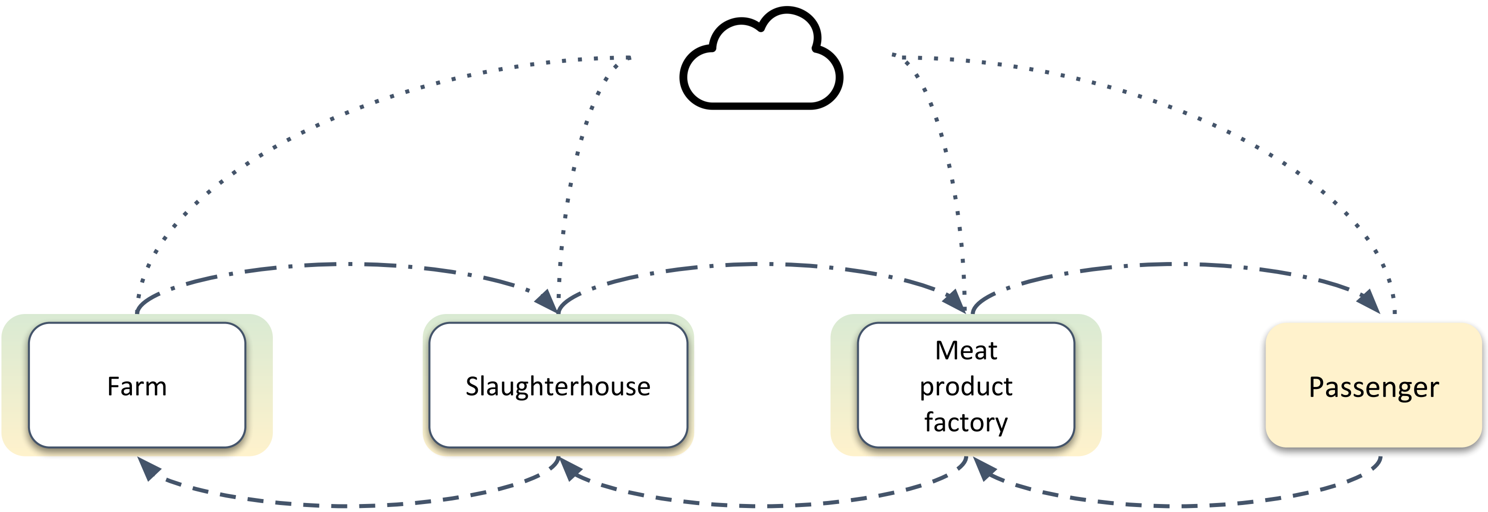


Information Flow in Meat Production

Scenario 01
Flight_Cultural Diversity

Information that flows in the production of meat supports the current trend of customer review culture. In review culture, customer decision-making is not only based on the end product but also on information gathered from production, such as animal and worker well-being and waste management related to community living and the environment.

Customer concerns about meat processing relate to lifestyle, culture, and religion, requiring end-to-end transparency in sourcing and processing.



Worker well-being
Animal well-being
Cleaning and feeding method
Chemicals used for cleaning and feeding
Special treatment for animals

Worker well-being
Animal well-being (stalling and stunning)
Slaughter method (related to religious preferences)
Waste management (related to community living and environment)

Worker well-being
Processing technique used
Meat specifications:
fat reduction and nutrition based on cooking technique and time
Packaging specifications

Allergic profile
Food preferences
Trends in passenger demands

Add-On Technology in Meat Production

Scenario 01
Flight_Cultural Diversity

Add-on technology in meat production will strengthen information gathering, support information flows, and enhance the quality of the production process to address customer review culture and concerns related to health, well-being, and social and environmental impacts.

Add-on technology can be used for information gathering such as breed and genetic makeup of animals, feeding sources, and postmortem techniques that reveal meat's nutritional value.

Add-on technology also facilitates quality enhancements such as worker health and sanitation stations, which support worker well-being.

Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety	• Animal health	• Unwanted materials in end product detector • Duration and timing (monitoring) • Inspection device with OMO (Online-Offline Management) system concern
	Nutrition	• Breed of animal • Feeding source • Genetics of animal • Postmortem techniques	
Social Impact	Lifestyle, culture, religious expression	• Slaughter method related to religious preferences • Chemicals used	• Worker health and sanitation stations • Device for cutting meat for less physical work and increased safety
	Worker well-being		
	Community empowerment	• Community impact	
Environmental Impact	Energy efficiency	• Energy sources and usage	
	Waste management	• Waste management method	

Scenario 02
Hospital_Diet and Healing

Hospital patients have a variety of physical and mental health conditions. Healing is a holistic process, which means treatment should be based not only on physical evidence, but also on serving patients their favorite meals—foods they believe in.

Authentic home meals, sometimes based on old family recipes, are usually the most convenient. Interconnectivity of information enables hospital kitchens to extract recipes from libraries that store legacy recipes from every country. Patients can have menu options that reflect both DNA-based diet technology and individual culture—convenient, curing foods that support holistic healing.

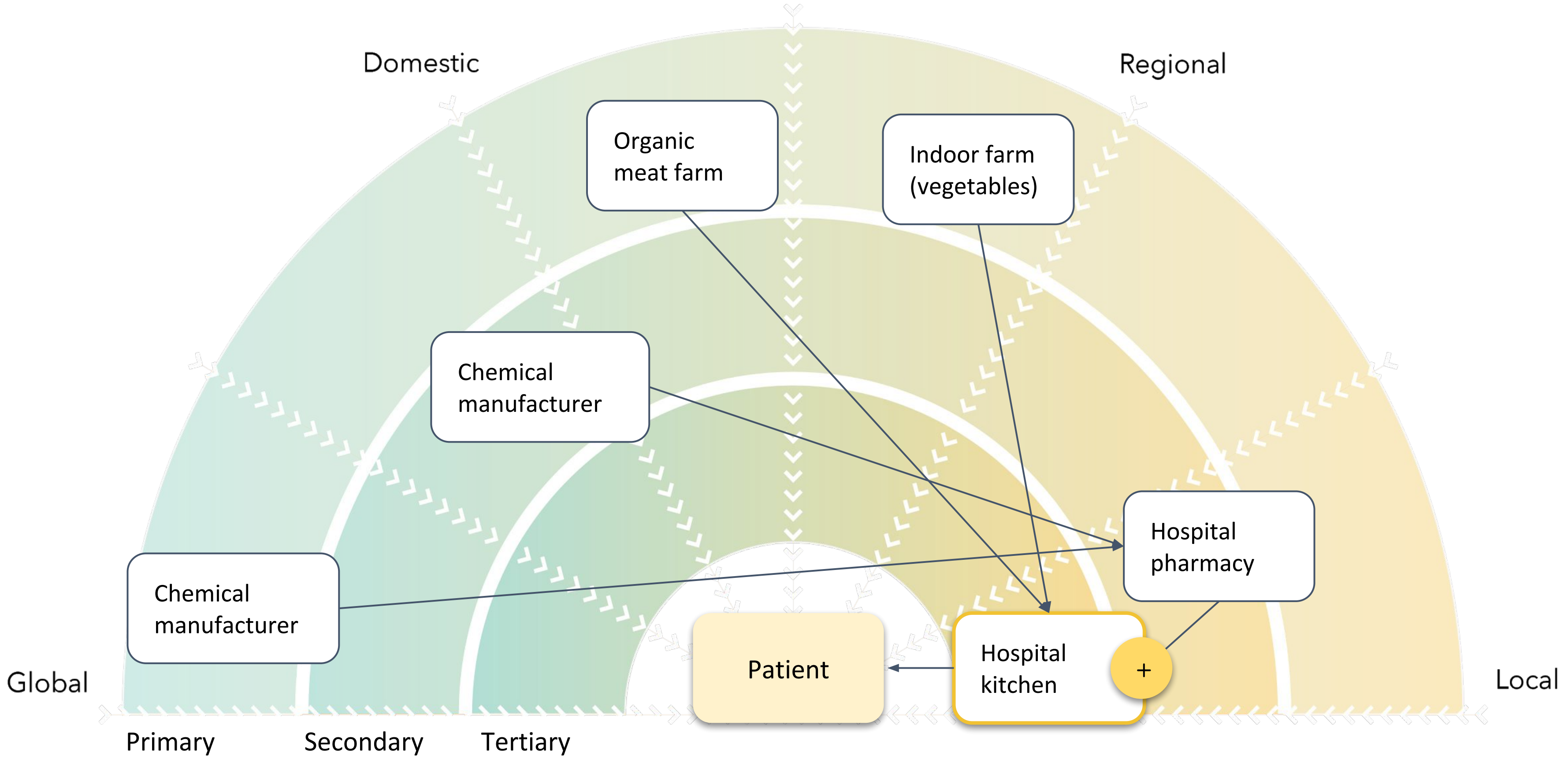
Trends considered:
Cellular agriculture
Review culture

Hybrid Supply Chain

Scenario 02
Hospital_Diet and Healing

Foods that support the healing process provide both sustenance and comfort. Hospital meals should reflect both balance and precision—in nutrition, texture, flavor, and dietary restrictions.

This scenario—serving food with the precision of meeting demands for hyper-customized service, a DNA-based diet, and specific food preferences—shows that a hybrid supply chain offers varied sources, from imported chemical products to sourcing organic meat from farms and vegetables from regional indoor farms. A hybrid supply chain serves the entire spectrum of DNA-based diet and food preferences.

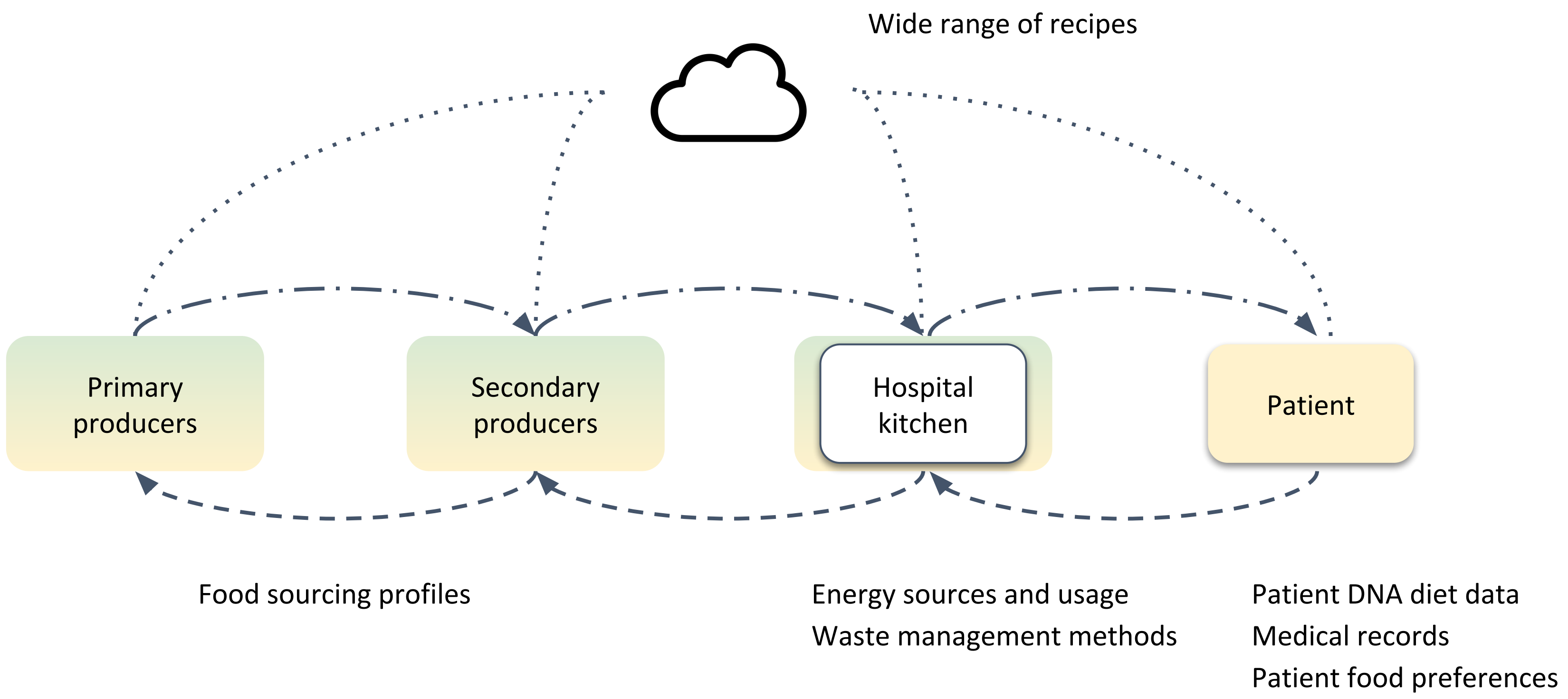


Information Flow in Hospital Kitchen

Scenario 02
Hospital_Diet and Healing

Information flows in a hyper-customized kitchen should support healing, including both a DNA-based diet and the patient’s food preferences.

Hyper-customization in healing requires in-time connectivity and end-to-end transparency in patient DNA diet data, medical records, and patient food preferences, as well as information from “outside intelligence” such as recipes from a library’s database and food sourcing profiles.



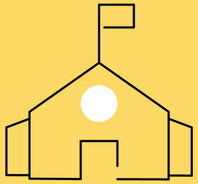
Add-On Technology in Hospital Kitchen

Scenario 02
Hospital_Diet and Healing

In this scenario, precision is very important to support hyper-customization for holistic healing. Add-on technology in hospital kitchens assists with internal information gathering, such as DNA-based diet data, medical records, and patient food preferences, as well as information from "outside intelligence" such as recipes from a library's database and food sourcing profiles.

Add-on technology—using RaaS for precision in production, making improvements for workers in high-risk jobs, and improving automation for data analysis—enhances quality.

Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety Nutrition	• Food sourcing profile • Patient DNA diet data • Medical records	• Automation for (cross) data analysis
Social Impact	Lifestyle, culture, religious expression	• Wide range of recipes • Patient food preferences	
	Worker well-being		• RaaS for precision in production • RaaS for high-risk job
	Community empowerment		
Environmental Impact	Energy efficiency	• Energy sources and usage	
	Waste management	• Waste management methods	



Scenario 03
School_Policy Compliance

Schools are always highly connected to government policy. It becomes necessary to engage in activities like sourcing local food and monitoring compliance with regulations.

As places for learning, schools can demonstrate local food sourcing and explain food policy, balanced nutrition, and the cultural aspects of food to their students.

Information flows and add-on technology used to monitor policy compliance also enable adaptive learning.

Trends considered:
Urban farming
Adaptive learning

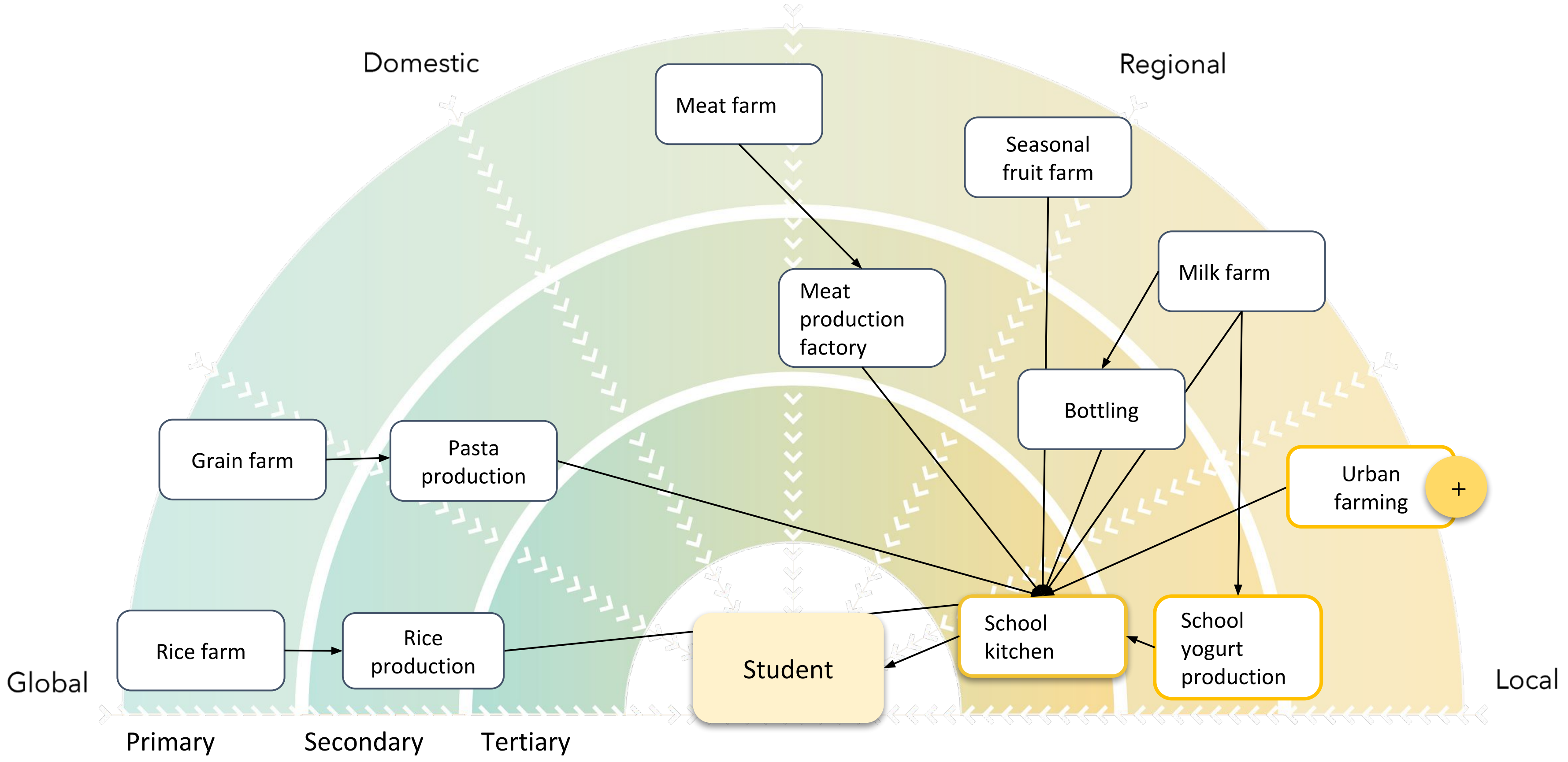
Hybrid Supply Chain

Scenario 03
School_Policy Compliance

A government policy to source local food requires following initiatives and actions that shape food supply chains.

This scenario shows how a policy of local sourcing affects the supply chain, supported by a local milk farm, urban farming, and school yogurt production. But to deliver balanced nutrition and address the cultural aspects of food for their students, schools cannot rely only on local sources.

A hybrid supply chain balances policy compliance with the cultural needs of students.



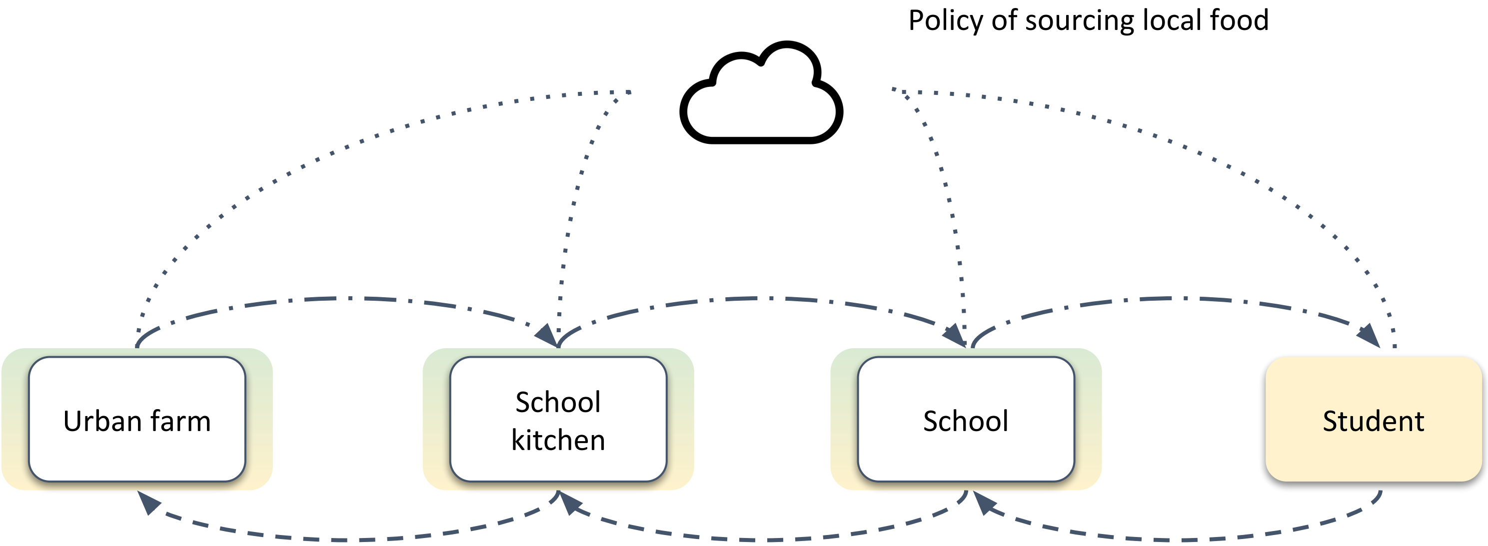
Information Flow in Urban Farming

Scenario 03
School_Policy Compliance

Information flow in urban farming and schools can support sourcing local food and help monitor both policy compliance and adaptive learning.

The flow of information in urban farming—such as source profiles, growing methods, and chemical and energy usage—helps with monitoring local sources and production for both policy compliance and educating students about food.

Monitoring policy compliance in concert with tending to student well-being and active learning requires in-time connectivity and end-to-end transparency across all aspects of providing food in schools–source profiles, urban farms, kitchen demands, policy regulations, and the allergies and diet requirements of students.



Sources profile
Growing methods
Handling details
Chemical use
Nutrient
Energy usage

Demand
Delivery tracking

Local food policy regulation
Materials for learning about urban farming
Learning methods
Learning tools

Food preferences
Allergies and diet
Preferred learning methods

Add-On Technology in Urban Farming

Scenario 03
School_Policy Compliance

Monitoring compliance with government policy requires information transparency with regard to local produce. Technology add-ons are crucial to monitoring information—to knowing the details of local sourcing as they relate to personal wellness and social and environmental impacts.

In urban farming, add-on technology is used for internal monitoring of production and information gathering such as source profiles, growing methods, handling details, chemical use, nutrients, energy sources and usage, and waste management methods.

Add-on technology focuses on information gathering to help monitor policy compliance and enhance quality.

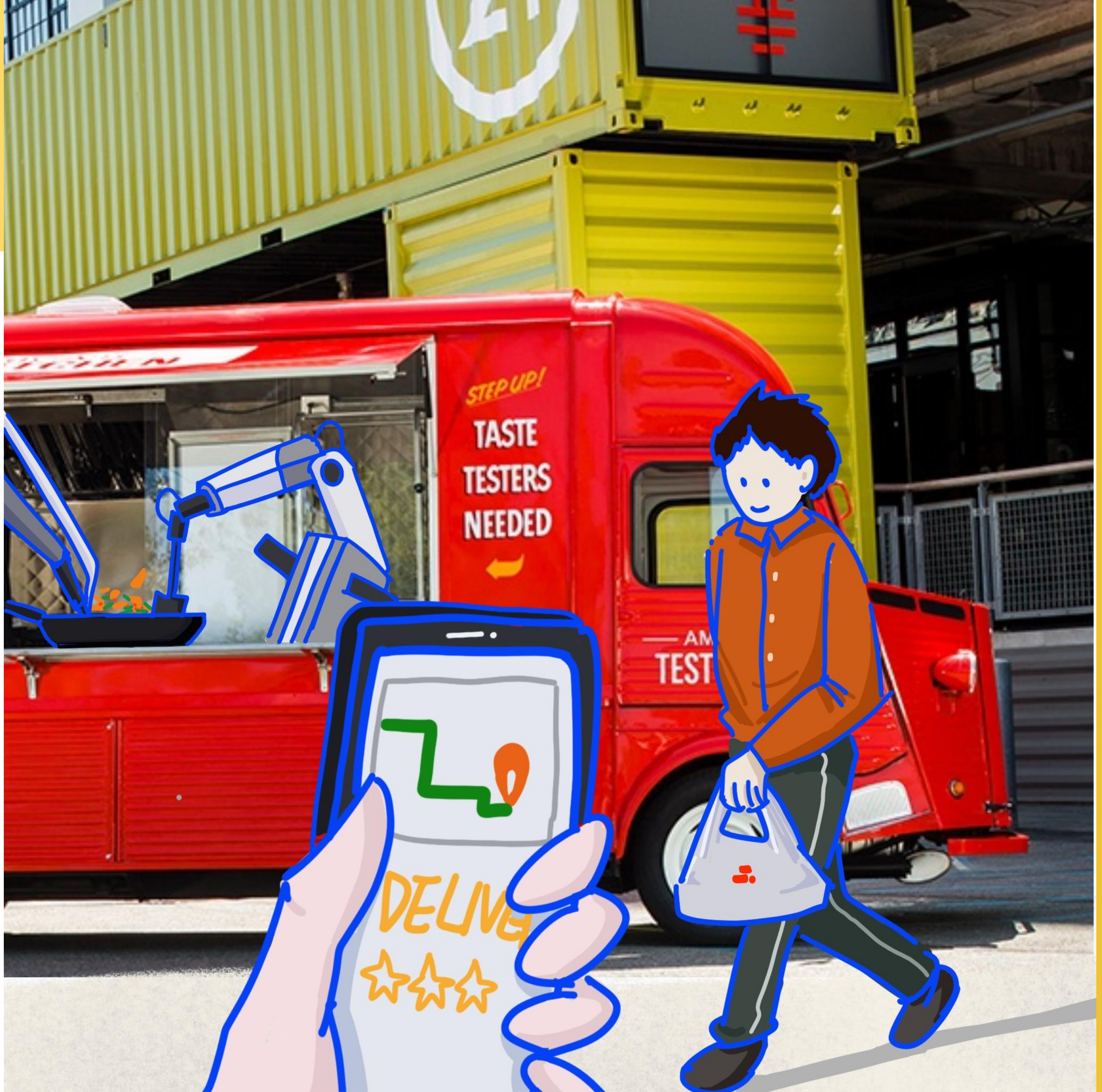
Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety Nutrition	• Sources profile • Growing methods • Handling details • Chemical use • Nutrients • Allergies and diet	
Social Impact	Lifestyle, culture, religious expression	• Food preferences • Learning method preferences • Local food policy regulation	
	Worker well-being		
	Community empowerment		
Environmental Impact	Energy efficiency	• Energy sources and usage	
	Waste management	• Waste management methods	

Scenario 04
Fast Food_Customer Satisfaction

The Internet of Things (IoT) in the fast food industry informs delivery as a replacement for dining in, but brand and unique qualities remain important. The fast food business is no different from most others: customer satisfaction is key to brand loyalty.

Serving hot, “fresh from the oven” food is a challenge for delivery services, but new technology such Robot as a System can be embedded in the delivery vehicle, so food can actually be prepared and cooked on the way to delivery to support in-person service.

Trends considered:
Robotics as a Service (RaaS)
In-person service



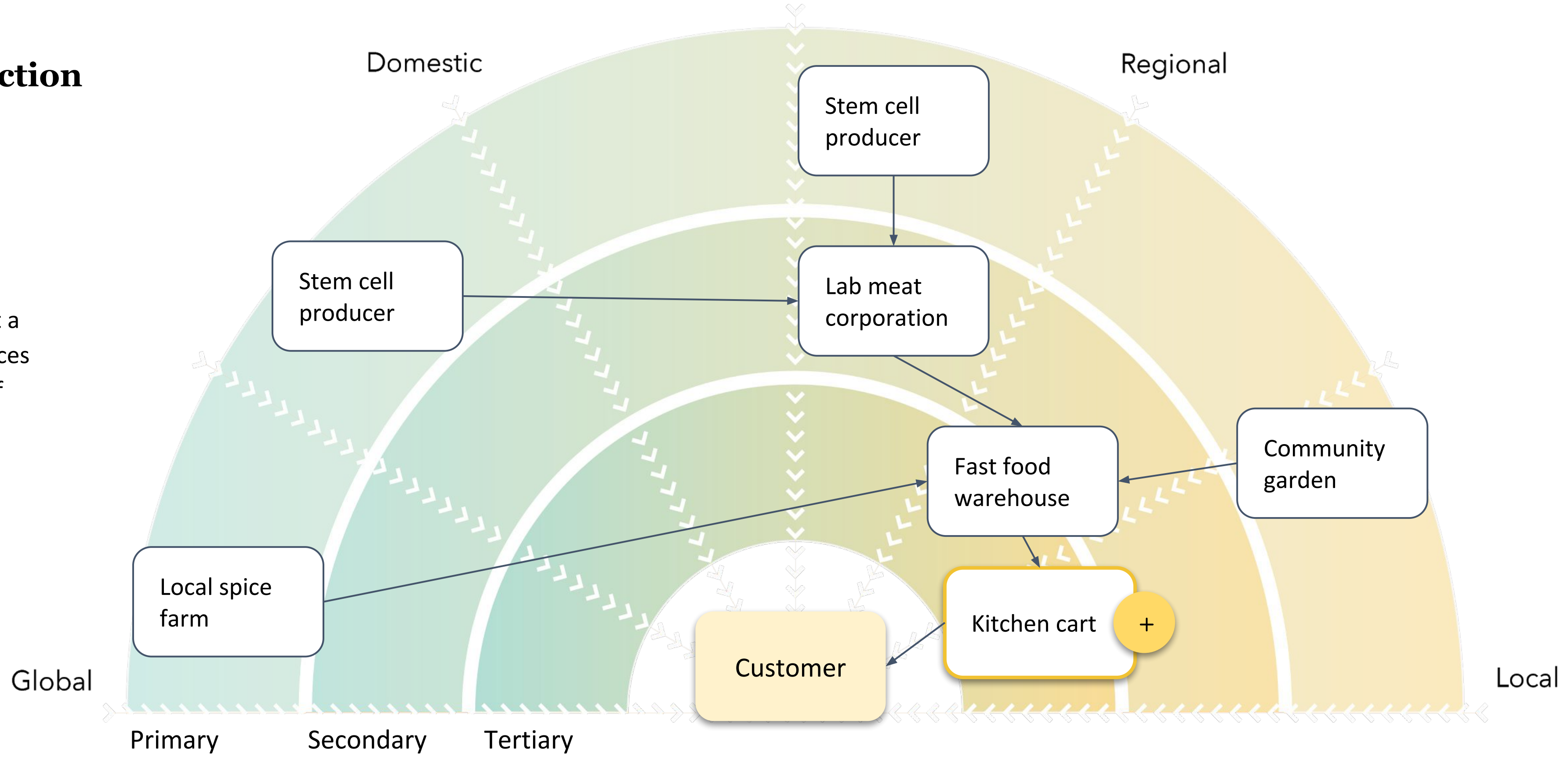
Hybrid Supply Chain

Scenario 04
Fast Food_Customer Satisfaction

Ensuring customer satisfaction and the brand loyalty it inspires means serving an authentic and consistent product.

This scenario—delivering fast food that tastes authentic, with in-person service—shows that a hybrid supply chain provides variety, from spices imported from all over the world to the use of lab-grown meat with just the right texture.

A hybrid supply chain serves customer satisfaction through authentic and consistent products.



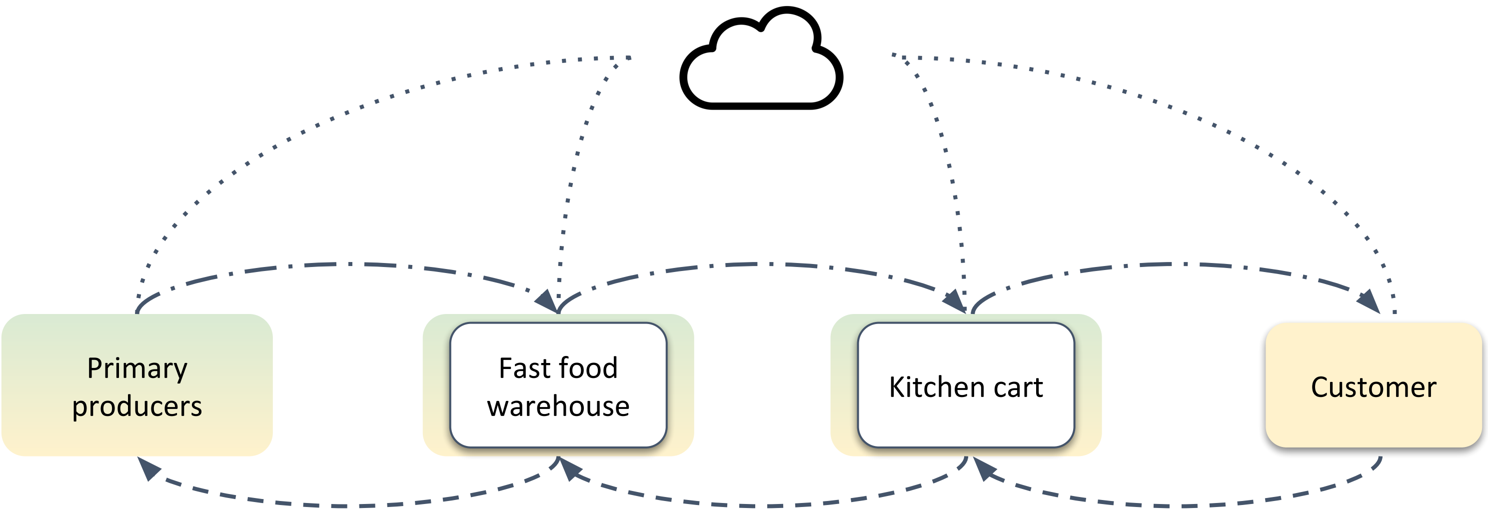
Information Flow in Kitchen Cart

Scenario 04
Fast Food_Customer Satisfaction

Customer satisfaction in fast food delivery relates to both quality of product and precise timing.

In-time information that flows among customer, kitchen cart, and the fast food warehouse serves customer satisfaction through precision of order, raw material, customer and cart locations, and delivery time.

Other information that relates to quality of product, such as nutritional information, is based on cooking techniques and packaging specifications as they advance health and well-being and address social and environmental concerns—all part of building a strong future fast food brand.



Profiles of companies

Worker well-being
Waste management

Location
Raw material stock
Processing and delivery times
Nutritional information based on cooking techniques and time
Packaging specifications
Energy consumption

Food order
Location
Payment method
Customer satisfaction rate

Add-On Technology in Kitchen Cart

Scenario 04
Fast Food_Customer Satisfaction

In this scenario, customer satisfaction with both product and delivery service is the goal. Add-on technology in kitchen cart can be used for information gathering that supports production and delivery such as raw material stock, customer orders, and precision in recipes, processing, and delivery time, as well as to gather information on traffic conditions from “outside intelligence.”

Add-on technology such as RaaS for precision in timing and production also helps lower job risks—a human side to quality enhancement.

Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety Nutrition	• Nutrition based on cooking techniques • Packaging specifications • Raw material stock • Sourcing profile	
Social Impact	Lifestyle, culture, religious expressions Worker well-being Community empowerment	• Precision in recipes • Customer order • Geo location • Processing and delivery time • Traffic condition	• RaaS for precision in production • RaaS for precision in timing • RaaS for high-risk job
Environmental Impact	Energy efficiency Waste management	• Energy sources and usage • Waste management methods	

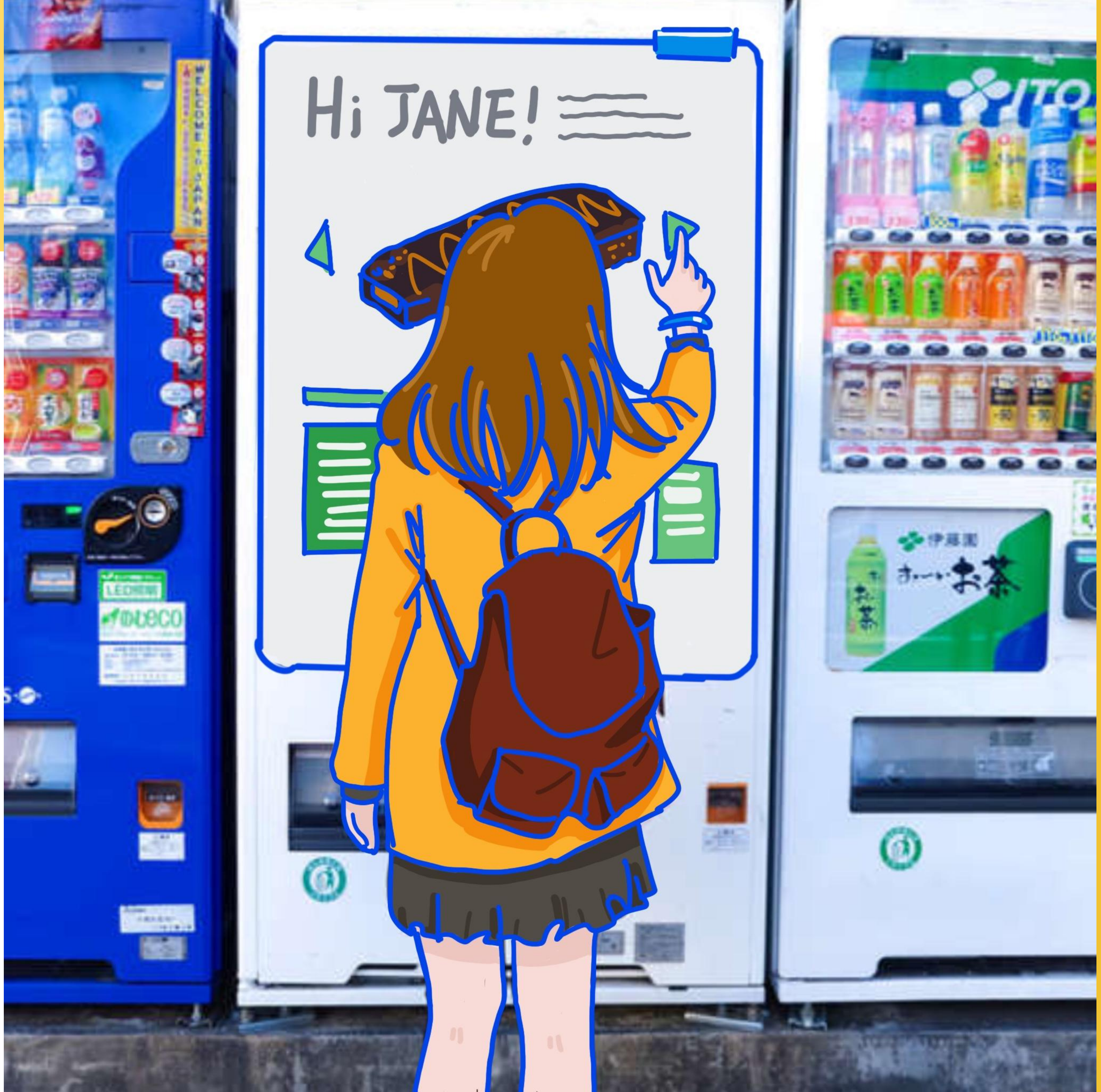
Scenario 05
Vending Machine_New Materials

Vending machines are on standby, ready to provide various choices to customers at any time.

Prepackaged snacks, such as a protein bar made of bugs, can deliver a variety of flavors for different tastes, as well as nutrients that match with various needs and physical conditions.

Wearable devices that collect personal data can provide information about customer health and diet—a profile that can be the basis of snack recommendations offered by the vending machine.

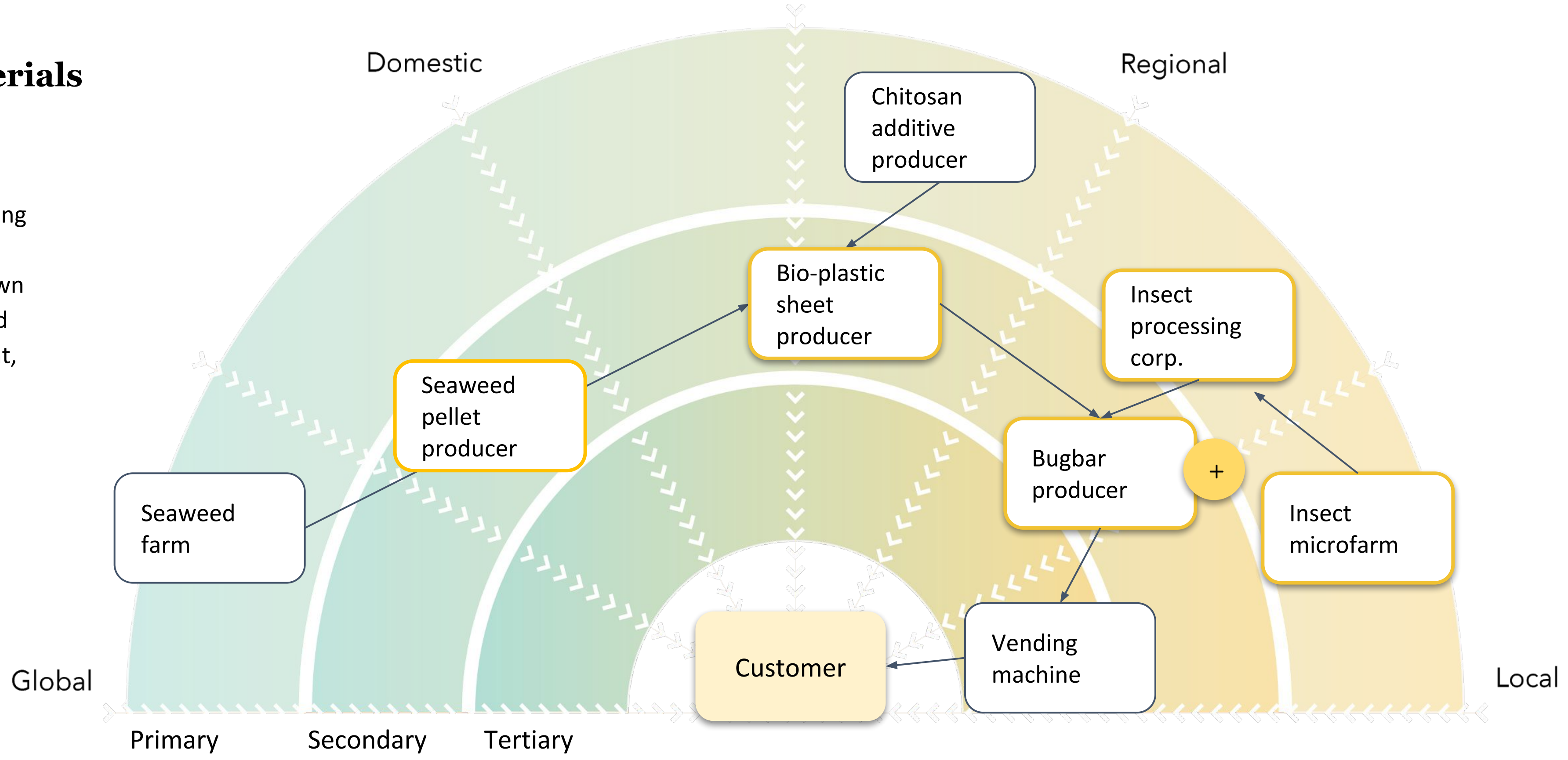
Trends considered:
Wearable devices
Freedom of choice



Hybrid Supply Chain

Scenario 05
Vending Machine_New Materials

This scenario—providing customers with new materials related to environmental concerns—shows a hybrid supply chain enabling a BugBar prepackaged in seaweed. New materials for packaging, such as seaweed grown naturally at specific locations in the world, and edible bugs grown in a controlled environment, are combined for a new product.



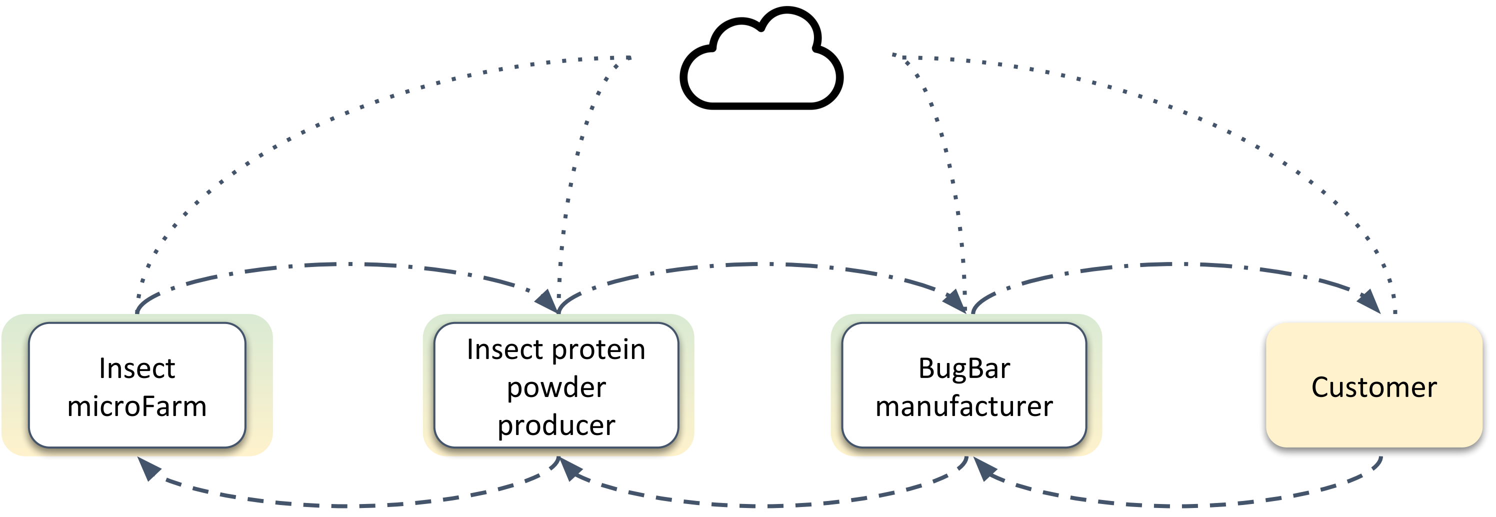
Information Flow in BugBar Manufacturing

Scenario 05
Vending Machine_New Materials

Information flow can support freedom of choice in new materials (such as insects) as a food source—with use of personal data from a wearable device for health customization.

New materials in food are always associated with health risks, making end-to-end transparency in information flows necessary, from details of nutritional composition to customer allergen and diet profiles.

In the production of new materials, such as fast-growing bugs, in-time information about customer demands helps facilitate optimization of production.



Dynamic demand forecasts

Nutritional requirements

Stock levels
Nutritional composition
User preferences
Use frequency

User profiles
Activity levels
Diet requirements
Allergen information
Flavor preferences
Nutritional requirements

Add-On Technology in BugBar Manufacturing

Scenario 05
Vending Machine_New Materials

In this scenario—customer freedom of choice supported by prepackaged food with new materials—add-on technology supports quality of product. In BugBar manufacturing, customer nutrient needs can be combined with variations in flavor preferences.

Add-on technology can be used for information gathering and quality enhancement, assuring the suitability of the new materials for customers: delivering nutrients, avoiding allergens, and satisfying flavor preferences. Add-on technology is also used for monitoring the environmental impacts of sourcing and manufacturing.

Principle	Application	Information Gathering	Quality Enhancement
Health and Wellness	Food safety	• Micronutrient information • Sourcing and handling details • Hygiene and feed quality in insect farms	• Tracking system for distributing customized orders • Increasing food safety compliance for outsourced materials
	Nutrition		
Social Impact	Lifestyle, culture, religious expressions	• Managing dietary restrictions and preferences of user base • Procurement from local producers	• Forecasting for consumption trends
	Worker well-being	• Labor conditions	• Blockchain for traceability for fair labor (globally sourced seaweed) • Transparency and traceability for urban insect microfarms
	Community empowerment		• Measuring social impact
Environmental Impact	Energy efficiency	• Carbon footprint	• Transparency for sustainable practices for packaging and waste management
	Waste management	• Waste generated for each bar	

Conclusions

Hybrid Supply Chain

Wide spectrum
Low tech to high tech
Agile to lean
Global to hyperlocal

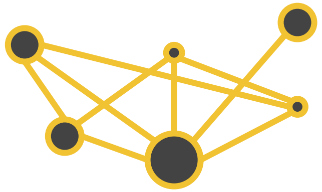
Information Flow

End-to-end and in-time
Connectivity
Transparency
Traceability

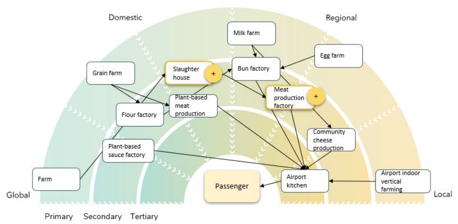
Add-On Technology

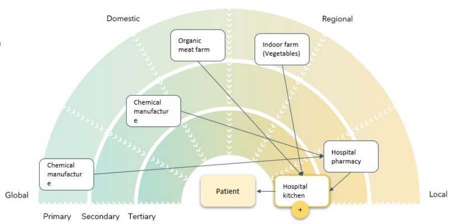
Across the supply chain
Information gathering
Enhancing production quality

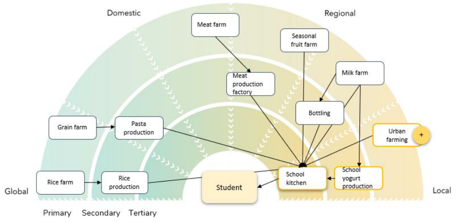
Hybrid Supply Chain

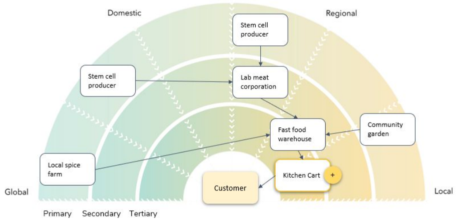


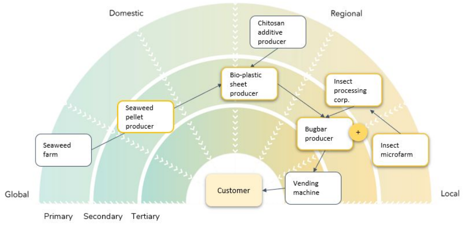
Meeting the different goals of the Five Speculative Scenarios will vary the requirements of the supply chain, which operates on a spectrum of low to high tech, agile to lean, and global to hyperlocal manufacturing. Cultural diversity entails a complex, hybrid supply chain, due to the many variations of individual preferences (related to individual lifestyles, cultures, and religious expressions). The goal of manufacturing foods for diet and healing, in terms of producing functional food, involves a less complex supply chain. Policies such as sourcing local food also operate on the hybrid supply chain model. Customer satisfaction in the context of a niche market can be achieved with a less complex supply chain, but when satisfaction relates to a specific cultural expectation, the hybrid supply chain becomes necessary. The desire to use new environmentally friendly materials relates to a natural ecosystem, as specific sourcing in the global market will require the full spectrum of local to global in the hybrid supply chain. The logistical requirements and complexities of global-local manufacturing demonstrate the growth of local sources.











01
Flight

Cultural
Cultural diversity

Cellular agriculture
Review culture

02
Hospital

Physical
Diet and healing

DNA-based diet
Hyper-customized service

03
School

Policy
Policy compliance

Urban farming
Adaptive learning

04
Fast Food

Service
Customer satisfaction

Robotics as a Service
In-person service

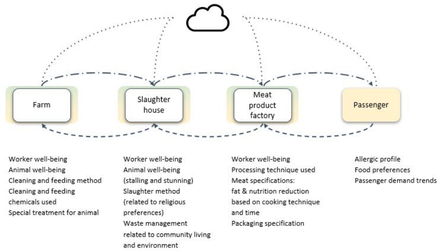
05
Vending Machine

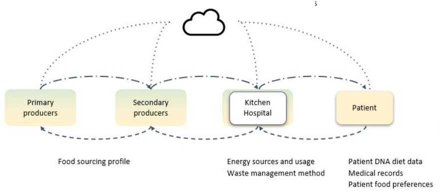
Self-service
New materials

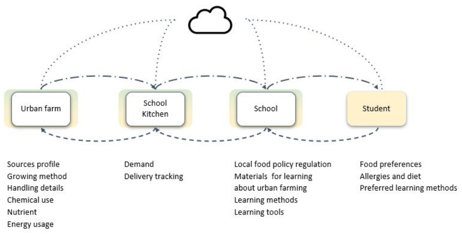
Wearable devices
Freedom of choice

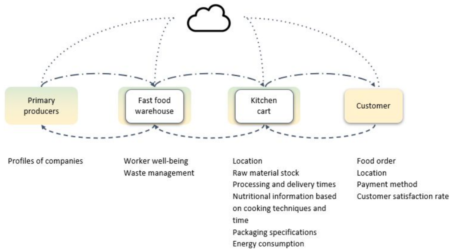
Information Flow

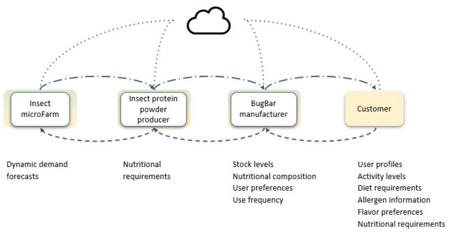
The goals of the Five Speculative Scenarios require end-to-end and in-time connectivity, transparency, and traceability. To express cultural diversity, food manufacturing must reflect continuous learning, gleaning insights on varied lifestyles, cultures, and religious expressions through primary, secondary, and tertiary production. To support goals in diet and healing, personal data can be mined to achieve precision in meeting the preferences and needs of individual consumers. Goals in policy compliance, such as sourcing local food, require end-to-end transparency and traceability across the supply chain. In the context of niche markets, information flows between consumer and provider, including in-time communication, can help ensure customer satisfaction. The use of new materials requires information flows with end-to-end traceability for food security, and personal health data can lead to precision in food production and consumption related to health and safety. Achieving high-level customization and personalization requires intense data analysis and end-to-end traceability for food security, customer needs, and sustainability.











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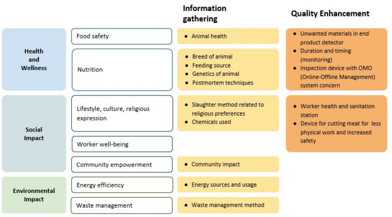
Add-On Technology

The goals of the Five Speculative Scenarios attest to the value of add-on technology applied across the supply chain to both enable a new focus on information gathering and enhance production quality in food manufacturing. Achieving cultural diversity in offerings requires specificity in the information gathered, making add-on technology in primary, secondary, and tertiary production valuable for learning about cultural preferences but also for ensuring quality. To support the goals of diet and healing, add-on technology focuses on information flow and enhancing quality as it relates to health and well-being rather than to social and environmental impacts. Complying with government policy, such as sourcing local food, requires add-on technology to support end-to-end transparency and traceability across the supply chain. Customer satisfaction requires that information flow intensively between customer and provider for reliable in-time information and communication, which add-on technology supports mainly through information gathering and precision in quality of product. The use of new materials in food involves add-on technology to support information flows with end-to-end traceability and quality of product for health and food safety. Optimization for customization requires modular fragmentation and highly flexible add-on technology to support end-to-end and in-time connectivity, transparency, and traceability–and to enhance product quality for health and well-being, as well as for positive social and environmental impacts.



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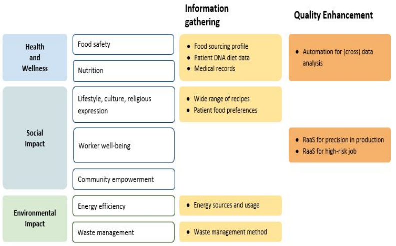

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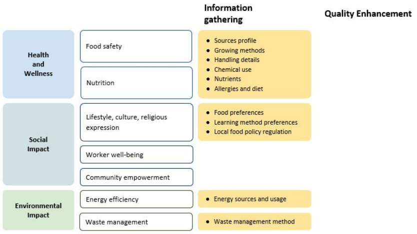

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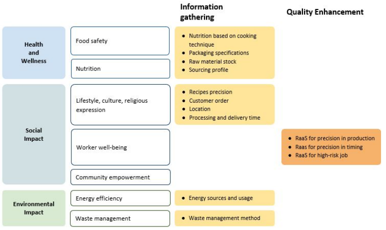

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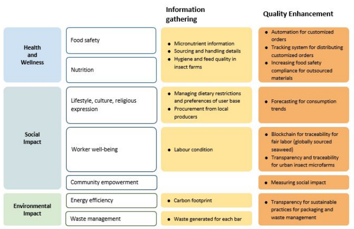

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New materials

Wearable devices

Freedom of choice

The Future of Food Manufacturing: Essential Ingredients

The pursuit of human well-being and environmental sustainability will shape the future of food manufacturing as both an economic activity and a factor in social dynamics. Institutional and customer decisions will focus on process, engaging in pre-production rather than an end product that merely reflects current review culture and the brandless trend. **Optimization that at present aims for efficiency in mass production will shift to mass customization, as customers demand highly customized products and services that demonstrate high standards–cultural diversity, health, well-being, and policy compliance.**

There are three enablers of optimization for customization:

A hybrid supply chain that operates and delivers along a wide spectrum, from low tech to high tech, agile to lean, and global to hyperlocal (showing the growth of local sources)

End-to-end and in-time connectivity, transparency, and traceability for information flows in primary, secondary, and tertiary food manufacturing, with intense data analysis in food security, as well as personal, public, and environmental data

Modular fragmentation and highly flexible add-on technology that supports end-to-end and in-time connectivity, transparency, and traceability, to enhance quality in products by aligning them with health, well-being, and concerns for the social and environmental impacts of food

March 27,2020