An Application of Systems Thinking

Food Systems

Authors: Edward Tettamanti, Mo Mansouri

School of Systems and Enterprises, Stevens Institute of Technology

Presenter: Edward Tettamanti
Contact Email: etettama@stevens.edu

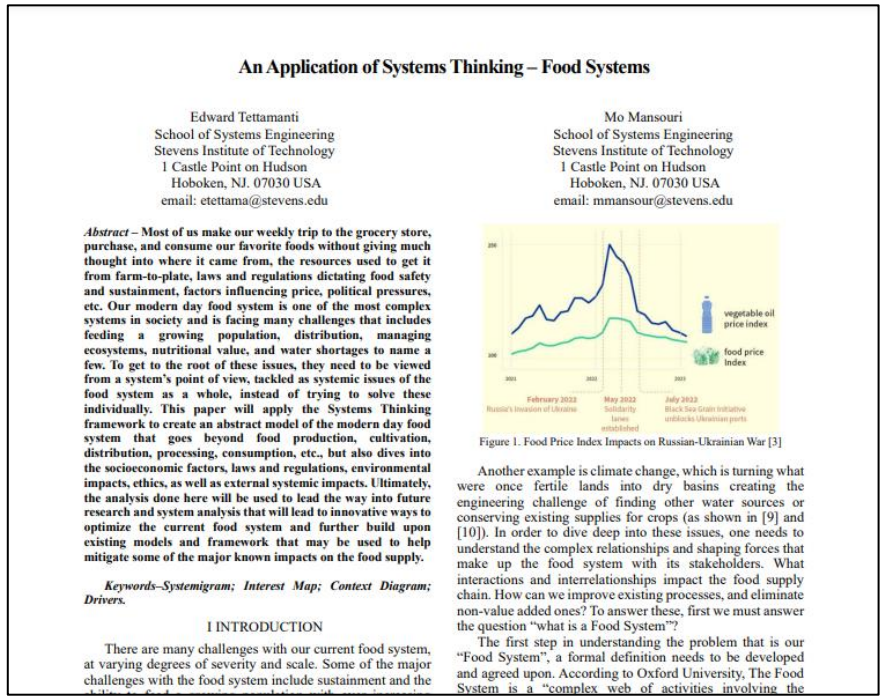
The Presenter – Edward Tettamanti

- Academic Career
  - Rutgers University School of Engineering
    - B.S. in Mechanical Engineering
    - Minor in Physics
  - Stevens Institute of Technology
    - ME in Systems Engineering
    - Concentration in Large-Scale Cyber Systems
- Professional Career
  - Raytheon Technologies (2018 – 2019)
    - Systems Engineer, Product Line Engineering, Navy Radar and Missile Defense
  - L3Harris (2019 – Present)
    - Systems Engineer, Defense/EW

STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Aims of the Paper

- The modern-day “food system” is one of the most complex systems in society that faces many challenges
  - Growing Population
  - Geopolitical concerns
  - Water Shortages
  - Prices
- The aim of this paper is to apply the systems thinking methodology to break down the problem that is our “food system”
  - Proof of concept on how systems thinking can be used to understand a system as complex as our modern-day food system
  - Begin to identify and tackle the major issues contributing to disturbances of the food supply on a worldwide scale
  - Treat these challenges as systemic issues, rather than as individual processes that require fixing (systems thinking philosophy)



An Application of Systems Thinking – Food Systems

Edward Tettamanti
School of Systems Engineering
Stevens Institute of Technology
1 Castle Point on Hudson
Hoboken, NJ. 07030 USA
email: etettama@stevens.edu

Mo Mansouri
School of Systems Engineering
Stevens Institute of Technology
1 Castle Point on Hudson
Hoboken, NJ. 07030 USA
email: mmansour@stevens.edu

***Abstract* – Most of us make our weekly trip to the grocery store, purchase, and consume our favorite foods without giving much thought into where it came from, the resources used to get it from farm-to-plate, laws and regulations dictating food safety and sustainment, factors influencing price, political pressures, etc. Our modern day food system is one of the most complex systems in society and is facing many challenges that includes feeding a growing population, distribution, managing ecosystems, nutritional value, and water shortages to name a few. To get to the root of these issues, they need to be viewed from a system's point of view, tackled as systemic issues of the food system as a whole, instead of trying to solve these individually. This paper will apply the Systems Thinking framework to create an abstract model of the modern day food system that goes beyond food production, cultivation, distribution, processing, consumption, etc., but also dives into the socioeconomic factors, laws and regulations, environmental impacts, ethics, as well as external systemic impacts. Ultimately, the analysis done here will be used to lead the way into future research and system analysis that will lead to innovative ways to optimize the current food system and further build upon existing models and framework that may be used to help mitigate some of the major known impacts on the food supply.**

Keywords–Systemigram; Interest Map; Context Diagram; Drivers.

I INTRODUCTION

There are many challenges with our current food system, at varying degrees of severity and scale. Some of the major challenges with the food system include sustainment and the

Figure 1. Food Price Index Impacts on Russian-Ukrainian War [3]

Another example is climate change, which is turning what were once fertile lands into dry basins creating the engineering challenge of finding other water sources or conserving existing supplies for crops (as shown in [9] and [10]). In order to dive deep into these issues, one needs to understand the complex relationships and shaping forces that make up the food system with its stakeholders. What interactions and interrelationships impact the food supply chain. How can we improve existing processes, and eliminate non-value added ones? To answer these, first we must answer the question “what is a Food System”?

The first step in understanding the problem that is our “Food System”, a formal definition needs to be developed and agreed upon. According to Oxford University, The Food System is a “complex web of activities involving the

This paper will not solve world hunger but will be used to establish a better understanding of the food system as a whole.

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

What is Systems Thinking

- Systems thinking can be thought of as both a philosophy and a methodology [11]
  - As a philosophy, systems thinking is using our mental capacities to seek the big picture, understanding cause and effect, understanding and acknowledging different perspectives, etc.
  - As a methodology, it provides a means of using systemic tools and a holistic approach to systems to better understand the nature of a system when treated as a whole, rather than a collection of its constituent parts. It includes tools and methods such as:
    - Perspective Analysis
    - Interest Maps and Context Diagrams
    - Identifying value-added and non-value-added processes
    - Shaping Forces
    - Systemigram Analysis
  - Systems thinking focuses on
    - Relationships among the parts that make up a system rather than the individual parts themselves
    - Recognizing patterns in the system
    - Interconnectedness

What is a Food System?

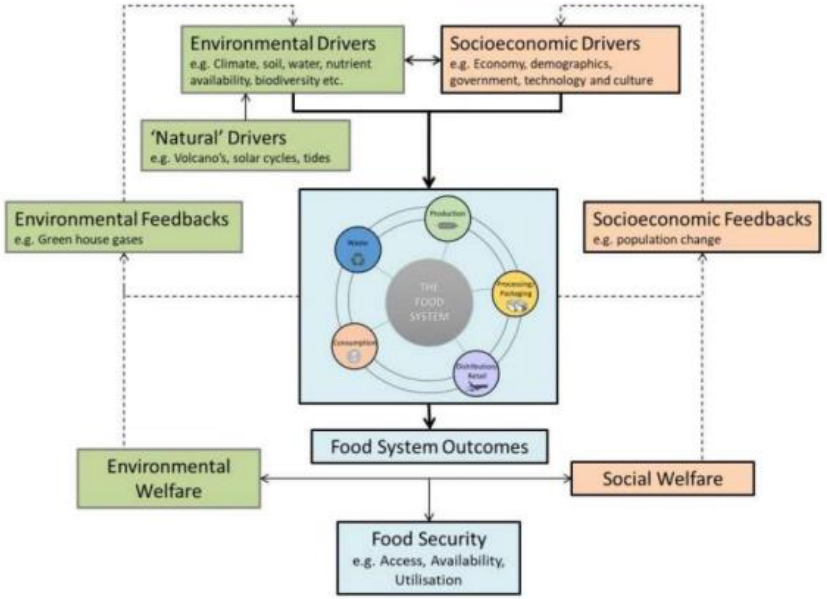


Figure. Food System Drivers [2]

- Goes beyond the processes and technology we normally associate with food systems (I.e., growing and cultivating, distributing, processing, and consuming food)
- Involves governance of food, the economics of food, sustainment of the food supply and the environment, even the current geopolitical state of the world

"A complex web of activities involving the production, processing, transport, and consumption [of food]. Issues concerning the food system include the governance and economics of food production, its sustainability, the degree to which we waste food, how food production affects the natural environment and the impact of food on individual and population health" [1].

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Stakeholder Perspective Analysis - System Considerations

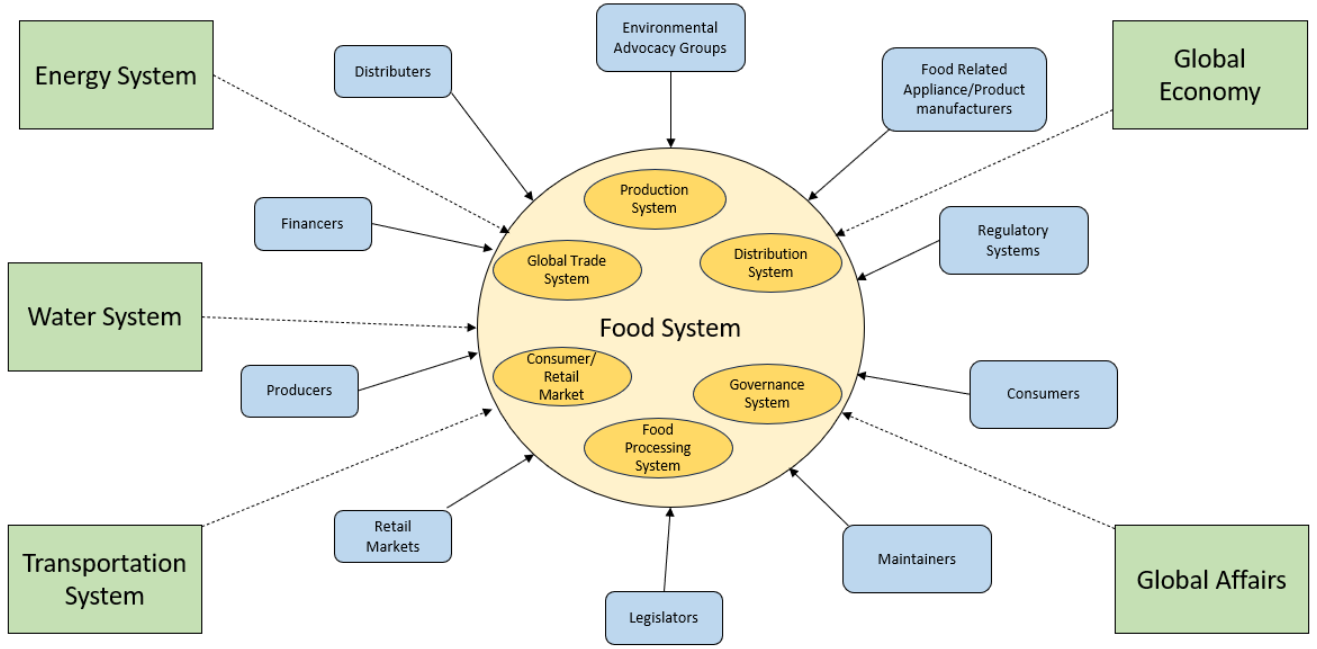
Food System Considerations	
Considerations	**Description**
Environmental	Includes anything from fertility and climate to availability of water supply, environmental welfare, and impacts on local ecosystems
Sustainability	Long term sustainment of resources, land, food supply, trade routes, etc.
Supply and Demand	Ensure a steady supply to meet demand
Costs	Costs due to production, distribution, governing, etc.
Mass Production	Mass production system that is sensitive to demand, ethical, minimal downtime and disturbances, etc.
Distribution	Distribution from trade amongst countries to grocery store deliveries down to the customer
Efficiency	Producing and distributing food costs resources, making efficient use of these resources vital to keep costs reasonable, remain sustainable, keep a steady supply, etc.
Stakeholders	See Context Diagram on Next Slide
Safety and Governance	FDA, world trade laws, etc.
Future Generations	Availability of food supplies in the future
Economy	State of economy impacts food availability and prices
Demographics	Cater food supply to regional demographics
Technology	Technology available in support of food production, distribution, etc.

- First step in stakeholder perspective analysis is identifying the key system considerations
- The table on the left lists the major food system considerations provided the definition discussed prior

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Stakeholder Perspective Analysis - System Context

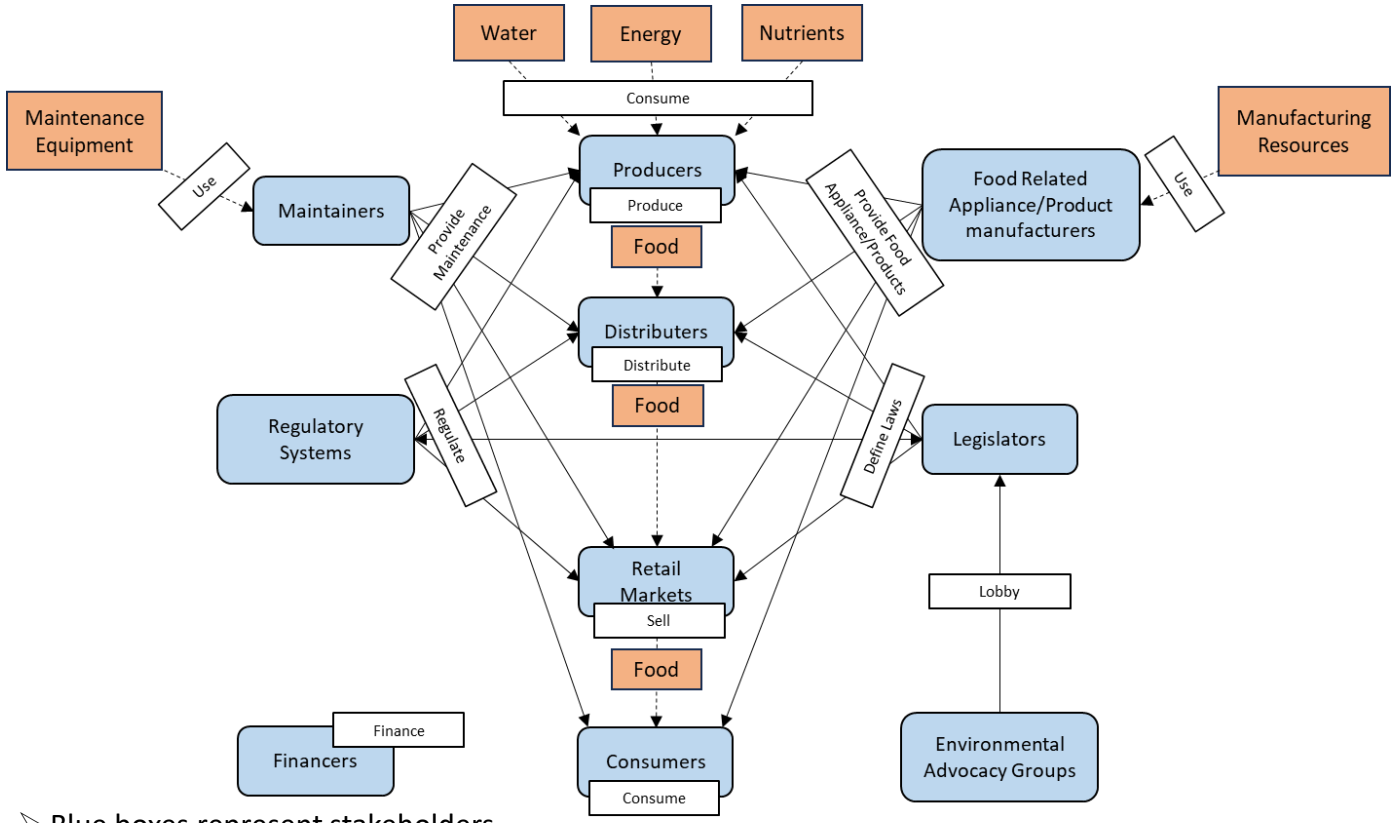
- The system boundary and external interactions are conceptualized using a system context diagram
- Represent the highest level of abstraction for the Food System



- Green Boxes indicate an external system
- Blue Boxes are external actors (stakeholders)
- Lightly shaded yellow circle represents the system boundary
- Dark shaded circles represent some of the major lower lower-level components

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Stakeholder Perspective Analysis - Interest Map



- Blue boxes represent stakeholders
- Orange boxes represent resources
- White boxes represent a behavior or action

- The diagram to the left depicts an interest map for the Food System
- Provides an early concept of System, Resource, and Stakeholder dynamic interaction

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Value-Adding Processes Analysis Stakeholder Values

Stakeholder Food System Values	
Stakeholders	**Food System Values**
Environmental Advocacy Groups	Highly Sustainable, Minimal Disturbances to Environment, Abides by all Environmental Protection Laws and Regulations, Adapts to Future Energy Trends, Provides Food for Consumption
Producers	Provide Food, Maximize Profits, Meet Demands/Needs, Feed Population, Provides Food for Consumption
Financers	Low Risk, Food Systems Related Projects and Efforts Completed With Budget and Schedule, Returns plus Interest, Provides Food for Consumption
Distributers	Resources Necessary to Distribute Goods, Follows all Laws and Regulations, Provides Goods in a Timely Manner, Maximize Revenue, Provides Food for Consumption
Retail Markets	Provide Food to Customers, Maximize Profits, Maintain Customer Satisfaction, Accessibility to Food, Provides Food for Consumption
Legislators	Satisfactory Regulatory Requirements, Provides Food for Consumption
Maintainers	Ease of Maintenance, Maximize Profits, Availability, Provides Food for Consumption
Consumers	Ease of Access, Low Cost, Nutritional Value, Variety, Freshness, RM&S of Food Appliances, Safe, Sustainable for Future Generations, Provides Food for Consumption
Regulatory Systems	Satisfies all Regulatory Requirements, Provides Food for Consumption
Food Related Appliance/Product Manufacturers	Customers/Market for Food Appliances, Maximize Profits, Sustainable, Provides Food for Consumption

Value-Adding Processes Analysis Stakeholder Perspectives

1. Growing/Harvesting Crops and Livestock
2. Trading Crops and Livestock with Other Parties of Interest
3. Distributing Food to Retail Markets for Consumers
4. Retail Markets Selling Food and Food Related Products
5. Regulators Routinely Inspecting Food at Various Points Along the Supply Chain
6. Food Preparation and Processing
7. Rotating Crops (sustainment)
8. Food Laws and Regulations
9. Water Irrigation Systems
10. Food Production Equipment Maintenance and Customer Support

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

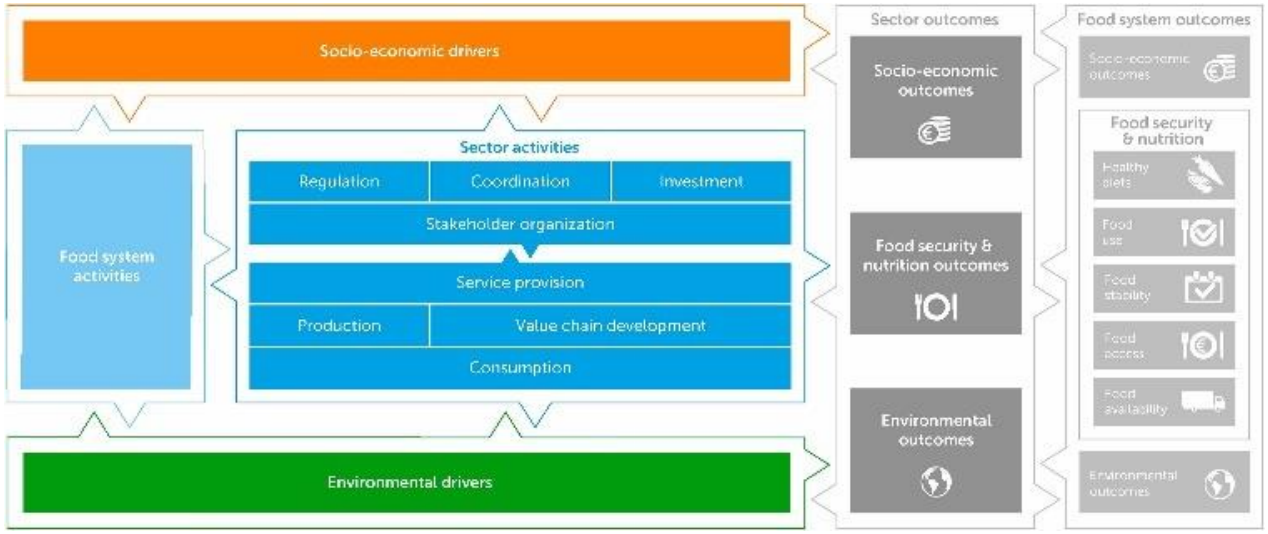
Value-Adding Processes Analysis
External System Perspectives

1. Energy System
   a. Energy is Needed to Support Food System from Production to Consumption
   b. Maximize Profits for Energy Producers
   c. Incentive for Efficient Energy use
   d. Provides Jobs
2. Water System
   a. Crops, Livestock, etc. Requires Water
   b. Maximize Profits
   c. Incentive for Efficient Water Use
   d. Provides Jobs
3. Transportation System
   a. Vital for Distributing Food
   b. Maximize Profits
   c. Provides Jobs
4. Global Economy
   a. Maintaining low food prices reducing food price index which has positive effect on global economy
   b. Lower food prices allow for better quality food in impoverished nations
5. Global Affairs
   a. Trade binds nations
   b. Food variety around the world

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Analysis of Shaping Forces
Integrated Food System Framework

- State of Global Economy
- State of Global Climate
- Human Population
- Latest Nutritional Guidelines
- Food Market
- Geopolitical Environment (wars, unrest, etc.)
- Cultures
- Technology
- Resource Availability
- Water
- Energy
- Environments



Integrated Food Network [2]

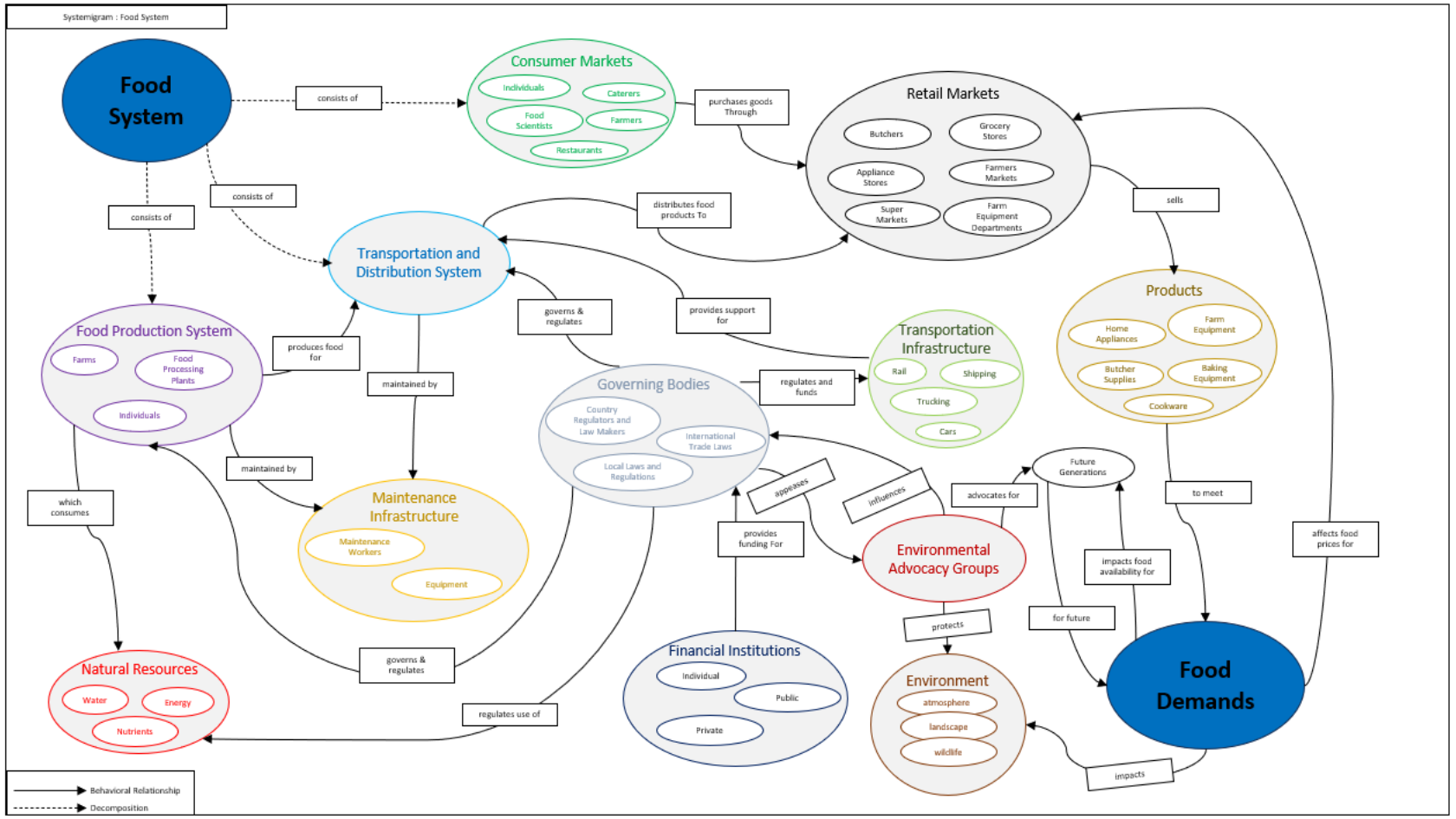
STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Analysis of Shaping Forces
Missing Value-Added Processes

- Integrate agricultural efforts with the existing landscape, as opposed to reshaping the landscape [4].
- Implement cultivation techniques that minimally disturbs or impacts fertile soil
- Raising livestock in a more ethical manner
- Utilizing green energy where applicable
- Purchase and consume from local markets (removing middle-man)
- Re-establish nutritional guidelines more frequently
- Incentivize locally produced food
- Create programs that allow for selling/giving away unused food

STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Systemigram Analysis



STEVENS INSTITUTE of TECHNOLOGY
1870
THE INNOVATION UNIVERSITY

Conclusion and Future Work

- Conclusion
  - Applied the systems thinking methodology to characterize the modern-day food system
    - Case study/proof of concept
    - Established formal definition and system context for the food system along with stakeholder perspectives
    - Defined high level system behavior and interactions, along with value added processing and shaping forces
- Challenges and Limitations
  - Characterizing an extremely complex, widely scoped system
  - Establishing system boundary (requires further refinement)
  - Highly abstract
  - Future Work and Other Areas of Research
    - Further decomposition of the food system
    - Further cause and effect analysis on known systemic issues
    - Apply M&S to predict and validate system behaviors

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

References

[1] University of Oxford, “What is the Food System?,” Future of Food, https://www.futureoffood.ox.ac.uk/what-food-system [retrieved: October, 2023].

[2] G. D. Borman, et al., "Putting food systems thinking into practice: Integrating agricultural sectors into a multi-level analytical framework," 17 November 2021. [Online].Available: https://www.sciencedirect.com/science/article/pii/S221191242 1000997. [retrieved: October, 2023].

[3] European Council, “How the Russian invasion of Ukraine has further aggravated the global food crisis,” www.consilium.europa.eu. https://www.consilium.europa.eu/en/infographics/how-therussian-invasion-of-ukraine-has-further-aggravated-theglobal-food-crisis/ [retrieved: August, 2023].

[4] B. Sonja, et al., “Sustainable Agriculture | Learn Science at Scitable,” Nature.com, 2011. https://www.nature.com/scitable/knowledge/library/sustainabl e-agriculture-23562787/. [retrieved: October, 2023].

[5] Ali, H. B., Mansouri, M., Muller, G., & Salim, F. A. Supporting Systems Thinking Application by Data Analysis. [retrieved: October, 2023].

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

References

[6] N. Carter and M. Mansouri, "Safety Management Complexity: A Systems Thinking Approach," 2022 IEEE International Symposium on Systems Engineering (ISSE), Vienna, Austria, 2022, pp. 1-6, doi: 10.1109/ISSE54508.2022.10005353. [retrieved: October, 2023].

[7] Engen, Siv & Mansouri, Mo & Muller, G.. (2019). Application of system thinking to frame the problem in a subsea development projects with high-level business requirements. 10.1109/SYSOSE.2019.8753859. [retrieved: October, 2023].

[8] M. Kjørstad, M. Mansouri, G. Muller and S. Kjenner, "Systems Thinking for Early Validation of User Needs in the Front End of Innovation; a Case Study in an Offshore SoS," 2019 14th Annual Conference System of Systems Engineering (SoSE), Anchorage, AK, USA, 2019, pp. 382-387, doi: 10.1109/SYSOSE.2019.8753865. [retrieved: October, 2023].

[9] Sabbaghi, M. A., Nazari, M., Araghinejad, S., & Soufizadeh, S. (2020). “Economic impacts of climate change on water resources and agriculture in Zayandehroud river basin in Iran”. Agriculture Water Management, 241. https://www.sciencedirect.com/science/article/pii/S037837741 930842X?casa_token=A8X0P6y48i4AAAAA:9H_5ZGlnzAu FzP6EKFSpjF_hQ3Sr7fU2ooS8TfQGv2N9VB8LTG2t_TzjFb3SxBFYQSF-SbSLIg [retrieved: October 2023]

[10] Prosser, I. P., Chiew, F. H., & Stafford Smith, M. (2021). Adapting Water Management to climate change in the murray–darling basin, Australia. Water, 13(18), 2504. https://doi.org/10.3390/w13182504[retrieved: October 2023]

[11] Boardman, J., Sauser, B. (2008). Systems Thinking: Coping with 21st Century Problems. United States: Taylor & Francis.

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY