Mission SDGs Through Food Waste Management: Nature and Approaches

Arindam Chakrabarty and Uday Sankar Das

Abstract The global fraternity has been embarrassed to understand how to feed the elephantine population of this planet. The greed of comfort, convenience, and technology ecosystem has mesmerized our life in such a fashion that the human society has been up-rooted from the nature. The wave of infrastructure development results in heavy encroachment of fertile land as well as yielding to regressive fertility of land. On the contrary, the society has not learned to optimize the utilization of resources whatever forms it may be. These compel the United Nations to formulate specific target-oriented Sustainable Development Goals that need to be achieved by 2030. Food waste is still a menace of mankind. It may be of many forms and dimensions. Food waste exists in every phase of supply chain. Most surprisingly, the stigma of this menace reaches to our household also. The irony of life is that, on one hand, we are habituated to accept that wastage in foodstuff as part of our livelihood, and on the other hand, the United Nations reveals its concern for poverty, hunger, and many other unaccomplished goals. The world is now on the verge of Fourth Industrial Revolution. The IoT-based ecosystem has been emerged as an inseparable entity of the modern societies. This paper has attempted to assess and account the loss of economy for wastage of food items from global canvas to national perspective. This study has also focused on how to use IoT platform so that the food wastage can be reduced up to a considerable amount both in the supply chain and even in household practices. This research work is based on secondary information like research papers, reports, and results of other relevant studies. The paper has attempted to develop and devise a conceptual and strategic model where the IoT ecosystem can be incorporated to ensure real-time solutions and to curb on massive food wastage practices. If the model is implemented and practiced with appropriate case specific modifications

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and customizations, it would make the economy more efficient and address different perspectives and dimensions of UN Sustainable Development Goals (UNSDGs) to a larger extent primarily in Indian Context.

Keywords Food waste management · Supply chain · Fourth Industrial Revolution IoT ecosystem · UNSDGs · India

1 Introduction

The journey of human civilization started with the ignition of fire, invention of wheels, and creations of indigenous tools and techniques through the passage of various ages. Today, we are in the age of information automation and moving toward Fourth Industrial Revolution. The success of our human civilization is based on key primary needs, i.e., food, clothing, and shelter. However, this is the irony of life that in spite of achieving various developmental indicators, the human society is still unable to fulfill the basic needs like food which is reflected in various literatures, research outcomes and from the experiences of reality. To cater the critical issues, the United Nations move ahead from achieving Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs) where poverty and hunger were given primary thrust.

1.1 Food Waste Across the Globe

Around 1.3 billion tonnes of food produced gets wasted globally which account to around one third of the food produced. A whopping US$680 billion and US$310 billion are lost in the industrialized countries and developing countries, respectively. A 670 and 630 million tonnes of food are wasted for industrialized countries and developing countries. Perishable items like fruits and vegetables account for the highest losses post-harvest. Food loss and food waste per year are roughly account to 20% of oilseeds, 35% for combined for meat, dairy and fish, 30% for cereals, and 40–50% for root crops. Per capita food lost or wasted every year is between 95 and 115 kg/year in Europe and North America. While 6–11 kg a year is wasted in countries of South-Eastern Asia and sub-Saharan Africa. A 40% loss of food items occur at post-harvest or at processing level in developing nations, and same amount is lost at retail and consumer levels in industrialized nations (Table 1; Fig. 1).

Table 1 Per capita food losses and waste (kg/per year), at consumption and pre-consumptions stages, in different regions [1]

Region	Production to retailing	Consumer
Europe	187	94
North America and Oceania	181	115
Industrialized Asia	165	70
Sub-Saharan Africa	159	7
North Africa, West and Central Asia	181	31
South and Southeast Asia	115	13
Latin America	198	24

Adapted from key finding of Food and Agriculture Organization of the United Nations

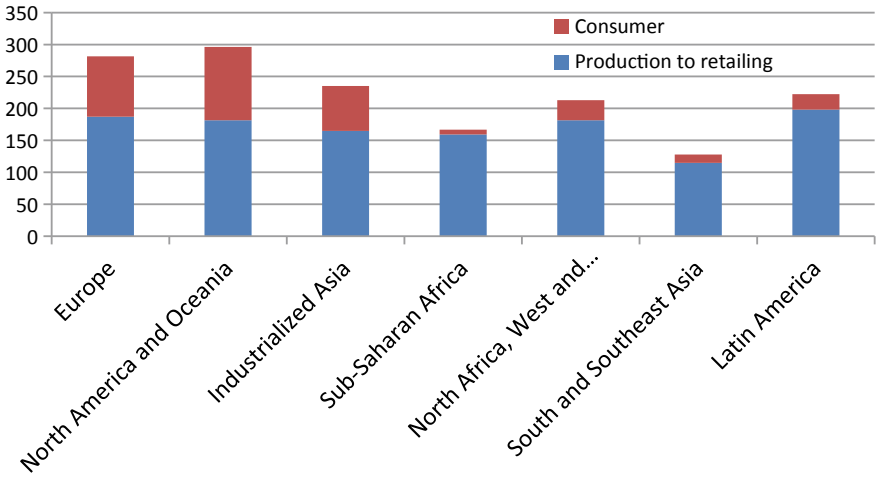

Fig. 1 Per capita food losses and waste (kg/per year), at consumption and pre-consumptions stages, in different regions (adapted from key finding of Food and Agriculture Organization of the United Nations) [2]

1.2 Food Waste in India

India has adorned the developing nation tag since the dawn of independence and is at the frontiers of food loss and food waste. India is ranked at 103 in the latest Global Hunger Index [3] report published in 2018 while a large section of the population still live below poverty line (21.92% of the total population as per RBI data published on Sep 16, 2015) [4] bureaucratic loopholes and intentional ignorance towards the issue has kept the problem alive till date. FCI, a premier food distribution corporation and a state owned utility is yet to fix the grain drain problem. It is reflected in numerous news reports that the food loss by FCI was in the tune of 1.94 lakh MT food grain that had been wasted between 2005–2013 [5]. Apart from this, India still lacks organized

cold storage facilities or processing plants within proximity of farmers producing perishable food items like fruits and vegetables.

1.3 Socio-economic Impact of Food Waste in the Context of Sustainable Development Goal

The Global Hunger Index [3] of 2018 point a staggering 124 million people across the globe suffer from acute hunger due to malnutrition, internal displacement, refugee status and poverty. Four of the total 17 goals prescribed by the United Nations SDGs focus on Poverty, Hunger, Good health and wellbeing, and responsible consumption and production (Goal 1: No poverty; Goal 2: Zero hunger; Goal 3: Good health and well-being; Goal 12: Responsible consumption and production). Food loss [6] is the primary reasons why most of the developing world still suffers from malnutrition and hunger which is caused by poor storage and processing in the post production phase and developed nations are highest contributor towards food waste [6] due to fast pace life, irresponsible and ignorant behavior towards the issue. While the former can be solved by application of technology and infrastructure management the later can be solved by improving upon the social physiological behaviors of the masses.

1.4 Introduction to Fourth Industrial Revolution

The term Fourth Industrial Revolution or 4IR [7] was coined by Professor Klaus Schwab, founder and executive chairman of the World Economic Forum in his book "The Fourth Industrial Revolution" based on the technologies of the artificial intelligence, machine learning, quantum computing, 3D printing, and the IoT. Around the year 1760, First Industrial Revolution started in Great Britain, which was powered by the invention of steam engines. Almost a century later, Second Industrial revolution started which was characterized by mass production (from craft-oriented production to mass production) in various industries like steel, oil, and electric. Some of the greatest inventions like internal combustion engine and light bulb came through in the same period. The Third Industrial Revolution or "The Digital Revolution" started somewhere around 1960s powered by the greatest inventions of the century, semiconductor chips, which gave rise to personal computing and eventuality made the Internet a real possibility. Now, 4IR is knocking on the doorsteps of humanity which will eventually change the way we eat, live, think, or nearly everything we do to sustain our life.

2 Literature Review

The unprecedented developments in the fields of digital, physical, biological technology are the three major drivers of the Fourth Industrial Revolution. There is an attempt to understand the impact of these technologies on various global, industrial, economic, and social developments [8].

One quarter of the food supplied for human consumption is wasted across the food supply chain. High-income countries generate food waste at all levels including household which is the highest. The study gathers data from 1062 Danish respondent measuring the intention and attitude not to waste food. Food waste can be controlled by making perceived behavioral control [9].

Sustainable Development Goals (SDGs) are successor of Millennium Development Goals (MDGs). It proposes 17 goals with 169 targets with numerous indicators [10].

Large-scale food waste in the global food supply chain has attracted attention due to its environmental, social, and economic impacts. There has been an attempt to understand the difference between food surplus, avoidable and unavoidable food waste by various specialist, to manage the waste, and to identify the most appropriate mechanism to create a sustainable supply chain management. There is also an attempt to understand and distribute the food surplus to poor people or to convert it as an animal feed [11].

The UN organization, Food and Agriculture Organization estimates a 32 percent loss of food produce in 2009 based on weight while a 24 percent in terms of calorie. Food wastage has negative impact on economy, and it represents a wasted investment, consumer expenses, and farmers' income loss. While food loss refers to losses incurred due to spills and spoils, food waste refers to losses due to infrastructure limitations or post-consumer waste which is generally fit for consumption. Food waste is generally a conscious decision to throw away the food [12].

Wireless sensor network (WSN) surrounds all living beings in the modern era and influences day to day living. A communication between all these wireless-enabled network creates the Internet of Things (IoT) to form a seamless environment to create a common operating picture (COP). The IoT has evolved from the static web2 (social networking web) to web3 (ubiquitous computing web) increasing the data demand [13].

Continuous population growth will keep a continuous demand for food supply for another 40 years approximately, while there will be a decrease in the capacity to produce food due to overexploitation of land and other natural resources including a threat from climate change. However, a more efficient ways of food production can be explored [14].

In order to feed the nine billion human populations by 2050, a review of food waste in the global supply chain is discussed. Data of post-harvest losses of grains are outdated, and current global losses are unknown. The impacts of food waste in the development of BRIC economies are also unknown while developing nations face food wastage post-harvest due to its perishability developed countries contribute to

high post-consumer food wastage which suggest a scope for behavioral change to reduce wastage in affluent population [15].

There is an attempt to understand the link between inflation in food prices and riots or food riots. Demonstrators of the riot pointed political repression injustice and inequality which mobilized and bought together various political coalitions to promote human dignity [16].

Electronic nose has been a trending technology for the last two decades largely due to numerous applications built around the sensors. Recent changes in the computing power have given the electronic nose a new possibility of various applications. It has provided a numerous benefits in the fields of biomedical, agricultural, environmental, food, cosmetics, manufacturing, military, pharmaceutical, and various scientific researches. Now, electronic noses can monitor all phases of industrial manufacturing [17].

An introduction to radio frequency identification systems and their strength, weaknesses along with deployment challenges is discussed along with various extensions that offer read/write memory and environmental sensing along with social issues [18].

Electronic noses (e-noses) are sensors that can detect various volatile organic compounds. A wide range of applications can be designed based on pattern recognition with the help of artificial intelligence or neural network. The future trend of the sensors is also explored [19].

3 Objectives of the Study

1. To explore varied forms of agriculture food loss at different stages up to the phase of consumption.
2. To provide an IoT-based solution for reducing food waste to a considerable amount primarily in closed system or household condition.

4 Research Methodology

This paper has attempted to understand, study food waste and its impact in the global context, provide solution through existing technological framework (IoT and electronic nose), and achieve related SDGs. This paper has been developed using secondary information collected from various relevant sources and documents. The paper has focused on how a technological solution would help achieve sustainable development goals of the United Nations by 2030.

5 Analysis and Interpretation

Analysis I

The various forms of agricultural food loss can be expressed by using the flow chart diagram as mentioned below.

Loss of Agricultural Produce at Farming Stage

- Agriculture food loss starts at the very beginning when farmers produce crop without adequate planning and sharing information among the producer's community and other stakeholders, and as a result of that, food loss occurs with overproduction of crops [20].
- Farmers harvest their crop prematurely for his personal consumption or to earn money. This accounts both the economic and nutritional loss of food grains [20].
- Massive use of pesticides and fertilizers diminishes the nutritional value of the food grains, and at times, it could be deterrent to human life.

Loss of Agricultural Produce at Transportation/Supply Chain

- During the movement of crops or food grains from field to warehouse or market, there are several supply chain/transportations loopholes like lack of refrigeration system, using FIFO technique or VED analysis (Valuable, Essential, and Desirable) (Fig. 2).

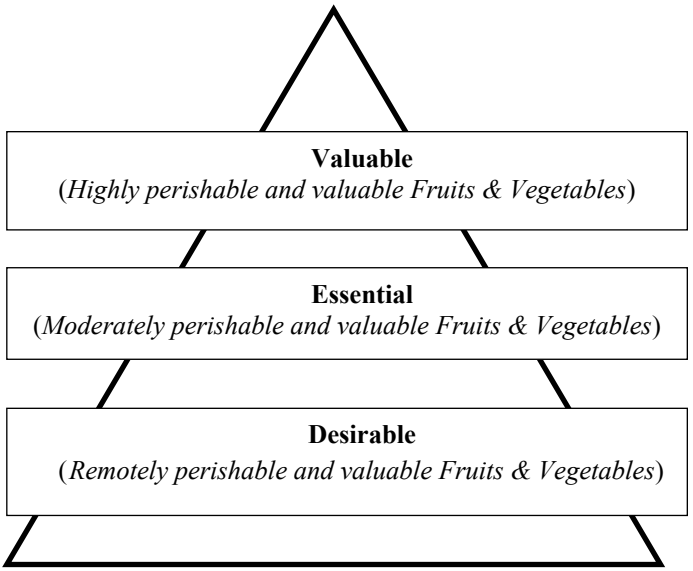

Fig. 2 Schematic diagram of application of VED analysis

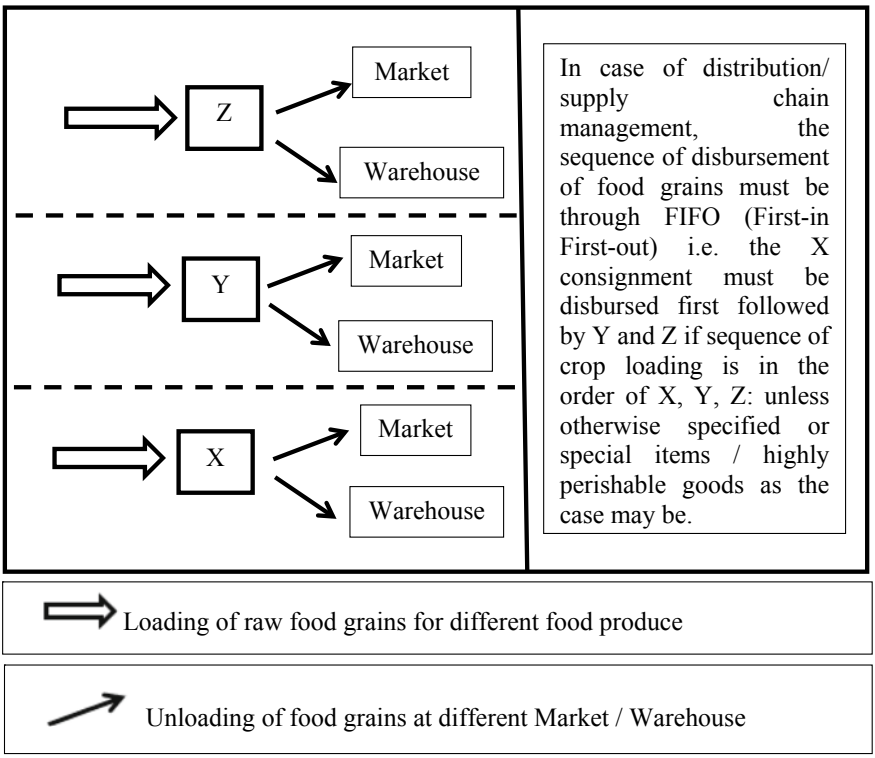

Fig. 3 Schematic diagram: application of FIFO method

Loss of Agricultural Produce at Warehouse/Cold Storage

See Fig. 3.

Loss of Agricultural Produce at Market Place

- In course of selling of food grains in the market, it is difficult to predict actual demand for each variety of food grains or crops. As a result of that, there is substantial loss of food grains in the market places which could not be sold at all or may be sold at a tendered expiry mode.
- In fact, accurate demand forecasting for every set of crops is next to impossible due to uncertainty of market dynamics and impulse purchasing behavior of the consumer.
- Lack of adequate refrigeration and cold storage system.
- Lack of Warehouse facilities.
- Due to excessive overproduction of crops, it results in higher storing cost and stagnation of crops which yield loss of food value, nutrition, and economy (Fig. 4).

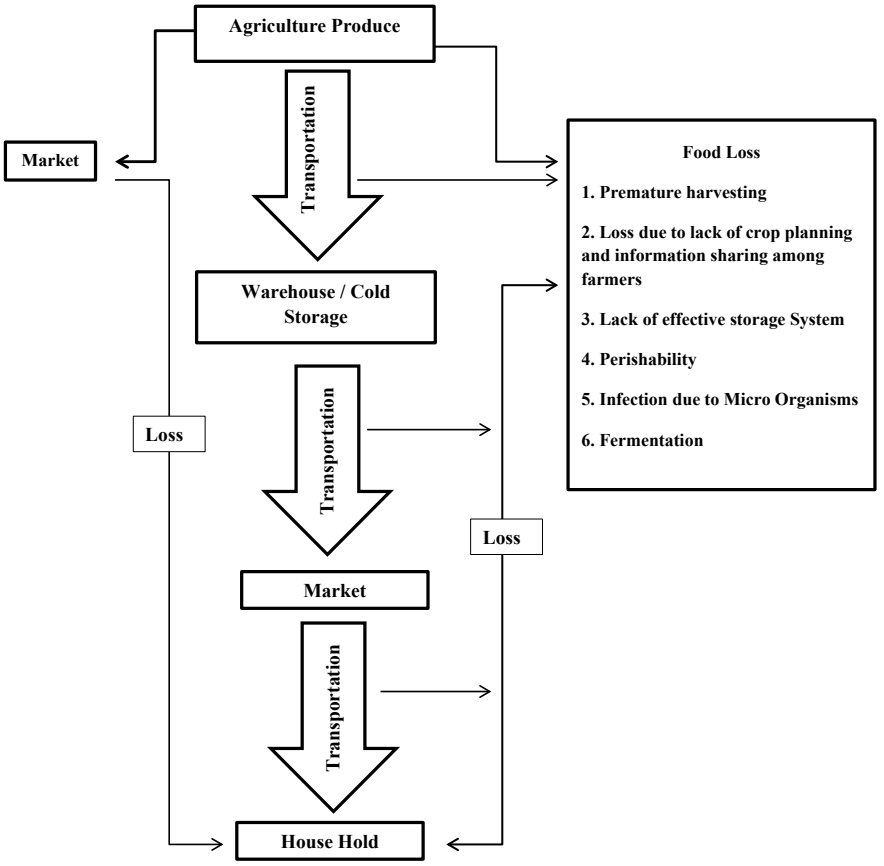

Fig. 4 Schematic diagram of food wastes at various stages

Loss of Agricultural Produce at Household

- Various ways of food waste take place at the household level both in uncooked and cooked format.
- The loss of uncooked produce is primarily because of oversupply of vegetables or food grains due to lack of ready information about the food reserves in the household. From lower middle class and above category, the family depends on household refrigerators for the purpose of preservation of food grains, vegetables, etc.
- The loss of cooked food occurs due to overestimation of perceived demand of food for day to day domestic consumption. This loss can be managed by experiential learning of the household and commitment of the members toward sustainable use of resources.

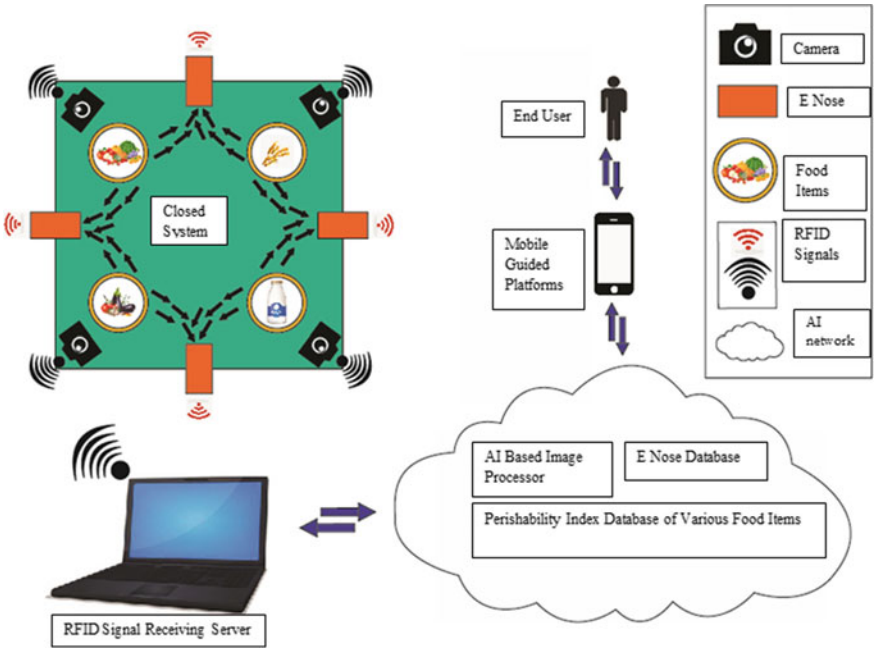

Fig. 5 IOT-based solution for reducing food waste primarily in closed system or household condition

- In fact, the loss of uncooked produce at the household level may be solved with appropriate smart in-house storage system and economic usage mechanism led by IoT intervention.

Analysis II

See Fig. 5.

Indicative algorithm for the model

1. The confined storage system (e.g., household refrigerator) needs to be augmented by multiple IoT devices that would act as E-Nose and E-iris as a means of sensory devices.
2. The IoT, E-nose and E-Iris would be provide adequate database for image processing for with pigment support (e-iris) and aromatic database (e-nose) on each specific food grains and vegetables generally stored in the system.
3. The sensory device will receive appropriate stimuli both aromatic and pigment and that would process using IoT, intelligence system (AI) by matching the preset database and finally the system would generate its predictive analytics about the nature of food produce stored in the system.
4. The processed results would be transferred at all the connected portals with the IoT ecosystem on real-time basis so that the user can be aware of the quantity and quality of each of the variants food products.

5. Based on this input, the user can take most appropriate purchase decision for further procurement of food grains, i.e., the set of variants to procure or not to procure and at what quantity. This real-time information would enable the household to prioritize which vegetables to cook immediately on priority basis in order to minimize both the nutritional and economic losses.

6 Conclusion

Food waste management has multiple implications on society as well as its economy. The world is highly apprehensive on the issues of food security, fertility of land, and nutritional benefits for upbringing off the human civilization. The sustainable development goals firmly advocate that poverty, hunger, and responsible production and consumption are the few integral dimensions which need to be improved if the world would like to achieve the essence of sustainability. Whatever the policy is formulated at macro level, finally the success depends on what extent it has been implemented and practiced at the very micro household level. This paper has emphasized on developing a sustainable solution to address the food loss issues at the household level with the intervention of IoT led smart technology.

Limitation of the Study

This paper has designed and developed a strategic solution in order to combat household syndrome. However, if the model is efficiently implemented, the degree of minimization of food loss could be explored so that the impact of the model could be studied, and necessary improvement on the structural morphology could be incorporated.

Working definition:

e-nose: An electronic nose is used to identify odors by detecting the "fingerprint" of a chemical compound using pattern recognition software [21].

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