A Mobile-Centric Conceptual Framework for Food Security Assessment

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Food security is a critical research area with significant implications for population well-being and sustainable development. Existing standards, procedures, and methodologies for food security assessment mainly rely on indicators defined at the national level and derived from macro-level data. In this paper, we propose a mobile-based solution that enables real-time assessment of food security through indicators computed at multiple levels, including individual, household, regional, and national scales. The proposed solution models the interaction between food producers, retailers, and consumers, allowing data aggregation and analysis at the national level. Data are collected from heterogeneous sources - such as sensors, Internet of Things (IoT) devices, human input, and open data sources - using diverse formats. These data are normalized and aggregated through a dedicated processing component. Based on these elements, the paper introduces a conceptual architecture that integrates data acquisition, processing, and indicator computation components within a unified mobile-centric framework. The main objective of the proposed architecture is to increase transparency and enhance individual awareness, thereby supporting informed decision-making related to food security.
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1 Introduction

Food security is a domain of research concerned with the level of availability and access of population to food so that a normal way of life is assured. Interest in this area of study has grown in the past years because of the rapid growth of population and climate changes that threaten agricultural areas. There are numerous studies at national and international level regarding food security strategies and policies [1], [2], [3].

Mobile devices have a range of application from entertainment, commerce, education or social interaction with a strong integration with cloud computing [4]. The fast rate of adoption of mobile devices and expansion of mobile data networks make them suitable for tasks that require data collection directly from the field. The ecosystem that revolves around mobile applications also creates an opportunity to broadcast information packaged in a digital form to create awareness on topics of interest.

In this paper, we propose a mobile solution and architecture for measurement of food security indicators. There are several mobile solutions that provide information regarding the food security status at a regional or national level. Our objective is to propose a solution that deals with all levels: individuals, households, regional and national. It also integrates the food producers and sellers, to have a holistic view over this strategic aspect. The producers and sellers provide data to public and private organizations.

A mobile solution is appropriate for this objective, given that the number of mobile users worldwide is over 5.5 billion, according to [5], that representing about 71% of the world population.

The paper is structured as following. In the first part, a literature review is performed to analyze the field of study and present the current state of art in the domain. The second part consists in a classification of indicators and approaches for measuring food security done in previous research papers. The third part describes the process of data collection. An architecture is proposed for data gathering and data publishing via mobile applications. Results are discussed along with conclusions and future work.

2. Literature Review

According to [6], food security is concerned with access for all people, in any moment to nutrients that allow a healthy and active life. Food security measurements may be at a global and national level or may refer to household and individual level. On the other hand, food insecurity evaluates the risks of individual to be in danger of not having the necessary supplies to obtain food for a healthy way of living. The Global Food Security Index (GFSI) is a composite indicator that evaluates food affordability, availability and quality and safety for 113 countries [7]. Each dimension consists of several indicators that are composed in a score from 0-100 where 100 is the best. In 2022 Romania ranks on the 45 places. The evolution of the score is depicted in Figure 1.

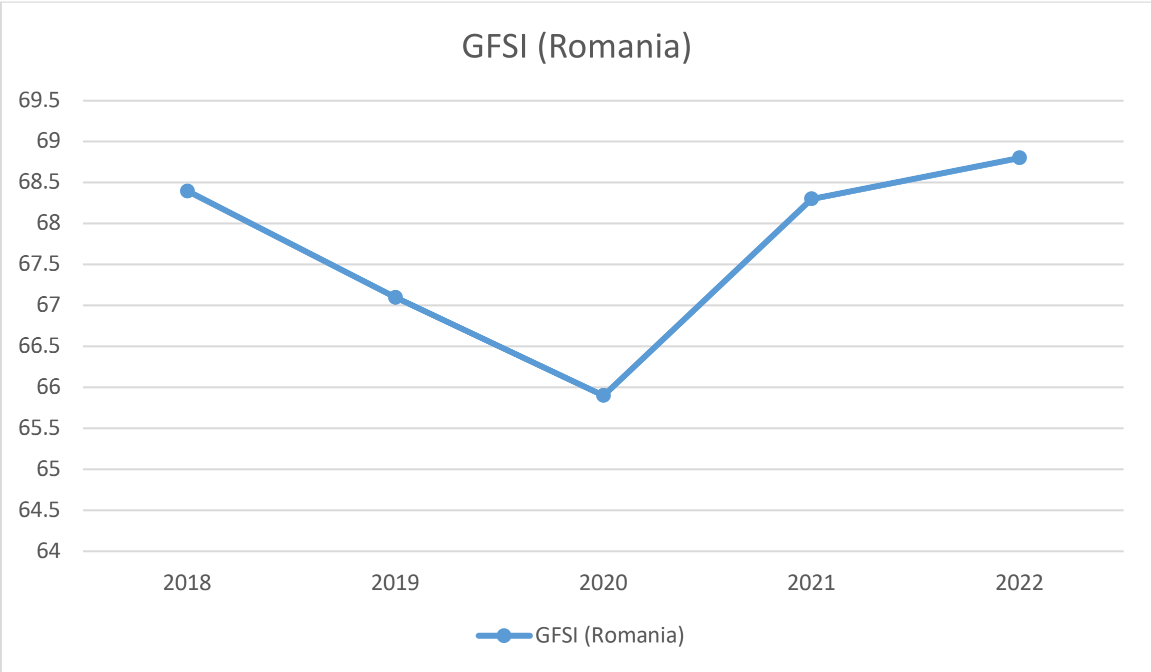

Fig. 1. Romania scores on the Global Food Security Index [7]

Food security, safety and quality is considered one of the strong points for Romania as per alignment with the certification standards in the European Union [8]. The weak point, according to the report, is volatility of agricultural production due to low development of agricultural infrastructure. While the tool provides a great overview on the macro level, allowing trend analysis and comparison between countries, specific data on national level for households and individuals is required to plan interventions in areas where people are more likely to experience food insecurity. In our country the national strategy regarding food security and safety was published in 2014 by The Romanian Academy [3]. The document includes 10 strategic objectives for 2016 – 2035 period based on the analysis of strengths, weaknesses, opportunities and threats (SWOT).

We further investigate what technologies are used in the food industry for data gathering, analysis and presentation. Technologies investigated are RFID, Wireless Sensors Network, Geographical Information Systems (GIS), blockchain, cloud computing, artificial intelligence. Mobile devices have boosted Internet use in the past years with convergence of multiple technologies like 4G networks, decreasing device prices and access to cloud computing resources. Application driven development has led to a rapid increase in the mobile ecosystem with platforms that allow social interaction, media distribution, entertainment, e-commerce, mobile payments and resource sharing systems like AirBnB or Uber. Future implementation of 6G networks

[9] and Internet of things [10] will allow even greater connectivity while providing access to real time data gathering directly from the field. Rolling out of artificial intelligence algorithms aims to increase the productivity and are considered to reshape the job market by replacing mundane tasks that can be easily automated.
In [11], the authors illustrate the complexity of measuring food security due to its evolving definition and the inter-disciplinary approach to researching this topic that leads to multiple interpretations. Usually, food security metrics fall in one of the three dimensions of availability, access and utilization. Food availability metrics measure the quantity of calories available to a population. The idea of access refers to either physical or economical access to basic food supplies. In the utilization category we find metrics that evaluate allocation of food in households, nutritional quality of the food and impact in the individual diet.
In [12] is proposed a mobile solution for collecting food security in Central African Republic. The authors developed a mobile application for information gathering regarding vulnerabilities related to malnutrition, access to resources and ability to cope with living conditions. Satellite data regarding weather, soil and humidity was correlated with information gathered from households to demonstrate the proof of concept, technical feasibility and application of listed technologies. Results show that mobile technologies are suitable for data collection in a flexible, efficient and user-friendly way.
Tracking the food supply chain is a challenge due to the complex ecosystem of parties involved in the process. Technologies like Radio Frequency Identification (RFID), wireless mobile sensors and geographic information systems are proposed for monitoring food quality along the distribution chain in [13]. Authors asses the challenges in applying mobile technologies by evaluating technical and non-technical problems. In [14] a real time RFID enhanced haulage monitoring system is proposed for collecting data from trucks transporting perishable comestibles such as fruits, vegetables, dairy products, wine etc. Cost optimization remains an important challenge when designing a complex system because of the amount of data that is transferred daily via the mobile network.
Recent research is focused on practical applications of ICT in food security with case studies and lessons learned. In [15] the food security system in Karnataka, India is analyzed. State intervention in terms of an anti-poverty scheme named Public Distribution System (PDS) is rolled out by making use of ICT that prevents misuse of the program resources. The system is composed of a back-end process that manages the supply chain and a front-end component that allows biometric tracking of the beneficiaries.
ICTs enables better traceability of the food supply chain [16], but impose limitations regarding trust, accountability and security of information exchange [17]. In [18] a blockchain and IoT based food traceability is proposed that would reduce the risks of data corruption that arise when dealing with centralized database systems either by bad intentions or system malfunction. In [19] authors show how easy RFID tags can be manipulated and how vulnerabilities might be exploited. Blockchain is a technology that relies on decentralized computing where no single actor can manipulate data due to the existence of a transaction ledger that is distributed between all the participants sustaining the network.
Software architecture describes the overall components of the information system and relations between components. Software implementation projects are preceded by a design activity that can be formally documented [20]. In software development the concept of architecture is constantly evolving with the emergence of new technologies and design patterns [21]. System level architecture may be centralized with a single source of truth or distributed among different data centers with parallel processing capabilities [22]. Mobile application-level architecture is comprised of storage units like relational or non-relational databases, data access layers and graphical interfaces that allow users to retrieve, create, update and delete information [23]. In order to propose a mobile solution for food security

measurements we further analyze the types of indicators and data collection process.

3. Research methodology

We used applied research with the main objective to increase transparency among individuals for better awareness regarding food security by designing a solution accessible to all mobile users.

Mobile application development is an iterative process that starts with the envisioning of the high-level architecture of the solution. A qualitative assessment of the domain is initially performed to define the scope of the application. Further on, main actors of the application are identified so that an appropriate user experience is assured. Sources of data are analyzed to select suitable technologies for implementation and to create a data model for the developers to use in the implementation phase.

To achieve this objective, the following activities will be carried out:

- analysis of existing food security standards and regulations;
- analysis of the current food security indicators and measurement procedures;
- analysis of the application domain, related to food security indicators and measurement, at various levels;
- proposal and validation of new indicators related to food security;
- proposal of an architectural model and validation ways through experience with its use.

The proposed architectural model will be implemented, and its validation will be discussed in future work. Formal requirements are elaborated by confronting the proposed architecture with the parties involved and feature prioritization is performed with data collected from the beneficiaries. The results of the analysis are presented through the following sections of this paper.

4. Food security indicators

As we analyzed several research papers, reports and strategic documents we can classify food security indicators on individual, household, regional and national levels.

Each ***individual*** has different standards of living and personalization is required when addressing food security. Mobile applications that allow tracking of eating habits, food nutrients and calories are already available in app stores for the public use, but these applications are in general owned by private companies and data is not open for analysis. Also, the resulted data is not provided and aggregated at regional or national level to track the population health status.

Beside the existing indicators, we propose several indicators that could be useful both individual and national level.

A generic *goal achievement indicator* (I_T) is proposed as:

$$I_T = \frac{R_T}{P_T} \qquad (1)$$

where R_T represents the value of current target and P_T represents the value of the target. This could be used to monitor how an individual achieves his/her goals in terms of food security. For example, it can track the food availability, calories and proteins consumed.

Individual level of food security is tracked with statistical methods by evaluating samples and proposing models regarding the entire population.

The ***household*** level of food security includes families that can be further classified in families without children, families with single child or multiple children and families with single adults raising one or more children. Having a detailed breakdown allows custom interventions for categories that presents greater risks of food insecurity.

We can use the same goal indicator, defined by (1), at a household level, but we can also define several indicators, specific to this level, related to food availability, internal food production, emergency supplies etc. In addition, a weighted average for each indicator can be calculated for each member of the family.

A proposed indicator to show the *waste* (I_W) could be calculated as:

$$I_W = \frac{C_F}{P_F} \qquad (2)$$

where C_F represents the consumed food by the family members and P_F represents the purchased and produced food. C_F and P_F could be expressed in USD or EUR. In turn, C_F can be broken down into family members.

Another useful indicator is food availability (I_A):

$$I_A = \frac{A_F}{R_F} \qquad (3)$$

where A_F represents the available food and R_F represents the required food, based on family requirements. Also, A_F and R_F could be expressed in USD or EUR or they could be broken down on food categories with the specific units.

The indicators presented in equations (2) and (3) depend on time. They also have to keep track of updates during the monitored period (week, month etc.).

The ***regional*** level of food security is tracked by local authorities, institutions, producers, sellers, farmers associations and NGOs to assess the effectiveness of the programs. In order to have a clear overview of progress both quantitative and qualitative data is required. With an open data model, collaboration between entities is enhanced allowing a more in-depth analysis. The use of a GIS is required for a better analysis at this level.

For the ***national*** level of food security, we identified several sources including research reports, and national statistics. The *Global Hunger Index* (GHI) indicates the level of hunger and undernutrition worldwide [24]. National statistics provide detailed reports on agricultural and food production along with population statistics.

The *Global Food Security Index* (GFSI) provides data based on four pillars: *affordability*, *availability*, *quality and safety*, and *sustainability and adaptation*. Country scores are calculated based on the weighted values on each dimension. All dimensions have 68 indicators assessed like proportion of population under the poverty line, agricultural research and development, dietary diversity, disaster risk management etc. Table 1 presents GFSI values for 2022 for the first state (Finland), Romania and the last state (Syria) in a top based on this index. As example, the table also presents values for three indicators (Change in average food costs, Supply chain Infrastructure and Food security and access policy commitments) used for GFSI calculation.

Table 1. Sample data for GFSI 2022 [7]

Indicator	Finland	Romania	Burundi
Rank	**1**	**45**	**113**
Food Security Environment	83.7	68.8	36.3
Change in average food costs	97	84	0
Supply chain Infrastructure	85.6	53.4	19.5
Food security and access policy commitments	52.5	0	0

As example, we selected several indicators used by GFSI that are suitable for publishing within the proposed mobile-centric framework [7]:

Change in average food costs is a measure of the change in average food costs, and the main source of data are national accounts. Tracking individual food expenditure using a mobile application creates more awareness for categories of users with a higher risk of food waste. A gamification system might reward users when they reach certain goals, or automatic donations can be made to organizations concerned with reducing world hunger if a person realized he/she wasted too much food.

Dietary diversity is a measure of the dietary sources. To sustain a healthy way of living, people are encouraged to include other sources that do not rely on carbohydrates. Food guides that are hard to follow can be included in an interactive mobile application.

Nutritional standards is also an indicator included in the index. Mobile devices are suitable for multimedia broadcasting to make the content user friendly and accessible.

To integrate several sources, we further describe the data collection process as an important component in the system architecture. Because of the lack of standardized formats and sparse data we envision a process for extraction and transformation into suitable data structures for making information accessible on mobile devices.

5. Data collection

In order to have an up-to-date system, high quantity of high-quality data has to be used. The process of data collection can be done manually or automatically.

The collected data could be raw (primary, non-processed data) or processed (secondary data). Raw data is collected form sensors or from other sources (individuals or household data) and it is obtained automatically, or manually. Secondary data is obtained by processing raw data or by using other sources (public data, statistics, private data etc.).

The proposed application targets individuals, householders, producers and public and private organizations. Figure 2 presents the data flow between these entities. Food producers and sellers collect specific data, manually or automatically, and they send it both individuals and public and private organizations.

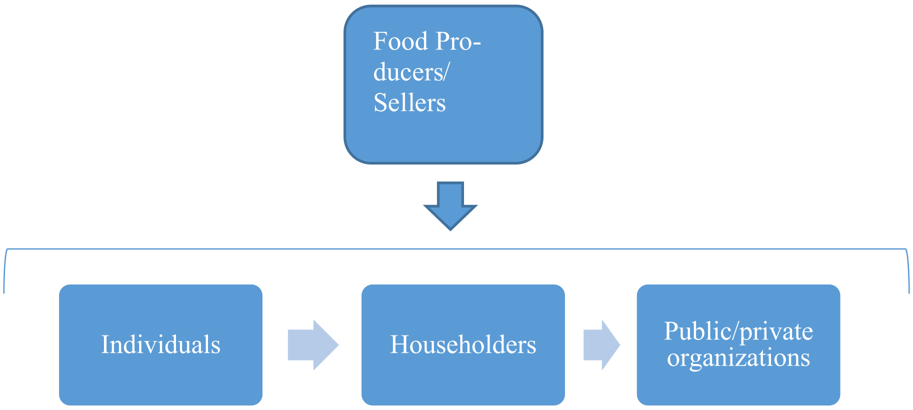

Fig. 2. Data flow between the entities

The data flow depicted in Figure 2 is seen as follows:

1. Producers and sellers (FSD) send data to individuals, households and regional/national organizations;
2. Individuals collect data (ID);
3. Households responsible collect data (HD); these data are combined with ID;
4. Regional data (RD) is based on HD;
5. At national level, data (ND) is aggregated, based on RD.

Food producers and sellers are part of the food security supply chain (FSSC). This food security supply chain is an important source of data, related to the entire process, from producers to consumers. These data are related to food production and could help individuals and public and private organizations in taking decisions related to food security. Data is provided by various sources, and it is used both for internal processes and for external entities. Table 2 presents several examples of data sources and the data they provide. Some of data are used only within the FSSC, other are sent to other interested parties like individuals, households or private or public organizations.

Table 2. Examples of data sources

Data Source	Provided data
Global positioning systems	Animals and food location, speed and altitude
Temperature sensors	Soil, air, water, body temperature
Humidity sensors	Soil and air humidity
Weight sensors	Animals and food weight
Light sensors	Light presence/absence, intensity
RFID Tags	Animals and food identification
Spectral imaging	Level of proteins
Water sensors	Water and moisture presence and level
Accelerometer and gyroscope	Animal movements and behavior
Thermal camera	Thermal maps

Table 2 shows the existence of numerous sensors that have to be connected in an IoT. Beside these data provided by the sensors, there is data that has to be loaded manually by the users (availability, orders, required ingredients, fertilizers etc.).

Regarding the individuals, households and interested organization, they have to provide and collect information related to each entity. Table 3 presents some examples of data specific to each level considered.

Table 3. Examples of data required on each level

Level	Examples of required data
Individual	Personal information (gender, weight, height, age) Performed activities (sport, jobs) Personal targets (calories, weight, food availability etc.) Personal constraints (proteins, calories etc.) Food information (structure, levels, sources etc.) Health status Income
Household	Number of members Family structure Property type (house, flat etc.) Food production facilities Family income
Regional	Geographical information Population (number, structure etc.)
National	Aggregate data from the other levels Input from producers and sellers

The examples from Table 3 show what data needs to be collected from each level. This data has to be integrated with data provided by the food suppliers. All of these will be integrated and processed, in order to provide high quality, error free results.

6. The Proposed Architecture

Based on these analyses, we propose the architecture of a mobile-based solution. The objective of this system is to monitor the level of food security through resources, access to resources, availability, and constraints. Figure 3 presents the main components of the system.

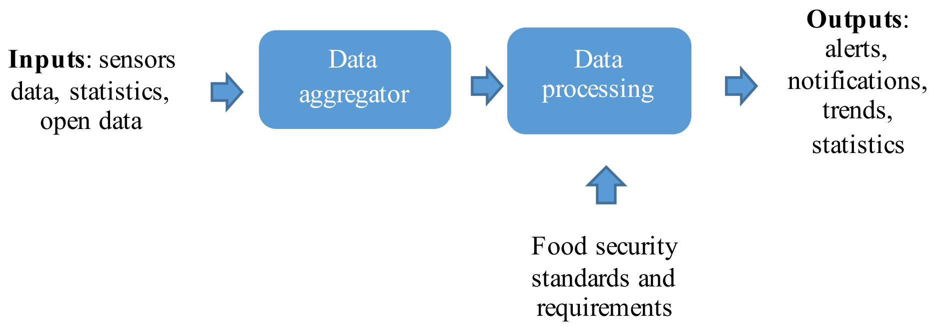

Fig. 3. The proposed system components

Inputs are collected from various sources (IoT sensors, high-level sources). This component can collect data from several levels (individuals, households, producers, institutions etc.). It also allows producers and sellers to provide data to regional and national organizations. Example of input data are presented in tables 2 and 3. For example, an individual could enter data as presented in Table 4.

Table 4. Examples of data input for an individual

Category	**Inputs**	**Values**
Personal information	gender weight height age	male 80 kg 166 cm 42
Performed activities	sport job	none desk-type
Personal targets	calories weight food availability	2500 kcal/day 80 – 81 kg every morning: 3 eggs, 1 liter of milk, 100 grams of bread etc.
Food information	structure levels sources	Proteins: 10% – 35% Carbohydrates – 45% - 60% Fat: 20% - 35%
Health status		Healthy
Income		1500 EUR/month

These values presented in Table 4 will be used as basis for indicator calculation and regional and national statistics.

In order to receive data from different sources, it is required a protocol that allows the interconnection between them.

Data aggregator levels data collected from several sources. The input for this module is represented by data collected from sensors, entered manually or taken from external sources (statistics, providers etc.). This module prepares the data in order to be processed. Raw data is aggregated and normalized.

Data processing includes implementation from simple formula to complex algorithms using artificial intelligence and machine learning. Depending on the level, food security standards and requirements will be used for data processing. For example, an individual could provide targets, requirements, quantities etc. and, depending on the inputs, the indicators will be calculated. At a national level, there will be used standardized indicators and metrics to comply with the requirements.

The ***outputs*** of this system consist of calculated indicators, forecasts, and statistics,

filtered by the usage level (individual, household etc.).
The system will also provide notifications and alarms that are activated when a specific condition occurs, related to food availability, waste increasing, non-healthy food consumption, the amount of calories, carbohydrates or proteins etc.

As an example, for an individual or household, the mobile solution components are presented in Figure 4. The mobile application allows entering specific user data (requirements, targets, quantities, consumption), or to place orders and will notify the users when certain conditions will occur food stock levels, target levels, temperature, humidity, abnormal situations etc.

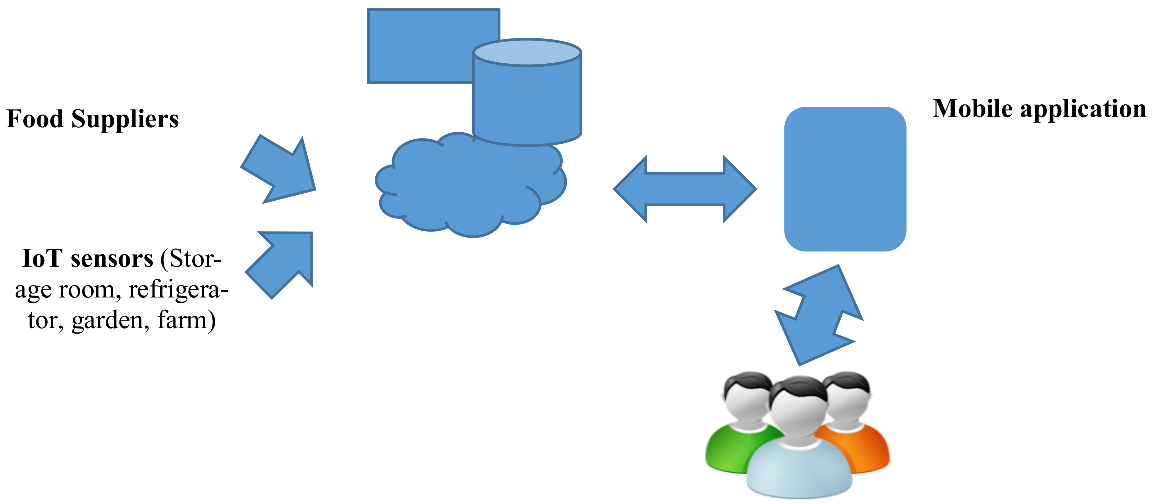

Fig. 4. System components at an individual or household level

The household uses an IoT with sensors connected to refrigerator, storage room, garden, animal farm etc. The sensors will send specific data through the Internet to a cloud-based system. In addition, the food suppliers will send data related to food availability, the status of placed orders etc. All data is stored in a cloud-based database, and it will be available to other components within solution. These data will be processed, and it will be available to private and public organizations. This will allow calculating all indicators related to food security defined at a regional or national level.
A very important aspect is related to security. There is sensitive data that has to be protected against cyber-attacks. A high level of security can be reach by using the latest technologies and guidelines.

7. Conclusion and Future Work

Food security is very important for every country, starting from an individual to the whole nation. Measuring and monitoring food security data is easier by using a dedicated system implemented at different levels. The easiest way to be notified and to provide data is by using a mobile application.
In order to manage food security levels, a large amount of data needs to be processed. The analysis of big data requires the use of dedicated software and hardware infrastructure that is available through cloud computing providers.
The advantages of the proposed solution are:

- real-time access to data;
- reduction of data collection costs;
- support for forecasting and trends.

We observed some limitations of this proposal, but they can be overtaken by using adequate solutions:

- it involves specific implementation costs;
- users could not be confident in using the application;
- users could not provide enough or consistent data;
- users are skeptical regarding data protection.

These limitations could be eliminated or reduced by finding funds, using a gamification system, promote the solution and other means. Next steps include the implementation of a prototype, based on this architectural model, and using it in practice for an appropriate duration. Then, the results will be validated and published in a future paper.

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