A multi-actor ICT platform for increasing sustainability and resilience of small-scale farmers after pandemic crisis

Antonio Cimino
Department of Innovation Engineering, University of Salento, Lecce, Italy, and
Francesco Longo, Vittorio Solina and Saverino Verteramo
Department of Mechanical, Energy and Management Engineering, University of Calabria, Rende, Italy

Received 18 January 2023
Revised 21 February 2023
Accepted 5 March 2023

Abstract

Purpose – This paper proposes an Information and Communication Technology (ICT) platform to increase the sustainability and resilience of smallholders to face supply chain disruptions in the event of COVID-like crises. The platform facilitates interactions between smallholders and buyers, workers and freight transport companies in agri-food ecosystems. Furthermore, this research work presents the implementation of the freight transport companies' platform module.

Design/methodology/approach – The research work begins with a literature review aiming at analyzing current available ICT solutions supporting smallholders and other actors in the agri-food supply chain. This analysis identifies the research gaps which have to be filled by the platform. Then, the authors proceed with the analysis of the operational scenarios of each platform actor by interacting with experts and operators working in the agri-food sector. The results of such analysis resulted in a comprehensive, unambiguous and consistent set of specification being used to define the platform structure and modules architecture. The platform modules have been developed by using the web-application framework Laravel.

Findings – Preliminary tests show that the proposed platform is usable and promises to improve the resilience and economic, social and environmental sustainability of agri-food supply chains, with a focus on smallholders.

Originality/value – The research work allows players in the agri-food supply chain and in particular small local producers to react and mitigate the impact of COVID-like crises through development of a platform in which smallholders, citizens (buyers and workers) and freight transport companies are simultaneously present.

Keywords ICT platform, Food supply chain, Smallholder, Freight transport company, Sustainability, Resilience

Paper type Research paper

1. Introduction

The recent COVID-19 crisis has highlighted the limited resilience of supply chains globally (Alabi and Ngwenyama, 2023). Many actors have had to rethink their business model and operating practices to profitably face the new challenges caused by the pandemic (Longo *et al.*, 2023). The players in the agri-food sector have suffered enormously from the occurrence of these unexpected and disruptive events, considering that the products have the specific characteristic of being perishable and having to meet strict quality and safety standards (Kumar *et al.*, 2022). In many cases, the high spread of the infection has limited the manpower available in the fields, with the consequence of not being able to harvest fruit and vegetables in time. On the other hand, the countermeasures taken by several governments have led to the closure of multiple distribution channels (e.g. shopping malls, school canteens, open-air

This work is part of the research project entitled "Smart Models for Agrifood Local vaLue chain based on Digital technologies for Enabling COVID-19 Resilience and Sustainability" (SMALLDERS), co-funded by the PRIMA Program–Section 2 Call multi-topics 2021.

0007-070X
DOI 10.1108/BFJ-01-2023-0049

markets, bars, restaurants) and therefore many agri-food products have perished within warehouses. In both situations mentioned above, the main effect was food waste, therefore a significant impact on economic, environmental and social sustainability. It is important to underline that this global disaster has especially impacted small-scale farmers (i.e. smallholders) (Quayson *et al.*, 2020; Huss *et al.*, 2021). In fact, they already operate in difficult conditions from an operational point of view as they tend to have difficulty accessing credit, are often overwhelmed by big competitors (e.g. large-scale food producers, large-scale food retail trade operators, etc.) and have a limited number of customers and distribution channels (therefore they are less resilient to disruptive political decisions), due to the small amount of product put on the market each year.

The main purpose of this paper is the proposal of an Information and Communication Technology (ICT) platform to increase the sustainability and resilience of smallholders in the face of COVID-like crises. The proposed framework facilitates interactions between smallholders and other actors considered of crucial importance in agri-food ecosystems: buyers, workers and freight transport companies. Even smallholder-to-smallholder interactions are guaranteed. Furthermore, the paper aims to show the implementation of the smallholder–freight transport company interaction module.

Section 2 explores the literature about the existence of ICT platforms designed and developed to specifically help smallholder agricultural practices. It concludes with the identification of the main current research gaps and the definition of the innovative contribution of the paper. Section 3 summarizes the main methodological steps that have been carried out in order to develop the proposed platform; section 4 describes the ICT platform designed to increase the sustainability and resilience of smallholders, while section 5 shows the application developed for the interaction between smallholders and freight transport companies. Finally in section 6 conclusions and future remarks are discussed.

2. Literature review

In this section, a state of the art is provided about the approaches and methodologies available in the literature to support smallholders. Basically, the focus is on the most common and promising ICT solutions (e.g. platforms, architectures, infrastructures, technical ecosystems). In more recent years, with the advent of Industry 4.0, there has been a proliferation of ICT-based approaches aimed at supporting the various supply chain actors to increase profits, improve the management of warehouses, distribution activities and therefore exploit the potential of the large amount of data available. To quantitatively understand the scientific interest in ICT systems in recent years, it is possible to consult Scopus, one of the most recognized and reliable scientific databases on a global level. If you perform a generic query by using the keyword "ICT" within the field "Article title, Abstract, Keywords" and consider the results in the period 2011–2022 (note that 2011 is the advent year of the Fourth Industrial Revolution), (you get more than 74,000 documents with a clearly increasing trend: about 3,500 documents were published in 2011, around 4,500 in 2021 and over 5,300 in 2022). A refinement of the query by introducing the word "food" shows around 800 documents characterized by a very similar trend, confirming the recent scientific interest in the use of Industry 4.0-based platforms to help agri-food systems. However, the most interesting result comes out if we consider the following two queries: (1) "ICT" AND "smallholder" and (2) "ICT" AND "small farmer". In both cases, less than 140 documents come out. The literature analysis below shows the most relevant scientific contributions, filtered starting from the last query. The aim is to show the current state of the art about the design, development and implementation of ICT platforms to support the operational practices of smallholders.

Bouali *et al.* (2022) have recently proposed a smart agriculture solution, where the use of an IoT (Internet of Things) system supports smallholders especially in irrigation activities,

which are made more efficient through real-time data monitoring. This interesting approach improves quality and quantity of crops. Irrigation issues are addressed also by Mdemu *et al.* (2020), who combine monitoring tools and an agricultural platform for improving several aspects. A case study in Tanzania shows that farmers can better understand soil moisture and fertilizer dynamics, then improve productivity and even food security. Chaudhuri and Kendall (2021) show how the use of ICT solutions can help to: (1) promote the collaboration between multiple smallholders, (2) positively change daily practices and (3) be more resilient to recent climate change. The concept of collaboration is also addressed by Omulo and Kumeh (2020), who report the experience related to the adoption in Kenya of "Wefarm", an ICT-based platform, which promotes knowledge-sharing between small-scale farmers, with the aim to improve access to information about agricultural production, marketing and financial services. Van Campenhout *et al.* (2021) recently evaluated the impacts of using ICTs to address the problems of some maize smallholders in Uganda. They focus on three main technologies: time-sensitive short messages as a reminder for some critical activities, audiovisual messages for providing information on agricultural practices, interactive voice responses. The experimental results of the study show that ICTs can significantly decrease food waste and improve yield. Other documents show that ICT tools can support smallholders in solving multiple issues such as access to knowledge (Ortiz-Crespo *et al.*, 2021) and development of business networks (Krone *et al.*, 2016), sustainability of agricultural practices (Mapiye *et al.*, 2021) and credit access (Agyekumhene *et al.*, 2018).

According to Bhaskaran (2013), ICT adoption is an efficient strategy to help profitability and business growth of Small and Medium Enterprises (SMEs), especially in the food sector. Moreover, a very recent study by Cane and Parra (2020) shows that digital platforms represent a useful tool for detecting and distributing products destined to become food waste. A study recently conducted in Ethiopia has shown that providing agricultural extension services, through the use of videos, significantly increases the adoption of information and communication technologies by farmers and especially their knowledge (Abate *et al.*, 2023). Basically, ICTs are extremely useful today to limit rural poverty, improve agricultural practices, increase the resilience and sustainability of smallholders. However, the use of modern technologies is not yet fully established and widespread, especially among small-scale farmers in developing countries (Kabirigi *et al.*, 2022). The main reason can be found in the existence of significant barriers of various kinds: socio-cultural (e.g. lack of knowledge, attachment to tradition), technical (e.g. limited connectivity), regulatory (e.g. regulations frequently changing or even absent for some domains) and economic (e.g. difficulty in significant investments) (Ferrari *et al.*, 2022; Arora *et al.*, 2022). Agyekumhene *et al.* (2020) have recently explored the benefits of involving smallholders in the design of a smartphone platform. Specifically, they have experienced that a co-designing approach can improve their understanding of the technology and help break down socio-cultural barriers, as well as improve production performance.

Table 1 compares our paper with the closest ones in the literature in terms of methodology used and/or topic addressed. Specifically, we refer to all the papers, which propose ICT solutions to support smallholders and we focus our attention on three main dimensions: actors simultaneously present within the platform, functionalities offered, expected or actual benefits.

2.1 Research gaps and our contribution

Based on Table 1, two specific research trends can be identified: (1) ICT solutions supporting small farmers in carrying out cultivation activities (irrigation, fertilization, definition of harvest and conservation times) and (2) ICT solutions enabling interactions with other farmers in order to facilitate relationships and share knowledge. Moreover, the literature overview reveals the following research gaps, which need to be filled:

Reference	Actors involved	Main functionalities	Main benefits (expected or actual)
Mdemu *et al.* (2020)	• Smallholder • Input/output market	• Farmer-friendly monitoring tools • Agricultural platform	• Smallholders' food security enhancement • Better irrigation and farm management practices • Smallholders' income increase
Agyekumhene *et al.* (2020)	• Smallholder • Multi-stakeholder perspective for platform co-design	• Access to farmer-friendly smartphone-based platform	• Better farm monitoring • Increase in ability to communicate • Improved confidence with technology
Ortiz-Crespo *et al.* (2021)	• Smallholder • Advisor	• Access to a set of pre-recorded messages • Possibility to ask questions in a mailbox • Smallholder-to-Advisor communication	• Better access to agricultural information for smallholders
Omulo and Kumeh (2020)	• Smallholder	• Possibility to ask questions on production systems and to receive feedback via SMS and online chat (Machine Learning-based) • Farmer-to-Farmer direct communication	• Profitable knowledge exchange on production systems • Getting solutions faster via farmer-to-farmer collaboration
Van Campenhout *et al.* (2021)	• Small-scale farmer	• Audiovisual messages • Video with an interactive voice response • Time-sensitive messages	• Knowledge increase • Better adoption of recommended practices • Increase in yields
Bouali *et al.* (2022)	• Small or medium farmer	• Real-time data acquisition and control • Data processing, visualization and storage • Fuzzy irrigation control	• Optimal usage and conservation of groundwater • Reducing dependence on fossil fuels • Increase in quality and quantity of crops
Our paper	• Smallholder • Buyer • Worker • Freight transport company	• E-commerce channel • Chat • Historical data analysis • AI-based Knowledge Navigator • Shipment Tracking • Job offers/requests	• Product enhancement • Fairer price • Efficient interactions • Unemployment reduction • Increasing earning opportunities for smallholders and carriers • Increasing resilience and sustainability against COVID-like crises

Table 1.
Comparison between our paper and the others existing in the literature

(1) First of all, despite the significant interest in ICT platforms in the agri-food sector, there is no holistic platform capable of simultaneously connecting smallholders and multiple other players to facilitate the exchange of data and information and make practices more efficient. Basically, most of the platforms present in the literature only

see the presence of smallholders, therefore they are "closed" with respect to other stakeholders. Specifically, there is a need for solutions able to simultaneously connect smallholders with: (1) buyers to ensure fairer prices and a direct seller-to-buyer connection, (2) workers, to quickly address any labor shortage, (3) freight transport companies to plan distribution activities in the best possible way (also guaranteeing an adequate level of customer service) and (4) other smallholders to promote profitable collaborations.

(2) Industry 4.0-related technologies are still not widespread in the agricultural sector due to economic and socio-cultural barriers. There is a need to make better use of available technologies, with the aim of helping smallholders to improve the performance of their agricultural practices. The features offered by the available platforms, especially in developing countries, are extremely limited. There is a need to make greater use of Big Data, artificial intelligence, GPS, web-applications.

Based on the gaps identified above, the main purpose of this paper is to propose and describe a multi-actor ICT platform to support smallholders and increase the sustainability and resilience of their practices. The platform aims to bring together smallholders, citizens (buyers and/or workers) and freight transport companies in a single ecosystem. Moreover, it is able to offer multiple functionalities such as: (1) the possibility for the citizen to buy online through an e-commerce channel and to view a catalog even with the support of an AI-based Knowledge Navigator, (2) the opportunity for all actors to quickly communicate with each other through a dedicated chat, (3) the possibility for smallholders to exploit a job module to recruit workers (and for workers to quickly find a job) and (4) the GPS for track deliveries and offer valuable information to the customer. Such a platform increases sustainability and resilience of smallholders for different reasons, explained in the following sections of the paper.

3. Material and methods

This section summarizes the main methodological steps that have been carried out in order to develop the proposed platform. The research steps can be conceptualized as follows:

(1) STEP 1 - Need analysis: This research step has been devoted to depict the operational scenario of the platform and in particular to investigate the operational needs of smallholders and other actors (buyers, workers and freight transport companies) considered of crucial importance in agri-food ecosystems. In this regards, questionnaires and interviews have been used to collect information from experts and operators working in the agri-food sector.

(2) STEP 2 - Definition of the platform functional requirements: As far as the platform end-users' needs are clear, next step has been to define the functional requirements of the platform and therefore all the functionalities which had to be necessarily incorporated into it in order to fulfill end-users' needs. These latter have been represented in the form of input to be given to the platform, operations to be performed by the platform and outputs to be provided by the platform to the end-users.

(3) STEP 3 - Definition of the platform conceptual architecture: The outcome of this step resulted in the definition of the platform conceptual architecture (whose detailed description is reported in section 4). The architecture has been expressed in terms of modules where each of them needs to respond to the specific functional requirements defined in the previous step (a strong connection with the research step 2 has been therefore established).

(4) STEP 4 - Tools and technologies choice for the platform development: Within this research step, the authors have focused their efforts to review the state-of-the-art tools and technologies used in the domain investigated by this research work. The review has been completed by roadmaps underlying how the research challenges have to be tackled and what is their success criteria. The outcome of this step has resulted in the choice of the tools and technologies used to develop the platform and which are detailed named in Section 5.

(5) STEP 5 - Platform implementation: Here, the results gained in the previous steps have been used by the authors as input to proceed with the technological implementation of the platform. In this research work, the implementation of the platform freight transport module is described in Section 5.

4. Proposed multi-actor ICT platform

In this section, the conceptual architecture of the proposed ICT platform is shown and described. As it can be seen from Figure 1, the platform is characterized by the simultaneous presence of three main players: smallholder, citizen (buyer and/or worker) and freight transport company.

One of the main purposes of the platform is to enable and facilitate interactions between the different actors. Basically, it is based on three modules:

(1) Smallholder's module: within this module, each smallholder can take advantage of multiple functionalities. First, they have the possibility to offer their products through an e-commerce channel. As previously explained, one of the main weaknesses of

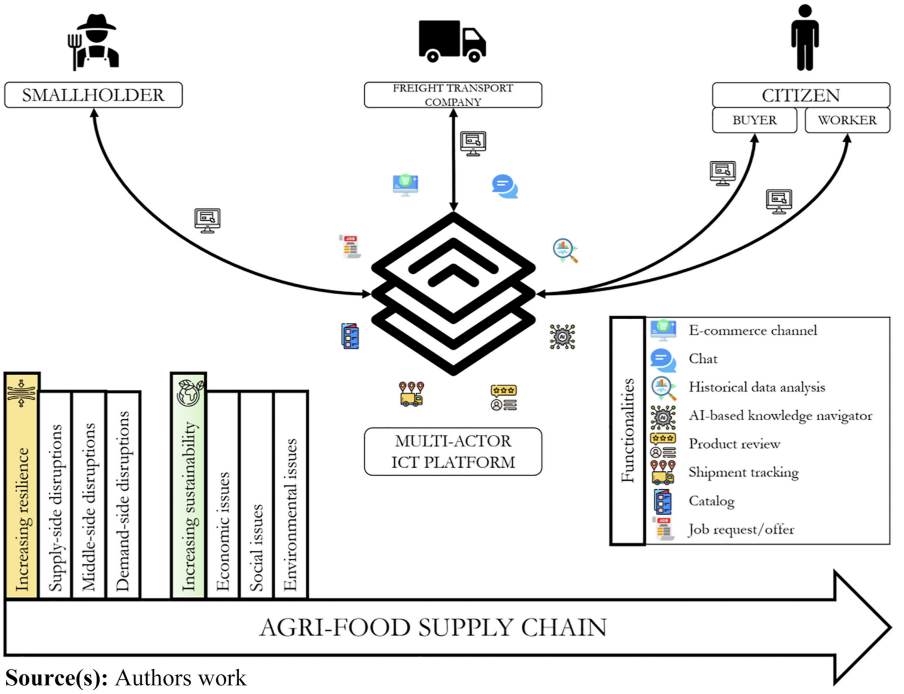


Figure 1.
Multi-actor ICT platform: conceptual architecture

Source(s): Authors work

small agricultural producers is the limited number of customers they can usually reach. This makes them not very resilient, with reference to unexpected and disruptive events (for example, during the COVID-19 pandemic several governments decided to temporarily close multiple distribution channels, with the aim of limiting the spread of the infection. The more limited the number and type of customers served, the higher the economic impact of a decision of this type). In this context, the e-commerce channel considerably increases the marketability of agricultural products and limits any loss of revenue as the set of potential customers becomes global. Basically, smallholders have the possibility to highlight the specificities of their agri-food products (e.g. organic products, KM0 products, etc.) using an online catalogue. Photos, videos, accurate descriptions justify the price of each product, which becomes fairer. Furthermore, since the platform enables the direct smallholder–buyer connection, the number of intermediaries is reduced, then the producers can operate within the concept of short food supply chain (SFSC) (Michel-Villarreal, 2022). Another important function offered to smallholders concerns the possibility of requesting or offering work. On the one hand, it is possible to publish job advertisements, so that the workforce is always available to carry out the harvesting activities on time. On the other hand, it is possible to make one's workers available to other small-scale farmers to stimulate collaboration mechanisms.

(2) Citizen's module: Citizens can access the platform in two different ways, as buyers and/or as workers. Working citizens can consult the job offers published by smallholders at any time. On the other hand, potential buyers can instead use the e-commerce channel to buy quickly and safely.

(3) Freight transport company's module: the direct connection between smallholders and freight transport companies within the platform is of significant importance because the latter bring the products to market by offering distribution services. The platform has been mainly though for medium-small transport companies whose flexibility and local presence in the territory can be considered a clear competitive advantage. Indeed, to make the most of the platform functionalities, the freight transport companies have to be either local or count on the reliability of a network of several local service providers, thus minimizing physical distances with the smallholders. In this context, one of the purposes of the platform is to find the right balance between the needs of the two types of actors. Essentially, each freight transport company can efficiently share information about availability throughout the day and scheduled routes, then each smallholder can choose the most convenient option. Couriers are equipped with GPS-based technologies to enable real-time tracking of shipments: on the one hand, the smallholder can monitor the progress of the products being delivered, on the other, the citizen buyer has visibility on the status of the products ordered. Clearly, this service tends to increase the value of the products themselves, therefore their marketability and consequently the profitability for each smallholder.

Overall, this type of platform improves the resilience and sustainability of the agri-food supply chain, according to a smallholder-centric approach. Regarding resilience, as indicated by Longo *et al.* (2023), disruptions can be classified into:

(1) Supply-side disruptions: unexpected and disruptive events that break the balance of the nodes located in the first level of the supply chain; in this specific case, reference is made to the smallholders who are those who make the finished product. An example of supply-side disruption is the unavailability of manpower for harvesting activities, due to the high rate of spread of the COVID-19 infection.

(2) Demand-side disruptions: unexpected and disruptive events involving the last level of the supply chain. Examples of demand-side disruptions are: the temporary closure of some distribution channels, the sudden increase in demand from end consumers, due to the fear of not being able to find the product on the shelf.

(3) Middle-side disruptions: unexpected and disruptive events involving the portion of the supply chain located between the first and last level. Examples of middle-side disruptions are failure of intermediate nodes, unavailability of operators involved in the transport of goods, due to the spread of the COVID-19 infection. In this latter case, freight transport companies take advantages of the platform use by directly and quickly communicating with the smallholders in order to promptly agree on shipments rescheduling in terms of time, transport modalities and good quantities;

The functionalities indicated in Figure 1 impact on resilience and sustainability as explained below. The use of the e-commerce channel and the online catalog enable an efficient and effective response especially to demand-side disruptions. It is possible to sell regardless of the possible temporary closure of physical distribution channels. Furthermore, there is a significant impact on social sustainability, as even in the most acute periods of the crisis, access to food would be guaranteed to all through home deliveries. The presence of an Artificial Intelligence (AI) Knowledge Navigator, of an online catalog and of the possibility of leaving reviews for each product by citizens, increases the intrinsic value of agri-food products and justifies their price to the final consumer; this significantly impacts on the economic sustainability of smallholders, who can increase their margins.

The presence of a module for job offers/requests has an impact not only from an economic point of view, but also and above all from a social and environmental point of view. Recruiting personnel efficiently means being able to carry out harvesting activities in the right time and limit any food waste (i.e. unharvested products). However, this also has a social impact because it lowers the unemployment rate. Product value is even increased by the possibility of tracking shipments because the customer is always aware of the delivery's status. Furthermore, through a messaging system (chat) the various players on the platform can communicate quickly with each other and therefore make the various processes much more efficient.

5. Module for freight transport companies: architecture, technologies and implementation

This section describes the module developed for the interaction between smallholders and freight transport companies. The module aims at bringing together supply and demand for transport in order to enable the best matching between the needs of smallholders and the activities of transport companies. It can be accessed through a web-application and its development involved three different phases:

(1) module requirements analysis in order to correctly identify all the questions that the module itself, through its operation, must answer;

(2) design and development of the module architecture that properly reproduces all the processes behind the interaction between smallholders and freight transport companies;

(3) development and implementation of a web-application in order to allow smallholders and freight transport companies the exchange of services related to the transport of goods.

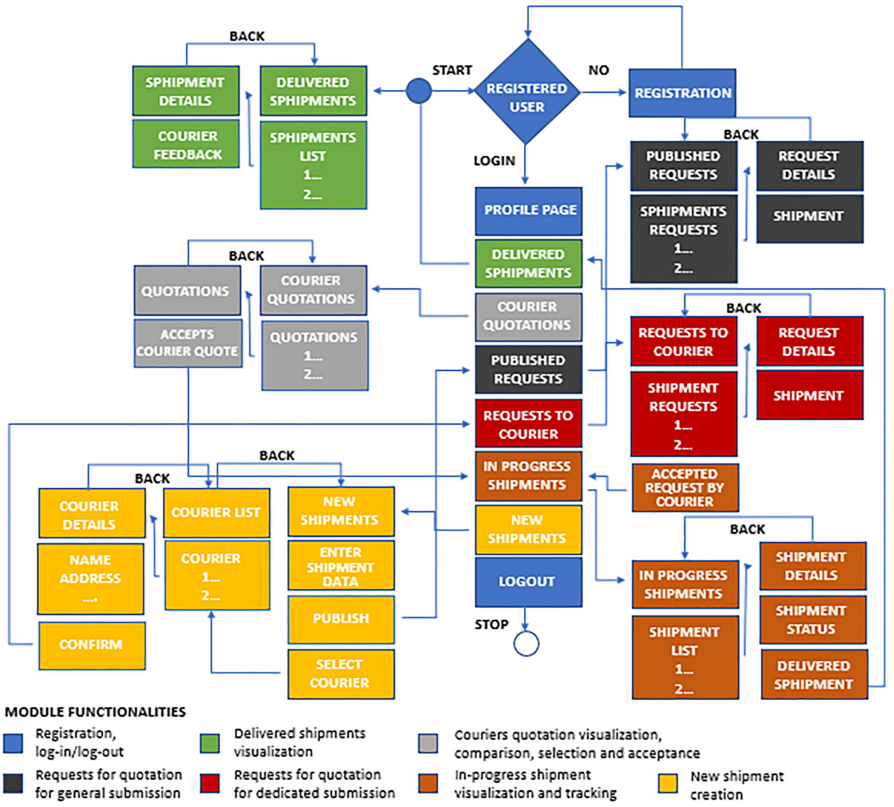
As first step, the authors spent a period of several months in order to define in detail the main requirements of the freight transport company's module. This activity has been possible

through the direct interaction with both technical experts and operators working in the transport of goods sector. The requirements validation took place incrementally through frequent meetings between the various involved experts. This approach resulted in a comprehensive, unambiguous and consistent set of specification being used to define the module architecture, which is presented and described as follows. The architectural frame has been broken down into two sub-frames in order to identify the logic for organizing and managing all the actions that end-users (smallholders and freight transport companies) of the platform can do. Figure 2 shows the module architecture including all the functions and actions that the smallholders can perform while using the ICT platform. The module functions are reported and shortly described below:

(1) User Registration: it allows each smallholder to create an account in order to register and to access the ICT platform through credentials;

(2) Delivered shipments: it displays a list of shipments which have been already completed for the final customer; for each of them, further details, such as customer addresses, shipments dimensions and weight, etc., can be visualized;

(3) Courier quotations: it shows the list of several couriers' quotations for each published shipment by a smallholder within the ICT platform. Each smallholder has the



Source(s): Authors work

Figure 2.
Smallholder-side module's architecture

possibility to compare the quotations and select the most suitable one in terms of costs and delivery conditions;

(4) Published requests: this function allows each smallholder to publish requests of shipment within the platform and make them visible to the freight transportation companies. The published requests can be visualized by the freight transport companies, which can select the ones of interests and for this latter submit a quotation, waiting then for the smallholders' feedback (i.e. acceptance or rejection) before proceeding with the shipment;

(5) Requests to the courier: this function allows each smallholder to submit a request for shipment to a selected courier;

(6) In progress shipments: it displays the list of shipment for which either a courier has been selected and/or the shipment has already started. In both cases the shipment process has begun but the goods haven't not been yet delivered to final customers. The smallholders can visualize the shipment details such as shipment route and real-time tracking.

(7) New shipments: this function allows each smallholder to create a request of new shipments by entering shipping data. The request can be then either published within the platform or submitted to a selected courier.

Figure 3 displays the freight transport companies-side architecture and summarizes all the functionalities that the module offers to the transport service providers as well as all the actions that they can perform while using the platform. The main functionalities are here below listed and shortly described:

(1) User Registration: it allows each courier to create an account in order to register and to access the ICT platform;

(2) Shipment proposals: it reports the list of shipments which have been published by the smallholders within the platform. Each courier can decide to provide a quotation for a selected shipment and if the smallholder accept it, an "in progress" shipment for the courier is generated.

(3) In progress shipments: it displays the list of shipments for which either the courier has been selected and/or the shipment has started. In both cases the shipment process has begun but the goods haven't not been yet delivered to final customers. The courier can visualize the shipment details such as shipment route and real-time tracking.

(4) New shipment: this function allows each courier to publish, within the ICT platform, new shipments by entering routes and picking/delivery times. These shipments enlarge current supply offers and can be selected by the smallholders.

(5) Shipments requests: this function allows each courier to visualize the shipment requests which have been submitted to them by the smallholders. The courier can decide to accept or not the request.

The last step of the freight transport company's module development was the implementation of the web-application to be used by the end-users to exploit the benefits of ICT. A preliminary study has been carried out to identify the Web-App main functional requirements; among the others the main ones are listed and described below:

(1) The Web-App allows different types of users (administrators (and non-administrator) to use the module's functionalities.

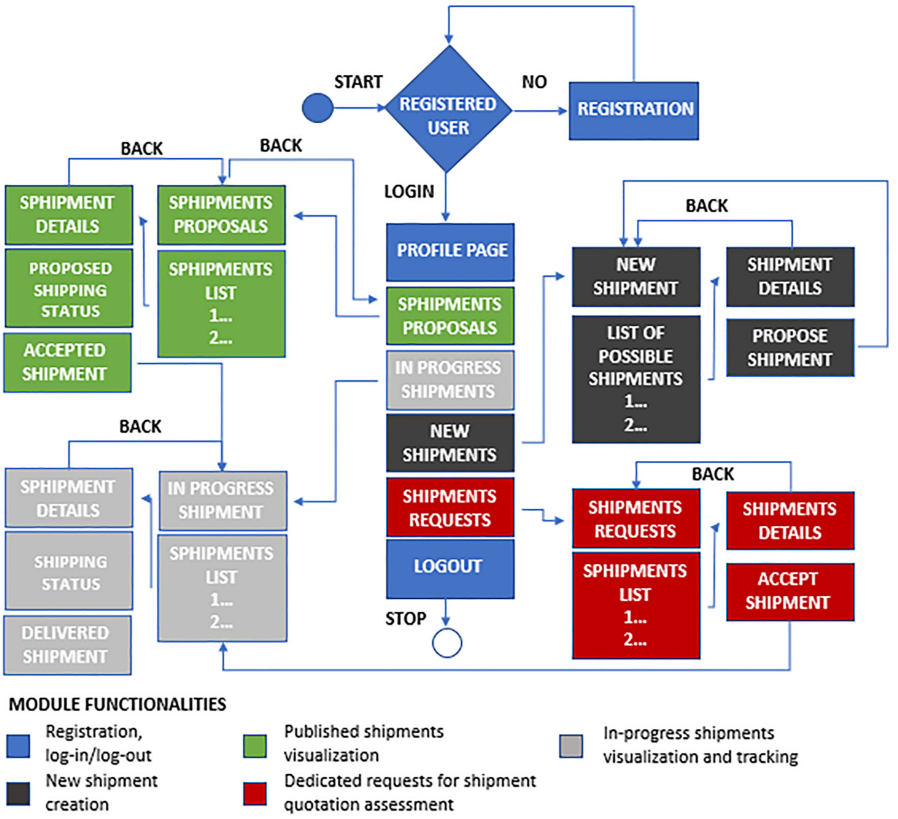


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Figure 3.
Freight transport company-side architecture

(2) The Web-App allows administrator users to create, edit or delete users.

(3) The Web-App allows the use of a credential-based system (username and password), which enables "Login" and "Logout".

(4) The Web-App guarantees diversified (i.e. partial or full) access to the various functionalities, based on the type of user. The following users are set:

- Administrator: it approves the registration of users and can delete existing users. It can manage all the contents of the platform and has access to all its functionalities.
- Freight transport company: this user accesses all the functionalities developed for the freight transport companies;
- Smallholders: this user accesses all the functionalities developed for the smallholders;

(5) The Web-App allows each user access to a personal area (or profile page) in which he/she can modify all information about him/herself (i.e. name, surname, address, mobile phone, password, profile picture, etc.).

(6) The Web-App allows communication between users through the exchange of messages in single chat (two users) or group chat (group of users).

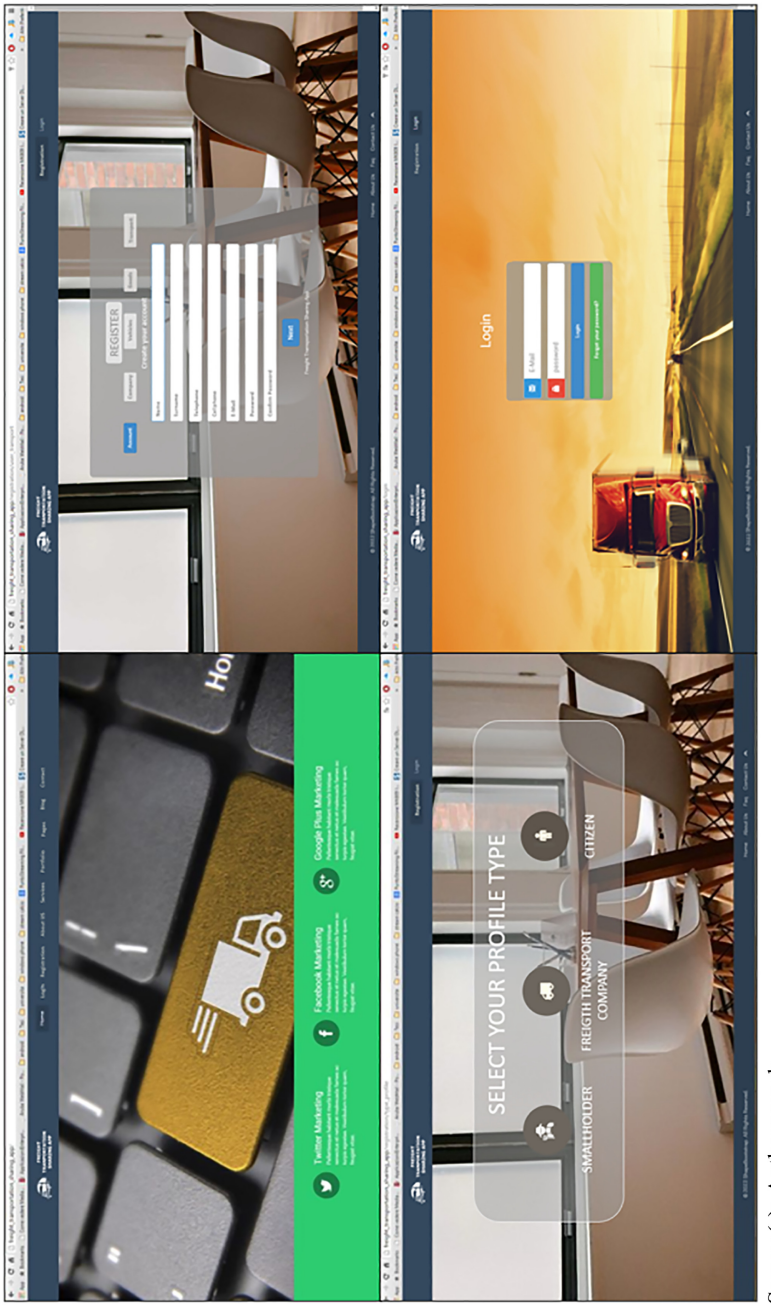
The authors have used *Laravel*, a web-application framework, to develop the Web-App (further information on Laravel can be found in the Laravel website, https://laravel.com/). Among the technologies, *MySQL* has been used to deploy the Web-App database, *Hypertext Preprocessor (PHP)* as scripting language to implement the processes logics behind the Web-App (Back-End) and *HTML Visualization* together with *Bootstrap* and *jQuery* to develop Web-App graphics (Front-End). Table 2 summarizes the list of ICT platform freight transport company's module features as well as the end user that can access to each of them, while several screenshots showing the main features of the Web-App are reported below. In particular, Figure 4 shows the home page (upper left corner), the registration page (upper right corner), the profile selection page (lower left corner) and finally the login page (lower right corner). Figure 5 shows the web page which allows a smallholder the entry of a new transport with the relevant shipment details (i.e. type of goods, description, pick-up, delivery, loading details, etc.).

5.1 Preliminary and expected results

The testing and validation phases of the proposed platform are still in progress. However, on the basis of the first tests carried out and some interviews conducted with the end-users, it is possible to provide some preliminary and expected results, with particular reference to the module designed for freight transport companies. First of all, the platform will ensure a direct

Table 2.
ICT platform freight transport company's module features

Freight transportation module features	End-user's Smallholders	Company	Citizen
Registration			
Profile selection	x	x	x
Profile creation	x	x	x
Accessibility			
Log-in	x	x	x
Log-out	x	x	x
Services			
New shipment request	x		
New shipment proposal		x	
Request for quotations submission	x		
Request for quotations visualization	x	x	
Request for quotations assessment		x	
Request for quotation acceptance		x	
Quotations submission		x	
Quotations visualization	x	x	
Quotations comparison	x		
Quotation selection	x		
Quotation acceptance	x		
Shipments details visualization	x	x	
In-progress shipments visualization	x	x	
In-progress shipments tracking	x	x	x
New shipments proposals submission		x	
Shipment proposals visualization	x	x	
Shipment proposals comparison	x		
Shipment proposals selection	x		
Shipment proposals acceptance	x		



Source(s): Authors work

Figure 4.
Home page, registration page, profile selection page and login page

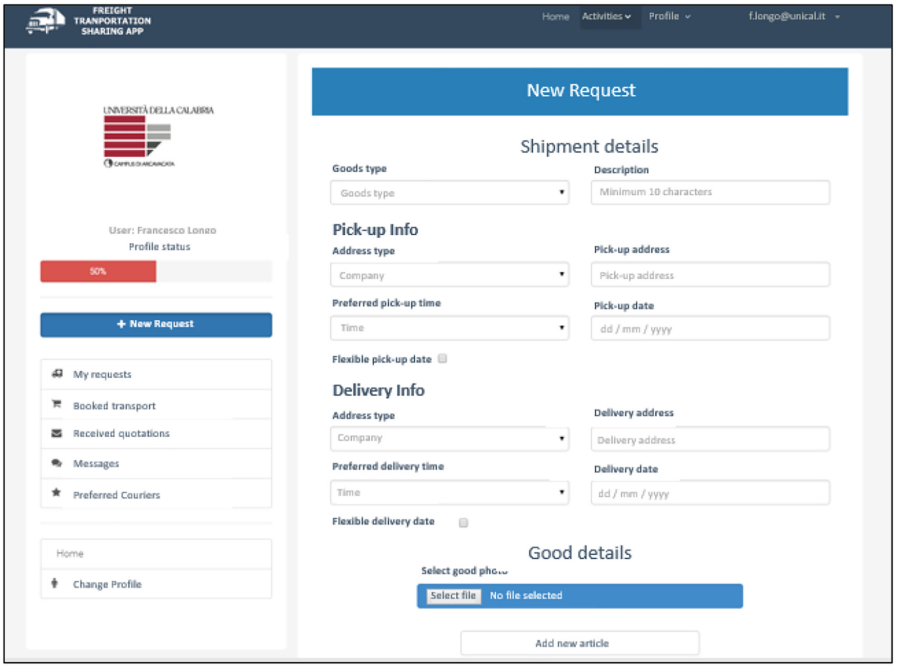


Figure 5.
New shipment request

Source(s): Authors work

smallholder–freight transport company connection in terms of information sharing: this aspect will increase the margins of both types of players because, on the one hand, the smallholder will be able to choose from time to time the most convenient transport in terms of price and service level; on the other hand the carrier, by sharing information about its vehicles and routes, will be able to travel as much as possible with a full load, taking into account the requests from the producers. Basically, a win-win paradigm is expected. The platform will also be able to store the history of all deliveries, therefore smallholders will also be able to exploit this significant amount of data to choose in the best possible way how to conduct distribution activities (e.g. carriers with a history of deliveries made in the right manner will be preferred). Sustainability will grow for the following reasons. From an economic point of view, each smallholder will be able to take advantage of the best offers relating to the distribution service, and therefore will be able to increase margins; on the other hand, the reduction of travels with a partially empty vehicle will limit CO_2 emissions to the benefit of the environmental sustainability. It is possible to state that the platform will reduce the number of intermediaries, therefore the length of the supply chain, ensuring greater control for smallholders. All these advantages will have beneficial social consequences on final consumers, who will have: (1) fresher products due to the better organization of distribution activities, (2) fairer prices, thanks to a shorter supply chain and (3) better quality of service as via GPS they will be able to monitor the various deliveries. Preliminary tests show that the platform is easy to use and increases the willingness of smallholders and freight transport companies to adopt modern Industry 4.0 technologies to improve their practices. A more complete picture about the goodness of the platform will be available as soon as all the modules are implemented and tested through testbeds located in different areas. However, the first preliminary results are extremely promising.

6. Conclusions

In this paper, a multi-actor ICT platform has been proposed to contribute to the improvement of smallholder practices, in terms of resilience and sustainability in the face of COVID-like crises. The proposed platform facilitates interactions between smallholders and other actors considered of crucial importance in agri-food ecosystems: buyers, workers and freight transport companies. As first step, the authors have carried out a literature review in order to identify the research gaps to be filled and which can clearly create a significant progress beyond the state of the art. Among the others, the research gaps to be solved include: (1) connecting simultaneously smallholders and multiple other players to facilitate the exchange of data and information and make practices efficient; (2) facilitating the interactions between smallholders and (potential) workers; (3) enabling the cooperation between smallholders in sharing workforces; (4) allowing better interactions and mutual benefits between smallholders and local/regional freight transport companies; (5) giving freight transport companies the opportunity to directly contact smallholders in order to optimize and make more efficient their services. Next step was the description of the conceptual architecture of the proposed ICT platform, which is characterized by the simultaneous presence of three main players: smallholder, citizen (buyer and/or worker) and freight transport company. Then, the research work focused on the implementation of the freight transport company module by summarizing the main steps driving the authors to its development. Firstly, an analysis of requirements has been conducted in order to identify all the questions that the module itself must answer; secondly, the authors described the design and the development of the module architectures (smallholders' -and freight transport companies' sides) and, finally the web-application, which allow smallholders and freight transport companies the exchange of services related to the transport of goods, has been presented. Further research is still on going with the aim of covering the following aspects. Once the stability and usefulness of the platform have been confirmed through several case studies, other types of actors could be included to make it completely holistic. Furthermore, it could be integrated with a blockchain module, considering the potential of this technology in the traceability of agri-food chains (Mirabelli and Solina, 2021). Another possible improvement concerns the interaction with a simulation-based optimization module to help the platform actors in decision-making, at a tactical and operational level. Finally, additional features could improve end-user satisfaction, such as the ability to rate each shipment, with the aim to create a trusted network.

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Further reading

Laravel Web Application framework (n.d.), available at: https://laravel.com/

Corresponding author
Antonio Cimino can be contacted at: antonio.cimino@unisalento.it