Design of an Architecture for the Evaluation of Traceability in the Supply Chain of Fresh Produce

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Abstract

In current context of globalized markets, competitiveness of agricultural producers faces challenges derived from national and international standards that impose high-quality requirements to access important markets and implement measures to warrantee safety in food, especially in fresh produce. Under this context, traceability of supply chain plays an essential role of giving information that aloud to establish improving points in each link of the supply chain. Current traceability approaches are based on conventional commercial solutions used on industrial products, leaving out fresh produce features that make necessary having into account a higher level of information all over the entire supply chain. Throughout this research work, it is presented a proposal to evaluate fresh produce traceability systems taking into account technological systems that aloud to monitor the product transport conditions and the design of an architecture to facilitate its visualization, tracking and control in any part of the chain. This research work pursue the construction of easy-to-employ quality indicators in order to evaluate the traceability and the decision making throughout technological monitoring, design methodologies and the construction of approval and verification instruments using a case study of the supply chain of Solanum Quitoense (Lulo in colombian spanish).

Key Words

(01) Architecture, (02) Traceability, (03) Quality (04) Fresh Produce, (05) Decision Making.

Introduction

The competitivity on regions brings the potential to augment production on a sustained way through investment on technological agendas and innovation (INCODER, 2010). The creation of a traceability system us necessity and tracing on the different chain links of suminister for example the harvest, the distribution, and commercialization allows to exist a quality control and to identify the critical facts; it also allows, the construction of management of knowledge to support and create better practices, technology and innovation starting to break walls that makes regions and its products being straggled for demand because cannot support quality against the global market. Currently the research group Society, Economy and Product (SEPRO) performs the study of traceability on products like Solanum Quitoense and tomato on the tree of sumapaz region and its agro- industrial corridor with the objective to propose a traceability system differentiator on the implementation of better practices to increase its competitivity, nevertheless after great efforts on the lifting of information it verify the existence of a system for the evaluation on traceability for fresh products in the country. The theoretical framework and practice states that there is little content

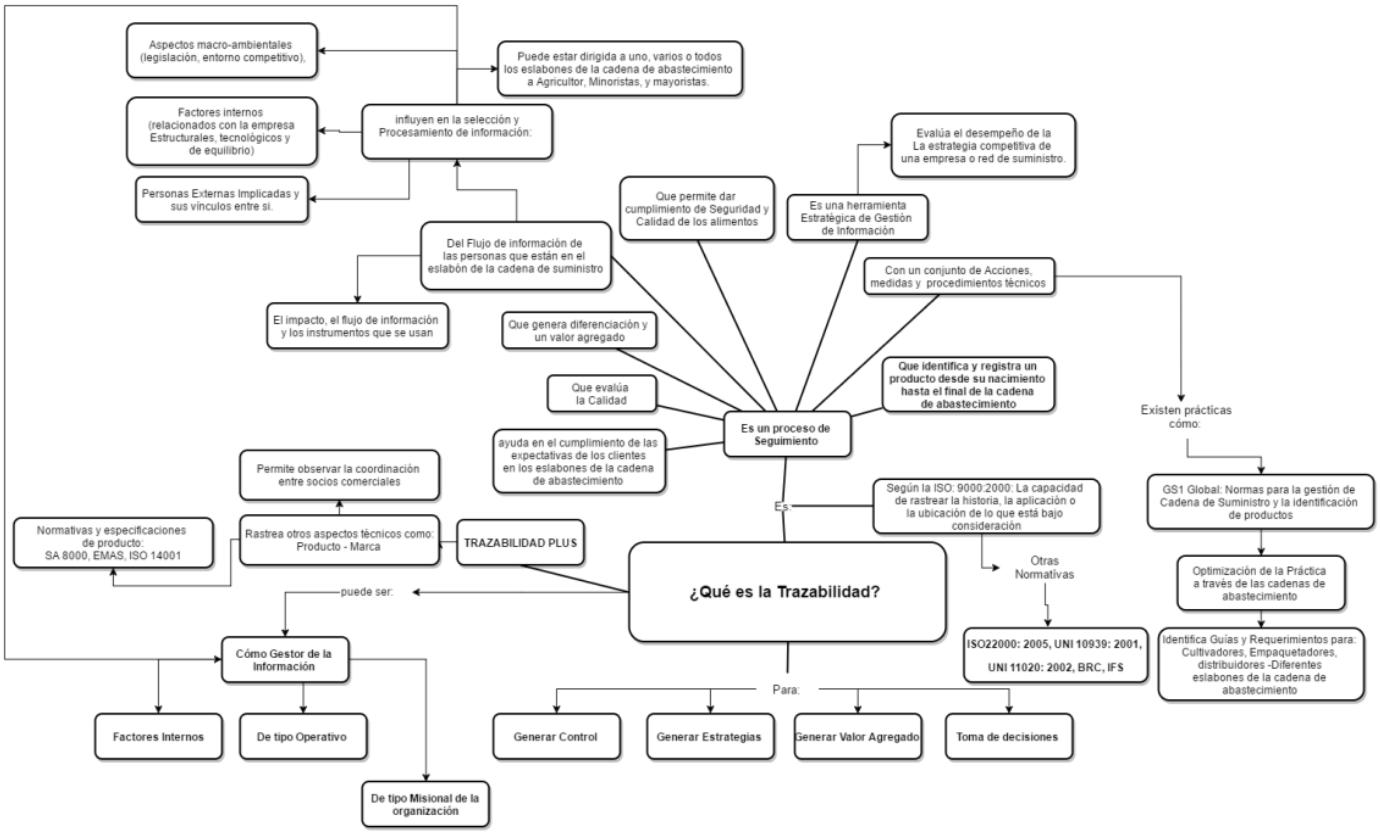
that contribute to demonstrate that the result and the decision making that is realized is the most adequate, is for that reason that makes necessary the construction of an architecture that allows evaluate the traceability in this products and serve as a reference for the next.

This investigation is described through the theoretical framework and continue with the description of the traceability architectures on trends and concludes with the construction of indicators on traceability quality, given to its development we opt for methods of technological surveillance and quality evaluation associated to quality on design methods.

Interests of control of traceability on the food industry

The traceability plays an important role on the verification of food quality because tracks the product from the beginning to its end, nevertheless it's a set of processes with difficult to configure because each product and its link on the supply chain can be unic (Mishra & Garciam New trends and Recent Advances, 2015), is for that reason that we will adjust the term of supply chain to a theme of design which is life cycle us a holistic referent on the construction of information. But before describing the interests of quality control its necessary to perform a short theoretical framework of what is traceability and which role takes us strategy on competitive. For the international standard organization (ISO) the traceability is the capacity to track the history the application or the location of which is in consideration (INTERNATIONAL ORGANIZATION FOR STANDARIZATION – ISSO , 2017), for the security food committee AECOC is the set of those pre-established procedures and self-sufficient that allows to know the faithful, the location and the trajectory of a product or batch of products along the supply chain between determined tools, nevertheless they are big concepts which goes further than legal laws and extends to be an operative strategy, productive and of competitive (Canavari, Centonze, Hingley, & Roberta Spandoni, 2010). In this sense traceability is converted to an strategy to add value in which interact several sources of information through the chain supply link, actions, measurements and technic facts in which track a product from its beginning to the end of the commercialization chain (Clemares, Moltoni, Moltoni, & Lucas, 2013) with the clear objective to show critical facts, ensure quality and to develop best practices making people that uses this processes more competitive to the global market, next you will see the illustration of basic characteristics of a traceability process.

Illustration 1. What is traceability? Prepared by: The authors



Traceability Architectures

It has been shown that there is no solid theoretical framework that shows the implementation of the systems of tracking on fresh products (Dabbene & Gaym Food traceability systems: Performance evaluation and optimization, 2011); That is the processes of traceability tend to be unic and its realization depends on the interpretation and manipulation on each process, this entails that can solve an objective but not be efficient (Karlsen, Dreyer, Olsen, & Elvevoll, 2013). According to Opara exists 6 aspects in which realize the traceability which are, (01) Traceability on product, determines were is physically located each product; (02) traceability of the process, that stipulates the type and sequence which affect the product; (03) Genetic Traceability, which is the manager of the constitution of what is tracked; (04) Deceases and pests traceability, determines the biological danger of the product; (06) Measurement of traceability, relates the results of These measurements with established protocols (Opara, 2003). Opara also poses the next question ¿Is there a common theoretical framework to implement food traceability?, and identify 10 facts of traceability on fresh products adapting a model of traceability connectors of Oslen in 2009, describing this connection in the next facts: Legislation, production optimization, bioterrorist threats, communication chains, competitive advantages, certification, wellness, Sustainability, Quality, Food Safety, characteristics that can be measured through design engineering methodologies.

Traceability is presented internally and externally; for some authors like Moe the benefits of performing internal traceability can be as follows: a better planning in the resources to be used, there is a process control, a satisfaction of standards, a quality control through management, implementation of best practices among others (Moe, 1998); For other authors the benefit of application of external traceability are the following "satisfaction of legal requirements, avoidance of repeated measurements, opportunity to market products, materials or product characteristics, better Incentives for the inherent quality of raw materials, efficient procedures of better quality and control of processes "(Karlsen, Dreyer, Olsen, & Elvevoll, 2013), in this sense and under the case of use, we will enter to evaluate the external traceability of the product and for this is divided into three phases before, during and after implementation of traceability.

Traceability architectures trend

For the construction of innovation you must have a holistic look through various disciplines that will help us to observe the problem from different perspectives and how they affect and interact in each process of the life cycle focusing on the farmer and intermediary (Becerra & Cervini, 2005). Trends can be established through a set of problems, contexts and indicators through 3 axes described from the following way in methodologies of engineering of the design but that also has been adapted in processes of traceability.

Table 1. Trend Classification. Elaborated: Adaptation of Eco-design.

Socio-Cultural trends	Technology trends	Environmental trends
Relationship between products and services, with wishes	Development of technique and science. There are generalized techniques, experimental, possible and emerging markets.	Management of the conjunctural conditions, political, economic and environmental, observing in parallel the conditions of Context and time.

This research extracts quality indicators from traceability through 3 ways: (01) methods and Indicator tools; (02) Standards and legislation and (03) Quality evaluation architectures.

Traceability indicators

Certifying that a fresh product has a traceability system has a competitive advantage in the national and international market, this is a motivation for many companies since they can be competitive in a global standards market. Some methods used to evaluate and control traceability can be: Interviews, focus groups, surveys, mechanisms control,

case studies, simulations and checks, among others. The following table summarizes the methodologies, methods, tools and technologies used for the application of traceability and that contain quality in their processes:

Table 2. Constructions of Traceability Architectures. Elaborated by: compilation of multiple sources.

Method, methodology or tool	Name	Interesting aspect evaluated
Method - Technologic tool	Food track and trace Ontology (FTTO)	It provides principles and guidelines for implementing traceability in the chains of food value
	The concept of Critical monitoring (CTE)	Collect data to focus on events that manipulate products in the supply chain. Events are data related to specific locations, dates and times are stored for future retirement.
	Critical Tracking Point (CTE)	Security and easy access in obtaining the data.
	Quality proposal Oriented monitoring and Tracking (QTT)	The QTT concept represents a perfect alliance between logistics and traceability, improving the supply chain
	Improved Traceability Of the IFT	Identifies and gathers information on methods to improve tracking Of the products The supply chain and evaluates methods for quickly and effectively identify the food recipient to prevent or mitigate foodborne illness.
	FEFO	Implements Radio Frequency Identification
	PDA	Real-time data and accurate data acquisition and transmission, and the high efficiency of information tracking and tracking through supply
Manual Tool	Matrix Actor Case GS1	To identify the cause of the problem and find out what elements traceable may have the same problem. It is divided into several aspects according to the information flow of the business
Method	Chemo modeling metric	Model that applies analytical data to obtain chemical information Of the fresh product. Technological tools: Hyperspectral, Micro-Optical, Near Magnetic, Resonance, Near infrared (NIRS) spectroscopy NIR spectroscopy, Near Infrared Spectroscopy (NIRS)
	Devices for wireless monitoring	Analysis or bar code of DNA and QR.
Technological tool	The Isotope	It details the authenticity of agricultural products.
	NFC	It allows the final consumer to know the history of the product.
	FCM	Modeling system that allows to observe the most Important in the supply chain its status and the transitions
	Fuzziness Cognitive Maps (FCM)	Web-based system for data processing, storage and transfer. Integrates all the information in the food chain Oriented to the consumer needs.

	DC model (detection Compressed)	Look at temperature data under varying conditions, such as Constant temperature conditions. The system is able to recover the sensor data in the sample with precision and efficiency, which Reflects the real-time temperature change in the refrigerated truck During the logistics of the cold

The lack of follow-up in logistics processes significantly affects Colombian according to the National Logistics Survey, the quality of the transport service was rated at 6.8 (scale Of 1 as very low and 10 as level of excellence), one of the reasons for which such qualification was obtained was the lack in the use of technology to have a tracking of the cargo from source to destination. Of the 31.8% of Companies that have a traceability system implemented 63.0% cover upward traceability, 83.3% Cover internal traceability and 59.3% downward traceability (National Planning Department, 2015). These confirm the importance of good management and information management within the process of catering. The following table describes the methods, manuals, and standards that are used by Traceability systems that some Colombian producers adapt.

Table 2. Methods, tools, manuals and standards are associated with traceability processes. Made by: Compilation from multiple sources.

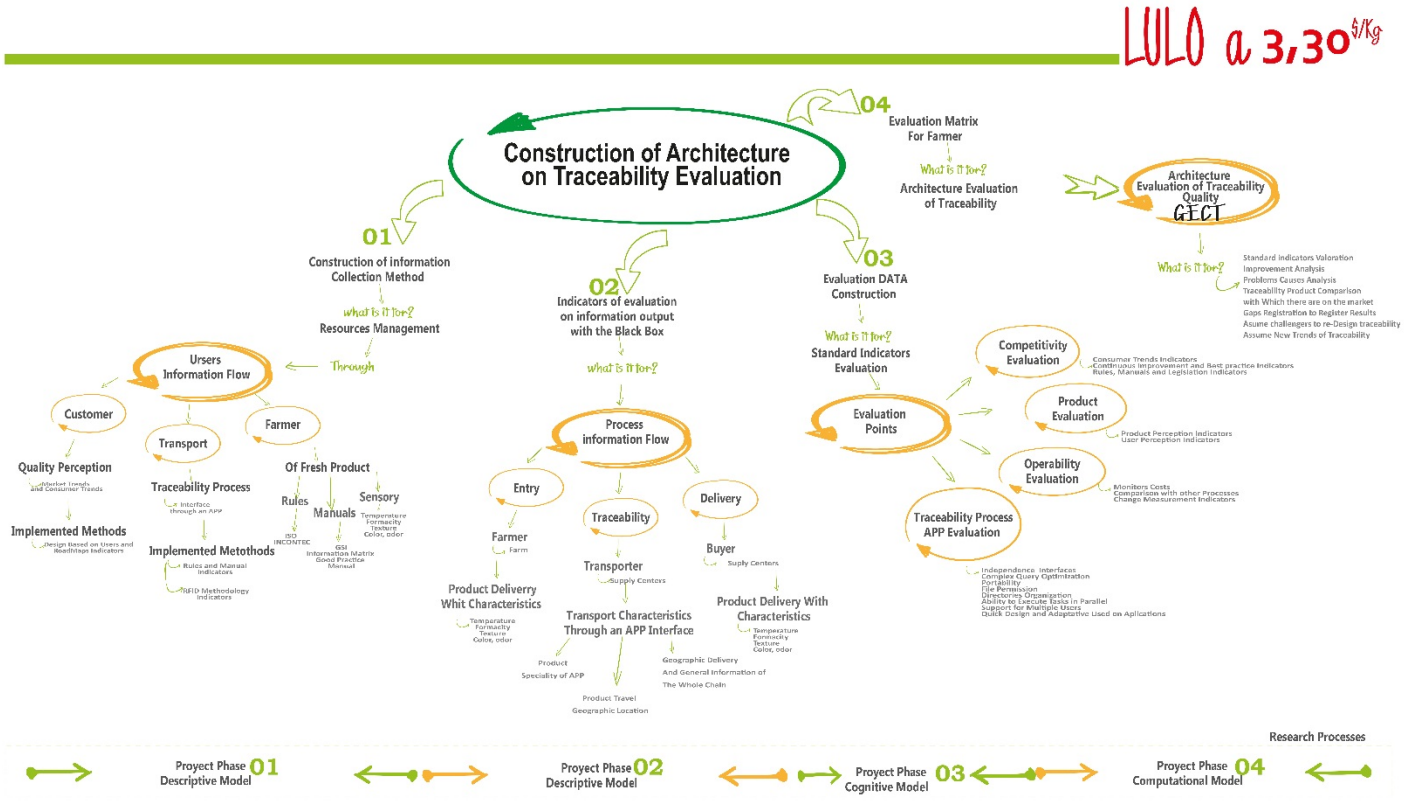
Method	Principal component analysis PCA
	Discriminating analysis PLS -DA
	Linear discriminating analysis LDA
Manual tool	GS1 General Specifications
	GS1 Global Traceability Standard
	GS1 Fish Traceability In Europe Guideline
	GS1 AIDC Implementation Guide for Fresh Foods Sold at Point-of-Sale
	U.S Seafood Traceability Implementation Guide
Rule tool	ISO Standard 12875:2011 Traceability of Finfish Products (Captured Finfish)
	ISO Standard 12877:2011 Traceability of Finfish Products (Farmed Finfish)
	ISO 9001: 2000

Proposal of a Quality Traceability Architecture:

Duply was the first to worry about the evaluation and optimization of traceability systems and several Authors afterwards initiated efforts to apply their methods, others like Tamayo used algorithms to Optimization of processes, Wang proposed in 2010 a joint optimization between batch-making and Dispersion of lots introducing risk functions (Dabbene & Gay, Food traceability systems: Performance Evaluation and optimization, 2011). This proposal chooses to include several aspects within a life and takes it as a constant and dynamic flow of information; Takes as its main source the information of the different types of users described in illustration No. 1 and No. 2 and converge in two areas of knowledge, the engineering and design and sustains the construction of architecture systemically.

The product life cycle management has as main objective the reduction of errors, elimination of processes, reducing time, optimizing resources, increasing productivity, improving quality, cost reduction and regulatory compliance among others (Stark, 2006). The more relevant notion in the intervention model is the role, defines the behavior and responsibilities of an individual, or a group of individuals who work as a team (Higuera, 2014). In conclusion, these advantages and activities for improved traceability are linked to decision-making and role-taking that are based on a product lifecycle management. The construction of a system of indicators through the study of traceability adds value in the product life cycle, intervening different approaches (redesign, User-centered, collaborative, experience, D+i, eco-design), with the ability to articulate and interrelate internal and external elements of the company, with the objective of obtaining continuous improvement and excellence that is perceived by the user as quality. This systemic vision requires management with various tools and Techniques, which must be selected and implemented according to the traceability in this sense, the construction of the traceability evaluation architecture was proposed as follows:

Illustration 2. Architecture of quality on traceability



In the architecture there are aspects of quality such as security, handling, flexibility, Cost of current and future development effort applied in architectures such as (01) Software Architecture Analysis Method (SAAM) b (02) ATAM - Architecture Tradeoff Analysis Method, (03) Active Reviews for Intermediate Designs (ARID) (04) GAPs, GMPs and HACCP and (05) Audits of each Company

Manuals and standards provide attributes that allow generating indicators based on the flow of information Based on the production methods of the system and based on the comparison of variables in the Efficiency of the supply chain as described by the RFID system (Badia-Melis, Mishra, & Ruiz-García, 2015); On the other hand, intelligent logistics suggest us to capture information flow indicators from the Product life cycle since the traceability is dynamic and the information varies according to the characteristics of (GS1 Manual), in this sense a system for evaluating the traceability of If not this should allow a flexibility with high change variables and possible scenarios future, this is where other design methodologies allow us to use their tools for the construction of Technological surveillance and possible future scenarios, either in the correction of traceability, for adaptation to New constructions or to enter another component that can be a critical point in the aspects of quality of the same.

Table 3. Some Design Methods associated with Quality. Elaborated: compilation of multiple sources

Name	Detail	Tools To Extract
Design Focused on the user	It allows to know of primary sources, the Interaction of the product in its different Stages, obtaining valuable information	Open and closed slopes, interviews, Workshops, brainstorming, evaluations

	Of the user, allows you to complexity of the human being and answers more aware of that diversity (Martínez, 2003).	Qualitative and quantitative (Prototypes).
Analysis PESTEL	It is a planning tool strategic context of a company, which is essential because analyzes external factors that affect directly or indirectly, the company	Protocol of characterization of an activity, company or process, is determined in detail all interactions in a process.
(ROAD MAPPING):	Let you know a vision of the future desirable from the perspective of the producer.	Panel of experts: make a reflection Of an environment, where technological actions and agents that is to the future vision (Observatory of Prospective Technological Industrial, 2009).

The previous table describes 3 design processes in which content is extrapolated for the construction of those requirements that must be evaluated in the traceability system, as described by Dabbene and Gay in 2011 there are the following considerations to observe the performance of cost-focused traceability, these are, (01) evaluation of the performance of a given Traceability system; (02) Design the chain of supply. The environment permanently influences directly or indirectly in the company, this repercussion makes imperative the constant analysis of the information about the environment, in order to prepare the company or farmer before any situation and must be taken into account for the decision making in the short and long term, the previous ones methods allow us to respond to international specifications of Quality, Political and Legal characteristics, Economic, Social, Technological, Demographic and ecological characteristics and life cycle characteristics

In the construction of the Matrix of Architecture of quality evaluation of the traceability points to evaluate Have reliability characteristics, they must be available, they must be consistent so that they can have readability according to the person who needs to evaluate, in this case farmers or owners of farms, must evaluate the robustness, program independence, security and auditing, duplicate elimination, concurrency of access, referential integrity, complex query optimization, connectors with programming languages, Control Transactional and Failover, Portability, Efficiency, Hardware Management, persistence of files and organization in directories, ability to execute tasks in parallel, support for multiple users, real-time operations support, distributed and parallel operation support, fast-paced environment development, rapid and adaptive application design, database development, rapid customization of views and reports, fast deployment, easy scaling, low server resource consumption (Foundation for Development Fruticola, 2005).

In the construction of the evaluation architecture there are 3 dimensions, information elements (which can identify and perceive one's own message); Independent networks (have the ability to autoconfigure) and intelligent applications (Applications for intelligent control and treatment of the same information) (BadiaMelis, Mishra, & Ruiz-García, 2015), in this sense as described by FAO in 2010, there are strategies of supply and distribution in which in this architecture construction are extracted indicators that best practices in traceability activities and to be exploited in the productive (FAO, 2010). Global Traceability Standard GS1, provides requirements in traceability processes such as construction of possible scenarios and their specifications, being an essential source in the construction of requirements, it also divides the information through the research of the producer, the buyer and the because they are the ones who ensure that traceability processes are effective and efficient (GS1 Standards Document, 2012). The system identifies, evaluates and controls significant food safety hazards (Paz & Gómez, 2015) from a systematic approach in the identification, valuation and control of risks, monitoring weaknesses, setting priorities and planning HACCP or HACCP - Hazard analysis and critical control points) as the final component in the evaluation for the farmer.

Discussion

The development of traceability systems for supply chains of fresh products implies the articulation of multiple actors and technological infrastructures as they adapt to the particularities of each product and productive context. By the hand of these systems, it becomes necessary to develop mechanisms that allow monitor and follow-up processes and handling of fresh products along the chain supply, with the purpose of generating useful information that allows the identification of opportunities for improvement in the processes of the chain.

This article proposes a structure to evaluate the traceability of fresh products contemplating the appropriation of the elements of conventional quality management systems in harmony with the application of technological systems that allow to capture a greater volume of information through the nodes of the chain of supply by means of the implementation of sensors that monitor the conditions of transport, storage and handling of fresh products, this architecture facilitates an understanding of the role of traceability in the quality management in fresh food supply chains.

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- To the *Society, Economy and Productivity Research Group* -SEPRO- (Sociedad, Economía y Productividad), from National University of Colombia.

Biography Statement

Lina Nataly, Industrial designer and holder of a master's scholarship in Industrial Design at The National University of Colombia. She works at COLFUTURO, foundation for the future of Colombia, in the Program of Recruitment of Talent (PRT). Her research projects are divided on three lines of innovation: 1. Competitive strategies, (Best undergraduate work award of National University of Colombia for developing new products and processes for SME. 2. Communication strategies, (awarding a Guinness World Records for creating a mobilization and empowering project of public policy in Colombia. 3. Social innovation creating a research group about this subject. She holded a scholarship from INCAE Business School and VIVA Trust in the Social Entrepreneurship Congress, managing projects of social impact. Beyond her academic distinctions Lina's main interest is to generate reflections about how any kind of profession can make a positive impact in societies.

Delio Alexander, Industrial engineer and MSc. in Industrial Engineering at District of Bogotá University Francisco José de Caldas. At present he is a PhD student in Engineering, Industry and Organizations at The National University of Colombia. He works as research teacher in operation managing, logistics and supply chain management. He has participated in research projects with SEPRO group from National University of Colombia. His research interests are related to global planning and supply chain management, urban logistics, and optimization models.