Technology Platform for the Information Management of Theobroma Cacao Crops based on the Colombian Technical Standard 5811

Eduard Guevara, Alix E. Rojas, and Hector Florez

***Abstract*—Currently, Colombia is the tenth largest producer of cacao in the world and the third in Latin America. However, its production, marketing, and quality are affected by different factors, especially in its production processes. Some phases such as fermentation and drying guarantee a high-quality grain as long as it is made using a good practices methodology. Unfortunately, rudimentary methods are currently carried out based solely on the experience of cacao farmers. This article presents the design of a Technology platform that generates value to this business through an architecture model, which manages the processes defined in an IT strategy. Based on the current state and characterization of the Colombian Technical Standard NTC 5811, we propose the design for the management of information in the pre-planting, planting, maintenance, production, and benefit phases of Theobroma cacao crops. This project demonstrates the importance of incorporating information and communication technologies in the cacao value chain and quality standards in good cacao cultivation practices at the international level.**

***Index Terms*—Technology platform, Theobroma Cacao, Enterprise Architecture, TOGAF, NTC 5811.**

I. Introduction

CACAO is one of the crops with the most significant presence in Colombia and specifically in one region called *Santander*. It is internationally recognized for its quality in taste and aroma, having a good position of special cacaos worldwide [1]. However, it has several disadvantages in harvesting and post-harvesting processes generating low quality in the cacao bean, lack of quality certifications, few Technology development indexes in the activities of crop transformation, post-harvesting, and production, ignorance in the importance to have excellent quality parameters required to export cacao and its products, lack of support for cacao producers, and low grain export index. Currently, cacao is one of the most important crops in Colombia since it is part of the government's agriculture strategy, which will generate significant growth in its production and industrialization, based on some government strategies with foreign countries that are interested in the production of the cacao bean due to its organoleptic properties.

In this project, we proposed the design of a Technology platform with web and mobile functionalities that will manage the information of the pre-planting, planting, harvesting, maintenance, and production phases of the Theobroma cacao crops based on the Colombian Technical Standard NTC 5811 that establishes agricultural good practices for cacao [2]. This design includes all the processes and functionalities applied to good cultivation practices in the region *Santander*. In this way, it seeks to strengthen good practices in cacao producers, improve product quality, and enhance their export processes.

This article is structured as follows. Section II presents the background, where we describe the main concepts related to the Theobroma Cacao, cacao supply chain, and quality management systems. Section III explains the development process of the technology solution following the TOGAF Architecture Development Method (ADM). Section IV concludes the article, while section V presents some recommendations.

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II. Background

A. Theobroma Cacao

All cacao grown for the world market is obtained from forms of the species of Theobroma cacao. Its center of diversity is in the Amazon region in Brazil, Colombia, Ecuador, Peru, and Venezuela [3]. This crop has great social and economic importance for Latin America and the Caribbean regions since it is one of the main export products, either raw or processed. This crop is key for achieving peace processes and a viable option to substitute illicit crops and other less profitable crops.

In Colombia, cacao has been produced since the colonial era and it can be grown in all regions of the country. Specifically, *Santander* is the region with the highest production rates with a participation of 42.07% in 2018. Fig. 1 presents the Colombian production by region. Colombian cacao has some advantages as an agricultural export product such as climate, humidity, and environmental conservation due to agroforestry, which gives its production value compared to other American countries.

There are different organizations in *Santander* dedicated to generating cacao clones through research and innovation of their different types of native cacao. Some organizations such as Fedecacao and Universidad Industrial de Santander have worked together to create innovations in the genetics of clones that have better physical and chemical properties than natural cacao [4]. Theobroma cacao produced in *Santander* has been identified as excellent quality; nevertheless, this region lacks the infrastructure, culture, and strategies to promote farm quality certifications to market cacao with better prices than the countries that manufacture it [5].

Based on the aforementioned reasons, all research and innovations are aimed at creating new genotypes that improve

Fig. 1. The region outlined in red represents the department of Santander in Colombia

the quality of cacao production. However, the quality of cacao is also measured by its aromatic composition, which is obtained in good practices in the fermentation, drying, and roasting processes of the bean, which give aroma and flavor to cacao. Colombia is characterized by its quality in composition and production, which is the reason for the ICCO (International Cacao Organization) in 2008, 2010, and 2015 has classified Colombian cacao with 95% in its exquisite aroma.

B. Cacao supply chain in Colombia

Taking into account the stages of the production process, we can establish that there are three links: primary, marketing, and industrial. The primary link has cacao planting, maintenance, and harvesting. Within this link, there are all farmers, farm owners, and providers of vital inputs for the fulfillment of activities. The marketing link refers to the activities for selling the products nationally and internationally. In the industrial link, there are the companies in charge of cacao processing [6]. In this work, we detailed additional links, which are described below:

1) **Input suppliers** integrate the activities of those who sell inputs and raw materials necessary for the cultivation of cacao and the transformation processes of the agroindustry.
2) **Grain producers** groups located in the cacao production regions of the country, where business projects aimed at improving production levels and their benefit structures coexist.
3) **Grain marketers** located at the head of the production municipalities, who collect the grain and are the bridge between the grower and the industry.
4) **Cacao agroindustry** integrates activities aimed primarily at the processing of products for the chocolate food industry.
5) **Sellers** are responsible for the sale and distribution of large quantities of processed products.
6) **Retailers** bring together the actors who market the processed products in retail.
7) **End consumers** select and acquire the cacao product with value-added.

C. Quality Management Systems

Standards are essential to the industry because they guide organizations in meeting criteria that ensure repeatable, documented, and agreed-upon production processes to meet the needs of customers and other stakeholders[7]. There are national and international organizations that develop standards related to specific management systems and practical tools in all companies. For example, ISO 9000 establishes the requirements for quality management [8]; ISO 27000, which contains the information security management system requirements [9]; and NTC 5811, which defines the requirements and recommendations of good agricultural practices for Colombian cacao farmers[2].

The concept of quality is highly related to standardization because quality refers to refined processes that generate products that are assessed, improved, and ensured. According to ISO[1], Quality is the degree to which a set of characteristics inherent in an object (product, service, process, person, organization, system, or resource) meets the requirements. Consequently, the quality management systems appear and they are in charge of guiding processes and procedures towards better behavior for their clients [10]. Then, companies decide to implement these quality strategies when they realize that they provide benefits that generate an organizational impact on each of the organization's performances by providing sustainable development initiatives.

Some of the benefits that organizations, business systems, or any type of company can acquire by implementing quality management in their processes can be: a) providing products and services that meet customer needs, b) identifying risks as well as their improvement plans, c) giving clients a degree of confidence in their products, services, and quality of processes. It is not an objective of the standard to impose how the processes must be done, but it is a uniformity of the internal processes that structure the quality management system, alignment of the documentation, and development standard in each process.

III. Development of the Proposed Technology Solution

We followed the TOGAF 9.2 Standard which is an Enterprise Architecture (EA) methodology and framework used by several organizations to improve business efficiency, and we chose it because it is one of the most reliable Enterprise Architecture standards in the market [11], [12]. The core of TOGAF is the Architecture Development Method (ADM) which describes a recommended sequence of phases

[1]https://www.iso.org/

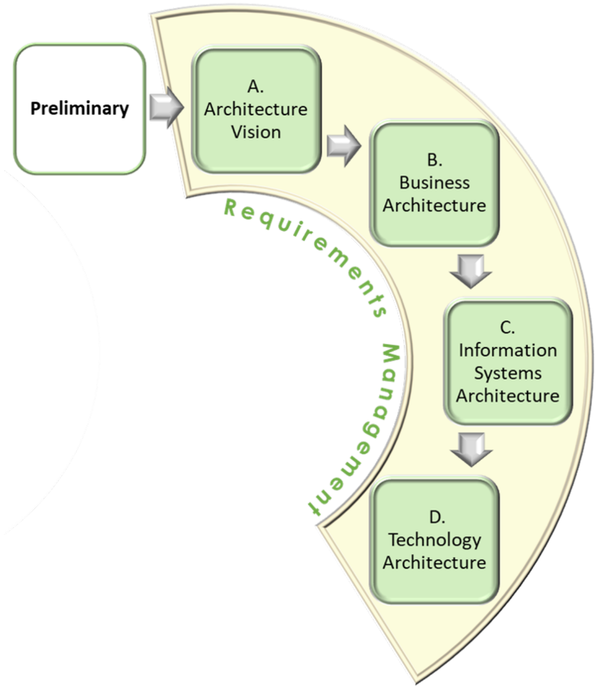

Fig. 2. Requirements Management phases

and steps involved in developing an architecture. Fig. 2 depicts the requirements management phases developed in this project.

Preliminary Phase: ***Framework and Principles***

This Phase is about two main aspects: defining the framework to be used and defining the architecture principles that will guide architecture work.

1) Framework: While the ADM is iterative, over the whole process, and between and within phases, it is also a generic architecture development framework. It is highly recommended to modify and adapt it to the real needs of the business [13]; and since this development starts from new, we took the phases highlighted in yellow to establish the scope of this proposal, such as shown in Fig 2. As Open Group indicates, ADM phases E through H focus on deployment and migration activities, which are not part of the scope.

2) Architecture Principles: They are used to capture the global vision of how the organization will use and deploy IT resources. They were identified and redacted during the project formulation by the master student, and critical business stakeholders validated them. Following the recommended format in TOGAF, part of the architecture principles identified is presented below.

- *Business Principle:* High-Quality Standards.
  Statement: Develop cacao production processes with high-quality standards through the Colombian Technical Standard 5811 implementation.
  Rationale: The only way we can provide a consistent and measurable level of quality is by standardization of the productive process.
  Implications: Without standardization would rapidly undermine the international market.
- *Application Principle:* Service-oriented Platform
  Statement: Flexible applications that allow reuse and therefore can operate on a variety of technology platforms.
  Rationale: In a service-oriented approach, applications are developed, updated, and operated for consumption by customers in different applications or business processes in a more cost-effective and timely manner.
  *Implications:*This principle will require Integration with legacy systems and modernization of outdated systems.
- *Data Principle:* Quality and reliability data.
  Statement: The data must be of quality and reliability and comply with security policies.
  Rationale: Data management must maintain a structured language, allowing comprehensive control of the data life cycle with security policies and information protection.
  Implications: (1)Policies and procedures must be developed to prevent and correct errors in the information.(2) The processes that produce erroneous information must be improved. (3)The quality of the data must be measured to improve its quality.
- *Technology Principle:* Adaptable to Change.
  Statement: In response to business needs and cost/benefit, changes are made to applications and technology.
  Rationale: A change in technology focused on business, not technology needs.
  Implications: (1) Procedures for implementing technology to meet evolving requirements will have to be developed.

A. Phase: ***Architecture Vision***

To establish the scope of the architecture project, we determined the current state of information management in the cacao value chain. We also characterized the standard NTC 5811 of good agricultural practices to define the information requirements in the design of the Technology platform in the cultivation phases of Theobroma cacao. Then, we identified the stakeholders and their vision, concerns, and cultural factors. In addition, we established the modules of the functional processes, specification, and validation of the business requirements.

1) Current status of information management in the phases of Theobroma cacao crops: We conducted direct observation and interviews with cacao production stakeholders, such as cacao farmers, agronomists, cacao associations, and producers of chocolate inputs. After this, we identified the phases and activities of the productive cacao process and how data are collected.

The diagnosis was made at the Aguas Calientes farm located in El Playón (see Fig.3), a municipality in the department of Santander in northeastern Colombia. With direct observation and meticulous accompaniment by the agronomist in charge, who has 20 years of experience in the management of cacao production processes in the Santander regions, we reviewed the processes, procedures, and information management in the phases of pre-sowing, sowing, and maintenance of Crops of Theobroma cacao. We identify various procedures and activities represented through the flow chart of Fig. 4. Each of these processes is the one currently running on the farm. Although we found a large

Fig. 3. Aguas Calientes Farm (ACF)

amount of information in the logs, there was no record of the monitoring of the crop.

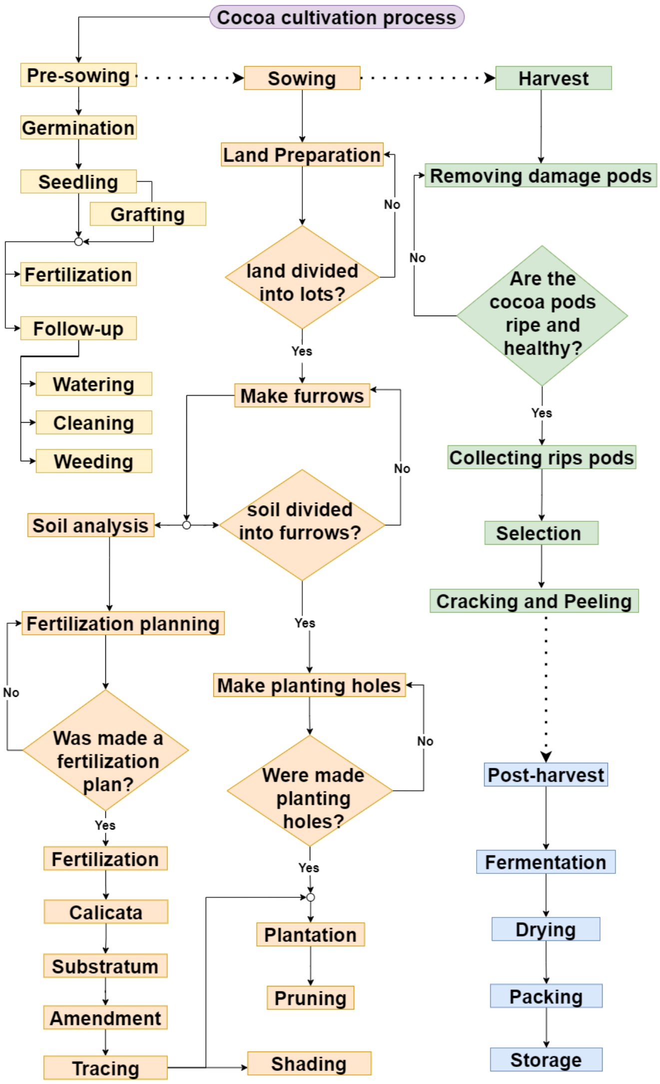

Fig. 4. Flow diagram of cacao cultivation in ACF

- Pre-sowing: In this stage, processes are carried out that are fundamental for developing the plant and the sowing of cacao. First, the necessary inputs are prepared for the generation of seedlings that will later become trees for the production of cacao pods. The essential food of the plant is the substrate that feeds the seedling from its birth and is responsible for providing nutrients in the first years of the seedling's life. This procedure is carried out according to the indications offered by the Agrosavia research, development, and innovation center, starting from the compound of earth, sand, and organic fertilizer.
- Sowing. This phase begins with the preparation of the ground. First, the soil is analyzed through a hole of 1x1x1 meters to verify the profile and characteristics of the earth, such as its depth and composition: puddles, rocks, water, or gravel. This analysis allows knowing if the ground is optimal for the growth of a cacao crop or if fertilization strategies should be used. The two-year-old plant must be in total production, and a well-managed plant must produce at least 1 kg of dry cacao per year. When the cacao yield increases, all the fertilizers essential for its production must be applied appropriately and at the established times, in addition to having proper irrigation management. The optimal growth of the crop in terms of quality and profitability depends on its monitoring and control. It is crucial having good agricultural practices concerning the control of pests, diseases, flower applications, and other activities.
- Harvest. In this stage, the agronomists must estimate the times for which it is verified that the plants have the expected production. They also confirm that the cacao pods meet the maturity requirements. Cacao pods should be grouped on the same mound in the collection and storage and should not be exposed to the sun after being cut. Good agricultural practices in cacao recommend these should not be stored for more than three days since it causes damage to the raw material. For the selection of the cacao pods, it must be verified by the observation method that it does not contain diseases or pests such as monilia, phytophthora, shell damage, or over maturation. Later, they break and peel, caring not to cut the almonds or dirty the wet almonds with foreign particles. The cacao almonds must be placed in a container raincoat to preserve all the mucilage. Once all the pods have been degreased, they must be weighed on a scale, and their weight in slime must be recorded to multiply by 38% to calculate how much cacao will obtain.
- Post-harvest: This phase starts with fermentation in wooden crates. There are two types of fermentation, anaerobic (without air) and aerobic (with air). It starts with the anaerobic process in which the slime cacao is covered with banana leaves and a few sacks for 48 hours without mixing or moving it at a temperature between 28 to 30 Celsius. After this time has elapsed, a first turn is given with a shovel, it is shaken well and stirred, and here the anaerobic process ends. For four days more, cacao beans are uncovered and shaken twice every 24 hours. The drying phase should be done in wood because it absorbs the moisture from that cacao. It carries on for three days with the first 3 hours of sun (7 am to 10 am) and then in the afternoon, with the last 3 hours of the sun. A hygrometer is used to measure the humidity, which must be at 7% according to the ICONTEC 1252 standard. When the grain has the

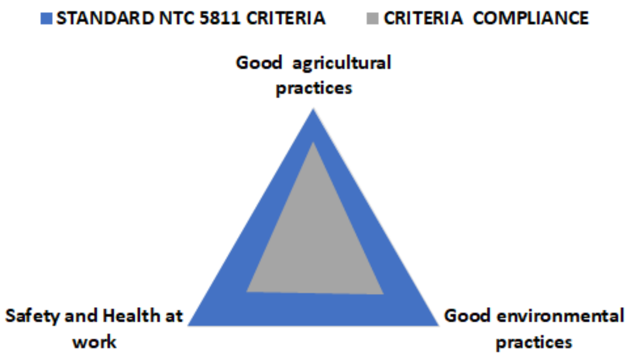

Fig. 5. Criteria compliance by a process according to standard NTC 5811 in ACF

appropriate characteristics, it is packed in new and dehydrated fique bags that comply with organic certification. These should be weighed and marked bags and marked with the batch code according to the packing date. The bags are separated and tagged in a clean and well-ventilated warehouse to maintain the bean's properties, and those are stored for two months maximum. The relative humidity of the cellar should be between 60% and 70%.

After exploring the documents and records on the farm, we noticed that no data or production references, fertilization plans, pruning, sanitary controls, species, or perennials are kept, which are essential data in good agricultural practices.

2) Characterization of the Standard: The Colombian Technical Standard NTC 5811, which is related to good agricultural practices for cacao and is edited by ICONTEC (Colombian Institute of Technical Standards and Certification). Some characteristics regarding the processes that take place in good agricultural practices in the production chain of Theobroma cacao were characterized under this standard [14]. This characterization was carried out through observation, interviews, and the verification of documents published by cacao farms. The interviews were also conducted with experts in the areas of quality, environment, and ICT to understand how to focus this research study.

The characterization of the standard was carried out under the criteria or general requirements that standard NTC 5811 must have. Fig. 5 shows the fulfillment of criteria by processes in which Good agricultural practices meet 77% of conditions, Good environmental practices 56%, and Safety and Health at work 53%. The blue region shows what remains to be implemented according to the standard.

3) Stakeholder Identification: Below, we describe the identified key roles and activities related to the system stakeholders that will interact with the technology platform.

- Agricultural engineer: she/he is in charge of the analysis of soil, the fertilization plans, and management of the: substrate, germination, graft, furrow, plant, shady, product, amendment, disease, pest, follow-up in planting, pruning, collection, selection, and storage of pods, breaking and unwinding, fermentation, drying, and container storage.
- Farm manager: She/He is responsible for pruning, collecting, selecting, and storing the pods, breaking and uncurling, fermentation, drying, packing, storage, plant nursery, sales, and traceability crop.
- Environmental Engineer: she/he is in charge of the management of energy consumption, water consumption, solid waste, and usable waste.
- Food Engineer: she/he is responsible for cacao administration, supplies inventory management, inventory control, cacao processing, chocolate processing, production control, and traceability of the final product.
- Administrator of the Occupational Health and Safety: she/he is responsible for designing occupational health plans at work, evaluating and inspecting, training employees, investigating incidents and accidents, keeping records, and documenting occupational health and safety events.
- Farm employee: she/he is responsible for activities related to cacao cultivation, and reports to the farm manager.
- Information system administrator: she/he is in charge of performing user management, system reviews and updates, and security checks.
- internal/external user: she/he can consult information related to the cacao cultivation process.

*B. Phase:**Business Architecture***

We describe the organizational service strategy, the processes, and the functional aspects of the business environment.

1) Mision: SENA is a public institution in charge of investing in Colombians' social and technical development by offering and executing professional training programs for the incorporation and development of people in productive activities that contribute to the country's growth. This project seeks to contribute with a technical platform for the national chocolate school to standardize cacao production processes with high levels of quality and strengthen all those involved in the Theobroma cacao production chain.

2) Vision: The vision leads the construction of the social and economic capital of the country through increased productivity and competitiveness of cacao with high-quality standards in agricultural, production, environmental, and occupational safety and health. All these through the NTC 5811 standard of good cacao agricultural practices and the development of the national school of cacao quality.

3) Business Drivers: The requirements derived from the business objectives are the drivers of the architecture, which are in charge of guiding or guiding the system architecture design. A good system structure allows each of these drivers to be met.

- Cacao market – Goal: Fulfill expectations of cacao farmers, associations, and production companies and Impact on society to standardize quality processes with good cacao agricultural practices. Objectives:
  - Evaluate and improve good agricultural practices carried out by cacao farmers to improve processes and mitigate risks for increased production.
  - Increase the production of quality cacao due to the deficit levels of cacao worldwide.

- Increase in the productivity of cacao trees and chocolate production companies.
  - Increase in quality cacao exports.
  - Contribute to the competitiveness of the country in the cacao sector.
- Information Systems Technologies – Goal: Develop a better product based on technological innovation. Objectives:
  - Automate and digitize processes.
  - Control, monitor, and manage cacao production processes.
  - Control of the application of good agricultural practices under standard 5811.
- Continuous improvement – Goal: Improve production processes. Objectives:
  - Ensure the proper functioning and improvement of the Technology platform in all its processes, ensuring data and information management in each of the aspects under standard 5811 of good agricultural practices for cacao.
- Costs – Goal: Manage resources efficiently. Objectives:
  - Reduce operating costs.
  - Mitigate risks of production and diseases.
  - Data analysis for decision making.
  - Strengthen the management of the organizational infrastructure.

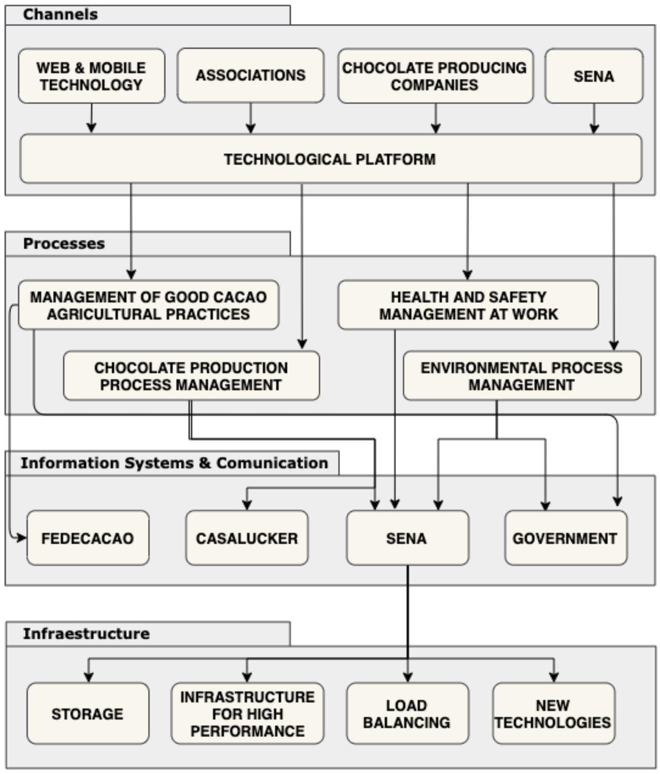

Fig. 6. Solution concept diagram

4) Architecture Vision: The vision of the technological platform design for managing information on Theobroma cacao crops based on the Colombian technical standard 5811 is described below. Fig. 6 shows the solution concept diagram for representing a high level of the expected solution at the outset of the engagement.

5) Business processes Modeling: We perform structural analysis and use case analysis to model the business scenario to discover essential system requirements within the scope of the architecture. Fig. 7 identifies the key functions and maps them onto the organizational units within the scope of the architecture. Each box in the diagram identifies a module of functionalities for the technology platform. It is divided by the requirements outlined in standard 5811 regarding good practices in production processes, health and safety at work, and environmental aspects. Also, the conditions related to commercial management are considered.

We include the use case diagrams in Fig. 8 and the description of requirements to detail the behavior of the good agricultural practices process through its interaction with users.

- UC-TB01: Manage cacao farming. The agronomist engineer manages the activities in each cacao cultivation process based on the soil analysis issued by the chemical laboratories, which deliver a report with the characteristics that must be developed in the pre-planting and sowing to obtain cacao with high-quality indices.
- UC-TB02: Manage cacao quality. The agronomist performs all the procedures set forth by the technical standard NTC 5811 of good agricultural practices for cacao according to the aspects required by the standard in monitoring the harvest and Postharvest. In addition, he must carry out the information flows between each of the processes through the norm.
- UC-TB03: Manage raw material. The agronomist is in charge of monitoring the processes of uncoiling, fermentation, and drying of cacao to measure the quality levels of cacao and characterize the types of cacao obtained in places that meet the appropriate conditions according to the NTC 5811 standard.
- UC-TB04: Sale of cacao. The administrator is in charge of making strategic alliances with external users such as associations, chocolate plants, and foreign companies to find the best alternatives to generate strategies in cacao sales according to quality levels. Also, she/he manages fluctuations of the price of cacao at the national and export levels.
- UC-TB05: The administration of farm. The agronomist is in charge of making a plan for administering annual resources depending on the activity plan recommended by the soil analysis without neglecting the aspects required by the NTC 5811 standard.
- UC-TB06: Consult cacao production processes. The administrator is in charge of consulting the techniques developed according to the activity plan that complies with standard requirements. External users can verify and consult each crop to follow up on crops anywhere in the Santander region.
- UC-TB07: Generate reports. Employees, external users, and the administrator can generate reports.
- UC-TB08: Buy Supplies: The administrator is in charge of carrying out an inventory of the supplies and purchasing the necessary supplies according to the plan

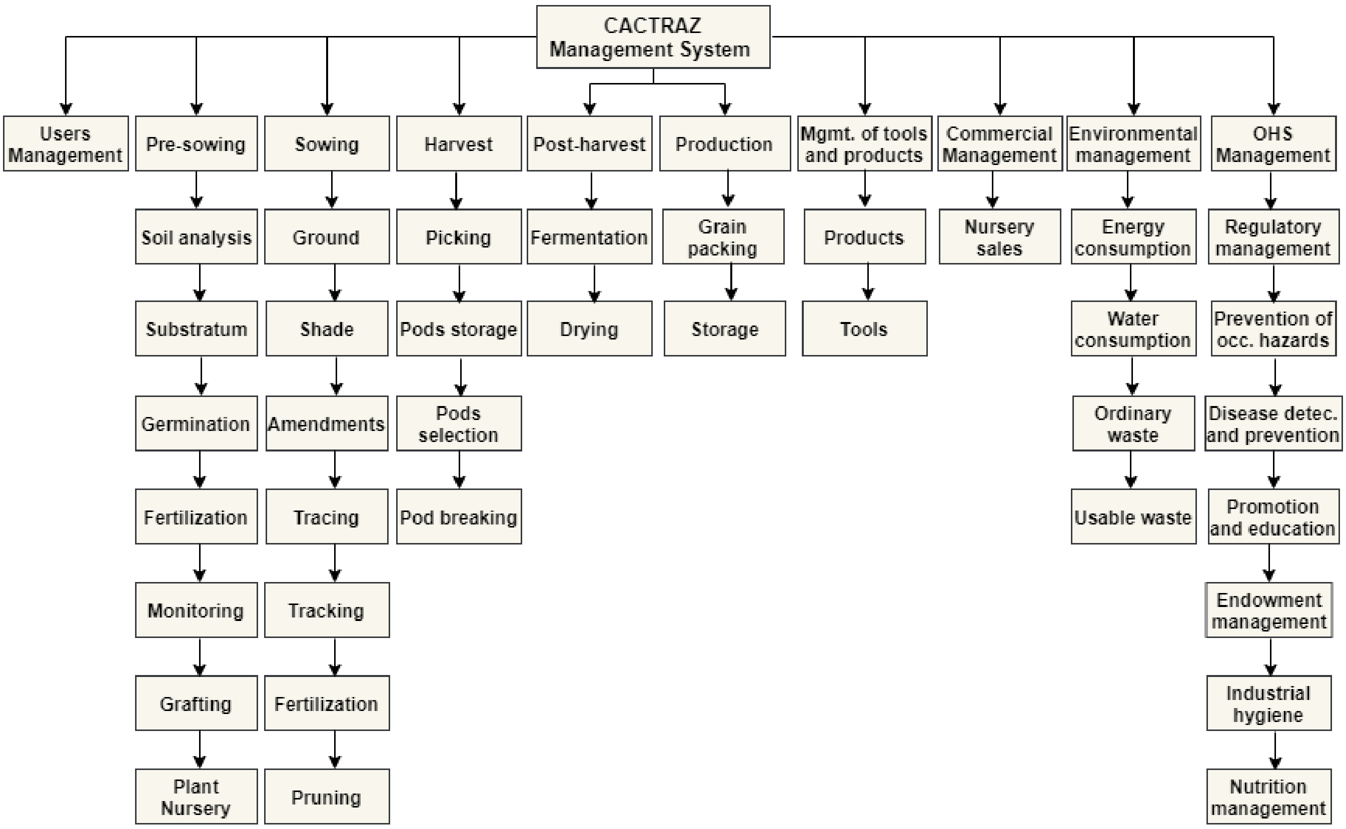

Fig. 7. Functional Decomposition diagram

of activities and essential resources.

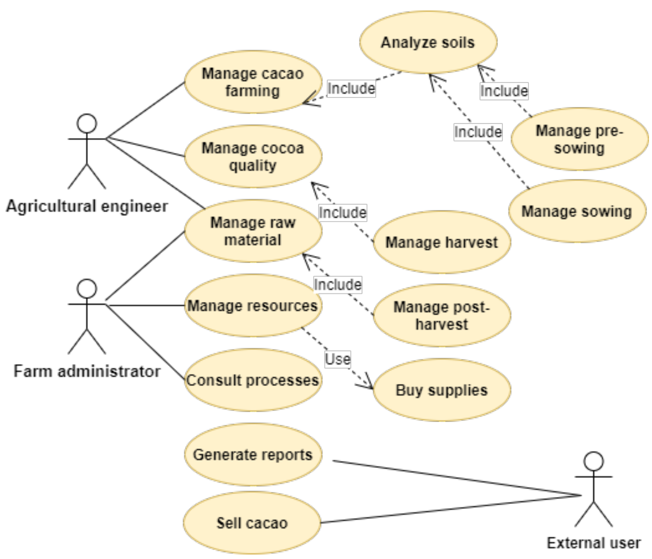

Fig. 8. Business Use Case Good Agricultural Practices

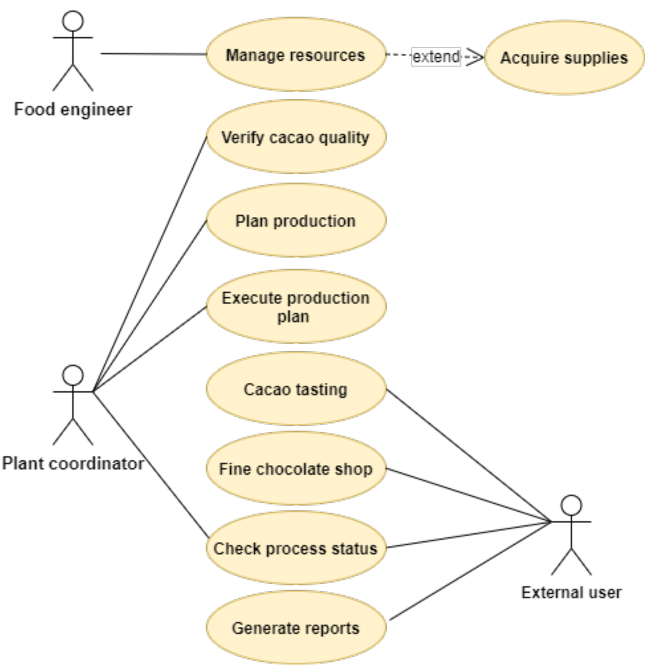

Fig. 9. Production Management business processes

Fig. 9 shows the use case diagrams of the Production Management process. Then, we include the description of the requirements to detail the behavior through your interaction with users.

- CU-TB09: Plant resource management. The plant administrator makes a plan for the administration of resources annually depending on the schedule of activities recommended by the agronomist; to supply the necessary resources and inputs in the production of chocolate and its derivatives.
- CU-TB10 Acquire cacao raw material. The Food Engineer monitors the processes of uncoiling, fermentation, and drying of cacao to measure the quality levels of the beans and characterize the types of cacao according to

the NTC 5811 standard.

- CU-TB11 Verify cacao quality: The food engineer consults the processes and performs procedures to verify the cacao quality according to the standard. Check the chemical and physical characteristics.
- CU-TB12 Plan production. The food engineer performs strategic planning of the resources necessary for display in the year to maintain control and minimize losses.
- CU-TB13 Execute Production Plan. The food engineer executes the production plan designed and analyzed by the agronomist, complying with the execution of the resources and the times established in the execution plan.
- CU-TB14 cacao tasting processes. The food engineer measures the percentages and quality levels of cacao, using cacao's physical and chemical properties performed by a group of tasters.
- CU-TB15 Sale of fine chocolate. External users, such as chocolate companies and associations in the country, intervene in the sales processes to develop marketing strategies.
- CU-TB16 Consult chocolate production processes. The engineer can consult each of the functions and data flows in the entire chocolate production chain in the production plant. An external user can know the qualities and properties of the products through traceability queries of cacao production.
- CU-TB017 Generate reports. An employee, an external user, and the administrator can generate reports.

Fig. 10 shows the use case diagrams of the Production Management process. Then, we include the description of the requirements to detail the behavior through your interaction with users.

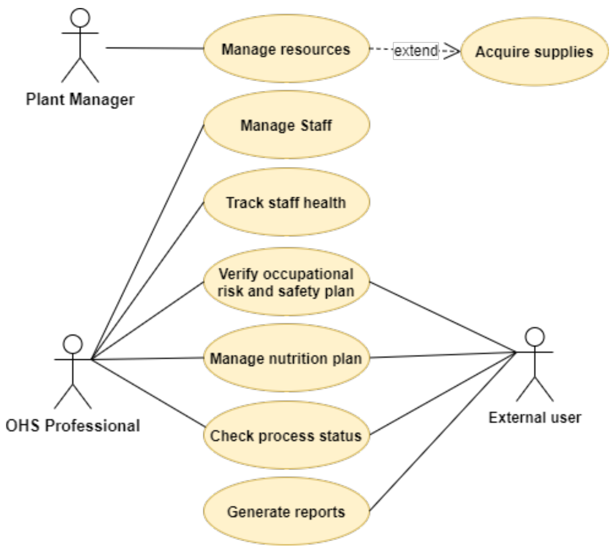

Fig. 10. Occupational Health and Safety Management business process

- CU-TB18 Administration of health and safety resources at work. The farm and plant administrator plans the administration with the help of the activity plan recommended by the expert in health and safety at work to supply the resources and supplies necessary in health and safety processes.
- CU-TB019 Manage Personnel. The occupational health and safety expert manages each employee's information flows regarding aspects of health, nutrition, functional assessment, and functional assessment.
- CU-TB020 Staff health monitoring. The occupational health and safety expert verifies and performs follow-up procedures on each employee concerning the minimum requirements that a worker must have to comply with her work activities.
- CU-TB021 Verify risk plan and recommendations. It must be verified that the risk plan and requests defined by the occupational health and safety expert comply with each of the employees.
- CU-TB22 Manage nutrition plan. The occupational health and safety expert performs a data analysis according to the stored information and grants a nutrition plan to each employee to meet the nutritional requirements.
- CU-TB023 Generate reports. For this activity, an employee and the occupational health and safety expert can generate reports of the processes defined in each specified role.
- CU-TB24 Consult occupational health and safety processes. The occupational health and safety expert and the employee can make the necessary consultations depending on their roles' activities.

Fig. 11 shows the use case diagrams of the Production Management process. Then, we include the description of the requirements to detail the behavior through your interaction with users.

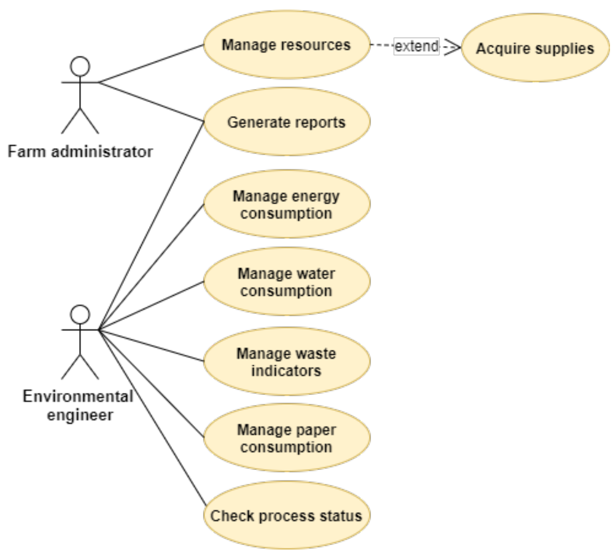

Fig. 11. Environmental Management business processes

- CU-TB19 Energy consumption management. The environmental engineer manages the information flows,

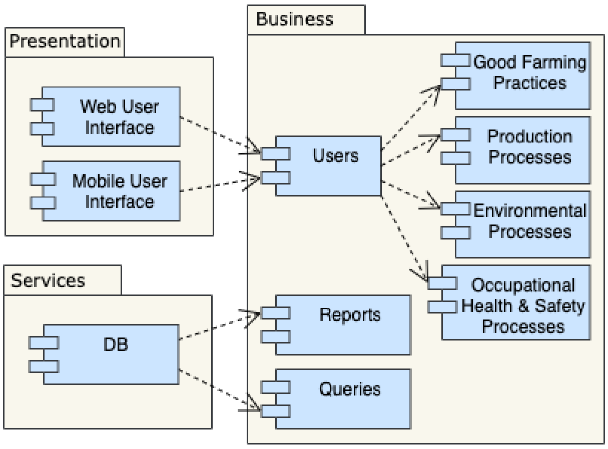

Fig. 12. Packages Diagram

taking into account the indicators defined according to the standard's requirements. They continuously monitor the information for decision-making.

- CU-TB20 Water consumption management. The environmental engineer manages the consumption of the water processes on the farm at the plant. He also carries out ecological activities to maintain the indicators in a range that has already been established and defined according to annual planning.
- CU-TB21 Management of waste indicators. The environmental engineer manages KPIs of composting, usable waste, ordinary waste, and hazardous waste to keep track of waste during the entire process.
- CU-TB22 Paper consumption management. The environmental engineer analyzes and reduces paper consumption all the procedures developed in the cocoa value chain.
- CU-TB023 Generate reports. For this activity, the employees and the environmental engineer are responsible for generating reports on the processes defined in each specified role.
- CU-TB24 Consult occupational health and safety processes. The environmental engineer and the employee can make inquiries according to the activities defined in each role.

C. Phase: *Information Systems Architecture*

The application architecture is composed of different application layers with their corresponding components [15]. Fig. 12 presents a package diagram with the components that belong to each layer. This diagram details how the components interact with each other and what is the communication system between each component to be able to describe the information flows with the logical artifacts of the system.

- Good Agriculture Practices: soil analysis, pre-planting management, germination management, grafting, seeding management, harvest management, post-harvest management, fermentation, drying, storage, resources management, process management, report generation, and sale of quality cacao beans.
- Production Processes: acquire cacao raw materials, verify cacao quality, production plan, run production plan, cacao cupping process, and chocolate products sale.
- The Safety and health processes at work: staff management, staff health monitoring, verify footprint analysis, plantar footprint tabulation management, problematic and recommendation management, verify risk and security plan, staff nutrition management, and reports generation.
- Environmental Processes: energy consumption management, water consumption management, paper consumption management, waste consumption management, resources management, report generation, and processes management.

Once we defined the package diagram, we proceed to make a diagram with the logical components, which are described through the component's diagram presented in Fig. 13. This diagram contains the following layers as well as communication and data flow between layers.

- Web access technology platform: Through this layer, users can interact with each process of the technological platform. The information must flow between the nodes and external requests have security policies with SSL encryption. All interfaces are developed under an HTML 5 tagging standard with JavaScript validation systems, and everything has responsive technology for the interfaces to be rendered on any device.

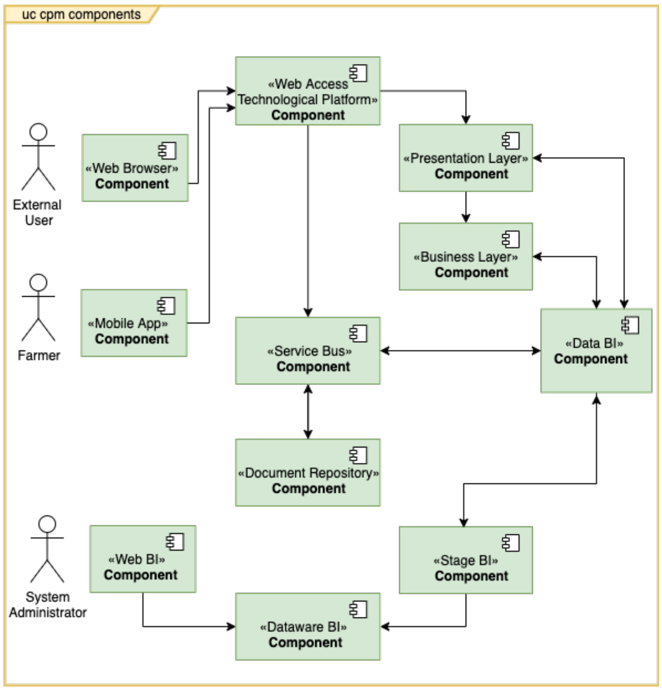

Fig. 13. Components Diagram

- Service bus layer: This layer orchestrates the communication between each web service and application. Some features have been managed such as innovation, routing, mediation, message transmission, service management, among others.
- Business layer: This is synchronized with the logical components and is a layer with available properties that meets the functional and non-functional needs and requirements of the technological platform. This layer has

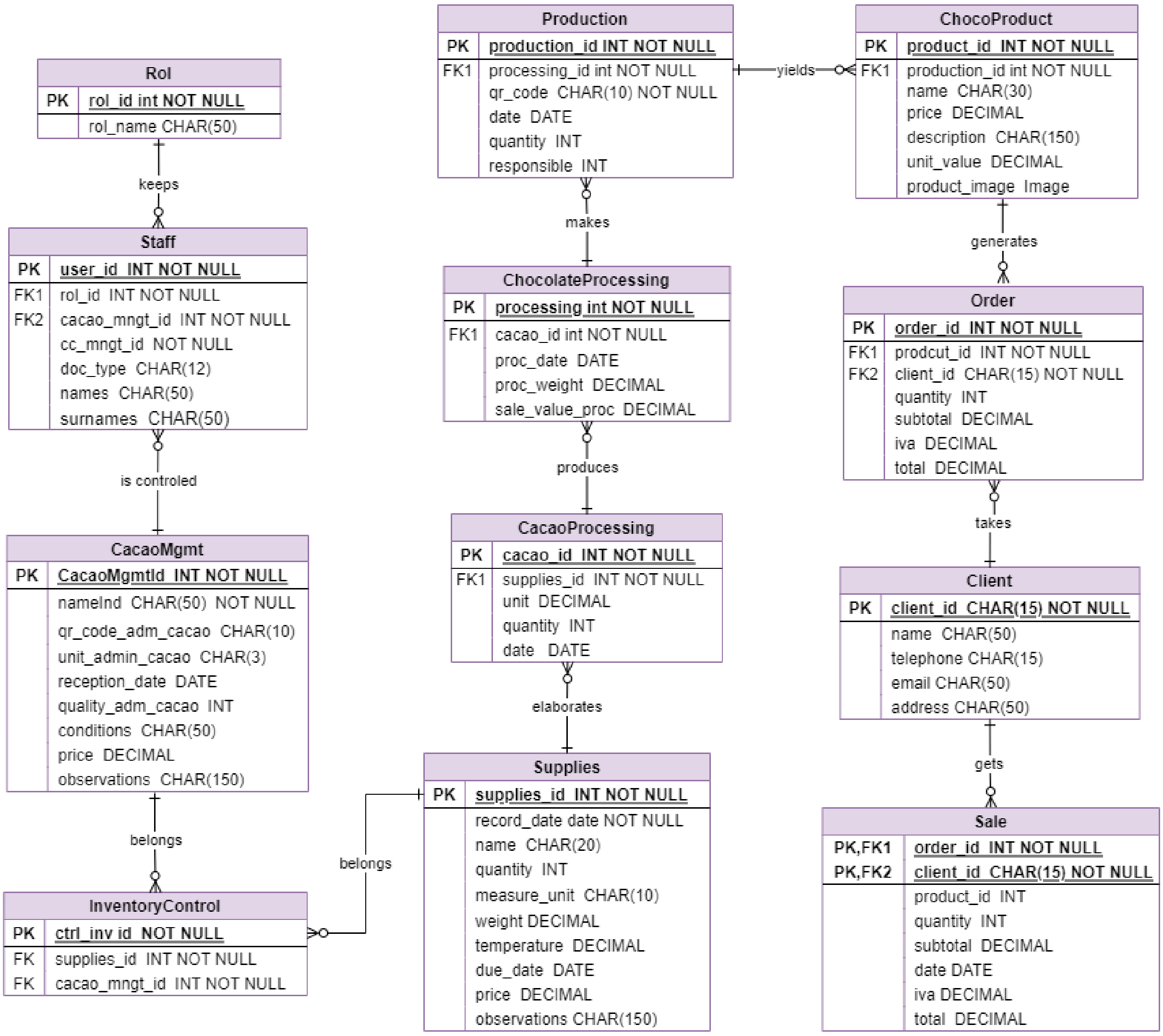

Fig. 14. Relational Database Model: Chocolate production management

bidirectional communication with the presentation layer, service bus, and data persistence. This communication is carried out through requests that are routed to fulfill the required services.

- Data persistence layer: It provides information access policies and data management stored with persistence in database administrators. They have read and write properties, maintaining data independence regarding the database administrator.
- Get and post web and mobile requests. Within the component diagram, the communication and data flow between each layer is evident, which is why it is represented through two communication diagrams that identify the aspects, variables, and resources used in the information flow processes.

1) Data Architecture: We designed for each module a relational model and the data dictionary to manage the data of the processes: good agricultural practices of cacao, management of chocolate production, management of safety and health processes at work, and good environmental practices. Fig. 14 presents the relational model for chocolate production management.

- Entity: Staff. It stores the identification data of the people who work in the chocolate processing plant. Associations: 2. Attributes: 7.
- Entity: Rol. It stores the name of the role that a worker performs in the plant. Associations: 1. Attributes: 2.
- Entity: CacaoMgmt. It stores the cacao data that arrives from the farm, and its identification is kept to carry the traceability of it according to the standard. Number of associations: 2. Attributes: 9.
- Entity: InventoryControl. It stores the data of the inventories of production inputs and raw materials of cacao. Number of associations: 2. Attributes: 3.
- Entity: Supplies. It contains the data of all the inputs that are needed for the elaboration of chocolate products. Associations: 2. Attributes: 10.
- Entity: CacaoProcessing. It stores the data of cacao processes. Associations: 2. Attributes: 5.
- Entity: ChocolateProcessing. It stores the data of chocolate production processes according to the product to be produced. Associations: 2. Attributes: 5.
- Entity: Production. It stores the data of chocolate production processes according to the product to be produced. Associations: 2. Attributes: 6.
- Entity: ChocoProduct. It stores chocolate-based prod-

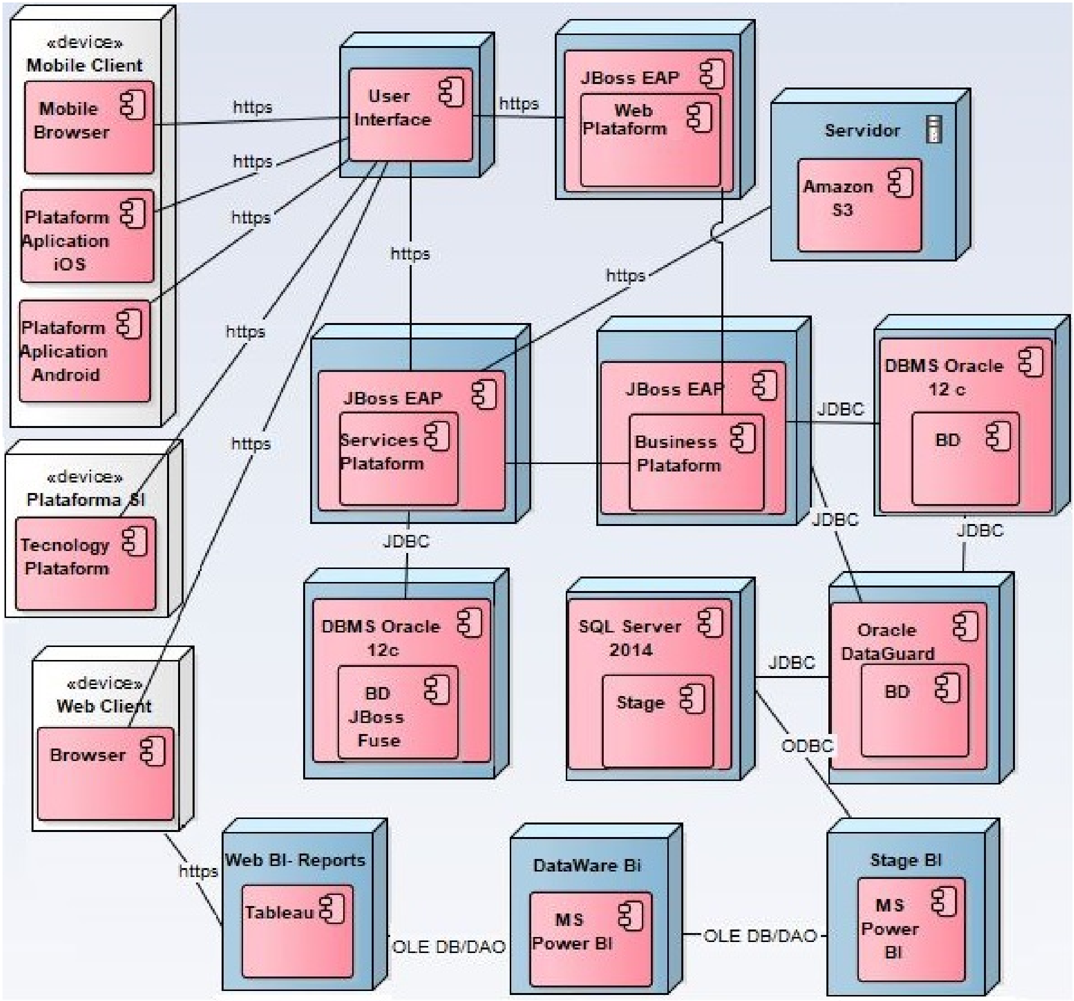

Fig. 15. Deployment Diagram

ucts that make up a customer's order are stored in this entity. Associations: 2. Attributes: 7.

- Entity: Order. It stores the data regarding to the orders made by the client. Associations: 2. Attributes: 7.
- Entity: Client. It stores the data of the buyers of chocolate products. Associations: 2. Attributes: 5.
- Entity: Sale. It stores the data of sales made by clients. Associations: 1. Attributes: 8.

D. Phase: ***Technology Architecture***

1) Deployment: For the Technology platform of information management for Theobroma cacao crops, we took into account requirements and aspects such as interoperability, data security, data logic, functionality, usability, and efficiency [16]. Fig. 15 presents the deployment diagram, which includes the following elements.

- Apache Application Server: It is a free and open-source web server software.
- Oracle 12 database engine: Database server for the storage of information on the web and mobile technology platform for information management of theobroma cacao crops.
- Service bus: Service platform, where the services of the Technology platform are exposed.
- File Repository: Amazon's storage platform called *Amazon S3*, which makes storage of objects easy, scalable, secure, and highly available.
- Java 1.8: Java Application Programming Language.
- JEE 7: Java Enterprise Application Execution Platform.

2) Infrastructure Description: It corresponds to the different components that are exposed in the architecture are presented in Fig. 16. These components are made up of the hardware type load balancer with at least two presentation servers as well as two application servers to provide availability. The architecture, according to its design, is oriented to the scalability of the Technology platform horizontally and vertically.

According to the requirements for the application architecture, the infrastructure architecture is defined as follows. The requests or needs required by users in both web or mobile environments and other information systems will consume the services through HTTP and HTTPS requests according to the authentication of each of the roles defined for the users. To maintain good practices in information security, a firewall is defined which filters the attacks that may arise. The load balancer aims to route each of the requests according to the user's need, assigning the connections through SSL certificates.

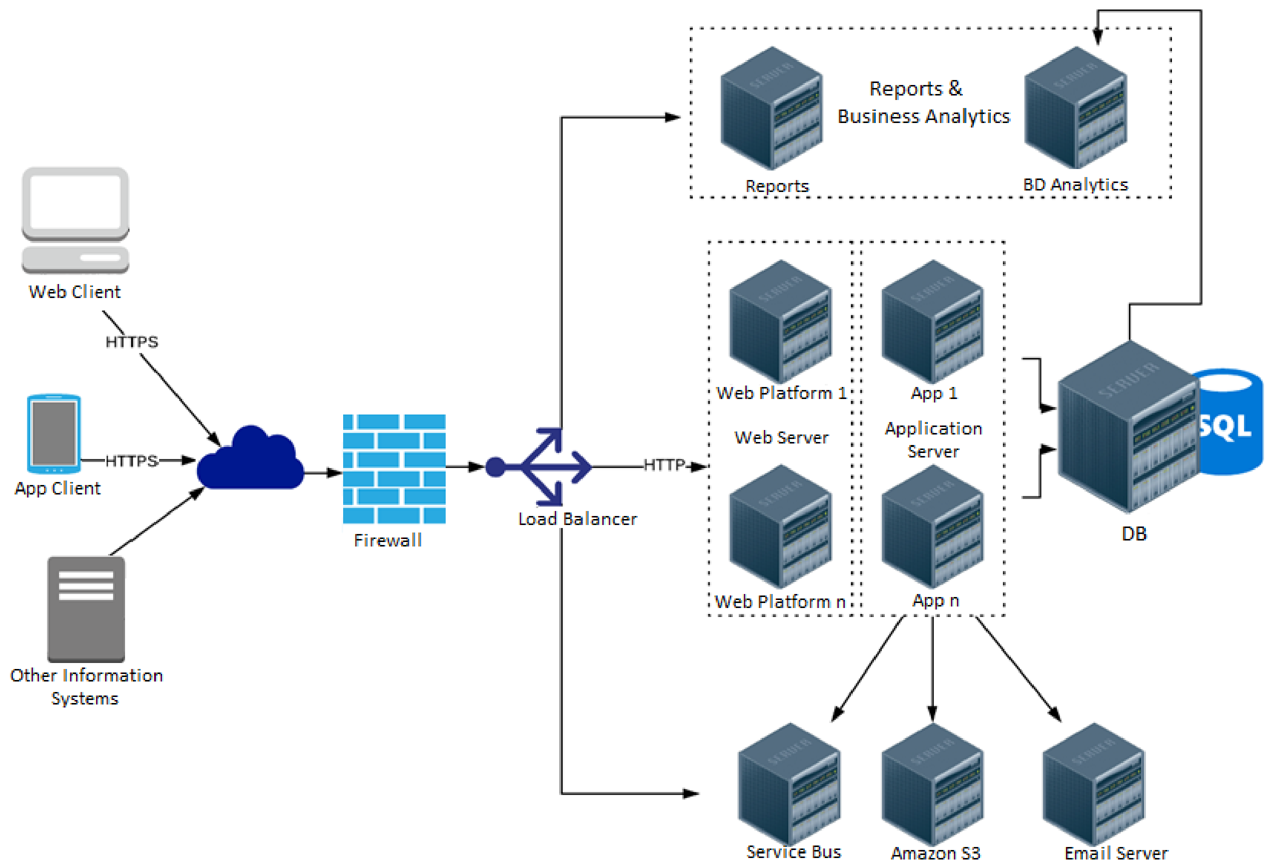

Fig. 16. Infrastructure Diagram

The architecture has three machines for the storage of information which must have a contingency or backup plan, for which an ODS storage transactional platform is offered that serves as a support for the generation of reports. This does not affect the processing of transactional operations data [15].

IV. Conclusions

We identified that in the cacao production process located in *Santander*, there is no knowledge of technical tools in the production processes. There is also no organizational or technological culture, so updated information on production processes is not managed and human resources and farm information are not taken into account. Finally, there are no good practices regarding environmental aspects.

Based on the instruments of a business architecture model, it was possible to identify the technology gaps that the agricultural sector has in the cacao production chain, where stakeholders, roles, process flows, types were identified. Also, information management and strategic business objectives were defined.

Different methods were used to collect information based on the principles of the NTC 5811 standard of good cacao agricultural practices. All this is to generate the characterization of the standard, the identification of its own needs that generate business value, and the necessary inputs for the design of the Technology platform based on a TOGAF business architecture model aligned to the IT strategy.

In the cacao production chain, none of the stakeholders involves information technologies because everyone works according to their needs and priorities. Therefore, the different stakeholders in the chain must be aware that IT investments bring them high impact benefits such as more agile, reliable, and efficient communications, less processing in the value chain, benefits in resources, cost reduction, greater financial profitability, new business models, increase production, and traceability in processes and information. This generates business and market organization's own characteristics that are obtained with the application of the business architecture methodology through a framework.

V. Recommendations and Future Work

The development of this technology platform would allow the collection and analysis of data and the monitoring and control of the entire cocoa production process. However, it could have a high implementation cost, so we recommend a combination of these financial alternatives: an investment based on a crowdfunding model for agricultural enhancement [17], a donation or reward-based model, or a nonprofit project formulation with the alliance of organizations working in this economic sector [18].

A second technology stage for this agricultural product is traceability with IoT to record and find out each product's use, location, movements, and trajectory along the chain, from its origin to its arrival at the final consumer [19]. Traceability would make it possible to know where the components of the cacao come from, what treatments are applied to it, and how the distribution takes place. This technology enhancement, such as the authors propose, would bring benefits such as improvement in product quality and aggregated value to the final consumer [20], [21].

Finally, it is crucial to work closely with farmers to promote good agricultural practices and green economic models [22] and collaboration throughout the supply chain [23]. These sustainable and equitable initiatives generate tangible benefits for farmers and healthy products for the final consumer [24], [25].

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