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General introduction

Historically, people satisfied their alimentation needs from producers available to their locality. But, with the passage of time, people's changing desire to eat different things and lack of resources (water, proper land condition, weather etc.) generated the need of finding the alimentation outside their local reach. Now, mode of food consumption has evolved. People procure food from different available places like restaurants, coffee shops, fast food chains, vending machines, etc., specializing the food of different sources and types (region and culture). Nowadays cities have become cosmopolitan, movement of people from one country to another is common phenomenon. People of one ethnicity enjoy the food of other. Taking into account this human evolution, food producing companies came into existence. Today, most of the food consumed by the world population is supplied by the food industry. Food Business in our day is globalized. International imports and exports have become common to bring the food from faraway locations. Need of profit and low-cost opportunities have led the delocalization and outsourcing of production in different regions and this is also true in the context of food. Production is nowadays distributed over several faraway production sites. Therefore, food products need to be transported between these sites and final products to be distributed to faraway retailer sites and consumers.

This demand of bringing food from distinct locations is increasing with the growing population. Each day almost 200,000 more people are added to the world food demand (UN population Division, 2007). Hence stressing the Food EcoSystem (FES) to increase the food production, where FES is the environment consisting of all the things (in any form) and entities (from farmers, livestock owners, to producers, distributers and retailers) associated with food directly or indirectly. Bringing food from distinct sites also requires their quality preservation and quality is associated with respecting food's perishability constraints like short shelf-life, temperature sensitiveness, hot or humid weather, etc. Perishability constraints are the particularities of food that need to be handled throughout all the activities of production, distribution, sales, etc. These activities are performed by several distinct entities from individual, small & medium sized (SME) to large enterprises.

In FES, for a particular type of food, we can identify different collaborations of such entities forming a network of business called Food Supply Chain (FSC). Food ecosystem consists of several such FSC and entities of one FSC are part of several FSC. FSC is one of the most complex and largest industry sectors in the world. In FSC, agricultural, farming and sea merchandises are used as raw materials for producing consumer products with higher added value. In most cases, conservation and conditioning processes are performed to extend the shelf-life of these products. Unlike other supply chains, FSC has to maintain an efficient cold chain, because most of the food products are temperature sensitive and have to be kept under temperature control environment throughout the activities of FSC. Different type of food products (fresh, refrigerated and frozen) require different temperature conditions, so they need to be transported and stored separately. Today, food products are gathered at the same place for sale called retailers and constant and continuous flow of products to retailers is a critical link in FSC.

This constant flow of products requires enormous transportation network to connect all the concerned entities in FSC, such as manufacturers, retailers, consumers, etc. With the increasing food transportation, leads to an increasing in the number of transport travels, environmental pollution and transportation cost, which is becoming the major concern for the FSC entities. More often companies, especially SME, wanting to reach faraway customers could not possibly purchase their own transport carriers to deliver their goods. Necessity to cope with transportation demand led to the advent of specialized transport enterprises often called third party logistics provider (3PL), which emerged as a new actor in FSC. These transporters take charge of partial or whole process of transportation from loading products from suppliers' warehouses to the distribution of goods to retailers. These transporters need to collaborate with producers and retailers within FSC to take into account future demands and trends to organise their transport network and resources to make possible the delivery of food products with quality. They even need to collaborate with other transporters to reach faraway locations, outside their limited geographical operating area.

Considering the context of FSC, it inherits not only the common problems faced by other supply chains (bullwhip effect, aggressive competition, uncertainty, interoperability), but also has to deal with the challenges arising from the perishability of food products. Therefore, it becomes extremely important for

FSC, to handle issues such as maintaining food products quality, forecasting the product demand, managing the inventory according to the forecast to reduce out of stock or excessive inventory of products, improving the efficiency of replenishment, production & transportation by taking into account product future demand and tracing & tracking to react to disturbances. It is therefore necessary to institute collaboration between the main entities of FSC to deal with all of these issues, because all of these issues are related to FSC partners in joint manner. In a collaborative supply chain, individual partner companies work jointly to plan and execute supply chain operations with greater success than alone. Thus collaboration became vital for FSC.

Existing collaborative approaches like Quick Response, Vendor Managed Inventory and Collaborative Planning Forecast & Replenishment etc. do not take into account transporter actor, which today is the important link for food supply chain. Additionally, they consider production planning as the implicit part of replenishment process not a collaborative task. The conventional transportation planning solutions have not explicitly considered interoperability among producer and transporter systems and in the context of food products, focus is normally on timely delivery of products, capacity constraints or determining the optimal roots delivery, but not on consideration of perishability constraints. The current supply chain management information systems such as Advanced Planning System, Transport Management System, Supply Chain Execution system, etc. are integrated solutions but do not support inter-organizational collaboration.

The global objective of our research work consists in developing a reference model for collaboration of food supply chain including the transporter actor and detailed objective consist in yielding an interoperable transportation planning model based on the principles of the reference model. Therefore, three challenges are investigated in this thesis:

- *What to collaborate?* In order to let actors of FSC, including transporter to collaborate, it is important to identify all collaborative activities, their input data, their output data and interaction links.

- *How to collaborate?* It is necessary to build interoperable model that institute collaboration among producer and transporter systems for transportation planning without bothering their individual systems.

- *Handling perishability constrains?* While proposing the transportation planning, it is necessary to take into account food's perishability constraints.

This thesis is organized into two parts. First part, including the first two chapters, aims to give a more precise description of the study background, in order to clearly understand the scientific key issues of this work. The second part includes three chapters, comprises of solutions proposed and their application.

Chapter 1 focuses firstly on introducing the food ecosystem. This section explores the world around the food, its evolution towards the industrialization of its production. What impact this industrialization has caused on overall ecosystem, in how many categories food is classified & sold and list of constraints associated with food products. Secondly, concepts related to FSC are introduced. This section intends to describe general concepts of supply chain like flows, activities and structures and then details growing interests in food supply chain, challenges faced of FSC, supply chain management (SCM), SCM software solutions and limitations.

Chapter 2 focuses on the collaboration in FSC. This part intends to define the scope of our research problem by answering the following question. Which level of collaboration we are interested in? What collaborative areas we want to focus? What are the existing collaborative approaches? What are their limitations? Finally what problems we are going to solve?

In chapter 3, we present the model C-PRIPT (Collaborative -Planning Replenishment Inventory Production and Transportation), which extends the functionality of CPFR model. C-PRIPT includes transporter actor with producer and retailer in collaborative process of FSC and elaborates production and transportation planning as collaborative activities.

In chapter 4, we propose a distributed and interoperable transportation planning model I-POVES (Interoperable - Path Finder, Order, Vehicle, Environment & Supervisor) to realise collaborative transportation planning by making collaborate producers and transporters. It aims at a better use of transport resources, by minimizing transport travels, cost and pollution by grouping similar food product transport orders for collective delivery.

Chapter 5 is dedicated to present the application of the proposed models, in the context of the European project TECCAS, for which this research work is realized. This chapter briefly introduce TECCAS project followed by SOA framework proposed for it on the basis of C-PRIPT model.

Afterwards, we describe the pilot case study extracted from TECCAS project and present its step by step execution with I-POVES. In the end we present analysis of the results acquired. At the end of this thesis, a general conclusion states the main contributions, lists down the deliverables obtained and presents the major limitations and perspective of this work.

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Chapter1

Problem description of food supply chain

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"You can have the best product in the world, but you need the best process to get it into stores and sold." [1]

1.1 Introduction

Due to varying taste, cultural and religious norms, humans have adopted a range of dietary patterns through both genetic specialization and cultural conventions demanding food sourced from different regions of habitation. Bringing food from distinct regions require its quality preservation due to its perishability constraints (short shelf life, temperature sensitiveness, climate, etc.). In addition to food quality, increasing human population demands an increasing in food quantity. Respectively, increase in food quantity requires an increasing in food production. Need of profit and low-cost opportunities have led the delocalization and outsourcing of production in different regions and this is also true in the context of food. Production is nowadays distributed over several faraway production sites. Therefore, food products need to be transported between these sites and final products to be distributed to faraway retailer sites and consumers. Consequently, involving several distinct entities from small & medium sized to large enterprises, distributed in various regions of the world.

Each distributed entity performs its action, from food cultivating, growing, harvesting and farming to processing, producing, packaging, distributing, etc. All the things (in any form) and entities (from farmers, livestock owners, to producers, distributors and retailers) associated with food directly or indirectly form an environment called food ecosystem. These distributed entities together for a particular type of food product form a network of enterprises called Food Supply Chain (FSC). Food ecosystem consists of several such FSC and entities of one FSC are part of several FSC. Due to FSC distributed and large scale nature, FSC inherits problems faced by other Supply Chain (SC), but also has to deal with the challenges arising from the perishability constraints of food products. This perishability nature makes extremely important for FSC the handling of issues such as maintaining the quality of food products, forecasting the product demand, managing the inventory according to the forecast to reduce out of stock or excessive inventory of products, improving the efficiency of replenishment, production & transportation by taking into account product future demand and tracing & tracking to react to disturbances. Hence, to deal with all of these issues, it is necessary to institute collaboration between the main entities of FSC,

[1] http://www.aacs.org.au/supplier-retailer-collaboration/

because all of these issues are related to FSC partners in joint manner. Thus collaboration becomes more and more important in FSC in order to achieve high level performance.

This chapter is divided into two parts: first part is presentation of food ecosystem, which explores the world around the food and its evolution towards the industrialization of its production. What impact this industrialization has caused on overall ecosystem, in how many categories food is classified and constraints associated with these food products. Second part is dedicated to food supply chain, in which we present some general concepts of SC like flows, activities, structures. Then, we present challenges faced by FSC. Afterwards, we describe the concept of Supply Chain Management (SCM) which has been developed and studied for trying to solve various SC problems. This section describes principles of SCM through the house of SCM and lists down well known SCM softwares developed to perform different functions of SCM and their limitations, eventually rising the need for collaboration.

1.2 Food ecosystem

In this section, we define food ecosystem and present food classification and constraints.

1.2.1 Food ecosystem definition

Food ecosystem involves all the activities from food cultivating, growing, harvesting and farming to processing, producing, packaging, distributing etc. and all the entities from farmers and livestock owners to producers, distributors, retailers and consumers. Figure 1.1 depicts the typical representation of food ecosystem. This figure illustrates different source of food (meat, fish, vegetables & fruits), food transformation process from production to consumption, factors affecting the food ecosystem such as, food wastage, weather, transportation technology, etc. In food ecosystem, historically people satisfied their alimentation needs from producers available to their locality. But, with the passage of time, people's changing desire to eat different things and lack of resources (water, proper land condition, weather etc.) generated the need of finding the alimentation outside their local reach. Now, mode of food procurement and consumption has evolved. Currently food producing, processing, distribution companies came into existence. Today, most of the food energy consumed by the world population is supplied by these food industries including restaurants, coffee shops, fast food chains, schools, bars, vending machines, etc. International imports and exports become common. People of one ethnicity enjoy food of another, for example we can find food products originating from other countries at supermarkets or at specialized restaurants of Chinese, Italian, French, Indian, Thai, etc. World Bank reported that the European Union was the top food importer in 2005, followed at a distance by the USA and Japan. The variety and availability of food is no longer restricted by the diversity of locally grown food or the limitations of the local growing season [Regmi, 2001].

Figure 1.1: *Food Ecosystem*

But as this food revolution brought substantial pros for food ecosystem, there have also been emergence of other cons that pose threats to food ecosystem.

Each day almost 200,000 more people are added to the world food demand[2]. The result is increasing consumption of food per capita and increasing demand in food production. Food production is also affected with changes in diets towards a higher proportion of meat [Vasileska and Rechkoska, 2012]. Animal protein requires more land, water, and energy to produce than plant protein. Today, nearly half of the world's cereals are being used for animal feed. Due to increase in food demand forests are being converted in agricultural lands. Deforestation is a significant cause of climate change and results in the loss of ecosystem services that are critical inputs to agriculture, including erosion control, climate regulation, water regulation, etc. [FAO., 2010]. Climate change impacts exacerbate food production conditions, especially in the developing countries where rural depend on weather conditions for sustenance and livelihoods [Ranganathan and Hanson, 2011].

Food ecosystem is also affected by food wastage. It is estimated that half of total food produced worldwide is wasted, according to the British Institution of Mechanical Engineers (IME) [Post, 2013]. In developing countries about 100 kilograms per consumer per year is wasted at the consumption stage [Gustavsson et al., 2011]. Causes of food waste can be severe weather, machinery used in harvesting, attack of pests and micro-organisms, influence of economic factors, etc. [Kantor et al., 1997, Parliament, 2009]. Other reasons are throwing away large quantities of food that surpass their best before dates at retail stores, food wastage after eating and food contaminated due to pollution. Food pollution means the presence of toxic chemicals or biological contaminants in food, making it dangerous for human consumption. Food pollution can emerge during a process of getting into contact with other polluted food and by several other ways, such as growing food in polluted soils, solid wastes or areas with polluted groundwater or polluted air. Food is also polluted through the processes of packaging materials, processing/cooking equipment or naturally occurring toxins, presence of pesticides, etc [3].

These reasons eventually increase the cost of production, which results an increasing in commodity prices and inflation. Rise in food prices affects more to the poor in developing countries, who spend roughly half of their household incomes on food. There are several reasons for the rise in inflation: increased transportation costs, government taxes, import & export duties, etc. On the contrary, globally human well-being has improved over the past 50 years, as measured by the United Nations human development index [Board, 2005]. We live longer, are better

[2]http://esa.un.org/unpd/wpp/unpp/panel_population.htm
[3]http://en.wikipedia.org/wiki/Food_contaminant

nourished, yet the health of ecosystem has been declined. Humans have degraded the majority of ecosystem services. For example, introduction of aquatic alien fish species has led to the extinction of native species in many parts of the world.

In order to address these issues, some actions are also being taken, for example creation for European Food Law to insure food safety. According to this law, each food product to be sold in Europe should be traced and tracked. So that in case of its contamination, origin of contamination can be tracked. Scientifically modified crops are being cultivated providing more production at lesser space. Despite of that, food business is continuously being shaped by the evolving demands of customers and technologies. Foods are processed and added with preservatives in order to reduce the generation of bacteria in them to increase their life. Foods are kept under different temperature conditions to provide them different shelf-life and endurance. Foods are transformed and presented in different forms to pleasure and serve different consumers' needs. Eventually, we can see that there are normally four categories in which food is made available to consumers: Hot, Normal, Refrigerated and Frozen. We detail this classification in next section.

1.2.2 Food classification

1.2.2.1 Food products with hot temperature

Under this category, comes normally the cooked food, served in restaurants, hotels, cafeterias, food vehicles, different social events or at homes. It also includes the beverages like, coffee, tea, etc.

1.2.2.2 Food products with normal room temperature

This category concerns the food types, which are not very temperature sensitive and can be kept under normal room temperature, but should not be placed under direct sun heat. These foods are for example rice, dry fruits, bread, biscuits, sweets cereals etc. These products have life-span from one day to weeks and months even few years. This category also includes preserved food. Beverages like plain water, alcoholic, non-alcoholic drinks and soft drinks can be kept under normal room temperature, but they are served usually cold.

1.2.2.3 Refrigerated food products

Refrigerated food includes fresh vegetables, fruits, meat and sea food. Fruits and vegetables benefit from proper post-harvest care, otherwise they lose moisture, and degrade rapidly. Meat is also sold in pre-packaged cuts like chuck, leg, rib, flank, etc. In addition to cold temperature, sea food is kept on ice, to minimize its fishy smell, due to the breakdown of amino-acids present in it. Fish and meat products deteriorate more rapidly in comparison to vegetables and fruits.

1.2.2.4 Frozen food products

Fruits, vegetables, sea food and cooked meal can be frozen to slow down their decomposition by turning residual moisture into ice, inhibiting the growth of most bacterial species. Frozen products do not require any added preservatives because microorganisms do not grow in ice and these foods may be preserved for several months by maintaining a constant temperature of -18°C or less.

Above presented type of food products arrive from several distinct regions of the world. Recently in 2014, we have seen a million dollar contract signed between China and France to import baby milk in China from France. Food business has become globalized phenomenon. Bringing food from distinct sites requires their quality preservation and quality is associated with the food's perishability constraints that should be respected in order to prevent them from pollution and deterioration. Next section is dedicated to present these constraints.

1.2.3 Food constraints

In this section, we detail constraints associated to food products. Constraints are the particularities of food that has to be respected and taken care of, to preserve food quality, to slow down the degradation and prevent from getting contaminated.

1.2.3.1 Short shelf-life

Shelf-life is the length of time that a commodity may be stored without becoming unfit for use or consumption [Dictionary, 2004]. Shelf-life is the recommended maximum time for which products can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected (or specified) conditions of distribution, storage and display [Gyesley, 1991].
Shelf-life is influenced by several factors: exposure to light and heat, transmission of gases (including humidity), mechanical stresses and contamination by things such as micro-organisms [Lawrie, 1998]. Many food products especially fresh vegetables, fruits, meat and seafood are subjected to this constraint and require temperature controlled environment to prolong their shelf-life.

1.2.3.2 Temperature sensitiveness

Nearly all chemical reactions occur at normal temperatures (although different reactions proceed at different rates). However most reactions are accelerated by high temperatures and the degradation of foods is no exception. Temperature increase speed ups the reactions and temperature decrease reduces them. Many food products are sensitive to temperature conditions. Therefore, to make bacteria slow down their growth, they can be cooled. That is why shelf-life is generally extended by temperature control.

1.2.3.3 Spoilage or deterioration

Spoilage is the process in which food deteriorates to the point in which it is not edible by humans, or its quality of edibility becomes reduced. Signs of food spoilage may include an appearance different from the food in its fresh form, such as a change in colour, texture, an unpleasant odour or an undesirable taste. A large number of people get sick every year due to spoiled food. A number of methods of prevention can be used that can totally prevent, delay, or otherwise reduce food spoilage. Preservatives, refrigeration or canning of food can preserve food for particularly longer period of time.

1.2.3.4 Cold chain costs

Now, one country can enjoy the food from another country or even continent. For that reason, storage and distribution of food need to be temperature-controlled by maintaining a cold chain for temperature sensitive food products. Maintaining this cold chain is costly for both storage of goods and transportation, because all the storage docks and transportation carriers should be equipped with refrigeration facility, which eventually increase the expenses. To reduce this cost, optimal methods should be searched to reduce the storage of goods, the distance and duration of transportation.

1.2.3.5 Separate storage and transport facilities

Frozen food cannot be kept or transported together with fresh fruits or vegetables due to different temperature requirements. Live animals cannot be stored or transported with vegetables, otherwise they will eat those vegetables. Live animals also cannot be kept or transported with frozen food or ice creams due to different temperature requirements. Therefore, separate facilities are needed to store and transport different type of food products.

1.2.3.6 Climate effects

Climate change can affect food systems in several ways ranging from direct effects on crop production (e.g. changes in rainfall leading to drought or flooding, or warmer or cooler temperatures leading to changes in the length of growing season), to changes in markets and food prices. For example the combined effects of high ambient temperature and high relative humidity reduce the milk yields of lactating dairy cows. Other reasons can be due to negligence, for example storing a unit load of milk on a dockside in the burning sun.

Objective of this thesis is to propose solutions taking into account food product constraints

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These perishability constraints need to be respected and taken care of, to preserve food quality throughout all the activities of production, distribution, sales, etc. These activities are performed by several distinct entities from individual, Small and medium-sized enterprises (SME)s to Large enterprises (LE)s. These include but not limited to: farmers, livestock owners, producers, distributors and retailers. In food ecosystem, for a particular type of food, we can identify the different collaborations of such entities forming together a network usually called a FSC. Remaining part of this chapter is dedicated to the concepts related to of FSC.

1.3 Food supply chain

FSC is one of the most complex and largest industry sectors in the world. FSC includes processes of production, distribution, sale, etc of food products and may comprise several individual and large enterprises from growers, auctioneers, wholesalers, importers & exporters, retailers and speciality shops [Vorst et al., 2000]. In FSC, agricultural, farming and sea merchandises are used as raw materials for producing consumer products with higher added value. In most cases, conservation and conditioning processes extend the shelf-life of these products.
Food products in FSC have gone through dramatic changes since few decades. Today, two types of food industry sectors (grocery, prepared) are in constant race for the retail food[4]. The grocery industry provides the fresh and largely

[4] http://en.wikipedia.org/wiki/Food_industry

raw food ingredients to consumers to use them in personnel cooking, whether at home or at restaurants. On the contrary, the prepared food industry offers ready-made food available for direct eating. Products of both industries arrive at the same place (retailer stores) which are the defining point for the food industries, because at this place consumer decides to buy the product or not. FSC in general terms is a SC for food products. There exists several such SCs for other types of products (electronics, textiles, auto, etc). All these SCs share some common concepts. Subsequently, we present these concepts starting with generic definitions of SC found in the literature.

There are number of generic definitions proposed in the literature for the concept of SC, however there is not any official definition of SC. It is relatively broad and encompasses different perspectives. Certain adopts the point of view of the product, other enterprise or customer.

La Londe and Masters [La Londe and Masters, 1994] proposed that *"a supply chain is a set of firms that pass materials forward. Normally, several independent firms are involved in manufacturing a product and placing it in the hands of the end user in a supply chain. Raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain."* This definition focuses on different actors involved in SC.

In [Stadtler, 2009], authors describe SC as *"a supply chain consists of two or more legally separated organizations, being linked by material, information and financial flows. These organizations may be firms producing parts, components and end products, logistic service providers and even the (ultimate) customer himself.* This definition extends SC definitions by material and information flows. Figure **??** depicts a simple representation of a SC

In [Zuurbier et al., 1996, Vorst et al., 2000] authors suggest as *"Supply Chain comprises of organizations that are responsible for the production and distribution of vegetable or animal-based products"*. This definition considers SC for food products.

By reviewing the definitions of SC, we deduce that each participant: supplier, manufacturer, distributor, retailer and customer (indirect and not bound) is a member of the SC and share some common concepts with each other like:

- **Flows:** There are three flows: material, information and financial. Material flows from upwards supplier to downwards customer. Information flows in the both direction and financial flows from downwards to upwards.

- **Activities:** Activities of SC are procurement, production, distribution, storing (inventory) and sale.

- **Structure:** All the members of SC are connected through a network or channel through which materials, finance and information are transferred.

Based on the observations above and considering our context of food, we propose our own definition of FSC:

A food supply chain is a network of heterogeneous but interdependent enterprises. These enterprises perform set of activities to transform food substances to final food products and sell them to end customers. Food material flows downstream and finance flows upstream, while information flow is attached to both food material and finance and it flows in both directions.

Subsequently, we describe SC flows, activities, structures and specific challenges faced by FSC.

1.3.1 Supply chain flows

- **Material flow:** Material flow includes the flow of raw ingredients / semi-products from suppliers to producers and flow of final products to customers (retailers and consumers).

- **Information flow:** Information flow involves transmission of information between the actors of SC. Each material in SC is attached with some sort of information, which is passed on among the actors. Information flow consists of product orders, their status update, delivery, etc. This flow flows in both the direction of SC upwards to downwards and vice versa and there are information loops between actors of FSC.

- **Financial flow:** Financial flow consists of credit terms, payment schedules, invoices and consignment, title ownership arrangements etc. It goes from customers to suppliers.

We intend to deal with the synchronization of the material flow and information flow, especially the synchronization of material flow during the transportation processes. The financial flow is not the focus of this thesis.

1.3.2 Supply chain activities

SC consists in set of activities that carry out SC flows presented before. Activities define the roles and relationships and systematize the SC processes in order to achieve SC goals. We describe here the five basic SC activities: procurement, production, distribution, stock and sale.

1.3.2.1 Procurement activity

The procurement activity focuses on gathering all the necessary manufacturing components or raw materials. There are two main phases in this activity. First phase is the selection of suppliers. The choice of suppliers is done according to different criteria such as quality, price, on time replenishment of raw materials or components, their capacity, ease to accept highly variable demands, their ability to technically evolve the components. Second phase is the procurement, consisting in placing orders for the components to the suppliers and product verification after delivery. Verification is performed in order to be ensured that components are delivered in good condition, means that the delivery has the right components as the quality and quantity demanded. Raw ingredients or semi-finished products procured are 60% to 70% of the cost of goods manufactured in almost all enterprises [Ouzizi, 2005].

1.3.2.2 Production activity

The production activity consists in a set of transformations for the processing of raw materials to fabricate the semi-finished or finished products. The goal of the production activity is to manufacture the required products by better utilizing the production resources. Production may be distributed to several sites, each site manufactures some semi-products and finally all the semi-products are assembled to form the final product. Food production during the industrial revolution took advantage of new emerging markets by using preservation, packaging. It brought the advantages of pre-prepared time-saving food in bulk for ordinary people who did not employ domestic servants [Toussaint-Samat, 2009]. Advanced technologies have also been invented to change food production like computer-based control systems, sophisticated processing & packaging methods, etc.

1.3.2.3 Distribution activity

Distribution or transportation concerns all the activities necessary for moving goods, animals from one location to another. In SC, distribution activity concerns the delivery of raw materials or semi-fished products to manufacturer sites and finished products to clients or wholesalers. Due to regular rise in oil prices, cost of transportation is increasing which is a major concern for the enterprises running their own fleet of transport vehicles in. Moreover, with their transport resources they can cover limited geographical area and in order to reach the faraway customers, it could not possibly be feasible for the enterprises to purchase their own ships or planes to transport the goods. Additionally, SMEs involved in SC cannot afford to have their own transport vehicles. Therefore, transportation is normally outsourced to professional logistics companies usually called Third party logistics (3PL) [Francois et al., 2006]. They manage their resources in different modes of transportation that include air, rail, road, water to provide logistic services, etc. 3PL is an organization that takes responsibility of all or part of the logistics activities that have traditionally been performed with an organization [Marasco, 2008]. 3PL is still an emerging area in many countries.

1.3.2.4 Inventory activity

Managing inventory has always been the great concern for SC. To determine the correct level of stocks is one of the most researched works in SC to avoid excess or lower level of products in stock. It becomes more crucial in case of food products, which have determined shelf-life. A number of stock or warehouses are needed by SC for keeping goods. These warehouses are kept by almost all the members of SC. Supplier or manufacturer uses them to store the products manufactured in advance or in surplus in order to have flexibility or rest the production. Transporter uses them to store products on temporary basis for transit purpose: these temporary warehouses are used as loading docks where vehicles load and unload. Customer (retailer) buys products in large quantities and stores them in warehouse(s) and takes out slowly as they are sold.

1.3.2.5 Sales activity

The sales activity consists in developing relationships to sell the products to customers, including price negotiations, product delays, order entry, etc. and by extension a better knowledge of the consumer market. This business activity is also responsible for determination of the forecast demand and integration of business aspects like life of the product to anticipate changes in sale. Marketing aspects like market analysis, advertising, promotions ... are also managed in this activity. Customer feedback, satisfaction, point of sales data and future demand forecasts are the outputs of the information generated from this activity. Sales activity contains study of where product should be placed on the shelf, how and where the product is promoted (radio, TV, newspapers, social medial etc.).

Our global objective is concerned to replenishment (part of the procurement activity), production, distribution and inventory activities and detailed objective is concerned to distribution activity.

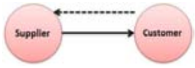
All of these key activities of SC must be coordinated in order to take consistent decisions. However, interaction of these activities highly depends on the structure of SC, that how different partners are arranged in the network forming a SC. In the next section we present SC structures found in the literature.

1.3.3 Supply chain structures

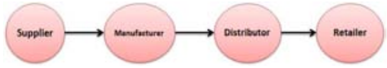
SC structure details how different enterprises supply products (or services) to customers via a chain of facilities. It is important to have a clear understanding of these structures in order to perceive the complexity of the managed supply chain. The complexity and nature of businesses rise the need of classification of structures of supply chains. In the literature [Beamon and Chen, 2001, Huang et al., 2003], six structures have been proposed: Dyadic, Serial, Convergent (assembly), Divergent (arborescent), Conjoined and Network as shown in figure 1.2.

1.3.3.1 Dyadic structure

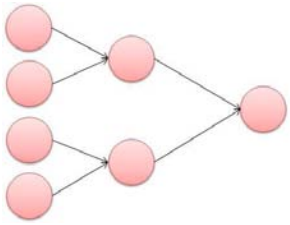
The simplest SC structure is the dyadic structure, containing only two entities: customer and supplier. Supplier provides products or services to satisfy the demands required by the customer.



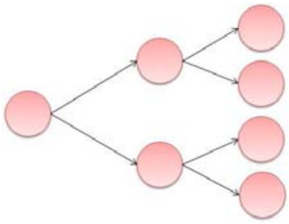
(a) Dyadic



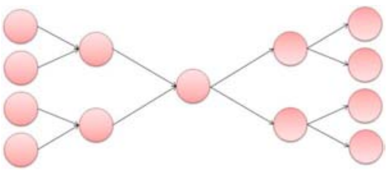
(b) Serial



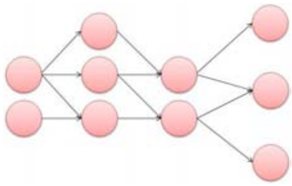
(c) Convergent



(d) Divergent



(e) Conjoined



(f) Network

Figure 1.2: *Supply chain structures [Beamon and Chen, 2001]*

1.3.3.2 Serial structure

The serial structure is obtained by cascading several dyadic structures. A typical serial SC in the literature usually consists of retailer, distributor, manufacturer and supplier.

1.3.3.3 Convergent structure

A convergent structure is a modified serial structure. Each node in the convergent structure has only one successor node at most, but it may have any number of predecessors. Examples of a convergent SC structure are shipbuilding, airplane or automotive manufacturing and building construction where finished product is assembled from many semi-finished products. For example in automotive industry, for the company which manufactures cars, its tier 1 suppliers are manufactures of body, seat, windshield, ... and tier 2 suppliers are producers of textile materials for body and seats.

1.3.3.4 Divergent structure

A divergent structure is another modified serial structure. It is completely opposite of convergent structure. In divergent, each node may have any number of successors, but it has at most only one predecessor. For example in case of electronic industry, if the concerned company is a supplier of silicon crystals, tier 1 customers are chip manufacturers, tier 2 customers are integrated circuits manufacturers, finally, tier 3 customers are assemblers of mobile phones.

1.3.3.5 Conjoined structure

Conjoined structure is combination of convergent and divergent structure. A convergent and a divergent sub-chain are connected in a sequence to form a single chain. Examples are farming, merchandise catalog and web-based companies.

1.3.3.6 Network structure

Network structure can be classified as convergent, divergent or conjoined and is more complex than the three previous types. It has discrete structure which does not follow any pattern, it may be convergent or divergent in different activities of SC.

We consider FSC as of network structure, because many SMEs and LE are involved for producing food products and semi-products at different production levels.

Generally most of SCs lie in the category of network structure due to continuous addition of new SC members as business expands, adding more links to the chain. Especially for complex products, a company can be associated with several suppliers. These networks become more and more complex with the increasing size of SC.

Above we presented some generic concepts of SC. Now we are going to present aspects specific to FSC. Following two sections are dedicated to developments and challenges specific to FSC.

1.3.4 Growing developments in food supply chain

In [Stadtler, 2009], authors distinguish three main categories of growing interests in FSC: Socia-economic, market structure, procurement and technological developments.

- **Socia-economic developments:** Recent socio-economic developments have caused change in performance requirements for FSC as a whole and locally for all activities of FSC. Because of demographic developments (increase of the aging population, one income families and changing social concerns), the buying behavior of consumers is changing constantly, and becoming unpredictable. For example some growing food trends from [Hughes, 1994] are given here.

  - increasing trend towards simple prepared food and covenant in eating like snacks and chilled and ready-made meals.
  - increased demand for refine foods and for foreign ethnic or religious. For example halal meat or foods and beverages without alcohol, Italian pasta, etc.).
  - shifts towards lighter and healthier meals (less fat, sugar free). Consumer wants fresh and natural foods, because they have doubts about food produced with the help of bio-technology and conserved by means of controlled environments.

- **Market structure developments:** The second area that changes the market structure as mentioned by [Cohen and Huchzermeier, 1999] is the world-wide reduction of trade barriers and the development of regional, multi-country economic zones (globalisation). The installation of the European Union has led to open markets. This has increased the number of competitors, but it has also made it easier to purchase raw materials all over the world.
- **Procurement developments:** The material procured for food production is divided into two types. The first type is the raw material and ingredients, which are purchased from open markets or annually contract basis. Second type is the packaging and labelling material. Now retailer / distributor demands products supplied under his own brand name.
- **Technological developments:** This third area can be further divided into two categories.
  - *Development in process technology:* This category refers to advent of new techniques for cooking, processing, packing, conditioning and transportation. Other developments are new bio-technological breakthroughs, which have begun to change the nature of food products. A critical factor is health risks and decreasing food taste, quality caused by mass production of the food through these technologies to meet the growing population.

  - *Information technology (IT):* Increasing IT developments play a very important role for integrating and analysing the information generated throughout the processes of FSC. The introduction of bar coding, RFID and scanning technologies and Point of sales (POS) has resulted huge amount of data, which is transferred and processed by IT systems for example EDI (Electronic Data interchange) and ERP (Enterprise Resource planning).

Moreover, food safety and quality also possess the high priority. This is comprehensible considering current food safety scares, which have revealed that inadequate control can lead to high impact on the costs and trademark image of retailers, food manufacturers, and health authorities. Moreover, food sustainability risks like environmental, social, ethical, religious and animal health issues are acquiring significant consumer attention. Due to FSC's such complex environment, especially considering the perishability nature of food products, FSC has to face some specific challenges. These challenges need to be dealt in order to sustain the profitability of FSC.

1.3.5 Food supply chain challenges

There are many factors affecting the FSC. Globally flourishing the FSC industry, derives the demand for higher value food products. However, supplies to meet this demand have to face many risks, because with great responsibilities comes the great challenges: the challenge of identifying fraud, challenge of maintaining safety, risks, quality, increased cost etc. We detail here some important problems and challenges faced particularly by FSC.

1.3.5.1 Food sustainability

Food sustainability has become part of the mission and strategy of many food companies, starting with large international firms operating in developed countries. Food sustainability involves environmental, social, ethical and animal health care issues. These issues reverberate throughout the whole FSC. Consumers expect that animal welfare and social/ethical responsibility is already assured. Often we see that the consumer is not aware of how this assurance is obtained in practice. When negative incidents are reported in the press, public awareness and interest in sustainability suddenly increases. The growing number of sustainability requirements increase costs in the SC and someone has to pay for these costs.

1.3.5.2 Fraud

Due to globalization, fraud is becoming increasingly common in food trade. One example of that is mislabeling. While doing grocery shopping, many consumers rely on food labels and packaging to decide which foods to purchase. In 2013, there has been a scandal of horse meat mixed with beef meat without mentioning it[5]. Therefore, fraud doesn't only harm the consumers' wallet but also poses health risks by wrongly mentioning product ingredients or correct consumable date.

1.3.5.3 Insuring food safety

Food safety is intended to protect consumer's health by providing better quality food. Nowadays consumers demand food or food ingredients from faraway countries or continents, but problem is that they arrive with a less apparent SC. Safety measures [Aruoma, 2006] must be taken into account for the range of different products by all the relevant actors including producers, manufacturing sites, central depots, transporting vehicles and even at retailer's place. Hazard analysis, critical control points (HACCP), good manufacturing practice (GMP) and good hygiene practice (GHP) are major components of the safety management systems in the FSC [Aruoma, 2006].

1.3.5.4 Maintaining food quality

Food quality [Grunert, 2005] is the quality features of food that are acceptable to consumers (size, shape, color, gloss, consistency, texture, and flavor). Food quality is an important factor of manufacturing requirement, because consumers are concerned to any form of harmful contamination. There should be proper handling of food preparation to minimize the risk of food contamination. There are many existing international quality institutes testing food products in order to indicate consumers the higher quality products. Founded in 1961 in Brussels, the international quality institute "Monde Selection"[6] is the oldest one in evaluating food quality, which focuses on imposing European Food Law on food industries [O'Rourke, 2005].

1.3.5.5 On-time delivery

Service quality has a high importance, when shelf-life of goods is very short. Thus, it becomes very important for all the partners of SC especially distributor or

[5] http://en.wikipedia.org/wiki/Fraude_a_la_viande_de_cheval_de_2013
[6] http://www.monde-selection.com/

transporter to evaluate their performance for on-time delivery of product. On-time product delivery is an important service component of perishable merchandise. A customer typically orders a product for delivery on a specified date. The customer expects that the delivery will be no later than that date [Martin et al., 1999].

1.3.5.6 Tracking & Tracing

Tracking and Tracing concern a process of determining the current and past locations (and other information) of a unique item or property. It refers to the capability for tracing goods along the distribution chain. It is important, because when national authorities or food businesses need to identify a risk they can trace it back to its source in order to isolate the problem and prevent contaminated products from reaching consumers. The European Union's General Food Law [O'Rourke, 2005] came into force in 2002, making traceability compulsory for food and feed operators and requiring those businesses to implement traceability systems. Under this Law, "traceability" means the ability to track during all the stages of production, processing and distribution, any food, feed, food-producing animal or substance that is used for consumption. [7].

1.3.5.7 Demand forecasting

Demand forecasting is the activity of estimating the quantity of a product or service that consumers will purchase. Demand forecasting involves techniques including both formal and informal methods, such as educated guesses, and quantitative methods (use of historical sales data or current data from test markets). Demand forecasting may be used in making pricing decisions, in assessing future capacity requirements, or in making decisions on whether to enter a new market. Generally correct demand forecasting is an important factor in almost all businesses SCs, but it is extremely important in case of FSC, where products are bound with perishability constraints especially short shelf-life.

1.3.5.8 Traffic jams or vehicles break down

FSC need effective reactive strategies to handle the situation of perturbation for example, if a vehicle breaks down or their refrigeration facility stops working for whatever reason or vehicle is struck in traffic jams circulation. It risks not only the delay in shipment delivery but also the threat of spoilage of contamination of food

[7] http://ec.europa.eu/food/food/foodlaw/traceability/factsheet_trace_2007_en.pdf

that transport vehicle is carrying. There should be pre-emptive strategies thought of before these situations arrive.

In addition to exclusive challenges of FSC presented above, at generic level of strategic, tactical and operational levels, the SC remains complex. Complex SC structures, large scale, several partners, their individual business preferences and working patterns and several other issues generate lots of problems for SC. Some well-known, traditional and generic SC problems are bullwhip effect [Forrester, 1958], uncertainty or demand volatility [Gangadharan, 2007], aggressive competition [Ai et al., 2012], confidentiality [Li and Zhang, 2008], software integration and interoperability [Zbib et al., 2012], different goals and objectives, etc.

FSC therefore has to face generic problems faced by all other SC, but has also to deal with the challenges specific of its own. Due to most of these problems, challenges, processes and activities, FSC become hard to control and difficult to synchronize.

It requires an efficient approach to manage these complexities in the FSC. There exists the concept of supply chain management, which deals with the controlling the total flow of materials and activities from suppliers through end users [Jones and Riley, 1985].

1.3.6 Supply chain management

A supply chain exists when at least two enterprises work in the completion of a given product. If and only if the association is deliberately controlled in order to maximize performance, then we can talk about supply chain management [Berry et al., 1994, Dominguez and Lashkari, 2004, Lambert, 2008]. Many definitions of SCM have been proposed in the literature.

In [La Londe and Masters, 1994], authors propose as "*Two or more firms in a supply chain entering into a long-term agreement, the development of trust and commitment to the relationship, the integration of logistics activities involving the sharing of demand and sales data, the potential for a shift in the locus of control of the logistics process.*"

Stadtler and Kilger in [Stadtler and Kilger, 2008] describe "*SCM as the task of integrating organizational units along a supply chain and coordinating material,* *information and financial flows in order to fulfill (ultimate) customer demands with the aim of improving the competitiveness of a supply chain as a whole.*"

From these definitions, it can be seen that the definitions of SCM are still evolving and therefore, there is no universally agreed definition at this time. For the purpose of this thesis, we deduce our own definition of SCM considering FSC:

Supply chain management aims at building the inter-organizational trust to integrate, coordinate, communicate, manage and control the flow of food products and information to integrate supply and demand management across companies with the aim of improving competitiveness of a food supply chain as whole.

Different aspects of SCM presented above in the definitions are gathered in a form which the authors calls in [Stadtler, 2009] as "House of SCM" as shown in figure 1.3. The roof of this house corresponds to the global objective of SCM in terms of better responding needs of the customer service and competitiveness. This global objective resides on two pillars Integration (network of all the partners in SC) and Coordination (coordination of material information and financial flows). On the bottom is foundation that details some more factors of SC that are needed for managing the successful supply chain.

Both pillars of house of SCM (coordination and integration) need to be applied on all SC activities (1.3.2) by taking into account their different planning intervals and SC flows. SCM concept describing the principles of hierarchical planning is called supply chain planning matrix [Rohde et al., 2000]. Planning matrix illustrates the horizontal and vertical connections of SC activities and specifies the places where coordination and integration is needed. All the partners of SC participate in the planning of the activities described by supply chain planning matrix. However, partners using their own processes for functioning generate the problem of communication. They need to follow some similar processes in order to function in with each other. One such standard, which defines common processes is called Supply Chain Operations Reference (SCOR) model, developed by the Supply Chain Council (SCC)[8] in 1996. Authors in [Naslund and Williamson, 2010] elaborate SCOR model as "A unique framework that links business processes, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of

[8]https://supply-chain.org/

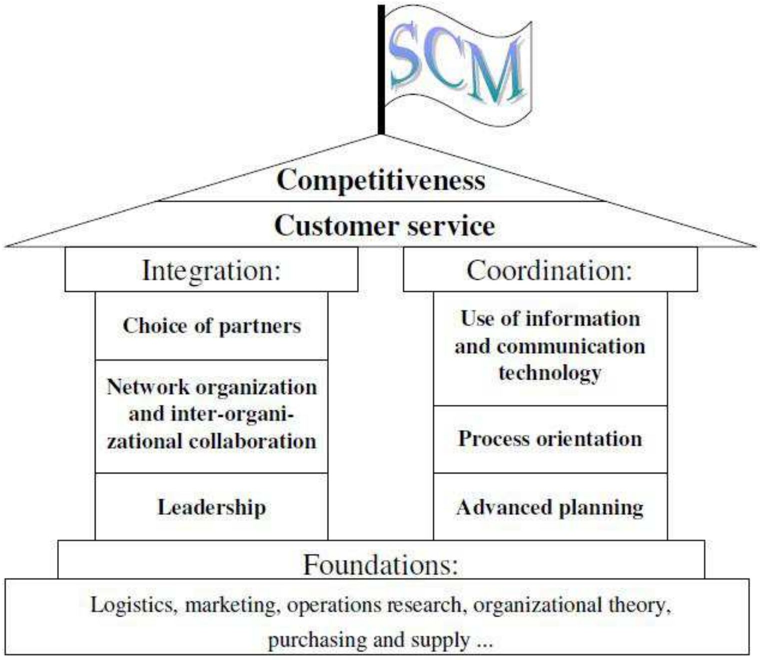


Figure 1.3: *House of SCM* [Stadtler and Kilger, 2008]

supply chain management and related supply chain improvement activities".

Many software information systems are developed on different foundations of the SCM concepts presented above. These solutions are developed to perform specified functions in SC and adapted in various industrial practices. In the next section, we present classification of these well known SCM softwares and their limitations.

1.3.6.1 SCM softwares

Currently, there are many products available in the market providing technology solutions to the management of a SC. These softwares are classified in to six well known categories: ERP, APS, SCE, MES, SRM and CRM. We explain them one by one.

ERP (Enterprise resource planning): Enterprise resource planning (ERP) system focuses on the internal management of the company and it interfaces with suppliers and distributors. ERPs are software packages that enable the integration of all the traditional functions of a business such as sales, human resource management, financial management, production, etc. Using such integrated system, users belonging to different professions working in the same environment can ensure data integrity, non-redundant information and reduced processing time

[Kelle and Akbulut, 2005]. MRP (Materials requirement planning) and DRP (Distribution requirement planning) are the two planning functions normally included in an ERP. MRP calculates the demand of component items, keep their track and generate orders when needed. DRP analyses sales, forecasting and other data to plan purchasing and distribution requirements [Ross, 2004]. ERPs are used in intra-organization and there installations, customization and usage expertise are extremely costly.

APS (Advanced Planning System): APS systems allow the optimization of material flow for remote production sites [Stadtler, 2009]. The use of advanced planning tools might suggest that it is easy to integrate the decisions of each entity in the chain. However, optimization, which aims to be a strong point of these tools, requires control and increased knowledge of all components of the network. In practice, the overall coordination leaves very little autonomy to each entity in the chain and is practicable only when these entities belong to the same industrial group [de Kok and Fransoo, 2003]. APS components are usually integrated within the context of SCM and also supplied independently for planning and production purposes [Klčová et al., 2009].extremely costly.

SRM (Supplier Relationship Manager): It addresses the entire interactions with third party organizations that supply goods and services. It evaluates spending, assets and capabilities to determine what activities are needed to engage in with different suppliers for the reduction of overall materials costs [Scavarda et al., 2010].

CRM (Customer Relationship Manager): This tool is concerned about the interaction between business's current and future customers. It matches the customer's needs with product plans, develop and implement business strategies and supporting technologies that close the gaps between an organization's current and potential performance in customer acquisition, growth, and retention. Examples of its functionality are sales force automation, data warehousing, data mining, decision support, and reporting tools. CRM is the logical counterpart of SRM [Tseng and Huang, 2007].

SCE (Supply chain Execution): SCE is intended to automate the different steps of SC and to execute SC planning. SCE's planning capabilities are limited to stock levels. SCE is less dependent upon gathering information from within the company, so it tends to be independent of the ERP decision. But chances are it should be needed to have the SCE software applications communicate with ERP in some fashion. Supply Chain Execution (SCE) integrates three major functions: TMS, WMS and AOM.

- TMS (Transportation Management Systems): TMS facilitates the procurement of transportation services, the short-term planning, optimization of transportation activities and the execution of transportation plans [Group, 2011]. It can include everything from network-design tools for routing deliveries to operational applications for tracking shipments, scheduling drivers and calculating how much run a shipment between any two points will cost [Taylor, 2004].

- WMS (Warehouse Management Systems): It manages inventory control, products placement and picking in a warehouse [Kahl, 1999]. Just like ERP and APS, it is highly modularized, with different sets of modules for managing supply, demand and internal operations. The modules on the supply side automate the process of receiving incoming goods and assigning them to the appropriate storage locations. The ones on the demand side assist in assembling outbound orders and preparing them for shipment. There is usually an inventory management or materials-handling module to bridge the gap between supply and demand modules [Taylor, 2004].

- AOM (Advance Order Management): AOM is a component of SCE packages, supporting the management of administrative proceedings of orders and promotions and can enhance order tracking and increase order fill rates.

MES (Manufacturing Execution system): MES is used in manufacturing plants to provide the real time information about the execution of manufacturing orders. MES might operate across multiple function areas, for example: management of product definitions across the product life-cycle, resource scheduling, order execution and dispatch. Hence, it may overlap some functions of ERP. With the increasing function of ERP, MES space for growth is limited.

1.3.6.2 Need for collaboration

Above presented software solutions covers the particular needs of the organizations. Figure 1.4 presents distribution of these SCM softwares. This figure shows reconciliation between the different softwares and decision-making levels. Each

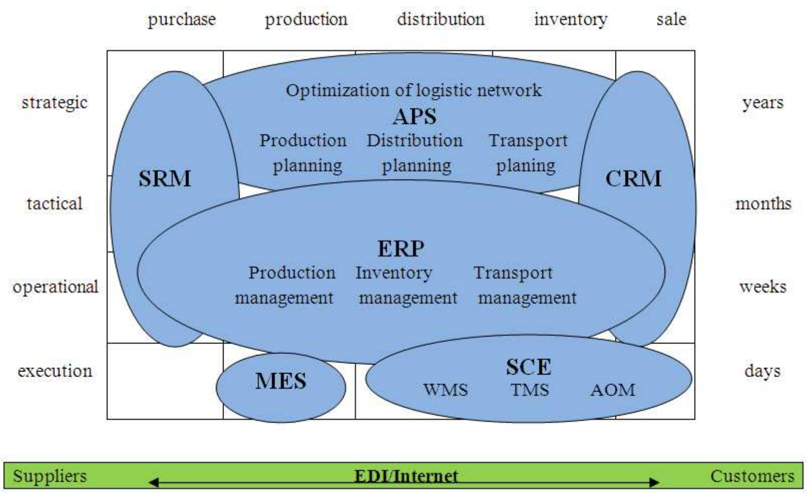


Figure 1.4: *SCM software classification* [Scavarda et al., 2010]

information system has its own functionility and focuses on different SCM areas. APS helps SCM to optimize the production and distribution planning and sales but is dependent on ERP systems for forecasting and inventory management. ERP is more focused on the internal functions of the organization and is not concerned about the collaborative activities in SCM. CRM and SRM both extend the functionality of ERP for managing relations with suppliers and customers. MES and SCE manage real time execution decisions. AOP, WMS are independent tools that can be used separately or can be integrated with ERPs. [Akkermans et al., 2003] deduce major limitations of ERP systems are: (1) inflexibility to accommodate changes of supply chain structures,(2) lack of modular and open system architecture, (3) lack of functionality beyond managing transactions and (4) inability to share internal data efficiently with supply chain partners. Furthermore TMS used by a single transporter is not interoperable with the TMS of other transporter. Although SCM softwares largely increases the efficiency of decision making, the implantation and configuration of these solutions in enterprises are time and resource consuming. These solutions lacks the mechanisms for dealing the specific challenges faced by FSC like food sustainability, safety and more important food quality, which is normally handled by the human intervention. All of the above SCM softwares are integrative solutions but do not support inter-organizational collaboration [Jia, 2012]. Thus, there exists a research gap in inter-organizational collaboration of FSC actors.

Consequently, this thesis has global objective to propose a collaborative framework for food supply chain. Within that context, more detailed objective is to propose and develop methods for interoperable transportation planning while considering the food product constraints.

1.4 Conclusion

We divided this first chapter in to two major parts. First section is dedicated to food ecosystem, presenting the particulars of food and evolution of its production, pros and cons etc. This part also lists down food products classification and constraints. Second part is devoted to the concepts of food supply chain (flows, activities, structures, growing developments and challenges) and supply chain management. Ensuring a good understanding of food ecosystem, FSC and SCM background, solutions and limitations, we deduce that the collaboration is the concluding argument that needs to be explored for better managing and improving supply chains for food items. The collaboration is considered in the context, where there are independent companies having their independent way of working and operating different software platforms. There is no centralized supervising. Information is local to each partner and is available in a form that may not be fully understandable by other partner.

The work carried out in this research concerns the study of finding problems and challenges with food supply chain and how they can be dealt. The aim is to seek for efficient ways of production, transportaiton, forecasting and managing inventories of FSC and finally collaboration of these activities. Next chapter is dedicated to understand the concepts of collaboration, current available collaborative approaches, their limitations and what need to be done to deal with these limitations to improve the functioning of FSC.

Chapter2

Collaboration in food supply chain

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"If you are not collaborating, you won't be around in 20 years. You'll be gone" [1].

2.1 Introduction

Under traditional supply chain, each partner strives to develop local strategies for optimizing his own organization without considering the impact of his strategies on the performance of other members [Sari, 2008]. Each partner may have different local objectives but improving the overall performance of SC will subsequently benefit to individual partner [Mentzer et al., 2001]. Considering the house of SCM presented in previous chapter, SCM stands on two pillars: coordination and integration. In the past, SCM has been well developed on these principles. However, FSC has become globalized and everything has become distributed from FSC suppliers to customers and their information systems. Now, individual partners are part of the many FSC at the same time.

In a collaborative supply chain, individual partner companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation [Simatupang et al., 2002]. Collaboration deals with forming a trust relationship between all of its members, by investing their resources, sharing information, resources, incentives, responsibilities and working jointly to mutually achieve goals [Cao and Zhang, 2011]. Consequently, empower partners to plan their SC actions faster to react rapidly market changes. Collaboration for gathering partners feedback and their up to date sales information will enable FSC to determine sales and order forecasts and quickly respond to volatile demands. Collaboration plays an import role for achieving escalated FSC performance. Therefore, this chapter is dedicated to identifying FSC areas, needing the incorporation of collaboration to elevate FSC performance. Along with investigation of existing collaborative approaches to find out their standing for the collaboration needs.

This chapter is divided four sections. We first present different collaboration levels proposed in the literature describing the ladder of increasing collaboration among SC. Second section details specific collaboration areas in FSC. In third section, we list down the existing collaboration approaches and present their comparative analysis. In fourth section, we describe limitations of theses collaborative approaches and what needs to be done to overcome these limitations.

[1] http://www.aacs.org.au/supplier-retailer-collaboration/

2.2 Collaboration levels

SC collaboration deals with forming a trust relationship between all of its members, by investing their resources, share information, resources, incentives, responsibilities and working jointly to mutually achieve goals [Cao and Zhang, 2011]. Authors in [Kampstra et al., 2006] have proposed five levels of collaboration: arm's length, communication, coordination, intensive collaboration and partnership.

1. The first level of collaboration is "arm's length". The collaboration at this level concerns only transnational level relations. This collaboration starts and ends with the transaction, there is nothing more to it. This level of collaboration do not justify the essence of collaboration.

2. The second level of collaboration is "communication". This level emphasizes on improving the productivity of SC, while focusing only on the physical SC constraints. Communication enables SC actors to enhance decision-making by sharing information, forecasts through simple IT systems which may lead to improved delivery rates and less inventories. This level is a true start of collaboration.

3. The third level of collaboration is "coordination". This level emphasizes on physical as well as policy constraints. The main purpose at this level is to synchronize and automate processes to improve speed and accuracy. Focus on inter-organization integration and interoperability increases. This level requires additional investments in IT infrastructure and planning modules.

4. The fourth level of collaboration is "intensive collaboration". This level increases the actors' involvement further in policy issues with the goal to improve the strategic management decision making and enhance innovation in the chain. Here collaboration spreads to further areas along the logistics flows.

5. The fifth level of collaboration is "partnership" which extends the relationship to the level of financial associations, such as sharing of investments and profits. This level aims to extremely increase the knowledge sharing between actors and reduce research and development time. This level requires higher degree of trust within partner enterprises. This level of collaboration may benefit a lot but also brings the higher level of risk, because partner companies know each other's business secrets.

In this thesis, we are oriented towards the third level of collaboration. This thesis focuses on inter-organizational coordination and interoperability issues for production, transportation and replenishment planning, which involves the distributed partner organizations in FSC

In the next section, we present different collaboration areas in FSC with a simple case study for the third level of collaboration involving distributed actors.

2.3 Collaboration areas

We distinguish here some specific areas within FSC partners, on which we will be focusing for collaboration in this thesis. These areas are collaboration between: multiple producers, producers and retailers, producers and transporters, transporters and retailers, multiple transporters. We use an example of FSC of cake product to explain all of these collaborations. In the example, there are four actors, one cake retailer (R), two producers: one is cake producer (CP) and second is butter producer (BP) and fourth is a transporter. R purchases cakes from CP to sell them to consumers, CP purchases butter from BP (butter is a semi-product for cake) and transporter provides the logistic services to CP, BP and R. These areas are explained as follows:

2.3.1 Collaboration between producers

Distributed collaborative production among dispersed yet cooperative partnered companies is considered as an effective approach to grasp transient opportunities in a highly uncertain market without investing much in assets [Huang and Wu, 2003, Huang et al., 2008]. Operations of such production relies on system architectures such as virtual enterprises, extended enterprises or distributed production systems [De Sousa et al., 2000, Jagdev and Thoben, 2001, Lima et al., 2006]. Within a distributed collaborative production system, the participated companies should be autonomous and be able to rapidly form (reconfigure) a supply network with other companies to meet the dynamic market demands [Lima et al., 2006].

Though this concept has been studied by many in literature (e.g. [Lu and Yih, 2001, Huang et al., 2008, Jung, 2011, Guan and Liu, 2011, Su and Chiang, 2012, Arrais-Castro et al., 2012, Lim et al., 2013]), it still needs an application to specify the required elements and to show how the concepts can be deployed and integrated within a production planning environment. Especially, when each local company has its own legacy production planning system, to interoperate with those systems into a reconfigurable multi-enterprise collaborative network with the respect of autonomy is not simple [Chen et al., 2009b]. We explain this collaboration with the help of cake product FSC example as shown in figure 2.1.

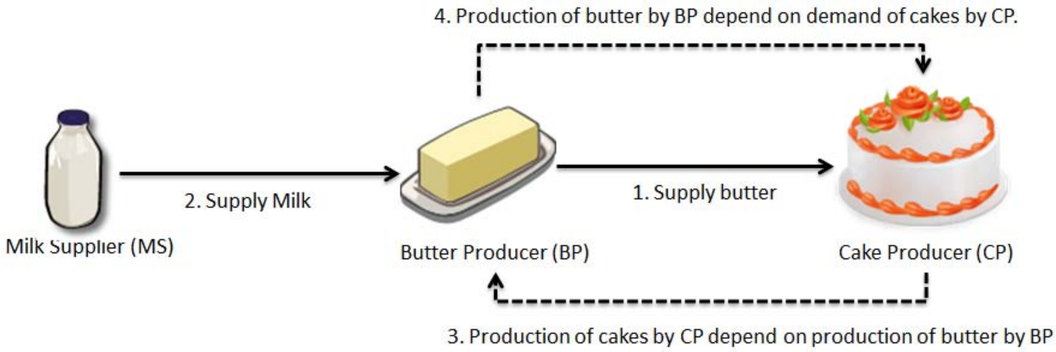

Figure 2.1: *Collaboration between producers*

CP produces cake products, for which it requires ingredient butter, which it purchases from BP (1). BP on the other side produces butter, which has raw ingredient milk supplied from the local farmer (2). CP's production of cakes depends on the production of butter from BP (3) and BP's production depends on the demand of butter for CP (4). Their production is inter-dependent on one another. Both CP and BP need their respective raw ingredients at the right time to produce their products at right time. Moreover, the idea of how much inventory BP should manage to complete current and future demands also depend on the current and future production orders from CP. Similarly what is the capability of production of BP, determines that how much inventory of butter CP should keep for its uninterrupted production. Collaboration is extremely important here in order to reduce the risk of losses by sharing any change in their business which can have an effect on other partner. For example, when CP is associated with new retailers or dis-associated with the retailers, means its future demand will be changed for cakes, so that BP is obliged to adapt its production and inventory to meet CP's future requirements. Similarly, if BP has faced decrease in its milk supplies, then BP must communicate CP the decrease of butter supplies in the future, so that CP finds other opportunities.

Producers can collaboratively plan their production, inventory and can also reduce uncertainty by sharing more information with each other. Despite of coordinating only for sending production orders, they can protect each other's business or even grow it.

2.3.2 Collaboration between producers and retailers

Retailers conduct extensive sourcing studies to assure they have selected the proper suppliers, or at least those with the lowest prices. They also spend significant amount of time and resources to find suppliers that are critical to their success and which are easily replaceable. They even implement "Supplier Performance Management" programs to assure suppliers have goals to improve quality, cost and delivery. But that's when they stop, before reaping the benefits of collaboration[2]. Retailers can dramatically accelerate their shift to a more collaborative approach with their key suppliers by implementing supplier collaboration. Moreover producers can better understand the retailer's need and adapt and improve their production. Consequently, leads to the mutual benefit for both of them. Producer and retailer collaboration is also named in the literature as supplier and retailer collaboration [Sheu et al., 2006]. The issues related to collaboration in a specific supplier and retailer inter-organizational relationship have been of great interest in the literature. Producer and retailer relationships have received a great deal of attention [Mesquita and Brush, 2008, Yeung et al., 2009, Forslund and Jonsson, 2009, Autry and Golicic, 2010, Stuart et al., 2012, Zamith Brito and Mariotto, 2013]. We explain here this collaboration with the help of cake production example as shown in 2.2.

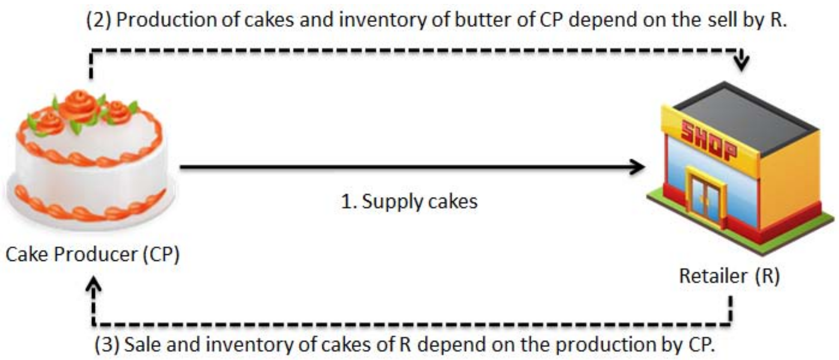

Figure 2.2: *Collaboration between producers and retailers*

R is the retailer, which purchases cakes (1) from CP and sells them directly to

[2] http://www.cgnglobal.com/system/files/CGN_Supplier_Collaboration_White_Paper.pdf

consumers. Production of cakes and inventory by CP depends on the sales of cakes by R (2). Similarly sales and inventory of R is connected to timely delivery of cakes of CP. Increase or decrease in the sales of R affects the production and inventory of CP. Furthermore R has to take into account the uncertainty and volatile demand of its customers. For example cakes demand increase on Valentine's Day, beer demand increases on New Year eve or during football matches and chocolates demand increases during Christmas and Easter. To deal with this uncertainty and volatile demands, R must collaborate with CP by providing more information about these changing demands, so that CP can also increase or decrease its production to better satisfy R's needs. By providing that information, R can make sure without uncertainty whether CP can cope up to these demand changes. Otherwise R will look for other cake producers to satisfy its customer needs. Thus collaboration is needed to better manage CP's production, inventory of both CP and R, and accommodate any change in the businesses of both CP and R. They can even collaboratively create future promotion sales, by analysing sales trends and consumer tastes, hence mutually achieving benefits.

2.3.3 Collaboration between producers and transporters

It is easy to show that, if one only considers production and transportation scheduling problems separately and sequentially, without taking into account the nature of inter-process coordination, it will not necessarily yield a global optimal solution [Zegordi et al., 2010]. This can lead to inefficiencies, especially when inefficient uses of transportation resources can increase the cost a lot if not took into account the production scheduling. SC environment requires a production-distribution planning systems to enable the collaboration between production and distribution units more quickly and orderly. Generally collaboration in a SC needs to resolve conflicts between two decentralised functional units, because each unit tries to locally minimize its own costs, not the overall supply chain costs. Also, there exists incomplete information sharing according to the privacy of each functional unit. This collaboration in the literature is known as decentralised production-distribution planning system (DPDPS) [Jung and Jeong, 2005]. This collaboration has sought great attention from researches and several different approaches have been proposed like fuzzy logic [Selim et al., 2008], genetic algorithm [Zegordi et al., 2010], multi agents [Jung and Jeong, 2005], etc.

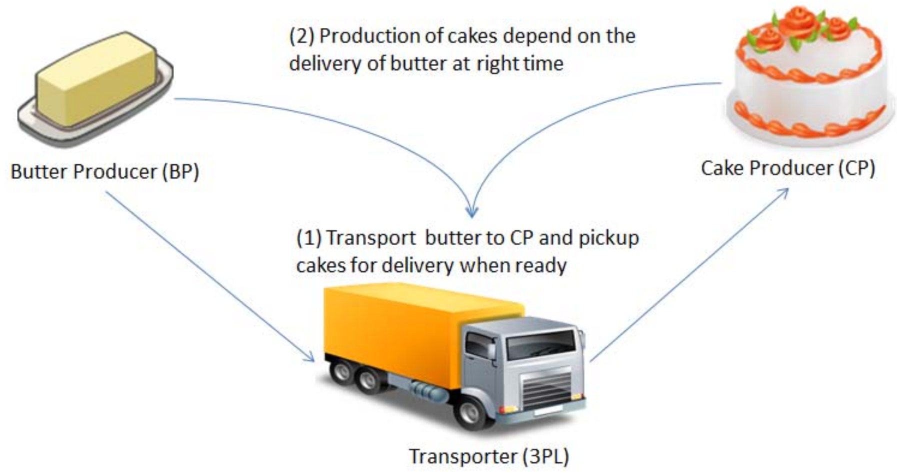

Figure 2.3: *Collaboration between producers and transporters*

A producer's business is highly dependent on efficient transportation. We assume that due to large scale nature of FSC, external transporters are responsible for both transporting the raw ingredients at producers' production site from other producers' sites as well as delivery of final products to their retailer customers. Producer plans its production on the delivery of raw ingredients at right time from transporter and expects the loading of final products, when they are ready for the delivery by transporter. In our cake product SC example (figure 2.3), transporter proposes transportation of butter and delivery of cakes (1), so (2) production of cakes depends on the delivery of butter at right time. If butter products are not ready as planned it will delay the delivery of butter for CP, causing delay the cake production. Eventually transporter is obliged to change its whole transportation planning for delivering butter and cakes. Similarly, if transporter vehicle breakdown or unable to deliver the raw ingredient for whatever reason, it will cause change in the production plan of CP and BP. So, there is a mutual dependence loop between producers and transporters. Any change in production planning will cause change in transportation planning and any change in transportation planning will cause change in production planning. Furthermore, transporter must also provide up to date information about the product quality while transportation (for example constant temperature readings of temperature sensitive products). Moreover, transporter must provide tracing & tracking information for the timely delivery of products to producers. Therefore, transporter and producers have lots of information to share rather than just sending transport orders containing origin, destination and delivery time windows, if they want to increase their business efficiency.

2.3.4 Collaboration between transporters and retailers

Retailers are dependent on transporters for the delivery of products while maintaining their required quality. Transporters must make transparent the whole delivery information for the retailer. Transporters must share delivery schedules to retailers for their respective transport orders. Transporters must also provide up to date real time information form loading the products at producers' site and during the transportation, so that Retailers can better plan their sales. In our cake product example, (1) sale of R depends on the delivery of cakes (2) at right time as shown in figure 2.4.

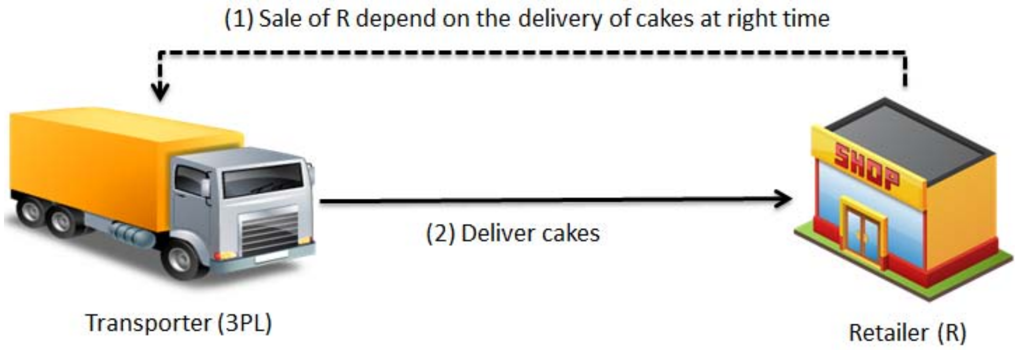

Figure 2.4: *Collaboration between transporters and retailers*

Tracking & Tracing can be seen as an effective solution for firms to gain control for the delivery of products while maintaining their quality. Each of these solutions have their own objectives, requirements, methods, techniques and tools, namely: Global Positioning System (GPS), Mobile Phone Approximated GPS (AGPS), Java Mobile Cell Tracking, Web-based telephone tracking [Roos et al., 2005]. R itself can provide its customers real time information about their cakes delivery time and reserve commands more in advance. Another concern is the quality of products that transporters must ensure, for example cakes must be transported in vehicles equipped with refrigeration facility and sensors can be used to monitor the cakes real time temperature information.

2.3.5 Collaboration between transporters

Transportation planning or vehicle scheduling is one of the operational tasks of purchasing and distribution. Often, several logistic service providers are involved in the main purchasing and distribution process of an enterprise or a certain part of the SC. This is another aspect of collaboration in FSC, which is very recent as emergence of 3PL and 4PL enterprises. 3PL is a transporter company which provides the logistics facilities. There are many 3PLs companies and more are emerging. Each 3PL operates in some geographical are. What if a transport order needs to be picked from the region operated by one 3PL1 and needs to be delivered in the region operated by another 3PL2. 3PL1 and 3PL2 cannot deliver the order independently but can deliver it, if they both collaborate with each other.

This collaboration is seen often in 2PL (Second party logistics) companies like courier companies [Fischer et al., 1996, Berger and Bierwirth, 2010]. Transportation planning by 3PL has been widely researched area and widely known as Vehicle Routing Problem (VRP) and Pickup and Delivery Problem (PDP) [Parragh et al., 2008]. Yet, collaborative transportation planning among different transporters is new research area, and needs to be researched and incorporated in FSC, where more than one 3PLs collaboratively proposes transportation planning.

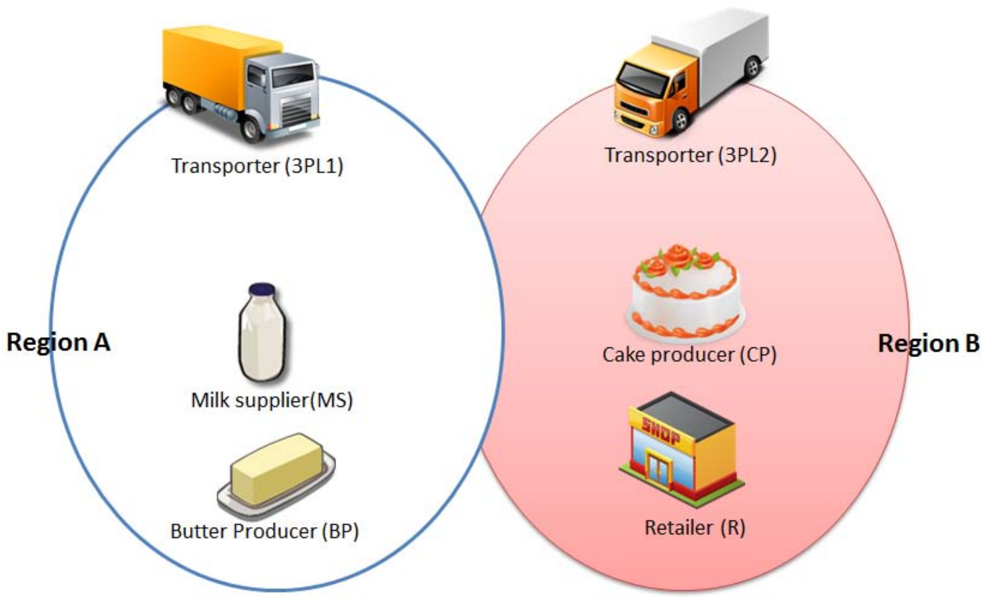

Figure 2.5: *Collaboration between transporters*

In cake product SC example as shown in figure 2.5, MS and BP reside in region operated by 3PL1 and CP and R reside in the region operated by 3PL2. So 3PL1 and 3PL2 must collaborate for successful delivery of all products to respective actors in FSC. Moreover, if there are any disturbances during transportation, then 3PL1 and 3PL2 must be able to re-configure their planning to adapt the changes and synchronize the global delivery plan. They should also provide the continuous updates of the product status and location to provide the product visibility throughout the FSC.

The detailed objective of this thesis is to propose an interoperable framework for collaborative transportation planning

---

We conclude this section with an argument that, combining all of these collaboration areas will sum up to a collaborative FSC and we need to find solutions that propose this collaboration. In the next section, we present the existing SC collaborative approaches used in practice, their merits and demerits and also present their comparative analysis.

2.4 Collaborative approaches

SCM has moved to a new level with the introduction of collaborative approaches involving multiple partners. We present here different collaborative approaches and reason their applicability for above mentioned collaborative areas. There are several approaches proposed, but common and widely used approaches include: Just in time replenishment (JIT), Quick response (QR), Efficient consumer response (ECR), Continuous replenishment program (CRP), Vendor Managed Inventory (VMI) and Collaborative Planning, Forecast and Replenishment (CPFR). We explain them one by one respectively.

2.4.1 Just in time replenishment (JIT)

JIT means making what the market wants, and when it wants [Skagen, 1989]. The concept of Just In Time replenishment has been influential in Japan since the 1950s, but only came to the attention of western manufacturing practitioners and academics around 1980, as a result of the great success of Japanese automotive and electronics manufacturers, particularly after the oil crisis in 1973. The essence of Just In Time is "to produce the necessary units in the necessary quantities at the necessary time" [Skagen, 1989]. JIT focuses on achieving following goals: secure a steady flow of quality parts, reduce the lead-time required for ordering product, reduce the amount of inventory in the supply and production pipelines and reduce the cost of purchased material [Aghazadeh, 2004].

2.4.2 Quick response (QR)

QR refers fundamentally to speed-to-market of products which move rapidly through the production and delivery cycle, from raw materials and component suppliers, to manufacturer, to retailer and finally to end consumers [Perry et al., 1999]. QR is an initiative initially developed for the textiles, clothing and footwear industry in 1980s. QR is an apparel industry initiative intended to cut manufacturing and distribution lead times through a variety of means, including information technology such as electronic data interchange.

SCs adapting QR, generally consider the situation in which market demand is extremely unpredictable and replenishment lead time is long. As an outcome, QR is found to be critically important in industries such as consumer electronics, toys, etc. Implementing QR programs is usually believed to be beneficial to the SC and the retailer by lessening the bullwhip effect, improving inventory management by better matching supply and demand in a timely manner, enhancing customer service in avoiding stock-outs, and improving the delivery speed. There is a danger that in adopting a business strategy which includes the element of speed, the time factor for developing a long-term, workable structure may be downplayed. Perhaps a compromise solution is required for companies, trading off the benefits of thorough structural planning and implementation with the benefits of speed [Perry et al., 1999]. The importance of SC partnerships for QR was established clearly by writers [Blackburn, 1991, Iyer and Bergen, 1997, Choi, 2006, Choi and Chow, 2008]. In food industry, QR also got great attention [Larson and Lusch, 1990, Fiorito et al., 1995, McKinnon et al., 1998].

2.4.3 Efficient consumer response (ECR)

A group of grocery industry leaders created a joint industry task force called the ECR working group in 1992, which proposed the ECR [Frankel et al., 2002]. ECR is a joint trade and industry body working towards making the grocery sector as a whole more responsive to consumer demand and promote the removal of unnecessary costs from the supply chain [3]. ECR Europe [Europe, 2011] was launched in 1994. With its headquarters in Brussels, the organization works in close co-operation with national ECR initiatives in most European countries. ECR strategy aimed at making the FSC more competitive and bringing greater value to the consumer. Manufacturers, wholesalers and retailers work together as business

[3] http://en.wikipedia.org/wiki/Efficient_Consumer_Response_(organisation)

allies to reduce total system costs, inventories and physical assets while improving the consumers' choice of high-quality products.

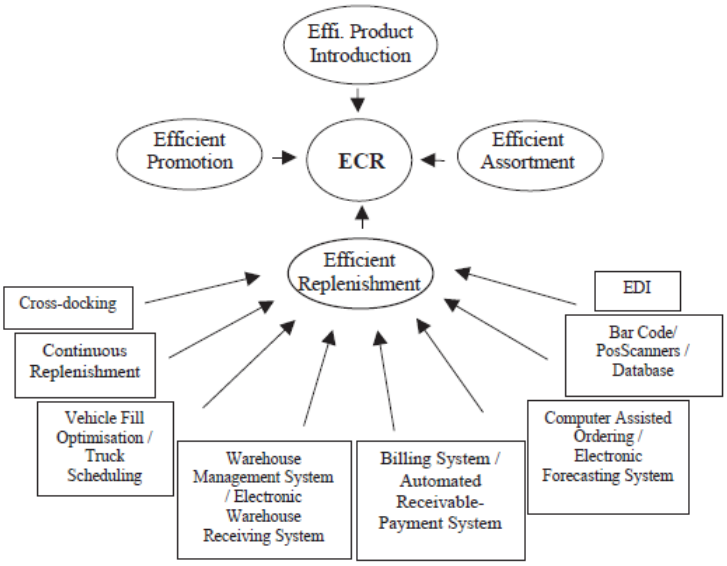

Figure 2.6: *Efficient consumer response (ECR)* [De Toni and Zamolo, 2005]

The theory proposes a re-planning of SC, acting on the various production-points (figure 2.6), that is, the area of promotions (efficient promotion), assortments (efficient assortment), development and introduction of new products (efficient new product introduction), and logistics that considers replenishment processes (efficient replenishment). ECR has two components in its definition, consumer and effective response. The former emphasizes the needs of consumer and the latter orients to a FSC optimization process [Seifert, 2003].

2.4.4 Continuous replenishment program (CRP)

From ECR, the concept of CRP is developed [De Toni and Zamolo, 2005]. CRP reorganizes the traditional system of ordering and replenishment characterized by the transfer of purchase orders from the retailer to the manufacturer. CRP is a process of restocking, where the manufacturer sends to the retailer's distribution centre full loads of products whose composition varies according to sales and in conformity with a prearranged level of stock [Derrouiche et al., 2008]. Using CRP (figure 2.7), manufacturers and retailers share inventory status information, increasing replenishment frequencies and reducing inventory for both firms. In this case, the manufacturer no longer observes consumer demand through the retailer's order quantities but determines it directly from end consumers, though the manufacturer still receives orders from the retailer (i.e., the retailer is responsible for placing orders). CRP requires the manufacturer to implement a continuous replenishment process with the retailer increasing the frequency of replenishment [Yao and Dresner, 2008].

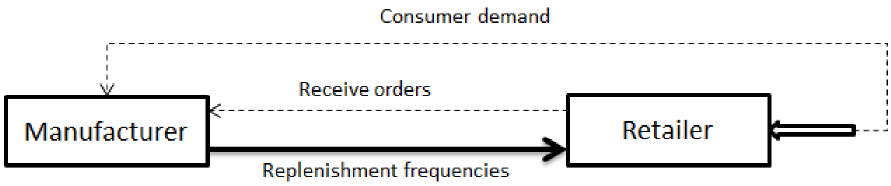

Figure 2.7: *Continuous replenishment program (CRP)* [Yao and Dresner, 2008]

2.4.5 Vendor managed inventory (VMI)

VMI, also known as continuous replenishment or supplier-managed inventory, is one of the most widely discussed partnering initiatives for encouraging collaboration and information sharing among trading partners. Under a VMI system, the supplier decides on the appropriate inventory levels of each of the products (within previously agreed upon bounds) and the appropriate inventory policies to maintain these levels [Simchi-Levi, 2009]. The retailer provides the vendor with access to its real-time inventory level. In this partnership program, the retailer may set certain service level and/or self-space requirements, which are then taken into consideration by the vendor.

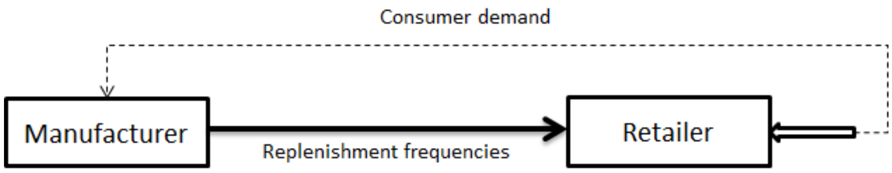

Figure 2.8: *Vendor managed inventory (VMI)* [Yao and Dresner, 2008]

In VMI system (figure 2.8), the retailer's role shifts from managing inventory to simply renting retailing space [Sari, 2008]. VMI ensures that the production and consumption are keeping the same speed, consequently bullwhip effect is effectively avoided. The implementation of VMI requires customer's confidence whose business depends on supplier's proper inventory management. It represents the highest level of partnership, where the vendor is the primary decision-maker in order placement and inventory control [De Toni and Zamolo, 2005]. Nevertheless, retailers, most of the time, do not desire to engage in information sharing because it provides ignorable levels of benefits for them. Therefore, this requires upstream members (e.g. suppliers or manufacturers) to offer incentives for retailers in return for information sharing.

2.4.6 Collaborative planning, forecast and replenishment (CPFR)

CPFR began first with a pilot program between Wal-Mart and Warner-Lambert, called CFAR (collaborative forecasting and replenishment). In the late 1990s the voluntary inter-industry commerce standards (VICS) association developed the CPFR initiative and published a first 'CPFR guidelines' [Planning, 2002]. CPFR is defined as follows [Li, 2007]:

"Collaboration process whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers".

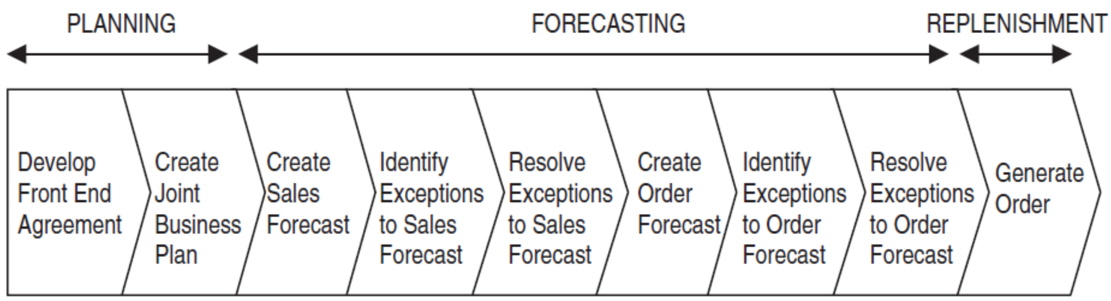

Figure 2.9: *Collaborative Planning, Forecast and Replenishment (CPFR)* [Danese, 2006]

CPFR covers from suppliers to distributors with the objective to optimize SC by improving demand forecasts, reducing inventories, avoiding stock-outs, and improving customer service. CPFR emphasizes the importance of directly obtaining information of customer POS, inventory, and marketing plans. Broad exchange of forecasting information improves forecasting accuracy when both the buyer and seller collaborate through joint knowledge of sales, promotions, and relevant supply and demand information. CPFR is a set of business processes that are established and empowered by a formal agreement to cooperate on strategy, tactics and execution by resolution of exceptions. Basics of CPFR are straightforward (figure 2.9). Step 1 and 2 are the foundation for the rest of steps. Step 1 is 'front-end agreement', under which the roles of the buyer and supplier and their capabilities to perform these roles are assessed. In this step, targeted performance and measures are also adopted. In step 2, strategies and tactics are specified in detail. Then, significant differences between the buyer's and seller's demand forecast, labelled 'exceptions', are discussed and resolved. These are steps 3 to 5 above. Then, buyer and supplier share plans for orders that the buyer will place with the supplier, based on the shared demand forecasts. Subsequently, using the shared order plan, actual orders are generated (step 9) [Derrouiche et al., 2008].

Above we presented well famous collaborative approaches widely used in industries and in the next section we present their comparative analysis.

2.4.7 Comparative analysis

ECR was the first initiative created to promote SC collaboration with the aim of leading exceptional transformation in business practices. Moreover, it was created for the grocery sector [Janvier-James and Didier, 2011]. In parallel to that, a similar standard was created for the textile industry names QR. The theory of both proposes re-planning of SC [De Toni and Zamolo, 2005, Kurnia et al., 1998]. JIT is also similar to QR and ECR which existed much before QR and ECR but came into attention internationally when its similarities were found with ECR and QR [Skagen, 1989]. Focusing on the efficient replenishment, a new approach was proposed called CRP [De Toni and Zamolo, 2005]. Using CRP, buyers and suppliers share inventory status information so that they can increase replenishment frequencies and reduce inventory for both firms. Decision point of order generation is usually based on contractual agreed levels. However, when the control shifts completely in the hands of vendor to manage the inventory of customer, this was the emergence of VMI. Authors in [De Toni and Zamolo, 2005] considers CRP and VMI same thing.

Researchers in [Disney and Towill, 2002] claims that VMI comes in many forms like synchronized consumer response (SCR), rapid replenishment (RR) and centralized inventory management (CIM). Under VMI, the retailer provides the distributor with access to its real-time inventory level as well as its POS data (Fig 2.10). In return, the distributor takes the responsibility of managing the inventories of retailer. That is, under VMI, the distributor does not only need to take into account its own inventories while making inventory plans, but also the inventories of the retailer. Therefore, under this structure, the distributor follows an echelon-based policy in his replenishment planning [Sari, 2008]. Authors in [Simchi-Levi, 2009] propose the degree of partnership as criteria of differentiation between the different collaborative strategies. The degree of partnership ranges from information sharing, where the retailer helps the vendor to plan demand more efficiently, to consignment schemes where the vendor completely manages and owns the inventory until the retailer sells it. Using this criteria, the present authors classified QR, CRP and VMI with the increasing degrees of partnership.

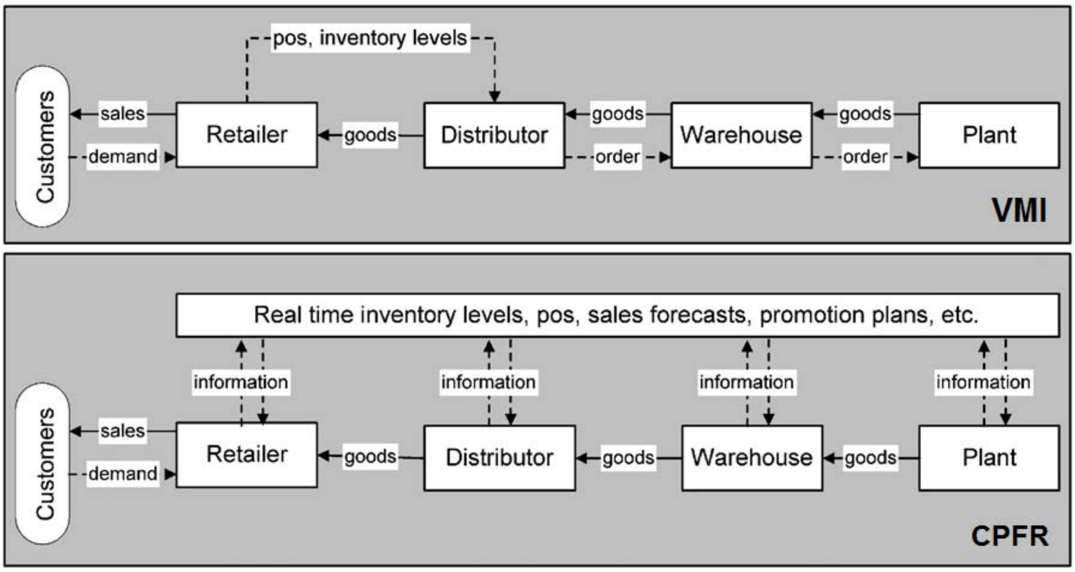

Figure 2.10: *Comparison of VMI and CPFR* [Sari, 2008]

CPFR, on the contrary, can solve majority of the problems that are encountered in the adaptation of VMI, because it requires all members of a SC to jointly develop demand forecasts, production and purchasing plans, and inventory replenishments [Aviv, 2002] as shown in figure 2.10. It is a business practice that combines the intelligence of multiple trading partners in the planning and fulfilment of customer. CPFR extends the objectives to planning and forecasting. In case of VMI, there is a high level of power and responsibility for the supplier (and low level power for the retailer). However CPFR disposes a high degree of power and responsibility for all the partners [Derrouiche et al., 2008].
Above we presented the collaborative approaches and their comparative analysis, in the next section we present their limitations and what we consider in this thesis to overcome them.

2.5 Limitations

Previously presented collaborative approaches take into account only two types of actors of SC: buyer and seller. They do not include transporter in the collaborative process. SC usually includes suppliers, producers, distributors and retailers and considers transport as the responsibility of either of them. The evolution of the role of transportation makes a new independent SC member: transport operator. Nowadays with 3PL and Fourth party logistics (4PL), transportation has been separated from manufacturing enterprise and therefore SC structure and business processes become more complex with the appearance of transport operators. The 16th Annual Third Party Logistics Study [Langley, 2012] has shown that nearly two-thirds (64%) of shipper respondents report an increase in their use of outsourced logistics services, and 76% of 3PL respondents agree this is what they are seeing from their customers. Regionally, 58% of North America shippers reported increased use, as well as 57% of European, 78% of Asia-Pacific and 73% of Latin American shippers. Moreover, these approaches do not consider production planning as a collaborative task and elaborate it. Production planning is considered as the internal part of replenishment process. However, production is distributed to several sites and several producers produce semi-products which are assembled to form the final product. Collaborative replenishment process from these approaches propose to generate the orders from forecasts to reduce the uncertainty, but how production of these orders are planned is itself a collaborative activity among different producer partners in the SC.

Considering the above limitations related to production and transportation, we conclude that production planning and transportation planning should be very much part of the collaborative approaches beside the collaborative replenishment and inventory management, which have been the main focus of the collaborative approaches like VMI, CPFR, etc.

We clearly see the research gap in this area and consequently, our research is to get rid of these limitations and propose an effective approach to incorporate the transportation and production planning along other collaborative issues.

2.6 Conclusion

We identify here inter-organizational collaboration areas in FSC on which we are focusing in this work. These areas are collaboration between: multiple producers, producers and retailers, producers and transporters, transporters and retailers, and multiple transporters.

Different collaborative approaches proposed since few decades can address some of these mentioned collaborative areas. Some well-known approaches are JIT, QR, ECR, CRP, VMI and CPFR. From these approaches, CPFR looks more interesting and can solve majority of the problems, because it requires all members of a traditional FSC to jointly develop demand forecasts, production and purchasing plans, and inventory. Nonetheless, it does not consider the production and transportation planning as collaborative activities and elaborate them. Production planning among different producer partners in the FSC is itself a collaborative activity. Similarly, the evolution of the role of transportation makes a new independent FSC member - transport operator. Nowadays, with 3PL and 4PL companies, transportation has been separated from production enterprise. Moreover in order to reach faraway regions, these transporters also need to collaborate with each other to make possible the delivery of products. Therefore FSC structure is evolved and business processes become more complex with the appearance of transport operators.

We recommend an extension to CPFR model with production and transportation planning by proposing a model called C-PRIPT (Collaborative - Planning, Replenishment & Inventory, Production and Transportation). Chapter 3 is dedicated to present C-PRIPT model.

Within C-PRIPT model, our detail focus is the collaborative transportation planning. Therefore, in chapter no 4, we propose an interoperable distributed model called I-POVES (Interoperable-Path Finder, Order, Vehicle, Environment and Supervisor). I-POVES offers collaborative transportation planning and cater two collaborative areas of: producers and transporters and multiple transporters aiming at reducing the cost of transport, environmental pollution by respecting food constraints.

We conclude with chapter 5, in which we present the application of our work within the context of a European project TECCAS.

Chapter3

C-PRIPT (Collaborative-Planning, Replenishment, Inventory Production and Transportation)

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3.1 Introduction

Driven by changing social, technological innovations, the leading food producers, distributors and retailers have to develop an improved FSC collaborative infrastructure that would benefit all organizations involved in it. Today, regardless of the competitive working environment at different stages at FSC, collaborative activities are the more effective mode of operation. Such as sharing transport carriers to share cost and better utilize resources. In a collaborative SC, information is shared and becomes available among the members. This enhances SC visibility and avoids information delays and distortions. Sharing information such as demand, sales, inventory status and order fulfilment status can help companies to reduce inventory cost, shorten time-to-market, and improve decision making. This leads to the focus on integrative heterogeneous systems solutions in the planning of the basic functions like replenishment, production and distribution [Selim et al., 2008].

Previously proposed collaborative approaches like CPFR and VMI take into account only two type of actors of SC: buyer and seller, but since the advent of 3PL enterprises, a new actor called transporter or logistics provider came into existence, which is not yet considered as the part of SC collaborative processes. Initially producer or distributor was responsible for transportation, but now it is being outsourced to 3PL, which has become very significant link in SC since recent years. Moreover, collaborative approaches do not consider the production planning as a collaborative activity, but as an implicit part of replenishment activity. Taking into account above limitations, we propose a model called Collaborative - Planning, Replenishment, Inventory, Production and Transportation (C-PRIPT), which includes transporter actor and elaborates production and transportation planning as collaborative activities. We explain here some basic terminologies and then explain C-PRIPT model in the rest of the chapter.

3.2 Terminologies

While describing the proposed model, we use some specific terminologies. We define these terminologies in this section.

- *European Article Number (EAN):* Global standards 1 (GS1) is a neutral, not-for-profit, international organization that develops and maintains standards for supply and demand chains across multiple sectors. Companies come to GS1 to acquire bar code numbers for their products. International Article Number or formerly known as European Article number (EAN) is a 13 digit bar code standard defined by GS1[1], that is used worldwide for marking products often sold at retailer point of sale [Brock, 2001].

- *Stock keeping units (SKU):* SKU is a unique identifier for a distinct item, such as a product or service. Some retailers give their own SKU name to the products and they use them in their systems to manage their inventories. EAN identifier remains identical throughout the entire retailer and producer systems, however SKU name is specific to each retailer. SKU distinguishes one product that it represents from all other products. It includes attributes like: producer, product description, material, size, colour, packaging, and warranty terms. SKUs are not always physical objects. Anything that can be sold separately from anything else has a stock keeping unit, such as extended warranties, delivery fees, installation fees, and licenses[2].

- *POS:* POS is the place where a retail transaction is performed. It is the point, where customer makes the payment of the products (s)he has purchased. When a product's EAN bar code is passed through that point, it is noted in the retailer's system as sold and system decreases the quantity of the product with the number of products sold. These everyday transactions are saved in the retailer's database and are called POS data[3]. POS data gathered at normal price under normal conditions is called "base POS" data and POS data gathered during promotion period is called "promotion POS" data.

- *Inventory on order:* Inventory on order is the product quantity already ordered for retailer, but it did not yet deliver at the warehouse[4].

- *Inventory on hand:* Inventory on hand is the total product quantity available at the retailer's warehouse or inventory. This does not include product quantity available for sale at the retailer's store[4].

- *Withdrawals:* Withdrawals are the product quantity taken out from retailer's warehouse and placed in its store for sale on every day[4].

- *Opportunity loss/ cuts :* Opportunity loss / cuts means the product is out of stock at retailer's store and it is not even available at its warehouse[4].

[1] http://en.wikipedia.org/wiki/International_Article_Number_(EAN)
[2] http://en.wikipedia.org/wiki/Stock_keeping_unit
[3] http://en.wikipedia.org/wiki/Point_of_sale
[4] http://www.covesys.net/streamv-erp-help/default.htm?turl=replenishmentinventory.htm

- *Discording Loss:* Discording Loss means product was available at retailer's store or warehouse in excessive quantity and was not sold as planned and might be wasted due to deterioration. It may also include damaged products[4].

3.3 C-PRIPT model description

The C-PRIPT model propose the activities and interactions necessary for collaboration between all the participants of FSC. In C-PRIPT, producer produces the food product and it manages its own inventory plus the inventory of retailer. Transporter provides the logistic services, it also manages its own warehouses, to use it as temporary transit for products delivery. Retailer collects POS data and updates its inventory status and shares them with the producer. We do not consider supplier or distributor explicitly in the model, because we assume that their function is performed by producer and transporter respectively.

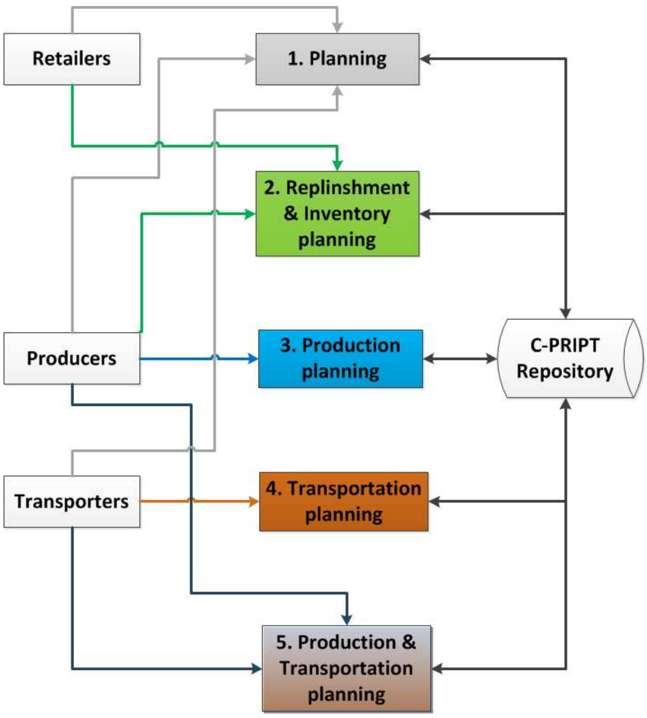

Figure 3.1: *C-PRIPT model*

Our model is highly inspired by CPFR model. CPFR is the latest initiative for collaborative FSC which was proposed in late 1990s. However, since then there is emergence of new collaborative phases that were not existed before. Appearance of 3PL enterprises and distribution of product production at several sites bring production planning and transportation planning in attention demanding greater space in collaborative strategies. CPFR model consists of three planning phases planning, forecasting and replenishment, while C-PRIPT consists of five phases. Figure 3.1 illustrates the proposed CPRIPT model.

With C-PRIPT, FSC members agree to develop a collaborative business relationship based on exchanging information to support the synchronization of activities and make visible the product from production until the sell to end consumer. With C-PRIPT, members can detect any change occurred in any part of the FSC activity and in reaction can adapt their business planning accordingly and quickly, minimizing the risk of losses. C-PRIPT is classified in five interlinked phases: "Planning" and "Replenishment & inventory planning" are based on the CPFR model. The remaining three phases are: "Production planning", "Transportation planning" and "Production & Transportation planning". The Planning phase involves preparation to evaluate companies internal requirements and capabilities, trading partner segmentation and implementation strategy [CPFR, 2008]. The replenishment & inventory planning phase is an ongoing iterative process, involving forecasting such as creation of sales and order forecast, exception handling and generation of production orders. The third phase is production planning, which includes product production planning, generating delivery orders for products and handling production disturbances. The fourth phase is transportation planning, which concerns the delivery of the raw materials and final products to producer's site and retailer's depot respectively. The fifth phase is production-transportation planning, which concerns the interactions between production and transportation planning. In all last four phases, FSC partners work together to achieve common goals defined in the first phase. We explain each of these five phases one be one respectively.

3.3.1 Collaborative planning

In this phase, producer, retailer and transporter come to an understanding about their relationship and establish product and event plans. They need to state their company's needs, values, culture, strategies, trading partner relationships, and track record of previous partnerships. The most crucial prerequisite for successful collaboration is to have strategic alignment with participating partners as well as internally-alignment of the process, organizational and technology strategies with collaborative business strategies. Members must refine their business strategy to focus on collaboration. A fair negotiation and reasonable arrangement that will benefit all trading partners is critical in creating a successful and collaborative relationship [CPFR, 2008]. Another aspect to be considered is confidentiality, sharing sensitive data reinforces the need to define rules around confidentiality. Confidentiality agreements should document common understanding around areas, where confidentiality is paramount between the trading partners. Members should also be aware of their responsibilities regarding competition law at a national, European and global level [CPFR, 2008]. In order to ensure the desired behaviours of all involved parties, reward structure within each organisation needs to be aligned with the objectives of collaboration. The close collaboration needed for C-PRIPT implementation drives the planning for an improved business plan between all partners. The strategic business advantage directly translates to increased category sales.

Planning phase contains two collaborative activities: collaboration agreement and joint business plan as shown in figure 3.2. collaboration agreement is the process of setting the business goals for the relationship, defining the scope of collaboration and assigning roles, responsibilities, checkpoints and escalation procedures and joint business plan identifies the significant events that affect supply and demand in the planning period, such as promotions, inventory policy changes, store openings / closings, product introductions and product delivery [CPFR, 2008]. We explain both of the steps respectively.

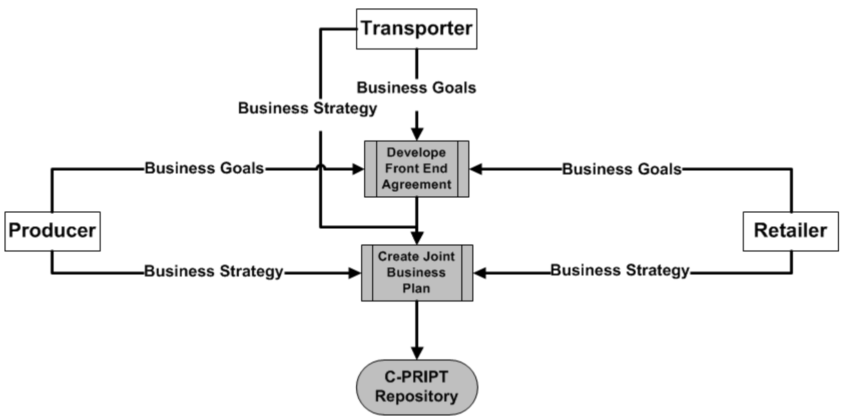

Figure 3.2: *Collaborative planning*

3.3.1.1 Develop collaboration agreement

The entities involved in a collaborative relationship (producer, retailer & transporter) establish guidelines and rules for the collaborative relationship. The collaborative agreement addresses each party's expectations, actions and resources necessary for success. To accomplish this, the three parties co-develop a general business agreement that includes the overall understanding and objectives of the collaboration, confidentiality agreements, and the empowerment of resources (both actions and commitment) to be employed throughout the collaboration process. Following steps needs to be achieved in collaborative agreement [CPFR, 2008].

- Determine business goals and objectives
- Discuss competencies, resources & systems
- Determine information sharing needs
- Define service and ordering commitments
- Determine resource involvement and commitments
- Determine how to resolve disagreements
- Determine review cycle for collaboration arrangement
- Communicate collaboration arrangement and top management buy-in

3.3.1.2 Create joint business plan

This activity pinpoints the major actions that affect supply and demand in the planning period. Examples of these are introducing new products, store openings and closings, changing inventory policy, promotions and product delivery constraints and regulations [CPFR, 2008].
In this activity, the entities (producer, retailer and transporter) exchange information about their corporate strategies and business plans in order to collaborate on developing a joint business plan. The partners first inspect shelf positioning and exposure for targeted products to ensure adequate days of supply, and proper exposure to the consumer [Europe, 2001]. This scrutiny will result in improved shelf positioning and facings through sound category management. Then, they create a partnership strategy and then define category roles, objectives, and tactics. The product management profiles (e.g., order minimums and multiples, lead times, order intervals) for items to be collaborated on are established. Additionally, it contains the space for future product changes like product evaluation and additional product opportunities [VICS, 1999].

3.3.1.3 C-PRIPT repository

When both the steps of planning phase are done and documented, it is necessary to keep them in a common place accessible to every collaborative partner. C-PRIPT includes a data warehouse named "C-PRIPT repository" to store that information.

This repository will also be the storing place for all the data generated by all the collaborative activities involved in the rest of the C-PRIPT phases. Such sharing of information will lead to availability of required information throughout the FSC, thereby increasing the efficiency and accuracy of planning, forecasting and replenishment, production and transportation and laying the foundation for a wide scale C-PRIPT adoption.
Shared data enables C-PRIPT participants to act on opportunities, issues and misunderstandings. It facilitates also a fast and thorough understanding of the challenges among partners. Based on the arrangements chosen between trading partners, the following information are exchanged [Europe, 2001]:

- Business plan
- Promotion plan
- New product introduction information
- Inventory data
- POS data
- Sales forecast
- Order forecast
- Production plan
- Delivery plan
- Production status
- Product delivery status and etc.

3.3.2 Collaborative replenishment & inventory planning

This phase contains the list of iterative activities as shown in figure 3.3. These activities are *Create Sales Forecast*, which projects consumer demand, and can be performed by either retailer or producer as decided in collaboration agreement. The other collaboration activity is *Create Order Forecast*, executed by producer which uses factors such as transit lead times, sales forecast and inventory positions of retailers to determine future product ordering forecasting. Then producer uses order forecasting in the activity *Generate orders* to generate product delivery orders for retailer. The retailer steps related to this collaboration activity is to acknowledge the orders, and the producer steps are production and supply.

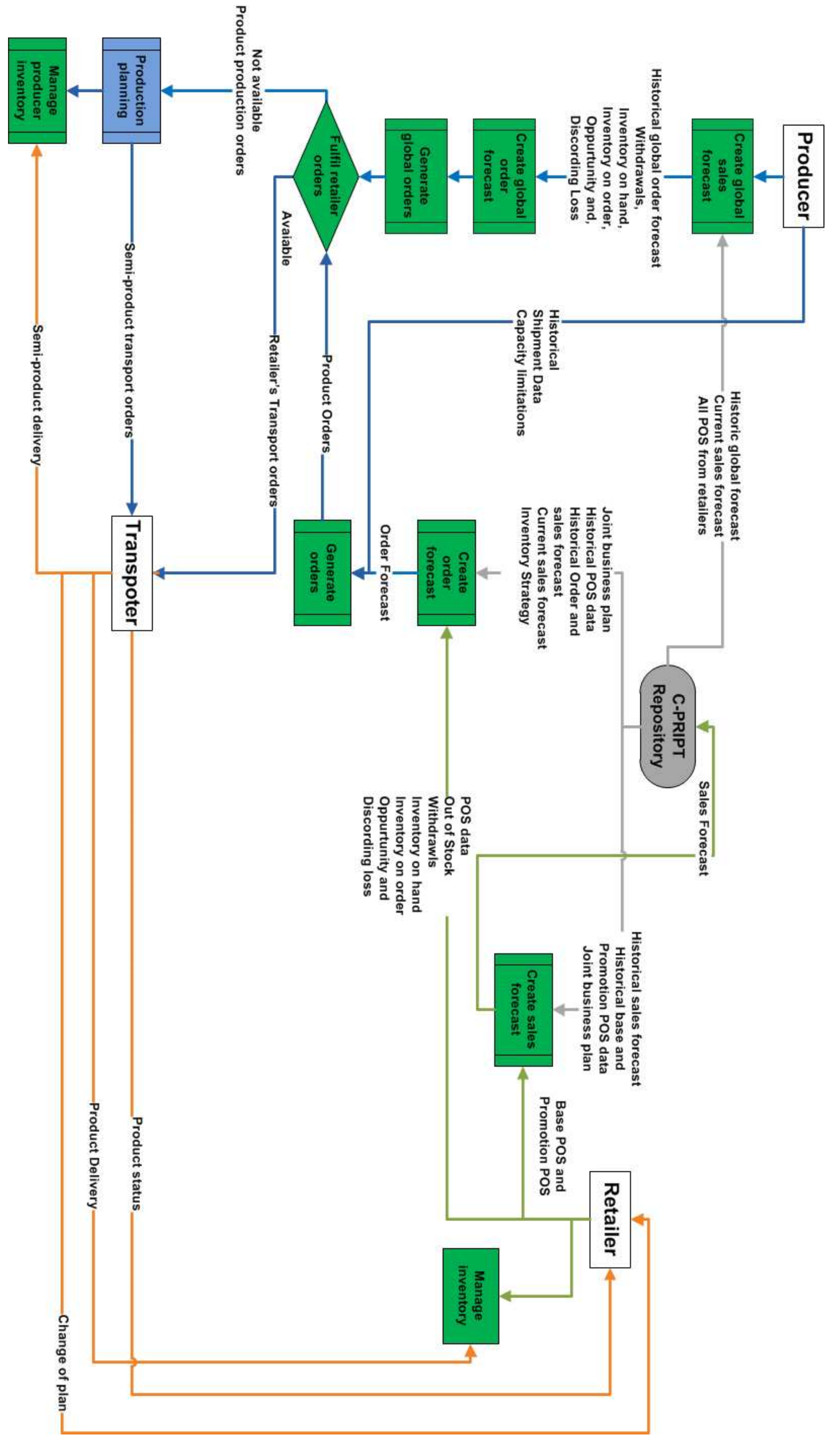

Figure 3.3: *Collaborative replenishment & inventory planning*

Then the *Plan retailer inventory* activity updates the product inventory of retailer on the delivery of products to its warehouse(s).

Create global sales forecast is a collaborative activity which combines POS data, sales forecast data from all the retailers and generate a global forecast for a product for the producer. Then there is *Create global order forecast* activity, which generates product production orders. Afterwards producer verifies its product availability in his inventory by the task *Fulfil retail orders*. If product is available, then it generates the delivery orders for transporter, otherwise it launches the production. When the product is ready it is then sent to the retailer and *Manage retailer inventory* activity updates the retailer's inventory. Then producer compares its inventory with the product orders and launches the production orders for the remaining quantity and brings the inventory levels up to fulfil product's future product demand as determined by global sales forecast. *Manage producer inventory* activity then updates the producer's inventory, when product is produced. We explain each of these activities one be one below.

3.3.2.1 Create sales forecast

In this activity, retailer POS data, causal information and information on planned events and historical forecast data are used to create a sales forecast for single product for single retailer. This activity can be carried out by the retailer, or producer as decided in the joint business plan, but results are shared in the C-PRIPT repository for all trading partners. POS data gathered during promotion will be used to analyze the product demand and plan the future promotions.

Sales forecast is prepared normally weekly for the short shelf-life perishable food items, monthly for medium shelf-life food products and annually for long shelf-life and stable food products. Forecast created on base POS data is called "base forecast" and forecast created on promotion POS data is called "promotion forecast". The sales forecast is generated by forecasting tools that calculate of all the relevant information and set guidelines [VICS, 1999].

This activity directly affects shelf availability, because POS data depends heavily on the consumer's purchases. This activity also takes as input the historical POS data and historical sales forecast. Historical data is used as reference to compare it with current POS data, in order to determine that whether new methods are needed to propose better sales forecasting. This activity also comprises of identifying the exceptions found during in the sales forecast result and to resolve / collaborate on these exception items. Resolution involves querying shared data, email, telephone conversations, meetings, and so on and submitting any resulting changes to the sales forecast. The exception criteria for each item are agreed in the collaborative agreement. "Collaborative negotiations between producer and retailers resolve item exceptions" [VICS, 1999]. Following are the input and output data items for this activity.

Input: *Base POS data, Promotion POS data, Joint business plan, Historical base POS data, Historical promotion POS data and Historical sales forecast.*
Output: *Sales forecast*

3.3.2.2 Create order forecast

In this activity, POS data, causal information and inventory strategies are combined to generate order forecast that supports the shared sales forecast and the joint business plan. The short-term portion of the forecast is used for order generation, while the longer-term portion is used for planning. The retailer is responsible for sending the current inventory status data like inventory on hand, inventory on order quantity, withdrawals, opportunity loss and discording loss. Order forecast is determined for each SKU that is going to be replenished. Order forecast is determined by the producer and shared in the C-PRIPT repository for all trading partners. Additionally, historical order forecast is used as reference to compare it with current forecast results to determine whether it was accurate or new methods are needed to improve the forecasting results. Order forecast also comprises the identification of the exceptions and involves the process of investigating those exceptions and resolving them. Following are the input and output data items for this activity.

Input: *Base POS data, Promotion POS data, Joint business plan, Historical POS data and Historical sales forecast, Current sales forecast, Historical order forecast, Inventory strategy, Out of stock, Withdrawals, Inventory on hand, Inventory on order, Opportunity loss, Discording Loss.*
Output: *Order forecast*

3.3.2.3 Generate order

This activity marks the transformation of the order forecast into committed orders for each SKU. Order generation is performed by the producer by taking into account his competencies, systems and resources. The created orders are expected to consume the order forecast. List of orders generated are sent back to retailer, so that retailer can have the idea of its future shipments and can simulate its future inventory levels. Retailer can acknowledge these orders and confirm their acceptance with producer. If retailer wants any change in the orders, it can then communicate to the producer. Following are the input and output data items for this activity.

Input: *Order forecast, Historical product orders data, Capacity limitations*
Output: *Product orders*

3.3.2.4 Manage retailer inventory

Producer ships products from several plant warehouses to retailer warehouses, from which the stores operated by retailer are resupplied. When products are about to finish from retailer's super store, it withdraws certain quantity of the products from its own warehouse and place it in the store for sale and updates its inventory levels to the new ones by subtracting the quantity that it withdraws. Products placed in the store are not counted in the inventory as they will be sold at any time. Total retailer inventory is inventory on hand cumulated with inventory on order. A minimum inventory level is determined for each product, and for any product below its minimum, a shipment is made sufficient to bring the product inventory to at least the minimum level.

To fulfil retailer's product orders, producer checks its own inventory status, if it can fulfil generated product orders, it launches transport orders for transportation, otherwise it launches the production. Retailers also run promotions in collaboration with producer. When products are shipped from producer's depot and arrived at retailer's depot, retailer updates its inventory on hand. Following are the input and output data items for this activity.

Input: *Product delivery*
Output: *Inventory on hand, Inventory on order*

3.3.2.5 Create global sales forecast

Above presented activities (*Create Sales forecast, Create order forecast, Generate order and Plan retailer inventory*) were retailer oriented and concerned for retailer's planning of replenishment & inventory for the retailer. Although, create global sales forecast concerns to producer, where it creates a global sales forecast to determine the global product demand. Global sales forecast is used to determine the aggregate consumer demand to derive in the target future planning. There exists several methods and algorithms (Linear Approximation, Least Square Regression, Weighted Moving Average, etc.) to create the forecast. Though accuracy of the forecast can be determined by comparing historical global sales forecast with current global sales forecast that how closely accurate they are. If sales forecast does not properly determine the demand, than it is better to change the method of forecasting. Not a single forecast method can provide the accurate forecast for all the products, for different products different forecast methods can be efficient. Following are the input and output data items for this activity.

Input: *Base POS data and Promotional POS data of all retailers, Current sales forecast of all retailers, Joint Business plan, and Historical global Sales forecast.*
Output: *Global sales forecast*

3.3.2.6 Create global order forecast

Similar to order forecast, global order forecast activity determines order forecast that supports global sales forecast and inventory strategies of the produce's internal organization. This activity is also a collaborative, because it uses the shared data provided by all the retailers who purchases the particular product. This data include POS data from retailers and global sales forecast and previous global order forecasts and generated orders. It will also take into account the producer's inventory status. Following are the input and output data items for this activity.

Input: *Historical global order forecast, Global sales forecast, Withdrawals, Inventory on hand, Inventory on order, Opportunity Loss, Discording Loss*
Output: *Global order forecast*

3.3.2.7 Generate global orders

This activity generate list of product orders according to global order forecast. The short-term portion of the forecast is used for production order, while the longer-term portion is used for planning. Order generation takes into account producer's competencies, systems, and resources. These orders are related to produce the product and maintain the inventory of producer at the level to fulfil future product orders of all of producer's retailer customers. Following are the input and output data items for this activity.

Input: *Global order forecast*
Output: *Global product orders*

3.3.2.8 Fulfil retailer orders

This activity takes into account initially, order generated for each retailer by the generate order activity and checks producer's inventory. If inventory is sufficient enough to fulfil individual orders of retailers, it generates transport orders for the product delivery. This activity verifies the producer inventory levels corresponding to global order generation. It launches the production orders subtracting the retailer individual orders from 'generate order activity' for which shipment is already planned, to maintain the inventory levels according to 'global order forecast' activity. Following are the input and output data items for this activity.

Input: *Global product orders, Retailer transport orders, inventory levels of producer*
Output: *Transport orders for transporter, Product production orders*

3.3.2.9 Production planning

Production planning activity is similar to "Order Fulfilment" activity of the conventional CPFR model. This activity is related to launching production for products, for the remaining quantity of the product to be produced which involves collaboration with other producers and transporters. This activity consists in developing production planning and generating the transport orders for transporters for the delivery of raw materials. This activity is handled by the producer and uses the production orders generated with the help of collaborative forecasting activities. Production involves the gathering of all the necessary ingredients for the final product and utilizing the production resources at optimum by generating the efficient production planning. This production might comprise of several distributed sites. We explain this activity as a complete phase later in this chapter. Following are the input and output data items for this activity.

Input: *Production orders*
Output: *Production orders for semi-products, Transport orders for raw material, Transport orders for final product delivery*

3.3.2.10 Manage producer inventory

This activity is similar to manage retailer's inventory activity. In C-PRIPT model, both the inventory activities are managed by the producer. When producer warehouse receives raw materials from other suppliers and producers, it updates its raw material inventory status and when it receives final product after production, it updates final product inventory. Inventory actually depends heavily on the whole replenishment list of activities. Collaboratively planning these activities will help reduce the bullwhip effect and maintain the inventory at the needed levels, so that it does not go out of order or go over availability.

Input: *Final products delivery, Raw material delivery, Transport orders for product delivery*

Output: *Inventory on hand, Inventory on order*

Replenishment & inventory planning causes the reduction of out-of-stocks and shorter cycle times which leads to a more responsive and reliable FSC, thereby increasing consumer satisfaction. Accurate forecasting potentially reduces lost sales and increases on-shelf availability. Other benefits are improved promotional execution, reductions in overstock, improved in-stocks, etc. Next section is dedicated to collaborative production planning, which actually elaborates *production planning* activity of replenishment & inventory phases presented above.

3.3.3 Collaborative production planning

Collaborative production planning (see figure 3.1) is the phase of proposing the positioning in the organization in time and space the activities to fabricate the product.

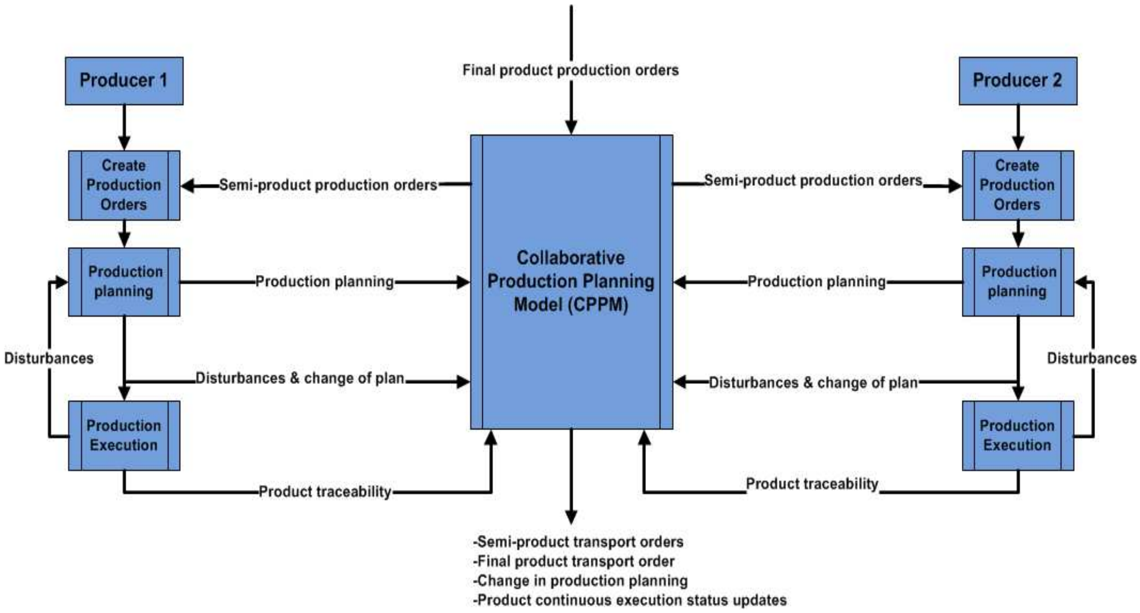

Figure 3.4: *Collaborative production planning*

Single product can be produced by a single producer on a single site or in collaboration of multiple producers distributed across several sites, each producing semi-product(s) of the final product. Assembly of these semi-finished products (ingredients) in a respective order will form final food product. All of these producers run separate production plants with their own planning systems at their sites for preparing their semi-products. In case of single producer, there is a need of coordination for production as it is managed by single entity. However in case of multiple producers, there is a need of collaboration between different planning systems, because if any ingredient not ready at the needed time will delay the production of final product and can entail heavy losses.

As we see the sales forecast and order forecast activities in previous replenishment phase are determined for the final product. These forecasts have direct impact on the demand of the semi-products, so the producer of final product must share this information to other semi-product producers. It will help them manage their inventory according to the need of final product's demand. By aligning the production planning with the agreed forecast, costs can potentially be reduced [Kuo et al., 2014].

For collaboration between multiple producers, *production planning* activity contains a Collaborative Production Planning Model (CPPM) as shown in figure 3.4. CPPM provides the integration of heterogeneous production systems to collaboratively plan and synchronize their production. CPPM performs four things.

- Firstly, CPPM receives final product production orders and generates the semi-product production orders for other concerned producers and it dispatches them to respective producers. CPPM ensures that each producer must receive its production orders of their respective semi-product in the sequence of the assembly of final product that they must be ready according to dead line.

- Secondly, CPPM collaborates production planning of all the individual producers' planning systems.

- Thirdly, if any disturbances occur while any of the semi-product production execution at any of the producer's local site during its fabrication (machine failure, etc.), producer modifies its production plan and coordinates with CPPM. CPPM then synchronizes this information with other producers and final producer to adapt their production planning according to new information.

- Fourthly, as output CPPM provides: semi-product transport orders, final product transport order, change in production planning and product continuous execution status updates at all of their production stages ensuring product visibility throughout the FSC.

This collaboration phase results in improved production resources utilization. A more accurate forecast leads to more efficient production capacity utilization as planning information is more reliable and distributed to every member of FSC having a direct or indirect impact [Kuo et al., 2014].

3.3.4 Collaborative transportation planning

As there are number of producers and retailers involved in FSC, there are number of transporters as well. Nevertheless, transport orders more often require the delivery of the products from one region to another region or even in same region. Single transporter might not be able to cover every region, where producers or retailers are situated. Moreover, single transporter might not have resources to transport all kinds of food products with different constraints. More than one transporter increases the chance of product delivery and price reduction due to competition. Each of the transporters operates their own software system, which performs the transportation planning for its own vehicles according to received transport orders. In that case, there is a need of collaborative transportation planning to generate the delivery plan together involving the transport carriers of all the transporters involved.

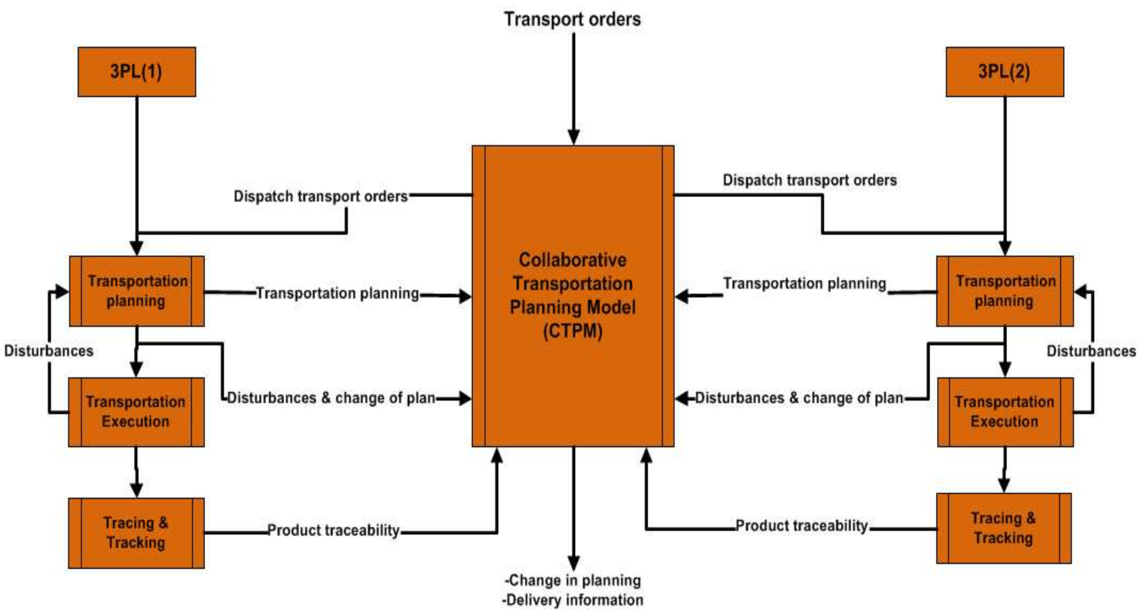

Figure 3.5: *Collaborative transportation planning*

In C-PRIPT, we consider the transportation planning as a collaborative activity to help transporters within FSC to work together to make possible the delivery of products involved. Similar to production planning, here we have a Collaborative Transportation Planning Model (CTPM) as shown in figure 3.5, which performs four things.

- Firstly, CTPM receives the transport order from the producers and finds the effective route from origin to destination of the order.
- Secondly, CTPM sends this route to all of the participating transporters and waits for their proposed planning. Each transporter planning system then propose the planning of the order for the complete or partial route according to their vehicles specified route network, capacity and food products constraints that it can transport.
- Thirdly, when CTPM receives planning from all transporter systems, it chooses the best proposed planning and generate a planning of a complete route for the order. It is possible that this route involves the transshipment from one transporter's vehicle to another transporter's vehicle. In that case a collaborative planning is delivered to customers (producer, retailers) comprising of delivery of a single order by more than one transporters.
- Fourthly, with the use of tracing & tracking technologies, each transporter has to provide up to date delivery status of order to both retailer and producer in order to follow the principle of product visibility throughout FSC. Moreover, if any disturbances occur during delivery, for example vehicle breaks down or traffic jam, then CTPM re-plans the route in coordination with the transportation systems of the concerned transporter. It then communicates this change of planning to its customers.

The detailed objective of this thesis is to design and develop this CTPM. Chapter 4 is dedicated to present such model.

3.3.5 Collaborative production & transportation planning

In the earlier section of collaborative production planning, we explained that many producers produce semi-products and collaborate with each other to produce the final product. These semi-products must be transported between sites of different producers to assemble the final product. Moreover, final product needs to be transported to retailers as well. For that reason, producers need to collaborate with the transporters for the delivery of both semi and final products. This planning of production and transportation are generated collaboratively. Different interaction in this collaboration are showed in the figure 3.6.

When producer generates its production plan for the final product, CPPM generates the list of semi-product production orders. When semi-product production planning, which contains the expected date of their production completion is finalized, CPPM generates *semi-products transport orders* for their delivery and send them to CTPM. CTPM then determines transportation planning and communicate back the *delivery information* of these semi-products to CPPM. According to this delivery, producer proceeds with planning of production of final product and generates *transport orders for final product* delivery to retailer(s) and communicates them to CTPM. Then, CTPM generates the transportation planning for the delivery of final product and communicates that planning back to the producer and retailer for the expected date of delivery. At this stage, we have production planning for semi-products and final products and transportation planning for semi-products and final product. Both production and transportation planning are inter-dependent on each other. Any disturbance in production will cause *change in transportation planning* and disturbance in transportation execution will cause *change in production planning*. For example, if production of any semi-product delays, it can cause delay in production of final product, eventually delaying delivery of final products to retailers.

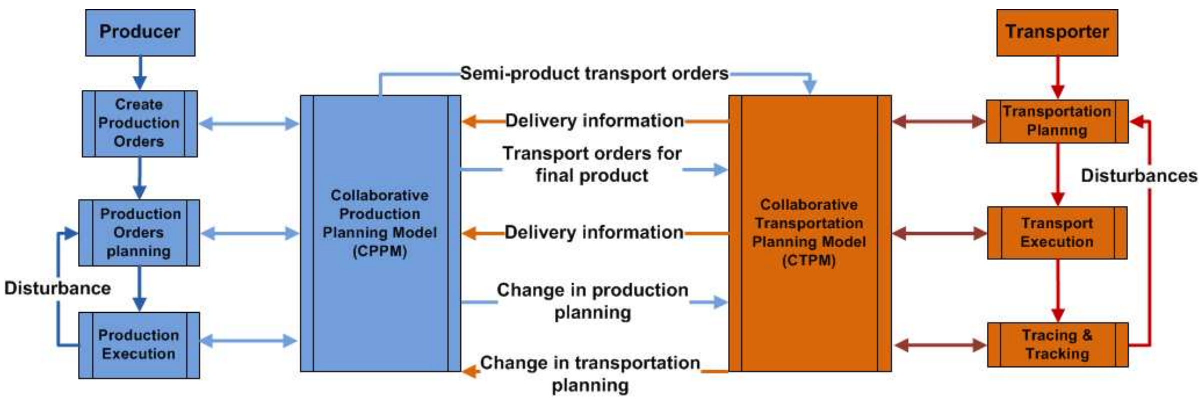

Figure 3.6: *Collaborative production & transportation planning*

All the phases of production planning, transportation planning, inventory and replenishment planning form a complete C-PRIPT, that contains collaborative activities to improve the overall efficiently of FSC. C-PRIPT does not only provide the collaboration within these individual activities but also list down the interactions for the integration of these activities. It is necessary because these activities are inter-related and function in collaboration with each other to make-up a complete FSC. C-PRIPT model insists on the product visibility throughout the FSC with the activities like tracing & traceability for product localization and products status updates to ensure that products are at the right time, at the right place and in right form.

Figure 3.7 illustrates the complete interaction diagram of C-PRIPT model. By summarizing the C-PRIPT model, it globally consists of three main entities of FSC; retailer, producer and transporter. Retailer is responsible for collecting POS data during promotion dates and normal dates and creating sales forecast based on that. Retailer is also responsible for updating its inventory, when products are sold and when it receives shipment from Producer. Producer collects sales forecast from all of its customers (retailers) and performs individual order forecast for each customer. Based on that forecast, it creates shipment orders for the retailer. If product is available in its inventory, it creates transport orders for the delivery; otherwise it launches the production. Beside that it creates global sales forecast on its own from that it creates global demand forecast. It checks whether its inventory can accommodate all of its future demand, if inventory is not sufficient it launches the production considering the product orders created for each retailer. Transporter when receives transport orders from producer, finds the best and economical route to deliver the products.

3.4 Conclusion

Considering many SMEs in FSC, currently the members that make up the food chain run their processes in the absence of information in real time and without a full understanding of the processes that are carried out in LEs. This causes poor planning of operations, the accumulation of inventories and inefficient transportation. Previously proposed collaborative approaches like CPFR and VMI did leverage better forecasting and planning through information sharing, but they were limited to buyer and seller collaboration. With the advent of 3PL logistics companies the new member emerged as a transporter which needed to be included in collaborative process. Additionally these approaches did not consider production planning as a collaborative activity, indeed which involves collaboration of multiple producers, producing several semi-products forming the final product.

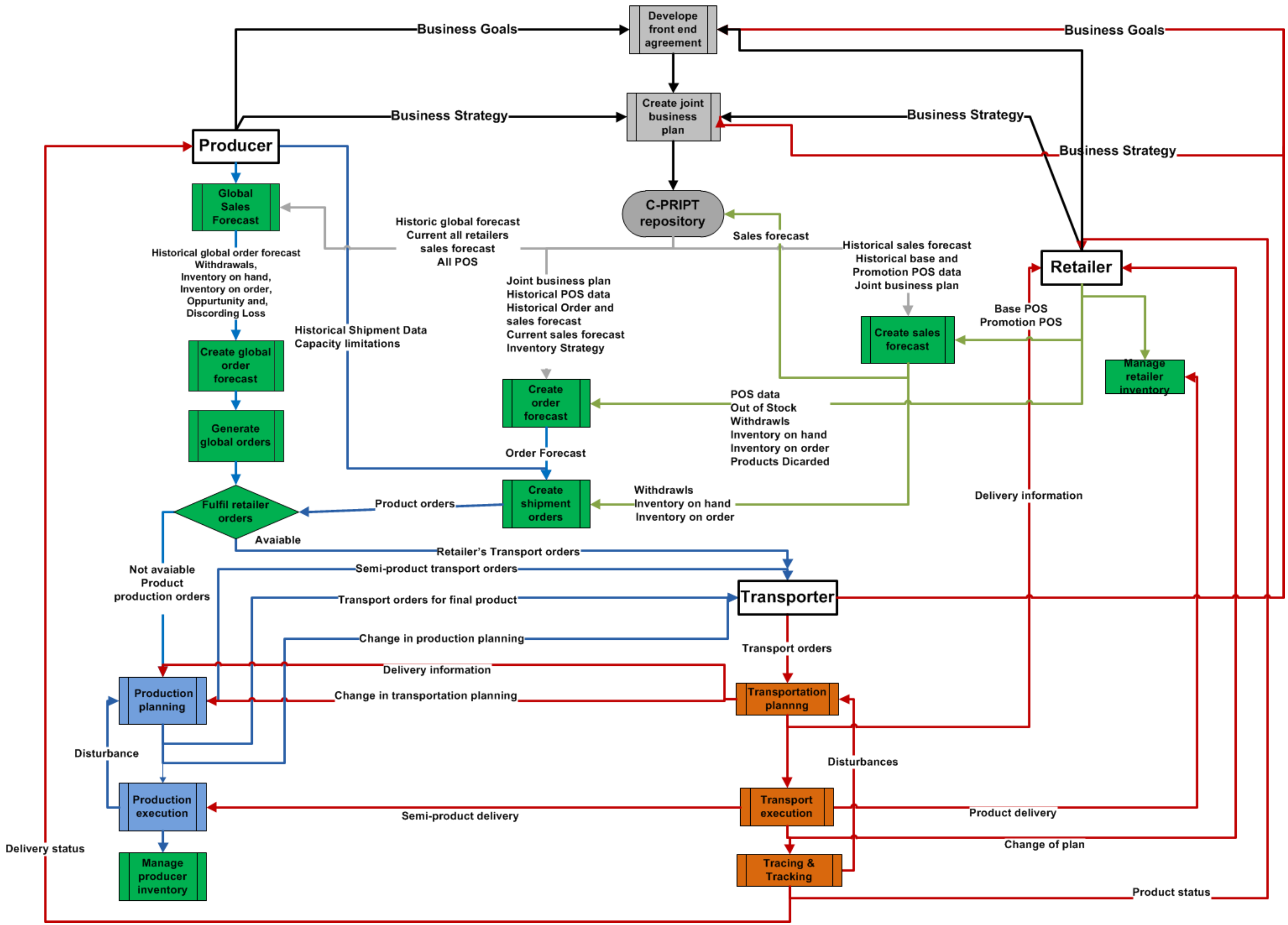

Figure 3.7: *C-PRIPT complete interaction diagram*

Proposed C-PRIPT model will serve as a bridge between SMEs and LEs by proposing minimum and simple collaborative activities and interactions that promote collaboration across the FSC, so that FSC can achieve greater efficiency. Within the context of the model presented in this chapter, our detailed objective is to develop and demonstrate the collaborative transportation planning model and deliver the schedule of delivery orders for food items by interoperating different software systems of multiple transporter and producer actors. Next chapter is dedicated to present this model.

Chapter4

Interoperable transportation planning

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4.1 Introduction

In the previous chapter, we presented a collaborative model C-PRIPT, comprising of collaborative activities of FSC including the transportation. There, we explained the collaborative transportation planning model in more general way. This chapter is dedicated to present its realization.

Collaborative transportation planning involves a good understanding of exchanged information between producers and transporters and between transporters, especially about locations, product constraints, vehicles types, and etc. An issue of interoperability arises, when transporters have to process different transport orders arriving from several customers in different formats and terminologies. Secondly, how transporters will collaborate with each other following different working standards for collaboratively delivering transport orders, which single transporter cannot deliver alone due to its limited operational geographic area. Therefore, there is a need of an interoperable mechanism to transform information in an understandable form. One solution is to let entities work in their own manner, using their own terms, using their local ontologies and let interoperable service utilities (ISU) handle the transformations on the basis of common semantics [Zbib et al., 2012, Karray et al., 2010]. Thus, the schedule of all transport orders has to be achieved by several interoperable scheduling systems. Interoperability to achieve collaborative transportation planning is our concern in the context of this chapter.

In the first section, we describe our transportation problem based on the literature review. Subsequently in the second section, we present the multi-agent SCEP (Supervisor, Customer, Environment and Producer) model that provides generic scheduling algorithm. Third section is dedicated to modelize the SCEP model for transportation domain. In fourth section, we present I-POVES (Interoperable, Path Finder, Order, Vehicle, Environment and Supervisor) model proposed in this thesis for interoperable transportation planning.

4.2 Problem description

Transportation planning problem can be classified into three different groups [Cordeau et al., 2004]. The first group consists of many-to-many problems, in which any location can serve as an origin and a destination at the same time. Second group is of one-to-many-to-one problem. In this problem, commodities are initially available at the depot and are destined to the customer locations; in addition, commodities available at the customers are destined to the depot. Finally, the third group is of one-to-one problems, where each commodity (which can be seen as a request) has one origin and destination. This one-to-one problem is usually called Pickup and Delivery Problem (PDP) in the literature [Parragh et al., 2008].

One can distinguish between three well-known types of PDP [Cordeau et al., 2004]. Single-commodity PDP: where a single type of goods is either picked up or delivered at each node. Two-commodity PDP: where two types of goods are considered and each node may act as both pickup and delivery node. Finally, the n-commodity problem: where multiple types of goods considered for transportation.

PDP can be either static or dynamic [Cordeau et al., 2004]. It is said to be static when all the input data of the problem is known in advance. In a dynamic problem, some of the input data are revealed or updated during the period of time. The dynamic aspect in this problem is called the Dial-a-Ride Problem (DARP) [Berbeglia et al., 2010].

DARP is also categorized as single-vehicle DARP and multi-vehicle DARP [Cordeau and Laporte, 2003]. In single vehicle, a request is served by single vehicle from its origin to destination. In multi-vehicle, a request can be served by more than vehicle. We consider in our work that one transport order can be delivered by multiple vehicles and many transport orders can be delivered by single vehicle.

Generally solutions proposed for DARP propose routing algorithms to construct the vehicle route for number of requests and building the schedules of vehicles accordingly to serve those requests. However, we consider this assumption that by taking into account product future demand in the replenishment phase of C-PRIPT model and transporter's historical knowledge of customer demand, transporters in FSC already determine and fix the itineraries of routes between producer and retailer sites for their vehicles. Although, vehicles travel schedules can be both fixed and flexible. A variant of DARP that involves the characteristics of fixed/flexible route and fixed/flexible schedule is called DRT (Demand Responsive transport) [Cordeau et al., 2004]. DRT is used to define transportation problem for passenger and goods transportation with constraints by sharing the carrier such as taxis, busses, dial-a-ride minibus and trains etc.

As food products are associated with perishability constraints, therefore we investigated the existing related work done for perishable food items within the context of distribution, production & distribution and supply chain design. Doerner et al. [Doerner et al., 2008] study the pickup and delivery problem of blood products where the pickup plan is inter-related to the dispatching policy. There are strict time windows and after a certain time, the product is completely spoiled. Hsu et al. [Hsu et al., 2007] model a food distribution planning problem with stochastic and time-dependent and travel times. In order to solve this problem, they modified and applied the time-oriented nearest-neighbour heuristic. Osvald and Stirn [Osvald and Stirn, 2008] address distribution of fresh vegetables with time-dependent travel times, and propose a tabu search algorithm to solve it. Authors in [Tarantilis and Kiranoudis, 2001] develop an adaptive threshold accepting algorithm for the distribution of fresh milk with a heterogeneous fixed fleet, and develop a list-based threshold accepting algorithm for the distribution of fresh meat in a multi-depot network. Work in [Hsu et al., 2007] considers the randomness of perishable food delivery process, and constructed a stochastic vehicle routing problem with time-windows. Other work on production-distribution of food items is done by [Ahumada and Villalobos, 2011], which considers the perishability as a loss function in the objective function. Authors in [Yu and Nagurney, 2013] propose a model for competitive supply chain design problem including multiple transportation modes. They introduce arc multipliers to incorporate food deterioration and add costs of spoiled food to their objective function. Some more work reviewed on perishable food items are [Chen et al., 2009a, Akkerman et al., 2010, Rong et al., 2011, Farahani et al., 2012, Shukla and Jharkharia, 2013]. Form above presented work, neither of them exclusively considers the perishability constraints of the products. Their focus is only the timely delivery of products, capacity constraints or determining the optimal roots delivery.

Finally for the solution of planning problem, we have considered the traditional operational research methods (heuristics, fuzzy, linear integer, etc.), but these methods are based on global optimization and are used to construct integral transport schedules [Mes et al., 2007]. Firstly, most optimization algorithms require a lot of information in advance. Secondly, global optimization algorithms can be sensitive to information updates: a minor modification in information may have impact on the schedules of many vehicles. Thirdly, the time required for the algorithm may not permit timely response to unexpected events such as equipment failure and the arrival of rush order. Finally, flexible transportation networks requires collaboration of multiple independent transporters in FSC that are working in an autonomous, self-interested way. Therefore, these individual transporters are not ready to share all the information with other transporters, and need to preserve their confidentiality. These approaches are traditionally centralized and hierarchical approaches and are not applicable anymore [Mes et al., 2007].

An alternative that has been proposed within the literature is the multi-agent system (MAS). A MAS is a computerized system composed of multiple interacting intelligent agents within an environment. An agent is itself a computer system that is situated in its environment, and is capable of autonomous action in its environment in order to meet its design objectives. MAS seems to be a promising solution for controlling complex networks, providing more flexibility, reliability, adaptability, confidentiality and re-configurability [Wooldridge and Jennings, 1995].

Some interesting MAS platforms has been realized for transportation planning. Multi-agent based locad consolidation system (MABLCS) [Baykasoglu and Kaplanoglu, 2011] proposes grouping multiple orders together in a vehicle, but transport order agent is bound to accept the proposition from one truck agent. ICOMAS [Sprenger and Mönch, 2011] framework propose decomposing overall transportation problem into sub problems and solve those sub problems on autonomous basis with Ant colony Optimization approach. Cooperation of humans, and intelligent agents for auctioning in transportation logistics is implemented in platform developed by CWI and VOS logistics [Robu et al., 2011]. The LS/AT system [Neagu et al., 2006], is one of the most well-known systems that uses agent techniques (mostly constraint-reasoning type techniques) for dynamic transport optimization. The Magenta system [Skobelev et al., 2007] is another such system, which explores the use of swarm-based optimization techniques in this setting.

By contrast to these systems, the emphasis is not directly on optimization of the planning (though that remains, of course), but negotiation of customers and transporters in distributed, confidential and interoperable manner in order to achieve the best results possible for both the actors is our priority. A rare exception is a SCEP (Supervisor, Customer, Environment, Producer) model [Archimede and Coudert, 2001, Xu et al., 2012]. SCEP is a generic model implemented in RAMSES platform [Coudert et al., 2002] and presents a negotiation between agents based on a distribution of the decisional activities. Customer agent proposes the auction and producer agents bids for the auction. The suggested propositions made by the producer agents may be rejected by the customer agents, if they consider that the proposition can be improved in the future and this improvement is not effected with the arrival of new jobs. The most valuable advantage of SCEP is its flexibility and adaptive nature. SCEP has already been adapted and used with success for production [Archimede and Coudert, 2001] and maintenance scheduling [Coudert et al., 2002]. Hence, we would also like to adapt it for transportation planning.

Based on above presented problem description, we synthesize our collaborative transportation planning problem as follows. Our work lies in one-to-one group called Pickup and Delivery problem (PDP) and dynamic version of PDP is called Dial-a-ride problem (DARP). A variant of DARP that involves, fixed/ flexible route and fixed /flexible schedule is called Demand responsive transport (DRT). DRT is used for passenger and goods transport and our work is related to perishable goods of different types (n-commodity) in food supply chain. To propose the transportation planning, we choose to use multi-agent based generic scheduling model SCEP.

4.3 Multi-agent SCEP model

SCEP (Supervisor, Customer, Environment and Producer) multi-agent model (figure 4.1) is developed for all types of planning activities [Archimede and Coudert, 2001, Xu et al., 2012].

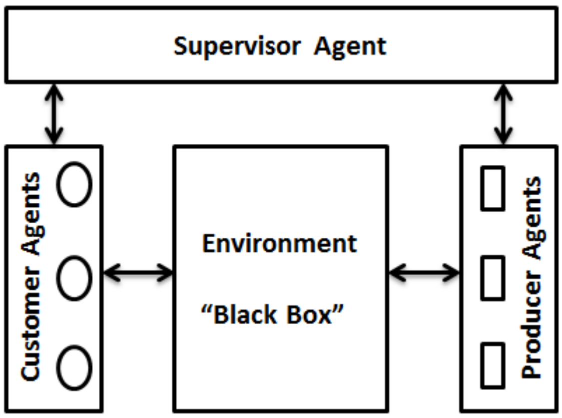


Figure 4.1: *SCEP model*

An activity can be manufacturing or maintenance activity. SCEP model introduces an indirect cooperation between two communities of agents (customer agents called C and producer agents called P), leading to a high level of co-operation. Each customer agent manages one project (manufacturing order, maintenance order...). A project is constituted to a sequence of jobs to realize and each job precises, which activity needs to be realized. Each producer agent manages one resource (machine, workshop, human and so on) of the organization. Each resource can be realize one or more than one activity and same activity can be realized be one or more than one resource. However realization of each activity is insured by minimum of one resource. The cooperation between customer and producer agents is performed synchronically through the background environment agent E. All planning functioning is controlled by the supervisor agent S.

The supervisor agent provides functions of creating the agent society and initializing the environment. Then, supervisor agent triggers the cycle of cooperation process by activating the customer agents and producer agents. Customer agents propose the Wished Position (WP) in the form of auction for each of the job related to routing (sequence of jobs of the project) followed by its intervention domain and send them to the environment. In response, producer agents bids Potential Position (PP) and Effective Position (EP) for each job that it can execute. The EP results from the scheduling of all the jobs associated with the positions collected from the environment. The PP results from the scheduling of one job associated with a position collected from the environment. PP and EP facilitate the customer agent to take the decision on all the available resources that can do the job. If the WP of one job is the same as the EP and PP, customer agent will make the confirmation and fix the Confirmed Position (CP) for the job. The CP is the final position after all the scheduling process. When entire jobs are confirmed, there are no WP from customer agents anymore. Supervisor agent then terminates the environment, customer and producer agents. The whole scheduling process is finished.

Now we are going to investigate use of SCEP for transportation planning. Next section is dedicated to analogize SCEP concepts for transportation domain.

4.4 Modelization of SCEP for transportation domain

As SCEP model is used for production and maintenance scheduling, in order to use it for transportation planning, we are going to inspect SCEP concepts for transportation domain. These concepts are as follows:

- **Activity:** Concept of activity for production is defined as one of the operations needed to manufacture the product like turning, milling and so on. [Archimede and Coudert, 2001]. On the other hand in transportation domain, activities can be seen as nonstop displacement from one location to another location.

- **Resource:** Resources like machines do not displace and are fixed in any factory and often work automatically. On the contrary, transport carriers are moving and need human driver(s) to displace them from one point to another. There is a need for definition of transport carriers.

- **Project:** SCEP is capable of understanding the production and maintenance orders (projects). It does not contain the formalism to comprehend transportation orders.

- **Routing:** In SCEP, routing is the fixed sequence of activities required to manufacture a product. When customer places the order, SCEP proposes a schedule based on that fixed sequences. However, for transportation planning, routing cannot be fixed, it is dynamic. There might be several routes possible from pickup and delivery location of a transport order.

- **Customer agent:** Customer agent manages the manufacturing or maintenance project in SCEP. For transportation, customer agent needs to manage a transport order. In the literature, for transportation planning, usually the agent name used for managing transport order is called order agent [Baykasoglu and Kaplanoglu, 2011].

- **Producer agent:** Producer agent manages the resources like machine, human, but for transportation, they need to manage transport carriers (vehicles, trains, planes etc.). In the literature, agent name used is vehicle or truck agent, which manages transport carriers [Baykasoglu and Kaplanoglu, 2011].

- **Job, Environment and Supervisor:** Job, Environment and Supervisor will be the same in transportation domain. However, they all need to be modified in order to understand formalism for transportation domain.

Above, we presented the analogies for SCEP for transportation domain. Now we present some other requirements that are not present in SCEP, but necessary for transportation.

- **Definition of transport network :** Transportation planning needs the definition of geographical network. SCEP does not have any mechanism to define such network.

- **Food product constraints:** SCEP does not consider any product constraints during planning. Although, considering our context of food products, we need to take into account the food product constrains while proposing transportation planning.

- **Pollution & cost minimization:** In SCEP, it is assumed that one machine is capable of performing one operation at one time. On the contrary for transportation, in order to minimize pollution (carbon emission) and minimize cost, transport carriers must group more than one transport orders in the same carrier and transport them at the same time. For that purpose, SCEP's planning rules needs to be modified to add the grouping functionality.

- **Interoperability:** Finally the other important issue is the interoperability to collaborate with other planning systems. SCEP has a distributed nature and can collaborate with other SCEP, following the same standards and terminologies. However it is not interoperable in heterogeneous environment with other planning systems. For transportation, multiple transporter and customer systems need to interoperate their systems to yield the collaborative transportation planning.

By taking into account above limitations of modelization of SCEP for transportation and issues (transport network, food product constraints, pollution & cost minimization and interoperability), we deduce that SCEP model is interesting but it is necessary to extend its functionality. Therefore, we modified SCEP model and transform in to a new generic model I-POVES for transportation. We present in the next section this I-POVES model.

4.5 Multi-agent I-POVES model

I-POVES is a multi-agent model developed for collaborative transportation planning activities and it is inherited from SCEP multi-agent model [Archimede and Coudert, 2001]. I-POVES is illustrated in figure 4.2. In I-POVES, we retain the supervisor agent and environment from SCEP model, but associate customer agent with order agent and producer agent with vehicle agent to represent transportation domain. These agents have been encapsulated within interoperable service utiliies (ISU) Virtual customer (VC) and Virtual transporter (VT) respectively. VC handle the interoperability between customer enterprise and I-POVES. Similarly VT handle the interoperability between transporter enterprise and I-POVES. To provide dynamic routing, we added a new agent called Path Finder agent. I-POVES is also appended with a global ontology and each component in I-POVES dialogue with each other using the standard terms expressed in that ontology.

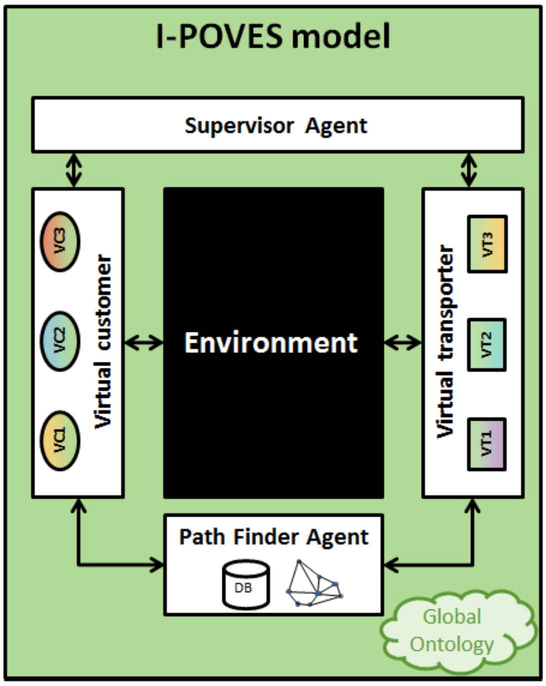


Figure 4.2: *I-POVES model*

We first present the definition of concepts used in our transportation planning problem and then explain I-POVES components and functioning respectively.

4.5.1 Definitions for transportation terminologies

In order to explain the proposed I-POVES model, it is necessary to explain some concepts used by it.

4.5.1.1 Activity

An activity is a nonstop travel (segment of road) from the loading location to the unloading location. It is to be noted that the loading and unloading locations are not necessary the origin and destination of a transporter order respectively. Activity may be a segment of road from the entire route between origin and destination of the transporter order. Activity also contains the food product type (Refrigerated, Frozen, etc.) that vehicle is equipped to transport. Therefore, an activity contain three parameters (Origin, Destination, ProductType), for example

(Paris, Bordeaux, TypeFoodFrozen). Food product type belongs to the food type tree as shown in figure 4.3. This tree is explained later.

4.5.1.2 Task

Task is simply a request for the execution of an activity. One task can be associated to only one activity. However for one activity many requests of tasks are possible. Task represents the same concept as a job in SCEP.

4.5.1.3 Food perishability constraints and grouping

Food product constraints are respected according to the type of food that is being transported. Type of food products are organized in a food product tree as shown in figure 4.3. If a vehicle propose an activity to transport food type of "TypeFoodFrozen" (see in figure 4.3), it can transport all types of frozen products, means all of its subcategories ("TypeFoodFrozenMeat", "TypeFoodFrozen" SeaFood and so on). Therefore, transport orders demanding different frozen products can be grouped in to this vehicle. However, if it proposes only to transport "TypeFoodFrozenMeat", means it can transport only frozen meat, nothing else. This product tree is implemented in the form of global ontology, which is presented later in this chapter.

4.5.1.4 Vehicle definition

Vehicle definition consists in set of some fixed and variable parameters. Fixed parameters are Resource, Location, Capacity and Activities. Resource represents the vehicle id, Location represents starting location of vehicle (for example any warehouse), Capacity represents vehicle's carrying capacity of products. Finally, Activities represent the list of activities assigned to one vehicle.

Variable parameters for vehicle are Availability, Duration, Coefficient, Maximum waiting time (MWT) and Schedule. Avail means, whether vehicle is available for travel or not. Duration represents the number of working hours for that vehicle. Coefficient defines the vehicle's ability to perform one activity. If it is equal to 1, it means the transport duration is covered in estimated standard time. If it is more than one for example 1.5 the duration will be 50% more than the estimated duration. MWT and schedule depend on the planning mode of I-POVES. If the mode is 'Fixed departure', then the planning will be calculated based on the fixed schedule of vehicles. If the mode is 'Demand responsive', the MWT parameter is set for each vehicle to help group multiple transport orders.

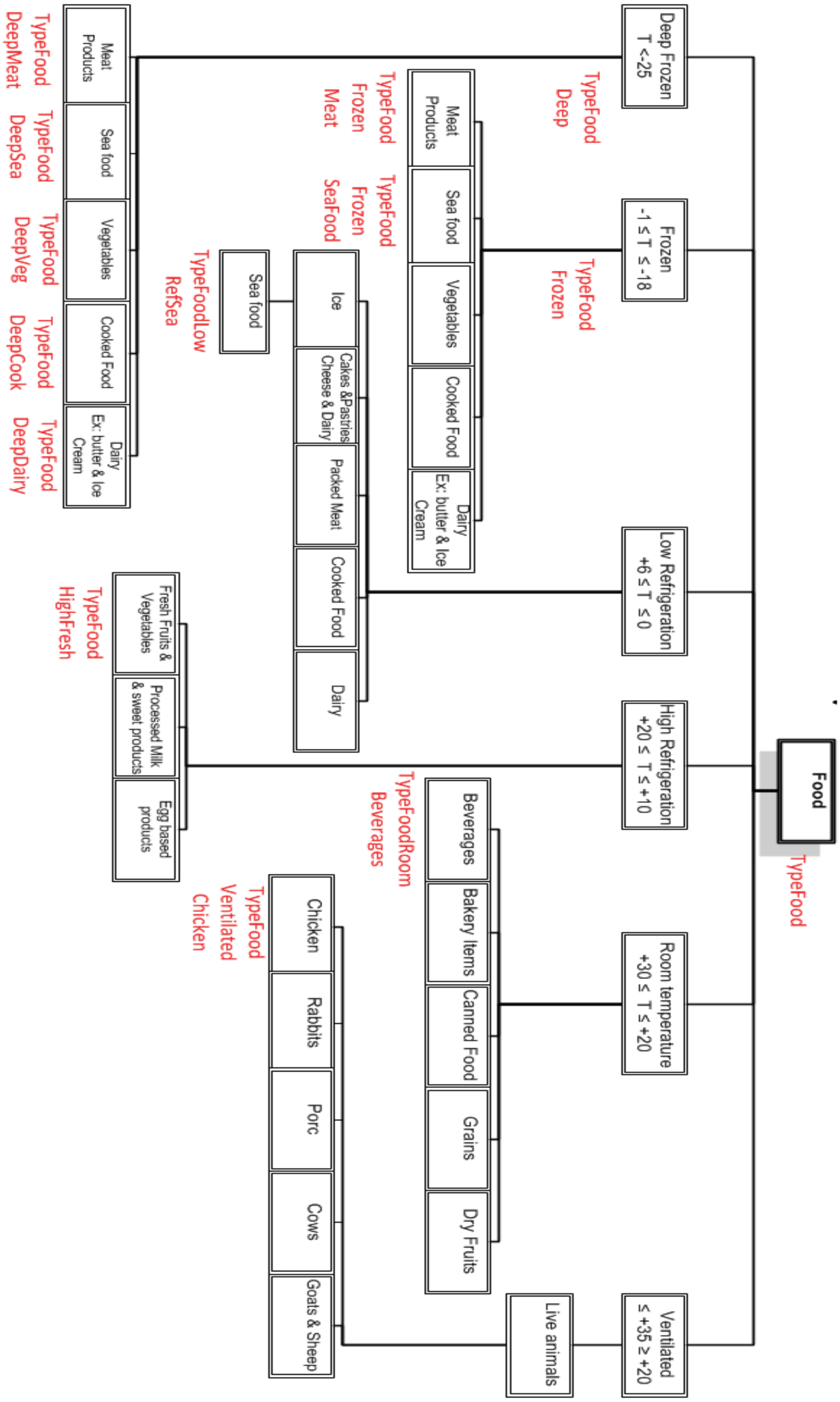


Figure 4.3: *Food product type hierarchy tree*

4.5.1.5 Transport network

Transport network is represented as a directed graph TN(N, E), where N is a set of nodes and E is a set of arcs. Transport network is formed by connecting all the activities performed by vehicles. Each arc in the graph represents an activity. A node represents the location, which may be either a start or destination point of the goods transfer. Each node $V_i \epsilon$ N is associated with a pair (x_i, y_i), where x_i, and y_i are coordinates on the map. Each arc $E_i \epsilon$ E is described by standard time period for traversing along. However this duration depends on vehicle's coefficient.

4.5.1.6 Transport orders

Transport orders are represented in 10-tuple (C, O, OB, P, PT, PL, DL, PT, DT, PQ). C is the customer id, O represents transport order number. OB represents the objective function describing the orders delivery for example: early, less costly, etc. P is the product name, PT is the product type. PL is the pickup location, DL is delivery location. PT and DT represent the pickup and delivery times. PQ represents the product quantity.

After describing the basic concepts, now we present the multi-agent structure of I-POVES model.

4.5.2 I-POVES components

I-POVES components are Virtual Customer, Virtual transporter, Path finder agent, Environment, Supervisor and Global ontology. We describe each of them one by one (see figure 4.2).

4.5.2.1 Virtual Customer (VC)

VC represents an ISU that integrates customer systems (producer enterprise in FSC) with I-POVES. Each producer enterprise has its unique ISU (VC) to connect with I-POVES. VC receives and manages transport orders from producer enterprise in the form of local ontology terminologies and translates them into global ontology terminologies. For translation, VC comprises of alignment of concepts between them on common semantics.VC interacts with the producer system only in the start and end of the planning process (figure 4.4). VC creates an order agent and associates with it a transport order. Order agent is a cognitive agent with knowledge of transport order. Order agent is responsible for following the objective associated with transport orders during planning. It possesses the reasoning of auction to propose Wished Position for each task and choose the best among the positions (Potential and Effective Positions) it receives during planning. Order agent functions on the terminologies of global ontology.

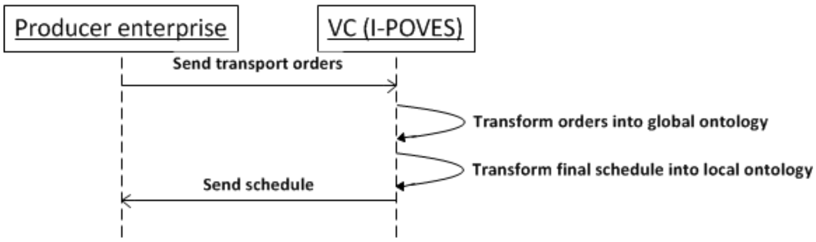


Figure 4.4: *Interaction between producer enterprise and I-POVES*

4.5.2.2 Vehicle Transporter (VT)

Similar to VC, I-POVES also has VT (see figure 4.2) as ISU for transporters. Each transporter system has its own VT to connect with I-POVES. It matches and translates the transporter local ontology terminologies to global ontology's terminologies. VT manages set of transport carriers (vehicles, trains, planes etc.) for transport enterprise. VT also creates and associates one vehicle agent to one vehicle of transporter. Similar to order agent, vehicle agent is also cognitive and functions on the terminologies of global ontology. It possesses the vehicle information and propose Potential Position (PP) and Effective Position (EP) corresponding to Wished Position (WP) in response to the auction through the environment.

As transporter enterprises operate their own planning systems, vehicle agents need to collect positions (PP and EP) from their systems in interoperable manner through VT. So, there is continuous interaction between I-POVES and transporter system. We present now, how VT can acquire PP and EP from transporter enterprises. There are actually two types of VT in I-POVES.

1. *VT between two I-POVES systems :* This type of ISU is for transporter enterprise, without their own planning systems. In that case they can use I-POVES as their local planning system and VT just do the translation of local and global ontology terminologies. VT retrieves the tasks from environment with Wished Position. These tasks are represented in the form of global ontology. VT transforms them and sends them into the format of local ontologies to respective transporter. When transporter I-POVES finishes its planning, VT sends back to the environment Potential Position and Effective Position after transformation from transporter's local ontology

to global ontology. Interaction between VT and transporter system continue until all the tasks of all the transport orders are confirmed. This interaction is shown in figure 4.5.

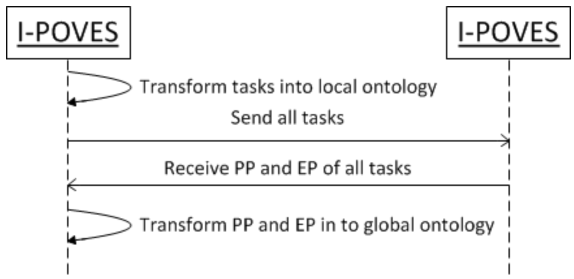
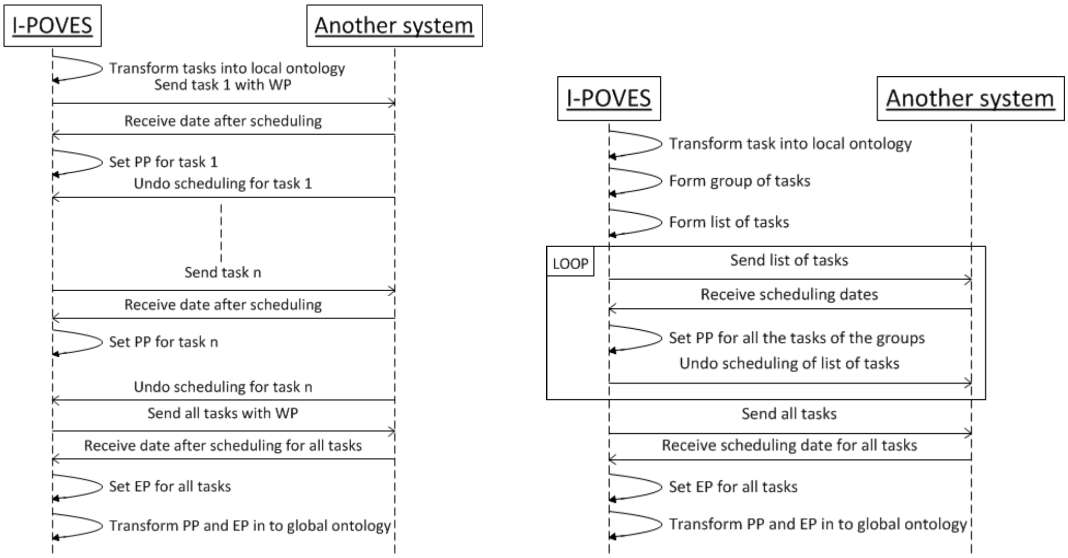


Figure 4.5: *Acquiring planning positions between two I-POVES systems*

2. *VT between I-POVES and another system :* This type of ISU is for transporters with their own planning systems. Therefore, in addition to the translation of terminologies between ontologies, VC also have to retrieve the planning results from another transportation system according to the functioning of I-POVES. Other transporter planning system proposes only final confirmed position after scheduling considering all the tasks. These positions correspond to EP of I-POVES model. External transporter planning system does not contain the notion of Potential Position. However, I-POVES planning mechanism functions on both Potential Position and Effective Position. There are two solutions (a) and (b) thought to achieve PP.

   In solution (a), VT sends one task to transporter system, get the planning, set the Potential Position for that task and then send request to transporter system to undo that planning. This functioning is illustrated in figure 4.6a. VT repeats this process for all the tasks one by one. When Potential Position is set for all the tasks, then VT send all the tasks to transporter system and receive the planning and set the EP for all the tasks. VT needs to repeat the process in each cycle until all the tasks are "Validated". This process is quite simple, but much time and resource consuming.

   In solution (b) (illustrated in figure 4.6b), VT first forms different groups of tasks, where each group contains the tasks with the same origin, destination and type of food product and have identical or nearby Wished Position. When these groups are formed, it takes a single task (as a representative for that group) from each of the groups and forms a list of these heterogeneous tasks. This list does not contain tasks from groups having similar origin or similar destination. It forms several lists in the same way until it covers all the groups. VT then sends each list to transporter system one at a time for planning. When transporter system finishes planning of all the tasks in the list, it sends dates to VT. VT sets Potential Position of all the tasks of a group from their representative task and sends request to transporter system to undo or delete the planning of all the tasks of the list. VT repeats the process for all the lists one by one. Finally, VT sends all the tasks together to transporter system to get Effective Position. This process is executed in each cycle, until all the tasks are validated. Solution (b) is less time and resource consuming than (a), but unlike it delivers approximate results.



(a) Between I-POVES (b) Between I-POVES and another systems

Figure 4.6: *Solutions for acquiring positions between I-POVES and another system*

These ISU (both VC, VT) consist within the alignment of concepts of local and global ontology to perform the translation. Alignment implemented here is based on the work of [Karray et al., 2010]. This alignment is based on finding correspondence between the concepts. To accomplish this correspondence, we consider associating each component (classes, data property, object property, etc.) annotations in the form of keywords. Each component therefore contains a number of keywords noted NOK. For a class C1 which contains number of keywords NOK1 in the ontology O1. There is another class C1 which also contains number of keywords NOK2 in the ontology O2. Alignment algorithm consists of counting the similar number of keywords NOS between two classes. We consider NOK1 is equal to NOK2, if NOS is superior to 60% of the total number of keywords; in that case C1 is equal to

C2. In another case, if NOK1 > NOK2, then NOS must be superior to half of the NOK1, therefore C1 is equivalent to C2, otherwise if NOK1< NOK2, then NOS must be superior to the half of the keywords of NOK2, then we can say that C1 is equivalent C2.

4.5.2.3 Path Finder agent

Path Finder is the new agent introduced in I-POVES to determine the dynamic routing for transport orders. Path finder receives vehicle and activities information from transporter enterprises through vehicle agents. Based on that information, it constructs a complete network graph comprises of geographical locations associated with the activities. Each arc in the graph is associated to minimum of one activity. One arc can be linked with more than one activity, when these activities propose the distribution of different food product type. Each arc is performed by minimum of one vehicle. Path finder updates this network graph each time with the information received from vehicle agents. In order to construct the network graph, we used adjacency table (adjacency list) data structure to access the node from another node. Because the adjacency-list representation provides a compact way to represent sparse graphs choice [Thomas et al., 2009]. Figure 4.7 shows the basic structure of the transport network. A vehicle's existence is meaningful to Path finder as long as the vehicle is assigned to a transport activity, which means we must also maintain such relationship between these two entities.

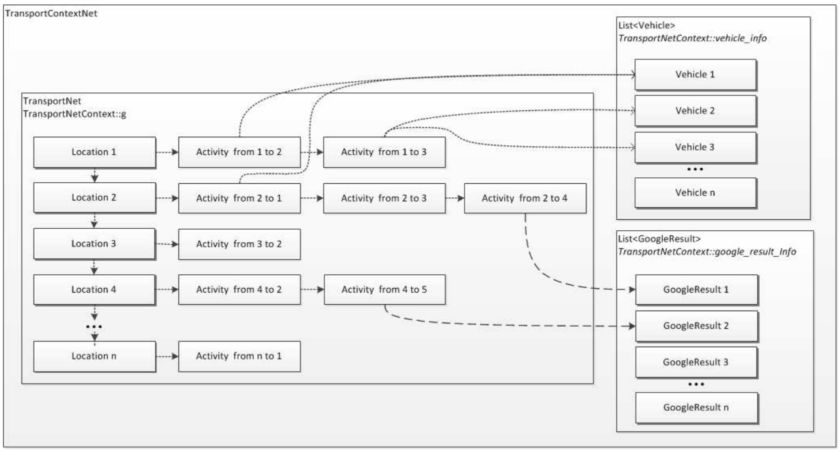


Figure 4.7: *Transport net context internal data structure design*

Path finder uses real geographic data by querying Google Maps through its API (Application programming interface) to estimate the time and distance for each arc in the network. Path Finder do not query these data in real-time, instead, it updates this information in certain time duration. Our transport network is a directed graph. So for finding the route, we considered very popular algorithms Dijkstra and A* algorithm for the best path and implemented both of them.

Before starting the scheduling process, all order agents are invited by the supervisor agent to contact the path finder agent in order to obtain their possible traveling routes. Orders arriving from customers provide minimum of three basic things: Origin, destination and the type of product. Between origin and destination there are several basic activities possible that are proposed by transporter vehicles. Based on transportation network information and vehicles related to activities between locations stored in the database, Path Finder agent elaborates for the managed transport order the traveling route consisting of a set of sequential activities necessary for a transport order. We illustrate the graphical representation of the path finder network on a case study in next chapter 5.

4.5.2.4 Environment

The cooperation between order agents and vehicle agents is performed synchronically through the background environment. It contains all the tasks that are to be planned. At the start of planning, task is in "Free" state, the resolution process is to change it to "Validated" state. Task in "Free" state means, it is simply associated with an activity and it does not have a definite position (that is to say that its start date and end date are indeterminate and no vehicle is assigned to it). A task is in "Validated" state means, it has a definite and unchanging position (start and end dates are specified and a vehicle has been allocated to it). The objective of the system is to move all the tasks from "Free" state to "Validated" state based on objective assigned to its order agent.

4.5.2.5 Supervisor

Supervisor agent activates the I-POVES components. It controls the access to the environment and information passing through I-POVES. It also has the role of transmitting the information demanded by one component from others. In general, supervisor controls the process of resolution of planning.

4.5.2.6 Global ontology

Global ontology lies in the internal part of the I-POVES (see figure 4.2) consisting of terminologies, used by all the components in I-POVES. Global ontology has consistent and coherent information. Figure 5.14 presents an example of a global ontology. All the components I-POVES dialogue with each other using terms expressed it. We explain it in detail its concepts in the next chapter with the application of I-POVES.

Figure 4.8: *Example of Global ontology*

In order to interoperate, we assume that each producer and transporter enterprise possess its own local ontology that models its working domain and on which its system functions. Global ontology provides the federation of concepts of producer and transporter ontologies. Local ontologies are subjected to evolve. This evolution will cause the enrichment of these local ontologies, also forcing the enrichment of global ontology at the same time in order to continue keeping the compliance. The use of local and global ontologies provides liberty to producers and transporters to work on their own standards without bothering everybody else's.

Next section is dedicated to present the overall functioning of the I-POVES model.

4.5.3 Functioning

The global functioning of I-POVES model is expressed in a sequence diagram shown in figure 4.10. Before the beginning of the planning process, supervisor agent first creates and initializes the agent path finder and ISU (VC and VT) and takes control of synchronizing the access of different agents to the environment. Afterwards planning process proceeds the following steps.

Step 1. Interoperating with transporter enterprise:
Virtual transporter VT receives the transporter vehicle and network information and associated routes consisting of activities from transporter enterprise (figure 4.9) in the form of its local ontology. VT also creates and activates the vehicle agents and associates one vehicle agent with one vehicle of transporter.

Step 2. Transformation of transport information into global ontology:
VT transforms transporter information into global ontology based on the alignment embedded in it and then sends it to the path finder agent. Path finder agent then updates its local database with that information. It constructs a large transport network combining the different zones operated by transporters and determines the estimated duration and distance for each activity in the network, in order to determine up to date best path for transport orders.

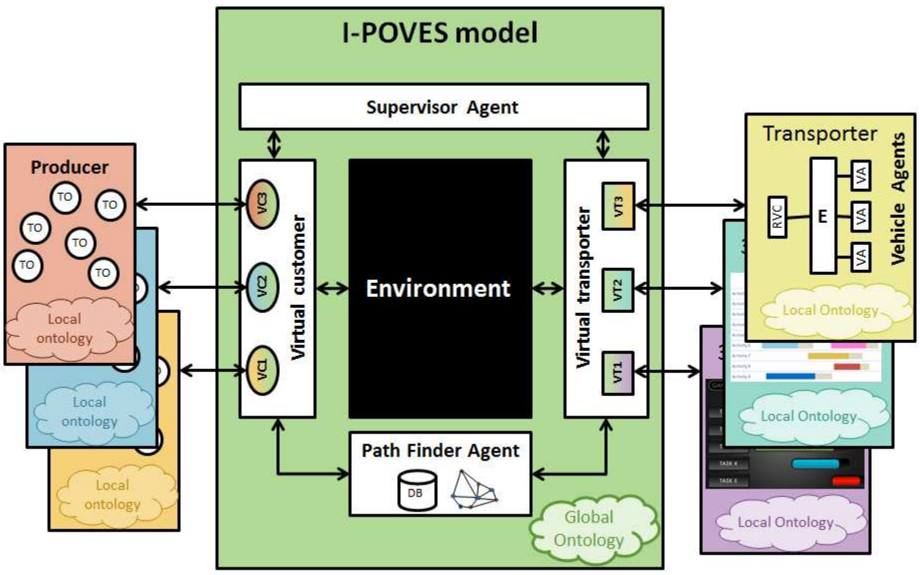


Figure 4.9: *I-POVES with producer and transporter enterprise*

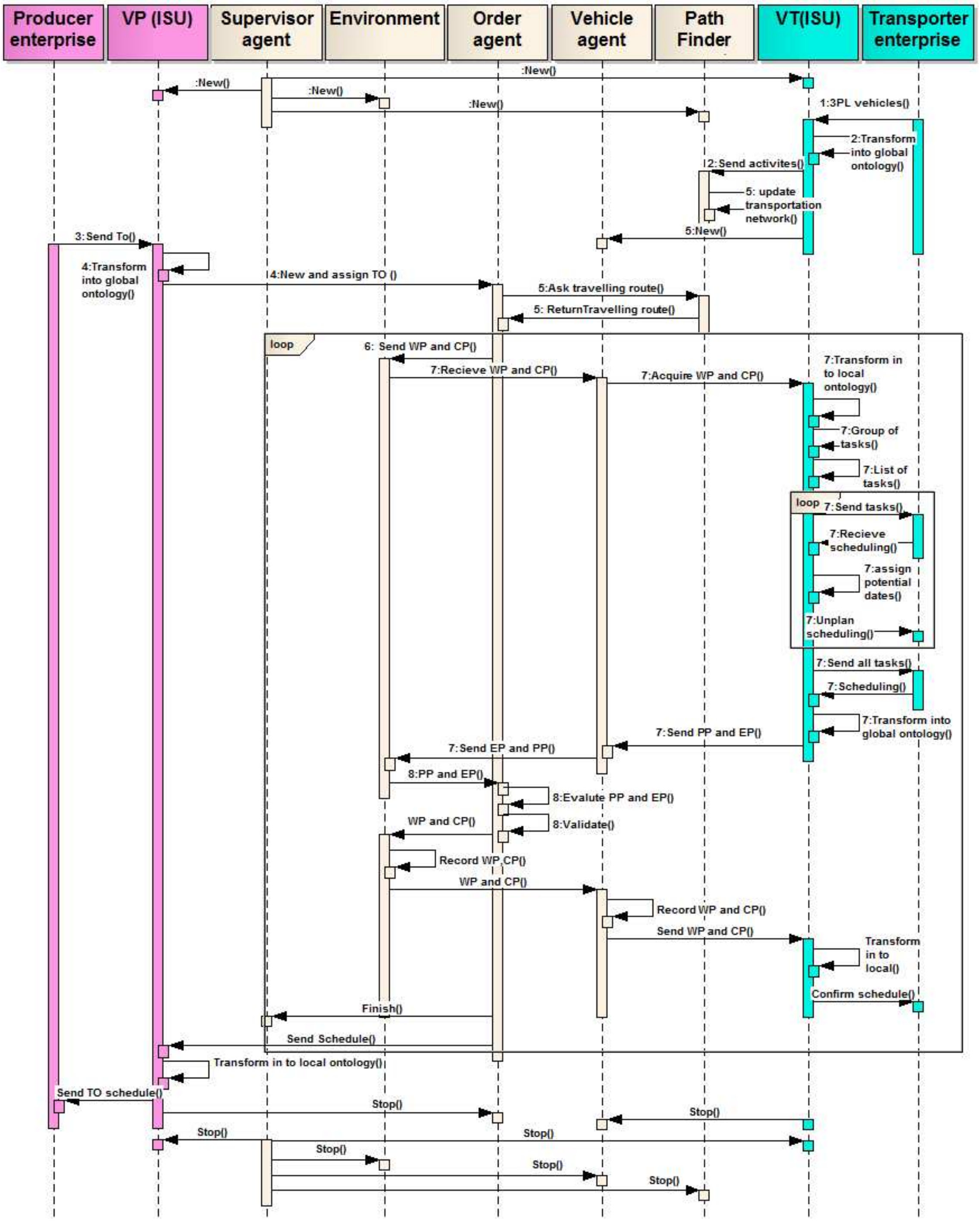


Figure 4.10: *Sequence diagram I-POVES functioning*

Step 3. Interoperating with producer enterprise:
Virtual Customer (VC) receives the transport orders from producer enterprise (figure 4.9) in the form of its local ontology. VC creates and initializes the order agents and associate one order agent to one transport order. Number of order agents will be equal to number of transport orders.

Step 4. Transformation of transport orders into global ontology:
VC transforms transport orders into the format of global ontology based on the alignment embedded in it.

Step 5. Finding the route for transport orders by path finder agent:
All order agents are then invited by the supervisor agent to contact the path finder agent in order to obtain their possible traveling routes from their pickup to delivery locations. Based on transportation network graph, activities between cities stored in its database, path finder agent elaborates for the managed transport order the traveling route (routing). This routing is a sub-graph of the overall transportation network graph. For order, these are the sequence of tasks, where each task corresponds to an activity achieved by transporter vehicle(s).

Step 6. (Scheduling phase 1) start of auction process by the determination of Wished Position (WP) by order agent:
Process of negotiation between order and vehicle agents is based on the notion of auction mechanism (figure 4.11). Each order agent plans at the earliest all of its tasks with infinite capacity (that is to say without worrying about the actual vehicles capacities and availability). For each task, the auction specifies Wished Position (WP). WP consists of three parameters: 1.required activity, 2. Wished Start Date (WSD), Wished End Date (SED), where WSD is the earliest date of departure and WED is the WSD+ estimated duration of the activity (recovered from the database of path finder) and 3. Type of food product for delivery. Order agent sends these tasks with their WP to the environment for auction. At this stage, all tasks in the environment are in "Free" state.

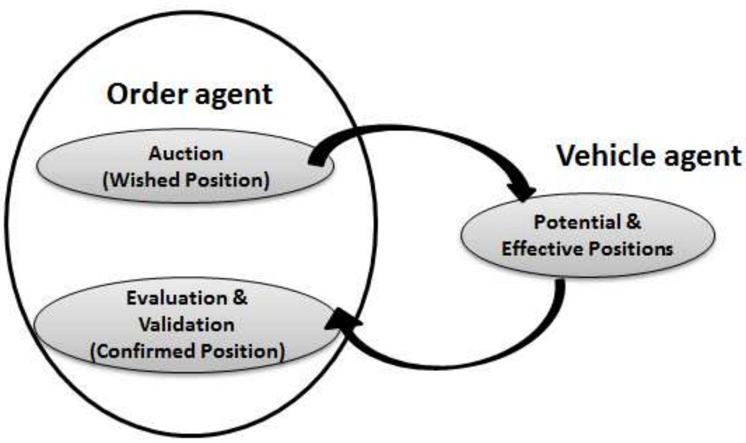
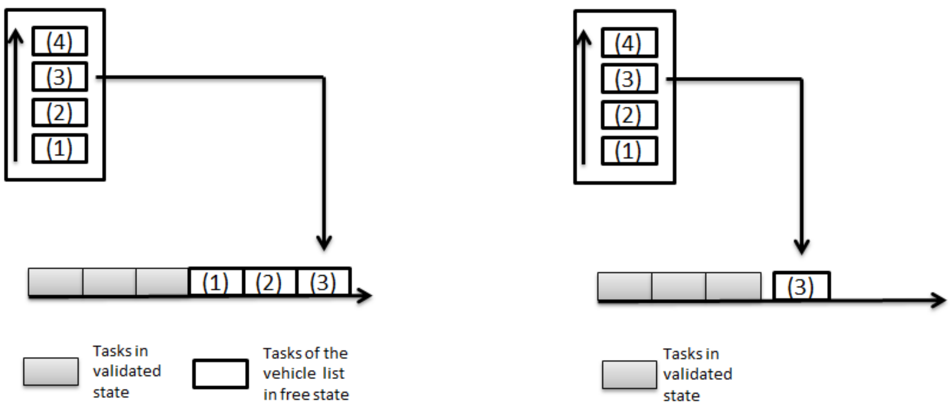


Figure 4.11: *Representation of auction between order and vehicle agents*

Step 7: (Scheduling phase 2) vehicle agents proposes the Potential and Effective Positions (PP and EP):

When actions of order agents are finished, supervisor agent then invites vehicle agents. Vehicle agents come and "read" in the environment the information about the tasks. Each vehicle agent selects the tasks corresponding to its activity, determines its "adjusted" duration according to its coefficient (coefficient of speed * estimated duration of the activity) and evaluates the cost of its realization (cost ratio * adjusted duration). It arranges these tasks in a waiting list sorted according to a priority rule (order delivery date, etc.) and proposes schedule at the earliest with vehicle's finite capacity. Therefore a start date and end date are determined for each task.

For each task selected from the priority list, a vehicle agent bids two positions for the auction: Effective Position and Potential Position. EP results from the scheduling of all the tasks collected from the environment for an activity. It is evaluated in supposition that all tasks in the priority list are realized and only by this vehicle. The PP results from the scheduling of only one task for an activity collected from the environment. EP and PP are illustrated in figure 4.12a and 4.12b respectively.



(a) *Example of effective position* (b) *Example of potential position*

Figure 4.12: *Planning of potential and effective positions*

Therefore for each task, positions bid by a vehicle agent has an EP (Effective Start Date (ESD) & Effective end date (EED)) and a PP (Potential Start Date (PSD) & Potential End Date (PED)) and the cost of each proposal. When all vehicles agents have completed their cycle, they come and "write" to the environment their proposals.

Step 8: (Scheduling phase 3) Evaluation and validation of the positions by the order agents:

Afterwards supervisor agent activates order agents. Each order agent comes and reads the positions in the environment and starts the evaluation and validation process.

The process of evaluation is to seek the best effective and potential position among the positions proposed by the vehicle agents. That is to say, proposals that are most likely to reach the objective assigned to the order agent. The objective of the evaluation process of positions is to determine the best potential and effective positions for a task from all the potential and effective positions submitted for a task. The criteria used by an order agent to evaluate positions are driven by the objectives set to the agent. These objectives can be "early" delivery or "less costly" delivery, or with the possibility to give more or less emphasis on one or the other [Coudert, 2000]. From the best potential position and the best effective position for a task, the validation procedure can be commenced.

The process of validation consists in comparing the best effective and potential positions with the wished position proposed to determine whether the task can be "Validated" directly or it is worth waiting for an improvement in proposals in the subsequent cycles [Coudert, 2000]. There are two possibilities: either the task is validated, if the order agent believes that effective position cannot be improved further. Otherwise a new auction is launched in the environment, if order agent believes that effective position likely to become better in subsequent cycles. The comparison is done using the following information:

- Auction:
  - Wished Start Date (WSD)
  - Wished End Date (WED)
- Best effective position:
  - Effective Start Date (ESD)
  - Effective End Date (EED)
- Best potential position:
  - Potential Start Date (PSD)
  - Potential End Date (PED)

The validation algorithm is given in the following figure 4.13.

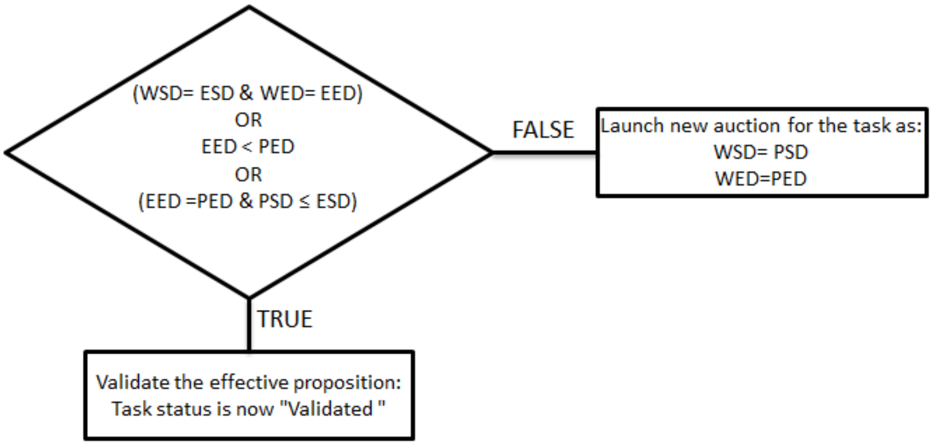


Figure 4.13: *Algorithm for the validation of task by order agent*

Thus, for a task, an order agent may accept directly a position if best effective position is identical to the wished position. The negotiation process is then terminated for this task and its status will change from "Free" to "Validated". An auction proposal can also be directly accepted, if the best potential and best effective positions are identical. In this case, order agent has no choice but to validate. However, if the effective position does not match the wished position and the potential position is better than the effective (that is to say, it ends earlier or both have same starting dates but the potential position takes less time), then order agent takes the risk to wait until the potential position becomes equal to effective position (or close to) in subsequent cycles. A new auction is then launched for this task on the basis of potential position and the state of this task remains "Free".

The objective of evaluation and validation processes are therefore to select the vehicles that offer the best compromising solution between minimizing the costs and respecting the time constraints. The limitations of this method come from its "myopia". The convergence of the model in the resolution process can be very slow, if in each cycle only single task is validated. Following these observations, model provides the process of global validation [Coudert, 2000], which provides better visibility in taking decisions.

When all orders agents have completed their evaluation and validation processes, a contract is made with vehicles that have been selected to perform the tasks. These tasks are then passed to the "Validated" state and have now the confirmed position (CP) (Confirmed Start Sate and (CSD) Confirmed End Date (CED)). A task validated by an order agent cannot be altered. A new cycle is then initiated for the tasks in "Free" state. The cycle between the activation of order agents and vehicle agents is repeated until the CP of all the tasks is fixed. When all tasks are confirmed, there are no WP from order agents anymore. VC transforms the delivery plan into local ontology of producer and sends it to the producer enterprise. VC then terminates the order agent. Similarly, VT terminates the vehicle agent and sends back the last result to transporter system. Supervisor agent then terminates the environment, VC, VT and path finder agent. The whole scheduling process is finished.

4.6 conclusion

In this chapter, we presented an ontology based interoperable model I-POVES (Interoperable Path Finder, Order, Vehicle, Environment and Supervisor) for collaborative transportation planning for the delivery of food products. I-POVES inherits the planning algorithm from the SCEP model. In I-POVES, transport orders arrive from producers and vehicles are managed by the transporters working in a food supply chain. Each of them operating their own systems and working on their own standards. We consider each producer and transporter system possess their own local ontologies and functions using terms described in it. In order to achieve interoperability, I-POVES also contains a global ontology on which I-POVES functions. To handle the transformation of concepts and planning with transportation systems, I-POVES is integrated with interoperable service utilities (ISU), virtual customer for each producer and virtual transporter for each transporter system.

In I-POVES, firstly path finder agent elaborates, when solicited for each order the traveling routes between pickup and delivery locations. Secondly order agents offer transport jobs (tasks) through sequential auctions and vehicle agents compete with each other to serve those jobs by proposing potential and effective positions. Vehicles propose grouping of these jobs together to execute them simultaneously depending on criteria (pickup and delivery of times, vehicles capacity, food product constraints).

In that way, multiple producers and transporters can collaborate with each other through this model to propose the delivery of transport orders, therefore reducing the transport cost, pollution and increasing the reach of FSC. One of the future directions of this model is to consider size, weight of the products, and handle penalties. We illustrate the application of I-POVES through a FSC case study in next chapter.

Chapter5

Application: The TECCAS project

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5.1 Introduction

This last chapter is dedicated to the presentation of European project TECCAS which supported us to implement the ideas and concepts presented in this thesis. Our role in this project was to develop the transportation interoperable planning in the context of collaborative food supply chain.

First section of this chapter describes the TECCAS project, including its objectives, partners involved and role of each partner in the project. Subsequently, we present SOA based framework based on C-PRIPIT model proposed for this project and specify positioning of I-POVES model in that framework. Afterwards, we present the transportation scheduling rules, proposed by taking into account working requirements of the enterprises, collected through their feedback in the project.

Second section presents the application of our work. This section starts with description of a food supply chain case study derived from TECCAS project, followed by presentation of ontologies and their alignment. Finally, we show the scheduling results obtained by execution of I-POVES on the case study.

Finally, in third section, we analyse the scheduling results with different planning evaluation indicators.

5.2 TECCAS project

TECCAS[1] name is derived from the Spanish words "Desarrollo de TEcnologias orientadas a favorecer la Colaboración entre agentes de la Cadena Alimentaria de Suministro" and its English equivalent is "Development of technologies to promote collaboration between the actors of food supply chain". Most of the enterprises that make up the food supply chain run their processes in the absence of information in real time and without collaboration between them, causing stock outs, poor planning and accumulation of inventories and transportation inefficiencies. This, together with problems of communication of the Pyrenean area of France and Spain, makes it very difficult the exchange of goods and economic transactions especially between small and medium sized enterprises (SME) on both sides of the border.

Therefore, objective of TECCAS project is the development and transfer of technologies that promote collaboration between the actors in the food supply chain in the border area, so that it can achieve greater efficiency in all logistics

[1] http://web.ita.es/teccas

operations. The application of technologies that integrate collaborative forecasting, production and transport will give greater visibility to the food supply chain in the context of Pyrenean area and in general will yield effective processes.

TECCAS project is awarded to following four partners:

- *L'Institut Technologique d'Aragon (ITA):* is a public technology center situated in Spain, whose mission is to contribute to the promotion and implementation of research and development along with focusing on activities to encourage technological innovation of enterprises.

- *L'industrie agro-alimentaire Association d'Aragon (AIAA):* brings together food companies located in Aragon and hosts more than 175 companies in various subsectors and represent them to the government of Aragon. In addition, it offers its members a range of common services.

- *La Chambre de Commerce et d'Industrie des Hautes Pyrénées (CCI):* is a leader in supporting the economic and commercial development of the Pyrenees area, including trade and traditional or artisanal food industry.

- *L'Ecole Nationale d'Ingénieurs de Tarbes (ENIT):* is a member of Polo d'Interop-VLab for enterprise interoperability. DIDS group (part of ENIT) that participates in TECCAS project specializes in the design of the interoperable technologies.

Role of CCIA and AIAA was to bring requirements, experiences and feedback of food industries located in the Pyrenees area. Role of ITA was to study and propose solutions for forecasting, replenishment and tracing & tracking. Our (ENIT) roles were to study and propose methods for collaborative food supply chain and propose framework for their realization. Within that framework, our work was concerned specifically for proposing and developing a platform of collaborative transportation planning.

For our objectives, we proposed C-PRIPT model for collaborative food supply chain and proposed and developed I-POVES model for collaborative transportation planning, both presented in previous chapters. Subsequently, we present the framework proposed for TECCAS project. This framework is based on the phases of the C-PRIPT model. This framework follows the activities and interaction defined in C-PRIPT model.

5.2.1 TECCAS framework

This framework comprises of 12 major types of interconnected components as shown in figure 5.1. We briefly explain these components one by one.

1. **SOA Bus:** This framework contains a service oriented bus, which connects all the software systems with each other in the form of web services through internet. All the interaction is possible only through this bus. This bus controls the information flow and accessibility between all the services.

2. **Sales and demand forecasting system:** This service actually performs the demand and forecasting activities of replenishment and inventory phase of C-PRIPT model. There are several instances of this system running in collaboration between retailers and producers. However, they all work in collaboration with each other.

3. **Generating orders for replenishment:** When demand forecasting is determined, replenishment planning system service generates the set of product orders according to the demand forecasted.

4. **Inventory planning:** This service continuously monitors the stock levels of each partner and continuously updates their stock. This system works in collaboration with service 2 and 3 to provide the complete functioning of replenishment and inventory phase of C-PRIPT model.

5. **Production planning:** This service is of production planning system which runs in producer enterprise. This is an autonomous and independent system. Upon receiving the products orders from replenishment and inventory activities, producer uses this system to do planning for production of products.

6. **Collaborative production planning:** This service actually presents the 3rd phase of collaborative production planning of C-PRIPT model by collaborating heterogeneous several production planning systems.

7. **Transportation planning:** This service is for transportation planning, which runs on the transporter's enterprise. This is also an autonomous and independent system. Upon receiving the transport orders, transporter system performs planning for transportation of products.

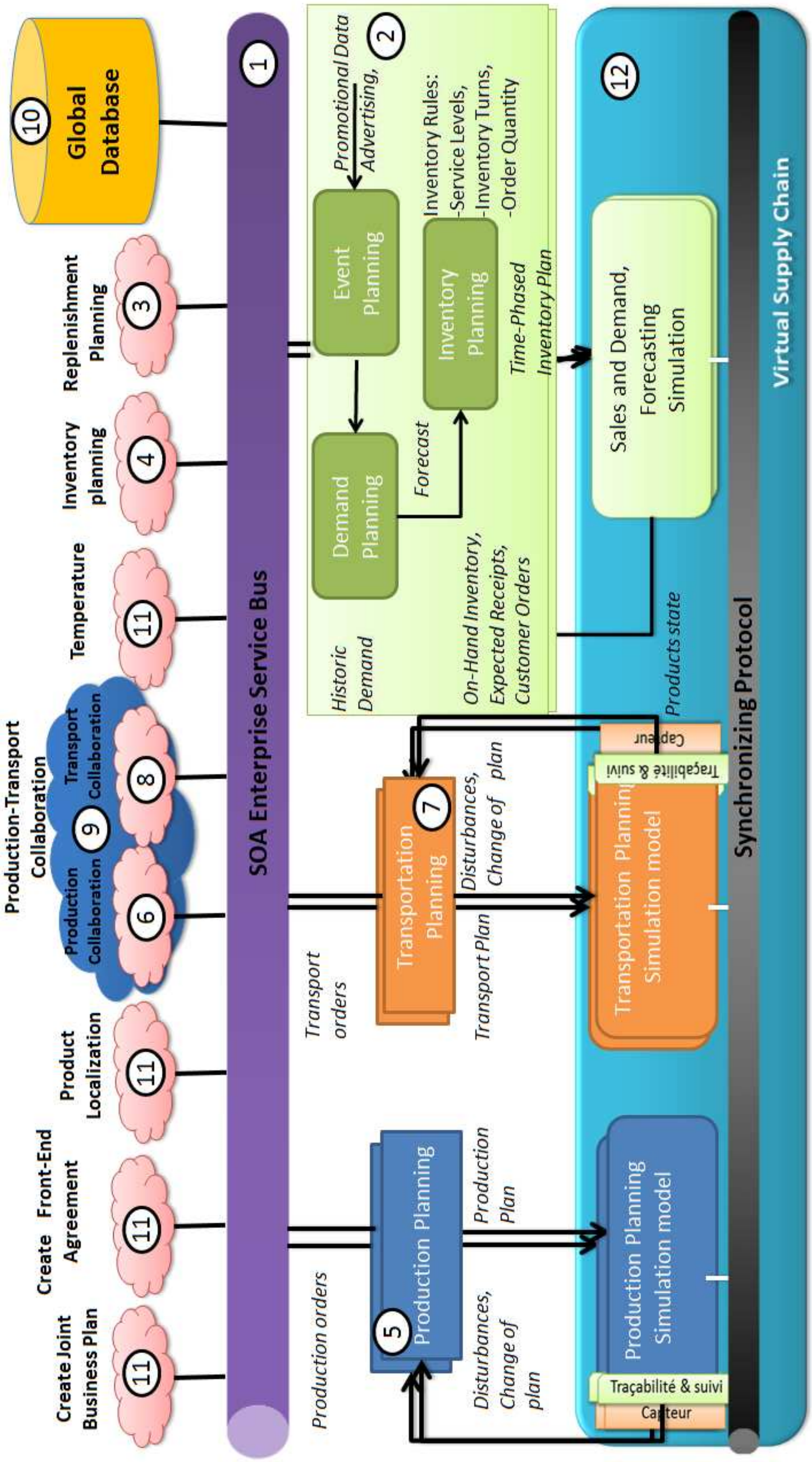


Figure 5.1: *TECCAS architecture based on C-PRIPT model*

8. **Collaborative transportation planning:** This service actually presents the 4th phase of collaborative transportation planning of C-PRIPT model by collaborating several heterogeneous transportation planning systems.

9. **Production-Transportation collaboration:** This service contains the interactions between production and transportation systems. This service is actually the 5th phase of C-PRIPT model.

10. **Shared repository:** This framework provides a central repository for sharing the related data for all the partners. All the information that needs to be shared among systems is stored in this repository.

11. **Supporting services:** This framework also provides set of supporting web services to aid the main functionalities. These services help localize the product, measure temperature of the shipment, trace and track the product during production and transportation etc. Other services like Create Joint Business plan and Create Front-End Agreement services provide the information about the business strategies used by all the systems throughout the framework.

12. **Virtual food supply chain:** To test this framework, we can simulate the functioning of collaborative food supply chain by simulating the data of each system of the framework. In order to synchronize and communicate all simulators, we can use a synchronizing protocol. This simulation will make a complete virtual food supply chain.

This framework helps sharing and viewing common data without distortion and restricts direct access to each other system. This framework share the common services, that can be used by all the systems, rather than developing each of their own. In this framework, our specific role was to define and develop methods to yield collaborative transportation planning which are actually 7th and 8th services. In order to achieve this object, we proposed and developed I-POVES model presented in chapter 4. In chapter 4, we have presented generic functioning of I-POVES model. This mechanism is tested by using different scheduling rules implemented in I-POVES. These rules are implemented, by taking into account the working requirements of the enterprises, collected through the feedback acquired by CCI and AIAA with these enterprises. In the next section, we present these rules.

5.2.2 I-POVES scheduling rules

In I-POVES, vehicle agents function on two types of DRT scheduling (see chapter 4, problem description): $Fixed\,departure$ and $Demand\,responsive\,depature$. In $Fixed\,departure$, vehicle has fixed pre-calculated time table for each activity and orders are scheduled according to that timetable. In $Demand\,responsive\,departure$, vehicle agents follow the arrival of orders and calculate their departure dynamically. Furthermore to set the priority of tasks, vehicle agents consider two priorities: Wished Start Date (WSD) and $Margin$.

For WSD, vehicle agent organizes the tasks in the ascending order of their wished start date. It means the order having the earliest pickup time will be served first. Tasks which are delayed will be given the premier priority in the list.

For $Margin$, vehicle agent determines the maximum time, that the task can be delayed to deliver the transport order on time or before. This maximum time is refereed as margin and the tasks are arranged from least margin in ascending order in the priority list. Therefore tasks are served according to their overall transport order delivery time. Hence by combining two types of schedules with two types of priorities, we formulate four rules:

1. $Fixed\,departure\,with\,WSD$
2. $Fixed\,departure\,with\,Margin$
3. $Demand\,responsive\,departure\,with\,WSD$
4. $Demand\,responsive\,departure\,with\,Margin$

These rules consists of conditions and algorithms for proposing potential and effective positions (refer to I-POVES functioning in chapter 4 for description of these positions). Vehicle agent uses any of these rules to propose the potential and effective position. We first explain the mathematical formalism and then explain the algorithms.

Mathematical Formalism

$V = \{v_j/j = 1, ..., nv\}$: Let V be the set of all vehicles of transport enterprise.

$A = \{a_i/i = 1, ..., n\}$: Let A be the set of all basic activities that can be accomplished by vehicle $v_j \epsilon V$.

$O = \{(OB^u, PT^u, PL^u, DL^u, PT^u, DT^u, PQ^u)/u = 1, ..., no\}$: Let O be the set of all transport orders, where OB^u is the objective, PT^u is the product type, PL^u is the pickup location, DL^u is the delivery location, PT^u is the pickup time, DT^u is the delivery time and PQ^u is the product quantity of the order.

$T = \{t^{u,c}/u = 1, ..., no \epsilon O, c = 1, ..., ntu\}$: Let T be the set of all tasks of all transport orders in the environment, where c is the number of a task of the transport order u.

$TO_u = \left\{t^{u,k} \epsilon T/k = 1, ..., ntu\right\}$: Let TO_u be the sequence of decomposed tasks between PL^u and DL^u for the transport order u computed by path finder agent based on activities proposed by transporters.

$ta : T \longrightarrow A \quad ta(t) = a \epsilon A$: Let the function $ta(t)$ define for each task $t \epsilon T$ the basic activity in A.

$at = \{t^{u,c} \epsilon T, \quad \forall \epsilon O, \quad \forall c = 1, ..., ntu/ta(t^{u,c}) = a\}$: Let the function at define for each task the basic activity $a \epsilon A$ for the set of associated tasks in T.

$Vt^{u,i} = \{v_b \epsilon V, b = 1, ..., nvt^{u,i}/ta(t^{u,i}) \epsilon V\}$: Let $\mathbb{V}t^{u,i}$ be the set of all vehicles that can perform task $t^{u,i} \epsilon \mathbb{T}$.

$T_j = \{t^1, t^2, ...t^q \epsilon T/ta(t^u) = a_i, \forall u = 1, ...q\}$: Let T_j be the set all of tasks for the activity a_i.

$Dur : A \longrightarrow R$: Let the function $Dur(a_i)$ define the duration of the activity $a_i \epsilon A$ determined with the coefficient of the vehicle vj.

CD_j : Let the parameter CD_j be the current date of the vehicle v_j.

$LoadR_j(x)$: Let the parameter $LoadR_j(x)$ be the resident load of the vehicle at date x and x may be CD_j.

Cap_j : Let the parameter Cap_j be the total capacity of the vehicle $v_j \epsilon V$.

WP^i : Let WP^i be the wished position requested by the task $t^i \epsilon T_j$, where $WP^i = (WSD^i, WED^i)$, while WSD^i and WED^i are the wished start date and wished end date respectively.

PP^i_j : Let PP^i_j be the potential position for $t^i \epsilon T_j$ proposed by the vehicle v_j, where $PP^i_j = (PSD^i_j, PED^i_j)$, while PSD^i_j and PED^i_j are the potential start date and potential end date respectively.

EP_j^i : Let EP_j^i be the effective position for $t^i \ \epsilon \ T_j$ proposed by the vehicle v_j, where $EP_j^i = (ESD_j^i, EED_j^i)$, while ESD_j^i and EED_j^i are the effective start date and potential end date respectively.

$Prior(WSD)a_i = \{t^i, t^{i+1} .... \ T_j \, / \, WSD^i < WSD^{i+1}, \forall \, ta(t^i) = a_i\}$: Let $Prior(WSD)a_i$ be the set of tasks $t^i \ \epsilon \ T_j$ organized in the ascending order of their wished start date for activity a_i.

$Margin_j^i(WSD^{u,i}) = \left\{DT^u - WED_j^{u,i} - \sum_{k=i+1}^{ntu} Dur_k / t^{u,i} \, \epsilon \, TO_u\right\}$: Let $Margin$ of a task t^i equal to delivery time DT^u of the transport order u subtract the wished end date of the task $t^{u,i}$ subtract the sum of the duration of all the subsequent tasks for the transport order u.

$Prior(Margin)a_i = \left\{t^{u1,1}, t^{u2,2} .... t^{un,l} \ \epsilon \ \mathbb{T}_j / Margin_j{}^u 1, 1(WSD^{u1,1}) < Margin_j^{u2,2}(WSD^{u2,2}) .... Margin_j^{un-1,l-1}(WSD^{un-1,l-1}) < Margin_j^{un,l}(WSD^{un,l})\right\}$: Let $Prior(Margin)a_i$ be the list of tasks arranged in their increasing order of their margin. Therefore first task in the list has the shortest margin so it has the highest priority.

Formalism specific to Fixed departure

$D_j = \left\{d_j^k \ \epsilon \ R / d_j^k < d_j^{k+1}, \ \ k = 1, ...n - 1\right\}$: Let D_j be the list of ascending dates of departure for the vehicle v_j

$NDD_j(x) = Min\left\{d_j^k\right\} \epsilon \ \ D_j / x \ \leq \ d_j^k, \ \ k = 1, ..., n$: Let $NDD(x)$ be the next date of departure of v_j from the date x and x may be the current date CD_j

$NDD(NDD_j(x)) =$ Let $NDD(NDD_j(x))$ be the subsequent departure following $(NDD_j(x))$.

Formalism specific to Demand Responsive departure

$MWT=$ Let Maximum waiting time (MWT) be the duration of the time imposed on the vehicle, when there is any order to transport. MWT forces vehicle to depart even if its capacity is not full.

$SetMWT_j^i = \{t^i, t^{i+1} .... \ \epsilon \ \ Prior(WSD)a_i / WSD^i \leq WSD^{i+1} + MWT\}$: Let $SetMWT_j^i(a_i)$ is the set of tasks $t^i \ \epsilon \ \ Prior(WSD)a_i$ associated with the activity a_i respecting the constraint of a MWT of the task t^i. Such that $t^s \ \epsilon \ \ SetMWT_j^1 a_i$, as $\forall t^t \ \epsilon \ \ SetMWT_j^1, t^t \ \leq \ t^s$ (implies that $WSD^t \ \leq \ WSD^s$) the last task in the group $SetMWT_j^i a_i$, for which WSD is the latest.

$SetCap_j = \{t^i \in T_j / WSD^i \leq WSD^k\}$ Let $SetCap_j$ is the group of first tasks that fill the capacity of the vehicle including its $LoadR_j(x)$, such that: $t^k \in T_j / PQ^k \leq Cap_j$ & $PQ^{k+1} > Cap_j$.

5.2.2.1 *Fixed departure with WSD*

In this rule, firstly to determine potential position, vehicle agent retrieves the tasks one by one from $Prior(WSD)a_i$ and check for timing and capacity condition for next departure $NDD_j(x)$. When timing condition is true, then vehicle agent checks the capacity condition. If both conditions are true for the task, vehicle agent will propose potential position for the task for $NDD_j(x)$, otherwise task is forwarded to subsequent departure $NDD(NDD_j(x))$ and son on. These conditions are illustrated in figure 5.2 in form of a diagram and are also given below:

Timing condition: Vehicle v_j compares the WSD^i with its next date of departure $NDD_j(x)$. This condition is given as follows:

if $WSD^i \leq NDD_j(x)$ **then**
| task can be accomplished by v_j at $NDD_j(x)$.
else
| WSD^i is checked for $NDD(NDD_j(x))$ and so on until above condition becomes true.
end

Capacity condition: Capacity condition checks whether vehicle has enough capacity to load the task. If it has, it proposes the potential position for it, otherwise it send it for verification with subsequent departure after next. Here it checks the load of one task on individual basis, not in accumulation with other tasks that need to be planned. This condition is given as follows:

if $PQ^u + LoadR_j(x) > Cap_j$ **then**
| vehicle does not have enough capacity and task is then sent to $NDD(NDD_j(x))$.
else
| $PP_j^i = NDD_j(x)$
end

Hence $grpP(NDD_j(x))$ represents the tasks, for which both timing and capacity conditions are true. All those tasks have the $PP_j^i = NDD_j(x)$.

$$grpP(NDD_j(x)) = \{t^{u,i} \ \epsilon \ Prior(WSD)a_i / \ WSD^{u,i} \leq NDD_j(x), \quad PQ^u \ + \ LoadR_j(x) \leq Cap_j, \forall u \ \epsilon \ O, \ i = 1, ..., T_j\}$$

All the remaining tasks are sent to $NDD(NDD_j(x))$ and so on, therefore:

$$T_j = \{t^i \, ... \, \epsilon \, T_j - grpP(NDD_j(x))\}$$

For effective position, similar to potential position, vehicle agent checks both timing and capacity condition, but the difference is for effective, it accumulates the load of the tasks until the vehicle is full. Vehicle v_j proposes the effective position $EP_j^i = NDD_j(x)$ for all the tasks of $grpE(NDD_j(x))$.

$$grpE_j(NDD_j(x)) = \left\{ t^{u,1}, ...t^{w,m} \, \epsilon \, grpP(NDD_j(x)) / \sum_u^w PQ + LoadR_j(NDD_j(x)) \leq Cap_j, \sum_u^{w+1} PQ + LoadR_j(NDD_j(x)) > Cap_j \right\}$$

All the remaining tasks are then sent to $NDD(NDD(x))$ and so on, therefore:

$$T_j = \{t^i \, ... \, \epsilon \, T_j - grpE(NDD_j(x))\}$$

5.2.2.2 *Fixed departure with Margin*

Similar to $Fixed\,departure\,with\,WSD$, for $Fixed\,departure\,with\,Margin$, vehicle agent compares the timing and capacity condition but only the priority list is now $Prior(Margin)a_i$. These conditions are illustrated in figure 5.2 in the form of a diagram.

$grpP(NDD_j(x))$ represents the tasks, for which both timing and capacity conditions are true. All those tasks have $PP_j^i = NDD_j(x)$

$$grpP(NDD_j(x)) = \{t^{u,i}\ \epsilon\ Prior(Margin)a_i/\ WSD^{u,i} \leq NDD_j(x),\\ PQ^u\ +\ LoadR_j(x) \leq Cap_j, \forall u\ \epsilon\ O,\, i = 1, ..., T_j\}$$

All the remaining tasks are sent to $NDD(NDD_j(x))$ and so on, such that:

$$T_j = \{t^{u,i} \,....\, \epsilon\, T_j - grpP(NDD_j(x))\}$$

For effective position, vehicle v_j proposes the effective position $EP_j^i = NDD_j(x)$ for all the tasks of $grpE(NDD_j(x))$.

$$grpE(NDD_j(x)) = \Bigg\{t^{u,1}, ...t^{w,m}\,\epsilon\, grpP(NDD_j(x))/\sum_u^w PQ+\\ LoadR_j(NDD_j(x)) \leq Cap_j, \sum_u^{w+1} PQ + LoadR_j(NDD_j(x)) > Cap_j\Bigg\}$$

All the remaining tasks are sent to the $NDD(NDD_j(x))$ and so on, such that:

$$T_j = \{t^{u,i} \,....\, \epsilon\, T_j - grpE(NDD_j(x))\}$$

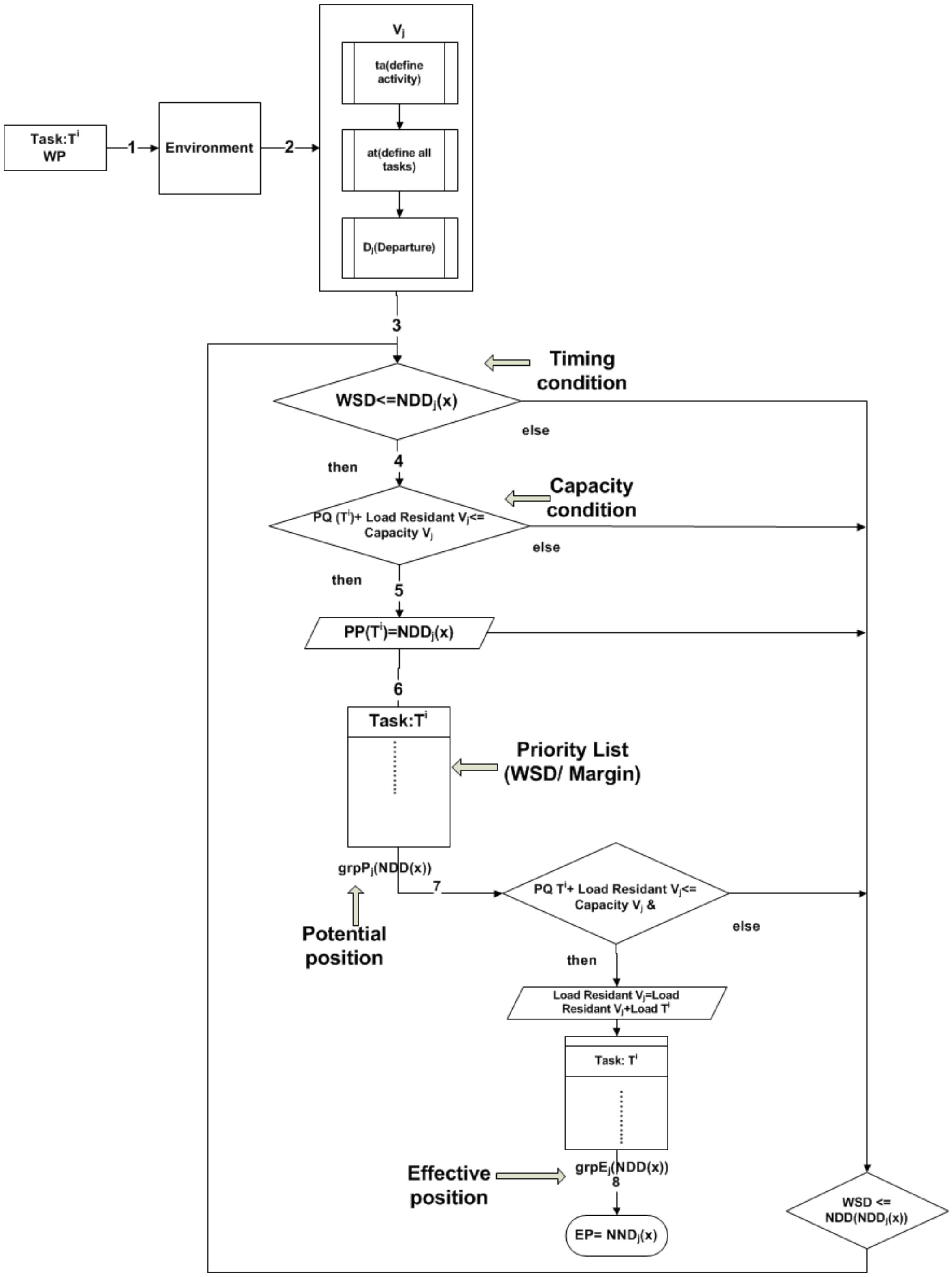


Figure 5.2: *Determine PP and EP for Fixed departure with WSD/Margin*

5.2.2.3 *Demand responsive departure with WSD*

In demand responsive departure, vehicle's departure is planned as per pickup time of the transport order. Therefore, if vehicle is not available at the origin of the activity a_i to transport the tasks, vehicle arrives at the origin of the activity on the request by executing other activities (empty or filled) in its pre-assigned route. Hence process of determining potential and effective position considers vehicle's capacity and active position.

Therefore, for determining potential position, vehicle v_j considers the tasks of $Prior(WSD)a_i$ equation. Hence algorithm 1 describes the method and figure 5.3 illustrates the method in form of a diagram.

if *vehicle is available at activity* a_i **then**
  if $PQ^{u,i} + LoadR_j(x) \leq Cap_j, \forall u \ \epsilon \ O, i = 1, ..., T_j$ **then**
    if $WSD^i \leq CD_j$ **then**
      $PP^i = CD_j$
    else
      $PP^i_j = WSD^i$
    end
  else
    $PP^i_j = \left\{ WED^i + \sum_{ai+1}^{ai-1} Dur(a) / a_{i-n}...a_{i-1}, a_i, a_{i+1}, ...a_n \ \epsilon \ A \right\}$
  end
else
  if *vehicle is not at activity* a_i*, but at some other* a_k*.* **then**
    $Displacement = CD_j + \sum_{ak}^{ai-1} Dur(a) / a_{i-n}.....a_{i-1}, a_i, a_{i+1}, a_n \ \epsilon \ A$
    if $WSD^i > CD_j + Displacement$ **then**
      $PP^i_j = WSD^i$
    else
      $PP^i_j = CD_j + Displacement$
    end
  else
  end
end

Algorithm 1: Algorithm to determine PP for tasks

For determining effective position, algorithm 2 in combination with algorithm 3 and 4 describe the method for tasks. Figure 5.4 illustrates the same method in the form of a diagram.

if *vehicle is available at activity* a_i **then**
  if $t^s < t^k$ **then**
    Execute algorithm 3
  else
    Execute algorithm 4
  end
else
  if *no task for activities between* a_i *and* a_k **then**
    $CD_j = CD_j + \sum_{ak}^{ai-1} Dur(a)/a_{i-n}.....a_{i-1}, a_i, a_{i+1}, a_n \ \epsilon \ A.$
    if $t^s < t^k$ **then**
      Execute algorithm 3
    else
      Execute algorithm 4
    end
  else
    Vehicle agent first realizes the EP for the tasks between a_i and a_k, afterwards for a_i
    if $t^s < t^k$ **then**
      Execute algorithm 3
    else
      Execute algorithm 4
    end
  end
end

Algorithm 2: Algorithm to determine EP for tasks

if $CD_j < t^s$ **then**
  therefore the asks are of group $SetMWT_1^j$. Vehicle's departure is equal to WSD^s of t^s.
else
  if $t^s < CD_j \leq t^k$ **then**
    therefore the tasks are of group $SetMWT_1^j$ added by all tasks between t^s and CD_j. Vehicle's departure is equal to CD_j.
  else
    if $t^k < CD_j$ **then**
      therefore tasks are of group $SetCap^j$. Vehicle's departure is equal to CD_j.
    else
    end
  end
end

Algorithm 3: If $t^s < t^k$ then execute this algorithm

if $t_k \leq CD_j$ **then**
    therefore tasks are of group $SetCap_j$ and the departure of the vehicle is equal to CD_j.
else
    if $CD_j \leq t^k$ **then**
        therefore tasks are of group $SetCap_j$ and departure of the vehicle is equal to WSD^k.
    else
        $\forall CD_j$ the tasks that will be grouped from group $SetCap_j$.
    end
end

Algorithm 4: If $t^s \geqslant t^k$ then execute this algorithm

5.2.2.4 *Demand responsive departure with Margin*

Determination of PP and EP for *Demand responsive departure with Margin* is similar to *Demand responsive departure with WSD* rule, rather here priority list is now $Prior(Margin)a_i$. Therefore, we do not explain this rule to avoid the repetition.

Figure 5.3 and 5.4 illustrates list of steps to determine PP and EP.

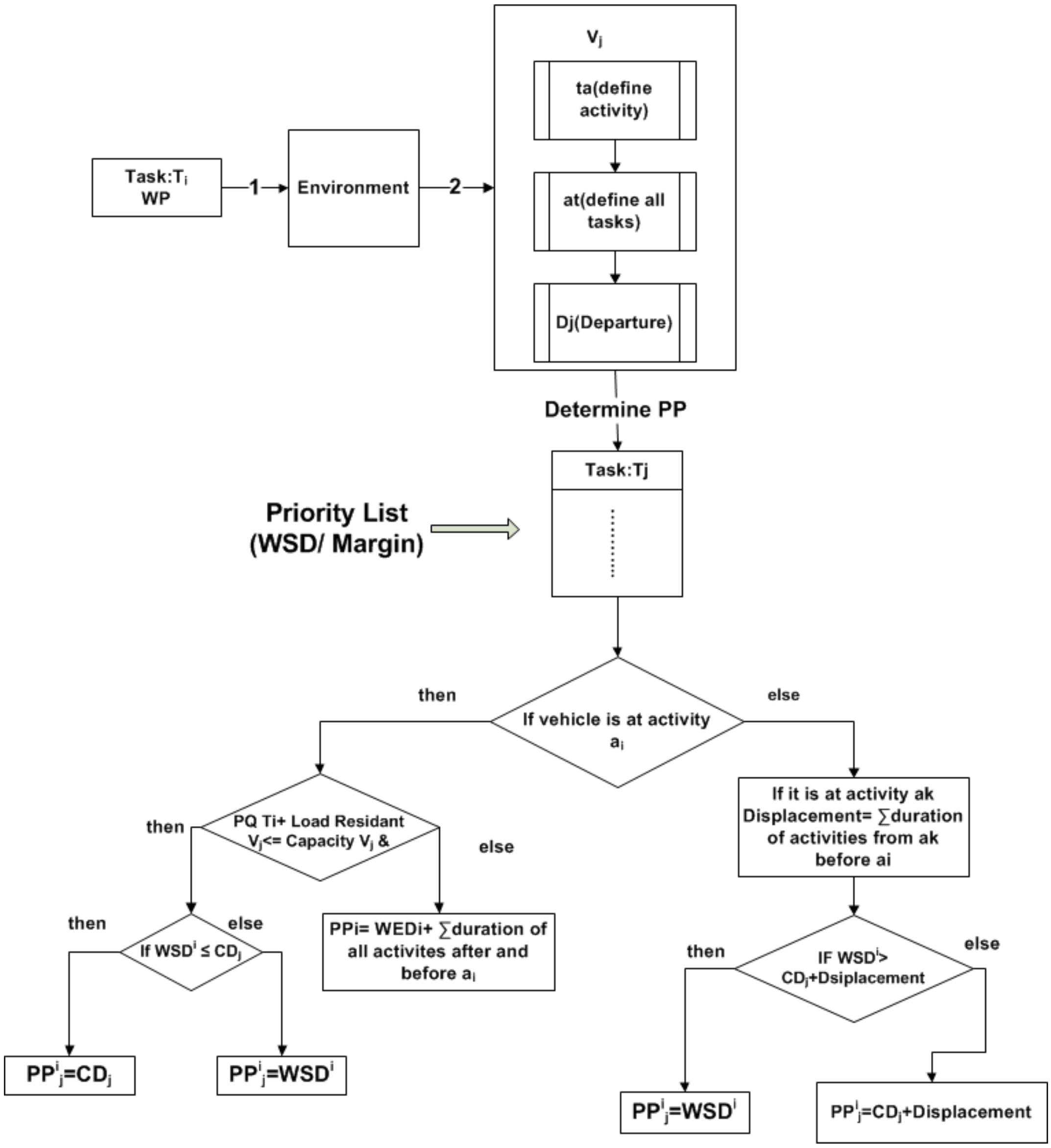


Figure 5.3: *Determine PP for Demand Responsive departure with WSD/Margin*

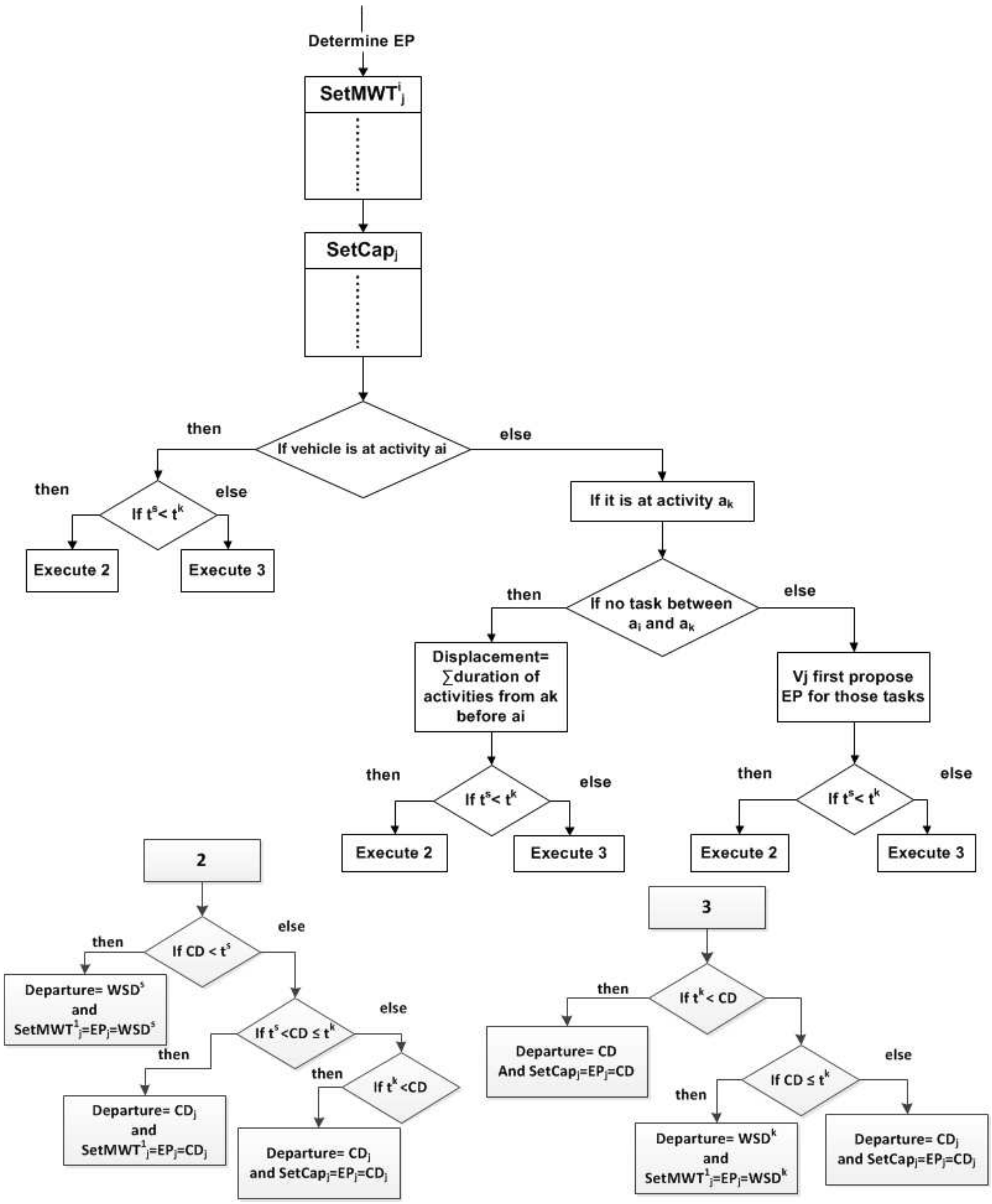


Figure 5.4: *Determine EP for Demand Responsive departure with WSD/Margin*

In TECCAS project, a pilot case study is defined. In order to validate and demonstrate the application of our work, we simulated this case study with I-POVES model. Next section is dedicated to present this this application with scheduling results.

5.3 Application

Here, firstly we present the description of case study. Secondly, we explain the ontologies and alignment used in the simulation. Finally, we present the scheduling results obtained.

5.3.1 Pilot case study description

Case study comprises of consideration of a simple food supply chain operating in the cross border area of France and Spain. This FSC consists of two producer enterprises, one situated in Spain (Producer-S) and other situated in France (Producer-F) and three 3PL transporters. One 3PL transporter operates in the south region of the France called 3PL-F. Second 3PL transporter operates in the border area of both France and Spain and is called 3PL-FS. Finally, third 3PL transporter operates in north region of the Spain called 3PL-S. All these transporters are specialized in transporting food products and manage their own fleet of vehicles equipped with different equipments to maintain certain temperature for different food products. Figure 5.5 illustrates the sites of both producers and operational geographical area of each 3PL.

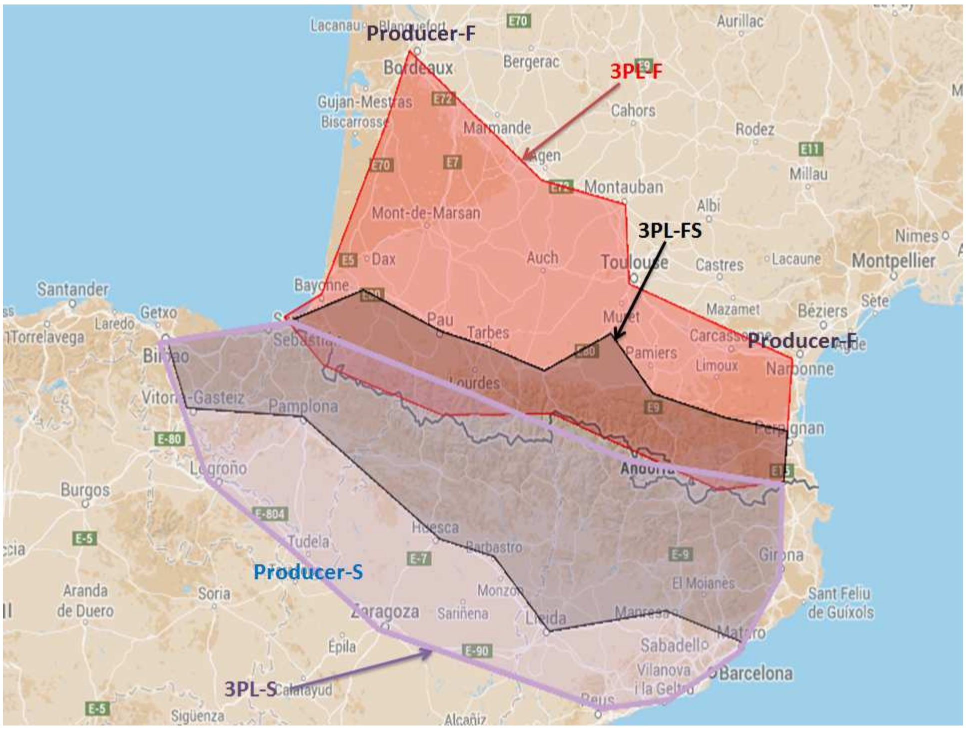


Figure 5.5: *Geographical operational area of 3PL-F, 3PLFS and 3PL-S*

We describe each producer and 3PL enterprise business one by one.

Producer-S (Producer enterprise in Spain)

Producer-S operates in the city of Tudela by producing frozen chicken pizza. In order to produce pizza, it mainly requires three ingredients: white flour, cheese and chicken. It imports white flour and cheese from France and buys chicken locally from Spain. After production, it distributes frozen pizza to retailer's distribution centers in France. Producer-S generates list of transport orders (table no. 5.1) for bringing semi-products cheese (order 1), white flour (order 2), and chicken (order 3) at its production site at Tudela (Spain). After producing pizza, order 4 demands the delivery of pizza to retailer's distribution center in Toulouse (France).

Table 5.1: *Transport orders of Producer-S in its local ontology*

Ship-no	Goal	Commodity	Charge	Discharge	Ch-Date	DisCh-Date	Batch
0001	Early	Cheese	Pau	Tudela	8 a.m 2-07-2014	8 p.m 2-07-2014	50
0002	Early	White flour	Dax	Tudela	8 a.m 2-07-2014	8 p.m 2-07-2014	100
0003	Early	Chicken	Girona	Tudela	8 a.m 2-07-2014	8 p.m 2-07-2014	100
0004	Early	Pizza	Tudela	Toulouse	8 a.m 2-07-2014	8 a.m 3-07-2014	200

Producer-F (Producer enterprise in France)

Producer-F has two production plants: one in Bordeaux and other in Narbonne. At Bordeaux, it produces orange juice and imports fresh oranges from Spain. At Narbonne, it produces alcohol and distributes it in France as well as in Spain. Producer-F generates list of transport orders (table no. 5.2) for bringing product oranges (order 1) at its production site Bordeaux (France) from Zaragoza (Spain). Order 2 and 3 are distribution of prepared juices to Perpignan and Lleda (France) from its site at Bordeaux. Order 4, 5, 6 are the distribution of alcohol from its other production site at Narbonne to both France and Spain.

Table 5.2: *Transport orders of Producer-F in its local ontology*

ID	Item	loading	Un-load	Loading Date	Unloading Date	Lot
1	Oranges	Zaragoza	Bordeaux	8 a.m 2/07/2014	8 a.m 3/07/2014	150
2	Juices	Bordeaux	Perpignan	8 a.m 2/07/2014	8 p.m 2/7/2014	100
3	Juices	Bordeaux	Lleida	8 a.m 2/07/2014	2 p.m 3/7/2014	100
4	Alcohol	Narbonne	Pamplona	8 a.m 2/07/2014	2 p.m 3/7/2014	100
5	Alcohol	Narbonne	Pau	8 a.m 2/07/2014	8 a.m 2/07/2014	50
6	Alcohol	Narbonne	Biblao	8 a.m 2/07/2014	2 p.m 3/07/2014	100

3PL-F (Transporter enterprise in France)

3PL-F vehicle information consisting of trajectories performed by each van, facility that vehicle is equipped with and its initial location are presented in table 5.3. We assume that 3PL-F do not possess its own planning system, but rather uses a local instance of I-POVES. Therefore, using that information, its local path finder agent generates the geographical network of 3PL-F illustrated in figure 5.6.

Table 5.3: *Van and their predefined trajectories for 3PL-F in its local ontology*

Van	Initial location	Trajectory(Departure/ Arrival)	Trajectory(Arrival/ Departure)	Facility
FV1	narbonne	toulouse	narbonne	Normal and Ventilation
		narbonne	perpignan	
FV2	marmande	marmande	montauban	Freezer, High-Refrigeration
		montauban	toulouse	Low-Refrigerated, Normal
FV3	biscarrosse	bordeaux	marmande	Low-Refrigeration, Normal
		bordeaux	biscaroose	
FV4	auch	biscaroose	mimizan	Normal and Ventilation
		mimizan	dax	
		dax	auch	
FV5	auch	auch	montauban	Freezer, High-Refrigeration
		auch	tarbes	Low-Refrigerated, Normal
FV6	lourdes	pau	tarbes	Freezer, High-Refrigeration
		tarbes	lourdes	Low-Refrigerated, Normal

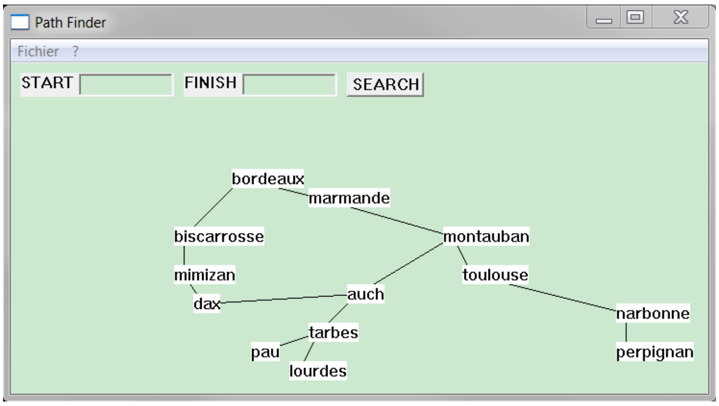


Figure 5.6: *3PL-F transport network construction by Path Finder*

3PL-FS (Transporter enterprise in France-Spain Border)

3PL-FS proposes in table 5.4, trucks, their travels information, their initial position and temperature conditions that vehicles can maintain in order to transport different kind of food products. We assume that 3PL-FS transporter has its own planning system named OpenTCS software. OpenTCS is developed by Fraunhofer IML in the project FAHRLOS. Since July 2012, openTCS is made available as free software under the MIT license[2]. OpenTCS is control system software for track-guided vehicles. The purpose of the OpenTCS is to provide an abstract driving course model of a transportation system/plant, to manage transport orders and to compute routes for the vehicles. Figure 5.7 illustrates its transportation network in the OpenTCS plant overview.

3PL-S (Transporter enterprise in Spain)

3PL-S bus information, their routes (start and finish) and kind of products that these buses can transport are given in table 5.5. For execution purpose, we consider

[2]http://www.opentcs.org/de/opensource.html

Table 5.4: *Trucks and their predefined travel for 3PL-FS in its local ontology*

Trucks	Initial-position	Travel(From/To)	Travel(To/From)	Temperature condition
FSV1	bayonne	bayonne	pau	Between -25 and +35
		pau	lourdes	
FSV2	lourdes	pau	tarbes	Between -25 and +35
		lourdes	tarbes	
FSV3	muret	muret	tarbes	Between +25 and +35
		muret	perpignan	
FSV4	jaca	lourdes	jaca	Between -25 and +35
FSV5	bilbao	huesca	pamplona	Between +25 and +35
		pamplona	biblao	
FSV6	huesca	jaca	huesca	Between -25 and +35
		huesca	lleda	
FSV7	barcelona	lleda	barcelona	Between 0 and +35
		barcelona	girona	

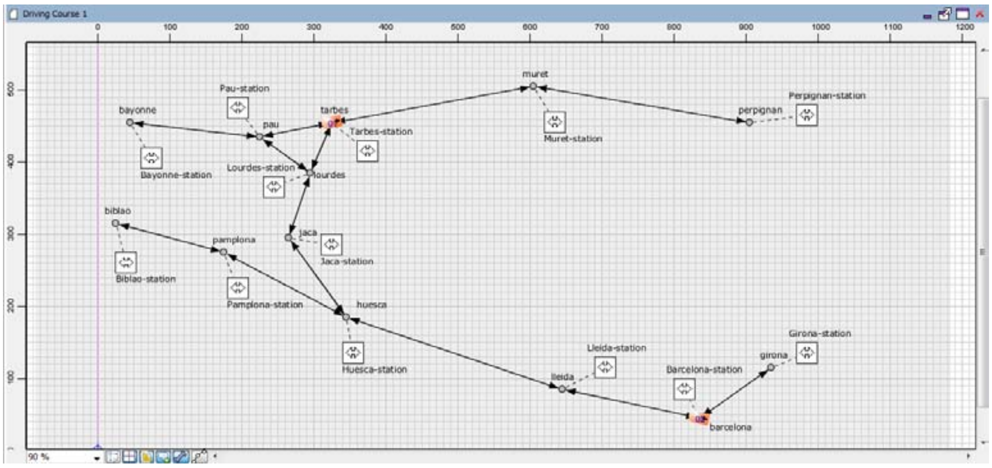


Figure 5.7: *3PL-FS transport network construction in plant overview of openTCS*

3PL-F transport enterprise use a local instance of I-POVES. Therefore, its local path finder constructs geographical network illustrated in figure 5.8.

Table 5.5: *Buses and their predefined routes for 3PL-S in its local ontology*

Bus	Starting position	Route(Start/Finish)	Route(Finish/Start)	Product kind
SV1	bilbao	huesca	pamplona	Normal and Ventilated
		pamplona	biblao	
SV2	jaca	jaca	huesca	Frozen, Refrigerated and Normal
SV3	barcelona	lleda	barcelona	Refrigerated
		barcelona	girona	
SV4	huesca	zaragoza	lleda	Refrigerated and Normal
		huesca	lleda	
SV5	barcelona	zaragoza	reus	Ventilated
		reus	barcelona	
SV6	huesca	huesca	zarogoza	Frozen, Refrigerated and Normal
		zarogoza	tudela	
SV7	bilbao	tudela	logrono	Normal and Ventilated
		logrono	biblao	

Producers in this food supply chain do not do the transportation by themselves, therefore they require services of the 3PL transporters to deliver their food products. Producers and transporters systems possess their own local ontologies.

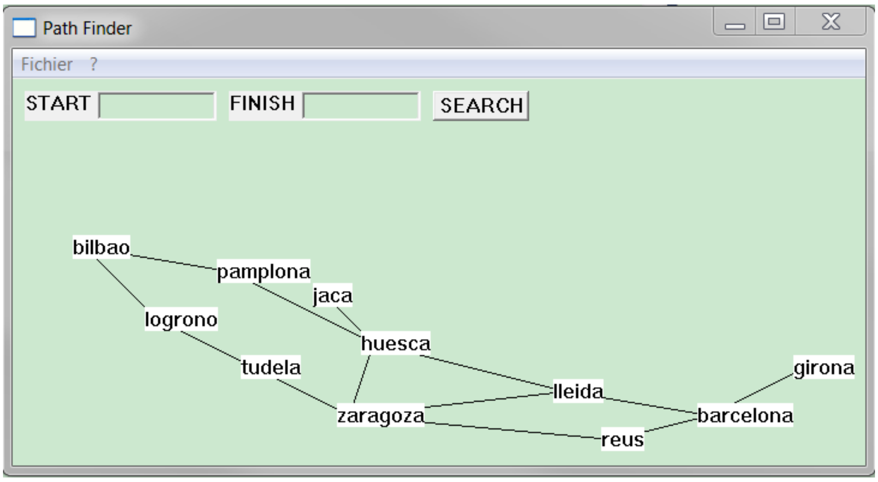


Figure 5.8: *3PL-S transport network construction by Path Finder*

Producers systems generate transport orders and transporters manage vehicle and network information according to terms expressed in their own local ontologies. Hence, objective of this case study is to illustrate that despite of heterogeneous systems, how I-POVES using ontologies and ISU interoperate with these systems in order to propose collaborative transportation planning, eventually grouping similar products for delivery to reduce the pollution and cost of the transport. We subsequently describe each producer and transporter system ontologies in next section, but before that we present some hypothesis considered for this case study.

- Products are delivered in a standard box of same volume, dimension and size. After packaging, box has the same weight for all products.
- For all boxes, number of products is constant. However quantity that box can contain for each product depends on the kind of product and not on the box. The number of boxes in a vehicle is always an integer constant.
- Each vehicle is of 200 capacity of the standardized box.
- A single transport order does not demand delivery of the products more than 200 boxes.
- Transport network routes of all the vehicles of 3PL transporters are determined with the product future demand of C-PRIPT model.
- Cost of carrying box is similar for each vehicle and for all kinds of products.
- Loading and unloading time for an order is included in the transportation duration.

5.3.2 Ontologies, perishability constraints & alignment

Here, we illustrate the ontologies used by all producers and transporters systems respectively. These ontologies are developed in Protégé tool and illustrated with ontology viewer tool OntoGraph. Figure 5.9 illustrates an example local ontology of Producer-S, in which Arc Types window represents the relation between the classes. Producer-S generates set of transport orders according to this ontology. Class 'Shipment-order' represents the concept transport order, which is associated to deliver a product represented by 'Commodity'. Commodities are of different kinds like 'Dry', 'Fresh', Refrigerated etc. Producer sets priorities for shipment orders represented by class 'Goal' and have instances like 'Less Costly', 'Urgent'. 'Date' class have instances 'Charge-Date' and 'Discharge-Date' for order. 'Address' class represents location and have subclass 'City'.

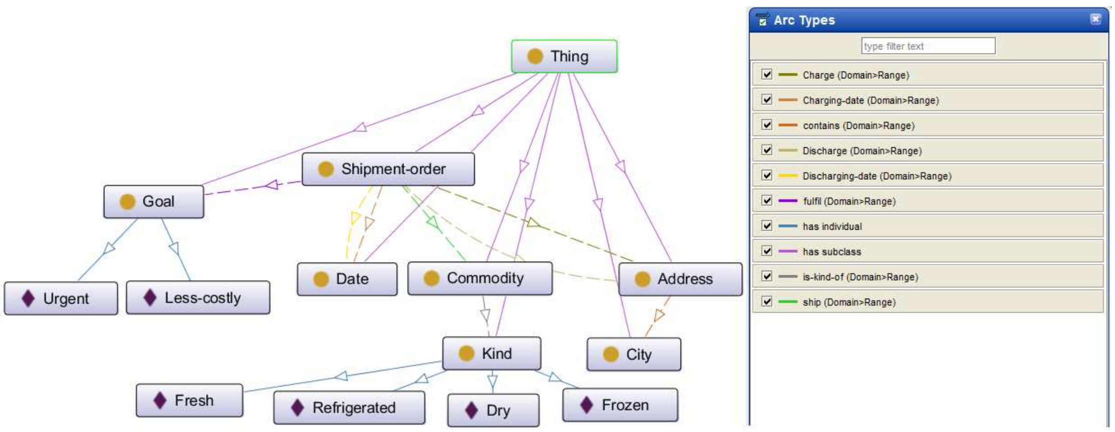


Figure 5.9: *Local ontology of Producer-S*

Similar to Producer-S, figure 5.10 presents an example ontology for producer-F. According to this ontology, transport order concept is represented by class "Delivery-order", which is concerned to deliver the product represented by class "Item". Other concepts are product pickup and delivery which are represented by object properties "Loading" and "Un-load" (see in ArcTypes window) and so on.

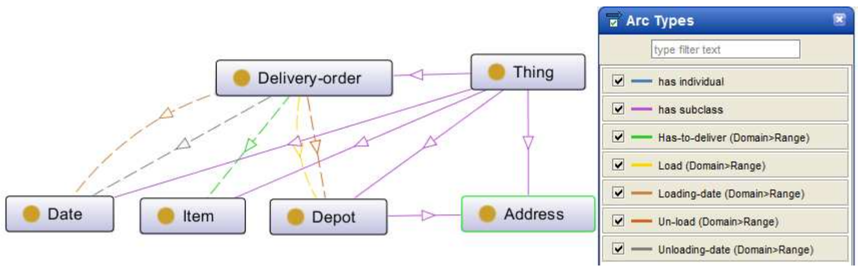


Figure 5.10: *Local ontology of Producer-F*

3PL-F transporter system ontology is shown in figure 5.11. 3PL-F owns fleet of vans represented by class 'Van'. These vans have facilities, represented by a class 'Facility', which has five instances to represent facility types: 'Freezer', 'Normal', 'Low-Refrigeration', 'High-Refrigeration' and 'Ventilation'. Class 'Van' has a relation called 'Has-A' with class 'Trajectory'. Trajectory represents the concept of activities in I-POVES. Each 'Trajectory' has location of 'Departure' and location of 'Arrival' represented by class 'Location'. Each location lies in a certain 'Region', where transporter provides its logistics services. Class 'Location' is associated with class 'Region' with the property 'Lies-In'.

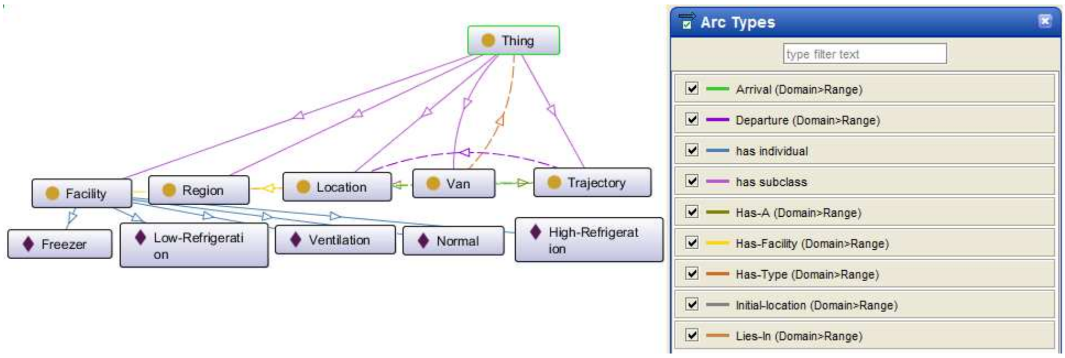


Figure 5.11: *Local ontology of 3PL-F*

3PL-FS transporter system ontology is shown in figure 5.12. It represents the concept vehicle with class 'Truck', which has object property 'Has-travels' (see in ArcTypes window) with class 'Travels'. Class travels represents the same concept as activity in I-POVES. Truck provides the temperature conditions represented by instances of class 'Temperature' to transport particular type of food products and so on.

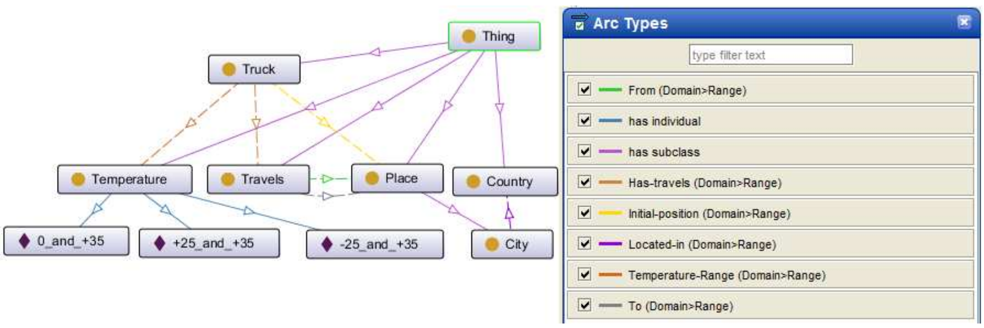


Figure 5.12: *Local ontology of 3PL-FS*

Figure 5.13 illustrates the local ontology of 3PL-S transporter. In this ontology, vehicle concept is represented by class 'Bus' and activity concept is represented by class "route". In order to propose delivery of particular type of food products, it consists of the instances like "Normal", Ventilated, Frozen, "Refrigerated" of class "Product_kind".

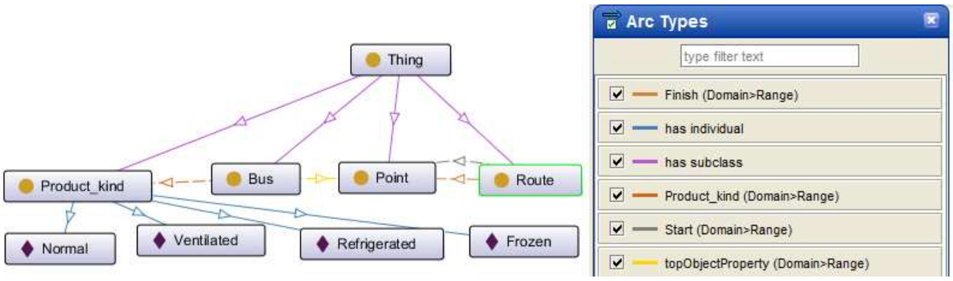


Figure 5.13: *Local ontlogy of 3PL-S*

All the concepts of producer and transporter ontologies have corresponding concepts in the global ontology of I-POVES.

Global ontology

We stated in the chapter 4, that I-POVES planning mechanism functions using terms expressed within its global ontology. Global ontology provides the federated concepts of producer and transporter systems's local ontologies. Global ontology is illustrated in figure 5.14. This ontology contains too much concepts to be shown by OntoGraph view, therefore we used another Protégé ontology viewing tool OWLVIz to show the important concepts. Global ontology contains two groups of concepts. One group is related to transportation planning algorithm concepts, while other group is related to concepts of food products and their constraints.

Transportation concepts used in the global ontology are loosely inspired from the Ozone ontology developed by S.Smith and al [Becker and Smith, 1998, Smith et al., 2005]. For transportation concepts, global ontology has the concept 'Vehicle'. Vehicle performs 'Activity' and has 'Category' partitioned and 'wholespace'. Global ontology has concepts 'Transporter-order', 'Objective' and 'city'. Geographical locations are represented by a chain of concepts like: 'City', 'Street', 'Zone' etc. There is class 'Transportation-mode', which has instances like 'Train', 'Road', 'Sea' etc. Class 'Transport-Order' is associated with class 'Product', which contains the concepts related to food products.

Concepts of food products in global ontology are inspired from the work of [Kolchin and Zamula, 2013, Pizzuti and Mirabelli, 2013]. Class 'Transport-Order' has object property 'has-to-transport' with class 'Product'. Product has two sub classes, 'Food' and 'Constraints'. Class 'Food' has further two sub classes,

Figure 5.14: *Global ontology of I-POVES*

'Food-Type' and 'Food-Category'. 'Food-Type' represents different type of food products (Bakery Items, Diary, etc.). The association between 'FoodType' class and class 'FoodCategory' is represented by the property 'HasCategory', each instance of 'FoodType' is associated with an instance of 'FoodCategory'. These instances are "High-Refrigerated", "Frozen" and so on.

Constraints

'Constraint' class contains the constraints of food represented by its instances 'Short-ShelfLife', 'Sunlight', 'Humidity' and subclass 'Temperature'. Another constraint called compatibility is handeled in semantic rules. These are explained as follows

Temperature: Temperature class has 6 instances (T1, T2, T3, T4, T5, T6), each of the instance is associated to certain temperature limit represented by data property. For example T6 is associated to (Tmin=-18°, TMax=-1°) temperatures. Each instance of class 'FoodCategory' is associated to one instance of 'Temperature' class.

Humidity: Humidity is an instance of class "Constraint". It is associated through object property "hasSensibilityWith" with specific food products directly. In our ontology, we associate it with product instances like 'butter' and 'ice cream' of class 'DairyFood' etc.

Sunlight: Sunlight is an instance of class "Constraint". It is also associated through object property normally with all the food products directly, except the food type of live animals.

Short-ShelfLife: Short-Shelf-life is an instance of class "Constraint". It is also associated through object property with the food types of "FruitandVegetable", "MeatProduct" and "SeaFood".

Compatibility: This constraint is handled by object property "hasNoCompatibilityWith". This constraint is associated between different food categories, for example category "DeepFrozen" has no compatibility with "RoomTemperature" category. If a transport carrier is carrying the product of "DeepFrozen" category, it cannot group with it product of "RoomTemperature" type or vice versa.

Grouping similar product based on the constraints

Activities contain the type of food products (for example frozen, refrigerated, etc.) that vehicle can transport, a list of products is generated (by querying the global ontology) for that activity and stored in the database. So each time when a customer demands delivery of particular kind of product, vehicle agent can propose the transportation based on that list. This list is generated with the help of SQWRL query. When global ontology is searched for the products corresponding to type frozen for example, a list is generated containing the products like: Packed_seaFood, Butter and Ice cream. This list will help group similar kind of products in the vehicle for delivery. Hence, if three orders arrive for Packed_seaFood, Butter and Ice cream respectively, vehicle can transport all three products together.

Alignment of ontologies

Based on the alignment algorithm expressed in chapter 4, alignments of concepts are generated between producer ontologies & global ontology and similarly between transporter & global ontology. Alignment yields similar concepts between ontologies, that are used by ISU (virtual customer and virtual transporter) for transformation between I-POVES and other systems. Their alignment results between above presented ontologies are given in table 5.6 and table 5.7 respectively.

Table 5.6: *Alignment concepts between global and producer ontology*

Global	Producer-S	Producer-F
Transport order	Shipment order	Delivery order
Objective	Goal	-
Early	Urgent	-
Less Costly	Economic	-
Product	Commodity	Item
FoodType	Kind	-
Origin	Charge	Load
Destination	Discharge	Unload
Pickup date	Charging date	Loading date
Delivery Date	Discharging Date	Unloading date
Quantity	Batch	Lot
City	City	Address
Freezer	Frozen	-
High-Refrigerated	Fresh	-
Low-Refrigerated	Refrigerated	-
Normal	Dry	-

Table 5.7: *Alignment concepts between global and transporter ontology*

Global	3PL-F	3PL-FS	3PL-S
Vehicle	Van	Truck	Bus
Activity	Trajectory	Travel	Route
Equipped	Facility	Temperature	Product kind
Origin	Departure	From	Start
Destination	Arrival	To	Finish
Task	Task	Type	Task
ESD	ESD	Status = BEING_PROCESSED	ESD
EED	EED	Status = FINISHED	EED
Capacity	Capacity	Current energy	Capacity
Default_location	Initial position	Default_location	Default_location
City	Location	Place	Point
Region	Region	-	-
Country	-	Country	-
Freezer	Freezer	<-25	Frozen
High-Refrigerated	High-Refrigeration	0 and 10	Refrigerated
Low-Refrigerated	Low-Refrigeration	10 and 20	Refrigerated
Normal	Normal	25 and +35	Normal
Ventilated	Ventilation	25 and +35	Ventilated

All these producers and transporters are connected to central I-POVES as shown in figure 5.15 to collaboratively yield the transportation planning. We present the scheduling results achieved through the collaborative planning in next section.

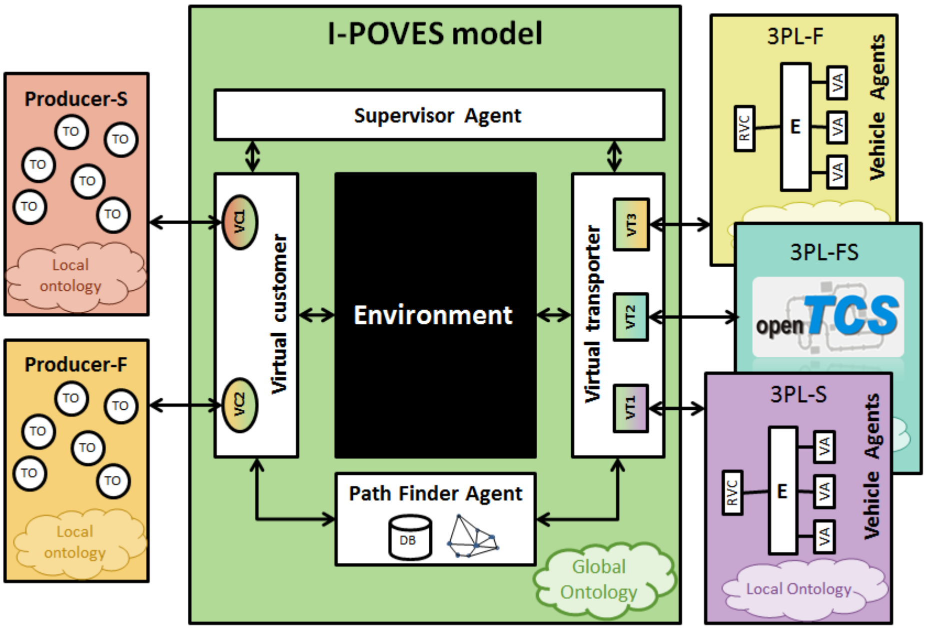


Figure 5.15: *I-POVES with TECCAS pilot case study partners*

5.3.3 Scheduling results

In this section, we present all the results obtained from beginning to end of the planning process.

First of all, all the vehicles and network information (expressed in tables 5.3, 5.4 and 5.5) of all three 3PL transporters received by I-POVES is transformed in to global ontology by respective ISU (virtual transporter). Transformed vehicle activities are then sent to the path finder agent. Path finder agent assigns each activity a unique identifier as shown in table 5.8 and stores this information in its database. Based on this information, path finder constructs the geographical network combining all the networks of all of three 3PL illustrated in figure 5.16.

Then, all the received transport orders from both the producers (expressed in tables 5.1 and 5.2) are transformed in to global ontology by respective ISU (virtual customer) as shown in table 5.9.

Afterwards, each order agent created for each transport order contact path finder agent to find out the shortest route from their origin to destination. Table 5.10 presents results received from path finder consisting of sequenced transport activities for each order.

Table 5.8: *Activities in I-POVES path finder database*

NO	Activity	NO	Activity	Product Category
TA1	(biscarrosse,bordeaux)	TA2	(bordeaux,biscarrosse)	L-Refrige, Normal
TA3	(mimizan,biscarrosse)	TA4	(biscarrosse, mimizan)	Frozen, H-Refrige, L-Refrige, Normal
TA5	(dax, mimizan)	TA6	(mimizan,dax)	Frozen, H-Refrige, L-Refrige, Normal
TA7	(marmande, bordeaux)	TA8	(bordeaux, marmande)	L-Refrige, Normal
TA9	(montauban, marmande)	TA10	(marmande, montauban)	Frozen, H-Refrige, L-Refrige, Normal
TA11	(dax, auch)	TA12	(auch,dax)	Frozen, H-Refrige, L-Refrige, Normal
TA13	(montauban, aush)	TA14	(auch, montauban)	Frozen, H-Refrige, L-Refrige, Normal
TA15	(tarbes, auch)	TA16	(auch, tarbes)	Frozen, H-Refrige, L-Refrige, Normal
TA17	(toulouse, montauban)	TA18	(montauban, toulouse)	Frozen, H-Refrige, L-Refrige, Normal
TA19	(toulouse, narbonne)	TA20	(narbonne, toulouse)	Normal and Ventilated
TA21	(tarbes, muret)	TA22	(muret, tarbes)	Normal
TA23	(perpignan, narbonne)	TA24	(narbonne, perpignan)	Normal and Ventilated
TA25	(pau, bayonne)	TA26	(bayonne, pau)	Frozen, H-Refrige, L-Refrige, Normal
TA27	(tarbes, pau)	TA28	(pau, tarbes)	Frozen, H-Refrige, L-Refrige, Normal
TA29	(lourdes, pau)	TA30	(pau, lourdes)	Frozen, H-Refrige, L-Refrige, Normal
TA31	(lourdes, tarbes)	TA32	(tarbes, lourdes)	Frozen, H-Refrige, L-Refrige, Normal
TA33	(lourdes, jaca)	TA34	(jaca, lourdes)	Frozen, H-Refrige, L-Refrige, Normal
TA35	(huesca, jaca)	TA36	(jaca, huesca)	Frozen, H-Refrige, L-Refrige, Normal
TA37	(pamplona, huesca)	TA38	(huesca, pamplona)	Normal and Vantilated
TA39	(pamplona, bilbao)	TA40	(bilbao, pamplona)	Normal and Ventilated
TA41	(logrona, bilbao)	TA42	(bilbao, logrona)	Normal and Vantilated
TA43	(tudela, logrona)	TA44	(logrona, tudela)	Normal and Vantilated
TA45	(zaragoza, tudela)	TA46	(tudela, zaragoza)	Frozen, H-Refrige, L-Refrige, Normal
TA47	(zaragoza, huesca)	TA48	(huesca, zaragoza)	Frozen, H-Refrige, L-Refrige, Normal
TA49	(lleida, huesca)	TA50	(huesca, lleida)	Frozen, H-Refrige, L-Refrige, Normal
TA51	(zaragoza, lleida)	TA52	(lleida, zaragoza)	H-Refrige, L-Refrige and Normal
TA53	(lleida, barcelona)	TA54	(barcelona, lleida)	H-Refrige
TA55	(zaragoza, reus)	TA56	(reus, zaragoza)	Ventilated
TA57	(barcelona, reus)	TA58	(reus, barcelona)	Ventilated
TA59	(barcelona, girona)	TA60	(girona, barcelona)	H-Refrige
TA61	(perpignan, muret)	TA62	(muret, perpignan)	Normal

Table 5.9: *Transport orders in to global ontology after transformation*

C	O	OB	P	PT	PL	DL	PD	DD	PQ
P1	TO1	Early	Cheese	Frozen	Pau	Tudela	8h 2-7-2014	20h 2-7-2014	50
P1	TO2	Early	White flour	Normal	Dax	Tudela	8h 2-7-2014	20h 2-7-2014	100
P1	TO3	Early	Chicken	H-Refrige	Girona	Tudela	8h 2-7-2014	20h 2-7-2014	100
P1	TO4	Early	Pizza	Frozen	Tudela	Toulouse	8h 2-7-2014	8h 3-7-2014	200
P1	TO5	Early	Oranges	L-Refrige	Zaragoza	Bordeaux	8h 2-7-2014	8h 3-7-2014	150
P2	TO6	Early	Juices	Normal	Bordeaux	Perpignan	8h 2-7-2014	20h 2-7-2014	100
P2	TO7	Early	Juices	Normal	Bordeaux	Lleida	8h 2-7-2014	14h 3-7-2014	100
P2	TO8	Early	Alcohol	Normal	Narbonne	Pamplona	8h 2-7-2014	14h 3-7-2014	100
P2	TO9	Early	Alcohol	Normal	Narbonne	Pau	8h 2-7-2014	20h 2-7-2014	50
P2	TO10	Early	Alcohol	Normal	Narbonne	Biblao	8h 2-7-2014	14h 3-7-2014	100

Subsequently, I-POVES commences the planning process. This process continues with consecutive auctions, until all the transport orders are assigned to vehicles, consisting of all the activities in their route.

In the end of the planning process, we receive the results in the form of a Gantt chart. We now present the planning results obtained by executing the I-POVES with scheduling rules presented in section 5.2.2. From these rules at this stage, we could have implemented first three rules. For the purpose of ease, we use in the rest of the chapter, we refer "Fix-WSD" for Fixed departure with WSD, "Margin" for Fixed departure with Margin and "DRD" for Demand responsive departure with

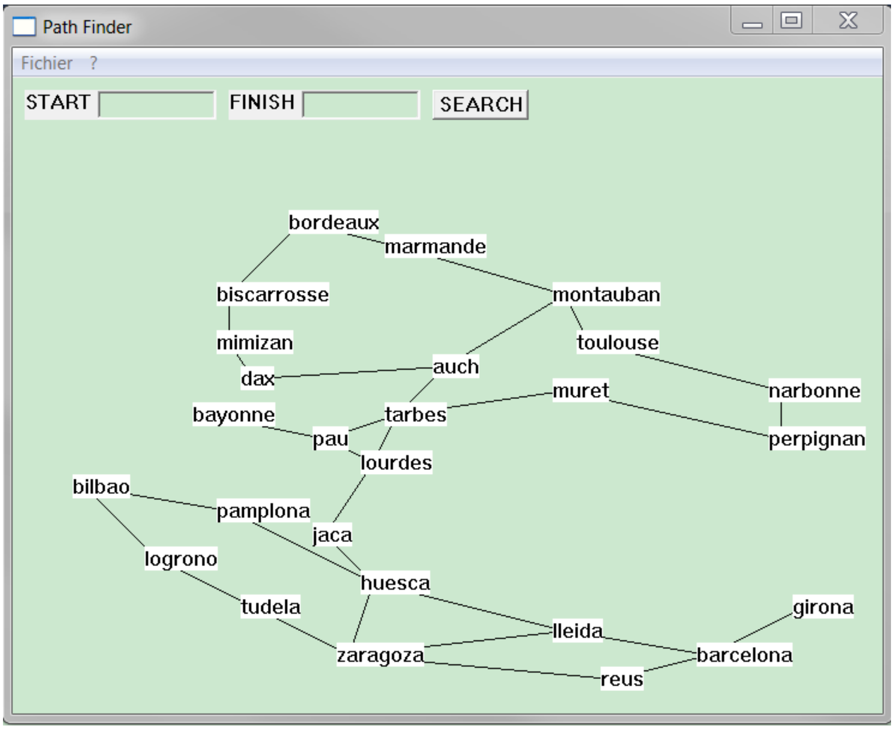


Figure 5.16: *Network construction by Path Finder combining all 3PL-F, 3PL-FS and 3PL-S*

Table 5.10: *Shortest route consisting of activities for each transport order*

Order	Route	Sequence of activities
TO1	Pau→Lourdes→Jaca→Huesca→Zaragosa→Tudela	30→33→36→48→45
TO2	Dax→Auch→Tarbes→Lourdes→Jaca→Heusca →Zaragosa→Tudela	11→16→32→33→ 36→48→45
TO3	Girgona→Barcelona→Lleda→Zaragosa→Tudela	60→54→52→45
TO4	Tudela→Zaragosa→Huesca→Jaca→Lourdes →Tarbes→Auch→Montauban→Toulouse	46→47→35→34→31→15→14→18
TO5	Zaragosa→Huesca→Jaca→Jaca→Lourdes→Tarbes→ Auch→Montauban→Marmande→Bordeaux	47→35→34→31→15→14→9→7
TO6	Bordeaux→Marmande→Montauban→Toulouse →Narbonne→Perpignan	8→10→18→19→24
TO7	Bordeaux→Marmande→Montauban→Auch →Tarbes→Lourdes→Jaca→Heusca→Lleda	8→10→13→16→32→33→36→50
TO8	Narbonne→Perpignan→Muret→Tarbes→Lourdes →Jaca→Huesca→Pamplona	24→61→22→32→33→36→38
TO9	Narbonne→Perpignan→Muret→Tarbes→Pau	24→61→22→27
TO10	Narbonne→Perpignan→Muret→Tarbes→Lourdes→Jaca →Huesca→Pamplona→Biblao	24→61→22→32→ 33→36→38→39

WSD. We explain result obtained by each rule one by one with the one randomly chosen transport order TO9.

5.3.3.1 *Fixed departure with WSD*

Gantt chart result for Fix-WSD is shown in figure 5.17. Gantt chart contains three views of tasks: from order perspective (GANTT TO window), from vehicle perspective and activities perspective (GANTT VEHICLE window).

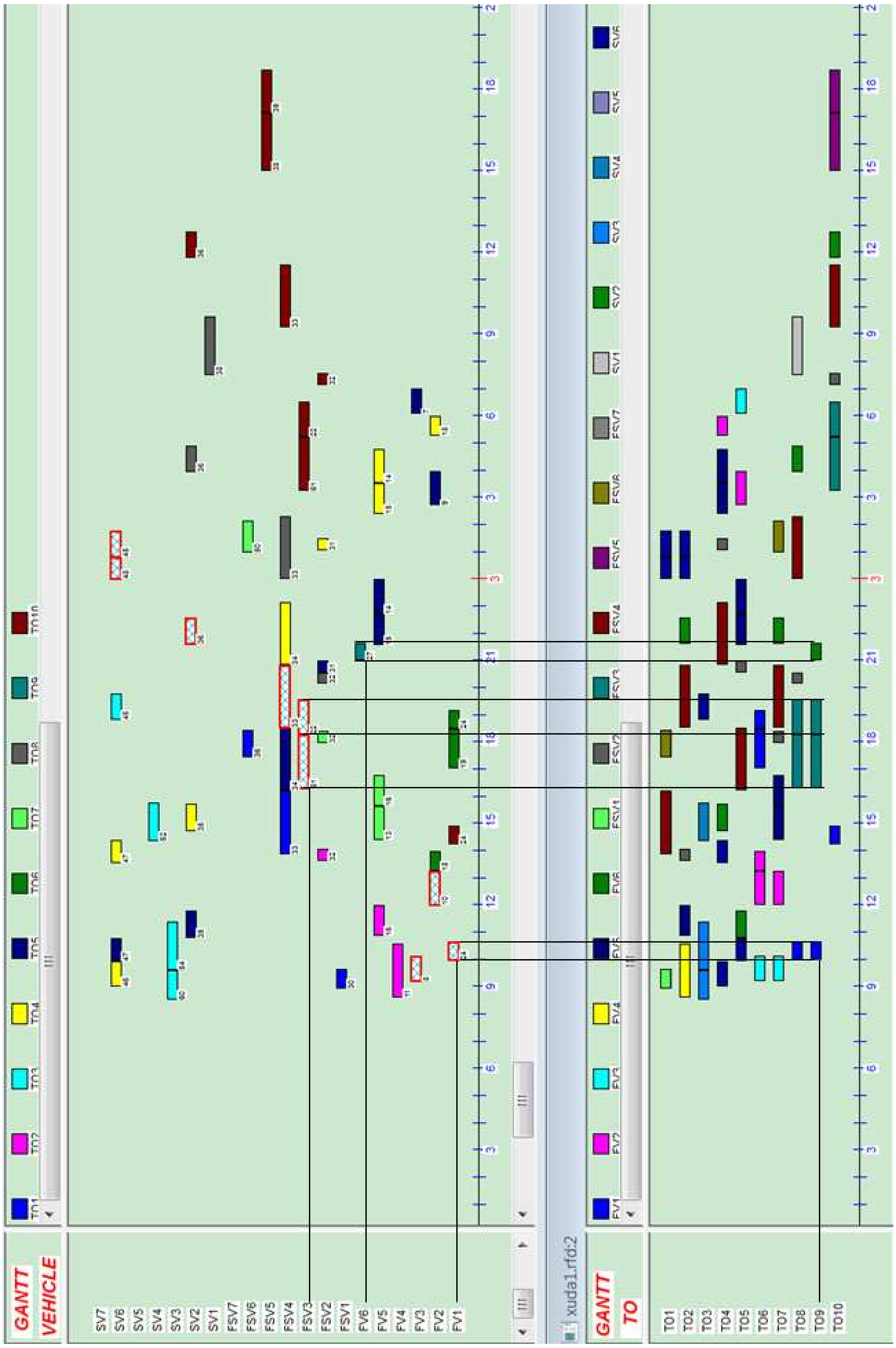


Figure 5.17: *Gantt chart resulted with Fix-WSD rule*

GANTT TO window, which is in bottom of figure 5.17 shows the order perspective, contains list of transport orders on the vertical axis and their corresponding scheduled tasks on the horizontal axis.
On top of the Gantt TO, there is list of vehicles represented by a unique colour. Same colour of the task and vehicle indicates which vehicle is transporting this task.

GANTT VEHICLE window, which is on top of figure 5.17 shows the vehicle and activities perspectives. It contains list of vehicles of all 3PL on the vertical axis and tasks on the horizontal axis. The number on the bottom left of each taks represents the unique identifier of the corresponding activity stored in I-POVES. On top of the GANTT VEHICLE window, we can see the list of transport orders represented by a unique colour. Same colour of task and transport order represents, that vehicle is executing the task for that particular transport order. All the coloured tasks in GANTT VEHICLE show individual tasks. However, tasks with red boundary and sky blue crosses represent the grouped task.

In figure 5.17, we can see in GANTT TO, the list of sequenced tasks of TO9 and corresponding execution by vehicles in GANTT VEHICLE. Table 5.11 details the TO9 schedule consisting of Confirmed Start Date (CSD) and Confirmed End Date(CED), vehicle executing the task and 3PL that owns the vehicle. TO9 is distributed with the collaboration of two 3PL transporters (3PL-F and 3PL-FS) and tasks TA24, TA61 and TA22 of TO9 are grouped with tasks of TO8 for the collaborative delivery. Vehicle FV1 groups TO9 with TO8 for TA24 and vehicle FSV3 groups TO9 with TO8 for TA61 and TA22 (figure 5.17). This grouping therefore, reduces the cost for both TO9 and TO8.

Table 5.11: *Scheduling results for order TO9 for Fix-WSD*

Activity	**CSD**	**CED**	**Vehicle**	**3PL transporter**
TA24	09:59 2/7/2014	10:40 2/7/2014	FV1	3PL-F
TA61	16:20 2/7/2014	18:19 2/7/2014	FSV3	3PL-FS
TA22	18:19 2/7/2014	19:36 2/7/2014	FSV3	3PL-FS
TA27	21:01 2/7/2014	21:40 2/7/2014	FV6	3PL-F

5.3.3.2 *Fixed departure with Margin*

Gantt chart result for Fix-Margin is shown in figure 5.18. In GANTT TO window, we can see the list of sequenced tasks of TO9 and corresponding execution by vehicles in GANTT VEHICLE window. Table 5.12 details the TO9 scheduling results consisting of CSD and CED and vehicles executing the tasks and 3PL that owns the vehicle.

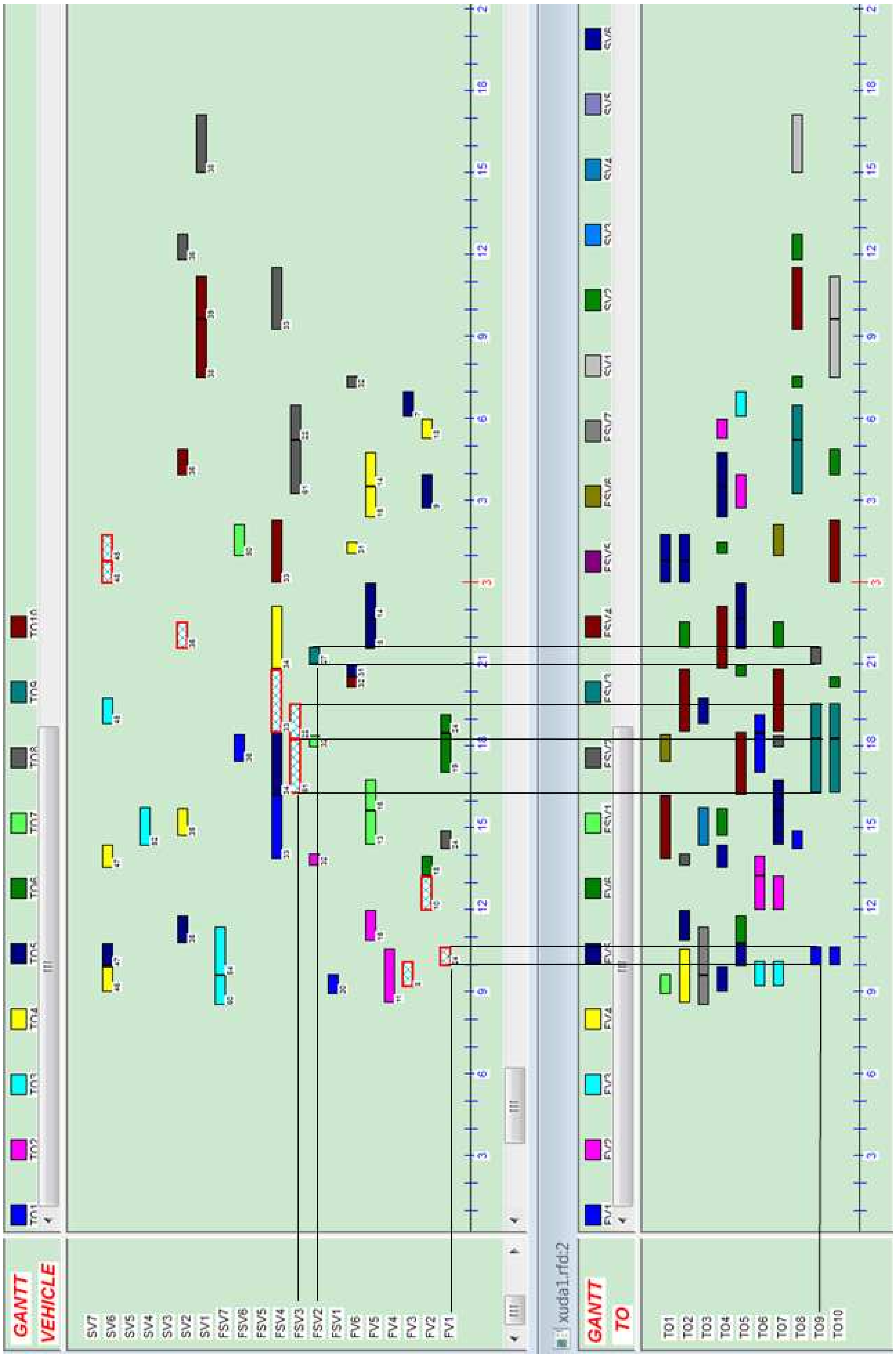


Figure 5.18: *Gantt chart resulted with Fix-Margin rule*

Table 5.12: *Scheduling results for order TO9 for Fix-Margin*

Activity	**CSD**	**CED**	**Vehicle**	**3PL transporter**
TA24	09:59 2/7/2014	10:40 2/7/2014	FV1	3PL-F
TA61	16:20 2/7/2014	18:19 2/7/2014	FSV3	3PL-FS
TA22	18:19 2/7/2014	19:36 2/7/2014	FSV3	3PL-FS
TA27	21:01 2/7/2014	21:40 2/7/2014	FSV2	3PL-FS

TO9 is distributed with the collaboration of two 3PL transporters (3PL-F and 3PL-FS). Similar to Fix-WSD, for the tasks TA24, TA61 and TA22, TO9 is grouped with TO8 for collaborative delivery.

Vehicle FV1 groups TO9 and TO8 for TA24, vehicle FSV3 groups TO9 and TO8 for TA61 and TA22 (figure 5.18). Scheduling results for TO9 of Fix-Margin are similar to Fix-WSD except in Fix-Margin, TA27 task is executed by FSV2 (3PL-FS) rather than FV6 (3PL-F).

5.3.3.3 *Demand responsive departure with WSD*

Gantt chart result for DRD is shown in figure 5.19. In GANTT TO, we can see the list of sequenced tasks of TO9 and corresponding execution by vehicles in GANTT VEHICLE. Table 5.13 details the TO9 schedule consisting of CSD and CED and vehicles executing the task and 3PL that own the vehicle.

Table 5.13: *Scheduling results for order TO9 for DRD*

Activity	**CSD**	**CED**	**Vehicle**	**3PL transporter**
TA24	08:00 2/7/2014	08:41 2/7/2014	FV1	3PL-F
TA61	09:59 2/7/2014	11:58 2/7/2014	FSV3	3PL-FS
TA22	15:56 2/7/2014	17:13 2/7/2014	FSV3	3PL-FS
TA27	20:39 2/7/2014	21:18 2/7/2014	FV6	3PL-F

TO9 is distributed with the collaboration of two 3PL transporters (3PL-F and 3PL-FS). Similar to Fix-WSD and Fix-Margin, for the tasks TA24, TA61 and TA22, TO9 is grouped with TO8 for the collaborative delivery. Vehicle FV1 groups TO9 and TO8 for TA24, vehicle FSV3 groups TO9 and TO8 for TA61 and TA22 (figure 5.19). Empty displacements are represented by white rectangle and dotted line. Empty displacement is performed by vehicle, when the vehicle is not present at the origin of the activity for which task is demanded.

In next section, we analyze the scheduling results obtained in all three rules and compare them on the basis of standard planing evaluation metrics and more.

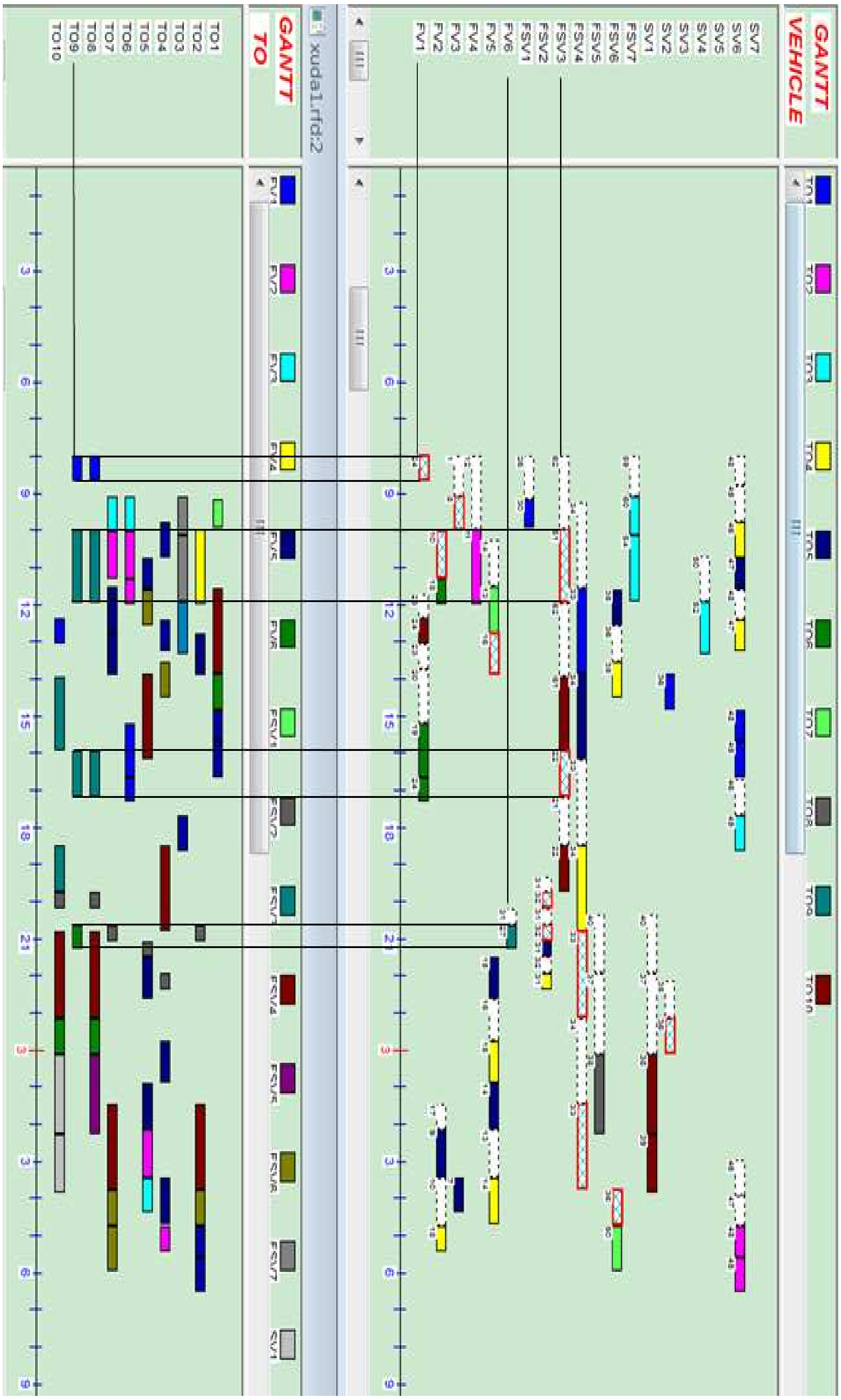


Figure 5.19: *Gantt chart resulted with DRD rule*

5.4 Results analysis

We here evaluate the scheduling results presented in previous section. We compare the results of all three scheduling rules on some well known planning evaluating indicators. These indicators are: Completion time (C_{max}), Tardiness (T_{max}) and Earliness (E_{max}) as shown in figure 5.20[3], while Avg(T) is average tardiness of the planning and Avg(E) is the Average earliness of the planning. Figure 5.20 illustrates the positioning of different parameters used by these indicators.

$C_{max} = C_j$
$T_{max} = \max(0, C_j - d_j)$
$E_{max} = \max(0, d_j - C_j)$
$Avg(T) = \sum_{TO_n}^{TO_i} \max(0, C_j - d_j)\ \forall i.....n$, where $\max(0, C_j - d_j) \neq 0$
$Avg(E) = \sum_{TO_n}^{TO_i} \max(0, d_j - C_j\ \forall i.....n$, where $\max(0, C_j - d_j) \neq 0$

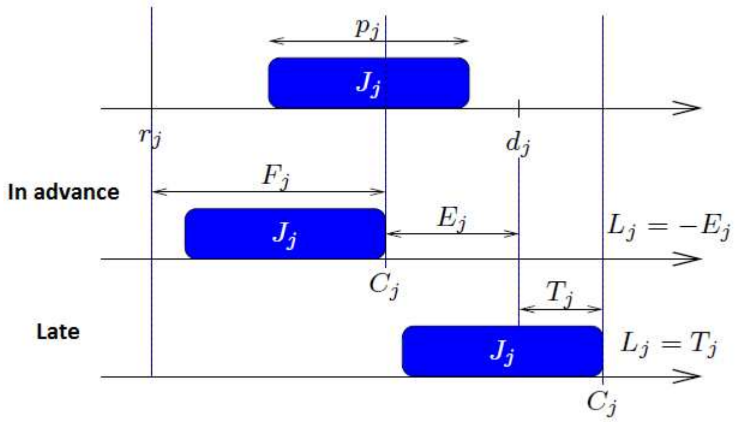


Figure 5.20: *Standard criterian for evaluating planning*[3]

C_{max} defines the final delivery date of the total planning. Table 5.14 presents the final delivery date of each transport order planned in each of the scheduling rules and C_{max} value for each rule. Considering the "Early" objective of transport orders, DRD rule planned the delivery of all orders earlier than the Fix-WSD and Fix-Margin. However, C_{max} value of Fix-WSD and Fix-Margin are very close.

Table 5.15 details the paramaters T_{max}, E_{max}, for each transport order for each rule and Avg(T) and Avg(E) for each rule.

[3]http://www.lamsade.dauphine.fr/ aloulou/cours/formalisation.pdf

Table 5.14: *Delivery time for each transport order in each rule, with C_{max} value*

Transport order	**Origin⟶Destination**	**Fix-WSD**	**Fix-Margin**	**DRD**
TO1	Pau⟶Tudela	03/07/2014 01:48	03/07/2014 01:48	02/07/2014 16:40
TO2	Dax⟶Tudela	03/07/2014 01:48	03/07/2014 01:48	03/07/2014 06:34
TO3	Girona⟶Tudela	02/07/2014 19:48	02/07/2014 19:48	02/07/2014 18:40
TO4	Tudela⟶Toulouse	03/07/2014 06:00	03/07/2014 06:00	03/07/2014 05:28
TO5	Zaragoza⟶Bordeaux	03/07/2014 07:03	03/07/2014 07:03	03/07/2014 04:25
TO6	Bordeaux⟶Perpignan	02/07/2014 19:12	02/07/2014 19:12	02/07/2014 17:21
TO7	Bordeaux⟶Lleida	03/07/2014 02:11	03/07/2014 02:11	03/07/2014 05:58
TO8	Narbonne⟶Pamplona	03/07/2014 09:40	03/07/2014 17:10	03/07/2014 02:18
TO9	Narbonne⟶Pau	02/07/2014 21:40	02/07/2014 21:40	02/07/2014 21:18
TO10	Narbonne⟶Biblao	03/07/2014 18:45	03/07/2014 11:15	03/07/2014 03:53
Cmax:		03/07/2014 18:45	03/07/2014 17:10	03/07/2014 06:34

Table 5.15: *T_{max}, E_{max}, Avg(T) and Avg(E)*

	T_{max} (hours)			**E_{max} (hours)**		
Transport orders	**Fix-WSD**	**Fix-Margin**	**DRD**	**Fix-WSD**	**Fix-Margin**	**DRD**
TO1: Pau⟶Tudela	5h	5h	5h	0	0	0
TO2: Dax⟶Tudela	5	5	10	0	0	0
TO3: Girona⟶Tudela	0	0	0	0	0	1
TO4: Tudela⟶Toulouse	0	0	0	2	2	1, 5
TO5: Zaragoza⟶Bordeaux	0	0	0	1	1	3,5
TO6: Bordeaux⟶Perpignan	0	0	0	1	1	2, 5
TO7: Bordeaux⟶Lleida	0	0	0	12	12	8
TO8: Narbonne⟶Pamplona	0	0	0	4	9	12
TO9: Narbonne⟶Pau	2	5	1	0	0	0
TO10: Narbonne⟶Biblao	5	0	0	0	3	10
Avg(T)	4h15min	5	5h20min			
Avg(E)				4h	4h40	5h30min

T_{max} represents the duration of tardiness after due date for an order planned. We can see in table 5.15 that TO1, TO2, TO9 and TO10 are planned with tardiness, where TO2 tardiness in DRD is almost double of the duration in Fix-WSD and Fix-Margin. However, Avg(T) which is the average tardiness value, there is very slight difference of tardiness in all the rules. Zero value in columns indicates that delivery date of order is scheduled on time or before.

E_{max} represents the duration of earliness before due date of an order planned. TO4, TO5, TO6, TO7, TO8 are planned early in all the rules. TO3 is early in DRD, TO10 is early in Fix-Margin by 3 hours but delay in DRD by 10 hours. Similar to Avg(T), Avg(E) is average earliness value also, which seems to be close in all the rules. Zero value in columns indicates that either order is on time or it is planned with tardiness.

Considering the delivery date given by producers for the orders as mentioned in table 5.9, order TO3 is delivered exactly on the time. Objective for all the orders for case study is the delivery with earliness or on time. Fix-WSD plans 6 orders with earliness, Fix-Margin plans 7 orders with earliness and DRD rule plans the 7 with earliness comparing the total of 10 orders. It means maximum of 70% success ratio.

Occupancy rate: Another important indicator is rate of occupancy, which is to determine the time that vehicle is busy during the transportation. Occupancy rate is the ratio between vehicle utilized time and total time during a certain time interval. Figure 5.21 presents the rate of occupation for all the 3PL vehicles for all the three rules. We can see that, rate is almost identic for Fix-WSD and Fix-Margin and does not surpass more than 50%. However for DRD, rate is much better, it even goes to 90% for vehicle FSV6. We can also identify that, rate for vehicle SV7 is equal to 0, means it is never utilized.

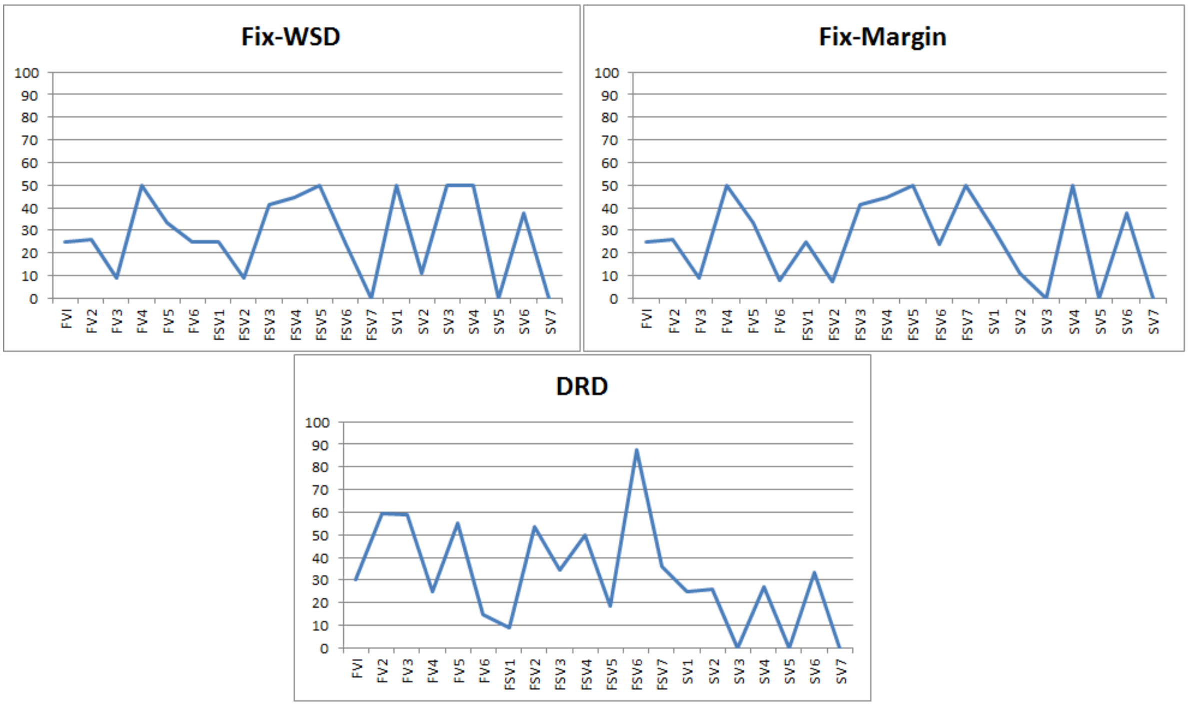


Figure 5.21: *Vehicles rate of occupation for all the three rules*

Other few criteria that we think that are important in our context are following:

Grouping: Here, we consider grouping of more than one tasks, means for how many displacements more than one transport orders are transported by the same vehicle at the same time. Figure 5.22 illustrates the total number of grouped tasks achieved in each rule. We see that 9 displacements are grouped for Fix-WSD and Fix-Margin, but 15 for DRD, so for grouping DRD performs better than other two.

Total displacements (excluding empty travels): For this criteria, we measure number of displacements that are performed by all the vehicles to deliver all the orders. If more than two orders are grouped for an activity, this displacement is

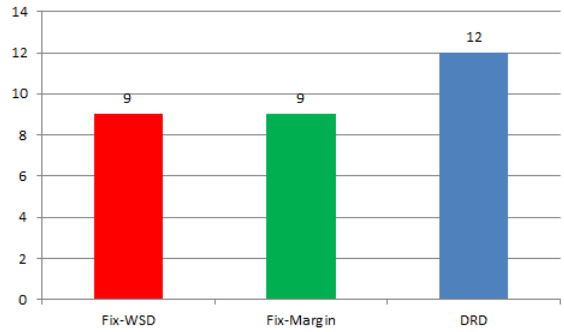
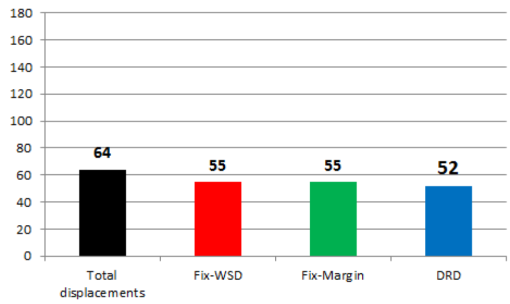


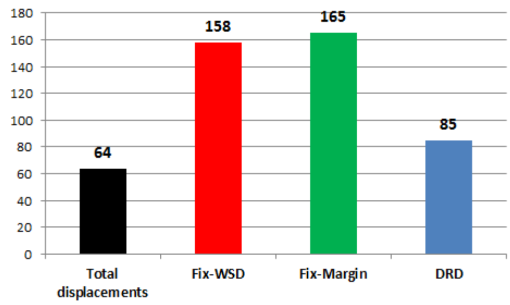
Figure 5.22: *Total number of grouped tasks in each rule*

counted as one and we do not take into account empty travels. Considering the route of all transport orders, there are total numbers of 64 tasks.
Figure 5.23a shows the number of displacements in each rule comparing to total displacements. As for DRD rule, grouping of orders is more than the other two rules, therefore total displacements by DRD are also less that other two rules.

Total displacements (including empty travels): This criteria is similar to previous one, except here we include empty travels in total number of displacements performed in each rule. Figure 5.23b illustrates the comparison. For Fix-WSD and Fix-Margin displacements are more, because vehicles run on the fixed schedule. However for DRD, displacements are much less, because vehicles perform travels when there is any demand of the order.



(a) Total displacements (excluding empty travels)



(b) Total displacements (including empty travels)

Figure 5.23: *Total displacement comparison*

Total Distance (excluding empty travels) : is equal to sum of the distance of all the vehicles in each rule excluding empty travels.

Total Distance (including empty travels) : is equal to sum of the distance of all the vehicles in each rule including empty travels. Table 5.16 details distance traveled by each vehicle and total distance in all three rules.

Table 5.16: *Total distance excluding and include empty travels*

	Excluding empty travels			Including empty travels		
Vehicles	**FIFO**	**Margin**	**DRD**	**FIFO**	**Margin**	**DRD**
FV1	351	351	251	942	942	636
FV2	392	392	392	1746	1746	534
FV3	182	182	182	1502	1502	256
FV4	155	155	155	155	155	310
FV5	549	549	477	1185	1185	723
FV6	47	92	47	47	258	70
FSV1	41	41	41	41	41	156
FSV2	138	93	92	1143	513	138
FSV3	710	710	710	1150	1150	1285
FSV4	762	762	635	1143	1143	508
FSV5	319	0	164	310	0	479
FSV6	189	189	343	567	567	420
FSV7	0	262	262	0	262	365
SV1	164	483	319	164	802	474
SV2	385	385	154	1694	1694	231
SV3	262	0	0	262	0	0
SV4	157	157	157	157	157	269
SV5	0	0	0	0	0	0
SV6	483	483	644	1610	1610	1172
SV7	0	0	0	0	0	0
Total distance	5286	5286	5052	13818	13727	8026

We can see that for travels excluding empty travels, there is no much difference in all three rules. However, by including empty travels, vehicles travel much less distance for DRD than other two rules. By analysing the all these results, we can deduce within the context of case study that, second rule Fix-Margin provides almost similar results as Fix-WSD in case of grouping, but slightly better in other criteria like distance travelled. However, DRD seems to be performing better than first two rules in almost all criteria, especially in case of grouping, empty, travels and total distance travelled and rate of occupation. This improvement really encourages us to continue implementing more rules and make the vehicle's movement more flexible in order to reduce the order delay and empty travels.
However, these results are not conclusive as there are only 10 orders. Moreover, purpose of using fixed route for vehicles is to consider the future product demand. Therefore as we can foresee, with the number of growing transport orders, Fix-WSD and Fix-Margin will also perform much better. Authors in [Li and Quadrifoglio, 2010] figured out that fixed-route systems perform best under high demand levels. Therefore, each result described here can be validated by the complete study with bigger and varying case study scenarios.

5.5 Conclusion

This chapter is dedicated to present the application of our research work realized in this thesis. This application is executed on a food supply chain case study retrieved from the European project TECCAS for which this thesis is prepared. The purpose of TECCAS project is to develop the technologies to promote collaboration between the actors of food supply chain in the cross border area of France and Spain.

Therefore firstly, we introduced the TECCAS project followed by its SOA based framework. This framework is the implementation of our collaborative model C-PRIPT. Subsequently, we presented the scheduling rules developed on the basis of industry feedback collected through the partners (CCIA and AIAA) involved in TECCAS project.

Then, we presented the application of I-POVES model with pilot case study focusing on the aspect of interoperability between actors of FSC (producers and transporters) and on solving the transportation problem collaboratively. We showed the final scheduling results in the form of Gantt charts with three implemented rules: Fixed departure with WSD, Fixed departure with Margin and Demand responsive departure with WSD and explained scheduling results obtained using these rules in I-POVES with the help of a randomly chosen transport order from the case study.

For evaluation, we performed statistical analysis of the scheduling results with different standard planning evaluation indicators. We deduce that our results are improving considering the selected case study but these results are not conclusive and are subjected to vary. Therefore more rigorous and large case study sets are required to be tested, in order to be certain about the consistency of acquiring better results.

General conclusion

The purpose of this thesis is the collaboration of actors of FSC including the transporter. Key starting points of this work is identifying collaboration areas among different partners involved in FSC, such as collaboration between: producers, producers & retailers, producers & transporters, transporters & retailers and transporters. These areas specify the focal points, requiring the need for collaborative activities in order to improve the overall performance of FSC. After studying the existing collaborative approaches like ECR, JIT, QR, VMI CPFR, we find out that these approaches do not take into account transporter actor, which today is the important link for FSC. Nowadays with advent of 3PL enterprises, transportation has been separated from manufacturing enterprise and therefore SC structure and business processes become more complex with the appearance of transport operators. The evolution of the role of transportation makes a new independent SC member: transport operator. Moreover, for transportation itself, several transporters and producers require cooperating to yield collaborative transportation planning in a complete heterogeneous environment. Hence, interoperability among these systems is the key to collaboration. Additionally, existing collaborative approaches consider production planning as the implicit part of replenishment process not a collaborative task. However, production is distributed to several sites and several producers produce semi-products which are assembled to form the final product. Replenishment process from these collaborative approaches propose to generate the production orders from forecasts to reduce the uncertainty, but how production of these orders are planned is itself a collaborative activity among different producer partners in the FSC. Based on these deductions, the main scientific issues have been identified and answered in this thesis:

- *What to collaborate?* Collaborative activities are defined with their input and output data among three types of actors of FSC: Producer, Transporter and Retailer. These activities collectively achieve the collaborative planning processes of: forecasting, storing, replenishing, producing and transporting.

- *How to collaborate?* Interoperable model based on ontologies and interoperable service utilities is developed to yield transportation planning by making collaborate producers and transporters systems.
- *Handling of perishability constraints?* Food product concepts of different food types, categories, temperature requirements and constraints are expressed in the form of ontology (part of the global ontology). These concepts are applied by the transportation planning model while proposing the planning

Thesis objectives and scientific contributions

The global objective of this thesis consists in developing a reference model for collaboration in FSC including the transporter.

- To achieve this objective, we propose the C-PRIPT model. C-PRIPT model consists of five collaborative phases, from which initial two phases: "Planning" and "Replenishment & Inventory planning" are based on the CPFR model. The remaining three phases are: "Production planning", "Transportation planning" and "Production-Transportation planning". All these phases contain collaborative activities, interactions, kind of data input and data output for the integration of these activities. These activities are inter-related and function in collaboration with each other to improve the overall efficiently of FSC.

The detailed objective is to enable interoperability among producers and transporters to result transportation planning collaboratively.

- To achieve this objective, we propose the I-POVES model. I-POVES is an ontology based interoperable model developed for transportation planning activities by collaboration of transporters and producers. I-POVES is designed especially in order to provide planning for food products delivery by considering their perishability constraints. It is assumed that transporter and producer systems possess their local ontologies. Interoperability of these systems is achieved by translating their concepts in the global ontology of I-POVES through interoperable service utilities. In order to validate the study, a pilot case study is retrieved from a European project TECCAS, for which this work is realized. We showed the execution of our model I-POVES on this case study and analysed the results.

Limitations

The main limitations of our work are actually the consideration of standardized box for all kinds of products and we did not yet define the carrying capacity of live animals and size and weight of the different products. I-POVES does not have any mechanism to handle penalties for transporters or producers in case of delay or damage or change of plan. Ontologies used are very basic and immature and need improvement. I-POVES does not take into account at this stage perturbation during transportation and reactive strategies to handle them, however reactive strategies are implemented in its ancestor model SCEP. They just need to be adapted in I-POVES. I-POVES does not consider the different cost structure of different type of products, frozen, Refrigerated; Normal etc. I-POVES does not have any mechanism to divide the transport order product quantity among multiple vehicles, in case if one vehicle lacks the capacity to transport it completely.

Perspective

Firstly and immediate perspective is to implement fourth scheduling rule that is proposed in the thesis, but not yet implemented. Secondly, work on limitations presented above. Thirdly, study state of the art of Tracing & Tracking methods and approaches and incorporate retailer actor in collaboration with I-POVES model. Thirdly, consider the food security information, like origin, lot, manufacturing date, best before date, etc. in order to improve planning. Fourthly, researching price negotiation mechanism and consider product weight, size parameters. Fifthly, test the I-POVES model with large data set and improve the GUI visualization of the scheduling results. Finally, the other perspective is to realize C-PRIPT based SOA framework of TECCAS project proposed in this thesis and tests it's working.

Terminologies

3PL Third party logistics. 14, 38, 46, 47, 51, 53

4PL Fourth party logistics. 46

C-PRIPT Collaborative - Planning, Replenishment, Inventory, Production and Transportation. 51, 53–57, 59, 60, 63, 67–69, 71, 75, 76, 104, 106, 123, 144

CPFR Collaborative Planning, Forecast and Replenishment. 39, 43, 46

CPPM Collaborative Production Planning Model. 65, 68

CRP Continuous replenishment program. 39, 41, 44

CTPM Collaborative Transportation Planning Model. 67, 68

ECR Efficient consumer response. 39–41

ERP Enterprise resource planning. 24–27

FSC Food Supply Chain. 3, 4, 10–12, 17, 19–23, 27, 28, 30, 32, 33, 36–41, 46, 47, 51, 53, 54, 57, 64, 66, 67, 69, 71, 75, 77, 86, 99, 119, 144

I-POVES Interoperable-Path Finder, Order, Vehicle, Environment and Supervisor. xii, 82–84, 86–94, 99, 106, 107, 118, 122, 123, 125, 126, 129–131, 134, 144

JIT Just in time replenishment. 39

LE Large enterprises. 10, 17, 69, 71

POS Point of sales. 19, 43, 44, 52, 59, 60, 62, 69

QR Quick response. 39, 40

SC Supply Chain. 3, 4, 11–17, 19–25, 30, 31, 35, 37, 39–41, 43–46, 51

SCE Supply Chain Execution. 26

SCM Supply Chain Management. 4, 22–28, 30, 39

SME Small and medium-sized enterprises. 10, 14, 17, 69, 71

VC Virtual customer. 82, 86–89, 93–95, 99

VMI Vendor Managed Inventory. 39, 42, 44–46

VT Virtual transporter. 82, 87–89, 93, 99

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Abstract:

Human's survival depends on both quality and quantity of food. Quality is associated with respecting food perishability constraints like short shelf-life, temperature sensitiveness, etc. Though increasing population requires an increasing quantity of food, causing increase in food processing, production, distribution, sales etc. and involving several entities like producers, distributers and retailers. All these entities jointly form the environment of Food Ecosystem (FES). In FES, we can identify the different collaborations of enterprises, for a particular type of food forming a Food Supply Chain (FSC). FSC requires enormous transportation network to connect all the concerned entities. This increasing food transportation leads to an increasing in the number of transport travels, environmental pollution and transportation cost. Necessity to cope with transportation demand led to the emergence of a new actor in FSC called transporter. Therefore, transporters also need to collaborate, with other actors (producers, retailers, etc.) for maintaining uninterrupted flow of products while preserving their quality. Hence, FSC inherits not only the common problems also faced by supply chains, but has also to deal with the problems arising from the perishability of food products. Therefore, it is necessary to institute collaboration between the main entities of FSC to deal with all of these problems. Existing collaborative approaches like Vendor Managed Inventory and Collaborative Planning, Forecasting and Replenishment do not consider transportation as collaborative tasks. Therefore, in this thesis, we firstly propose a model called C-PRIPT, for making different actors in FSC, including transporter to collaborate. Secondly, a model called I-POVES is proposed, to realise transportation planning by collaboration of producers and transporters, aiming at a better use of transport resources. Finally, we illustrate the functioning of I-POVES model by applying it on a case study of FSC.

Keywords: Interoperability, Transportation planning Multi-agent systems, Third party logistics, Ontology, food supply chain, Collaboration.

Résumé

La survie de l'humain dépend de la qualité et de la quantité de nourriture ingérée. La qualité est associée au respect des contraintes des produits alimentaires comme une courte durée de vie ou la sensibilité à la température. Cependant, l'augmentation de la population entraîne une augmentation de la quantité de nourriture nécessaire, qui entraîne augmentation de la production, de transformation de distribution et des ventes d'aliments. Les entités comme les producteurs, les distributeurs et les détaillants sont eux aussi en augmentation. Toutes ces entités forment conjointement l'environnement de l'écosystème alimentaire (FES). Dans le FES, nous pouvons identifier les différentes collaborations d'entreprises, pour un type particulier de nourriture formant une chaîne logistique alimentaire (FSC). Une FSC requiert un énorme réseau de transport pour relier toutes les entités concernées. Cette augmentation de transport d'aliments, menant à une augmentation du nombre de déplacements, de la pollution environnementale et des coûts de transport. Cette nécessité de faire face à la demande de transport a conduit à l'émergence d'un nouvel acteur dans FSC appelé transporteur. C'est pourquoi le transporteur doit lui aussi collaborer avec d'autres acteurs (producteurs, distributeurs, etc.) pour maintenir un flux ininterrompu des produits en préservant leur qualité. Ainsi, les FSC héritent des problèmes classiques des chaînes logistiques, mais doivent en plus gérer les problèmes découlant de la périssabilité des produits. Il est donc nécessaire d'établir une collaboration entre les entités principales de la FSC pour traiter tous ces problèmes. Les approches de collaborations existantes comme "Vendor Managed Inventory" et "Collaborative Planning Forecasting and Replenishment" ne considèrent pas le transport comme une activité de collaboration. Dans cette thèse, nous proposons tout d'abord modèle C-PRIPT permettant de faire collaborer différents acteurs de la FSC. Ensuite, nous proposons un model I-POVES réalisant la planification des transports en collaboration avec les producteurs et les transporteurs, visant à une meilleure utilisation des ressources de transport. Enfin, nous illustrons le fonctionnement du modèle I-POVES en l'appliquant sur un cas étude de FSC.

Mots clef : Interopérabilité, Planification de transports, Système multi-agents, Logistique tierce partie, Ontologie, Chaine logistique alimentaire.