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Collaborative transportation for small and medium enterprises for advancing the emerging countries

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Abstract

Food needs are growing rapidly with the growing population especially in case of developing countries where food preservation technology is not that much mature or even not available. It results enormous increase in prices of food commodities and higher growth rate of inflation each year. Additionally population is dispersed in the country in form of very small and large cities. Similarly, food grown in the country is also dispersed in the different areas of the country. This is highly necessary to use effective modes of transport, to collect food from these regions and distribute it with equilibrium in all the human living regions. Additionally to reduce the wastage of food in case of food shortage especially in some part of the African continent region. Food products and ingredients found and grown in one region are transported to another region, making it possible to use and eat them where they are not found. Small farmers or food producers to reach the scattered areas to distribute their products at time and cost effectively could not purchase their own vehicles, ships or planes to transport their goods. These companies contact third party transporter companies to transport their products, same as a courier company. These companies are called Third Party Logistics enterprises (3PL). These 3PL enterprises take the responsibility of performing logistics functions entirely or partially of an organization. They manage their own fleet of vehicles which drive in a certain and region. The diversity of clients due to different kind of product distribution (fresh, frozen etc.), distance from production companies and distribution cities, the size of the transport network make it even very complicated for a 3PL transporter to manage transportation planning and make efficient use of their resources. Moreover a single 3PL transporter also covers a limited region; they must collaborate with other 3PL enterprises which operate in other regions to make the delivery of the products to faraway locations. Complexity of transportation planning increases further in case of multiple 3PLE enterprises collaborating for the fulfilment of a transport order(s). The objective of this paper is to present a collaborative and distributed model for transportation planning activities aimed at better utilize transport resources by grouping several orders of transports for each effective displacement.

1. Introduction

In developing countries, qualities of roads do not let vehicles travel with low friction or cover the distance with the estimated standard time for that distance, causing delay in the transport. Additionally poor maintenance of transporting vehicles also decreases vehicles performance and increases CO₂ emission. Transporters providing the transport to small and medium enterprises are very rare and hence cannot cover each area in the country. Delay in transport product delivery generates risk of degradation and contamination of food products. Other

factors of degradation involve not following sanitary requirements as per standards set by International organizations like ISO. Thus resulting wastage of food and losing profit earning opportunities.

Transportation costs are increasing due to the steady increase in oil prices. These costs have become a major concern for the small and medium food generators, because it increases the cost of the raw materials that they procure as well as the distribution of products to consumers. The impact of transportation costs on products don't permit usually those companies which want to reach faraway clients and manage their own resources (vehicles, ships, aircraft, etc..) to transport their goods.

The effort to reduce the cost of transportation has encouraged the emergence of new third-party enterprises specializing in logistics and transport, commonly known as 3PLE (Third Part Logistics Enterprise [1]. These 3PLEs mutualize the exploitation, warehousing and transportation resources between several companies. They take charge of whole process of transportation from loading products since suppliers' warehouses to the distribution of goods to customers. The increase in number of transportation orders, diversity of clients due to different kind of business activities, distance from production companies and distribution sites, the size of the transport network make it even very complicated for 3PLE to manage transportation planning. To fulfil customers' demands and improve the performance of supply chains, it must manage its own resources and often collaborate with other companies 2PLE (carriers) and 3PLE.

In this paper we propose a framework for transportation planning for a 3PL enterprise in a distributed manner. This framework can help improve transportation for emerging countries by utilizing the resources at maximum. This framework will also reduce the transportation cost for small farmers or food products manufacturers by grouping multiple transport orders together which is the major concern for developing countries. The objective is to evaluate the ability of POVES (Path Finder, Order, Vehicle, Environment, and Supervisor) framework for transportation planning process. After a state of the art on the latest research on transportation planning, we describe POVES model and illustrate its application with a case study. Finally, we conclude with future work.

2. Related Works

Several approaches have been proposed to solve transportation planning problem. J. Sauer et al [2] proposed a centralized approach with a global scheduler, which schedules transportation planning activities. They model the problem by a 5-tuple(R, P, O, HC, SC), where R denotes the set of required resources, P the set of products, O the set of actual orders, and HC and SC the sets of hard and soft constraints, respectively. They use a rule-based approach and heuristics to produce several scheduling strategies. This approach is centralized and is limited to the planning of transportation activities of a single enterprise. Today, the enormous size of the transport networks requires, to realize the plan with collaboration of many transportation enterprises. These enterprises most often, wish to keep certain confidentiality of their organization, their models, their methods and their data. The need for confidentiality limits the scope of centralized approaches.

A.Baykasoglu et al [3] proposed a multi-agent approach to address collaborative transportation problem. This approach is based on cooperation between transport-order agents and truck agents, which propose grouping multiple orders together in a vehicle. Agents communicate with each other in order to choose the best economical way to transport the order. In this approach, transport order agent is bound to accept the proposition from one truck agent, which provide a nonstop delivery from origin to destination. However, in reality

considering enormous size of the transport network, a truck rarely alone transports a transport order. A transport order requires, most often, several trucks.

R.Sprenger et al [4] proposed a multi-agent system for cooperative transportation planning. This system decomposes overall transportation problem into sub problems and solve those sub problems on autonomous basis with Ant colony Optimization approach. This work neither explains suitably decomposition methodology and nor decomposition's effect on overall transportation problem. Additionally it does not consider privacy issues between manufacturers and they don't take into account multiple orders together while sharing vehicles.

S. Zegordi et al [5] study integrating transportation and production scheduling by considering multiple sourcing in a two-stage supply chain scheduling problem. In which the first stage is composed of multiple suppliers distributed over various geographic zones. In the second stage, vehicles transport jobs from suppliers to a manufacturing company. This transportation scheduling is based on genetic algorithm. Manufacturing company splits the order between multiple suppliers according to quota. Then, each supplier transports its quota of raw material to the single manufacturing company, which achieves an assembling of all the received raw materials. Suppliers located in the same geographical zone could transport their raw material to the manufacturing company by sharing vehicles. This approach is a centralized approach which will face the confidentiality issue. Additionally, due to critical economic conditions, this is not acceptable that vehicles return empty to suppliers that are resulted from this method.

Tchapnga et al [6] propose a multi-agent heuristic to address the transport problem with transshipment. Their methodology is decomposed in four steps. In first step they calculate PDP (pickup and delivery solution) without transshipment/ Cross Docking solution for all random requests. In second step they try to optimize the PDP solution with VND (Variable Neighbourhood Descent method) using Path Relinking. VND consists of three operators; SWR (swap requests between routes), RNR (remove and insert a request) and ADR (Advance or delay request). Path relinking is to transform new iteration with existing solution (I did not understand it properly). In the third step they calculate PDPT (PDP with transshipment) solution and compare it with PDP solution and keep the best one. This whole procedure is repeated to the number of iterations. They do the grouping, but vehicles number is not fixed, they calculate PDPT solution for each PDP solution whether it may be unnecessary in some situations. This work makes an assumption that number of vehicles is not fixed and if no vehicle can satisfy a request because of the noncompliance with the constraints (vehicle capacity, time windows etc.), a new route is created with the new vehicle to welcome the considered request. However in our work we consider that number of resources (vehicles) is fixed, they are not infinite, so if a vehicle cannot satisfy the request, that request has to wait until its return or some other vehicle can satisfy the request that follows the same route of the request entirely or partly. Secondly, this method first calculates PDP solution without transshipment and then improves it, by optimizing it and then it destroys the PDP solution to obtain PDPT solution with transshipment. In our method we try to find PDP solution if we cannot find PDP solution then we find PDPT solution. It is unnecessary to calculate PDPT solution for a request, whether if it can be transported without transshipment. It is possible that results of both methods may generate similar results. But this method is much lengthier than ours.

In further studies, a simulation framework is presented in [7] for assessing the performance of cooperative transportation planning and isolated transportation planning. Groupage systems [8] are introduced, which are defined as logistics an inter-organization system that interchange required information and manages capacity balances between different independent transporters. M.Mes et al [9] study the interaction between intelligent agent strategies for real-time transportation planning. A multi-agent theoretical approach on dynamic transportation planning is given in [10]. D.Yazan et al [11] examines the environmental impact of transportation and how it can be altered by showing current and reengineered supply chain through a case study.

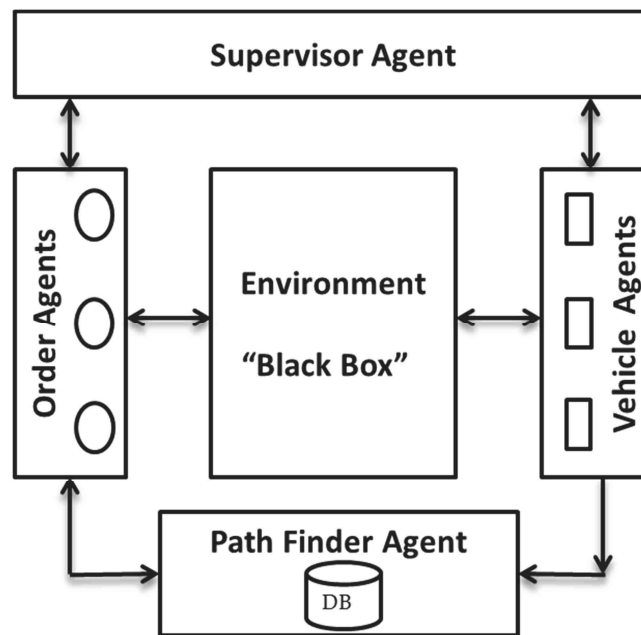


Fig:1 POVES Model

3. POVES MULTI-AGENT MODEL

3.1 Description of model

The POVES multi-agent model (Figure. 1) is developed for collaborative transportation planning activities. It is inherited from SCEP multi-agent model [12, 13]. Limitations restricted SCEP for transportation planning are given in [14], due to that POVES emerged after overcoming these limitations. POVES introduces an indirect cooperation between two communities of agents, Order agents called (O) and vehicle agents called (V), leading to a high level of co-operation. Each order agent manages one transport order from first party logistics (1PL). Each vehicle agent manages one vehicle of the organization. A supporting agent "Path Finder" elaborates for a managed transport order the traveling route between pickup and delivery locations. The cooperation between order agents and vehicle agents is performed synchronically through the background environment agent E. The model functioning is controlled by the supervisor agent S. The detail working procedures and dynamic of the model is introduced in next section.

3.2 Dynamic of model

In this model transport activities are associated to elementary travelings achieved by vehicles. A transport activity (TA) is a nonstop travel from the loading location to the unloading location. However, transportation planning needs the definition of all sequential TAs necessary between origin and destination for each transport order. This set of sequential TAs is important for each order agent for evaluating the predicted route to go from origin to destination. On the other hand, vehicles require most often the grouping of multiple orders according to their maximum loading capacity.

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 from their own pickup to delivery locations. Based on transportation network information graph and 3PL enterprise vehicle, TAs between cities stored in its database, Path Finder agent elaborates for the managed transport order the traveling route. This route is a sub-graph of the overall transportation network graph, where each arc corresponds to a TA achieved by 3PL vehicle. Order agents send to the environment tasks which represents the different requests for performing activities by vehicle. A task is an execution of TA. Each task in the environment is associated with one TA, which may be performed by several vehicle agents. The set of tasks related to the routing followed by a transport agent constitute its intervention domain. Two orders may have tasks that require same TA and these two tasks can be and may be grouped to perform by the vehicle at the same time, if these two tasks lie in close time interval and sum of their capacity is less than or equal to the capacity that the corresponding vehicle can accommodate.

In perfect correlation with the model definition, each task only concerns one order agent. But some TAs can belong to the intervention domains of several vehicle agents, because multiple vehicles may achieve the same TA. The position format of task A is $[(S, F), N]$, where (S, F) represents a continuous temporal interval between a starting date S and a final date F, and N represents the name of vehicle executing task A. Each task has four positions, wished position (WP), effective position (EP), potential position (PP), and confirmed position (CP). The WP is the position requested by the order agent. The EP results from the scheduling of all the tasks associated with the propositions collected from the environment. The PP results from the scheduling of one task associated with a proposition collected from the environment. The CP is the final position after all the scheduling process. The supervisor agent provides functions of creating the agent society, generating the inside tasks and initializing the environment. Then, the supervisor agent triggers the cycle of cooperation process by activating the order agents and telling the vehicle agents to wait. The order agents firstly ask for EP and PP of the associated tasks from the environment. The environment sends the results back, of course the result is null in the first cycle. The order agents schedule the operations which have not been validated, and influence the associated tasks by alternative WP. If the WP of one task is the same as the EP and PP, order agents will make the confirmation. At last, the order agents send CP and WP of the associated tasks to the environment. Each order agent performs its actions simultaneously but remains independently from others. It will inform the supervisor agent once its actions are finished.

Once the end of the action from the last order agent has been recorded by the environment, the supervisor agent activates the vehicle agents and sends the wait signal to the order agents. The vehicle agents firstly ask for the CP and WP of the tasks belonging to its intervention domain from the environment. The environment sends the results back; the vehicle agents record the CP and schedule the tasks which are not definitely positioned. They influence these tasks by alternative EP and PP to the environment. Each vehicle agent performs its actions independently and informs the supervisor agent as soon as its actions finished. When the end of the action from the last vehicle agent is recorded, the supervisor agent finishes the first

cycle of the cooperation and starts the next cycle immediately. In each cycle (except the first one), at least one task should be confirmed to avoid the deadlock problem (Figure. 2).

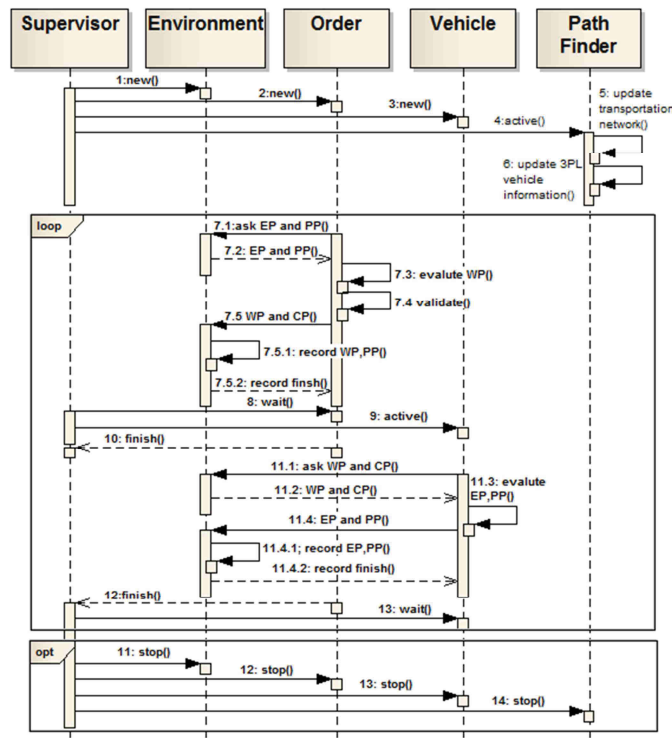


Fig:2 POVES sequence model

At each cycle, the choice of the best path in the sub-graph is achieved by order agents regarding criteria which may be shortest distance, earliest delivery or minimum cost to reach the delivery location. At each cycle the vehicle agents group the transportation tasks regarding their pickup time, associated quantity and achieve a plan based on Vehicle Routing Algorithm. Nevertheless these algorithms may introduce several empty travels. Figure.2 illustrates the sequence diagram of POVES model.

The alternation cycle between the activation of order agents and vehicle agents will be repeated until the CP of all the environmental tasks is fixed. When all tasks are confirmed, there is no WP from order agents anymore. The alternative (opt) area will be executed and the supervisor agent will terminate the environment, order, and Path finder and vehicle agents. The whole scheduling process is finished.

4. POVES MULTI-AGENT MODEL

4.1 Case study description

We consider a simple case study of transporting dairy products from manufacturers to large cities. We name this case study "Food Supply Case Study" (FSCS). A 3PL enterprise is responsible to transport those dairy products. 3PL transportation network is located in the central region of Cameroon. The network comprises of seven sites Mokolo (MO), Waza(WA), Maroua(MA), Yagoua(YA), Kaélé (KZ), Garoua(GA) and Kousseri(KO)(Figure. 3). From which two are Supplier sites (KO, MO), three are Intermediate Distribution Centers(WA, MA, KA) and all of the eight sites are customers. Supplier at MO produces two products (P1:Yogurt and P2:Cheese). Supplier at KO produces two products (P3: Milk and P4: Cream).

All of these four products need to be delivered at each customer site. 3PL uses these Intermediate distribution centres (IDCs) for transit purpose, to provide the facility to store the products on temporary basis. They are equipped with refrigeration facility and stock the products until they are picked by vehicles for delivery to another IDC or to city markets. 3PL manages its own fleet of 7 transportation vehicles (V1, V2, V3, V4, V5, V6), which are assigned default Start Locations (Loc), Avail (Availability Time at Loc) and MWT (maximum waiting time for an order when it is taken into account by the vehicle) by its management. The activities represent a direct nonstop travel from origin to destination. For example, a direct travel from Mokolo to Maroua is an activity “MokoloMaroua”, which is performed by V1 as shown in Table 1. A return travel from Maroua to Mokolo is another activity “MarouaMokolo” that is also performed by the same resource V1. Each vehicle follows the rule "FIFO-CUMUL". FIFO represents traditional "First in First Out" data structure, means vehicle will serve transport orders on FIFO basis. CUMUL represents cumulative, means vehicle can group more than one orders for delivery depending on its maximum capacity. Vehicles are also equipped with refrigeration facility. They charge different price for transportation, which is pre-negotiated between suppliers and 3PL enterprise management.

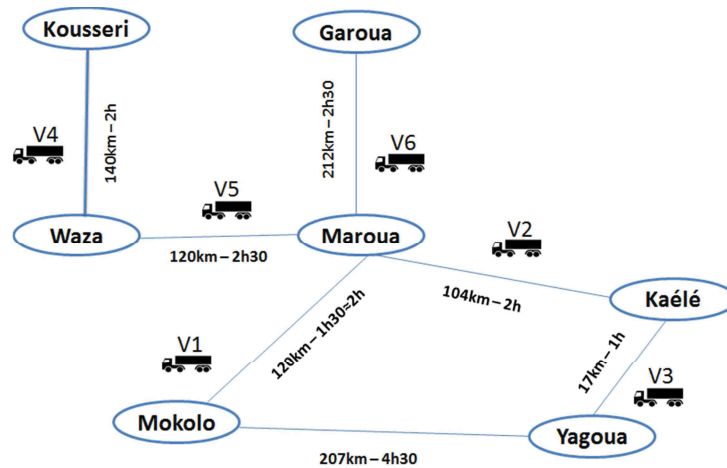


Figure 3. Food Supply Case Study (FSCS)

Table 1. 3PL Vehicles and activities

Resource	Loc	Capacité	Avail	MWT	Règle	Activité
V1	Mokolo	200	7h	1h	FIFO-CUMUL	MokoloMaroua
						MarouaMokolo
V2	Maroua	100	9h30	1h	FIFO-CUMUL	MarouaKaélé
						KaéléMaroua
V3	Kaélé	100	12h	1h	FIFO-CUMUL	KaéléYagoua
						YagouaKaélé
V4	Kousseri	200	7h	1h	FIFO-CUMUL	KousseriWaza
						WazaKousseri
V5	Maroua	150	9h30	1h	FIFO-CUMUL	MarouaWaza
						WazaM
V6	Maroua	50	9h30	1h	FIFO-CUMUL	MarouaGaroua
						GarouaMaroua

Each vehicle has different load capacity. In FSCS we consider a standardized box for packaging, for which we undertake following assumptions.

Assumption 1: A box of same volume, dimension and size is used for all kinds of products. After packaging, box has the same weight for all products.

Assumption 2: For all boxes, number of products is constant. However quantity that box can contain for each product depend on the kind of product and, not on the box.

Assumption 3: The number of boxes in a vehicle is always an integer constant.

Usually, in a 3PL enterprise, vehicles visit several sites. If the number of sites is superior to 2, the number of activities depends on the network organization. In our example, we assume that the number of sites visited by each vehicle is equal to 2. It means that each vehicle is reserved to perform two activities. Let us notice A and B the two sites and t_{AB} and t_{BA} the two activities. When a vehicle is at site A, t_{AB} is the next activity and t_{BA} is the return activity. When a vehicle is at site B, t_{BA} is the next activity and t_{AB} is the return activity.

For the Transportation network estimated distance and time between two sites are specified in the Table 2. Transportation time between two sites may variate depending on several conditions. If t_{AB} represents transportation time from site A to site B and t_{BA} from site B to site A, then $t_{AB} \neq t_{BA}$.

1. If vehicle is loaded when going from A to B and is empty when coming back from B to A or vice versa. Loaded vehicle will take more time to travel than when it is empty.
2. If vehicle is fully loaded when going from A to B and it is partially loaded when coming back from B to A or vice versa. Fully Loaded vehicle will move slower than when it is partially loaded.
3. If vehicle drive through a route which is inclined, so going upwards to the route is slower than coming downwards from the same route.
4. If there might be disturbances of traffic jam or vehicle broken or bad weather in either of the direction of going to A from B or coming back to B from A.

Table 2. Estimated distance and time between sites of Transportation network

Sites	KO	GA	WA	MA	MO	KA	YA
KO	-	-	192km (2h30)	-	-	-	-
GA	-	-	-	200km (2h)	-	-	-
WA	140km (2h30)	-	-	130km (2h30)	-	-	-
MA	-	200km (2h)	130km (2h30)	-	120km (1h30)	104km (1h30)	-
MO	-	-	-	120km (1h30)	-	-	-
KA	-	-	-	104km (1h30)	-	-	17km (1h)
YA	-	-	-	-	-	17km (1h)	-

In the context of this paper, we don't consider above time variation conditions. We use the same estimated time for going form site A to B and vice versa. In order to keep this case study simple, we consider that loading and unloading time of products to IDCs and supermarkets is included in traveling duration.

4.2 Illustrative Example

In our case study, we take a wallet of 4 Transportation Orders (TO) as shown in Table 3. TO arrives in the system as 9-tuple(O,P, PL, DL, PT, DT, PD, DD, and PQ) of attributes, where O is Objective(Less costly, early delivery), P is Product ID, PL stands for Pickup Location of

supplier from where vehicle loads the product packages. DL represents Delivery Location of customer where order should be delivered. PD and PT stands for Pickup Date and Pickup Time. On this date and time, TO is ready for loading at supplier's warehouses. Similarly DD and DT are Delivery date and Delivery time. DD and DT are the latest date and time on which TO should be delivered at customer site. Finally PQ is the Product Quantity (number of boxes).

Table 3. Transport Orders (TO)

NO	O	P	PL	DL	PD	PT	DD	DT	PQ
1	Moins Cher	P1	MO	KA	1/1/14	6h	1/1/14	19h	50
2	Moins Cher	P2	MO	YA	1/1/14	7h	1/1/14	20h	50
3	Moins Cher	P3	KO	MA	1/1/14	6h	1/1/14	19h	50
4	Moins Cher	P4	KO	YA	1/1/14	7h30	1/1/14	20h	50

Path Finder Agent receives input PL and DL of a TO and for it elaborates elementary traveling activities (sub-graph). Table. 4 describe the precise routing used by TO proposed by Path Finder Agent. For each step of the travel, task number, associated activity, colour and best estimated duration (taken from Table. 2 are given. Different colour is assigned to each activity for illustration purpose to distinguish similar activities. Same colour represents that two orders have two similar tasks that belong to the same activity, which can be grouped and performed by the vehicle(s) together probably at the same time. For example first task of TO1 and TO2 belongs to same activity “MokoloMaroua”. These two tasks can be performed probably at the same time by the same resource.

Table 4. Routing table

TO	Routing	Task	Activity	Color	Time
1	1	1	MokolaMaroua	Red	1h30
		2	MarouaGaroua	Green	2h
2	2	1	MokolaMaroua	Red	1h30
		2	MarouaKaélé	Yellow	1h30
		3	KaéléYagoua	Blue	1h
3	3	1	KousseriWaza	Cyan	2h30
		2	WazaMaroua	Black	2h30
		3	MarouaGaroua	Green	2h
4	4	1	KousseriWaza	Cyan	2h30
		2	WazaMaroua	Black	2h30
		3	MarouaKaélé	Yellow	1h30
		4	KaéléYagoua	Blue	1h

Order agents realize an infinite capacity planning for all tasks of their transport orders (TO1, TO2, TO3 and TO4), and generate for them the wished position as shown in Figure. 4(see section 3 for detail). After, the wished positions are sent to the environment. Taking into account their published basic activities, each vehicle agent perceives the different tasks to schedule. Then, vehicle agents realize simultaneously a finite capacity planning for all the perceived tasks considering their capacity and maximum waiting time duration for a transport order. For this, firstly vehicle agent sorts the perceived tasks according to the corresponding activity. Tasks associated to the same activity are arranged in FIFO order taking into account the ascending pickup date. Secondly, vehicle agent groups the different tasks of an activity according to the maximum waiting time duration and the capacity of its associated vehicle.

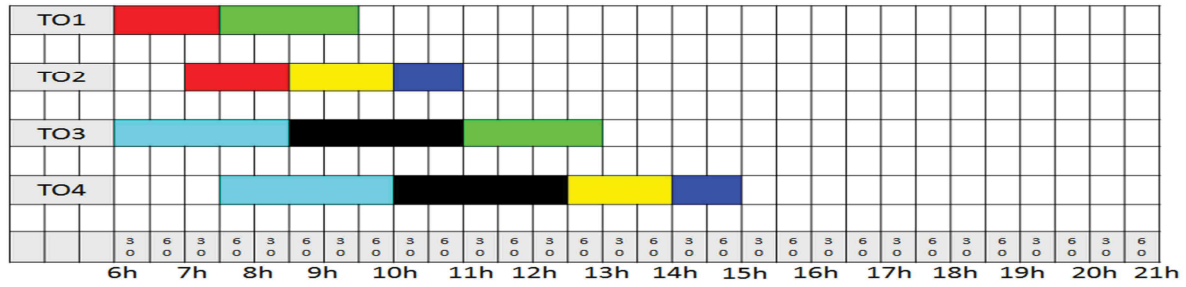


Figure 4. Wished Position for all transport orders

If associated vehicle's current standing position is at the beginning of the next activity then vehicle executes the activity for this group of tasks. If associated vehicle is not present at the next activity but it is at the beginning of another return activity, then vehicle agent first executes displacement from return activity and then generates the transportation plan for that next activity. Preventing the empty displacement from return activity, it first regroups the tasks at the return activity for delivery. Tasks that could not become part of the group in first place due to vehicle's finite capacity limitation are planned later on its return to the same activity. Tasks which are planned later may arrive late at their delivery location.

We can see in Figure. 5 the gant chart resulting from the complete planning process computed by "POVES" for all four TOs.

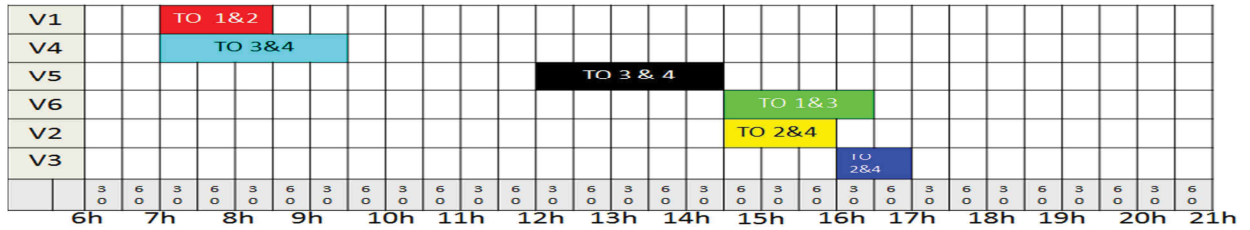


Figure 5. Grouped planification when Objective attribute for all TO1=TO2=TO3=TO4= Less Costly

As we stated earlier that the choice of the best path in the sub-graph is achieved by order agents regarding criteria, which in our case is objective attribute that is part of TO 9-tuple. Keeping the other attributes constant, if we set the value of objective attribute (TO1=Early, TO2=Early, TO3=Less costly, TO4=Less Costly), then we get the planning as shown in Figure. 6. If we change TO1 to Less Costly from Early, then we get the planning as shown in Figure. 7. If we set TO1 back to Early but change TO2 to Less Costly from Early, then we get the planning as shown in Figure.8. Change in objective attribute of TO3 and TO4 does not affect their planning, due to 3PL vehicle's availability in our case study.

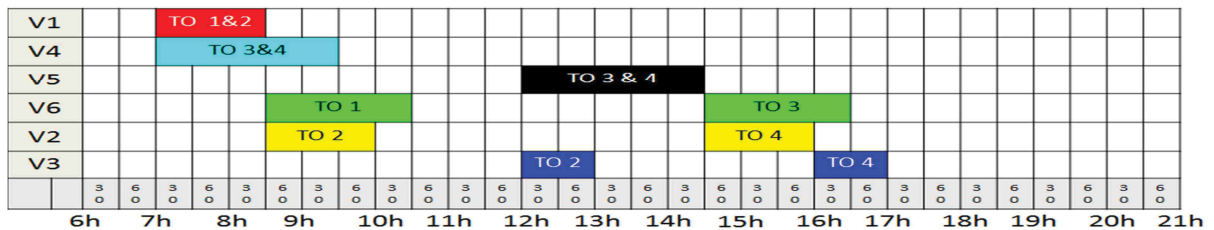


Figure 6. Grouped planification when Objective attribute for all TO1=TO2=Early & TO3=TO4= Less Costly

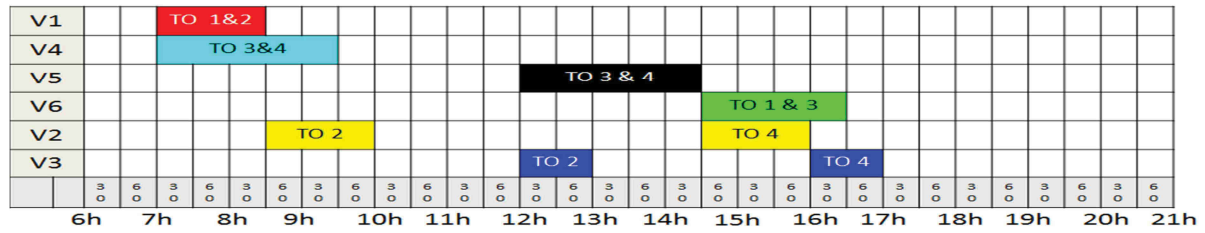


Figure 7. Groupped planification when Objective attribute for all TO2=Early & TO1=TO3=TO4= Less Costly

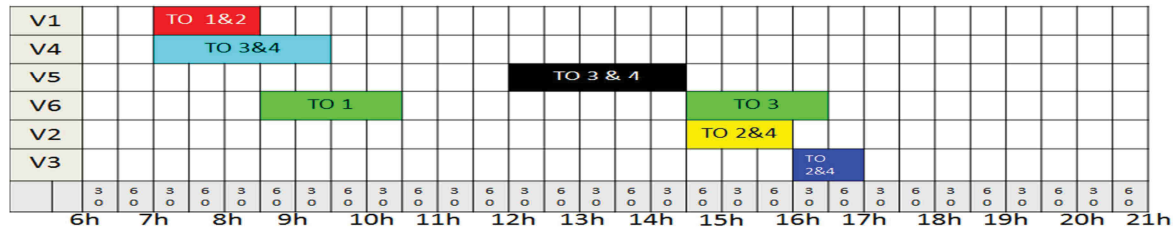


Figure 8. Groupped planification when Objective attribute for all TO1=Early & TO2=TO3=TO4= Less Costly

5. Conclusion

In this paper we discussed a collaborative transportation planning problem and to solve that, proposed a distributed multi-agent framework called "POVES" which functions on the cooperation between two communities of agents (order agents and vehicle agents). In 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 through sequential auctions and vehicle agents compete with each other to serve those jobs. Vehicle agents propose grouping these jobs together to execute them simultaneously. There are several directions for future research. Instead of one 3PL, multiple 3PL transporters can collaborate with each other to deliver the orders and how these 3PL enterprises will collaborate with each other needs to be investigated. Other parameters like size, type and weight of the transported products have to be considered and how much they effect on over all planning process. Agility is a very important factor in such kind of dynamic systems that need to be addressed effectively. Issues like traffic delays, vehicle breakdown and penalties have to be researched. To keep the case study simple and to facilitate the method understanding, we restricted the number of sites visited by a vehicle to two. The taking into account of more than two sites is also one of our future studies.

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