# DELIVERY TRACEABILITY SYSTEM USING IOT

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***ABSTRACT:*** *To ensure the product delivery vehicle traceability in the deadline, we offer a contribution to a smart tracking system in distribution logistics an indicator of modernity. The developed system consists of two components: a localization system for the customer and vehicle, as well as a second is planning system of the route followed to deliver the product. Finally, the two systems are connected to the database. This methodology contribution allows simultaneously connected customers to know the path crossed by their product, as well as their characteristics of quality in general by installing sensors and Radio frequency identification chips in the delivery means, also, something that allows real-time traceability of vehicles with consumer visit plan to achieve real-time information about vehicles, as well as customers' requests, can be collected and transmitted to the distribution center for analysis and making better decisions.*

***KEYWORDS:*** *Smart traceability, Transport optimization, Vehicle tracking system, Localization, logistics 4.0*

## 1 INTRODUCTION

In the current digital era, the Internet dominated the world through its direct or indirect impact where societies intermingled; their daily, economic and every human side have widely changed. Confinement during the covid-19 pandemic has not only proved this point but also confirmed the high necessity of this technology to serve inhabitants who live in different remote regions. Thus, the delivery services come to take the most appropriate place in maintaining the successful commercial activity (customer- goods) on time regardless distance and other hindering factors.

The Fourth Industrial Revolution (known as Industry 4.0) with its innovative technologies (such as the Internet of Things, Additive Manufacturing, Artificial Intelligence, and Virtual and Augmented Reality) has changed the production processes and business models (Aksa et al., 2021). Industry 4.0 obliges companies to adapt to the potential intricate transformations and disruptions in the whole world of markets, customers, and suppliers.

In effect, digitalization has transformed the overall outlook of the supply chain in various functional areas (Manufacturing, Warehousing, Inventory Management, Purchasing, Customer Service, Demand Planning, and Transportation).

Traceability is considered as the next Supply chain revolution. It is the association of the information flow to the physical one, where it is possible to obtain real-time information generated systematically through technologies dedicated to traceability.

Thus, it ensures an excellent quality of services, helps to avoid costly incidents, provides more transparency for customers, ensures instantaneous communication for drivers, and facilitates route management for carriers.

The optimization of transport and path of the distribution vehicle is a vital link in the logistics distribution system. It is a critical challenge for companies where route planning, vehicle routing, and fleet management, in general, are the pulp of transport planning problems. Vehicle Routing Problem (VRP), presented by (Dantzig & Ramser, 1959), is a combinatorial optimization problem and a high-level set of routing problems. One of the most complex variants of VRP in the enterprise logistics area is the Dynamic Vehicle routing problem (DVRP) which includes the following dynamics: service times, travel times, vehicle availability, or the appearance of customers. The availability of customers is the most considered aspect in which new customer requests are appeared and are revealed dynamically during the execution of the routes.

As a contribution, this article presents two proposed complemented algorithms to plan a set of routes taking into account the update of the routing plan and reconfiguration of new optimized routes at any instantaneous time. These algorithms aim to minimize the overall cost of travel, serve the maximum number of requests and increase customer satisfaction. The first algorithm is used for the real-time localization of a fleet of vehicles that must deliver goods to a set of customers from a single distribution centre and how to track these vehicles through the data transfer between them and the distribution centre. The second one is used to help to acquire better control over the supply chain, understand each step of the vehicle journey, and increase the experience of customers. During the tour, the vehicles can receive new requests from the distribution centre. For managing these requests in real-time, the proposed solution provides routing information besides all the services required by the autonomous vehicles in vehicular clouds.

The remainder of this article is organized as follows: An introduction to the problem study, application area and the organization of the paper is provided in Section 1. Section 2 introduces a brief definition of traceability and our objectives. Section 3 present an introduction of dynamic vehicle routing as a case for tracking solution. Section 4 offering a concise presentation of the proposed idea as a contribution to solve the delivery traceability system in real-time and the section 5 reserved for concluding remarks and research into the future. Finely, bibliographic references are given in section 6

# 2 TRACEABILITY 4.0

## 2.1 Traceability definition

Traceability is defined as follows: « Traceability is the information reproduction, use, and dissemination contained in an information product, the last one can be represented by RFID, Bar Code, Sensor...Information can be copied, downloaded, printed, sanded».

Smart traceability or traceability4.0 is the application of industry 4.0 concepts and their technologies to traditional ones. Thanks to this intelligence the products are complete transparency (components and path) as well as the information of different links in the supply chain is open, clear, and visible.

## 2.2 Research objectives

The objective of this article is to proposed a solution for the real-time dynamic delivery routing traceability problem in the context of industry 4.0. The article present a framework contribution to the real-time traceability field using the internet of things IoT through the design a smart algorithms and cloud computing that generates data in real-time in logistic distribution network In This way, it chose the dynamic vehicle routing problem DVRP, that it focuses on mobility and a set of vehicle integration; it is one of the well-known distribution logistics problems, this article provides a methodology for real-time traceability of vehicles and a Plan Consumers Visit PCV intending to achieve the best solution for the re-optimization on-the-fly or online optimization cost delivery.

# 3 DVRP IN THE AGE OF INDUSTRY 4.0

Dynamic Vehicle Routing Problem (DVRP) is an extension of the Vehicle Routing Problem (VRP), also known as Vehicle Scheduling Problems. VRP is a combinatorial optimization problem carried out by a fleet of vehicles to serve a particular set of customers. It uses several vehicles that depart from the depot to visit the customers and return to the depot again by taking into account minimizing distance, cost, number of vehicles, and maximizing the number of served clients (Mills et al.,2018),(Masudin et al.,2019),(Mohammed et al.,2017); in sum, finding the best route for visiting multiple destinations.

When the data related to the routing process are changed by the coming of a new customer’s request or by requests not known before planning, we are in front of a dynamic vehicle routing problem (Fig.1); called online or real-time VRP (Sabet & Farooq, 2022) Thus, in DVRP, customers appear dynamically in the system via receiving their demands at different times during the workday, which necessitates the change or update of the plan with an online optimization (Necula et al., 2017).

The DVRP applied by a modern supply chain that can work in a dynamic system has a high complexity depending on constraints, objectives, and the source of dynamism.

The nature of Dynamic VRP is different, and it depends on the type of problem and the nature of the dynamic element (Kucharska., 2019); indicated in Fig.1. According to (Rios et al., 2021), these dynamics are related to: Travel time, Service time, Vehicle availability, Customer demand and the appearance of new customers (includes: changes in location, and customer availability).

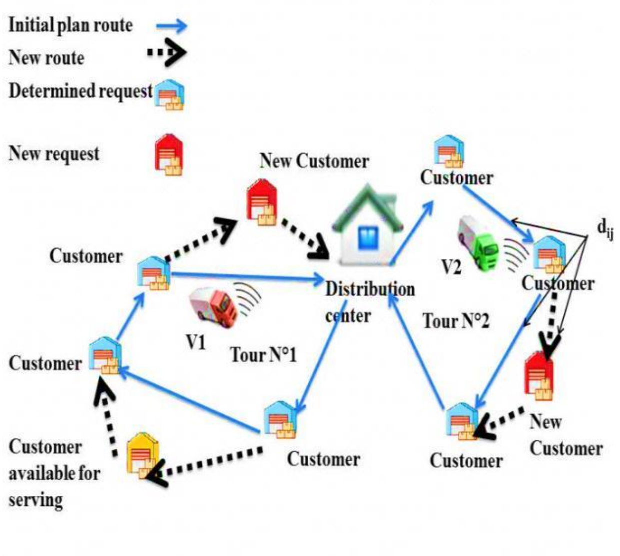


**Fig. 1 Dynamic Vehicle Routing Problem**

In the context of Industry 4.0, this work allows providing a vehicle traceability solution for delivery that enhances customer satisfaction as well as optimization of distribution logistics.

For this objective, two algorithms have been developed using certain Industry4.0 technologies, namely Internet of Things IoT, in order to obtain real-time information.

The flow chart below Summarize the methodology to which we have contributed.

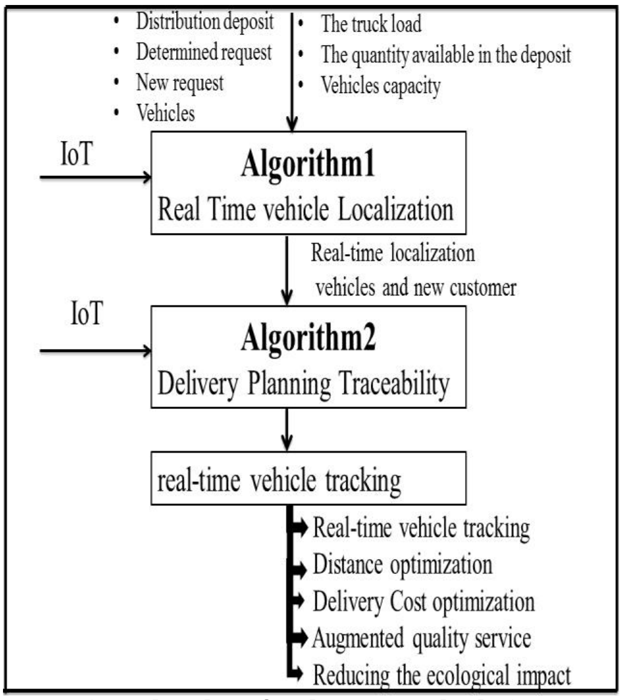


**Fig.2 Flowchart for the proposed solution**

Recently and with the rapid development of the logistics industry, IoT has marked its powerful presence in DVRP for the realization of Intelligent Transportation Systems. It is a solution for vehicle routing when real-time information about vehicles, customers' demands, and tasks can be collected and transmitted to the distribution center for analysis, making better decisions, and updating the delivery planning.

Fig.3. illustrates a concise presentation of DVRP in the Internet of Things era.

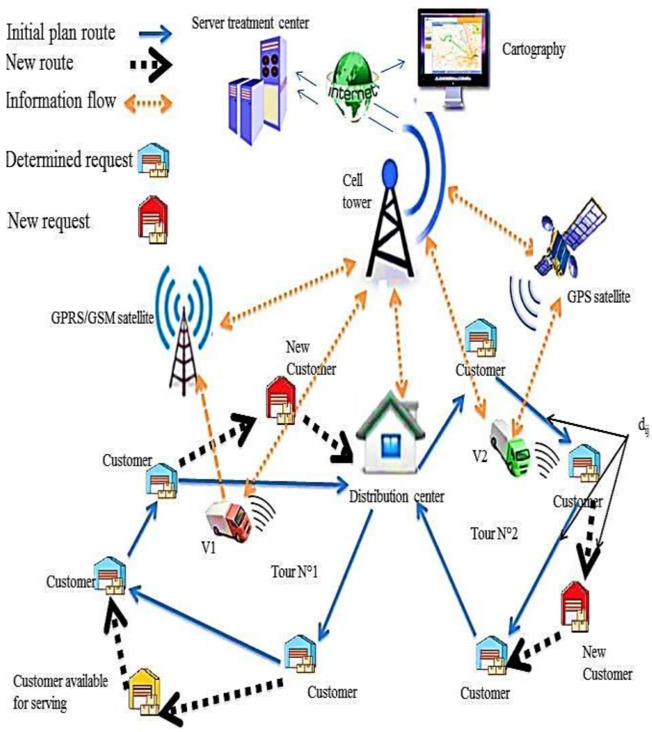


**Fig.3 IOT architecture for DVRP**

## 4 PROPOSED APPROACH

This section provides a concise presentation of the proposed traceability architecture to guarantee the delivery's control at a fixed time.

The proposed method uses two algorithms, presented in the following sections, for solving the DVRP by integrating static and dynamic cases based on a combination of constraints and parameters.

Fig.4. illustrates the architecture of the proposed traceability system in the distribution logistics using the Internet of Things technology to reduce fixed and total costs in logistics and distribution processes and maximize the number of requests to serve, maximizing the number of customers and increasing their satisfaction.

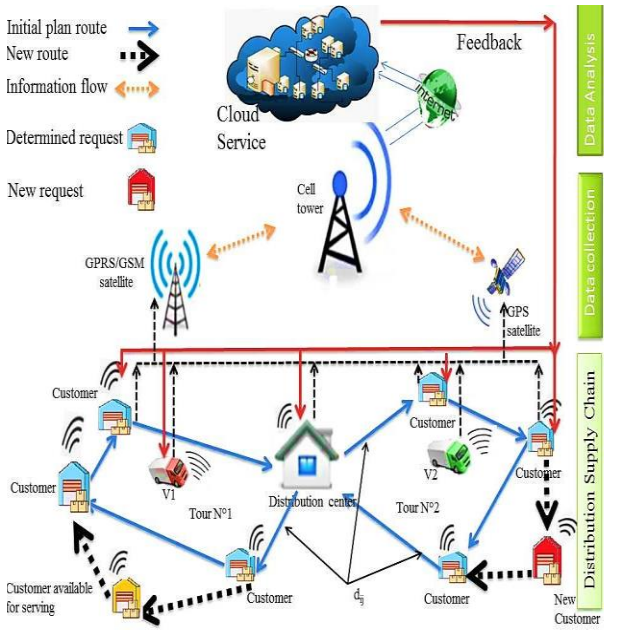


**Fig.4 Traceability Framework for the DVRP issue**

The basic principles of the proposed DVRP traceability system are:

- Defining the location of the customers and vehicles in real-time.
- Determining the plan for delivering the product to customers taking into account any changes that may occur.
- Using new technologies such as the Internet of Things, RFID, Sensors, and cloud computing; according to (Winkelhaus & Grosse, 2020), they are the most technologies mentioned in the logistics4.0 research.

Based on the Internet of Things Technology, the proposed idea gives a framework for designing a Customer visit plan (CVP). It allows gathering information about the vehicles' fleet, during their trip, by locating them in real-time and reconstruction of the visit plan when the data related to customers' demand are changed or receiving new requests.

## Real time localization algorithm

In recent years, the Internet of Things has caused an active earthquake in all fields, as well in the transport, where autonomous, intelligent and connected vehicles have appeared. This revolution is due to the rapid development of intelligent transportation systems based on cloud computing, the 5th generation mobile network (5G) (Lagorio et al., 2023), and sensor technologies. Through these emerging technologies, the precise localization of such objects, vehicles in our case, can be given in real-time.

This section presents an algorithm for the real-time localization of a fleet of vehicles that must deliver goods to a set of customers from a single distribution center and how to track these vehicles through the data transfer between them and the base station (distribution center).

The proposed algorithm depends on the following set of parameters:

- Distribution center, vehicles count, consumers count, distribution network.
- The existence of demand, the available quantity of a product (depending on the vehicle capacity),
- The exact time of a departure and a return depot, and the total tour length of each vehicle.
- Customers location (including new customers or new demands in real-time), vehicle characteristics, and customer value (it depends, for example, on the loyalty, the payment fast, and the payment way).

Furthermore, there is a set of conditions to be taken into account:

- The quantity available in the vehicle must be greater than the customer's demand quantity: $Q_{av} > Q_{NC}$
- The tour length must not exceed the maximum fixed distance; respect the specified period of each vehicle's return to the depot.

In the departure phase, three coordinates are assigned to each vehicle as follows:

- The first coordinate is the vehicle identifier; in our proposal, the identification is sequential and begins from 1to N vehicles.
- The second coordinate is the quantity available of goods ($Q_{av}$).
- The third coordinate is the real-time localization of vehicle (locV).

In its departure, the vehicle starts with the following information: the fixed quantity of goods shipped the customers' list to deliver their demands at an optimized time, and the fixed-time period from the departure to the return to the depot.

During vehicles tour and in case of receiving new demands in real-time from new/existing customers, the execution of each new customer's request will be as follows:

- Localize the customer who sends this request using GPS.
- Calculate the optimal distance between this

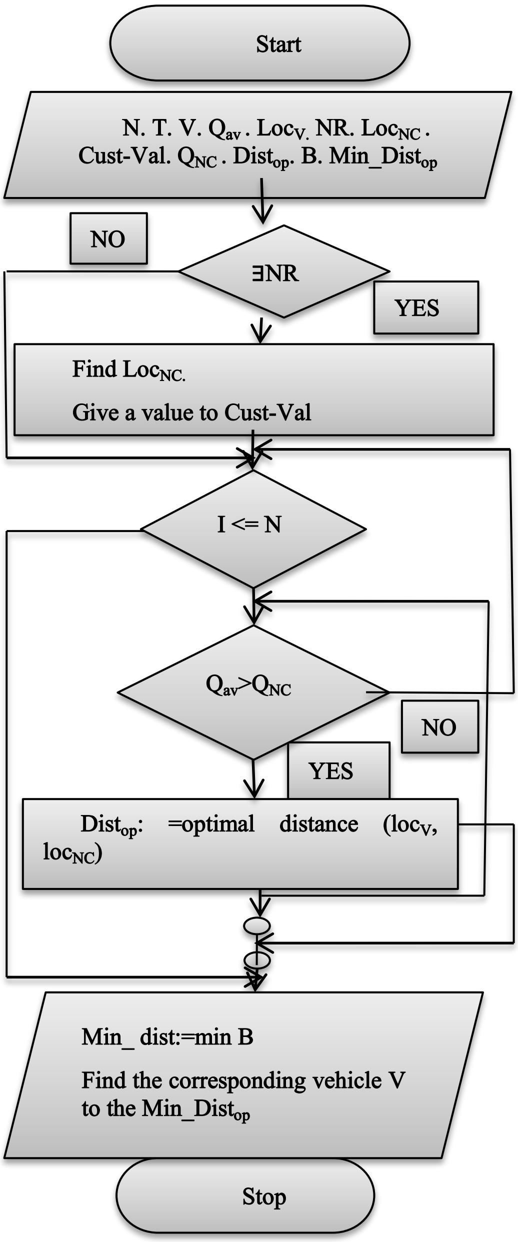


**Fig.5 Flow chart for real-time localization**

customer localization and each vehicle's localization.

- Chose the nearest vehicle to this customer for executing the delivery operation on time.
- Send the customer's demand to the selected vehicle in the precedent step by sending them a message containing the following information: Customer localization, the quantity of goods required from the customer, and the value of the last one.

The previous flowchart presented by (Fig.5) summarizes the proposed method for the real-time localization of a fleet of vehicles during their traveling.

## Algorithm for delivery planning traceability

The following vehicle traceability algorithm can help to acquire better control over the supply chain, understand each step of the vehicle journey, and increase the experience of customers.

This algorithm uses the same parameters and conditions mentioned in the precedent section.

To ensure delivery traceability using this algorithm, a list of some characteristics to apply as follows:

- Each request (R) has four coordinates;
- The name of the city of the customer (City);
- Requested quantity (Qty);
- The optimal distance between the current city and the city of the customer of the request (Dist);
- The value assigned to the customer of the request (Cust-Val). It can take, as mentioned before, the following values: Very Important, Important, and Less important.

In the departure, all vehicles have the same capacity and an available quantity of goods equal to the truckload.

They start their working day with a static route plan to deliver the goods to a list of customers (N customers) where the requests are sorted, using the MOACO (Multi-objectives Ant Colony Optimization) method (Yagmahan & Yenisey, 2008) according to Qty, Dist, and Cust-Val.

During the tour, the vehicles can receive new requests from the distribution center. For managing these requests and executing them in real-time, the proposed solution provides routing information besides all the services required by the autonomous vehicles in vehicular clouds.

As mentioned, each request sent to one of the fleet vehicles has as coordinates (City, Qty, Dist, Cust-Val). In this case, each of them deals the received request as follows:

- Add the received request to the existing ones;
- Sort the list of all requests using the MOACO method; sort them by following the priority of the request through the customer's value, the quantity request, the city of the customer, and the optimum distance between the current city and the customer's city;
- Execute the first request in the list by moving to the customer's city.

After delivery:

- Calculate the new quantity available as well as the new tour length;

- Archive the executed request;
- Calculate the optimum distance between the current city and all cities of the customer's request in the list;
- Sort the list of all requests using the MOACO method;
- Execute the second request from the sorted list and so on.

In case of receiving a new request, execute the same precedent steps until delivering all existing requests.

In case when the quantity available in the vehicle is not enough to serve a new demand, or the tour length reaches the maximum, or all requests are served, and there aren't new ones to serve, the vehicle returns to the depot.

The following flowcharts (Fig.6) summarize the proposed idea for planning traceability.

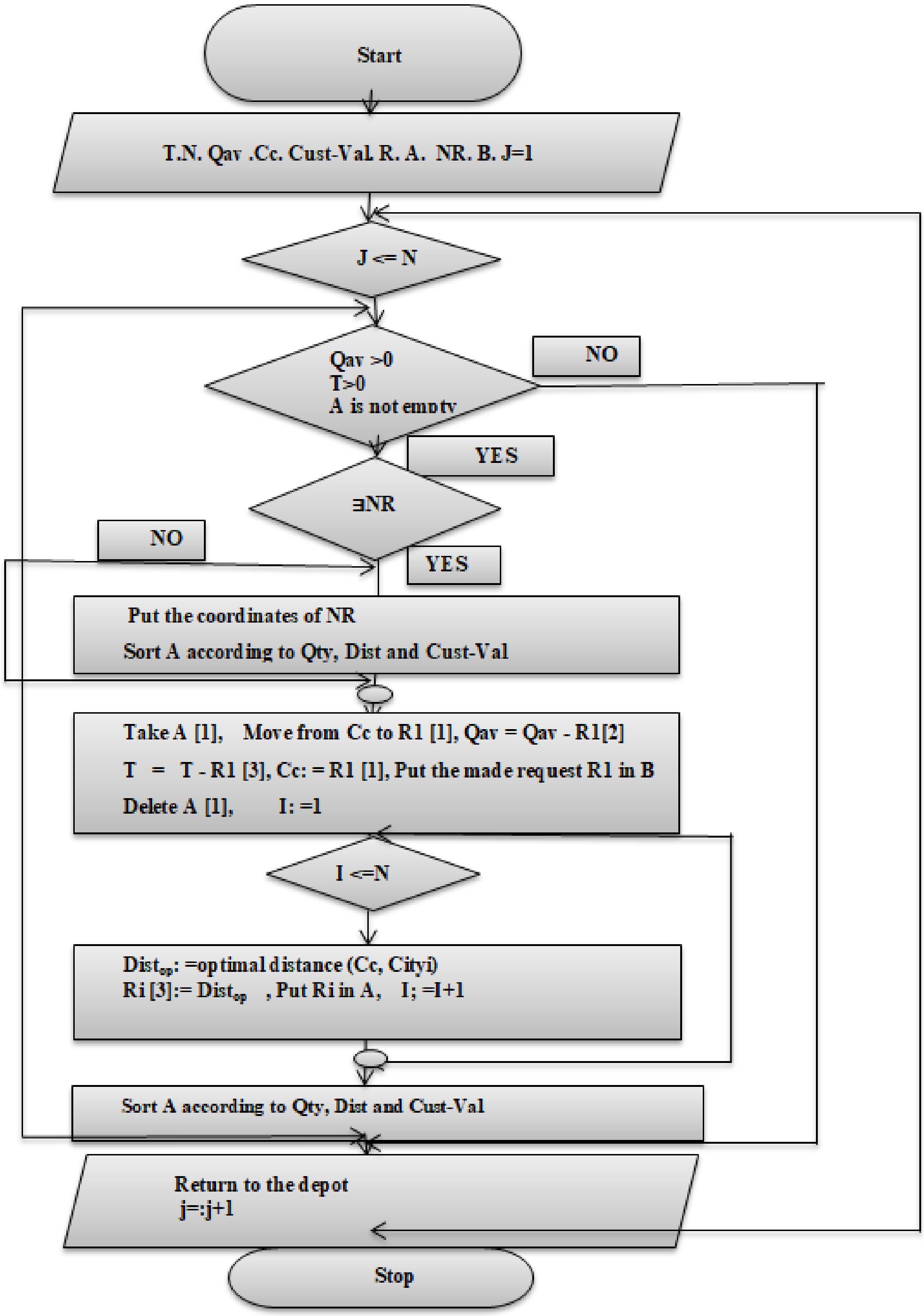


**Fig.6. Flow chart for reel-time planning traceability**

This flow charts aims to track and manage, dynamically, the daily routine of the delivery operations in real-time, even if there are new requests during the working day. Through this Algorithm, we can reduce the time of services (reduce the response time between receipt of the request and its delivery), optimize the distance for delivering, serve the maximum number of requests, and satisfy customers.

## 5 CONCLUDING REMARKS

Customers' satisfaction remains the most crucial part that has increased importance in the digital age to achieve a successful business for companies that constantly seek to increase their competitiveness. Transportation, delivery traceability, and distribution management are the main factors to attain this goal across the global supply chain.

One of the major variants of the Vehicle Routing Problem is the Dynamic Vehicle Routing Problem, in which not all customers' demands are known or are in the list of delivery requests prepared before starting the workday.

This article present an idea base an internet of things IoT through two proposed algorithms to solve vehicle routing traceability in logistics distribution networks, particularly dynamic delivery customers in real-time. It helps to optimize the Customer Visit Planning Process to serve the given customer requests without violating the vehicle capacity constraint, which allows for orchestrating and managing all requests as effectively as possible and increasing customer satisfaction.

In the future, this research work can be extended to track, monitor, and control product quality and safety, particularly in the food and medicine in real-time during the loading, routing, and delivery. This tracking of product quality needs the use of recent technologies such as Radio Frequency Identification RFID and smart IoT-Sensors that monitor factors like light, temperature, movement, and humidity. All of this can be managed through a proposed cloud-based platform for tracking product quality issues and we propose to hybrid machine learning with IoT, Mateo parameters and augmented reality for this traceability problem.

Using a distribution center as a real case to validate the proposed traceability solution is the objective of the next article.

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