TO3: LAST MILE DYNAMIC ROUTING

Market Research

14 SEPTEMBER 2020

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Contents

Acronyms

3PL	Third Party Logistics
AI	Artificial Intelligence
API	Application Program Interface
CRM	Customer Relationship Management
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
GHSC-PSM	Global Health Supply Chain – Procurement and Supply Management
GPS	Global Positioning System
HIPAA	Health Insurance Portability and Accountability Act
IT	Information Technology
MOH	Ministry of Health
PDF	Portable Document Format
REST	Representational State Transfer
SaaS	Software as a Service
SLA	Service-Level Agreement
SMS	Short Message Service
TMS	Transportation Management Solution
TSP	Traveling Salesmen Problem
UI	User Interface
VC	Venture Capital
VERSA	Vehicle Routing and Scheduling Algorithm
VRP	Vehicle Routing Problem
WMS	Warehouse Management System

Background

A dynamic route optimization tool will facilitate cost-efficient planning for distribution managers and help them tackle challenges associated with dispatching in the "last mile." Dynamic route optimization automatically factors in an operation's existing resources and availability and then determines the most efficient utilization. It also incorporates into its analysis external factors, such as weather, traffic, blockage and security patterns to adjust routes and keep drivers on the most efficient path possible. Last mile delivery logistics processes are becoming increasingly challenging due to changes in daily delivery requirements, inadequate infrastructure, unstable technology and the shortage of human resource capacity. Transportation for last mile distribution in developing countries includes multiple and often conflicting performance criteria for delivery, including delivery completion time, cost, coverage and reliability. Across Africa, governments and donor organizations are investing monetary and human resources to strengthen supply chains, especially for health commodities. Key supply chain challenges in developing countries include the following:

1) **Lack of sharing on the viable available approaches, solutions and services**: For example, distribution managers receive training on static routes and inadequate information on other viable solutions.
2) **Limited opportunity for sufficient advanced planning and strategy for dispatches:** When distribution managers encounter order delays, instead of planning for such delays, they run the static routes twice, which interferes with prioritizing and resource allocation.
3) **Lack of near real-time communication and tracking**: When central warehouse has limited supplies and is unable to fulfill all orders completely, the dispatch volume will be lower than planned. Distribution managers are not aware of this change until the dispatch is ready and on the floor of the dispatch area. Without timely communication and tracking of incoming dispatches, dispatch managers cannot adapt. Thus, many distribution managers operate under a static routing system; they are not able to adjust the routes they deliver, which makes it very hard to effectively plan deliveries.
4) **Scarce historical metrics and tracking**: Frequently, supply chain systems rely on serendipity for a successful delivery in contexts where commodities, vehicles and personnel operate just well enough to get the work done. Analysis of historical data strengthens tracking and planning systems and enhances reliable supply and demand planning.

This research assessment aims to provide insight and solutions to help solve these issues and enable more proactive planning for distribution managers to account for internal and external deliveries.

Research Methodology

In the context of these key supply chain challenges, the GHSC-PSM team focused its market research on three tiers of last mile dynamic routing offerings. Through this market research, the team identified similar challenges within last mile dynamic routing. In accordance with these findings, the GHSC-PSM team reviewed past performance and experiences in the last mile market; conducted interviews with select providers; and synthesized the findings from the reviews and interviews to develop a comprehensive list of three categories of dynamic decision support tools:

- Commercial tools

- Open-source tools

- Build-your-own tools

To provide a comprehensive analysis that is responsive to in-country needs, the GHSC-PSM team assessed each tool against the following criteria:

- Commercial/open-source/build-your-own

- Utility/viability in the developing countries

- Overall capability

- Application program interface (API)/cloud or web-based functionality

- Complexity of the design features

- Complexity of integration into existing systems

Table 1 features the findings of this analysis.

Comparison Matrix

Table 1. Comparison Matrix of Dynamic Routing Offerings

Name	License	Developing Country Availability	Capabilities	Solution Type	Complexity of the Design Features	Complexity of Existing Systems Integration
Wise Systems	Commercial	Limited	In-route optimization, on-demand dispatch, driver mobile apps (not specialized in multi-day deliveries)	Cloud-based	AI and machine learning	Offers variety of implementation alternatives
Descartes Route Planning Solutions	Commercial	Authorized resellers internationally located	Optimizes both static and dynamic routes	Cloud-based	Strategic delivery planning	Web-based modules that integrate easily
OmniTracs	Commercial	Yes	Roadnet offers multiple routing strategies, Fleet Telematics solution, and GPS fleet tracking	Cloud-based	Digestible route statistics, configurable planning criteria, configurable sales and service reports	No additional hardware needs
Project Last Mile (Coca Cola)	Commercial	Yes	Route optimization to improve route-to-market mapping and planning	Excel-based	Designed a fit-for-purpose and user-friendly data sets	SpatialXL and RouteXL
nuDeliverIt	Commercial	Limited	RESTful API/integration framework	Cloud-based	SaaS technology	Event-based architecture allows easy configuration

Name	License	Developing Country Availability	Capabilities	Solution Type	Complexity of the Design Features	Complexity of Existing Systems Integration
LogiNext	Commercial	Yes	Realtime field workforce management, delivery logistics automation, dynamic re-routing	Cloud-based	Big data analytics	Easy to integrate and highly configurable with multiple platforms
GraphHopper	Open source	Yes	Directions API allow for multiple integration (routing and navigation, route optimization, geocoding)	API	OpenStreetMap and API	Route optimization API can be integrated to any application
VillageReach	Open source	Yes	Optimization tool with factors such as time, road conditions, and risk	Excel-based	Backend Python	Solver: VERSA
ODL Studio	Open source	Yes	Territory design and management; Vehicle routing and scheduling	Desktop UI (Excel spreadsheet)	OpenStreetMap; non-Realtime	Easy integration using Excel
OptaPlanner	Open source	Yes	Integration with Google Map and OpenStreetMap, incremental score calculation, shadow variables, and advanced heuristics	API	Java, AI Optimization Algorithms	Easy integration with Google Maps or OpenStreetMap
MapQuestDeveloper	Build your own	Yes	Proven geospatial solution based on developers and entrepreneurs	API	Wide range of APIs offered based on need	Easy to integrate

Name	License	Developing Country Availability	Capabilities	Solution Type	Complexity of the Design Features	Complexity of Existing Systems Integration
Google OR-Tools	Build your own	Yes	Suite optimization tool with variety of solvers	API	Distance Matrix APIs and wide range of APIs	Program language of choice can be embedded with any of the solvers
Route4Me	Build your own	Yes	Route modification and addresses large number of constraints	Cloud-based	Variety of APIs (Telematic Gateway, Platform, Operational Assessment)	Runs smoothly on any tool
OpenRouteService	Build your own	Yes	Pelias geocoding, isochrones, time-distance matrix	API	Directions API	Easy to customize input information

International trend on Last Mile Dynamic Routing

In today's market there is growing demand for speed, cost and convenience, rendering flexibility, real-time visibility, customized automation and usability among the most important characteristics of routing software. Yael Almog, a product manager at Bringg, said, "Given the complexity of delivery and logistics operations, deep digital integrations across business and transportation platforms are required." Accessing and leveraging industry trends can help stakeholders in any field, such as medical supplies, e-commerce or retail, adjust their own practices to optimize order fulfilment processes, as necessary. The following are some growing trends in last mile delivery:

1. Gig economy and crowdsourcing:
   Venture capital (VC) firms are increasingly investing in supply chain and logistics start-ups. Many VCs are interested in companies with assets based on technology and information rather than physical assets, such as delivery vehicles. Companies like the Musanga Logistics (Zambia), Picup (South Africa) and Sendy (Kenya) provide spot-market deliveries by independent drivers. The companies advertise delivery jobs on their apps to notify drivers on available gigs. Although ad-hoc pickup and delivery are not as efficient as when a strong route management system guides delivery, these start-ups use technology that leverages vehicles of outside parties who want to earn extra money. These companies rely on analytics and information to figure out how to do the jobs for less while utilizing drivers with their own cars for excess capacity. In the words of Andrew Pharand, Accenture's Global Management Consulting lead for the postal and parcel industry, "There will be a battle between the guys with the buildings and assets, versus the guys with apps and information. The winner will be a combination of both."[1]

2. Rapid order fulfillment:
   Micheal Armanious, vice president of Sales and Marketing at Datexcorp (a 3PL management and warehouse solutions provider), said, "We're noticing a huge push and pressure on the fulfillment side to get orders turned around on a much faster scale and pace than a lot of technology is capable of doing today."[2] This example applies to pharmaceuticals; as it becomes faster and easier to find and purchase products online, customers want to receive products sooner. While 3PL providers rely on warehouse management software to optimize the fulfilment process, even most modern technology has its limitations.

3. Improved traceability:
   Improvements in technology have made it possible for shipping companies to provide step-by-step tracking information – from creation of the shipping label, to last mile delivery, to arriving at the doorstep; and drivers to provide proof of delivery when the shipment is complete. Challenges persist when regional or local last-mile delivery organizations must work in-conjunction with national carriers. Fortunately, smartphone technology is closing the gap and improving standards for traceability across the board.

4. In-house delivery services:
   Many companies are starting to use their own or shared vehicles for last mile delivery – such as the Jumia Group (Nigeria). Armanious said, "Traditionally our clients weren't in the transport business. They didn't own trucks or vans or vehicles, but now they're starting to deal with a co-op, with competitors or other companies in the regional area to utilize each other's transportation assets."

5. Anticipatory shipping:

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[1] https://www.supplychaindive.com/news/last-mile-spotlight-trends-tech-gig-perfect/443091/

There is a shift in inventory management where companies perform the bulk of their transportation before consumers purchase their products. For example, companies may use artificial intelligence (AI) to determine when consumers place large amounts of orders in certain regions and pre-ship those items to local warehouses.

6. Smart technology:

In addition to the desire for visibility at each point in the fulfillment and delivery process, customers want to track the temperature of sensitive items in industries such as pharmaceuticals and food (Vuba Vuba in Rwanda). Providers place smart technology and sensors inside packaging so customers can track conditions like temperature and humidity levels. In addition to advancements in-transit technology, 3PL providers and fulfilment centers also use smart technology to predict weather patterns to better plan their packaging to keep products safe along the entire delivery process.

7. Autonomous delivery vehicles:

The main constraints on deliveries are the cost of labor, worker availability and shifts. Autonomous delivery vehicles change those operational constraints dramatically as well as planning for distributions and the response to changes in demand. Initially, companies would use autonomous delivery vehicles in combination with existing distribution practices as distribution planning is evolving to greater use of autonomous delivery vehicles. However, there are regulatory and operational issues that will impact and limit their use, especially in highly urbanized areas.

8. Warehouses in major cities:

Increasing the number of warehouses or fulfilment centers is another way to improve delivery speed and offer benefits like same-day delivery. This works best in major cities, and it is a specialty that companies like Picup (South Africa) perfect with their 90-minute delivery option. The trend is for organizations to build or take advantage of urban warehouse space and have easy access to products for fast customer deliveries.

Challenges in Last Mile Dynamic Routing:

1. **Data:** One of the most difficult last mile challenges is data analysis. Many fleet managers struggle with data use to improve the bottom line. At a basic level, at any moment distribution managers are unaware when supplies come and go and whether supplies will be available for delivery prior to when deliveries dispatch on the floor. The lack of historical data to forecast deliveries and plan accordingly is becoming more costly. One of the most alarming aspects is when fleet operators do not know how to find the data to understand their cost per mile or cost per stop (see nuDeliverIt).

2. **Tribal Knowledge/Limited Information**: There are unwritten, cumulative pieces of knowledge that make routers and drivers more efficient. Unfortunately, often fleet managers are not aware of this until a knowledgeable employee leaves the company. Managers should ensure capturing employee knowledge and build it into their daily route plans. Examples of employee knowledge to capture include: when to deliver, where to park, who to ask for a signature, whether it is necessary to take a picture, or who to contact for getting paid (see LogiNext).

3. **Fleet Operation Black Holes**: It is imperative that fleet managers have real-time visibility into their drivers' locations, especially when it comes to last mile deliveries. Black holes are created when there is a breakdown in communication between the driver and fleet manager (see Wise Systems and Descartes Route Planning Solutions).

4. **Deadhead Miles**: Deadhead miles can become costly without close monitoring. These miles add up quickly if truck drivers do not follow their designated routes. Idling is one the often-overlooked ways that that fleets can lose money. Idling for one hour equals one gallon of lost gas. To reduce idling costs, fleets can integrate start–stop systems to shut off an engine that would otherwise idle and telematics systems that monitor usage parameters (see OmniTracs).

Infrastructure: The lack of infrastructure (roads, electricity, warehouse facilities, communication and computer networks) in the last mile severely limits the quality and availability of information regarding necessary supplies.

Introduction to Annexes

This section breaks down the specifications of different dynamic routing tools that the commercial, open-source and build-your-own markets offer. For each category of routing tools, it provides a holistic view of the tools' functionality by highlighting capabilities that were relevant to the last mile dynamic routing framework and the proof-of-concept we will build in the next phase of the deliverable. Except for the build-your-own bucket, each tool in the commercial and open-source offerings includes the following sub-sections as available. The tools introduced in the build-your-own bucket are mostly based on university research or community support; therefore, the information presented in the Annex is based upon the availability of information on that tool.

1. Description of the solution
2. Use of the solution
3. Targeted industries
4. Integration into other applications
5. Pricing

Annex A. Market Research

Commercial Solutions

1. **Name: Wise Systems**

Description: https://www.wisesystems.com/
- Using machine learning, Wise Systems automatically schedules, monitors and adjusts routes in real time to ensure the most efficient routes while considering multiple variables and constraints. Wise Systems continuously learns from fleet data to optimize and improve fleet performance over time.
- **Benefits:** Wise Systems decreases late deliveries, increases customer satisfaction with real-time visibility and improves overall fleet utilization.

Solutions Based On:
- Wise Systems understands the importance of the last mile and developed a last mile delivery software platform that empowers fleets to excel in this space with differentiated customer service and fleet efficiency. Autonomous dispatch and routing builds machine learning into powerful route optimization algorithms to automate dispatch and routing, and transforms the last-mile experience.
- In-route optimization, on-demand dispatch software, driver mobile apps and many more capabilities equip fleets to compete successfully in the last mile.
- Machine learning transforms last mile delivery by providing highly granular data about every aspect of the delivery day from drivers' preferred routes to learned service times and more.

Industries:
- Food and beverage, parcel and courier, retail, auto-parts, less than truckload, third party logistics (3PL) and business services

Last Mile Software Integration:
- Wise Systems offers an open API to easily communicate with many types of systems and has established integrations with several order management platforms.
- Cloud-based and flexible, Wise Systems is fast and easy to deploy. It does not require expensive on-premise software installations. Wise Systems offers a variety of implementation alternatives to bring the benefits of autonomous dispatching and routing to any team. It offers the option to adopt a single aspect, such as real-time routing for dispatchers and drivers, and add on other functionalities over time or consider adopting the full system. This flexibility allows organizations to customize the path towards making their fleet more dynamic over time.
- Wise Systems has real-time visibility and adjustment: Wise Dispatcher and Wise Driver

Pricing:
- $1,000/year per route (usually work with companies that have 25-1000 routes)
- Typically, a $115,000 investment: $15k/year for professional services and $1,000/driver per year

2. **Name: Descartes Route Planning Solutions**

Description: https://www.descartes.com/
- These tools provide advanced route optimization across a wide variety of planning scenarios from territories and master routes to extremely dynamic routing environments. Real time demand drives these dynamic routing environments at the point of sale.

- **Benefits:** Descartes Route Planning Solutions help to decrease costs, improve service, increase productivity and reduce the environmental impact of organizations' fleets.

Solutions Based On:
- Strategic delivery planning optimizes and builds new services, sales/distribution territories and replenishment strategies that maximize customer service and profit.
- Basic and advanced features for daily and multi-day route planning enable continuous creation of optimal reliable routes using fewer trucks, miles and drivers.
- Enables real-time appointment scheduling to make pick-up, delivery or service commitments that help keep fleet operations productive, profitable, and increase customer satisfaction.
- Straight forward planning and productivity management for mobile workers (sales, merchandisers and other field personnel).

Industry:
- Business services, public sector, retail, transportation and logistics, distribution

Last Mile Products/Solutions:
- Descartes Route Planner™ On-demand - multi-stop delivery fleets monitored in real-time
  - Descartes Route Planner™ On-demand provides an easy and affordable way to plan, optimize, and dispatch routes, and track and monitor delivery fleets in real time. This web-based on-demand fleet management solution combines sophisticated functionality with the simplicity of service delivery. It optimizes both static routes and dynamic routes to maximize efficiency by considering geographic zones, time windows and other physical constraints when planning delivery fleets.
  - Descartes Route Planner On-demand is comprised of several full-featured, web-based modules that are distinct in their functionality, operate independently and work together seamlessly to create an end-to-end route planning solution.

3. **Name: Omnitracs**

Description: **https://www.omnitracs.com/**
- Omnitracs Routing is simple cloud-based software that allows organizations to store custom, delivery-specific rules in the application that lead to more efficient routes. The software centralizes route history to one location and increases the ease and efficiency of organizations to evaluate and create routes.
- **Benefits:** The algorithms of Omnitracs' daily route planning software tracks and assesses customer needs and available resources while considering geographic areas, capacity and more.

Solution Based On:
- Fast, simple implementation
- Digestible route statistics for quick comparison and selection
- Configurable planning criteria
- Seamless integration of territory and route exceptions
- Configurable sales, service and distribution reports

Industry:
- Truckload, private fleets, service fleets, less than truckload (LTT), dedicated fleets, parcel and delivery

Last Mile Products/Solutions:
- **Roadnet:** No additional hardware requirements
  - Multiple routing strategies

- o Collection and use of customer information
- o Ability to route multiple vehicle types with different capacities and costs
- o Highly tunable algorithm to create custom answers to different industries and business models
- o Powerful "suggest route" tools to manage late orders
- o Routing scorecards to show the immediate impact of manual moves on cost and distance
- o Reporting tools – online and standard reports
- Omnitracs' Fleet Telematics solution is an easy-to-install vehicle monitoring system that goes beyond simple global positioning system (GPS) tracking and combines location monitoring, engine diagnostics, easy-to-use mapping and reporting software.
- With Fleet Telematics, an organization can also track certain driver behaviors such as idling, speeding and after-hours use, and improve the overall productivity and efficiency of the fleet.
- Omnitracs also offers a GPS Fleet Tracking solution focused on monitoring drivers through their mobile devices. Fleet Tracking allows one to proactively manage by exceptions through automated alerts. The solution allows managers to know if a worker is stationary too long, speeding, or goes off-route, and leverage this data to improve productivity.

4. **Name: Project Last Mile (Mozambique)**

Description: https://www.projectlastmile.com/category/mozambique/
- Project Last Mile identifies and adapts best practices in process, systems and tools from the Coca-Cola system.
- Mapping and analyzing process in partnership with FrontLine Market Research in Africa (www.frontlineafrica.com)
- It shares its areas of expertise with local governments (i.e. ministries of health (MOHs)), including supply chain logistics, strategic marketing skills and general business best practices.
- Project Last Mile is a commercial application that uses Excel extensions (SpatialXL and RouteXL).

Approach: Example from Mozambique
- It implements network/routing optimization models to reach health facilities to improve route-to-market mapping and planning.
- It outsources distribution of life-saving medicines through creation of potential supplier list and evaluative framework with benchmark data estimates for outsourcing, supplier performance metrics and contract management documents.
- The solution has logistics management capability development: development of job descriptions, performance metrics, training materials and management tools.
- It required significant setup data such as road network, locations of sites, vehicle resources and average volumes from order data (does not link directly to actual orders).
- Maintaining the tool (updating the road network and master input file as well as running, reviewing and adjusting the routing) requires discipline and technical resources.
- The routing solution is influenced by human expertise rather than hierarchy (assigning multi-day or overnight routes to specific vehicles and assigning truck types to specific routes).

Mapping and Analysis Process:
- Mapped and analyzed in SpatialXL
- Modified TomTom road network using GPS tracking
- Route optimization using RouteXL
- Excel-based geospatial analysis and routing tools

5. **Name: nuDeliverIt**

Description: https://www.nudeliverit.com/
- Affordable solution to systemically perform route planning and delivery execution, and obtain shipment visibility, creating a paperless environment for dispatchers, drivers and customers.

Solution Based On:
- Cloud-based: nuDeliverIt leverages the latest software as a service (SaaS) technologies to easily manage horizontal and vertical scale.
- Mobility: The solution has a robust communication framework between nuDeliverIt's dispatch portal and Android and iOS mobile applications.
- Representational State Transfer (REST)ful APIs/Integration Framework: nuDeliverIt supports all core business objects from routes, to drivers and riders, vehicles, reason codes and route update events.
- Data Security: nuDeliverIt has data encryption at rest and in transit both in nuDeliverIt's mobile applications and dispatch portal (a necessity for Health Insurance Portability and Accountability Act (HIPAA) compliance).
- Embedded DevOps: It has active upgrade and new feature introductions with little to no downtime.
- Shared Network: nuDeliverIt is built on a multi-tenant architecture that supports business partnerships and visibility across businesses all on the same platform, data and level of transparency.
- Configurable Workflow: Users are presented with workflows that are data-driven or have configurations that align with specific business needs.
- Event-Based Architecture: Each user action creates an event in nuDeliverIt. Users can configure each event, or actions such as sending emails, short message service (SMS), and integration with external systems, with any existing systems. This makes it flexible and customizable user functionality.
- Authorization/Authentication: Enables managed access to nuDeliverIt mobile applications and dispatch portal.

Industry:
- Carriers, 3PL & brokers, wholesale/manufacturer, retail, small business

Last Mile Products/Solutions:
- Two solution models: Enterprise customers or small business
  - Enterprise Customers: nuDeliverIt supports large scale transactions. It has had 99.7% system availability over the last five years and customer service support for a SaaS application. nuDeliverIt has easy integration with systems of record and flexible solution architecture to support custom workflows with continuous innovation.
  - Small Business: nuDeliverIt has easy or no integration. It requires two to three days of on-boarding. The solution has out of the box integration with some partners. It benefits from ongoing enhancements and has no information technology (IT) requirements. It involves pay for use.

6. **LogiNext**

Description: https://www.loginextsolutions.com/products/mile
- LogiNext features highly configurable enterprise logistics management software solutions.
- They are designed to serve all client needs using smart technology and big data analytics and to enable comprehensive field service management.
- LogiNext's Mile™, Field™, On Demand™, Haul™, and Reverse™ logistics and field workforce management solutions are automated, effective, secure and allow for seamless integration with multiple platforms to provide complete logistics automation.

Solutions Based On:

- Realtime Field Workforce Management: This tracks field agent movements, delivery associates, medical reps and field technicians and other field work assets by noting every single minute on a single map interface.
- Best Logistics Management software: Logistics analytics helps organizations to accurately predict the future with algorithm-enabled location intelligence and optimize logistics and field service management operations.
- Delivery Logistics Automation: This starts from pick-up and delivery automation to complete field service management analytics or from last mile delivery optimization to reverse logistics software.
- Easy integration with multiple platforms: Logistics management software can be set up as a standalone system or integrated with existing enterprise resource planning (ERP), customer relationship management (CRM), transportation management solution (TMS), or warehouse management system (WMS), which allows creation of a seamless experience for operations and field workforce management supervisors.

Industry:

- Courier, express parcel, retail, pharmaceuticals, e-commerce, transportation, banking/financial services, manufacturing

Last Mile Products/Solutions:

- Real time: This tracking allows sharing through secure links, push notifications or APIs.
- Automated planning: Optimization software for all distribution models, including single pick up, multiple drop and multiple pick up, and multiple drop algorithms.
- Electronic Proof of Delivery: Cash and card management at point of sale, electronic proof of delivery as image, timestamp and geo-coordinates.
- Dynamic Re-routing: Algorithm considers various parameters, including capacity, customer locations and time preferences, and traffic and weather conditions.
- Hardware Agnostic Platform: Last mile delivery app is hardware independent and has negligible impact on battery life.
- Real time estimated time of arrive (ETA) calculation: Real time re-routing, delivery route optimization and updated ETA based on change in conditions.
- Interactive Planning Dashboard: Enables analysis of entire delivery network using heat maps, trendlines and planned vs actual service-level agreement (SLA) comparisons.
- Delivery Route Planning Visualization: Allows comparison of planned route against actual route on map interface and identification of bottlenecks.

Pricing:

- Free: Test the software with 15-day free trials
- Basic: $20/month
- Premium: $30/month
- Advanced: $49/month
- Additional information on pricing available at: https://www.loginextsolutions.com/pricing/mile

Open Source Solutions

7. Name: GraphHopper

Description: https://www.graphhopper.com/
- With the GraphHopper Directions API, organizations can integrate A-to-B route planning, turn-by-turn navigation, route optimization, isochrone calculations and other features into existing applications.
- **Benefits:** GraphHopper has world-wide coverage, permissive terms, and easy integration, and it is cost-effective. Customers can discuss problems with the "community" and explore the rich content of routing questions from the forum.

Solution based on:
- OpenStreetMap API

Industry:
- Food delivery, parcel, waste management

Last Mile Products/Solutions:
- Routing and Navigation:
  - Organizations receive travel times, distances, turn instructions, and the route geometries based on one's travel profile, which then can display on a map of choice. This solution also provides an open source example to integrate turn-by-turn navigation into an Android app.
  - GraphHopper directions API comes as a RESTful web service, which allows for integration of routing into any application without knowledge of the complex algorithms behind it.
- Route Optimization:
  - Organizations that want to route a fleet of vehicles (or workers), to deliver items or services to customers, can integrate route optimization into their application. This process assigns routes to vehicles to minimize total transportation costs and can consider an arbitrary number of business-specific side constraints like time windows, driver skills, vehicle capacities and more.
- Geocoding:
  - Every location-based application requires address and point of interest search. GraphHopper allows customers to "reverse geocode," which means to obtain a current geolocation address or a coordinate for an address. The system also supports external geocoding services that complement the quality of this default solution.
- Map Matching, matrix calculations, isochrone calculation

Pricing:
- Free: five locations/one vehicle
- Basic (48 euro/month): 30 locations/ two vehicles
- Standard (128 euro/month): 80 locations/10 vehicles
- Premium (304 euro/month): 150 locations/20 vehicles

8. Name: VillageReach

Description:
- This is a user-friendly Excel-based optimization tool for routine and emergency use. It helps optimize routes, takes into consideration factors such as time and risk, considers road conditions, and does not require specialized software skills to produce results in minutes.
- Professors and researchers from the University of Washington developed and support it

- Limitations:
  - Entering the distance road and conditions matrix is difficult
  - Does not limit demand based on the storage capacity of facilities
  - Multi-day deliveries based on hours traveled without incorporating cost
  - Assumes all vehicles must make at least one trip
  - Minimizes total completion time without factoring in any costs
  - Requires defining when orders are ready for dispatch in advance
- No integration necessary because it is a stand-alone Excel-based tool
- Routing solver:
  - Vehicle routing and scheduling algorithm (VERSA)
  - VillageReach will test this tool in the next few months

9. Name: Open Door Logistics (ODL) Studio

Description: https://www.opendoorlogistics.com/software/odl-studio/
- ODL Studio is an easy-to-use stand-alone, open source desktop application for performing with an Excel spreadsheet (a) analysis of customer locations; (b) sales territory design and mapping; and (c) vehicle fleet routing and scheduling.

Solution Based On:
- OpenStreetMap
- Desktop-based application
- Non-real time

Industry:
- Logistics

Last Mile Products/Solutions:
- Territory design and territory management:
  - Designs territories visually using the mouse to "paint" them on the map
  - Sophisticated territory mapping allows one to color and shade territories and tailor territory maps to individual requirements
  - Automatically optimizes territories using a powerful algorithm
  - Generates sophisticated PDF reports with maps of territories and detailed breakdowns of their key statistics.
- Vehicle routing and scheduling
  - Automatically schedules an efficient set of vehicle routes to serve delivery points
  - Models routes using real road networks that are provided by the GraphHopper project
  - Edits vehicle routes and indicates how changes affect the route shape and key statistics
  - Allows viewing of tabular breakdowns of key statistics - e.g. total mileage and drivetime
  - Allows viewing of routes in an interactive map
  - Analyzes time usage using a Gantt chart control
  - Generates detailed reports and exports them to PDF or other formats

Pricing:
- ODL Studio is free
- ODL Live is cloud-based, real-time $665/month

10. Name: OptaPlanner

Description: https://www.optaplanner.org/

- OptaPlanner is the leading Open Source Java™ AI constraint solver to optimize the vehicle routing problem (VRP), the traveling salesman problem (TSP) and similar use cases. It covers any type of fleet scheduling, such as routing of airplanes, trucks, buses, taxis, bicycles and ships, regardless if the vehicles transport products or passengers or if the drivers deliver services.
- **Benefits:** Lightweight, embeddable

Solution based on:
- Java
- AI optimization algorithms

Industry:
- Supermarkets, retail, freight, ground transportation

Last Mile Products/Solutions:
- Scaling out
    - OptaPlanner scales out on the VRP thanks to incremental score calculation, nearby selection, shadow variables, and advanced construction heuristics and metaheuristics.
- Route Optimization:
    - Integration with Google Maps or OpenStreetMap is straightforward

Pricing:
- Free

Build-Your-Own Solutions

11. Name: Google OR-Tools

Description: https://developers.google.com/optimization/introduction/overview
- Google OR-Tools is an open-source software/toolkit suite for optimization.
- It is not the best 'beginner-friendly' tool, but the most customizable.
- Google OR-Tools can optimally schedule a complex set of tasks and pack objects into bins with maximum capacities. After modeling the problem in the programming language of choice, one can use any of a half dozen solvers to solve it, including commercial solvers such as Gurobi or CPLEX or open-source solvers such as SCIP, GLPK or Google's GLOP and CP-SAT.
- Its use cases include TSP, capacitated VRP, pickup and delivery VRP, VRP with time windows and resource constraints.
- APIs: Distance matrix API calculates a distance matrix for any set of locations defined by address, latitude, and longitude. Without downloading OR-Tools, users can solve simple TSPs with the Direction API. To use it for development, users need own free Directions API key. Commercial use of Direction API requires an enterprise key.

12. Name: Route4Me

Description: https://www.route4me.com/
- It is cloud-based software for route planning; this tool runs smoothly on any device.
- Among its advantages, users highlight the ease of creating new maps from imported addresses.
- Route4Me is also flexible in terms of route modification: its drag-and-drop feature inserts new addresses easily into existing routes.
- The Route4Me solution addresses many constraints, such as avoidance zones, predictive weather, weight and revenue constraints, and curbside/rooftop delivery.
- Route4Me offers the following APIs: Platform API's, Operational Assessment API, Telematics Gateway API, and Resource API, which organizations can use to build custom solutions.
- Route4Me's marketplace offers a range of Add-Ons in mobile, routing, telematic and operations that allows one to customize a plan that best fits with in-country business needs.

13. Name: MapQuestDeveloper

Description: https://developer.mapquest.com/documentation/
- MapQuestDeveloper is an online web mapping service by Verizon that is potentially the platform of choice when it comes to getting turn-by-turn directions from point A to point B, or points C, D and E.
- It is an open-source platform where 34,000 developers and entrepreneurs leverage the building blocks of a proven geospatial solution.
- It requires direct inquiries for customizable plans.
- MapQuestDeveloper offers a wide range of APIs based on business needs and there are also open-source alternatives: APIs for directions, elevation changes along a route, geocoding, location guidance, search API and Static Map API.
    - Directions APIs
    - Data Manager APIs
    - Directions APIs
    - Geocoding APIs
    - Icons APIs
    - Search APIs
    - Static Map API
    - Traffic API

- MapQuest for Business is available for free if use is limited to 15,000 transactions per month. Otherwise, organizations must pay starting from $99 per month for 30,000 transactions (Basic plan) up to $899 for 500,000 transactions.

14. Name: OpenRouteService

Description: **https://openrouteservice.org/**
- The OpenRouteService directions service covers the globe and allows organizations to compute routes and all sorts of navigation information.
- It offers a wide range of travelling options for multiple modes of transport, including cars, different bicycle types, walking, hiking, wheelchair and heavy vehicles. Each of these modes uses a carefully compiled street network to fit the profiles requirements.
- To help organizations individualize routes even further, the API provides the ability to customize input information with road type restrictions and vehicle characteristics.
- It is maintained by the Heidelberg Institute for Geoinformation Technology Group and is supported by the Klaus Tschira Foundation Heidelberg. It is also part of the GIScience Research Group at the Department of Geography, within the University of Heidelberg.
- **Benefits:** World-wide coverage, cost-effective, long distance routing.

Solution based on:
- API

Industry:
- Transportation, shipping

Last Mile Products/Solutions:
- Directions:
  - Organizations can use OpenRouteService's directions all over the globe and make use of plenty of options, ranging from different kinds of road restrictions to vehicle dimensions.
- Time-Distance Matrix:
  - Matrices allow organizations to compute many-to-many distances and the times of routes much faster than repeatedly consuming the directions API. Logistics companies frequently use this application in trying to figure out the most optimal route for deliveries.
- Isochrones:
  - Reachability has become a crucial component for many businesses from different kinds of domains. To this end, one can use OpenRouteService to obtain isochrones to help determine which objects one can reach in given times or distances.
- Pelias Geocoding:
  - Geocoding transforms a description of a location, such as a place name, street address or postal code, into a normalized description of the location with point geometry. Geocoding service is built on top of the sophisticated Pelias Stack, which aggregates several data sources.

Pricing:
- Free: 50 optimization requests/day
- Free: 2000 directions requests/day