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The use of autonomous coupling capable trailer to reduce the cost per delivery and increase profit for logistic companies: a simulative analysis

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Abstract

Last-mile distribution causes more obstacles in urban areas all over the world. Increased volumes of packages to be delivered for customer homes is directly increasing the number of delivery vans movement inside the urban areas and thus add to congestion and negative health impact. Therefore, it is anything but surprising that in recent years many traditional delivery concepts on the last mile have been innovated. Among the most prominent are unmanned aerial vehicles (drones) and autonomous delivery robots taking over parcel delivery. In this paper we introduce the autonomous latching and unlatching concept for urban vehicle with trailer. Considering the fact that latching and unlatching operations generally happen in unstructured environments where obstacles are left lying around, the whole latching and unlatching process is divided into two phases, namely the trailer repositioning phase and the autonomous latching and unlatching phase. The benefits in last-mile logistics of using this autonomous trailer for unattended deliveries are evaluated in simulation with Anylogic software. Four different scenarios are simulated and compared: traditional vans without trailers; traditional vans to which trailers can be added manually; traditional vans with autonomous coupling capable trailers; autonomous vans with autonomous coupling capable trailers.

Keywords: Urban-logistics; Last-mile deliveries;Trailer;Autonomous vehicles;Autonomous coupling capable trailer;Simulation.

1. Introduction

Last-mile deliveries in urban areas are increasingly a critical issue. This is because the number of trips made by commercial vehicles is increasing, with load factors often very low. The related problems are: commercial vehicles occupy public land, especially when parked, often irregularly, to make deliveries; commercial vehicles often produce emissions and noise that contribute to environmental and acoustic pollution in urban areas; commercial vehicles contribute to urban congestion and consequently to the increase of travel times.

Among the causes of the increase in the number of journeys made by commercial vehicles are: the reduction of storage space of shops in urban areas, the increase in e-commerce (an increase that has been further boosted by the limits imposed by the recent pandemic: see for instance, the boom in deliveries of ready-to eat meals), and the ever-increasing demand for customized products.

1.1. Potential solutions

- The clustering of deliveries of small parcels in a few common delivery locations (see lockers etc). This makes it possible both to reduce the number of kilometers that commercial vehicles have to travel in order

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to make deliveries to individual recipient doors and to reduce the number of stops to make deliveries to individual recipients doors and the associated occupation of public land. Instead, recipients must pick up their parcel at the place where it was left when it suits them best, within a defined time window. Delivery locations could be attended or unattended.
- The use of electric vehicles, which do not pollute in urban areas where population density is high.
- The introduction of unmanned vehicles that can operate autonomously during night, or in any case off-peak hours, lightening the traffic congestion of peak periods. The absence of the driver also leads to reduced operative costs and, for the same vehicle size, a higher load capacity.

The paper proposes the use of trailers to be attached to vans used for last mile deliveries in urban areas. The trailer allows to increase the load capacity of the van, when necessary. The trailer, which contains goods for only one commercial activity, is left in the vicinity of the retailer and, in the time that the retailers' personnel collect their goods from the trailer, the van can be used to complete deliveries in the area. The paper presents a system for automatically latching/unlatching of the trailer to the van. This allows to reduce the time of the operation that is currently done manually and, in the future, to prepare the possibility of using autonomous vehicles that can latch and unlatch their own trailer independently. A simulator was developed with Anylogic to be able to evaluate and quantify the benefits of the proposed logistics system in specific realities: the proposed logistics system was simulated for the city of Genoa, Italy for a known deterministic and fixed freight demand. The research question to be answered in the proposed research is what is the impact of the proposed system in terms of costs for those who provide the logistics service.

The article is structured as follows: Section 2 introduces the key concepts underlying the proposed logistics model: attended or unattended deliveries, use of trailers in logistics, transition towards autonomous vehicles in urban logistics. Section 3 describes the models proposed for trailer autonomous latching/unlatching operations and for the logistic service. Section 4 presents the scenarios that are compared and describes the KPIs that have been identified for their evaluation and comparison. There are 4 scenarios that have been simulated: the first one refers to a fleet of traditional vans and constitutes the reference scenario (non-intervention scenario); the second one refers to a fleet of traditional vans to which trailers can be manually attached; the third one refers to a fleet of conventional vans to which trailers can be autonomously attached and the last scenario deals with autonomous vans and autonomous latching/unlatching operations. Section 5 describes the simulation model developed with Anylogic and the Section 6 the simulation experiments and the results. Section 7 presents the conclusions and closes the article.

2. State of the art

In the following we referred to last mile deliveries in urban areas. Freight could be delivered to final customers who bought online or to retailers. The term "home deliveries" in the following could refer to deliveries to customer homes or to retailer shops. As it concerns the delivery location, this can be attended or unattended (Cepolina et al., 2021).

2.1. Attended deliveries

- Home deliveries: The customer has to stay at home waiting for the delivery. When the customer is not at home at the time of delivery, i.e., first time delivery failure, it causes higher operating costs for online retailers/carriers and inconveniences to customers that lead to lower satisfaction. The advantage is that the customer has not to cover any distance for collecting the products.
- Collection points like petrol stations or corner shops: the customer is free to choose his/her more convenient time for the collection but have to pass through the collection point, making a deviation in his/her daily route.
- Lockers/reception boxes: fixed location. DHL Parcel Germany runs the Pack-station service, which allows customers to self-collect parcels, 24 hours a day, seven days a week, in fixed locations. (Punakivi and Tanskanen, 2002) show that transportation costs using the shared reception box concept are 55-66 per cent lower in comparison with the current standard concept with attended reception and two-hour delivery time windows.
- Lockers which position is daily optimised.(Molfino et al., 2014) propose, within the FURBOT EU project (FP7-SST-2011-RTD-1), a last mile delivery system based on mobile safe parcel-lockers and a small electric vehicle (the FURBOT prototype). Parcel-lockers are consolidated in the Urban Consolidation Centre with packages addressed to many customers. Each parcel-locker is addressed to a temporary unloading bay where the customers need to self-collect the parcels. The unloading bay is selected in order to minimize the distance the customers have to cover for collecting their products from the parcel-locker (Cepolina, 2016). The parcel-locker is delivered to the assessed temporary unloading bay by FURBOT and is automatically unloaded (Masood et al., 2021) and left there for a given time window. Afterwards, the empty parcel-locker is automatically collected by FURBOT and moved to the Urban Consolidation Centre, for a new delivery trip.
- Lockers fixed on a van. The locker is fixed on the van and the customers collect their products directly from the van, while it is parked in a convenient place. This solution requires a narrow collection time. This service is cold, by the Udelv company, the Mobile Locker. Their autonomous delivery vans (ADVs) are filled with goods in one location. The vans drive to another 'hot

spot', where it sits while, as many as 32 delivery customers, come out to retrieve their goods. Udelv (Urban delivery vehicles) are already used as Mobile Locker for grocery delivery as well as Nuro R2 and CargoPod by Oxobotica. Draeger's Market, a San Mateo (CA) grocery store, is using the udelv ADV; the shop has an agreement with multiple office buildings, for free grocery delivery during a specific day of the week. Draeger's Market pickers load the udelv vehicle at 4:00pm. The vehicle arrives close to an office building by 4:30pm, and sits until 5:30pm. Customers retrieve their order when they exit from the office, before to take the car to go home(Cepolina et al., 2021).

2.2. Unattended deliveries

In the pandemic period, this delivery methods become more important for safety issues since they guarantee contact-less: products do not need to go directly from driver's hands to customer's hands. Unattended delivery can be simply leaving an item on someone's doorstep, or in their garden, but this brings many security concerns. Some of the secure unattended delivery methods are reported in the following.

According to (Coutinho, 2018), unattended reception is the optimal service concept from the perspective of cost efficiency. It allows for greater operating efficiency but requires investment in reception solutions at the consumer end. From e-shoppers' point of view, it could reduce the time in waiting for delivery. However, unattended delivery is not always the preferred choice for the customers: according to results of a survey related to online shopping in UK (El Raoui et al., 2018), most consumers resulted against unattended safe boxes; instead, they are in favour of using a neighbouring house or collection points, so long as these collection points are within short distance and is time convenient. As it concerns the delivery vehicle, the trailer, in road transport, is mainly used to temporarily increase the load capacity of a truck. There are a variety of trailer types and widths to transport different categories of goods. Each type of trailer is suitable for a specific purpose, e.g. a standard or oversized load. The use of trailers in logistics is also related to loading units and multi-modal transport. The crucial phase in multi-modal transport is the load breaking, when the goods move from one mode of transport to another one. The semi-trailer with the load it contains can become a load unit that is coupled/uncoupled to different tractor units in multi-modal transport. In rail wagons, the semi-trailer is transported without the tractive unit, which is uncoupled beforehand to lift the semi-trailer onto the wagon. At the end of the rail journey, the semi-trailer is re-coupled to a tractive unit that takes it to its destination. As far as we know, there is nothing in the literature on the use of trailers as temporary 'locker', meaning that the trailer is parked temporarily in an urban area and the recipients of the goods contained in it go to the trailer's temporary parking bay to collect their parcels from the trailer.

Unattended deliveries by using autonomous latching capable trailer, drones and droids in urban logistics face different kind of issues like cyber-attacks, insurance and permits. Government is in-charge of handling permit related issues. manufactures are in-charge of handling insurance. Cyber-attacks prevention can be managed by adding necessary equipment and anti hack safety systems installed.

3. THE PROPOSED MODEL

3.1. AUTONOMOUS LATCHING-UNLATCHING

Autonomous latching capability is a key technology in future logistic and manufacturing industries. In manual latching accurate vehicle parking operations are need to align the vehicle and the trailer parallel. Then, manually the coupler, coupler mount should be fixed. In general, autonomous latching and unlatching is defined as a problem of positioning a robot to a target with a desired orientation (Fujimoto and Tokhi, 2010), which is similar to the definitions of navigation or visual-servo regulation (Zhang et al., 2011; Li et al., 2015; Villagra and Herrero-Pérez, 2011). However, docking requires higher accuracy than these two problems because a less precise maneuver may result in a collision with the target (Elbert and Lehner, 2020), which can cause huge economic losses. Furthermore, docking operations may be subject to additional transient constraints introduced by the structure of the docking mechanism. In a modern automotive sector, physically connected robots will be deployed, which can be assembled by dynamically latching and unlatching individual robots into one unit in order to transport large objects, as well as autonomously self-detach to perform individual tasks In this paper we introduce the autonomous latching and unlatching concept for urban vehicle with trailer using relative position and orientation measurements of the target. Considering the fact that target is latching and unlatching operations generally happen in unstructured environments where obstacles are left lying around, the whole latching and unlatching process is divided into two phases, namely the trailer repositioning phase and the autonomous latching and unlatching phase. To achieve an autonomous latching to the vehicle by the trailer, continuous signals and data will be sent out from the sensors and the transmitters to control unit of the trailer and control unit sends the command to activate the latching or unlatching. 1 shows sensor placing and reading angles in both vehicle and trailer in the proposed model. In the latching stage, lateral and longitudinal movements of the trailer are required for the trailer to reposition itself and make its alignment to latch with the vehicle. In this research the trailer is a building unit.

Control unit is positioned in the trailer. Fixed to the trailer frame. This control unit controls the lateral, vertical and horizontal movement of the trailer. The vertical and lateral movement of the trailer is done by activating the

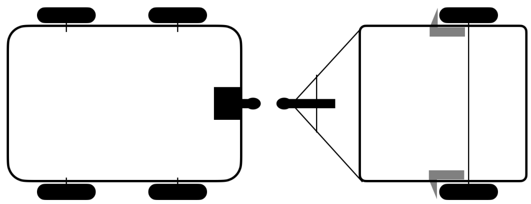

Figure 1. Sensor placing and Layout of both vehicle and trailer.

hydraulic cylinders. Control unit works based on the information is received by the sensors, latching-Unlatching command received by the vehicle. After procuring the image data of the sensor, the control unit commands to the actuators which handles the movement of AL-KO Mammut component, hydraulic cylinders to successfully latch and unlatch of the vehicle.

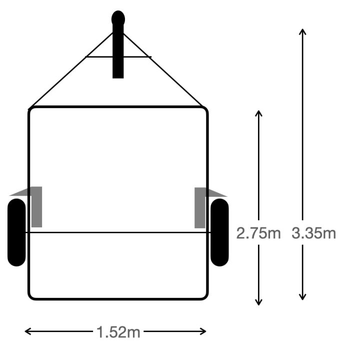

Figure 2. Top view blog diagram of the trailer.

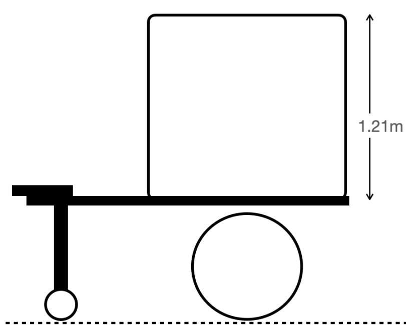

Figure 3. Side view blog diagram of the trailer.

The main requirements for autonomous capability are control unit, Hydraulic cylinders, position sensors, AL-KO AMS Mammut device. Initially, the trailer is in a parking position. The trailer is in the contestant position. Now, the vehicle moves near to the trailer and halts in a position which is at a visible distance from the vehicle and the trailer. Figure shows the possible layouts of how the vehicle and the trailer will be parked in a state. Sometimes, the vehicle coupler and trailer coupler align parallelly or both align at parallel distance or align at a certain angle. Now, after the vehicle alignment. The vehicle transmits the signal to the trailer for latching. the control unit of the trailer receives the signal and send the signal to actuators from the data received from the optical and positional sensors placed on the trailer. The sensors, reads the data of distance of the latch's coupler from the latch receiver. Height of the coupler and also sends the information about angular distance from the latch coupler to the latch receiver. Finally, after successful latching, the optical sensor sends the information to the control unit. Now, the control unit activates the actuator of the safety pin lock. This safety pin locks the latching coupler. After the locking done by the safety pin; the sensor data is again sent to control unit. The control unit reads the data and transmits that latching is successfully done or latching is not successful.

3.2. THE LOGISTIC SYSTEM FOR LAST MILE DELIVIERIES

Retailers place orders to producers. The goods are transported from the production sites to the distribution center. In the distribution centre, goods are stored temporarily and then consolidated. If a large volume of goods is destined for a single retailer, these are consolidated into a trailer. Small parcels, on the other hand, are grouped according to their delivery address and are loaded on a van. The trailer is then coupled to a van based on delivery addresses: the trailer will have a destination within the geographical area that the van is to serve. The delivery service is both assisted and unassisted: deliveries associated with the trailer are unassisted, those made by the van are assisted. For the clustering of parcels, the algorithms proposed in (Cepolina, 2016) are adopted. The trailer is hitched to the van. Van plus trailer reach the unloading bay of the trailer. The trailer is then left here. The van, without the trailer, continues to make deliveries in the area around. The van then, returns to the point where its trailer was left. The trailer is hitched to the van and van plus trailer travel again to the distribution center.

4. SCENARIOS TO BE COMPARED

Referring to the proposed last mile distribution logistics service, we want to compare different levels of automation associated with van driving and latching/unlatching operations. Four scenarios were therefore defined: Scenario 1 refers to a fleet of traditional vans. Scenario 2 refers to a fleet of traditional vans to which trailers may be manually attached: in this case the load capacity increases (to that of the van is added that of the trailer), the number of trips consequently decreases, the time of a trip increases for manual latching/unlatching operations. Scenario 3 refers to a fleet of conventional vans to which trailers can possibly be autonomously attached: in this case, the load capacity increases (and is the same as in scenario 2), the number of trips consequently decreases, the time of a trip decreases compared to scenario 2 because the latching/unlatching operations take place autonomously.

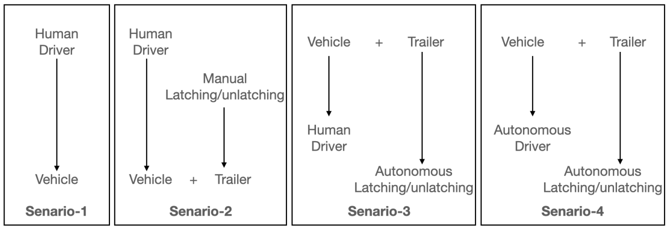

Figure 4. Types of vehicle and trailer scenarios.

Scenario 4 coincides with scenario 3 but here the van is self-driving and therefore the loading capacity is higher. In this scenario is not the driver and therefore it refers to a near future in which self-driving vehicles will be allowed to circulate in public roads in urban areas. The first experiments in Europe of logistics services operated by autonomous vehicles in urban contexts are taking place in some pilots financed by the H2020 SHOW project, for instance in the city of Trikala (Greece). In Figure 4 the proposed scenarios to be compared.

4.1. KPI definition

The comparison between the proposed scenarios is made by referring to one KPI that is expressed in terms of disutilities. The scenario with the lower KPI is preferable.

The KPI is the overall cost for delivering the whole freight demand. The cost has a fixed component and a variable component, which is a function of the time travelled. The fixed cost is given by the cost of a van multiplied by the number of vans in the fleet plus the cost of a trailer multiplied by the number of trailers in the fleet plus the maintenance costs. The variable cost is given by the number of hours travelled to satisfy the entire freight demand multiplied by the unit cost of the travelled hour.

$$KPI_1 = C_{tot} = C_{fix} + C_{var} \tag{1}$$

$$C_{var} = \frac{euro}{Km} * KmTravelled + \frac{euro}{h} * deliverytime \tag{2}$$

$$C_{fix} = \frac{euro}{van} * Vans_{fleet} + \frac{euro}{trailer} * Trailers_{fleet} \tag{3}$$

Please note that in euro/h it is include personnel costs (for driving and for manual latching/unlatching operations). The cost is carried at a daily cost. The costs of van and trailer are depreciated and carried at daily cost.

Loading operations in the distribution center are common in all the 4 scenarios and therefore have not been introduced in the comparison.

5. SIMULATION MODEL BY ANYLOGIC

This Simulation modelling solves real-world problems safely and efficiently. It provides an important method of analysis that is easily verified, communicated, and understood. Across industries and disciplines, simulation modelling pro- videos valuable solutions by giving clear insights into complex systems. Overall, multiple scenarios may be explored very quickly by varying parameters. They can be inspected and queried while in action and compared against each other. Therefore, the modelling and simulation results give analysts, engineers, and managers alike confidence and clarity. One of the main simulation and modelling software is AnyLogic, where the modelling and the simulation will be implemented. In this project, system dynamics (SD) and agent-based (AB) models are used. It is a hybrid approach that combines these two methodologies.

5.1. Agent Based simulation

An agent-based (AB) model is a computational model for simulating the actions and interactions of autonomous agents to understand the system's behaviour and what monitors its outputs. AB is a bottom-up approach. The AB simulation model consists of three components which are the agents, the environment, and the time. In an agent-based model, a system is modelled as a collection of decision-making entities called Agents. The agents are programmed to behave an interact with other agents and the environment in certain ways depending on time. These interactions produce emergent effects that may differ from the effects of individual agents. Each agent assesses its situation and decides a base of a set of rules. Agent-based models focus on micro-level interactions between entities.

In Anylogic it is possible to insert the GIS Map Location and rearrange the size of the map and change the routing servers from default to AnyLogic Routing servers. Next, we create the agents and place them on the map. In this supply chain GIS model, it contains one distribution center, several retailers spread across an urban area, and a fleet of Van-trailers that deliver the product from the distributor to retailers. In the AnyLogic PLE window, To the left of the graphical editor you can see the Projects view and the Palette view sharing the same area. The Projects view provides access to AnyLogic models that are currently opened in the workspace. The workspace tree provides easy navigation throughout the models. The Palette view contains all graphical elements that you can add onto the graphical editor of your agent simply by dragging and dropping. Model elements are grouped by categories in a number of palettes. The right side of the workspace contains Properties view, which allows to view and modify the properties of the currently selected model element(s).

By adding vehicle agent, we introduce the Van-Trailers

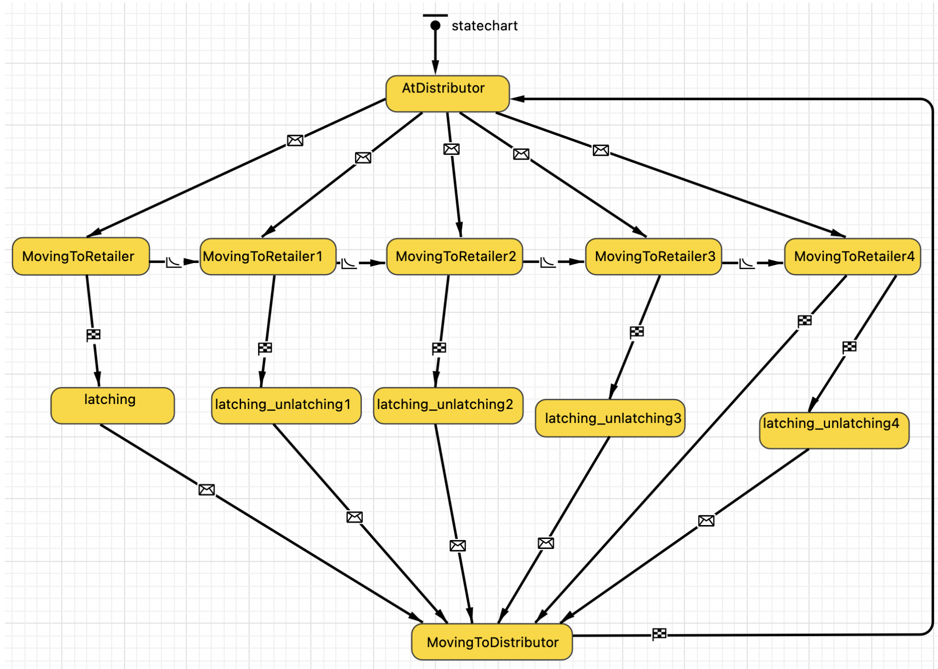

Figure 5. Layout of Agent-vehicle movement algorithm from distributor to the retailer.

in the simulation model. Here we develop the agent from the scratch. We create by using the 2D images van from the Anylogic library. Now, we start to develop the algorithm for movement of the Van-Trailer from the distribution center to each retailer as shown in figure 5.

We have drawn the states. Now it is time to define how the agent (van) will be switching from one state to another. To draw a transition, double- click the Transition element in the State chart palette to activate its drawing mode. Now draw a transition by clicking inside the state that it goes from, then click the border of the state that it leads to. After successful element connection, the point of connection will be highlighted in the green color.

Now we create the algorithm where trucks will start their movement to a randomly chosen retailer. We update the transition's trigger type to triggered by message as in figure 5. The message is sent when both of these conditions are fulfilled.

- In the warehouse, the goods have been loaded onto the van and possibly onto the trailer.
- The randomly chosen retailer is ready to receive and possibly unload the goods from the trailer.

To find the distance travelled by the Van-Trailer, we use getDistanceGIS(warehouse, retailer) function in figure 5 that accept as input the latitude and longitude positions of both the warehouse and retailer. During the exit of the van-trailer, the travel time, travel distance data is collected to compare the difference in the freight travellers and delivered to the retailer by using the autonomous latching capable trailer to manual latching trailer.

The urban logistic network simulation model is created using AnyLogic 8 PLE, a software from the AnyLogic Company. AnyLogic is widely used for studies in the field of logistics, transportation, supply chains. AnyLogic is based on Java and provides high modelling flexibility. In the figure 5 shows the algorithm used to create the logistic network in the Anylogic software.

5.2. System Dynamics modelling

System Dynamics (SD) is a modelling and simulation tool in management fields. Now, it became widely used in modelling real-world problems in economy, socioeconomic, and ecology. SD modelling provides a series of conceptual and quantitative methods to understand and simulate non-linear and complex interactions between system elements via feedback loops and provide measures for the future effects of decision-making processes by presenting the possible effects in advance and explaining long-term results. SD models are built based on the system structure and use differential equations to describe its behavior. SD is a top-down approach.

5.2.1. Demand Representation of each retailer

In the SD approach we started the model by giving the Retailer orders. This demand is considered as total warehouse order is divided into the retailer order and van orders.

5.2.2. Flow movement from distributor to retailer

After splitting the demand order to trailer order and vehicle order, the total warehouse order is released from the inventory. From the warehouse, the load is distributed to different retailers.

5.2.3. *Return goods symbiosis*

The return goods of each retailer are moved back to the warehouse, where the sorting and order of the products are done. To reduce the overall expenses and increase the revenue of the freights we use symbiosis method to reuse the return goods to the warehouse and reuse the freights to deliver to different order by same or different retailer.

5.2.4. *Cost, revenue, and profit calculations*

The total stock delivered to the retailer with the total cost is calculated for each scenario. Similarly total revenue of each retailer stock is calculated as well as the Total profit from return packages symbiosis.

6. SIMULATION EXPERIMENTS AND RESULTS

The simulation refers to the urban area of Genoa (Italy). The distribution center is held in Bolzaneto.

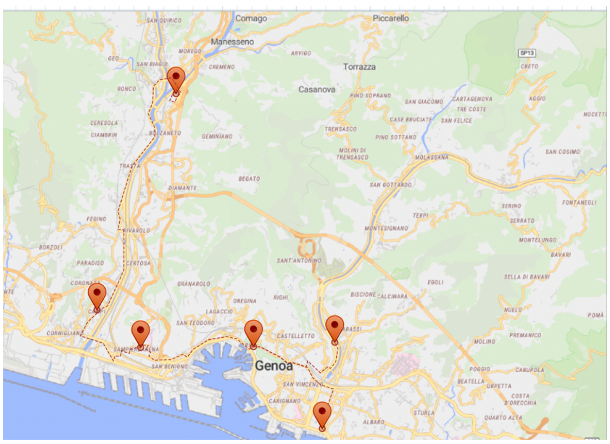

Figure 6. Case study area.

Five retailers are spread in a urban area which is about 30Km^2. The distance between the distribution center and the urban area where the 5 retailers are held is about 12 Km. The case study area is shown in Figure 6. During the day, the time required to reach the urban area from the warehouse is about 0.3h. During the night (when the delivery is carried out in Scenario 4), the travel time drops down to 0.17 h. Here with the data used for all the simulation experiments

- Autonomous Latching time up to 5 mins
- Autonomous Unlatching time 10mins
- Manual latching 15mins
- Manual unlatching 10mins
- Van Load Capacity 3300kg
- Trailer Load capacity 1500kg
- Extra van load capacity (scenario 4 driverless): 200 Kg

Freight demand of each retailer is different. The total

Table 1. parameters of each scenario

Parameter	$Time_{cycle}(h)$	$Time_{delivery}(h)$	$Fleet_{dimension}$
Scenario1	3.60	14.40	2
Scenario2	4.02	12.05	3
Scenario3	3.85	11.55	2
Scenario4	2.59	5.19	1

daily freight demand = 10000 kg

- Retailer1 = 1800 kg
- Retailer2 = 2400 kg
- Retailer3 = 2800 kg
- Retailer4 = 3000 kg

The delivery time window is 8 hours. All the freight demand has to be delivered by within this time window. Scenario 1: according to the vehicle capacity, 4 trips are required in order to deliver the total freight demand. In scenario 2 and 3 the number of required trips is 3 since the vehicle capacity is higher and in scenario 4 it is 2 since the capacity is even higher because there is not any driver. The time to complete deliveries in the area around each retailer is about 4 h in the scenarios 1, 2 and 3. In scenario 4 it is about 3.5 h since the mean speed is higher since the traffic flows are lower. The cycle time is given by: loading time in the warehouse+ travel time for the return trip (warehouse/urban area) + delivery time + latching/unlatching time. According to the assessed cycle times, it is possible to assess the number of trips that each vehicle is able to perform in the available time window in each scenario. Given the cycle times, the fleet dimension is assessed in each scenario and reported in table1.

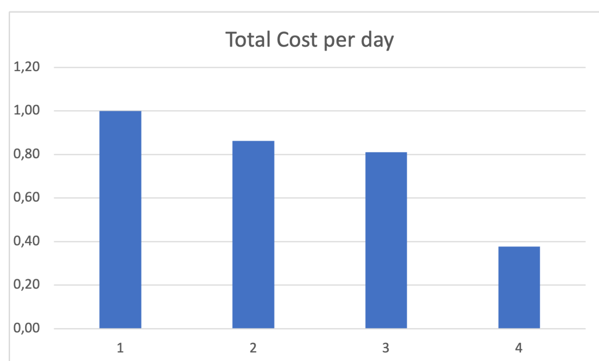

Figure 7. Total cost per day comparison of each scenario.

The total cost per day of each scenario is compared as shown in figure 7. The total cost per day to complete the delivery service is:

$$= requiedtrips * Time_{cycle} * 0.5 + \frac{Fleet * V_{cost}}{360 * 15} \qquad (4)$$

The comparison of delivery time of each scenario is shown in figure 8. The delivery time by each scenario

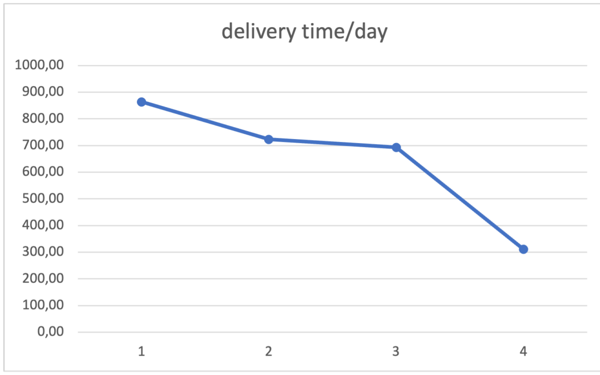

Figure 8. The Total delivery time comparison of each scenario.

is

$$= \frac{demand}{van + trailercapacity} * Time_{cycle} \quad (5)$$

7. Conclusion

The problem of goods deliveries in urban areas was addressed. A logistics system was proposed whereby goods are first delivered to a distribution center/warehouse in the suburban area and from there deliveries in the urban area are made by vans with trailers. The trailer makes it possible to increase the load capacity of the vans and thus reduce the number of trips required. A model is proposed to make the coupling/uncoupling of the trailer autonomous so as to also reduce the time required for the operation. Four scenarios were compared: traditional vans without trailers; traditional vans to which trailers can be added manually; traditional vans with autonomous coupling capable trailers; autonomous vans with autonomous coupling capable trailers. A simulator has been implemented with Anylogic to assess the benefits of the proposed system for the case study of Genoa. The scenarios were compared on the basis of the daily cost, the daily revenue and the daily profit from the point of view of the logistic service provider. The environmental impact of the logistic service is not taken into account since the vans are electrically powered in all the scenarios. In the proposed system, the goods in the trailer are all addressed to a single business while the small parcels in the van are distributed door-to-door to individual recipients. Another more promising system will be evaluated in the next future: in this system trailers are used as unattended collection points where individual recipients will pick up their small parcels while large goods addressed to individual businesses will be distributed to them by the van. The next step is then to load autonomous droids, loaded with small parcels, into the trailer. Once the trailer is parked in the urban area, the droids will autonomously proceed with door-to-door deliveries without the need for individual recipients to reach the trailer for picking up their parcels. Droids suitable for this function already exist, for example the Yape from e-Novia

8. Acknowledgements

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References

Cepolina, E. M. (2016). The packages clustering optimisation in the logistics of the last mile freight distribution. *International Journal of Simulation and Process Modelling*, 11(6):468–476.

Cepolina, E. M., Cepolina, F., and Ferla, G. (2021). On line shopping and logistics: a fast dynamic vehicle routing algorithm for dealing with information evolution.

Coutinho, J. S. P. T. (2018). Development of an alternative transportation service for e-commerce deliveries.

El Raoui, H., Oudani, M., and Alaoui, A. E. H. (2018). Abm-gis simulation for urban freight distribution of perishable food. In *MATEC Web of Conferences*, volume 200, page 00006. EDP Sciences.

Elbert, R. and Lehner, R. (2020). Simulation-based analysis of a cross-actor pallet exchange platform. In *2020 Winter Simulation Conference (WSC)*, pages 1396–1407. IEEE.

Fujimoto, H. and Tokhi, M. O. (2010). Emerging trends in mobile robotics: Proceedings of the 13th international conference on climbing and walking robots and the support technologies for mobile machines: 31 august-3 september 2010, nagoya institute of technology, japan.

Li, B., Fang, Y., and Zhang, X. (2015). Visual servo regulation of wheeled mobile robots with an uncalibrated onboard camera. *IEEE/ASME Transactions on Mechatronics*, 21(5):2330–2342.

Masood, K., Morales, D. P., Fremont, V., Zoppi, M., and Molfino, R. (2021). Parking pose generation for autonomous freight collection by pallet handling car-like robot. *Energies*, 14(15):4677.

Molfino, R., Zoppi, M., Muscolo, G. G., Cepolina, E., Farina, A., Nashashibi, F., Pollard, E., and Dominguez, J. A. (2014). An electro-mobility system for freight service in urban areas. *International Journal of Electric and Hybrid Vehicles*, page 21.

Punakivi, M. and Tanskanen, K. (2002). Increasing the cost efficiency of e-fulfilment using shared reception boxes. *International Journal of Retail & Distribution Management*, 30(10):498–507.

Villagra, J. and Herrero-Pérez, D. (2011). A comparison of control techniques for robust docking maneuvers of an agv. *IEEE Transactions on Control Systems Technology*, 20(4):1116–1123.

Zhang, X., Fang, Y., and Liu, X. (2011). Motion-estimation-based visual servoing of nonholonomic mobile robots. *IEEE Transactions on Robotics*, 27(6):1167–1175.