POLITECNICO DI MILANO

Scuola di Ingegneria di Ingegneria Industriale

e dell'informazione

Master's degree course in Mobility Engineering

Fleet optimization for print media distribution and study of the electric transition

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Academic year 2021/2022

Abstract

In this thesis project, i will analyze the sector and the problems of Printed Paper Distribution, considering the specific case of the companies ADP srl and Agenzie Riunite srl.

The project focus will be on two main themes:

1) the logistical optimization of the distribution of magazines and newspapers of two cooperating companies;
2) the electric transition of vehicles used for the delivery of goods

The first point will be studied by means of a technical approach with the final aim of reducing costs and arriving at an optimal solution for the two companies. However, the solution will be modified according to an entrepreneurial mentality and will not just follow the result worked out by calculations, but it will also be modified according to the experience of those people working in the company in order to obtain a solution that is actually applicable and not just theoretical.

The second point, on the other hand, would represent a real revolution for companies, as they have always operated with diesel vehicles. This second part of the work will therefore be accompanied by working hypotheses designed for the specific case.

Abstract - Italiano

In questo progetto di Tesi si analizzerà il settore e le problematiche della Distribuzione della carta stampata, considerando il caso specifico delle aziende ADP srl e Agenzie Riunite srl.

Questo progetto si concentra su due tematiche principali:

1) l'ottimizzazione logistica della distribuzione di riviste e quotidiani di due aziende cooperanti
2) la transizione elettrica dei furgoni usati per la consegna della merce

Il primo punto verrà studiato mediante un approccio tecnico con lo scopo finale di ridurre i costi e arrivare ad una soluzione ottimale per le due aziende; la soluzione sarà però modificata seguendo una mentalità imprenditoriale, non si andrà solamente a seguire il risultato elaborato dai calcoli, bensì verrà modificato anche in base all'esperienza di chi lavora in azienda per ottenere una soluzione effettivamente applicabile e non solo teorica.

Il secondo punto invece rappresenterebbe una vera e propria rivoluzione per le aziende, avendo esse sempre operato con veicoli diesel. Questa seconda parte di lavoro verrà quindi contornata da ipotesi di lavoro studiate per il caso specifico.

Summary

Introduction

In this thesis, I will describe the study and application of a model to optimize the organization of a fleet of delivery vans. The model will be developed considering the constraints of time, space and occupied volume. A further constraint lies in the different lay of the land and road network: city streets lead to very different timing and organization of work than main roads or motorways.

In order to better demonstrate how the model works, I will show the case of ADP srl and Agenzie Riunite srl, two companies operating, among other things, in the printed paper distribution sector.

Despite the fact that the two companies do exactly the same job (i.e. supplying newsstands and sales outlets), they operate differently, following a similar but different working method. This concept ties in with one of the main objectives of this Thesis: <u>to find a method that is congenial to all companies working in the distribution and delivery of goods.</u>

Subsequently, my analysis will focus on the possibility of replacing diesel-powered vehicles with electric vans, highlighting the potential and critical issues for this sector.

All the work in this thesis revolves around a few key words: **delivery rounds**. They simply represent the organizational method of distributing goods.

The first macro-objective of this thesis is referred to in the scientific literature as the *Vehicle Routing Problem*. The aim of the problem is to optimize the routes of a fleet of vehicles for the delivery of goods considering the constraints due to boundary conditions. The final result will be an improvement on the initial condition in terms of *distance travelled, time and,* above all, *cost*.

After a few brief chapters on my physical experience in the company and some considerations regarding the companies' field of expertise, the analysis and problem-solving part will begin.

But what is the problem that this paper is about? it can be summarized in the following points:

- In the face of an ever-increasing crisis in the newsstand and print media sector, is it possible to reduce operating costs without disrupting working methods?
- What organizational solutions should be followed to achieve a concrete improvement?
- Are the solutions proposed by a possible mathematical model practically applicable?
- Is a transition to electric vehicles feasible in this case?
- Is the transition economically viable? If so, which solutions are best to follow?

Answering these questions will not only require a theoretical and scholastic approach, which is however essential to use a scientific method and obtain a meaningful result. This Thesis also aims to take an entrepreneurial approach, following indications and suggestions directly from the people working in the companies. This is why many of the hypotheses and choices that are described in the body of this paper have matured after a period of one-month in which I worked firsthand in the various workplaces alongside employees.

Below is a brief description of the macro-areas into which the thesis is divided.

1) The first chapters are a brief description of the state of the art in the world of print media distribution in Italy and Europe where the main problems of the sector will be framed.

2) Next, my experience in the company is described, with a focus on the workstations I experienced during my internship.
3) In the third part there is a description of the data provided, with particular attention to the type of problems that occurred during the early stages of the project.
4) The fourth part describes in detail the steps followed to develop an effective method to optimize the logistics of delivery rounds.
5) In the fifth part I show and analyze the results obtained with the model; results which are then commented on and compared with the starting situation.
6) In this part, I discuss the second objective of the thesis: electrification. Based on several studies in the literature, I choose a solution for the case of ADP and Agenzie Riunite.
7) Accounts and considerations for the transition of diesel vehicles into electric vehicles.
8) Final conclusions accompanied by possible future development scenarios based on the solutions I will propose in the thesis.

State of the Art - Foreword

This section forms the basis of the Thesis, and considering the subject matter I decided to divide it into three parts:

1) Publishing sector
2) Optimization
3) Electrification
4) Cost of electric vehicles

The first two are discussed below, while the last two are given later in the discussion after the part of the paper concerning fleet optimization.

I made this choice because I believe it is important to consider and analyze the studies on the subject of the electric transition in relation to the results obtained from the first part of the paper. The subject has in fact been studied in countless articles and thus presents an infinite number of different facets and points of development.

The research I carried out focused mainly on articles and studies I found on the *Scopus* site and *Google Scholar*. The amount of general and specific information is very large, so of the dozens of publications I consulted, I only mention the studies that were useful to me and that helped me to make the decisions I considered most appropriate for this paper.

State of the Art – Publishing sector

It is no secret that the world of publishing and in particular the sale of publications through newsstands is in decline: numerous factors such as digitalization, advancing technology and the 2020-2021 marked by Covid19 have inevitably weakened this sector.

To quote some figures, [1] over the last 15 years, newsstands have gone from being 42,000 to around 25,000.

[2] In particular, there are 24596 newspaper kiosks in Italy today, but these outlets are divided into different categories: 6435 are kiosks that exclusively sell editorial products; 5909 are kiosks that offer publications of a prevailing size together with other products of a different commercial nature. Then there are 8723 shops that represent non-exclusive sales outlets such as tobacconists. The remainder are so-called promiscuous outlets, for which printing is a secondary activity.

The figures for March 2022, compared with those of March last year, show that 540 exclusive newsstands and 317 newsstands with a predominant activity have closed. Together these two numbers account for 85 per cent of all closures in the newspaper shop sector.

The figure for the other two categories may seem more comforting, 'only' 149 non-exclusive newsstands and 78 newsstands with secondary activities closed in the same period, but there is great uncertainty as to how the situation will evolve in the coming years.

This situation leads publishers and in particular newspaper distributors to update themselves in order not to move towards a future of bankruptcy. Many distributors in Italy are moving towards the e-commerce sector to keep their business flourishing.

Furthermore, it is becoming increasingly important to try to reduce costs and optimize the resources available to distribution companies, but how does the supply of newsstands in Italy work?

The process starts at the publishers, who, based on demand, commission the quantity of printed copies of each publication to be sent to the market. When the copies are ready, they are assigned to one of the 46 distribution companies in Italy. In the case of magazines and periodicals, these are first routed to a national center and then sorted to a number of local distributors in the territory. In the case of newspapers, for reasons of very limited time from when they are printed to when they are delivered to the newsstand, copies are directly sent to the various local distributors.

In order to cover all points of sale and to facilitate delivery, each newspaper is printed in several places throughout the country, using agreements with the various local printers.

The transport of the publications from the distributor to the newsstands is done by diesel vehicles, which pick up the goods already sorted at the company and then deliver them overnight to the point of sale.

To optimize time and costs, the return of unsold publications from the previous days is loaded immediately after the unloading of new goods. The return is then returned to the distribution company, which is responsible for sorting the unsold goods according to publishers and sending them back to the correct publisher.

State of the Art - Optimization

Newspapers are distributed all over the world following very different methodologies. This factor makes the subject very diverse and has led to numerous analyses in recent years. Depending on the geographical area in the world, different methods are used to deliver newspapers: trucks, bicycles, motorbikes, private cars, etc. etc.

In the following, some cases will be presented that are closest to the situation that will be studied in this Thesis project, including a brief mention of the model followed in these cases.

Generally speaking, the problem to be solved is called the Vehicle Routing Problem (VRP), which can be summarized as follows: a limited number of vehicles of a certain known load capacity starting from a known depot must reach a series of spatial points once, knowing the demand for goods that each point requires. In the case of this Thesis, the warehouse is represented by the ADP and AR companies while the points to be reached, divided into delivery rounds, are the kiosks.

An example of a related case study is presented in [3], held in Bangkok. The study aims to examine distribution problem of a morning newspaper and to minimize the total cost without violating the capacity and time window constraints. The problems consist of vehicle departure times, the routing of vehicles, the location of distribution centers and drop-off points and allocating drop-off points to distribution centers. Results provide evidence of the dramatic impact on costs achieved by developing routing and dispatching schedule simultaneously. The main aspects on which the study is based are strategic planning and the study of an algorithm to improve the morning distribution of newspapers.

The authors use a calculation model surrounded by conditions and limits in order to search for an optimal solution.

On the other side of the world, in Curitiba, Brazil, the study is carried out [4]. In this case, the optimization of the newspaper distribution problem is discussed. The purpose of this work is to present a methodology to provide a solution to a Bi-objective Green Vehicle Routing Problem (BGVRP). The methodology, illustrated using the newspaper distribution problem and instances from the literature, was divided into three stages: Stage 1, data treatment; Stage 2, metaheuristic approaches (hybrid or non-hybrid), used comparatively, and, Stage 3, analysis of the results, with a comparison of the used algorithms.

The aim is both to investigate a possible optimization of the total distance travelled and to show the related reduction in CO2 emissions. The similarity with this document concerns the objective of reducing total distance and thus consumption. This study is valuable despite the differences with the case of this Thesis: the use of motorbikes for the final delivery of newspapers and the numerous sorting points from which the goods depart.

Finally, reference is made to document [5], which deals with the problem of newspaper distribution in Sao Paulo, Brazil. The similarities with this document are many:

- The copies are printed in two printing centers and then transported to the distribution centers. From the distribution center some delivery vehicles like vans or scooters are used for last mile delivery.
- Delivery to the customer must be made by 6.30 a.m., so it is essential to work quickly and efficiently. This point also highlights how the case under consideration is an example of a vehicle routing problem with time windows.
- The goal is an optimization of the last mile delivery

Companies

The two companies involved in this Thesis project are ADP srl and Agenzie Riunite srl.

Figure 1: ADP Logo

ADP srl was founded in 1961 as a local press and magazine distribution agency. Over time, the distribution activity has been studied and evolved until today, in search of ever more modern and innovative methods to meet market needs.

ADP is based in Lainate and supplies over 200 newsagents, supermarkets and outlets; it also supplies the Milan Malpensa airport.

Over time, ADP also entered other sectors, first and foremost e-commerce, which today represents the company's strong point.

Figure 2: Agenzie Riunite Logo

Agenzie Riunite was founded in 2010 through the merger of two historic companies with expertise in the print media distribution sector. Despite its young history, the company operates in many sectors: from e-commerce to warehouse management, from national and international shipping to the supply of newsstands and supermarkets in its area.

Agenzie Riunite supplies around 250 newsstands in an area stretching from the Swiss border to the east of Milan.

The two companies operationally do the same thing: they supply newsstands; however, they manage their distribution processes in different ways, which will be analysed in the following chapters.

There are therefore several aspects common to both companies concerning the process that the goods follow from when they arrive at the company to when they are delivered:

1) In the morning, periodical publications (magazines, stickers, magazines etc. etc.) arrive in the form of parcels loaded onto pallets.
2) The first step is to sort the publications coming out on the day from the publications that are to be kept in the warehouse as a stock.
3) Then the copies are sorted and assigned to the newsstands that have requested them.
4) The newsstands to be supplied are divided into **Delivery Rounds**, i.e. groups of newsstands that are supplied by the same truck. Each kiosk is assigned a unique code and assigned to a delivery round.
5) During the night the vehicles leave the warehouse to supply the newsstands with the ordered goods, collecting the return immediately afterwards and returning it to the company
6) The next day the return is sorted or scrapped on the behalf of the publishers..

The companies are open every day developing working hours in shifts, so that work is divided over 24 hours and never stops, with a few exceptions due to holidays.

In-company experience

For the first three weeks of my internship, I went to both Agenzie Riunite and ADP srl to understand in detail how the process behind the distribution of copies works. I therefore toured the main workstations of the two companies, listed below:

- Distribution
- Goods return
- Supplies
- Night activity
- Delivery

In this chapter there is a brief description of the workstations just listed, I will separate the description for the two companies as there are some differences that should be emphasised.

ADP

Distribution

Distribution is the first step towards the delivery of goods to newsstands. The publications follow a sorting process consisting of several steps, which will be briefly described below.

1) During the morning, the suppliers bring the copies for distribution to the agency based on orders placed by the company itself. The copies are organised on pallets
2) The pallets are opened and analysed. It is a procedure to check the supplier's delivery note, which is present with the goods and on which the number of copies of the publications contained in the pallet is indicated.
3) The copies are then divided between goods to be delivered and goods to be kept in stock.
4) The goods for distribution are then brought to a location where an employee takes care of the first sorting stage. ADP in fact works with 3 sub-areas called islands, with each island collecting a group of kiosks according to the area to which they belong.
5) The attendant for each publication follows the following procedure.
    a. He scans a copy
    b. A program indicates how many copies or whole packages are to be sent to each island
    c. Based on the programme's indications, it manually divides the copies of the publication among 3 trolleys, one per island. There is also a dedicated trolley at Terminal 1 of Milan Malpensa Airport, but this is handled separately.
6) The trolleys are then taken to their own island, where 2 other employees use another programme to scan and divide the copies according to the indications on the monitor.
   The island is in fact a rectangular area with 3 sides occupied by shelves, which are in turn divided by labels indicating the delivery route and stopover. Baskets are placed under each label, each basket representing the kiosk belonging to the indicated round and stopover. In addition, there is an LED that indicates, each time a publication is scanned, how many copies to put in each basket by hand.
7) The operators divide the copies among the newsstands on the island, this can lead to errors made by the operators, but these are easily corrected: if, for example, a copy is not placed in the basket of a newsstand it will advance to the end, so all you have to do is recheck the baskets and find the one without a copy. The main problems with this procedure are obviously related to lost time.
8) When a basket is full it is identified with a round and stop number, closed, put on a trolley and replaced by a new one.

9) At the end of the day, the bubble with the list of all the copies distributed is inserted into the last basket of each newsstand. This method serves to certify the correct quantity of all publications requested by the newsstand.
10) Finally, all the baskets are organised on trolleys according to their route and organised in the warehouse, where the drivers will pass by at night to place them in the delivery vehicle compartment.

Figure 3: trolley

The use of these trucks is not accidental: they have the great advantage (apart from the practicality of movement) of reducing the use of forklifts. The direct consequence is a reduction in costs and an increase in safety in the workplace.

Supplies

Supplies are all those publications that are already in stock and that some newsagent requires from the distributor, they are therefore in most cases issues that have already come out.

This workstation at ADP is managed by an operator, and there are several tasks to be performed.

1) In the morning, the first task concerns the sorting on some shelves of the extra copies that were not distributed the day before. These copies form the stock of the warehouse.
2) Based on the requests of the newsstands, the operator has a program to list all the copies that need to go out for delivery.
3) The copies are taken from the shelves and divided, again thanks to the barcode, by delivery round.
4) In fact, the supplies are placed in different coloured baskets from those used for distribution, with only one basket per delivery round.
5) All copies of the publication destined for replenishment are then riveted and bubble-wrapped and placed in the basket for their delivery round.
6) The replenishment baskets are then taken to the standard parcel distribution station.

Standard Packs

The term '*Standard packs*' refers to whole parcels of cards or magazines requested by newsagents. In fact, it often happens that some newsagents, instead of asking for a few copies of a publication, request a whole pack. To avoid unnecessary sorting processes, the (standard) pack is left whole and taken directly to a special area.

1	**2**	**3**	**4**	**5**	**...**
29	**28**	**27**	**26**	**25**	**...**

Figure 4: trolley disposal

This area is located towards the exit of the warehouse, in which there are trolleys (one per Round) where the standard parcels are stored. In this trolley, the parcels from all the newsagents belonging to the Round are stacked on top of each other, to be collected in the evening by the assigned driver.

Goods Return

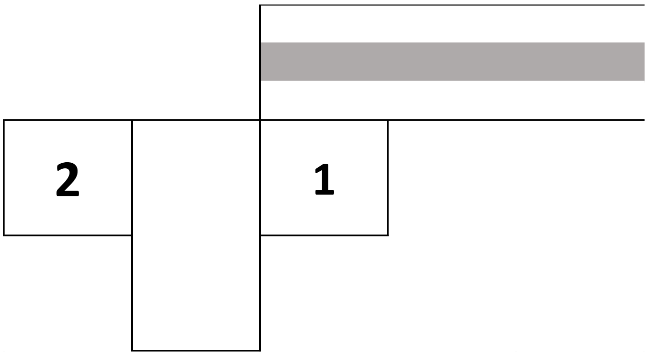
During the overnight delivery round, the drivers not only deliver the goods (on certain days of the week) but also collect unsold goods that the newsagents send back. Returned goods follow the following process:

- The baskets and parcels are loaded onto trolleys and taken to the rendering station.
- The return station is based on the machinery shown here:

Figure 5: return machinery

ADP owns two rendering stations and so two machines.

- The rendering station is organized as follows:



For each machine, two employees work, one inside the machine area and one outside.
The employ 1 (1 in the Figure) has several tasks:

- manually open, through the use of a programme, the file linked to a certain newsstand;
- the operator passes the copies on the roller one by one, with the barcode facing upwards, so that the barcode reader can identify the publication and dedicate it to its publisher.

Figure 6: machinery roller

- The copy proceeds on the roller where several photocells are positioned, one for each publisher. When the copy arrives near the corresponding publisher, the roller lowers, dropping the copy into an open box called a pall box.

Figure 7: sensor

Figure 8: pallbox

This operation is repeated for each copy.

- Once all the copies returned by the newsagent are finished, operator2 goes back to work on the program, saving the passage of all the copies returned. A check is then carried out by the program itself which informs the operator whether all the copies passed are all those expected from the return or whether there is a shortage or surplus of copies.
- The process is then repeated for all newsstands in the delivery round.
- Each newsstand also sends a Voucher, on which the returned copies are indicated, the Vouchers are divided by Tour and stored by the company.
- The process is repeated for all delivery rounds.

Agenzie Riunite

Distribution

Distribution in Agenzie Riunite works very differently from ADP. The main difference lies in the handling of goods. Below I briefly describe the process:

- In this case it all boils down to one large location which is called a 'Tavolo', of which I give a diagram of the view from above

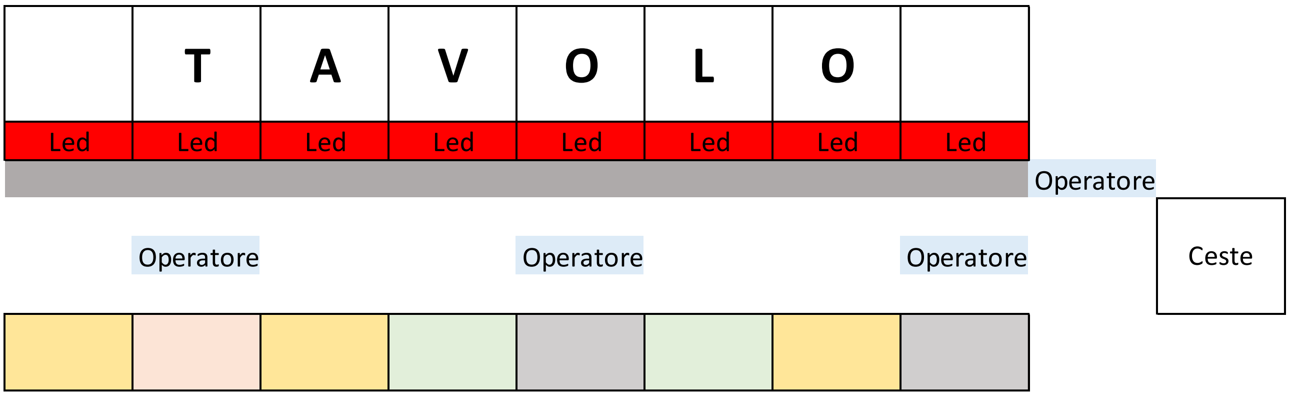


Figure 9: scheme of the 'Tavolo'

- During the day, the pallets containing the periodicals are unloaded and lined up along an imaginary line next to where the operators are positioned.
  The operators position themselves with the pallets of copies behind them.
- In the evening, the copies are placed on vertical shelves in front of the operators' station and a clearly defined position between the shelves is assigned to each publication. The position is in correspondence with the LEDs shown in figure 9.
- The operator on the right stands at the end of a roll (grey line in figure 9) and enters the code of the newsstand whose baskets are to be prepared into a program.
- The LEDs light up indicating the number of copies of each magazine to be delivered to the newsstand in question.
- The other operators place the required copies on the roller, which are brought to the operator on the right who is responsible for dropping them from the roller into the baskets. A sensor counts the copies that fall from the roller to check that the final number matches the kiosk's request.
- When a basket is full, it is replaced with the next one and when all the copies have been inserted, the next kiosk is reached.

- Finally, the baskets are placed on pallets, one per Round, and taken to the dedicated locations ready to be loaded onto vans by the drivers at night.

The strong point of this solution is the low handling of the goods, which do not change location from when they are unloaded to when they are placed in the baskets.

Probably the weak point of this choice lies in the counting: there is the possibility that the operators (or the sensor at the end of the roll) miscount the number of copies.

If this happens, all the baskets in the kiosk are taken to a station where there is an operator with a computer who scans the barcode of each copy by hand, checking if any are missing. If so, the copy is taken from the Tavolo and marked.

Unlike ADP in this case the standard packs are stacked inside the chests with the single copies.

The procedure just described is followed every distribution day except Monday. During this day, due to the distribution among others of foreign publications, distribution takes place on shelves following a process very similar to ADP. In this case, one basket per newsstand is placed on the shelves, and thanks to a computer program, once the publication is selected, it is indicated how many copies to distribute per newsstand.

Supplies

The supply station is essentially the same as the corresponding one already described for ADP. In this case, too, the copies, after being searched and collected from the warehouse stock, are taken to the distribution staff and sorted in the Rounds.

Good Return

This area of the warehouse follows basically the same process as ADP: the goods follow the same route through a machine that reads the barcodes of the copies and then sorts them by publisher in the pall boxes.

What changes is a few procedures:

- Before the copies are placed on the return machine, the newsstand code is not manually entered into a program. The use of the double barcode identifies both the newsstand and the publisher, effectively eliminating the time needed to switch from one newsstand to another.

- The sticker copies are not passed through the return machine, but are separated by hand by the operators and sorted by publisher in a separate location.

Good Delivery

The last place I worked in is the end point of the whole distribution process: the delivery of the goods. The delivery process is the same for both companies, the steps I will describe shortly are therefore to be understood as valid for both ADP and Agenzie Riunite.

1) During the early hours of the night, the drivers go to the company to carry out the unpacking of the newspapers. Packages of newspapers in fact, unlike other publications, arrive at the company during the night so that they can be delivered the same morning together with the other publications.
2) Each operator is responsible for sorting the newspaper copies of his Round and closing them in a bundle as shown in Figure 11 in the next chapter. The newspapers are then placed in baskets to avoid excessive clutter.
3) Once the operation of point 2) is completed, the driver places the newspapers and baskets of his Round on the van in a precise order.

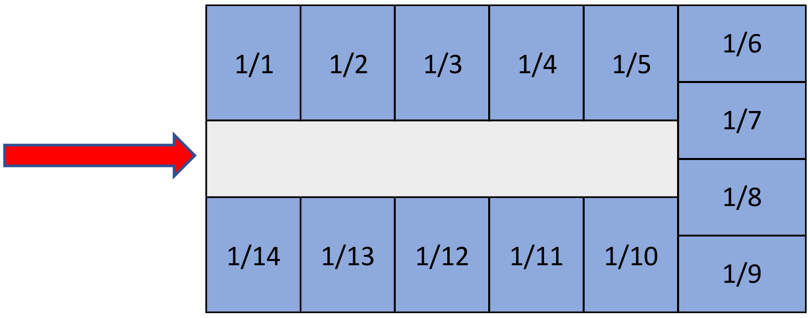


Figure 10: disposal of the chests in the van

The arrow points to the van door, the baskets are placed clockwise from left to right. If a newsstand has more than one basket, the baskets are stacked on top of each other. The newspaper packages (and standard ADP packages) are stacked on top of the baskets in turn.

4) Around 4:30 a.m. the driver starts the Tour, following a delivery order based on the distance of the newsstands from the company and the time at which the newsagents would like to receive the goods.
5) For each newsstand the driver collects the return, this takes place on the dedicated days of the week.
6) Once the deliveries have been completed, the driver returns to the company and unloads the returned goods in the warehouse, which will be sorted as described above on the next working day.

Project overview

Having completed the necessary introduction, we move on to the implementation part.

But why is it necessary to optimize the fleets of the two companies? The main reason is the decreasing number of newsstands open on Italian soil: with the constant reduction in demand, distribution companies are forced to reorganize their fleets.

The second reason is linked to the desire to reduce costs and delivery times. The aim of this first part of the analysis is in fact to reduce the number of rounds and therefore the number of vehicles used in order to save money for the two companies, while obviously staying on schedule and maintaining a high quality of service.

The optimization phase is divided into two sub-parts:

1) The first part concerns the optimization of the delivery rounds of the companies separately, i.e. the same procedure is performed but keeping the companies independent of each other.
2) The second part will consider reorganizing the division of newsstands between the two companies. This solution aims to avoid all those situations in which an ADP van, in order to reach its area of competence, crosses the area provided by Agenzie Riunite (and vice versa), thus covering an unnecessary distance.

Before proceeding with further details, I present the data and assumptions under which I will develop the entire project.

Data

In order to carry out the optimization analysis, a lot of data was required, which will be presented below, starting from the geolocation of the newsstands to the load volumes of the delivery vehicles dedicated to the Rounds. The study was carried out on the basis of delivery data for the week of 16 to 22 May 2022. The reason for this choice is the consideration of a period that was not affected by holidays closures or special events that could distort the average number of open newsstands and loading volumes.

In this paragraph the data provided in the same way by both ADP and Agenzie Riunite are shown; later in the section regarding data analysis I will describe the part of the data provided differently by the two companies. This part will aim to arrive at a common point to start with the implementation part.

Newsstands

Both the companies provided me some key information about the company, that information are listed in a big table. In the following table I report the example of a newsstand supplied by ADP:

DATA	TIPO	CodPV	RAG_SOC	Figu	cpRIVISTE	cpFIGURINE	PACCHI	cpVOLANTI	cpISOLE
16/05/2022	A	1	COCCIA MAURO	No	194	0	4	0	105

Table 1: main info of the kiosk

- Type: could be ‘A’ or ‘B’. ‘A’ stands for daily while ‘B’ stands for a periodical publication.
- CodPv: it stands for the unique code assigned to the kiosk
- RAG_SOC: refers to the kiosk name

- Figu: could be ‘yes’ or ‘no’, it refers to the presence of stickers/figurines in the copies, so if it is ‘no’ it means that the copies are only magazines.
- cpRIVISTE: refers to the total number of magazines/journals delivered to that kiosk.
- cpFIGURINE: total number of figurines delivered to the kiosk
- PACCHI: refers to the Standard Packs delivered to the kiosk
- cpISOLE: refers to the number of copies that are destined to be distributed in the ‘Isole’ of ADP.

Vehicles

Companies use diesel vans to deliver goods to newsagents. Each Round is assigned a van large enough to hold the goods to be delivered.

I will devote a separate chapter to this topic in the central part of this paper.

Preferred time of goods delivery

Many of the newsagents (about half) require distribution companies to deliver their goods at a specific time. It will be seen later on how this constraint is very limiting.

The other half of the newsagents, on the other hand, in agreement with the company, have a skip in which to put the goods; the driver has the keys to the skip (or to the newsagent itself) so that the delivery can be made without the newsagent being present.

Hypothesis

- Both the factories use chests to contain the type B publications.
  Chests dimensions are 60x40x30 cm.
- Both the factories do not put daily publications inside the chests, but they pack the type A publications as shown in the following picture.

Figure 11: newspaper pack

- This procedure is followed in order to save space: newspapers can be easily stacked on top of the baskets without being dispersed in the van.
  Based on my own experience, **one basket** takes up the same space as **180 newspapers**.
- ADP also follows the same procedure as for standard newspapers: they are loaded onto the vans outside the baskets.
  Agenzie Riunite unlike ADP fits standard parcels into the baskets.
  Based on my own experience, the space occupied by **one basket** is the same as that occupied by **8 Standard Pack**

Data Analysis

The first step in developing the analysis consists of analyzing and cleaning the data provided. The data Again, it is appropriate to separate the case of ADP from the case of Agenzie Riunite.

ADP

In this case I was also provided with the Latitude and Longitude of each newsstand. This data will be crucial for the reorganization of the Tours in the following chapters.

In addition, ADP provided me with information regarding the current order of the Delivery Rounds, the data was provided in the form of sheets of paper like the example below:

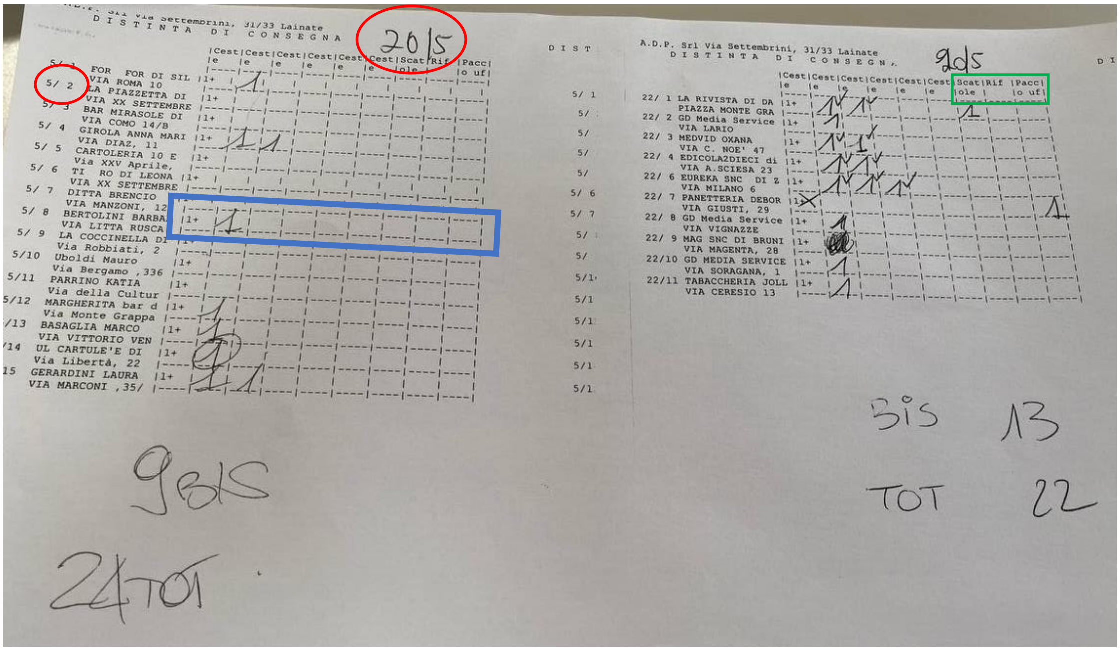


Figure 12: recap of delivery rounds

This type of sheet contains a lot of useful information for the thesis:

- In the top left-hand corner, the date is highlighted in red.
- On the left, the first column indicates the Tour and the number of the stop; 5/4 for example indicates that it is Round 5, stop 4.
- Immediately to the right is the name of the newsstand.
- For each newsstand, it is handwritten how many baskets are required to contain the copies sorted at the islands. (blue rectangle in the figure 12).
- Three product categories are highlighted at the top right in green:
    1) Boxes
    2) Supplies
    3) Office Parcels

  These three categories of goods are separate from the products distributed and subdivided in the islands, they are typically parcels kept in the passenger compartment of the van, so they will not be considered in the remainder of the elaboration.

As can be guessed, I had to transport this type of data (being handwritten) to an Excel spreadsheet, this for all ADP rounds for all days for which I had data.

The main objective was to obtain a single number that included the volume occupied by the goods (including baskets, standard parcels and newspapers) in the van compartment. To obtain this value, I used the assumptions described in the previous paragraph:

- One basket occupies the same space as 180 newspapers
- One basket occupies the space of 8 standard parcels

The result is a non-integer value that gives an idea of how much space is actually occupied by the publications. This value will be used to reorganize the Revolutions also based on the volume occupied.

Below there is a summary table showing the total number of 'baskets' for each day considered for each Delivery Round.

Round	Chests					Kiosk per Round
	17 05	18 05	19 05	20 05	AVG	
1	41.6	38.8	37.2	41.9	39.9	13
2	45.8	42.8	41.8	47.6	44.5	13
3	43.4	32.2	32.6	38.3	36.6	14
4	37.1	30.3	30.5	39.8	34.4	13
5	35.0	27.6	29.8	35.1	31.9	15
11	47.3	36.6	31.9	45.0	40.2	16
12	31.8	29.6	24.0	32.7	29.5	8
13	43.3	38.1	35.0	40.9	39.3	12
14	41.8	38.7	33.4	38.6	38.1	13
15	38.7	33.0	29.0	37.4	34.5	12
22	39.4	30.6	31.5	32.5	33.5	10
23	41.0	36.2	32.8	36.4	36.6	12
24	34.2	29.8	26.7	28.9	29.9	12
25	37.5	32.5	31.0	33.4	33.6	14
26	35.4	35.1	27.0	31.4	32.2	13
27	37.5	32.7	32.8	34.7	34.4	12
28	27.8	23.1	19.9	26.0	24.2	12
29	28.3	26.8	24.2	25.1	26.1	11
TOT	686.9	594.4	551.1	645.8	619.6	225

Table 2: quantity of chests day by day

Agenzie Riunite

In this case I did not have the geo localization of the newsstands, so in this case I used the site [31] to define the Latitude and Longitude coordinates which were then fundamental to the project.

On the other hand, I was provided with a File containing the precise number of Baskets delivered to each newsstand in the week under review. An example is provided here:

Cod	Cliente	Casse
	Giro 20	
1063	CALAMUS SAS DI BRE	3
1106	BERTOLINO ANTONIO	2
1073	EDICOLA CELESTINA S	3
1333	BENNET PONTE TRES	4
1061	FESTA PAOLO	4
1064	L'ANGOLO DELLA NOTI	2
1065	CARTOLERIA BOZZI DI	3
1066	CORVI CLAUDIA	4
1074	PACINI IVANA	2
1011	IL GIOCO EDUCATIVO	4
1330	COOP PONTE TRESA G	3
	Fine Giro 20	34

Table 3: chests of round 20, Agenzie Riunite

The main difference with the ADP data is that the amount of daily publications is not given, on the other hand Agenzie Riunite provided the total amount of periodical and daily publications.

Daily Distribution				
Day	**Night Distribution**	**Other**	**Table**	**TOTAL**
P	**71290**	**54400**	**159153**	**284843**
17/05/2022	12387	52763	26796	91946
18/05/2022	15224	25	29622	44871
19/05/2022	20694	1464	40903	63061
20/05/2022	12941	13	30773	43727
21/05/2022	5764	135	31059	36958
22/05/2022	4280			4280
Q	**187248**			**187248**
16/05/2022	30264			30264
17/05/2022	25405			25405
18/05/2022	25339			25339
19/05/2022	25157			25157
20/05/2022	26527			26527
21/05/2022	29086			29086
22/05/2022	25470			25470
TOTAL	**258538**	**54400**	**159153**	**472091**

Table 4: distribution data

The approach I have decided to follow to calculate how much space is actually occupied in the loading bays by the goods sold is therefore different from what was done for ADP.

1) From this data, it is possible to estimate the amount of daily publications per kiosk.
2) For each day of the week considered, starting from the total amount of tills, the percentage of tills of each kiosk is calculated.
3) Multiplying the percentage obtained by the total quantity of daily publications, the quantity of publications per kiosk is estimated.

An example is given below (Cod 1023)

One example for the kiosk 1023 is provided here:

- Total amount of chests for the Agenzie Riunite factory in 17/05/2022 = 621
- Chests delivered to kiosk 1023 in 17/05/2022 = 5
- % of chests over total = 5/621 = 0.8052%
- Total type A publications in 17/05/2022 = 25405
- Estimated amount of Type A publications of kiosk 1023:

$$Q = 0.805 * 25405 = 204.6$$

The same reasoning is applied to all the kiosks in all the days considered.

Then using the same assumptions as for ADP, I calculated the space occupied in the van compartment for each newsstand, adding up the space occupied by baskets and newspapers.

Finally, by adding up the space occupied by each newsstand within a Round, it is possible to obtain a summary table showing the space occupied in each van.

Round	Chests					
Round	1705	1805	1905	2005	2105	Media
1	45.4	39.8	40.5	41.1	45.4	42.4
2	52.8	39.8	40.5	43.7	46.7	44.7
3	43.0	27.8	29.7	33.1	37.4	34.2
4	46.6	33.1	33.8	38.4	40.0	38.4
5	50.3	47.7	39.2	42.4	48.0	45.5
12	65.0	50.4	43.2	49.0	50.7	51.7
13	38.0	30.5	25.7	35.8	48.0	35.6
14	56.5	47.7	40.5	47.7	48.0	48.1
15	54.0	39.8	41.9	38.4	44.0	43.6
16	61.4	41.1	39.2	42.4	45.4	45.9
17	77.3	49.1	48.6	58.3	60.1	58.7
19	54.0	37.1	35.1	41.1	41.4	41.7
20	63.8	43.8	40.5	43.7	53.4	49.0
21	41.7	31.8	31.1	29.2	32.0	33.2
22	7.0	7	4	10	7	7.0
TOT	**756.9**	**559.5**	**529.7**	**584.5**	**640.6**	**619.8**

Table 5: quantity of chests Agenzie Riunite

Geolocalization of the kiosks

The two companies supply newsagents in the area from north-west of Milan to the northern border between Lombardy and Piedmont overlooking Lake Maggiore.

As can be seen in the picture below, the two companies (yellow pointer) are about 20 km apart as the crow flies, which means that in order to deliver goods, AR's delivery vehicles often pass through areas belonging to ADP and vice versa.

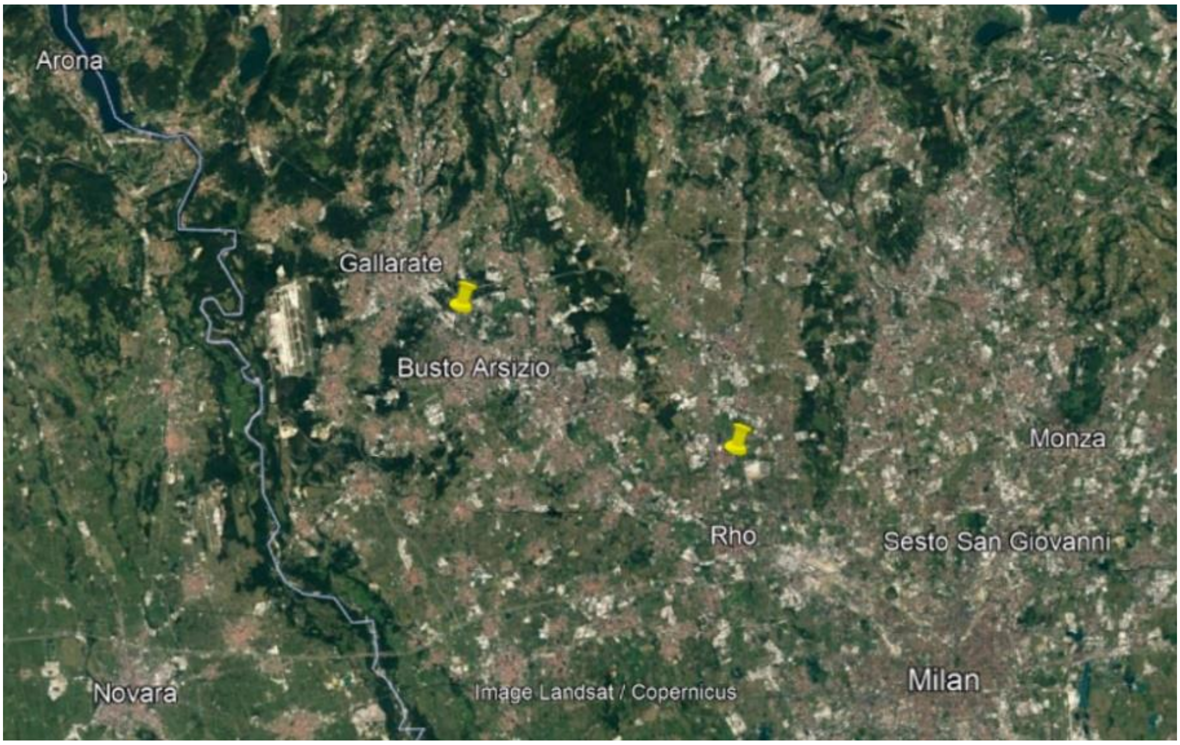


Figure 13: map of the Geographical area

Specifically, ADP provides two distinct zones:

- The area northwest of Milan
- The western zone from Gallarate to Lake Maggiore

The central part connecting these two macro-zones is instead supplied by AR, which takes care of the entire vertical section from north to south, i.e. from west of Milan via Varese to the northernmost part of Lake Maggiore.

The area in question is characterised for the most part by small towns and, especially going towards Lake Maggiore, by small settlements connected by main roads. This detail will be fundamental for the continuation of the elaboration.

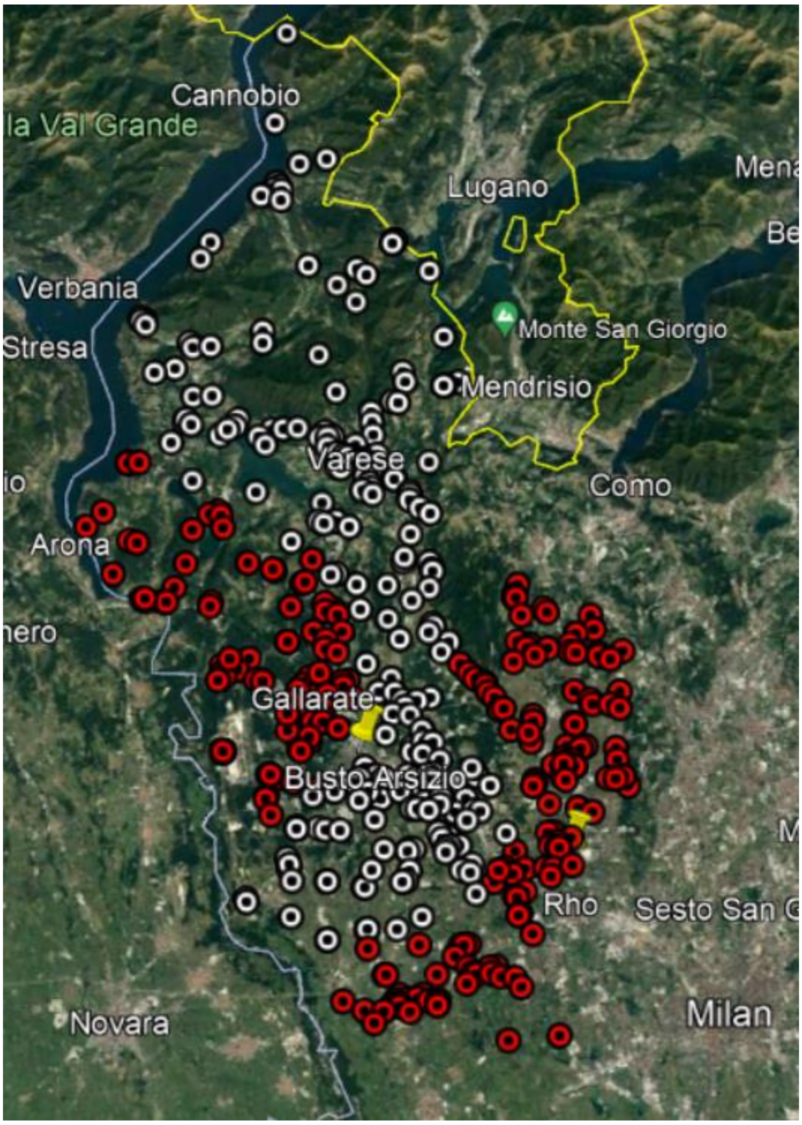


Figure 14: distribution of kiosks

The figure 14 shows all the newsstands served by the companies:

- Red dots are the newsstands supplied by ADP
- In white are the newsstands served by Agenzie Riunite

From this diagram, the clear division between the areas covered by ADP and Agenzie Riunite is very evident.

One detail to highlight is that ADP's vans supplying the north-west area have to pass through a very large area under the jurisdiction of Agenzie Riunite. This factor causes the vans to cover a not inconsiderable amount of kilometres on both the outward and return journeys, which is reflected in an extra cost for the company. This factor will also be considered later for the analysis to reduce the number of round trips.

Delivery Rounds organization

The two companies have a different view of product distribution, even though the number of newsstands supplied is more or less the same. ADP in fact has many more Turns than Agenzie Riunite, in particular we speak of 18 Turns for ADP and 14 Turns for Agenzie Riunite.

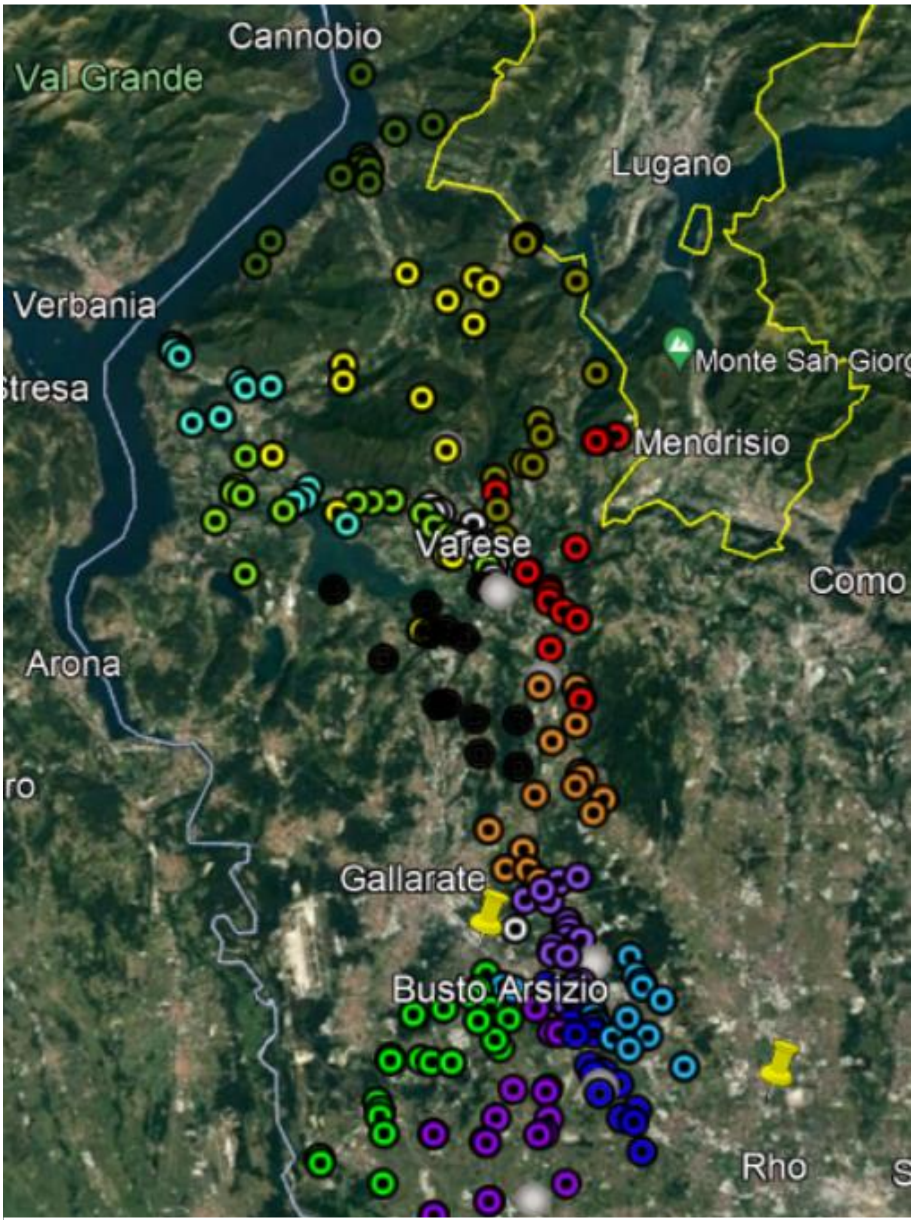
This different choice affects the volume inside the cargo area, as will be shown later the vans of Agenzie Riunite tend to be more heavily loaded. The two strategies lead to different advantages and disadvantages:

- Loading the vans more certainly leads to a greater optimization of space and a reduction in costs.

- On the other hand, managing fewer vans can lead to a worse division and organization of the kiosks.

In order to make this clearer, I provide below the turnaround maps for both companies.

Agenzie Riunite's delivery rounds



Round	N° stands
1	13
2	16
3	13
4	15
5	14
12	22
13	13
14	17
15	17
16	18
17	19
19	13
20	11
21	13

Figure 15: Agenzie Riunite's rounds

The Figure 15 shows the Tours of Agenzie Riunite divided by colour. The table next to the Figure 15 shows the legend of the Tours together with the number of newsstands assigned to each Round.

In addition to the delivery points shown in the tables, Agenzie Riunite supplies a number of newsstands in the Busto Arsizio area, which are assigned to Round 11. These newsstands are not taken into account in the processing as they go to the company to collect the goods themselves.

The main points on which action can be taken to improve the organisation of newsstands in the case of Agenzie Riunite are:

- The spatial distribution of newsstands
- The number of newsstands per delivery round

The first point means that some rounds are concentrated in the same area. This leads several vans to travel several kilometres in the same direction, perhaps crossing areas supplied by other vehicles. This factor leads to an increase in the total number of kilometres travelled by the vans and a consequent increase in costs.

This phenomenon is very evident in the area shown in the following figure, which represents the case of Tours 3,4,13 and 19:

Figure 16: intersection of Rounds 3,4,13 and 19

The second point, on the other hand, relates to the little hegemony in the number of newsstands allocated to each round. In fact, as can be seen in the table 1 on page 20, there are Tours to which 11 to 13 newsstands are assigned, while others where the number of outlets is as high as 20.

Round	Chests
1	45.4
2	52.8
3	43.0
4	46.6
5	50.3
12	65.0
13	38.0
14	56.5
15	54.0
16	61.4
17	77.3
19	54.0
20	63.8
21	41.7

Figure 17: quantity of chests per round

As can be seen from the Figure 17, the number of baskets carried by the busiest Round (17) is more than double the number of baskets carried by the unloadest Round (13).

My main objective for this company will not be so much to reduce the number of used vans, which is already very small, but mainly to better organise the spatial and quantitative organisation of the newsstands.

ADP's delivery rounds

Round	N° stands
1	13
2	13
3	14
4	13
5	15
11	16
12	8
13	12
14	13
15	12
22	10
23	12
24	12
25	14
26	13
27	12
28	12
29	11

Table 6: number of kiosks per Round, ADP

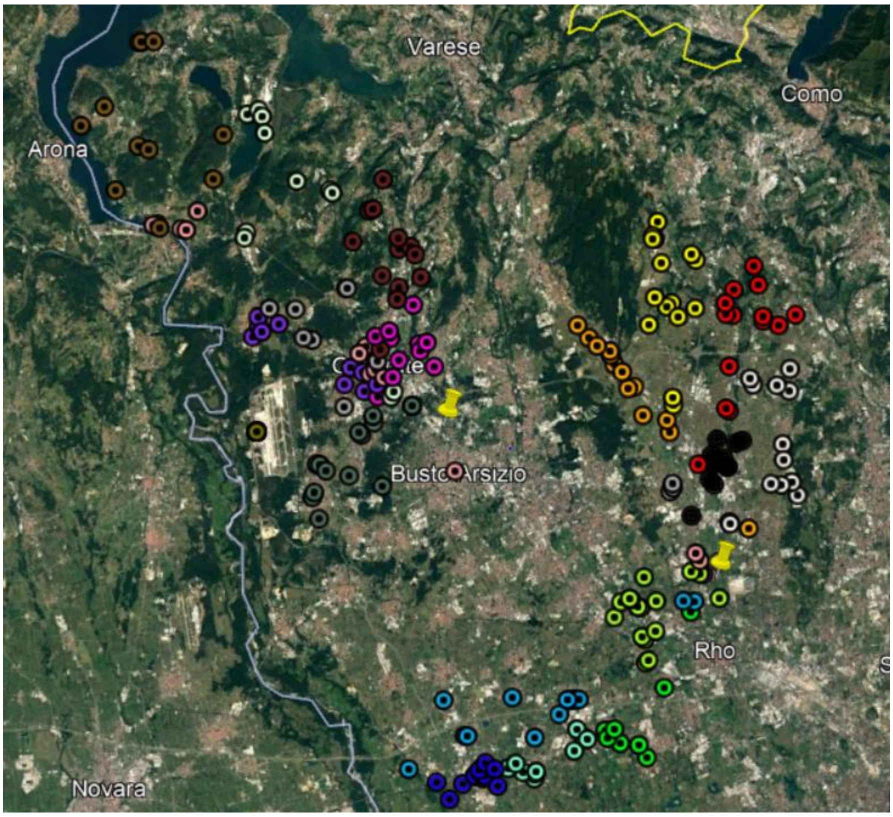


Figure 18: ADP's delivery rounds

As with the other company, the Rounds are listed in the table 6 next to the Figure 18 showing the Rounds divided by colour. The number of newsstands assigned to each Round is also shown

The main difference with the case of AR as can be seen from the data is the distribution of newsstands in the rounds: **the average number of newsstands** per round **of ADP is 12.5** while the average for **Agenzie Riunite is 15.3**.

Moreover, apart from a few sporadic cases, the newsstands are more evenly distributed.

The analysis and optimisation of the ADP shifts will therefore be aimed both, as in the case of AR (albeit to a small extent), at balancing the number of kiosks per Round and at a significant reduction in the number of Rounds. This will lead to a better utilisation of space in the vans and an increase in the number of kiosks assigned to each turn.

Procedure

As in the case studies mentioned in the previous part, this project also refers to the Vehicle Routing Problem, but before addressing this problem, it is necessary to reorganise the division of the kiosks into different delivery routes. The calculations were carried out separately for the two companies, and the results will be analysed later.

To complete this task, the steps outlined here were followed:

- The method of calculating the Euclidean distance between all newsstands supplied by the company is used, so that the relative distance between one newsstand and another can be known.
  The generic Formula for the Euclidean Distance is the follwing:

$$d = \sqrt{(X_i - X_{i+1})^2 + (Y_i - Y_{i+1})^2 + (Z_i - Z_{i+1})^2} \quad (1)$$

  X Y and Z are coefficients designed to simulate the Earth's curvature; they are based on the Earth's radius, latitude and longitude. The formulae of the coefficients are given below.

$$X = R * Cos\left(Lat * \frac{\pi}{180}\right) * Cos\left(Long * \frac{\pi}{180}\right)$$
$$Y = R * Cos\left(Lat * \frac{\pi}{180}\right) * Sin\left(Long * \frac{\pi}{180}\right)$$
$$Z = R * Sin\left(Lat * \frac{\pi}{180}\right)$$

- The previous step leads to a linear distance between two points. In the real world, of course, the connection between two points is not so simple: roads are needed.
- To obtain a more realistic formula, the distance values obtained with the formula in the previous step were compared with the values of real road distances calculated with google maps. This comparison is nothing more than a ratio between the real distance taken from *Google Maps* and the result of the formula.
- Afterwards, the average of approximately 30 ratios was calculated in order to have a value that considers a high number of cases.
  The result is the number **1.445** that represents a **corrective coefficient** that multiplies (1).
- The formula for the relative distance between the various newsstands then becomes:

$$d_R = 1{,}445 * \sqrt{(X_i - X_{i+1})^2 + (Y_i - Y_{i+1})^2 + (Z_i - Z_{i+1})^2}$$

The values obtained from this formula are expressed in kilometres [km].

- The next step is to construct a large table of size nxn representing the relative distances between all the newsstands served. (One table per company). The following is a fraction of the table concerning ADP newsstands.

	A	B	C	D	E	G	H	I	J	K
1		Chests	Round	Stop	New Round	COCCIA MAURO	NEW JOYCES di MALACRIDA STEFANIA	RIDEAL DI CASTIGN ANI RITA	COLMEG NA MARIA CHIARA	S.E. SERVIZI EDITORI LI S.A.S.
2	COCCIA MAURO	3.9	2	4		0.00	0.69	4.46	0.11	0.94
3	NEW JOYCES di MALACRID	4.0	2	11		0.69	0.00	4.49	0.75	0.70
4	RIDEAL DI CASTIGNANI RIT	1.6	29	4		4.46	4.49	0.00	4.56	3.79
5	COLMEGNA MARIA CHIAR/	3.9	2	12		0.11	0.75	4.56	0.00	1.04
6	S.E. SERVIZI EDITORIALI S./	4.6	2	6		0.94	0.70	3.79	1.04	0.00
7	ROSANO' ALESSANDRO	2.5	2	9		1.49	0.98	3.79	1.58	0.63
8	SARACINO MATTEO	2.2	29	8		4.55	4.62	0.33	4.64	3.93
9	BAR JOLLY DI BRITTANNI N	1.2	2	2		1.68	2.00	2.94	1.75	1.45
10	JOLLY SAS di Arasi Giovann	4.1	2	13		1.98	1.53	5.90	1.97	2.17
11	PAGANI ANTONIO	4.0	29	9		4.85	4.95	0.65	4.94	4.26
12	IANNUZZELLI LEONARDO	6.1	2	5		2.28	1.58	4.94	2.33	1.79

Table 7: example of relative distance table

Table 7 Description based on the columns:

A) All newsstands are listed in this column

B) Chests for each newsstand

C) Delivery round

D) The stop number of the newsstand in the current round, e.g. 11 indicates that the newsstand in question is the eleventh stop in the current round.

E) New Round, this column represents the output of the table: the new round to which the newsstand will be assigned.

G) From column G onwards, all newsstands are listed in the same order from line 2 onwards. The numerical values from cell G2 onwards represent the relative distance between the two kiosks expressed in kilometres. Obviously, the diagonal of this table only contains values equal to 0.

The next step is to divide the tables of companies into macro-zones.

The newsstands provided by ADP are divided into:

- North Zone, comprising rounds 1, 2, 3, 4 and 5 with a total of 68 newsstands.
- South Zone, comprising Round 11, 12, 13, 14 and 15 with a total of 62 newsstands.
- North-West Zone, which includes the remaining Round: 22, 23, 24, 25, 26, 27, 28 and 29 with a total of 95 newsstands.

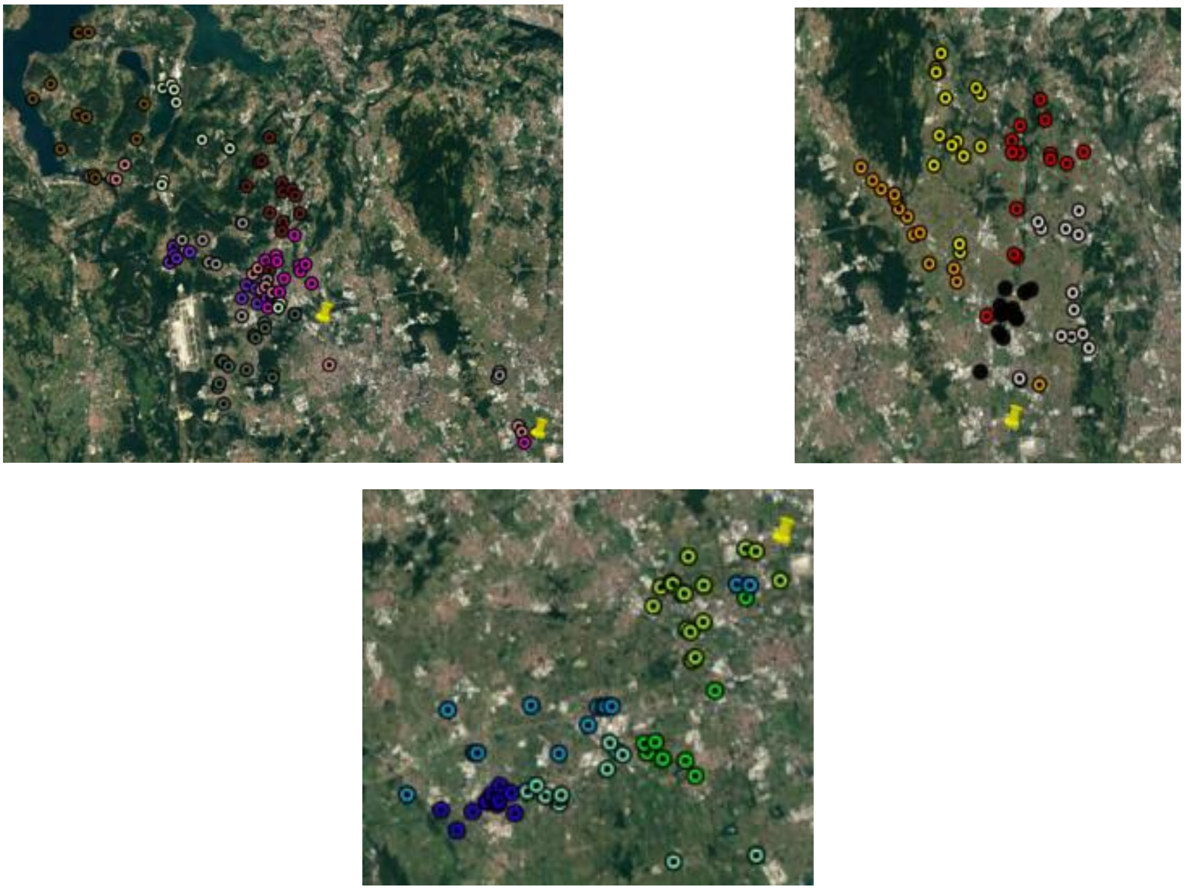


Figure 19: North-West zone; North zone and South zone

While newsstands served by Agenzie Riunite are divided into 2 Macro-Zones:

- The North Zone, which contains Round 1, 2, 3, 4 and 5 with a total of 126 newsstands.
- The southern area, which has rounds 11, 12, 13, 14, 15 with a total of 93 newsstands.

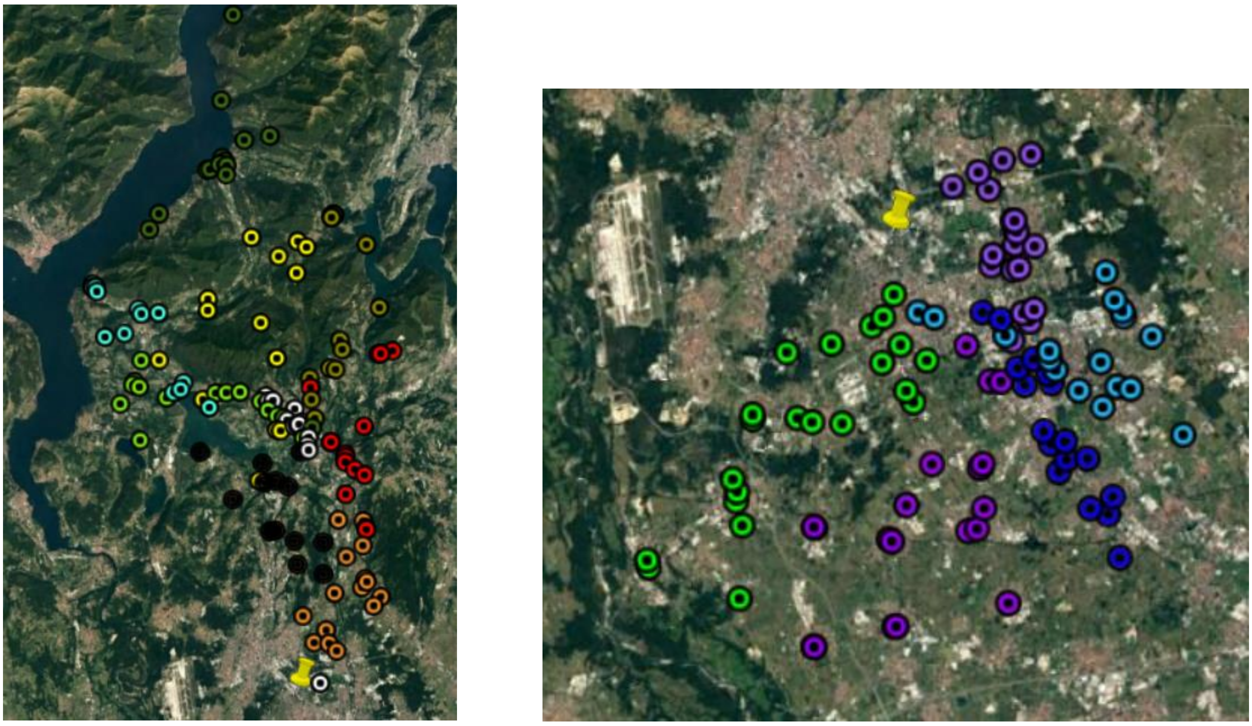


Figure 20: North zone and South zone Agenzie Riunite

For each Macro-Zone, a redistribution of the kiosks is then carried out following the directions given by the centroids of the starting rounds.

A **centroid** of the original Delivery Round is calculated by averaging the latitude and longitude coordinates of the newsstands belonging to that same Delivery Round. This results in a total of 14 Centroids for Agenzie Riunite and a total of 18 Centroids for ADP.

Pointer Legend:

- Blue: AR Centroids
- Red: ADP Centroids
- Yellow: companies

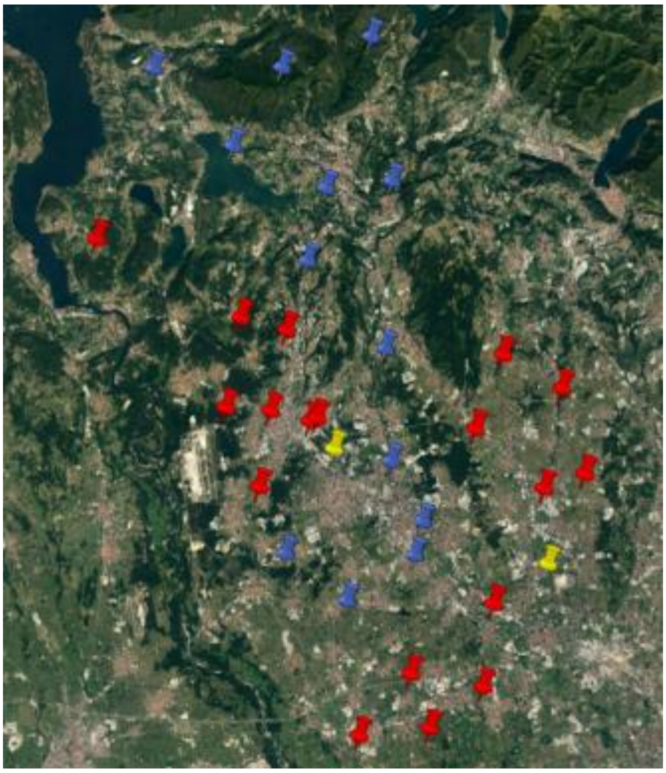


Figure 21: North zone and South zone Agenzie Riunite

The coordinates of the centroids are then entered into the nxn tables of the Macro-Zones. From there, following simple rules, the delivery rounds are redefined.

- Starting with the centroids furthest away from the company in consideration, approximately 10 newsstands were assigned to each centroid.
- To the total number of kiosks per centroid were then added those located on the road to the centroid in question.
- Whenever a kiosk is assigned to a centroid, the cell in column E of the table shown in the Table 7 is filled in with the number of the Round represented by the centroid.
- This step makes the assignment of each kiosk to a delivery round unique, thus preventing the same kiosk from being assigned multiple times once the next centroid is analyzed.

- This step makes the assignment of a newsstand to a delivery round unique.

	A	B	C	D	E	G	H	I	J	K
1		Chests	Round	Stop	New Round	COCCIA MAURO	NEW JOYCES di MALACRIDA STEFANIA	RIDEAL DI CASTIGNANI RITA	COLMEGNA MARIA CHIARA	S.E. SERVIZI EDITORIALI S.A.S.
2	COCCIA MAURO	3.9	2	4	**2**	0.00	0.69	4.46	0.11	0.94
3	NEW JOYCES di MALACRID	4.0	2	11	**2**	0.69	0.00	4.49	0.75	0.70
4	RIDEAL DI CASTIGNANI RIT	1.6	29	4	**3**	4.46	4.49	0.00	4.56	3.79
5	COLMEGNA MARIA CHIAR/	3.9	2	12	**2**	0.11	0.75	4.56	0.00	1.04
6	S.E. SERVIZI EDITORIALI S./	4.6	2	6	**2**	0.94	0.70	3.79	1.04	0.00
7	ROSANO' ALESSANDRO	2.5	2	9	**2**	1.49	0.98	3.79	1.58	0.63
8	SARACINO MATTEO	2.2	29	8	**3**	4.55	4.62	0.33	4.64	3.93
9	BAR JOLLY DI BRITTANNI N	1.2	2	2	**2**	1.68	2.00	2.94	1.75	1.45
10	JOLLY SAS di Arasi Giovann	4.1	2	13	**2**	1.98	1.53	5.90	1.97	2.17
11	PAGANI ANTONIO	4.0	29	9	**3**	4.85	4.95	0.65	4.94	4.26
12	IANNUZZELLI LEONARDO	6.1	2	5	**2**	2.28	1.58	4.94	2.33	1.79

Table 8: updated relative distance table

The result of these steps is the reassignment of all newsstands to new Delivery Rounds, which are numbered like the original Delivery Rounds.

Furthermore, the process ensures that the delivery rounds have a similar number of newsstands, making the distribution of the load in the delivery vehicles more balanced.

Finally, the rearrangement of the newsstands also leads to a reduction in the number of Rounds: in fact, some Delivery Rounds in the original situation supplied few newsstands, so it was possible to eliminate three Delivery Rounds for ADP and one for Agenzie Riunite. As will be shown on the following pages, in spite of this change, the kilometers travelled and the load volume transported by the delivery vehicles were not excessive. Below are the results of the reallocation of newsstands compared with the initial situation, first for ADP and then for Agenzie Riunite.

ADP

	Original		Optimized	
New Giro	Chests	Kiosk per Round	Chests	Kiosk per Round
1	41.6	13	48.4	14
2	45.8	13	41.5	12
3	43.4	14	41.6	16
4	37.1	13	44.3	14
5	35.0	15	35.0	15
11	47.3	16	43.7	14
12	31.8	8	0.0	0
13	43.3	12	58.7	16
14	41.8	13	45.3	14
15	38.7	12	49.1	15
22	39.4	10	50.5	15
23	41.0	12	44.6	17
24	34.2	12	51.9	16
25	37.5	14	43.2	16
26	35.4	13	37.1	13
27	37.5	12	52.1	18
28	27.8	12	0.0	0
29	28.3	11	0.0	0
Average	38.2	12.5	45.8	15

Table 9: comparison ADP

Agenzie Riunite

	Original		Optimized	
Round	Chests	Kiosk per Round	Chests	Kiosk per Round
1	45.4	14.0	46.6	14.0
2	52.8	16.0	50.3	17.0
3	43.0	14.0	0.0	0.0
4	46.6	15.0	55.2	17.0
5	50.3	14.0	60.1	16.0
12	65.0	22.0	55.2	19.0
13	38.0	13.0	56.5	18.0
14	56.5	17.0	63.8	18.0
15	54.0	17.0	47.9	16.0
16	61.4	18.0	61.4	17.0
17	77.3	19.0	68.7	18.0
19	54.0	13.0	61.1	16.0
20	63.8	14.0	67.3	17.0
21	41.7	13.0	52.8	16.0
Average	53.6	15.6	57.5	16.8

Table 10: comparison Agenzie Riunite

One figure that highlights the good result of the kiosk arrangement is the difference in the average number of chests and kiosks served in the two reported cases. The optimized case reports an increase in both values, which means that the capacity of the vehicles is better utilized. It is important to note that even in the optimized case, ADP's attitude of loading fewer vans than Agenzie Riunite is maintained.

The other result that was achieved, however, is more evident when shown via Google Earth. Also following the suggestions of the company presidents, the organization of the tours made the delivery rounds themselves more oriented along one direction. As can in fact be seen in the case of ADP but especially in the case of Agenzie Riunite, the delivery rounds in the original case are arranged in zones, which leads to a problem: delivery vehicles often find themselves passing through the area supplied by other vehicles, this generates a waste of time and resources.

The optimized organization tends instead, as mentioned above, to avoid several vehicles passing through the same zone and to make them follow different directions.

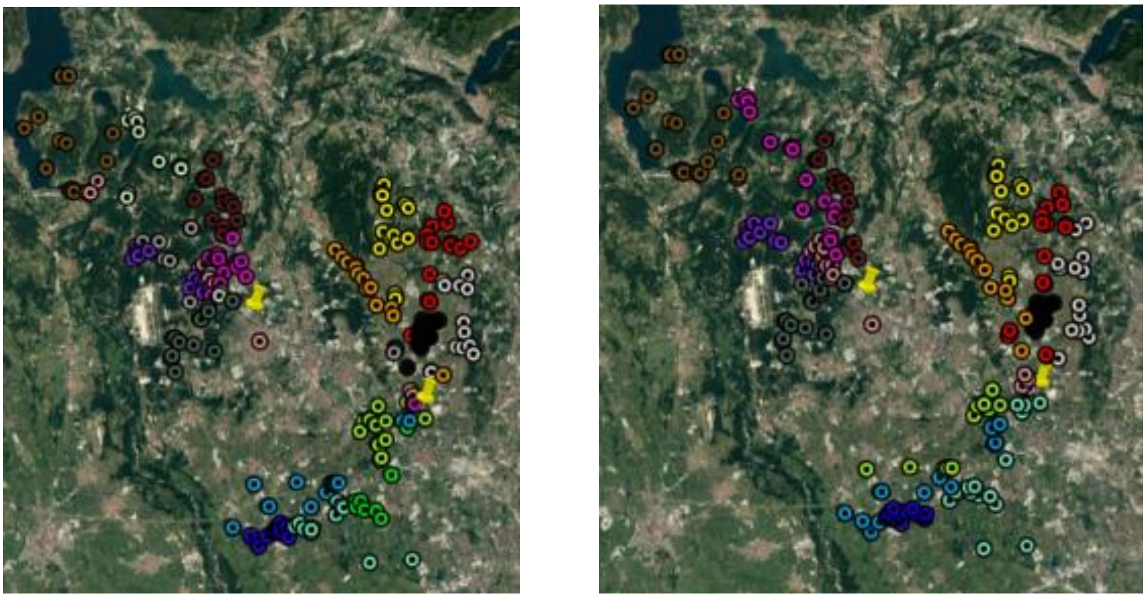


Figure 22: visual comparison ADP

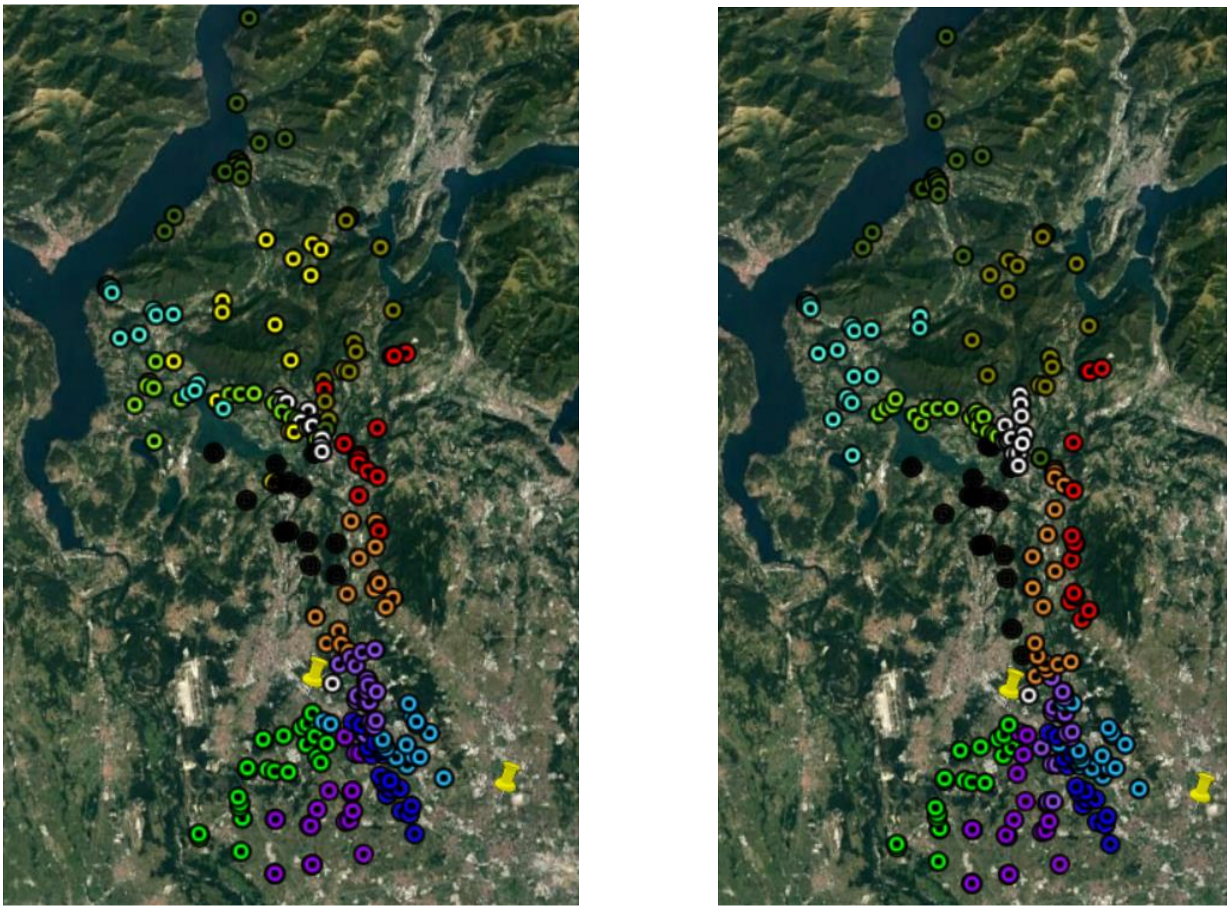


Figure 23: visual comparison Agenzie Riunite

The next steps in this study will be to verify that all the previously mentioned constraints, such as delivery times and vehicle loading capacity, are respected.

Analyses of the Scenarios

However, the organization of newsstands does not only lead to a different arrangement of delivery rounds, but it is also necessary to observe what magnitudes change between one scenario and the other.

In this chapter, the timetables of the delivery vehicles, the transported load and the kilometers travelled by them will be analyzed on the basis of data provided by the company.

In both scenarios, the following data were used:

- The relative distances between the newsstands and the company supplying them previously calculated
- The number of baskets per newsstand, used as a unit of measurement to assess the volume occupied in the delivery vehicles
- The cost of Rounds

The two scenarios will be compared on each Delivery Round considering the following magnitudes:

- Run kilometers
- Chests transported in the delivery round considered
- Time taken from when the vehicle leaves the company to when the vehicle returns to the company
- Time to make the last delivery
- Total cost of the Round

Original Scenario

First, a table nx(n+2) is created for each delivery round, where n is the number of newsstands supplied by the round in question. The two additional columns are due to the inclusion of the two companies ADP and Agenzie Riunite. The purpose of these tables is to represent the relative distance between the newsagents on the same tour and the distances to the starting company, again using the formula analyzed in the previous chapters with the same assumptions.

		LA ROSA (	ALLEDICO	IL PUNTO	PERAZZO	MANTEGA	GD Media	VECCHIAT	GIORNALI	PEREGO V	COLOMB(	MILLECOL	LA MIA EC	CLERICI ST	ADP	AGENZIE RIUNITE
1	LA ROSA (	0.0	0.1	5.8	5.9	5.0	4.5	6.6	7.5	11.5	11.5	13.1	11.1	11.6	3.0	23.9
2	ALLEDICO	0.1	0.0	5.8	5.9	5.0	4.5	6.5	7.5	11.4	11.4	13.0	11.0	11.4	3.1	23.8
3	IL PUNTO	5.8	5.8	0.0	1.1	1.5	2.3	3.0	4.2	8.2	8.8	10.0	9.4	9.9	7.9	28.3
4	PERAZZO	5.9	5.9	1.1	0.0	0.9	1.7	1.9	3.1	7.2	7.7	8.9	8.3	8.8	8.3	27.6
5	MANTEGA	5.0	5.0	1.5	0.9	0.0	0.8	2.0	3.2	7.4	7.9	9.2	8.2	8.7	7.6	26.8
6	GD Media	4.5	4.5	2.3	1.7	0.8	0.0	2.1	3.3	7.5	7.8	9.2	7.9	8.5	7.2	26.0
7	VECCHIAT	6.6	6.5	3.0	1.9	2.0	2.1	0.0	1.2	5.5	5.9	7.2	6.4	7.0	9.4	26.7
8	GIORNALI	7.5	7.5	4.2	3.1	3.2	3.3	1.2	0.0	4.2	4.7	6.0	5.2	5.8	10.4	26.4
9	PEREGO V	11.5	11.4	8.2	7.2	7.4	7.5	5.5	4.2	0.0	1.1	1.7	2.9	3.2	14.4	26.8
10	COLOMB(	11.5	11.4	8.8	7.7	7.9	7.8	5.9	4.7	1.1	0.0	1.7	1.9	2.2	14.5	25.9
11	MILLECOL	13.1	13.0	10.0	8.9	9.2	9.2	7.2	6.0	1.7	1.7	0.0	3.2	3.2	16.1	27.0
12	LA MIA EC	11.1	11.0	9.4	8.3	8.2	7.9	6.4	5.2	2.9	1.9	3.2	0.0	0.5	14.1	24.0
13	CLERICI ST	11.6	11.4	9.9	8.8	8.7	8.5	7.0	5.8	3.2	2.2	3.2	0.5	0.0	14.6	23.8

Table 11: relative distance Round 1 ADP

This case is certainly simpler that the Optimized one: the order of the newsstands (listed on the 1st left column) in the various Delivery Rounds is already established. From the data just listed, a table is constructed for each Round, the example for Round 1 of ADP is shown below.

Stop	1	2	3	4	5	6	7	8	9	10	11	12	13
Rag. Soc	LA ROSA G	ALLEDICO	IL PUNTO	PERAZZO E	MANTEGA	GD Media	VECCHIAT	GIORNALI	PEREGO V.	COLOMBO	MILLECOL	LA MIA ED	CLERICI ST
Relat Dist [km]		0.15	5.78	1.12	0.89	0.80	2.13	1.25	4.22	1.07	1.66	3.18	0.54
Min from start [min]	2.59	4.89	13.83	17.17	20.95	24.55	29.11	32.61	39.68	42.96	46.95	52.76	55.84
Chests	1.1	3.3	1.7	2.0	3.6	6.7	3.5	4.9	2.0	1.5	3.7	3.2	4.2

Table 12: round 1 recap ADP

1) The first line numerical order of the stops In the delivery round
2) 'Rag. Soc' indicates the company name of the newsstand.
3) 'Relat. Dist' is the relative distance between a stop and the previous one in kilometers. This table does not show the distance between the company and the first stop and between the last stop and the company at the end of the Round.
4) 'Min from start' indicates the minutes elapsed since the vehicle left the company
5) Chest is the number of chests needed by the newsstand

The relative distance between the various stops is taken from the nx(n+2) table shown above, outlining a route and thus a total distance travelled which will be calculated in the following steps.

To calculate the time taken by vehicles to reach the various stops, certain assumptions were made:

- The aim of this project is not to obtain an extremely detailed model of the routing of delivery vehicles, so three ranges of vehicle behavior were identified. These three ranges are based on the distance between one stop and the next, specifically on the 'Relat Dist' row of the table 12
  1) If the distance value is less than 1 km, the vehicle is assumed to travel that distance at a speed of 30 km/h
  2) If the distance value is greater, the section is assumed to be travelled at 50 km/h.
  3) If the stop is the first or the last of the Round, a speed of 70 km/h is assumed, because the vehicle travels along main roads or motorways to reach the first delivery point quickly.
- The above divisions assume that vehicles often pass-through built-up areas, little cities where speed must be moderate and where there are crossroads, pedestrian crossings and the slight traffic present at the times of delivery of goods, we are talking about the 4:30-7:00 am time slot.

Main Results

Using the values highlighted in the previous section, the quantities shown here are calculated for each Round (not all are shown below as once the optimized case is also described, the two scenarios will be compared Round by Round for both companies):

Round	Run Km	T[h]	T[min]	T,Last Delivery
1	40.4	1.2	70.3	55.8
			Comeback hour	Last Delivery Hour
			05:40	05:25

Table 13: Round 1 results ADP

Here there is a description of the magnitudes of table 13:

- Run km: is the sum of all the relative distances between one newsstand and the previous plus the distance between the Company and the first newsstand plus the distance between the last newsstand and the Company
- T[h] is the time in hours required by the delivery vehicle to complete deliveries and return to the company, the starting point is the company itself.
- T[min] is T[h] in minutes.
- T, Last Delivery is the time it takes for the vehicle to make its last delivery, so the time needed to return to the company is not taken into account. It is reported in minutes.
- Comeback hour is the time at which the vehicle returns to the company.
- Last delivery hour is the hour at which the last delivery is made.

Numerical Values - ADP

From these results, and in particular the kilometers travelled, it is possible to see the disparity between the various delivery rounds. As can be seen below, there are vehicles that cover up to three to four times the distance travelled by others.

The disparity is, however, also due to the different geographical areas supplied by the companies: this factor is especially evident for ADP, which has two areas very close to it (North and South) and one area (the North-West) further away, characterized by Rounds 22 to 29.

Round	Run Km	Round	Run Km
1	40.4	15	64.2
Round	Run Km	Round	Run Km
2	29.5	22	86.4
Round	Run Km	Round	Run Km
3	56.3	23	87.6
Round	Run Km	Round	Run Km
4	47.4	24	214.3
Round	Run Km	Round	Run Km
5	64.5	25	101.7
Round	Run Km	Round	Run Km
11	34.6	26	97.0
Round	Run Km	Round	Run Km
12	39.4	27	152.7
Round	Run Km	Round	Run Km
13	77.0	28	173.3
Round	Run Km	Round	Run Km
14	66.1	29	211.6

Table 14: distance travelled ADP

As will be seen in the next section, the cost of delivery rounds for ADP is divided into a fixed component and a variable component, linked to the amount of km driven by the driver, a reduction in the distance travelled and especially a reduction in the number of Rounds can lead to great savings for the company.

Numerical Values – Agenzie Riunite

Round	Run Km	Round	Run Km
1	92.1	14	57.1
Round	Run Km	Round	Run Km
2	52.7	15	49.0
Round	Run Km	Round	Run Km
3	119.9	16	44.1
Round	Run Km	Round	Run Km
4	95.8	17	60.8
Round	Run Km	Round	Run Km
5	186.3	19	91.6
Round	Run Km	Round	Run Km
12	66.4	20	116.4
Round	Run Km	Round	Run Km
13	107.2	21	81.9

Table 15: distance travelled Agenzie Riunite

The main difference with the ADP case is the length of the delivery Rounds: in the previous case, 5 out of 18 Tours are shorter than 50 km; here, however, only 2 out of 14 Rounds are slightly shorter than 50 km.

The explanation for this is due to several factors, certainly ADP provides a more circular area, hence not very elongated. In contrast, Agenzie Riunite expands its area of responsibility from north to south by several kilometers, going all the way to the Swiss border.

In addition, the main reason is still the different mentality regarding loading delivery vehicles, Agenzie Riunite has an average of 53.6 Baskets (unit of measurement of loading volume) per delivery vehicle, whereas ADP has an average of 38.2 Baskets. This different approach leads Agenzie Riunite's vehicles to serve more newsagents, thus making more stops and grinding out more kilometers.

The two methods lead to different strategic advantages; on the one hand, it is easier for ADP to cope with days when the delivery load peaks. On the other hand, however, the overall cost increases as this versatility leads to a few more rides and therefore a few more means to pay.

The vehicles of Agenzie Riunite, on the other hand, although they seem to carry a higher cost for the company as they have to cover more km individually, at the end of the day thanks to a greater optimization of loading capacity they cover fewer km in total. The big saving lies in reducing the number of round trips to the first newsagent supplied on the Round and back from the last newsagent to the company.

Cost - ADP

Finally, perhaps the most indicative parameter for the company is the cost of the Round, as well as indicating which are the most expensive Rounds is also a sign of what Round should be removed/modified if possible.

Round	Cost[€]
1	8.59
Round	Cost[€]
2	8.03
Round	Cost[€]
3	9.42
Round	Cost[€]
4	8.96
Round	Cost[€]
5	9.84
Round	Cost[€]
11	8.29
Round	Cost[€]
12	8.54
Round	Cost[€]
13	10.50
Round	Cost[€]
14	9.93

Round	Cost[€]
15	9.83
Round	Cost[€]
22	10.98
Round	Cost[€]
23	11.04
Round	Cost[€]
24	17.62
Round	Cost[€]
25	11.77
Round	Cost[€]
26	11.53
Round	Cost[€]
27	14.43
Round	Cost[€]
28	15.50
Round	Cost[€]
29	17.48

Table 16: ficticious cost ADP

The costs of delivery rounds of ADP are divided into 2 main factors: a fixed cost per round and a variable cost based on the kilometers travelled by the vehicle.

$$Cost_{R1} = [(km_{R1} * a) + CF]$$

The 'a' coefficient is deliberately hidden for privacy purposes, as well as the Fixed Cost coefficient CF.

The values shown in the table 16 therefore do not represent the actual costs of ADP. These distorted values are shown in order to be able to draw conclusions and highlight the results of this study.

As can be seen from the cost table 16, the most expensive tours are in the North-West, the reason being their distance from the company, which therefore increases the cost.

In this case, the difference in delivery method between the two companies is even more evident, making it very clear that the trips on which it makes sense to focus more on optimization (if possible) are those that are more distant and geographically dispersed.

Costs – Agenzie Riunite

Round	Cost[€]	Round	Cost[€]
1	12.2	14	10.9
Round	Cost[€]	Round	Cost[€]
2	10.1	15	10.2
Round	Cost[€]	Round	Cost[€]
3	11.6	16	10.4
Round	Cost[€]	Round	Cost[€]
4	12.4	17	10.2
Round	Cost[€]	Round	Cost[€]
5	16.3	19	10.0
Round	Cost[€]	Round	Cost[€]
12	10.4	20	12.4
Round	Cost[€]	Round	Cost[€]
13	12.1	21	12.6

Table 17: ficticious cost Agenzie Riunite

Unlike ADP, the cost of the Round does not depend directly on a fixed component and a variable component linked to the kilometers travelled.

Agenzie Riunite supplies a large area, which implies travelling on different types of roads: motorways, motorways, hill or city roads. To date, I have been provided with the costs of each individual Delivery Tour and the cost of each of them. As mentioned earlier, however, the model used in this project is an approximation, which does not take into account exactly the roads travelled by the vehicles in reality, but simulates the routes taken by the vehicles to reach all the stops within a route. This leads to the result that the km calculated using the model and the km travelled provided by Agenzie Riunite do not coincide perfectly.

This type of situation has led me to make a few assumptions:

- As a first assumption, the same ADP model is used, so a fixed cost per Round is assigned to which a variable cost linked to the kilometers travelled by the vehicle is added.
- A representative percentage coefficient is then calculated as the difference between the cost obtained from the previous hypothesis and the cost provided by the company in relation to the cost provided by the company.

$$c_{\%} = \frac{C_m - C_0}{C_0}$$

This coefficient indicates how much the cost that would only be given by Fixed Cost plus kilometers travelled has to be increased or decreased in order to have a realistic value.

Round	1	2	3	4	5	12	13
c%	8%	9%	-8%	8%	1%	4%	0%

Round	14	15	16	17	19	20	21
c%	16%	13%	18%	5%	-11%	-1%	17%

Table 18: cost coefficients

- The coefficient should then be multiplied by the km travelled in the optimized case. This assumption is valid because, as described in the assumptions at the beginning of the project, the optimized case is based on Centroids. The vehicles therefore have to follow the same directions as in the original case and travel approximately the same roads to reach the delivery area. Therefore, the increased costs due to e.g. motorway passage are also maintained in the optimized case.
- In the table above, it is therefore indicated that it will be used as a yardstick for the Optimised case.

Optimized Scenario

The basic concept is the same as in the previous scenario, with a few differences. The main difference is the lack of sorting of the newsstands, so far only which newsstands are in each round is known.

Below are the steps for this second scenario:

- For each Round a nx(n+2) table, with n number of the newsstands served in the round, is created
- Considering the distance of the newsstands from the starting company, a sensible order for the newsstands is decided. In general, the nearest newsstand is chosen as the first stop.
- Then a direction is chosen, the main one to follow: logically, it would be right to go to the nearest newsstand in terms of space, but this could lead to travelling too many kilometers overall. An example is given below.

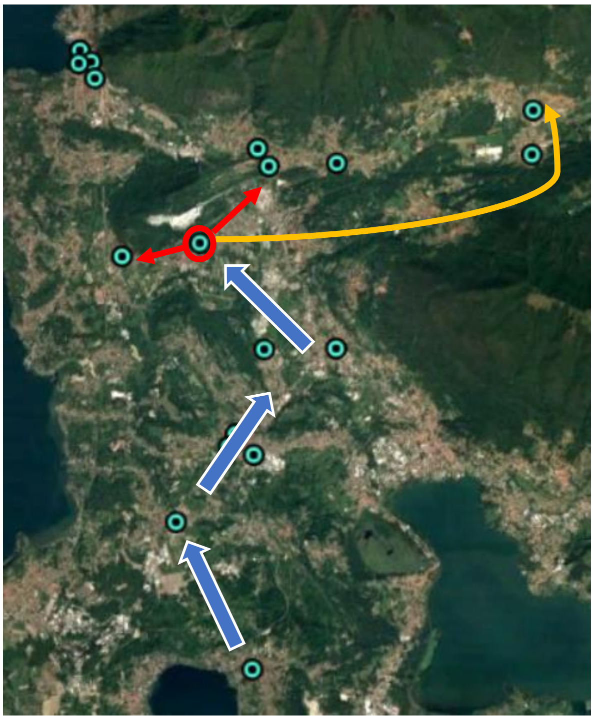


Figure 24: example of problems and solutions

The blue arrows are the correct route and are already suggested by the model that always goes to the next nearest newsstand. But once the order arrives at the newsstand circled in red, the algorithm would suggest following one of the two red arrows, as the newsstands indicated by them lead to the nearest un-serviced newsstands. However, this route would overall lead to travelling further than necessary.
The best solution is therefore to follow the route indicated by the orange arrow, forcing the choice on the two newsstands at the top right in the image.
This process generates the sorting of newsstands in Optimized Delivery Rounds.

- A table similar to the original case is constructed, this time with some information added. In fact, using the information regarding the goods delivery time preference of the newsstands that provided it, the theoretical time of delay or advance in delivery compared to the optimal time is also calculated. Below is an example, part of ADP Round 1.

			S1	S2	S3	S4
	Round	Dist ADP [km]	3.3	7.2	7.6	7.9
	1	Rag. Soc.	EDICOLA P	GD Media	MANTEGA	IL PUNTO
			3	13	2	4
		Relative Distance		3.9	0.8	1.5
		[min] From start	2.9	9.6	13.2	17.0
Starting h	05:25:00	Arriving Hour	05:27:52	05:34:35	05:38:11	05:42:01
		Optimal Hour		06:00:00		05:30:00
		Delta time		00:25:25		00:12:01
		Delay/advance		ADVANCE		DELAY
		Chests	3.8	6.7	3.6	1.7

Figure 25: Round 1 ADP recap

- Some of the quantities in the Figure 25 are the same as in the original case, so they will not be described again, but it is necessary to clarify the additional elements in this table.
  - Dist ADP is the distance of the stop in question from the starting company, in this case from ADP, it is expressed in km.
  - Starting h: the hour at which the vehicle leaves the company.
    A first decision-making difference to the current case lies in changing the departure time as well: as of today, in fact, all delivery vehicles leave at the same time, about 4:30 a.m. This is therefore the case for both tours that serve an area close to the company and tours that supply more distant areas. This factor combined with the fact that many newsagents have a preferred delivery time of around 6:00 to 7:00 a.m. forces some drivers to stop and wait for the correct time to deliver the goods. By changing the departure time, this problem can be limited, but not to the detriment of those newsstands that, on the contrary, require goods to be delivered at an earlier time. The aim in fact is to change the departure time by limiting late or early delivery of goods as much as possible. Although this objective is relevant, less weight has been given to it than to spatial optimization.
    The motivation lies in the intentions of both ADP and Agenzie Riunite: in the coming period, both companies aim to have the keys to most of the newsstands, so that they can better manage their delivery times without wasting the drivers' time, thus also reducing costs. In the ideal scenario in which the companies hold the keys to all newsstands, all rounds could start at the same time (e.g. 4:30 a.m.) in order to avoid return traffic in the following hours, thus reducing time and costs.
  - Arriving Hour: indicates the approximate arrival time at which the vehicle reaches the newsstand. This magnitude is calculated by adding the value of '[Min] from Start' of each newsstand to the time of departure.
    Hypothesis: unloading time is also taken into account in this magnitude. The unloading time has been assumed to be 2 minutes. This decision was made after getting into the delivery vehicles to follow the driver during the delivery of the goods, it represents an average time in which the operator gets out of the vehicle, unloads the goods and loads the return.
    So for the purposes of the count for each newsstand, two minutes are added to the elapsed time.
  - Optimal H: the optimal time provided by the newsagent, i.e. the time at which he would like the goods to arrive.

- Delta t: the difference between the Optimal Time and the Actual Time of delivery of the goods (again on a theoretical basis based on the calculations and assumptions described in the original case). If the cell is empty, the company has the keys to the kiosk or dumpster.
  As mentioned in the preceding paragraphs, priority was given to spatial rather than temporal optimization, however, as far as possible the ordering of the newsstands was also designed with optimal delivery times in mind, ensuring that the 'Delta t' remained within half an hour early or late.
- Delay/advance: Simple graphic representation indicating whether goods are delivered early or late.
- Chests: number of chests per each newsstand.

This type of table is constructed for each delivery round of the optimized case. From these new values, it is then possible to calculate the same values as in the original case with a few additions.

Round	Run Km	T[h]	T[min]	T,Last Delivery
1	48.7	1.3	79.4	67.0
Tot Delay/Advance	Tot Chests		Comeback hour	Last Delivery Hour
1	48.4		06:44	06:31

Table 19: results round 1 Agenzie Riunite

The new quantities that have been calculated are described below:

- Tot Delay/Advance is the number of delays or advances in the delivery of goods.
  Only delays/advances of more than 15 minutes are taken into account in this count. This time interval was chosen as it represents a good compromise that takes into account possible traffic problems or unforeseen events along the route.
- Tot Chests is the simple sum of the chests delivered to the newsstand of the Delivery Round.

Comparison

In this section, the results of the analysis of both the original case and the optimized case are reported, with consequent considerations concerning the differences between the two scenarios.

ADP

Original					Optimized				
Round	Run Km	T[h]	T[min]	T,Last Delivery	**Round**	Run Km	T[h]	T[min]	T,Last Delivery
1	40.4	1.2	70.3	55.8	**1**	48.7	1.3	79.4	67.0
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		41.6	05:40:20	05:25:50			48.4	06:44:22	06:31:59
Round	Run Km	T[h]	T[min]	T,Last Delivery	**Round**	Run Km	T[h]	T[min]	T,Last Delivery
2	29.5	1.0	60.6	54.9	**2**	24.1	0.8	48.3	41.5
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		45.8	05:30:39	05:24:55			41.5	06:08:21	06:01:31
Round	Run Km	T[h]	T[min]	T,Last Delivery	**Round**	Run Km	T[h]	T[min]	T,Last Delivery
3	56.3	1.5	89.8	81.1	**3**	51.4	1.5	89.2	84.7
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		43.4	05:59:48	05:51:03			41.6	06:39:12	06:34:42

Table 20: comparison from Round 1 to Round 3 ADP

Round	Run Km	T[h]	T[min]	T,Last Delivery
4	47.4	1.3	77.7	57.1

Chests	Comeback hour	Last Delivery Hour
37.1	05:47:45	05:27:03

Round	Run Km	T[h]	T[min]	T,Last Delivery
5	64.5	1.6	96.3	83.3

Chests	Comeback hour	Last Delivery Hour
31.0	06:06:20	05:53:17

Round	Run Km	T[h]	T[min]	T,Last Delivery
11	34.6	1.2	72.6	68.2

Chests	Comeback hour	Last Delivery Hour
47.3	05:42:39	05:38:09

Round	Run Km	T[h]	T[min]	T,Last Delivery
12	39.4	1.0	57.1	51.1

Chests	Comeback hour	Last Delivery Hour
31.8	05:27:07	05:21:06

Round	Run Km	T[h]	T[min]	T,Last Delivery
13	77.0	1.7	104.9	86.7

Chests	Comeback hour	Last Delivery Hour
43.3	06:14:57	05:56:42

Round	Run Km	T[h]	T[min]	T,Last Delivery
14	66.1	1.6	97.6	74.6

Chests	Comeback hour	Last Delivery Hour
41.8	06:07:35	05:44:34

Round	Run Km	T[h]	T[min]	T,Last Delivery
4	52.8	1.4	86.4	79.7

Chests	Comeback hour	Last Delivery Hour
44.3	06:26:25	06:19:41

Round	Run Km	T[h]	T[min]	T,Last Delivery
5	60.2	1.5	87.9	74.0

Chests	Comeback hour	Last Delivery Hour
35	06:17:53	06:04:00

Round	Run Km	T[h]	T[min]	T,Last Delivery
11	54.0	1.5	88.3	83.0

Chests	Comeback hour	Last Delivery Hour
43.7	06:38:20	06:32:57

Round	Run Km	T[h]	T[min]	T,Last Delivery
13	61.1	1.6	93.2	94.8

Chests	Comeback hour	Last Delivery Hour
58.7	06:18:12	06:19:49

Round	Run Km	T[h]	T[min]	T,Last Delivery
14	84.1	2.0	118.7	103.7

Chests	Comeback hour	Last Delivery Hour
45.3	07:13:45	06:58:39

Table 21:comparison from Round 4 to Round 14 ADP

Round	Run Km	T[h]	T[min]	T,Last Delivery
15	64.2	1.4	85.7	62.3
		Chests	Comeback hour	Last Delivery Hour
		38.7	05:55:44	05:32:17
Round	Run Km	T[h]	T[min]	T,Last Delivery
22	140.1	2.8	168.4	138.2
		Chests	Comeback hour	Last Delivery Hour
		39.4	07:18:25	06:48:14
Round	Run Km	T[h]	T[min]	T,Last Delivery
23	87.6	2.0	118.2	88.2
		Chests	Comeback hour	Last Delivery Hour
		41.0	06:28:10	05:58:14
Round	Run Km	T[h]	T[min]	T,Last Delivery
24	214.3	4.4	263.1	242.1
		Chests	Comeback hour	Last Delivery Hour
		34.2	08:53:06	08:32:04
Round	Run Km	T[h]	T[min]	T,Last Delivery
25	101.7	2.2	131.3	103.5
		Chests	Comeback hour	Last Delivery Hour
		37.5	06:41:20	06:13:32
Round	Run Km	T[h]	T[min]	T,Last Delivery
26	97.0	2.0	121.6	92.4
		Chests	Comeback hour	Last Delivery Hour
		35.4	06:31:36	06:02:25

Round	Run Km	T[h]	T[min]	T,Last Delivery
15	56.7	1.4	83.0	67.5
		Chests	Comeback hour	Last Delivery Hour
		49.1	06:22:58	06:07:30
Round	Run Km	T[h]	T[min]	T,Last Delivery
22	87.0	2.0	117.1	88.4
		Chests	Comeback hour	Last Delivery Hour
		50.49444	06:42:07	06:13:21
Round	Run Km	T[h]	T[min]	T,Last Delivery
23	109.2	2.6	155.1	121.7
		Chests	Comeback hour	Last Delivery Hour
		44.6	07:10:07	06:36:43
Round	Run Km	T[h]	T[min]	T,Last Delivery
24	72.4	2.1	123.1	117.6
		Chests	Comeback hour	Last Delivery Hour
		47.8	06:18:07	06:12:34
Round	Run Km	T[h]	T[min]	T,Last Delivery
25	87.2	2.0	118.6	93.2
		Chests	Comeback hour	Last Delivery Hour
		43.2	06:38:37	06:13:12
Round	Run Km	T[h]	T[min]	T,Last Delivery
26	86.3	1.8	109.6	73.1
		Chests	Comeback hour	Last Delivery Hour
		37.1	07:19:37	06:43:07

Table 22: comparison from Round 14 to Round 26 ADP

Round	Run Km	T[h]	T[min]	T,Last Delivery		**Round**	Run Km	T[h]	T[min]	T,Last Delivery
27	152.7	2.9	172.7	126.3		**27**	142.0	2.9	176.7	132.1
		Chests	Comeback hour	Last Delivery Hour				Chests	Comeback hour	Last Delivery Hour
		37.5	07:22:45	06:36:18				52.1	07:26:41	06:42:03
Round	Run Km	T[h]	T[min]	T,Last Delivery						
28	173.3	3.6	218.2	216.0						
		Chests	Comeback hour	Last Delivery Hour						
		27.8	08:08:11	08:06:00						
Round	Run Km	T[h]	T[min]	T,Last Delivery						
29	211.6	4.2	254.5	225.5						
		Chests	Comeback hour	Last Delivery Hour						
		28.3	08:44:27	08:15:32						

Table 23: comparison from Round 27 to Round 29 ADP

In the tables just shown, all the magnitudes of the delivery rounds are highlighted in the left column of the original case and in the right column of the optimized case.

The Rounds that were eliminated in the optimized case are:

- 12 southern area
- 28 north-west area
- 29 north-west area

The criteria followed in deciding which Rounds to eliminate by moving their newsstands to other are as follows:

1) Consider delivery rounds serving a low number of newsstands. This is a clear advantage in the reallocation of newsstands served: there are fewer newsstands to sort in neighboring rounds.
2) Try to eliminate rounds that were not isolated from the others, this to allow for a better distribution of the newsagents without overloading other rounds. An illustration of this point is the removal of Round 28 and 29, both in the North-West zone, which alone counted 8 of the total 18 Rounds.
3) Try to remove the most wasteful spins in terms of km. As described before, the cost of the Tour is directly dependent on the number of km travelled by the delivery vehicle. In the specific case of Round 28 and 29, the distance travelled is very high as space efficiency is sometimes sacrificed in order to follow the optimal delivery times provided by the newsagents.
   In contrast, this project aims to reduce consumption and emissions and puts space efficiency first. This approach is also facilitated by the companies' intentions to obtain the keys to all newsstands so that they can better organize the entire distribution chain and cut costs.

Following the three points just mentioned has led to a big reduction firstly in the kilometers travelled by vehicles, and consequently in the time taken to make deliveries. Below is a table summarizing the differences between the optimized case and the original case, which will be followed by some considerations.

Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
1	9.0	11.1	8.3	15	-2.8	5.2	-7.6
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
2	-12.3	-13.4	-5.5	22	13.1	14.5	0.6
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
3	-0.6	3.6	-5.0	23	36.9	33.5	21.6
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
4	8.7	22.6	5.4	24	-140.0	-124.5	-141.9
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
5	-8.5	-9.3	-4.4	25	-12.7	-10.3	-14.5
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
11	15.7	14.8	19.4	26	-12.0	-19.3	-10.7
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
12	-57.1	-51.1	-39.4	27	3.9	5.8	-10.7
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
13	-11.7	8.1	-15.9	28	-218.2	-216.0	-173.3
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
14	21.2	29.1	18.0	29	-254.5	-225.5	-211.6

Table 24: variation of magnitudes, ADP

- 'Δt[m] tot' represents the time difference in minutes between the optimized case and the original case. It refers to the total time from when the vehicle leaves the company to when it returns at the end of the tour.
  Excluding the 3 Rounds removed, 6 out of the remaining 16 Tours see this value increase, especially Round 23 which shows an increase of almost 37 minutes. The reason is that to date it only supplies 12 newsstands, in the optimized case it would supply 17.
- 'Δt[min] LD' like the previous magnitude represents the difference in time required to make the last delivery between the optimized case and the original case.
  This time, 9 of the remaining 16 rounds show an increase compared to the base case.
- 'Δspace [km]' represents the difference in km travelled by the delivery vehicles between the optimized case and the base case.
  Here only 5 Rounds see their km increase despite there being 3 Rounds less. This shows how important it was to reorganize the kiosks between the various Tours: not only from an economic point of view (as will be analyzed shortly) but also from a consumption and emissions point of view.

Excluding the North-West area, i.e. Rounds 22 to 29, the general trend is the one of a reduction in both space and time. The main reason for this is precisely to prioritize spatial optimization.

On the other hand, some Rounds see their kilometers and times going up, this is obviously because all the kiosks removed from Rounds 12, 28 and 29 have been redistributed to neighboring Tours.

From these results it can be seen that the study has led to a positive scenario for the company. The strength of this project is the fact that with just a few well-thought-out measures, great savings can be made both in terms of the space travelled and the human effort required to complete the daily replenishment of the newsstands.

Finally, I calculated the total daily values of the quantities described so far, comparing the original case with the optimized case.

Original				
			Tot time	Delivery Time
Tot Space[km]		min	1429.50	1182.60
1935.6		h	23.82	19.71

Optimized				
			Tot time	Delivery Time
Tot Space[km]		min	1288.93	1119.16
1269.4		h	21.48	18.65

Results	
% space	34%
% tot time	10%
% Delivery time	5%

Table 25: general results ADP

The magnitude that has been most affected is obviously the space travelled. The reduction of 34% compared to the original case is mainly attributable to the removal of three revolutions: 93% of the 567 [km] saved.

ADP – Costs

Finally, the cost differences between the two proposed scenarios are analyzed. The following table shows the costs of the optimized case, then compared with the original case.

Note that Rounds 12, 28 and 29 are not shown in the comparison, as they would obviously see a 100% cost reduction.

Round	Cost[€]	Δcost
1	9.0	5%
Round	Cost[€]	Δcost
2	7.7	-4%
Round	Cost[€]	Δcost
3	9.2	-3%
Round	Cost[€]	Δcost
4	9.2	3%
Round	Cost[€]	Δcost
5	9.6	-2%
Round	Cost[€]	Δcost
11	9.3	12%
Round	Cost[€]	Δcost
13	9.7	-8%
Round	Cost[€]	Δcost
14	10.9	9%

Round	Cost[€]	Δcost
15	9.4	-4%
Round	Cost[€]	Δcost
22	11.0	0%
Round	Cost[€]	Δcost
23	12.2	10%
Round	Cost[€]	Δcost
24	10.3	-42%
Round	Cost[€]	Δcost
25	11.0	-6%
Round	Cost[€]	Δcost
26	11.0	-5%
Round	Cost[€]	Δcost
27	13.9	-4%

Table 26: ficticious costs comparison ADP

'Δcost' is calculated as the ratio of the cost of the optimized Tour from which the cost of the original Round is subtracted to the cost of the original Round.

$$\Delta\text{cost} = \frac{\mathrm{C}_0 - \mathrm{C}_{\text{opt}}}{C_0}$$

This magnitude shows that 10 out of the 15 remaining rounds show a reduction in costs. In 7 of these rounds, the reduction is quite low but still considerable, around 5%.

A brief note on Round 24, the extremely high reduction in the Cost of this round is related as described before to the lack of spatial efficiency in the organization of it, in favor of going to what the newsagents want in order to receive the goods at their convenient time.

The reduction in costs is obviously linked to the reduction in kilometers travelled, which clearly shows how important it is to obtain the keys to the kiosks in order to be able to organize the delivery rounds in the best possible way.

In conclusion, the total cost of the two scenarios is shown:

	Original Scenario	Optimized Scenario	Saving rate
Tot Cost[€]	202.3	153.4	24%

Table 27: daily cost ADP

Most of the saving in the optimized case comes from the removal of the three Rounds. Of the 25% total saving, 6 is given by the spatial optimization of the Rounds that were not removed, while the remaining 19 is given by the removal of Spins 12, 28 and 29.

Finally, I report the account of the annual cost due to the Revolutions for Agenzie Riunite, always considering a fictitious cost per privacy.

	Original Scenario	Optimized Scenario	Saving rate
Tot Cost[€]	71813.1	54445.6	25%

Table 28: annual cost ADP

This table will be useful in subsequent chapters and for final considerations.

Agenzie Riunite

The same analysis that was performed for ADP is now presented for Agenzie Riunite

PRESENT					OPTIMIZED				
Giro	Run Km	T[h]	T[min]	T,Last Delivery	**Giro**	Run Km	T[h]	T[min]	T,Last Delivery
1	92.1	2.1	123.1	98.3	**1**	83.9	1.9	113.0	78.5
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		45.41	06:33:06	06:08:19			46.64	07:23:02	06:48:30
Giro	Run Km	T[h]	T[min]	T,Last Delivery	**Giro**	Run Km	T[h]	T[min]	T,Last Delivery
2	52.7	1.6	93.1	85.1	**2**	59.6	1.7	101.1	88.9
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		52.77	06:03:04	05:55:08			50.32	06:11:05	05:58:55
Giro	Run Km	T[h]	T[min]	T,Last Delivery					
3	119.9	2.5	152.2	119.5					
		Chests	Comeback hour	Last Delivery Hour					
		43.95	07:02:11	06:29:28					
Giro	Run Km	T[h]	T[min]	T,Last Delivery	**Giro**	Run Km	T[h]	T[min]	T,Last Delivery
4	95.8	2.1	125.7	96.2	**4**	83.9	1.9	117.0	85.2
		Chests	Comeback hour	Last Delivery Hour			Chests	Comeback hour	Last Delivery Hour
		46.64	06:35:43	06:06:09			55.23	07:26:59	06:55:10

Table 29: comparison Agenzie Riunite from Round 1 to 4

Giro	Run Km	T[h]	T[min]	T,Last Delivery
5	186.3	3.7	224.5	177.0
		Chests	Comeback hour	Last Delivery Hour
		50.32	08:14:28	07:27:03
Giro	Run Km	T[h]	T[min]	T,Last Delivery
12	66.4	2.0	121.9	93.0
		Chests	Comeback hour	Last Delivery Hour
		65.05	06:31:55	06:03:01
Giro	Run Km	T[h]	T[min]	T,Last Delivery
13	107.2	2.2	131.7	92.1
		Chests	Comeback hour	Last Delivery Hour
		38.05	06:41:40	06:02:05
Giro	Run Km	T[h]	T[min]	T,Last Delivery
14	57.1	1.6	98.5	85.6
		Chests	Comeback hour	Last Delivery Hour
		56.45	06:08:29	05:55:39
Giro	Run Km	T[h]	T[min]	T,Last Delivery
15	49.0	1.5	89.5	76.2
		Chests	Comeback hour	Last Delivery Hour
		54.00	05:59:32	05:46:11
Giro	Run Km	T[h]	T[min]	T,Last Delivery
16	44.1	1.5	87.5	78.1
		Chests	Comeback hour	Last Delivery Hour
		61.36	05:57:32	05:48:08

Giro	Run Km	T[h]	T[min]	T,Last Delivery
5	161.4	3.3	199.6	152.2
		Chests	Comeback hour	Last Delivery Hour
		61.36	07:49:37	07:02:12
Giro	Run Km	T[h]	T[min]	T,Last Delivery
12	64.1	1.9	111.9	100.5
		Chests	Comeback hour	Last Delivery Hour
		57.68	07:36:51	07:25:29
Giro	Run Km	T[h]	T[min]	T,Last Delivery
13	133.2	2.9	174.4	140.9
		Chests	Comeback hour	Last Delivery Hour
		56.45	07:24:23	06:50:51
Giro	Run Km	T[h]	T[min]	T,Last Delivery
14	43.7	1.4	86.5	77.5
		Chests	Comeback hour	Last Delivery Hour
		60.14	05:56:31	05:47:30
Giro	Run Km	T[h]	T[min]	T,Last Delivery
15	44.6	1.4	85.9	76.5
		Chests	Comeback hour	Last Delivery Hour
		51.55	06:35:53	06:26:29
Giro	Run Km	T[h]	T[min]	T,Last Delivery
16	52.5	1.6	95.6	87.3
		Chests	Comeback hour	Last Delivery Hour
		62.59	06:05:38	05:57:16

Table 30: comparison Agenzie Riunite from Round 5 to 16

Giro	Run Km	T[h]	T[min]	T,Last Delivery
17	60.8	1.8	105.3	92.4
		Chests	Comeback hour	Last Delivery Hour
		77.32	06:15:20	06:02:25
Giro	Run Km	T[h]	T[min]	T,Last Delivery
19	91.6	2.1	128.2	124.4
		Chests	Comeback hour	Last Delivery Hour
		54.00	06:38:12	06:34:22
Giro	Run Km	T[h]	T[min]	T,Last Delivery
20	116.4	2.3	140.9	94.4
		Chests	Comeback hour	Last Delivery Hour
		63.82	06:50:52	06:04:23
Giro	Run Km	T[h]	T[min]	T,Last Delivery
21	81.9	1.9	112.3	89.4
		Chests	Comeback hour	Last Delivery Hour
		41.73	06:22:19	05:59:25

Giro	Run Km	T[h]	T[min]	T,Last Delivery
17	60.2	1.7	102.8	88.2
		Chests	Comeback hour	Last Delivery Hour
		68.73	07:02:49	06:48:11
Giro	Run Km	T[h]	T[min]	T,Last Delivery
19	71.4	1.8	108.1	104.3
		Chests	Comeback hour	Last Delivery Hour
		61.36	07:18:05	07:14:15
Giro	Run Km	T[h]	T[min]	T,Last Delivery
20	128.9	2.7	161.9	121.1
		Chests	Comeback hour	Last Delivery Hour
		67.27	07:11:55	06:31:06
Giro	Run Km	T[h]	T[min]	T,Last Delivery
21	75.8	1.9	115.1	93.8
		Chests	Comeback hour	Last Delivery Hour
		52.77	07:25:07	07:03:46

Table 31: comparison Agenzie Riunite from Round 17 to 21

The table of each Tour is composed in the same way as the table of ADP Tours. The main difference with the previous case is that this time only one Delivery Round has been removed.

The reason lies in the fact that, as shown before, Agenzie Riunite tends to load more delivery rounds, so it is more difficult to remove rounds and redistribute them.

The main reasons why Round 3 was removed are the same as those already presented for the optimized case of ADP.

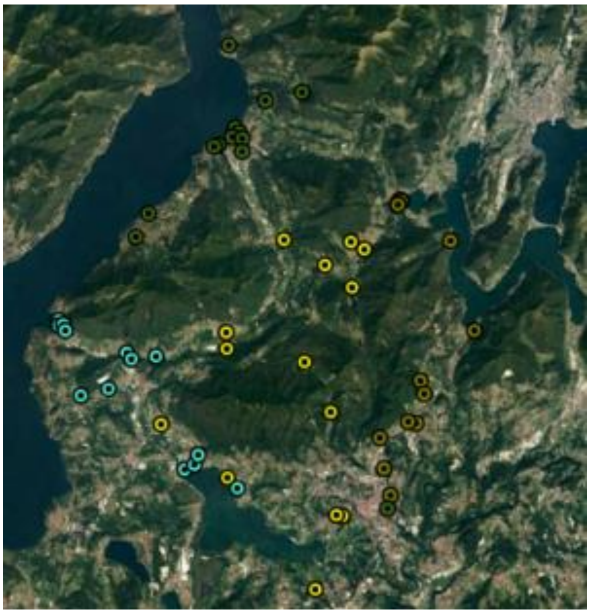


Table 32: example of a solution for Agenzie Riunite

Furthermore, as can be seen in the picture, Tour 3 (yellow dots) is in a central geographic area in relation to other neighboring Tours. This factor made it possible to distribute the newsstands of Round 3 among three other rounds.

As was shown for ADP, the difference in the main quantities between the Original and Optimised case is shown below.

Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
1	-10.1	-19.8	-8.3	14	-12.0	-8.1	-13.4
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
2	8.0	3.8	6.9	15	-3.7	0.3	-4.5
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
3	-152.2	-119.5	-119.9	16	8.1	9.1	8.5
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
4	-8.7	-11.0	-12.0	17	-2.5	-4.2	-0.6
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
5	-24.8	-24.8	-24.9	19	-20.1	-20.1	-20.2
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
12	-10.1	7.5	-2.3	20	21.0	26.7	12.6
Round	Δt[m] tot	Δt[min] LD	Δspace [km]	Round	Δt[m] tot	Δt[min] LD	Δspace [km]
13	42.7	48.8	26.0	21	2.8	4.4	-6.1

Table 33: difference of Agenzie Riunite's magnitude

The quantities are the same as those presented for ADP, so as before when a value is highlighted in green, it indicates a decrease in time or km required to complete the Tour.

- ‘Δt[m] tot’ Of the 13 remaining Rounds, eight saw a reduction in kilometers travelled. The reduction is not as considerable as in the case of ADP, the main reasons being two:
    1) Removing only one round leads to the redistribution of a low number of newsstands.
    2) As shown above, many Rounds are now intertwined by them but are not very spatially dispersed. Therefore, it is possible to organize the Rounds better in order to still achieve an improvement, but the improvement is less evident than in the case of ADP.

  On the other hand, there are 2 Rounds that have a considerable increase in time. The reason is that originally Rounds 13 and 20 supplied very few newsagents. Therefore, tending to equalize the number of kiosks for all the Tours, these two are the ones that have experienced the greatest increase in stops and therefore time spent.

- ‘Δt[min] LD’ same reasoning of Δt[m] tot
- ‘Δspace [km] The trend shown in the first two indicators is even more pronounced in the study of kilometers travelled. The results show the goodness of the optimization, where 9 of the remaining 13 Rounds show a reduction in the distance travelled. Again, however, except for R3, which was removed, the reduction in most cases is only a few kilometers.

Finally, a summary table with the same values just shown Round by Round is reported here, highlighting the overall scenario of the optimized case.

TODAY				
			Tot time	Delivery Time
Tot Space[km]		min	1734.40	1401.74
1221.3		h	28.91	23.36

OPTIMIZED				
			Tot time	Delivery Time
Tot Space[km]		min	1572.95	1294.70
1063.2		h	26.22	21.58

Comparison	
% space	13%
% tot time	9%
% Delivery time	8%

Table 34: general results Agenzie Riunite

Just a few comments on the percentages and values obtained:

- As might be expected, the magnitude that is decreased the most, as was even more evident for ADP, is the space intended as kilometers travelled. Once again, the reason lies in the fact that a Round has been removed, so the distance needed to reach the area that was originally supplied by Round 3 and back is removed.
- Furthermore, it is interesting to note that under the optimized scenario, both companies end up having to drive their vehicles approximately the same distance, even though ADP started from a much more expensive situation in terms of kilometers travelled. As pointed out in the first chapter of the introduction, in fact, the two companies agreed to supply approximately the same number of newsstands in a similar geographical area and making the vehicle trips more efficient shows this even more.

Cost – Agenzie Riunite

For the calculation of the costs, the assumptions shown above are used. Below are the steps for calculating costs in the optimized case:

- Following the model of the ADP case, the theoretical cost of the Tour is first calculated, consisting of a fixed component (the same for all Tours) to which is added a cost proportional to the number of km travelled. Here follows an example of it using Round 1:

km R1
83.9

$$Cost_{R1} = [(km_{R1} * a) + CF]$$

The 'a' coefficient is deliberately hidden for privacy purposes, as well as the Fixed Cost coefficient CF.

- Subsequently, the value obtained in the previous step is multiplied by the correction coefficient $c_{\%}$

$$RealCost_{R1} = Cost_{R1} * c_{\%}$$

$c_{\%1}$ is the coefficient that considers the additional increase or decrease in prices due to the use of different type of roads, it has been calculated for each round in the preceding paragraphs.

- The procedure is continued for all remaining delivery rounds, resulting in the following cost table.

Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
1	12.2	4%	14	10.9	8%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
2	10.1	-4%	15	10.2	3%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
3	11.6	-100%	16	10.4	-5%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
4	12.4	6%	17	10.2	0%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
5	16.3	9%	19	10.0	10%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
12	10.4	1%	20	12.4	-5%
Round	Cost[€]	Δcost	Round	Cost[€]	Δcost
13	12.1	-10%	21	12.6	3%

Table 35: cost difference Agenzie RIunite

- The table 35 shows how the trend shown by the quantity 'km travelled' is followed.
- As before Δcost represents the ratio of the cost of the original case subtracted from the optimized case to the original case.

Finally, the total cost of the two scenarios is shown:

	Original Scenario	Optimized Scenario	Savings
Cost[€]	161.7	148.0	8%

Table 36: daily cost Agenzie Riunite

The cost savings are half from the removal of Round 3 and half from the optimization of the remaining rounds.

Once again, it is emphasized that optimization brings more advantages to ADP than to Agenzie Riunite for the simple fact that the former has more room for optimization in terms of vehicle volume. However, this study was not useless for the case of Agenzie Riunite, as it is shown how good savings can be achieved just by reorganizing delivery rounds.

Also in this case, the company is moving towards having the keys to all newsstands and thus having to depend less on the delivery time requirements of the newsagents.

Then I report the annual cost related to Agenzie Riunite's Rounds, again considering a fictitious cost for privacy issues:

	Original Scenario	Optimized Scenario	Savings
Costo [€]	57412.5	52549.6	8%

Table 37: annual cost Agenzie Riunite

Those data will be useful in the last part of this project for final considerations.

Optimization ADP + Agenzie Riunite

The last section on optimizing the distribution of newspapers concerns a spatial problem: at present, companies operate in overlapping geographical areas. What would happen if the geographic areas supplied were divided in such a way as to avoid overlapping?

Note: For the calculations in this chapter, I will use the RPMs of the optimized case.

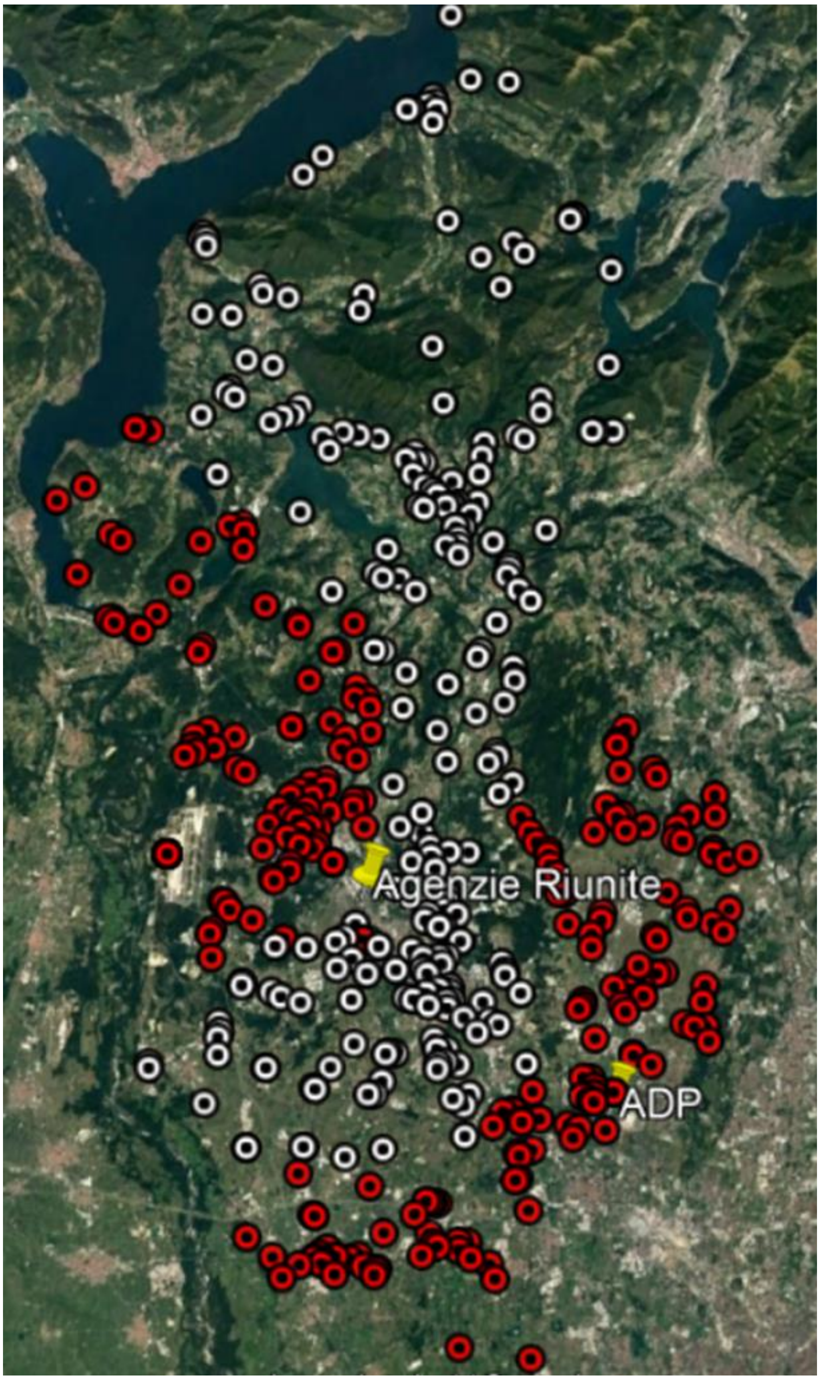


Table 38: distribution of kiosks

Below I show the steps I followed to find a solution:

1) I generated a database in which I entered all the newsstands, the database contains all the information presented in the previous chapters
2) In order to obtain a result congruent with the current situation, I calculated the total number of baskets distributed by each company (under the same assumptions as in the previous chapters).
3) As can be seen in the Table 38, Agenzie Riunite is located in the North-West of ADP and provides a very large area from North to South. At the same time, Agenzie Riunite is very close to the area of ADP defined as the 'North-West Zone' in the previous chapters.
   ADP, on the other hand, is geographically close to all those newsstands served by Agenzie Riunite that extend into what has been defined as the 'South Zone'.
4) On the other hand, there are numerous newsstands (and roundabouts) that it does not make sense to entrust to the other company: an example are the newsstands served by Agenzie Riunite in its 'North Zone' or the newsstands served by ADP in its 'South Zone'.
5) These points mean that some Rounds are not moved, while others are assigned to the other company; in the following tables, the Rounds that previously belonged to the other company are highlighted in the second column.

ADP	
1	12
2	14
3	15
4	16
5	17
11	
13	
14	
15	

AR	
1	22
5	23
2	24
4	25
13	26
19	27
20	
21	

6) Switches that remained assigned to the same company as in the original case obviously undergo no change in logistics
7) The Rounds assigned to Agenzie Riunite that were previously supplied by ADP also remain unchanged: the starting and finishing point has obviously changed, however Agenzie Riunite is still located south of Tours 22 to 27. The only factor that is changed is the distance between the starting point and the first newsstand supplied and the distance between the last newsstand and the finishing point.
   The only exception for Agenzie Riunite concerns three newsstands, closely linked to ADP, which are subtracted from Rounds 23 and 24 (in this scenario assigned to Agenzie Riunite) and left to ADP.

8) The case of ADP, on the other hand, is slightly more complicated: the new rounds allocated to ADP must be reorganized

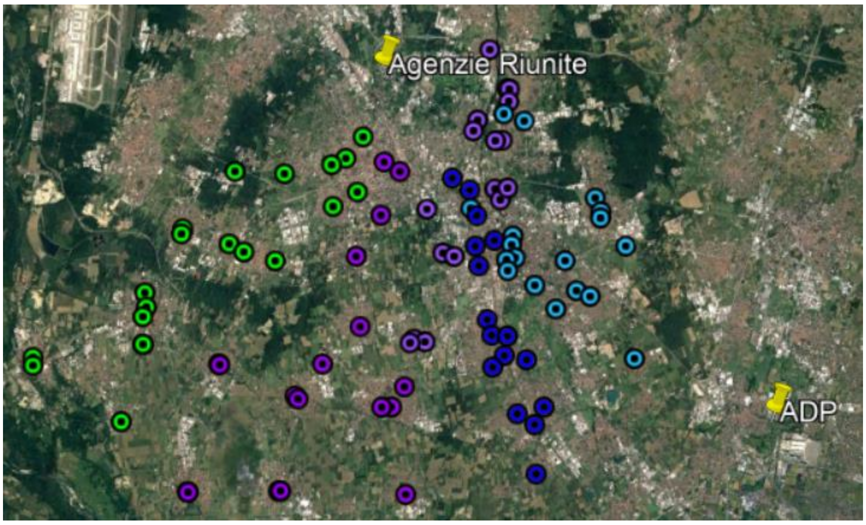


Figure 26: Rounds of Agenzie Riunite assigned to to ADP

As can be seen from the Figure 26, the Revolutions that were previously developed in the direction of Agenzie Riunite must be redesigned in the direction of ADP.

9) The process of reassigning the Turns is the same as in the previous chapters:
   - a table is created which contains the relative distances of all the aediculas of the Turns under consideration;
   - I define the Centroids for each Round;
   - I reorganize the Turns according to their distance from the kiosks and according to the direction to reach the Centroids from ADP.

10) The step immediately following the reorganization of the Turns is the calculation of the kilometers travelled in the Turns. However, I would like to emphasize that it is not possible to compare the Rounds one by one with their original counterpart; this is due to the fact that many Rounds have been assigned to the other company.

    It does, however, make sense to carry out an analysis of the total number of kilometers that the vans cover in this scenario and to compare this number with the counterpart of the starting scenario.

	km	Chests
ADP Optimized	1077.1	686.9
ADP New	903.3	683.3
Difference %	-16.1%	-0.5%

	km	Chests
AR Optimized	1063.2	750.9
AR New	1023.5	754.5
Difference %	-3.7%	0.5%

Table 39: general comparison

11) Results:
   - Keeping in mind that the Agenzie Riunite ' Rounds even in the optimized case tend to be more loaded than ADP's Rounds, this new scenario leads ADP to have one more Round than the initial situation (and therefore Agenzie Riunite to have one less).
   - The advantage in terms of distance travelled is very pronounced: with this solution, the distances between the newsagents and the starting company are greatly reduced. This is much more noticeable for ADP because in addition, one round is eliminated and entrusted to Agenzie Riunite.
   - This solution therefore has advantages and disadvantages for both companies while keeping the most significant figure as unchanged as possible: the number of chests delivered. This value is in fact indicative of the number of goods distributed and is therefore an estimate of the possible turnover.
   - The result is as follows:

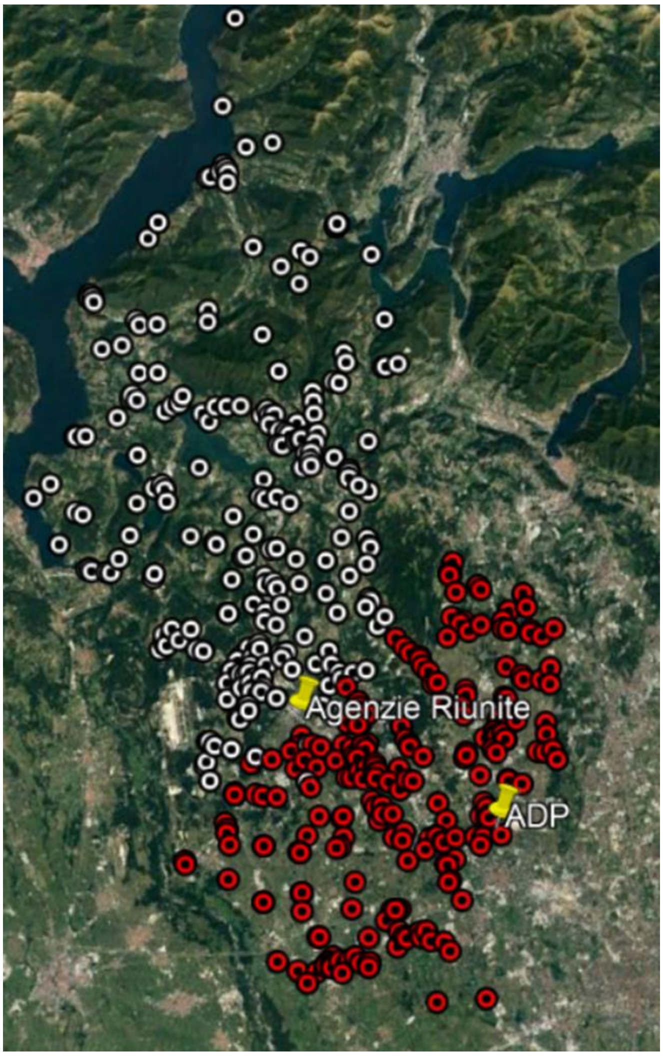


Figure 27: possible reorganization od kiosks

12) This scenario would therefore be a very attractive solution, both from an economic point of view and for the consumption/emission factor.

Delivery Vehicles

Last mile delivery of newspapers and magazines is made worldwide by vans. In Europe and In Italy in particular, road freight transport is by far the most popular solution. The reasons are certainly

- the morphology of the territory
- the capillary distribution of roads
- the low compatibility of the railways of the various European states.

The unit of measurement used by Eurostat for the analysis of goods moved by land is the tonne-kilometer[tkm]: is a unit of measure of freight transport which represents the transport of one tonne of goods (including packaging and tare weights of intermodal transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one kilometer. Only the distance on the national territory of the reporting country is taken into account for national, international and transit transport. Using this size, four classes of trips are created for the delivery of goods as follows:

- less than 150 km
- less than 300 km
- less than 999 km
- more than 1000 km

As reported by Eurostat [14], for each class the amount of [tkm] is calculated and then this amount is compared between states. In the following table is shown that all classes had an increase between 2020 and 2021 in the majority of EU states (including Italy).

Road freight transport by distance class, 2021

	Less than 150 km		From 150 to 299 km		From 300 to 999 km		1 000 km or more	
	2021	Growth rate 2020/2021	2021	Growth rate 2020/2021	2021	Growth rate 2020/2021	2021	Growth rate 2020/2021
	million tkm	%	million tkm	%	million tkm	%	million tkm	%
EU	406 321	5.5	363 644	6.5	781 454	7	364 176	7.1
Belgium	9 747	-1.1	12 513	7.0	19 388	4.0	1 489	20.6
Bulgaria	3 861	23.6	4 067	17.0	11 009	8.1	16 240	2.8
Czechia	15 277	4.3	11 176	3.9	22 169	14.0	15 269	33.9
Denmark	4 593	-1.1	4 410	-0.1	5 153	10.4	1 187	23.1
Germany	96 060	0.2	78 370	2.3	114 330	0.2	7 326	5.3
Estonia	980	32.4	923	42.7	1 492	6.1	1 817	24.4
Ireland	5 426	13.0	4 256	12.0	2 086	3.9	659	-12.9
Greece	6 161	13.0	3 706	14.6	7 512	28.6	3 683	-65.4
Spain	44 350	8.8	35 188	14.0	122 316	11.4	68 319	12.2
France	46 377	9.5	40 988	-0.9	84 165	1.7	3 329	7.1
Croatia	2 306	5.9	2 255	19.8	5 826	2.5	3 245	29.0
Italy	33 247	5.8	41 700	12.8	60 123	8.3	9 913	6.5
Cyprus	680	3.7	24	41.2	3	200.0	23	-32.4
Latvia	2 890	8.0	1 989	14.5	4 105	15.0	5 989	6.9
Lithuania	2 033	1.3	3 462	4.9	22 932	15.9	29 302	-2.9
Luxembourg	1 353	10.5	1 676	4.2	3 500	14.0	374	36.5
Hungary	7 655	13.8	7 484	14.3	15 495	12.8	6 242	24.7
Malta (¹)	:	-	:	-	:	-	:	-
Netherlands	28 372	4.8	20 285	3.7	17 226	1.3	4 748	11.2
Austria	10 697	10.7	6 035	6.9	7 775	4.7	1 789	10.0
Poland	44 205	8.6	49 595	9.2	167 450	7.1	118 587	5.4
Portugal	4 427	2.1	3 604	8.9	8 391	29.3	15 628	54.8
Romania	7 430	15.7	5 955	10.9	24 005	14.2	24 455	10.1
Slovenia	2 236	3.6	2 254	11.5	11 769	9.1	8 654	12.9
Slovakia	4 087	-2.7	3 531	1.3	11 013	-7.8	11 498	-3.8
Finland	8 451	14.9	6 301	-2.2	13 575	-7.3	1 062	-14.2
Sweden	13 419	-4.2	11 898	5.5	18 645	23.7	2 958	32.6
Norway	7 413	6.4	4 492	12.1	8 222	-3.0	1 506	-2.8
Switzerland	8 352	-1.1	2 723	8.0	1 344	14.0	:	-
Montenegro	33	0.0	24	-17.2	39	85.7	9	12.5

(:) Not available

(-) Not applicable

(¹) Data not available (see chapter 'data sources')

Source: Eurostat (online data code: road_go_ta_dc)

Figure 28: eurostat data

Italy has a very high value of è [tkm] compared to the total in the class below 150 and 300 km, having a value of 8% and 11% of the total respectively. The % value decreases considerably in the case of the third and especially the fourth class where it reaches 2% of the total. The reason for this is Italy's small surface area compared to other, larger European nations. This value is also reflected in the cases of ADP and Agenzie Riunite companies, where the vehicles have to cope with daily journeys in the order of a hundred kilometers.

As mentioned in the previous chapters, the two companies seen in this project use diesel vans to make their deliveries, a very common methodology in the industry, but this is not always the case. In the study [5] in fact they are only used to transport copies from the publisher to the distribution centers. The next stage of newspaper delivery is carried out using motorbikes and, in some cases, small vans. The logistics of the Sao Paulo area, an area of interest analyzed in [5], makes it necessary to use more agile and less expensive vehicles.

The aim of the paper is to optimize the delivery of newspapers in the Brazilian metropolis by considering the morphology of the territory, taking into consideration the production rate of the printing facilities, the location of the distribution centers, the transfer schedule, and the optimal types of vehicles to be used.

Contrarily to intuition and common sense, their results showed that key reductions in terms of required fleet and Vehicle Miles Travelled can be achieved if central and denser areas have their deliveries routes starting earlier, thus allowing the utilization of larger vehicles; more distant areas in the outskirts of a large city may not have density of deliveries to allow the use of large vehicles, even in case such routes start early, given that distances between consecutive deliveries are usually longer.

The objectives of this Thesis are the same as those pursued in [5], with the difference that only diesel vans with a load capacity of around 10 m^3 are used here.

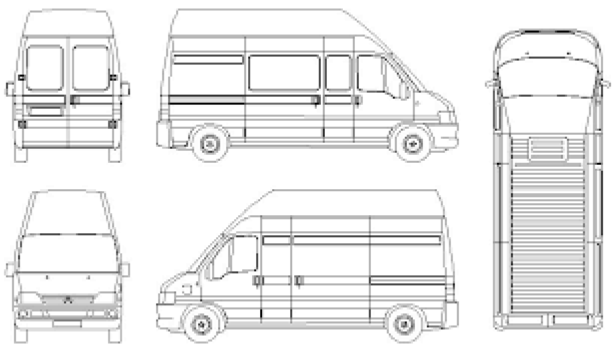


Figure 29: scheme of a van

The vans used are not owned by the company, but both ADP and Agenzie Riunite use external companies to rent the vehicles: the two companies pay a fee for each Delivery Round to be made. As has already been described in the previous chapters, the cost of the Rounds varies, it is not always the same, but the cost does not depend on the model of the vehicle used.

Hypothesis:

- Only one vehicle and therefore only one driver is assigned to each Tour.
- There are vehicles which are dedicated to escorting, if any driver assigned to the Tours does not show up the escort driver replaces the driver of the missing Tour and is paid according to the Round assigned to him.

Agenzie Riunite provided me with the list of vehicles, the next step was to search the web for all the technical data useful for the analysis:

- load capacity
- fuel consumption
- emissions.

Finding data for all vehicles used by companies was not easy for one simple reason: as the vehicles are not company-owned, a lot of data is not available, so I had to rely solely on the model of the vehicles and search for technical data individually.

The reasoning and steps I followed to find the data are listed here:

1) The lack of more specific data concerning the vehicles forced me to take a closer look at the roads travelled by the vehicles to reach the newsstands.
2) I therefore looked for data on the estimated consumption of vehicles based on European standards and thus on the WLTP cycle. This step is obviously crucial in order to have a consistent yardstick for comparing different vans from different car manufacturers.
3) From here, the next step was to find fuel consumption data in three cases:
   - The vans mainly drive on urban roads, which are often narrow and full of intersections. In addition, the Rounds have an average of about 15 to 18 newsstands, each newsstand obviously being a stop. These constant stops and speed changes increase the consumption of a diesel vehicle and are represented by what is called the 'Urban Context', the scenario with the highest consumption.
   - The second scenario is termed 'Extra Urban', the speed in this case undergoes much smaller changes, but reaches higher peaks. consumption in this case is lower. The Extra-Urban scenario is typical of some connections between two newsstands that are perhaps in different cities.
   - Finally, Mixed Consumption is defined as somewhere between the other two cases, the value is also intermediate.

   The division into these three macro categories serves to be able to estimate vehicle consumption fairly accurately without making the model too complicated.
4) Finally, I found the estimated CO_2 emission values for each vehicle, this value is unique and will be crucial in the following chapters to make the final comparison between the traditional solution and the scenario with electric vehicles.

Below are the main technical data of each vehicle belonging to Agenzie Riunite, with a list of the sources from which I took each piece of data.

Round	Vehicle	Urban [l/100km]	ExtraU[l/100km]	Mix [l/100km]	CO2[g/km]
1	Medium wheelbase van citroen jumper	6.7	5.9	6.2	163
2	Single box van Opel	10.0	8.5	9.1	239
3	Long wheelbase van iveco daily	9.3	7.8	8.3	225
4	Van iveco daily	8.7	7.8	8.2	215
5	Van iveco daily	8.7	7.8	8.2	215
12	Single box van Opel	10.0	8.5	9.1	239
13	Platform truck renault master	8.6	6.2	7.1	187
14	Platform truck mercedes sprinter	9.7	7.6	8.4	235
15	Long wheelbase van iveco daily	9.3	7.8	8.3	225
16	Van volkswagen crafter	10.3	9.0	9.5	248
17	Platform truck ford transit	8.6	6.2	7.1	186
19	Platform truck renault master	8.6	6.2	7.1	187
20	Platform truck fiat ducato	8.3	6.5	7.1	190
21	Platform truck with tarpaulin iveco daily	9.3	7.8	8.3	225

Table 40: data about vehicles

In the table 40, fuel consumption values are expressed in liters consumed per hundred kilometers, I chose this unit of measurement because one of the quantities calculated for each Round is the distance travelled expressed in kilometers; using another unit of measurement to express fuel consumption would have been unnecessarily complex

In most cases I was able to find all the data, but there were a few exceptions highlighted in red in the table 40. These values I was unable to find, sometimes there is no fuel consumption value in the Mixed context, sometimes I found only the Mixed Context value without the values for the Urban and Extra-Urban case. In these cases, the solution I have arrived at is to calculate the ratios of the three values for the vehicles for which I have all the data, i.e., the vehicles assigned to Rounds 1,3,4,5,14,15,17,20 and 21:

- the ratio of the Urban and Extra-Urban context values
- the ratio of Urban and Mixed context values
- the ratio of Extra-Urban and Mixed context values.

I then calculated, for each ratio, the average of the values obtained. This step allowed me to obtain a fairly reliable relationship between the consumption values allowing me to trace back an estimate of the missing values. For example, I was able to calculate for the vehicle assigned to Round 2 starting from the consumption in the mixed case the consumption in the Urban and Extra Urban case.

The following is a list of the sources from which I obtained the data shown in the table 40.

- Medium wheelbase van Citroen jumper [32]
- Single box van Opel [33]
- Long wheelbase van iveco daily [34]
- Van iveco daily
- Platform truck renault master [35] [36]
- Platform truck mercedes sprinter [37] [38]
- Van volkswagen crafter [39]
- Platform truck ford transit [40][41]
- Platform truck fiat ducato [43]
- Platform truck with tarpaulin Iveco daily[42]

I emphasize that the values of Agenzie Riunite and not ADP have been detailed because the latter uses the same van models, to avoid unnecessary repetition they have not been mentioned. I find it more interesting to focus later in the paper on comparisons in terms of both fuel consumption and CO2 emissions between the original scenario and the optimized scenario.

Calculation of the consumptions

This chapter shows the procedure I followed to apply the consumption and emission values to the case histories of both the original case and the optimized case.

Hypothesis

The three consumption classes described in the previous chapter are here associated with as many categories this time based on distance traveled. Specifically, I refer to the distance between two successive stops:

1) If the relative distance between two stops is less than two kilometers, the corresponding value of Urban Consumption is considered
2) If the relative distance between two stops is between two and five kilometers, the corresponding value of Mixed Consumption is considered
3) On the other hand, if the distance is greater than five kilometers, the corresponding value of Extra-urban Consumption is considered.

The reason I decided on this division follows the logic of the division between Urban, Extra-Urban and Mixed contexts. Especially for short distances it is more likely to accelerate and decelerate with greater frequency: two stops very close to each other are most likely within the same village. This leads the driver to face numerous intersections and increase the vehicle's fuel consumption. Given the lay of the land, the areas that the model goes to define as Urban are typically in the central part where cities are more geographically extensive.

Extra-urban consumption, on the other hand, is typical of the routes between the company and the first stop and between the last stop and the company. I developed this hypothesis is based on firsthand experience making deliveries. Drivers typically travel on freeways or main roads, only in some exceptions do they travel short stretches of highway, avoiding the intersection and driving at constant speeds that rarely exceed high peaks due to the weight carried in the cargo compartment.

Then I assigned the Mixed consumption type to those routes connect two newsstands that are not in the same city and at the same time are not excessively far away such that the driver has to take a freeway.

This is thus the case in small towns far from the main cities, where there is typically only one newsstand.

From this division, I was then able to calculate for each Delivery Round the fuel consumption and subsequently the CO2 emissions.

The easiest way to be able to do the calculation is to retrieve the tables described in the previous chapters and add two lines of calculation, one for fuel consumption and one for CO2 emissions.

Below I give the example of Round 1 of Agenzie Riunite in the original situation.

Stop	1	2	3	4	5	6
Rag. Soc	ZUCCOLI N	CACCIN ROM	BAR.DAKLANI	TIGROS SPA -	CAFFE'DELLA	3GI DI LUZI G
Relat Dist		4.6	6.1	1.3	1.4	0.5
Min from start	18.1	25.6	35.0	38.5	42.1	45.2
Arriving h	04:48:06	04:55:37	05:04:58	05:08:29	05:12:07	05:15:11
Optimal H						05:25:00
Chests	2.5	2.5	1.2	2.5	2.5	2.5
Consumption[l]		2.85E-01	3.62E-01	8.41E-02	9.18E-02	3.56E-02
CO2[g]		748.5	998.9	204.5	223.3	86.6

Table 41: Round 1 Agenzie Riunite

To the tables described in the previous chapters I have added two rows:

- The first represents the consumption in liters of fuel to travel the corresponding route. Using an 'IF' function, I calculated the consumption in liters as the distance traveled times the correct value of [l/100km].

$$Cons_{[l]} = Dist_{Rel}[km] * \left(\frac{1\ [l]}{100[km]}\right)_i$$

  The 'IF' function draws the fuel consumption value per kilometre from the three possible scenarios analysed above, depending on whether the distance between two stops is less than two kilometres, less than five kilometres or greater than five kilometres.

- Instead, this second row is a simple multiplication between the relative distance between two stops and the weight, expressed in grams [g], of CO2 per kilometer of the corresponding vehicle.

$$CO2\,[g] = Dist_{Rel}[km] * CO2\ [\frac{g}{km}]$$

Then I calculated these values for each delivery round in both the original and the optimized case.

The next step is to add up all the values to get the total fuel consumed and CO2 emissions for each Round. Below is the example of ADP's Optimized Round 1.

Tot [l]	TOT CO2 [kg]
3.98	10.46

The total amount of CO2 was simply calculated as the total kilometers travelled multiplied by the emission rate per kilometer of the vehicle assigned to the Tour.

$$TOT_{CO2}[kg] = TOT_{km} * CO2 \left[\frac{kg}{km}\right]$$

The fuel consumption needed to complete the Round consists of three components:

1) The sum of the consumption to travel from the first to the last delivery
2) The fuel consumption to reach the first newsstand, typically in an Extra-Urban context
3) The fuel consumption to make the journey from the last newsstand to the company.

These quantities were straightforward to calculate in the Original Case.

It was less intuitive from a code point of view to calculate them in the Optimized Case. As in the previous chapters, the main problem is that the order of the kiosks is not decided a priori but was in fact decided by me and the model.

The most critical points to calculate were 1) and 2). The problem was to index the first and last newsagents correctly in order to determine their distance from the source company.

Having solved this problem, I calculated the consumption and emissions for each Round for both ADP and Agenzie Riunite.

ADP – Consumption of Fuel

	Original	**Optimized**	
Round	TOT [l]	TOT [l]	ΔConsumption
1	3.40	3.98	17%
Round	TOT [l]	TOT [l]	ΔConsumption
2	2.56	2.04	-20%
Round	TOT [l]	TOT [l]	ΔConsumption
3	4.03	3.53	-12%
Round	TOT [l]	TOT [l]	ΔConsumption
4	3.69	3.65	-1%
Round	TOT [l]	TOT [l]	ΔConsumption
5	5.26	4.62	-12%
Round	TOT [l]	TOT [l]	ΔConsumption
11	2.96	4.26	44%
Round	TOT [l]		ΔConsumption
12	3.16		-100%
Round	TOT [l]	TOT [l]	ΔConsumption
13	6.40	4.93	-23%
Round	TOT [l]	TOT [l]	ΔConsumption
14	4.90	5.64	15%

	Original	**Optimized**	
Round	TOT [l]	TOT [l]	ΔConsumption
15	5.34	4.52	-15%
Round	TOT [l]	TOT [l]	ΔConsumption
22	6.35	5.89	-7%
Round	TOT [l]	TOT [l]	ΔConsumption
23	6.51	7.33	13%
Round	TOT [l]	TOT [l]	ΔConsumption
24	17.01	5.79	-66%
Round	TOT [l]	TOT [l]	ΔConsumption
25	7.33	5.88	-20%
Round	TOT [l]	TOT [l]	ΔConsumption
26	7.97	6.85	-14%
Round	TOT [l]	TOT [l]	ΔConsumption
27	10.97	9.49	-14%
Round	TOT [l]		ΔConsumption
28	11.36		-100%
Round	TOT [l]		ΔConsumption
29	16.82		-100%

Table 42: ADP consumption of fuel

Agenzie Riunite – Consumption of Fuel

	Original	Optimized			Original	Optimized	
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
1	5.5	5.0	-9%	14	4.7	3.7	-21%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
2	4.8	5.3	12%	15	4.1	3.8	-6%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
3	9.5		-100%	16	4.2	5.3	26%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
4	7.6	6.9	-9%	17	4.1	4.8	16%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
5	14.6	15.1	3%	19	5.9	4.7	-20%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
12	5.9	6.4	7%	20	7.7	9.6	25%
Round	Fuel[l]	Fuel[l]	ΔConsumption	Round	Fuel[l]	Fuel[l]	ΔConsumption
13	6.8	9.2	35%	21	6.5	6.3	-4%

Table 43: Agenzie Riunite's consumption of fuel

ADP – Emissions

	Original	Optimized			Original	Optimized	
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
1	8.68	10.46	20%	15	13.80	12.18	-12%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
2	6.94	5.66	-19%	22	16.42	16.53	1%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
3	10.70	9.76	-9%	23	16.64	20.74	25%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
4	9.01	10.04	11%	24	46.07	15.62	-66%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
5	13.87	12.93	-7%	25	19.31	16.56	-14%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
11	8.13	12.70	56%	26	20.86	18.56	-11%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
12	8.48		-100%	27	29.02	26.98	-7%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
13	18.10	14.37	-21%	28	32.93		-100%
Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2	Round	TOT CO2 [kg]	TOT CO2 [km]	ΔCO2
14	12.56	15.98	27%	29	45.49		-100%

Table 44: ADP's vehicle emissions

Agenzie Riunite – Emissions

	Original	Optimized			Original	Optimized	
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
1	15.0	13.7	-9%	14	13.4	10.3	-23%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
2	10.0	14.2	42%	15	11.0	10.0	-9%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
3	27.0		-100%	16	10.9	13.0	19%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
4	20.6	18.0	-12%	17	11.3	11.2	-1%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
5	40.1	34.7	-13%	19	17.1	8.6	-50%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
12	15.9	15.3	-3%	20	22.1	24.5	11%
Round	CO2 [kg]	CO2 [kg]	ΔConsumption	Round	CO2 [kg]	CO2 [kg]	ΔConsumption
13	20.0	24.9	24%	21	18.4	17.1	-7%

Table 45: Agenzie Riunites's vehcile emissions

The percentage is calculated as the ratio of the difference of emissions in the optimized case and the original case over the value of emissions in the original case. A negative value thus indicates a reduction in emissions; while a positive value indicates an increase in emissions.

Indicatively, the trends in the reduction or increase of fuel consumption (and especially CO2 emissions) follow what has been seen with the quantities described in the previous chapters, so the same considerations apply as above.

The values for emissions and consumption are not an end in themselves. They will be used to compare today's solution powered by internal combustion engines with the non-local emissions associated with producing the electricity to power the electric vans in the theoretical scenario.

The final aim of this part of the paper is to evaluate the electric scenario, showing how many advantages it could bring in both ecological and economic terms. However, the transition to electric vehicles would represent a radical change for companies and especially for workers. Therefore, I find the simple reorganization of revolutions, which also shows clear improvements in terms of emissions and consumption, very significant.

State of the Art - Electrification

The issue of decarbonization is a characteristic of hundreds of sectors from industry to mobility, and has consequently been presented and addressed in countless articles. The purpose of this project is not to present the current situation or to tell what decarbonization is, however, reference will be made to some of the publications and articles that are related to the situation of ADP and the Agenzie Riunite.

Worldwide, one of the most popular solutions is the transition from internal combustion engine vehicles to solutions that reduce local NOx and carbon dioxide emissions. In particular, despite the costs and potential problems it could bring, the most sought after and pursued solution is the electrification of vehicles. This trend is noticeable for both private individuals' cars and companies' vehicle fleets.

[14] is a study analyzing the feasibility of the electricity transition considering market trends in recent years.

This study uses two approaches in studying the market feasibility of the electric trucks conversion business.

1) The first approach is to analyze potential customers of electrical trucks.
2) The second is a competitor analysis which is conducted by gathering data of electric truck global companies.

Analysis of potential customers of electric trucks is used to get an overview of how the current trend of electric trucks in the market is, both locally and globally. The data used are in the form of electrical vehicle and electrical truck usage data, electrical truck registration data, and truck sales data. The data are obtained from various statistical center web portals, associations, official reports from companies, as well as other credible sources.

Competitor analysis is done to get an overview of the position of the electric truck conversion business, and to answer questions whether there are competitors who are already in the same area, are there still opportunities to enter/penetrate the market, and what are the possible prospects in the future. The data is obtained from the competitor's official website portal. The data collected includes product knowledge produced by competitors along with price and specifications.

Based on data compiled by the International Energy Agency (IEA), throughout 2020, more than 10 million electric vehicles were on the road, an increase of 43% over the previous year (Table 46). It is in line with consumer and government consumption data on electric vehicles. In 2020, consumer consumption of electric vehicles increased by 50% from the previous year to USD 120 Billion. Government consumption used for incentives and tax reductions for electric vehicles also increased by 25% from the previous year to USD 14 Billion.

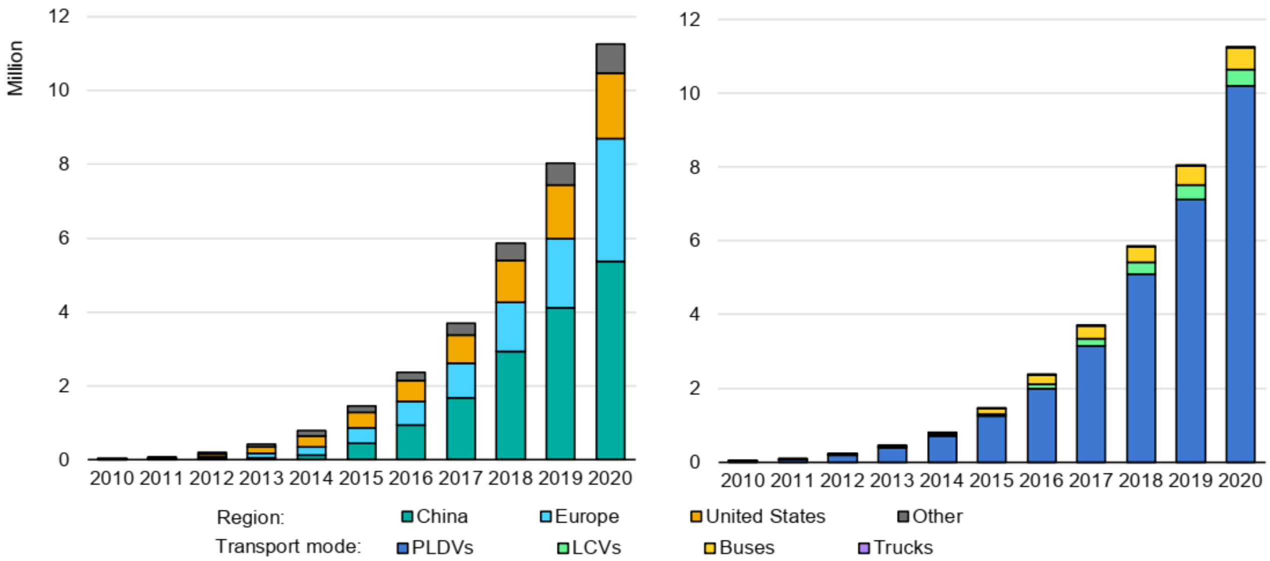


Table 46: electric vans sold through years

Figure 1. Global electric vehicle stock by region and transport mode (2010 to 2020) (Agency, 2021)

Based on the type of electric vehicle used, passenger light-duty vehicles (PLDVs) still dominate with a market share of nearly 50% of total global sales, followed by light commercial vehicles (LCVs), buses, and trucks. The market share for truck-type vehicles is still very low, which is below 1% of the total electric vehicles in circulation.

However, the growth of the world's use of electric trucks is increasing every year. In 2020, the number of registered heavy-duty electric trucks reached 7,400 units, an increase of 10% compared to the previous year. The largest contributor to the number of registrations of heavy-duty electric trucks is China, followed by Europe, and the United States, as shown in Figure 30 (Agency, 2021).

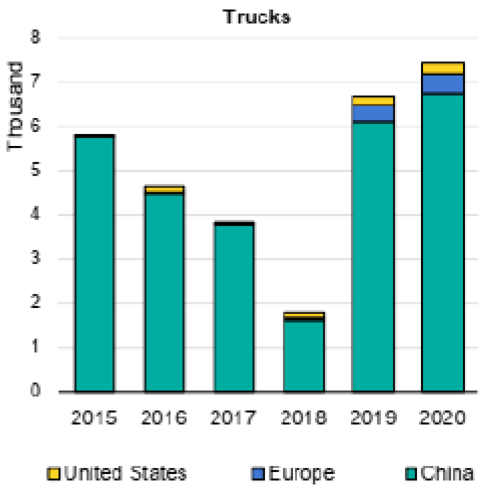


Figure 30: number of trucks sold per year

The phenomenon also includes the goods delivery sector. On the Internet, there are plenty of studies and case studies of companies that have switched from diesel to electric vehicles: from e-commerce to newspaper delivery.

The case of goods delivery is particularly interesting for electric vehicles, as reported in numerous studies including [6]. The authors report how on average delivery vehicles are divided according to their mission, specifically there are several classes into which vehicles are divided.

Class	Purpose	Cargo (kg)	0–30 mph (s)	0–60 mph (s)	Grade Speed 6% (mph)	Cruise Speed (mph)	Range (Miles)
4	Delivery	2755	9	30	50	70	150
6	Delivery	5146	14	50	37	70	150
8	Sleeper	17,329	18	60	32	65	500
8	DayCab	17,324	18	66	31	65	250
8	Vocational	6874	18	76	30	60	200

Goods delivery vehicles are therefore designed to have a shorter range than other types of vans or trucks, which is also confirmed by the average number of kilometers that a goods delivery vehicle has to cover on a daily basis. In this regard [6] gives an example from FleetDNA (database concerning commercial vehicles for modelling and research) in the United States.

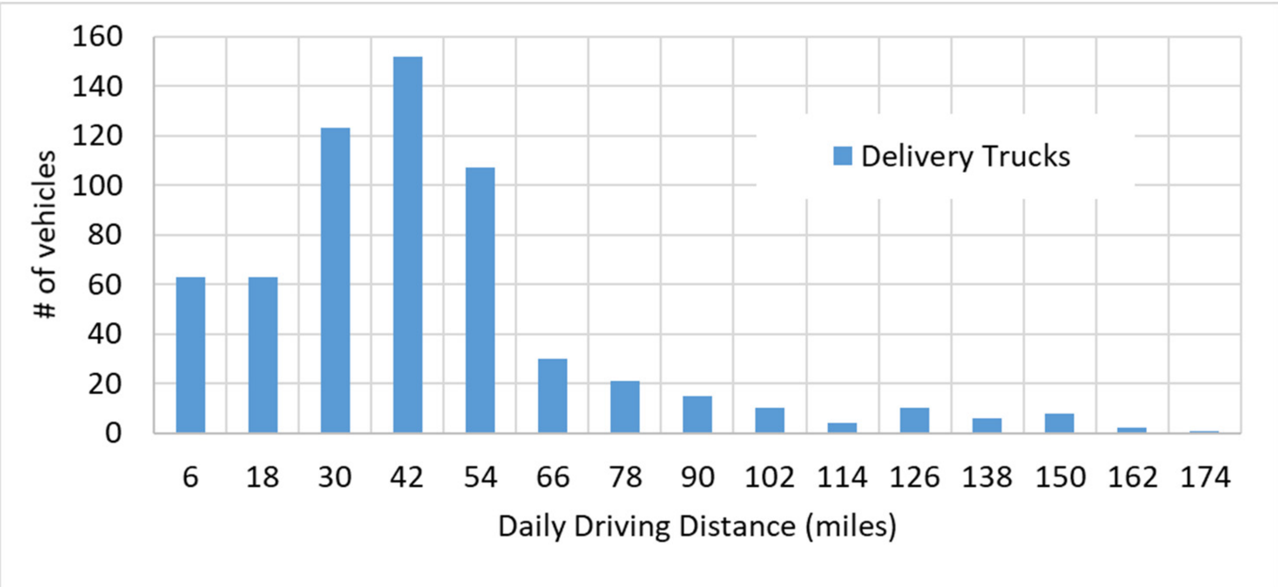


Figure 31: number of vehicles per distance travelled

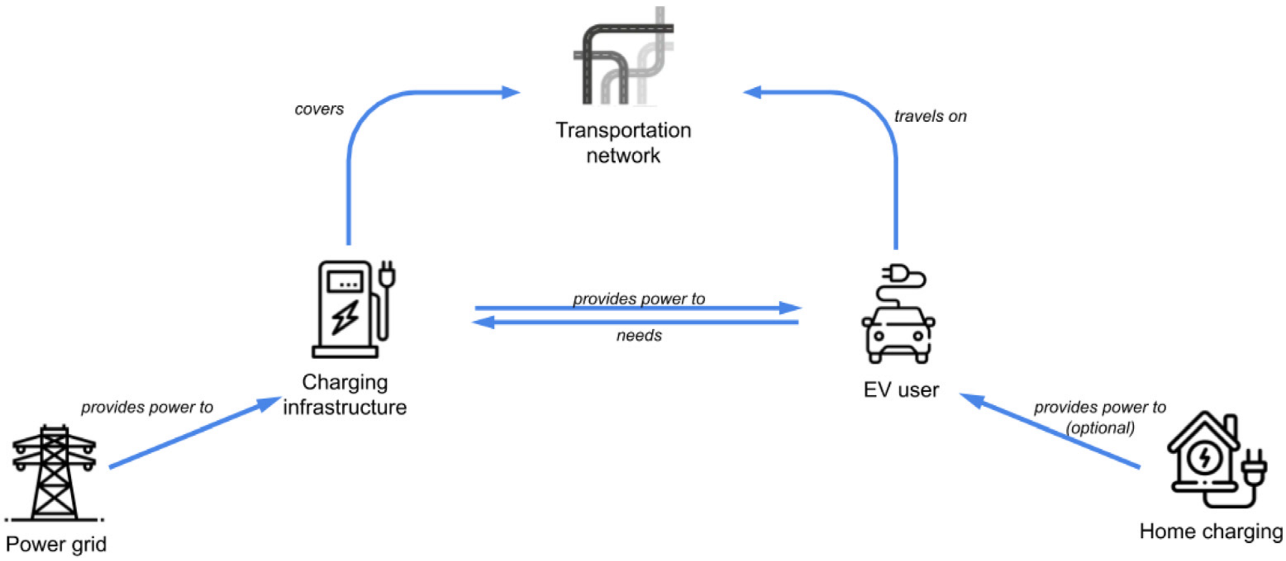
The graph shows, as reported in the study, that an average of 150 miles (around 240 km) encompasses the vast majority of daily use of delivery vehicles.

This factor is crucial, as one of the main problems with electric vehicles to date is range: vehicles with internal combustion engines generally have a much longer range. However, the advantage of the goods delivery sector, especially in Europe and Italy where distances to be travelled are shorter, makes a solution involving electric vehicles very attractive: being able to leave the company, make deliveries and then return to the company to recharge the vehicles during the rest of the day avoids the problem of limited autonomy.

ADP and Agenzie Riunite supply newsstands that fall within an area adjacent to them, which makes delivery rounds short in terms of kilometers travelled. Furthermore, the roads travelled by the vehicles are mainly urban and suburban roads, where the speed is moderate, a factor not to be underestimated as high speeds would be detrimental to the performance and efficiency of the electric motor.

Given that the autonomy problem can be solved, the issue of recharging must also be addressed. Unlike diesel vehicles, which fill their tanks in a few minutes, AC battery charging systems require several hours. As shown in study [7] commercial vehicles can take up to 20 hours to charge when connected to slow charging facilities. However, there are numerous modes for charging electric vehicles, the one chosen for this project is the so-called MODE 3, This mode requires that the vehicle is charged through a power supply system permanently connected to the electrical network. This is the mode of wallboxes, commercial charging points and all automatic charging systems in Alternating Current (AC). In Italy, it is the only mode allowed to charge the car in public spaces in alternating current.

Charging stations operating in mode 3 usually allow charging up to 32 A and 250 V in singlephase while up to 32 A and 480 V in three-phase, even if the legislation does not set limits.



This system therefore involves using charging columns to power the battery when the vehicle is not in use. As seen in the previous chapters, the delivery of goods for the two companies considered takes place during the night, between 4.30 and 8 a.m. This short time slot therefore leaves ample time during the day to dedicate to charging the vehicles.

In fact, in this project the solution of installing charging columns directly on the outside of the companies will be studied. As reported in [7] in fact one of the main problems for electric vehicles are charging points, to date in Italy there are 30270 charging points, of these 10.5% are direct current (DC) electric stations from 50 kW upwards, the fastest and most efficient charging mode on extra-urban roads and motorways, while 89.5% are alternating current (AC) electric columns with power up to 22 kW [9]. Although this number is still growing, the logistics of delivery rounds and tight timeframes lead to the choice of on-site installation of dedicated charging stations as the most suitable solution.

Figure 32: example of an electric van

With the problem of location comes the problem of sizing the charging stations at the chosen locations. This is mainly a matter of answering two questions: how many charging points should be placed at a location, and which charging speed should be chosen. Locations are also dependent on station capacity, i.e. the number of vehicles that can be served within a certain period. For example, if a station with a large service capacity is installed at one location, there is limited interest in placing another station near it.

Some studies only focus on the problem of locating charging stations, sometimes considering an infinite capacity [11,12] which does not represent a real situation where charging points can only accommodate a limited number of vehicles. But once locations have been found without considering this limited capacity, charging stations can be sized according to the demand at each station.

But sizing the charging infrastructure is not just a matter of deciding the number of vehicles that can be accommodated, but also the time spent at the station. It is not always inconvenient that the charging process takes several hours, but this is not always acceptable, such as during long journeys requiring a quick charge to reach the destination. That is why it is also important to wisely choose the power level of charging stations based on the use case, and many models incorporate power sizing. This sizing can also be done with each type of station chosen according to the type of targeted route, which allows fast charging stations to be placed where a quick charge is most useful. Indeed, even if increasing the charging speed of a station also increases its capacity as it serves EVs faster, slow charging stations are a more cost-effective option to meet the needs of a delivery company.

Vehicle recharging must therefore be studied according to the periods of the day when the vehicles are in the company. The main reason is of course to reduce costs, it would be optimal to buy energy at night so as to spend less money to recharge the vehicles. [8],[10] Here are the price ranges of the protected market and the free market as of October 2022 in Italy.

In this project, two possible solutions will be analyzed in this project:

1) buying energy from the grid directly when it is needed, i.e. following the time schedules of delivery vehicles by going to buy electricity perhaps when it is no longer convenient.
2) installing an accumulator. This solution is certainly more expensive in the beginning as a very high investment is required, but at the same time there is the possibility of always buying energy when it is cheaper and then distributing it during the day to the vehicles parked in the yard.

Another question to be clarified is whether vehicles should be bought or rented. So here too there are two cases:

1) Buying electric vehicles therefore means making a large initial investment and aiming to pay back the costs in the long run.
2) Renting electric vehicles. This solution is most attractive for all small to medium-sized companies that have to support medium to high delivery volumes but have no intention or possibility of investing a large capital to support the electric transition.

The second would be the case of ADP and Agenzie Riunite: even today, they use a third-party company that provides them with delivery vans.

In addition, considering how changeable the newsstand situation is, with changes in delivery times and a reduction in the number of newsstands open in the near future, going out and investing a large amount of capital to buy electric vehicles that might then remain redundant would make no sense.

The hypothesis of being able to rent electric vans in the future rather than owning them is made following the conclusions of [13]. In this study, it is stated that when analyzing the competitors that could provide EV the result is that the market demand is worldwide very large. Supported by several data included, the increasing annual truck sales, the global trend in the annual use of electric vehicles, including types of trucks, is still increasing significantly. Although the use and number of registered brands are still less compared to other types of electric vehicles, electric trucks have consistently increased with a positive trend from year to year.

Moreover, the market for this type of vehicle is still forming and evolving, both on the demand and supply side. There is therefore a great opportunity for different manufacturers to enter the market, who can focus on different standards of quality, cost and technology.

State of the Art - Costs

Considering a different historical period than the one we are in now November 2022, in general the cost of electric vehicles is mainly the battery, while the cost of electricity should be much lower than that of fuel. As shown in many studies, including [6], the larger the battery, the more the cost of the vehicle increases. The figure shows the main costs of a diesel vehicle and an electric vehicle according to vehicle categories.

Class	Purpose	Diesel		Electric	
		Engine ($)	Gearbox ($)	Motor ($)	Battery Pack ($)
4	Delivery	13,400	4700	5300	53,200
6	Delivery	13,100	4700	6400	79,300
8	Sleeper	29,200	11,400	18,400	382,200
8	DayCab	26,400	10,700	14,300	202,700
8	Vocational	17,000	5800	8700	143,300

This table shows that the cost of delivery vehicles is much lower than for vehicles that have to travel longer distances, this data is the basis for making a cost comparison between the two technologies, as is brought out in [6].

Note: this study was carried out in the USA with American prices and sizes, but the considerations are equally valid.

This study assumes a service period of 15 years for medium-duty trucks. While it is true that many fleets own the vocational trucks for the entire lifetime of the trucks, the fleets would want to see a shorter payback time for their additional investment in electric trucks. This payback period could be as low as 3 years. Class 4 delivery truck designed and driven for a daily trip of 75 miles is used for this analysis.

Class	Purpose	VMT	Service Period (Years)	Discount Rate (%)	Battery Cost	Electricity Cost	Diesel Cost
4	Delivery	18,000	15	7	$350/kWh to $80/kWh	10 c/kWh to 30 c/kWh	$2.5/gallon to $4/gallon
6	Delivery	18,000					
8	Sleeper	120,000	5				
8	DayCab	30,000	15				
8	Vocational	24,000					

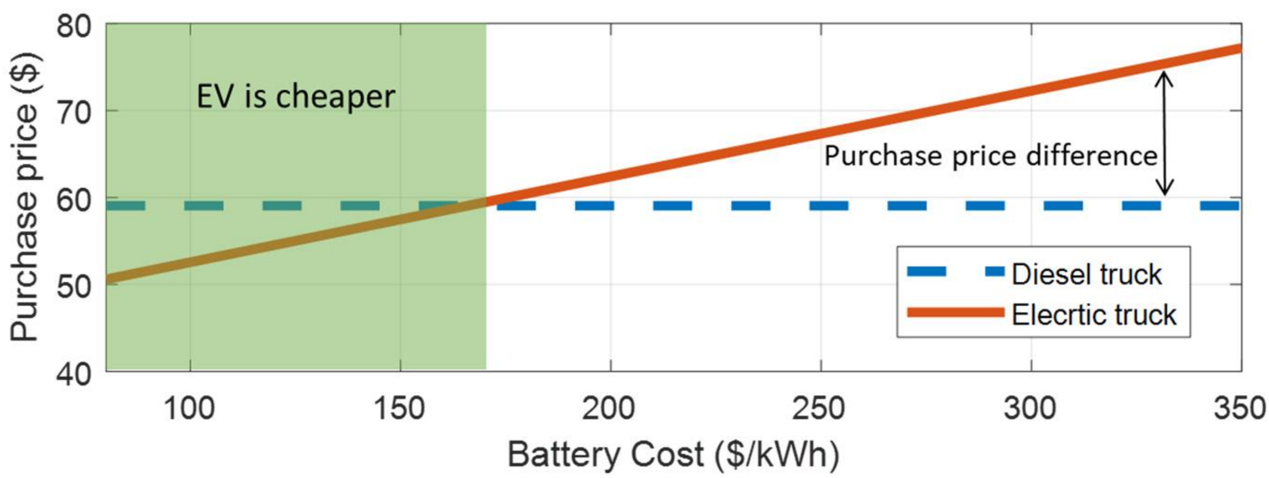


Figure 33: cost of the vehicle per battery cost per kWh

The figure 33 shows the purchase price estimates and the difference between the diesel and electric truck prices. If battery cost drops below $170/kWh, then an electric truck is cheaper to purchase. They estimate the energy consumption of 770 Wh/mile for the delivery truck. The operating cost associated with this is roughly 8 c/mile if the price of electricity is assumed as 10 c/kWh. For a diesel truck, the fuel cost will be 24 c/mile to operate at $3/gallon. For every mile, the EV will save 16 c for the operator. At 18,000 miles a year, savings for the operator is $2900 per year. The present value of such savings over the future years is quantified as shown in the following graph.

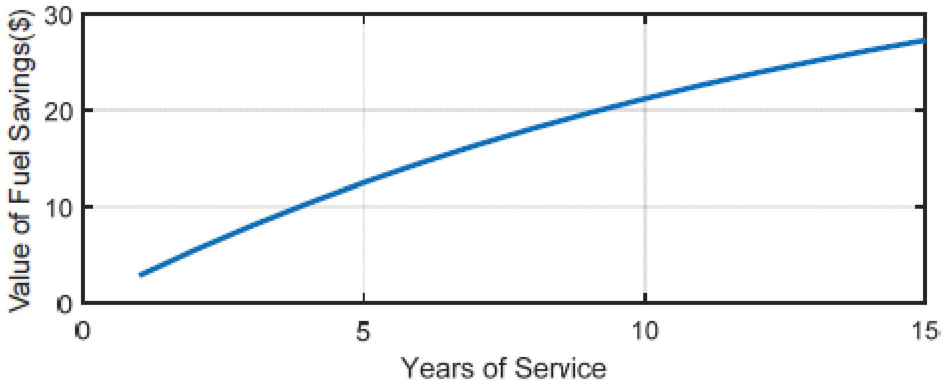


Figure 34: Fuel savings per years of service

It is not so important to focus on the numerical values presented in the graphs, as previously mentioned being a study done in another continent the prices, especially of fuel are very different, furthermore the volatility of market prices for both fuel and especially electricity make numerical values almost useless. The most important factor to take into account is the trend shown: electric vehicles are cheaper below a certain distance.

This trend will, assuming the European carbon tax guidelines are followed, be even more pronounced. As reported in [13] it was announced that Carbon Tax will increase by €7.50 per ton of carbon dioxide emitted, from €41.00 to €48.50. This applies from 12 October 2022 for auto fuels but will be offset by a levy reduction so that it will not result in a price increase. For all other fuels, the carbon tax will increase from 1 May 2023.

Hypotesis

In the following chapters, I will present the assumptions and calculations I made to arrive at a result to compare with the situation today where diesel-powered vans are used.

I find it necessary to emphasise that the values, especially concerning costs, of the quantities I will present are very volatile, especially in the historical period in which I am writing this paper.

An example is the price of electricity in Italy:

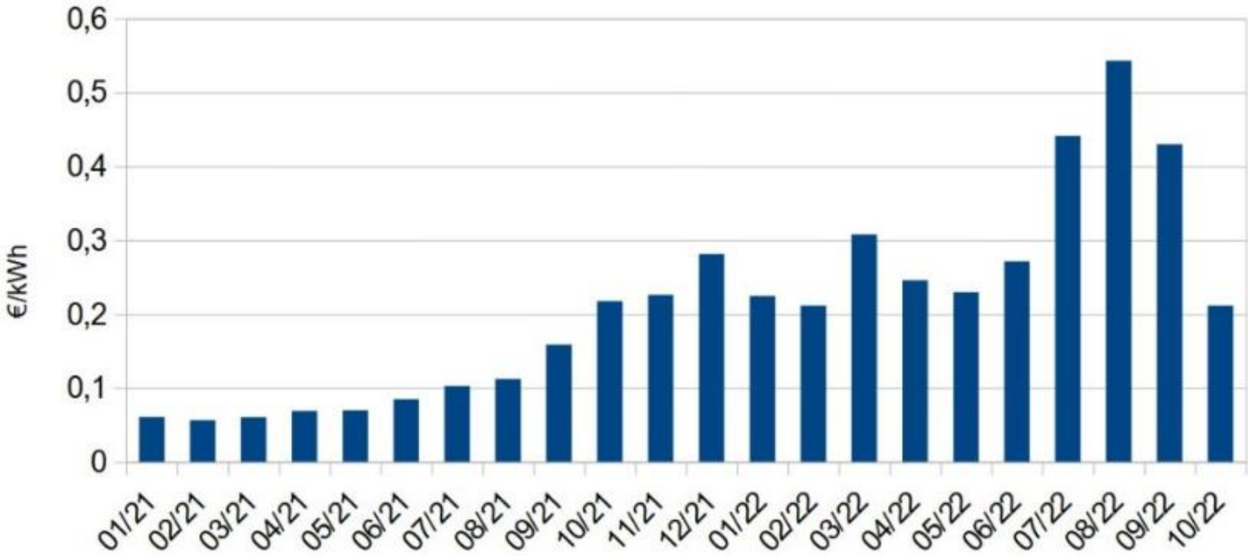


Figure 35: trend of the price of electricity through months

The picture shows how much the Single National Price (PUN) [24] has varied over the last two years. This fluctuating trend is assumed to continue for some time to come; the costs are therefore not to be considered reliable for the foreseeable future.

The same considerations apply to the projections shown in this paper: they are taken from scientific studies that report theoretical trends based on the current state of technology and research in the field of batteries and electricity generation.

The trend in battery costs is expected to go downwards, as reported by Annual Technology Baseline (ATB) [23] the cost per kWh of batteries will be lowered in the coming decades due to a broad development of technology. Specifically, there is talk of both more companies investing in the sector by bringing in more expertise and innovative ideas; and of different methods of using batteries when they have reached the end of their useful life.

Along the same lines of thought, scholars from the National Renewable Energy Laboratory [25] point out that, following an in-depth analysis of the market and other studies concerning storage systems, projections show a reduction in the capital cost of batteries, with an estimated reduction of 14-38% by 2025; 28-58% by 2030 and 28-75% by 2050.

Electric Van

Important: the considerations and steps performed from here on will concern the Optimized scenarios for both ADP and Agenzie Riunite; the relevant data concerning:

- Distance travelled
- Fuel consumption
- Delivery times
- Emissions

For the purpose of the project, I carried out a search to find an electric vehicle that could meet the following requirements:

- A load capacity comparable with the diesel vehicles used by the company to date
- As pointed out in the introduction, one of the most frequent problems for electric vans to date is range. I therefore took a range of around 250 kilometers as a reference in order to have a safety margin on all delivery rounds.

The biggest difficulties I encountered mainly concerned point 1): to date, there are numerous models on the market with limited load capacities.

The vehicle I decided to adopt for this part of the project is the Ford E-Transit.

Figure 36: ford E-Transit

This model fulfils all the above requirements and has already been on the market for more than a year. The main assumption I have made is that companies will not buy the vans, but will instead use an external company to rent the vehicles exactly as they do today.

This choice is dictated by the following factors:

- The newspaper distribution sector is in constant decline, investing considerably high capital to buy electric vans would be too risky. If it were to be necessary to organize delivery rounds again in the future and one or more of them were to be removed, there would obviously be surplus vans.
- Technology is constantly evolving: considering that in the near future more and more brands will invest in the production of electric vans and in the electric vehicle sector in general, it will be possible to change the delivery method or simply the vehicle model.

Here are the technical data that will be used for the following paragraphs. I took the values for the components directly from the Ford Italia website [15] and [16].

L3H3	Value	UoM
Rear door access height	1887	mm
Maximum load space length	3533	mm
Maximum load space width	1784	mm
Load space between wheel arches	1392	mm
Roof loading platform	2025	mm
Load height	692	mm
Maximum load space (with bulkhe	12.4	m^3
Loading space (with bulkhead) (VD	11.5	m^3

Table 47: geometrical magnitudes

Among the various models I decided to consider the L3H3 as it is the one most in line with the dimensions of the diesel vehicles used to date.

While to get more reliable values on performance and energy consumption, I compared the data taken from the Ford Italia site with tests carried out in the USA [17]. The reason is that two different methods are used, and considering both gives a more complete picture of the vehicle's performance, giving me confidence that it can support the scenario proposed in this paper.

Ford Italia

	L2 H2	L2 H3	L3 H2	L3 H3	L4 H3
Combined energy consumption [kWh/100 km]	30.7-36.0	32.6-37.8	31.1-36.4	33.0-38.3	33.7-39.0
Torque [Nm]	430	430	430	430	430
Vehicle Range	234-256	226-243	232-252	224-241	221-236
0-100% RECHARGE OPTIONS (MAX. HOURS)					
Home Recharge	51	51	51	51	51
Ford Wallbox 7.4 kW Single-phase	11.5	11.5	11.5	11.5	11.5
Ford Wallbox 11 kW three-phase	8	8	8	8	8
Recharge 11.3 kW three-phase	8	8	8	8	8
CHARGING OPTIONS 15-80% (MIN.)					
Fast charging 115 kW DC	34	34	34	34	34

Figure 37: technical data

Ford USA

KEY SPECS

Length	Regular	Long	Long	Long	Extended
Roof height	Low	Low	Medium	High	High
Cargo Van					
Max payload (lbs.)	3,880	3,776	3,628	3,553	3,330
Range (miles)*	126	126	116	108	108

Figure 38: Ford USA technical Data

The values reported by [15] refer to the WLTP standard for evaluating a vehicle's fuel consumption, emphasizing how the actual range varies according to driving style and environmental conditions.

[17] instead reports values due to the *US EPA MCT drive cycle methodology*. Here, too, conditions vary according to driving style, environmental conditions and, of course, the state of battery wear.

The values I have taken as a reference for this paper are those of the WLTP cycle, which in my opinion are more consonant and appropriate for the environment in which the project is carried out.

Despite the two different methods, the van manages to cover the distance of each Delivery Round (remembering that one van is allocated for each Round).

The only point of criticism, however, looking at the American study, concerns the Optimized Round 5 of Agenzie Riunite. In this case in fact, the estimated distance to be covered would be 161.4 [km] against the 176 [km] available from the data sheet. I nevertheless decide to consider this risk acceptable for the following reasons:

1) There is still a good margin: 15.6 kilometers is 9% of the remaining range.
2) Assuming a special case in which the van fails to complete the tour before returning to the company, there are several public charging stations along the route, two of them right in the area of the newsstands. (Data taken from the website [18] showing the presence of charging stations on Italian soil)

Figure 39: location of public charging stations

Charging Point

At this point some question arise: where, how and when to reload the vans? In this chapter I will propose the solution I think best suits the situation of the two companies.

Where

To answer this question, I have based myself on the position of vans to date. To better understand the solution I propose, I show below the case of ADP and the case of Agenzie Riunite separately.

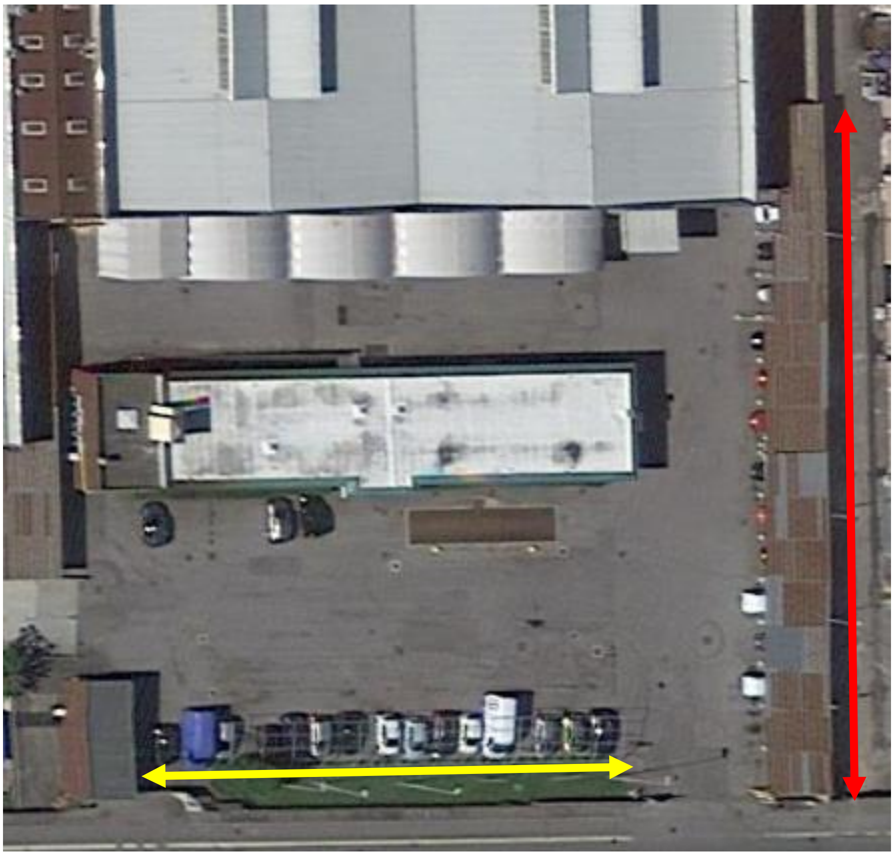


Figure 40: ADP's forecourt

The picture shows the forecourt outside ADP. Today, the vehicles are parked in individual covered parking spaces separated by columns (red line in the picture); the zone is 65 meters long and consists of 16 parking spaces.

Remembering that most of the vans only arrive at the company at night before starting the Tour, during the day these spaces are used as parking by ADP employees. These spaces are perfect for installing recharging sockets: considering the Optimized scenario comprising 15 Tours and therefore 15 vans, an equal number of spaces can be dedicated for recharging.

An alternative for placing charging systems is highlighted in the Figure 40 with the horizontal yellow line (45 meters long); however, it is less preferable as it is more exposed and does not have a clear division of space.

Agenzie Riunite

Figure 41: Agenzie Riunite's forecourt

The spatial layout of Agenzie Riunite is different, the van parking area is separate from the general parking areas. Furthermore, as can be seen from the figure 41, the vans are parked along a 69-metre line with the loading bay facing the warehouse. Behind there is a slightly raised wall facilitating the loading and unloading of goods.

Note: as you can see from the picture on the roof of Agenzie Riunite's warehouse, there are photovoltaic panels. Using the panels would be a possible and better solution in many respects, however, the energy produced by the panels currently serves to power the company's machinery. This topic will be addressed again in the chapter *'Possible future developments'* at the end of the paper.

How

The vehicle model supports Type 2 Mode 3 charging. I therefore searched the market for a system type that supports Mode 3, and the final choice fell on the following model [19]:

Charger		
Charging Mode	Mode 3 – IEC 61851	\
Current	16	A
Voltage	400 V Three-phase	V
Power	11	kW
Vehicle Linkage	Fixed Charging	\
Charging Socket	1 x Tipe 2 – IEC 62196	\
Opetating T	-30° to 50°	°

Figure 42: technical specifications charging stations

There are also wall rechargers on the market with dual output [20], thus enabling two vehicles to be recharged at the same time. However, this solution is less effective than having a dedicated charging point for each vehicle. The reasons are:

1) Space: as shown in the pictures above, the vans are positioned about two meters apart, a shared charging station could create problems.
2) Cost: charging devices with dual outlets on average cost more than twice as much as a single outlet system (1700€ versus 650€ on average).
3) Availability of charging: if one charging station failed, it would invalidate the charging of two vans.

When

The energy for the vans must be produced or bought from the national grid. For this project, I felt it was better to buy energy from the national grid. This choice has the following consequences:

- The initial investment is definitely reduced: as no solar panels have to be installed, the only high cost associated with the transition to electric vehicles is due to the purchase of charging systems.
- Barring exceptional events, electricity will always be available.
- Buying from the national grid means being subject to market prices.
- There are therefore two solutions to meet the demand for electricity:
  1) buy energy when the vehicles have completed their deliveries;
  2) by installing an energy accumulator, with this solution it is possible to buy energy at times of the day when it is cheaper and charge the vans arbitrarily.

In Italy there are 3 price bands for electricity and for this elaboration I have assumed to buy energy in the protected market.

The three price bands depend on the time of day at which you buy energy, specifically:

- F1 : Monday to Friday from 8 a.m. to 7 p.m., the most expensive band
- F2 : intermediate hours from Monday to Friday (7 a.m. to 8 a.m. and 7 p.m. to 11 p.m.) and Saturday from 7 a.m. to 11 p.m., excluding national holidays
- F3 : cheapest band, Monday to Saturday from 11 p.m. to 7 a.m.; Sundays and public holidays all day.

		Monday	Twesday	Wednesda	Thursday	Friday	Saturday	Sunday
AM	**00:00**	F3	F3	F3	F3	F3	F3	F3
AM	**01:00**	F3	F3	F3	F3	F3	F3	F3
AM	**02:00**	F3	F3	F3	F3	F3	F3	F3
AM	**03:00**	F3	F3	F3	F3	F3	F3	F3
AM	**04:00**	F3	F3	F3	F3	F3	F3	F3
AM	**05:00**	F3	F3	F3	F3	F3	F3	F3
AM	**06:00**	F3	F3	F3	F3	F3	F3	F3
AM	**07:00**	F2	F2	F2	F2	F2	F2	F3
AM	**08:00**	F1	F1	F1	F1	F1	F2	F3
AM	**09:00**	F1	F1	F1	F1	F1	F2	F3
AM	**10:00**	F1	F1	F1	F1	F1	F2	F3
AM	**11:00**	F1	F1	F1	F1	F1	F2	F3
PM	**00:00**	F1	F1	F1	F1	F1	F2	F3
PM	**01:00**	F1	F1	F1	F1	F1	F2	F3
PM	**02:00**	F1	F1	F1	F1	F1	F2	F3
PM	**03:00**	F1	F1	F1	F1	F1	F2	F3
PM	**04:00**	F1	F1	F1	F1	F1	F2	F3
PM	**05:00**	F1	F1	F1	F1	F1	F2	F3
PM	**06:00**	F1	F1	F1	F1	F1	F2	F3
PM	**07:00**	F2	F2	F2	F2	F2	F2	F3
PM	**08:00**	F2	F2	F2	F2	F2	F2	F3
PM	**09:00**	F2	F2	F2	F2	F2	F2	F3
PM	**10:00**	F2	F2	F2	F2	F2	F2	F3
PM	**11:00**	F3	F3	F3	F3	F3	F3	F3

Alternatively, there would be the F0 band, i.e. single-hour band where the price does not change depending on the time of day. This band will not be considered in this paper.

Below are the values for the price ranges, data are updated to November 2022 [21][22].

Time Slot	Price	UoM
F0	0.501	€/kWh
F1	0.521	€/kWh
F2 and F3	0.491	€/kWh

Figure 43: price of electricity from public network at November 2022

As can be seen from the Figure 43, buying energy at night would be the optimal solution: it costs less. To cope with the demand for energy to recharge the van batteries, two possible solutions are presented.

Without Battery Energy Storage System (BESS) Scenario

Assuming no storage system is installed, the energy request to the national grid should be made when the vans are on the farm.

The amount of energy and therefore the charging time required to recharge a van obviously depends on the energy spent by the van to complete the Delivery Round.

Below are the values I used for the analysis:

Battery Capacity	68	kWh
Consumption	35	kWh/100 km

On Ford's website [16] the declared consumption when analyzed using a WLTP cycle is 33.0-38.3 [kWh/100km]. Considering that vans do not exceed 70 [km/h] during the simulation, I considered a consumption of 35 [kWh/100km] to be appropriate.

Assuming the allocation of one van per Tour, ADP needs 15 vehicles, and Agenzie Riunite 13.

Below are the accounts for calculating the charging time of the vans for both companies.

ADP

Delivery Rounds	Starting Hour	Run km	Used Energy [kWh]	Remaining Capacity %	Time to Recharg
1	05:25:00	48.65	17.03	75%	01:45:19
2	05:20:00	24.07	8.42	88%	00:52:05
3	05:10:00	51.37	17.98	74%	01:51:11
4	05:00:00	52.82	18.49	73%	01:54:20
5	04:50:00	60.15	21.05	69%	02:10:12
11	05:10:00	54.03	18.91	72%	01:56:57
13	04:45:00	61.14	21.40	69%	02:12:21
14	05:15:00	84.11	29.44	57%	03:02:04
15	05:00:00	56.65	19.83	71%	02:02:37
22	04:45:00	87.02	30.46	55%	03:08:21
23	04:35:00	109.16	38.21	44%	03:56:17
24	04:15:00	72.64	25.42	63%	02:37:14
25	04:40:00	87.17	30.51	55%	03:08:41
26	05:30:00	86.33	30.21	56%	03:06:51
27	04:30:00	142.01	49.70	27%	05:07:23

Table 48: ADP's recharge of the vans

Agenzie Riunite

Delivery Rounds	Starting Hour	Run km	Used Energy [kWh]	Remaining Capacity %	Time to Recharge [h]
1	05:30:00	83.85	29.35	57%	03:01:30
2	04:30:00	59.62	20.87	69%	02:09:03
4	05:30:00	83.87	29.35	57%	03:01:32
5	04:30:00	161.44	56.50	17%	05:49:26
12	05:45:00	64.11	22.44	67%	02:18:47
13	04:30:00	133.19	46.62	31%	04:48:18
14	04:30:00	43.74	15.31	77%	01:34:41
15	05:10:00	44.56	15.60	77%	01:36:28
16	04:30:00	52.52	18.38	73%	01:53:41
17	05:20:00	60.16	21.05	69%	02:10:13
19	05:30:00	71.40	24.99	63%	02:34:32
20	04:30:00	128.94	45.13	34%	04:39:06
21	05:30:00	75.79	26.53	61%	02:44:03

Table 49: Agenzie Riunite's recharge of the vans

The data needed to perform the calculations are:

- The kilometers travelled by the vehicles in the optimized scenario
- The departure time
- The Power Factor assumed to be 0.9
- The efficiency of the charging station, considering cable losses, assumed to be 0.98

The energy consumed by the vehicle is expressed as the battery capacity consumed (Cc), it is calculated as the distance travelled multiplied by the energy consumption per kilometer. It is calculated for each Round i:

$$C_c, i\ [kWh] = km_i * \ 35\ [\frac{kWh}{100\ km}]$$

Instead, the remaining capacity is expressed as a percentage of the total capacity of 68 kWh:

$$C_r, i\ [\%] = \frac{1 - C_c, i}{C_{Full}}$$

Charging time is calculated as:

$$T[h] = \frac{C_c, i}{P * pf * \eta_{station}} \frac{[kWh]}{[kW]}$$

Where:

- P is the power of the charging station (11 kW)
- pf is the power factor assumed equal to 0.9
- $\eta_{station}$ is the efficiency of the station; it is assumed equal to 0.98

It can be seen from the tables that all vans are able to complete their task with a good margin on battery capacity.

Hypothesis:

1) Considering that the vans return to the company at a time towards the end of the F3 band (the least expensive), recharging the vans after delivery would lead to an unnecessary extra cost. The best solution is therefore to load the vans during the evening and night of the following day.
2) I assume the time to disconnect the van from recharging negligible.

The following tables calculate the time by which it is necessary to connect the van to the charging station in order to have a fully charged battery before the time set for the start of deliveries.

ADP	
Delivery Round	Hour Of the Day
1	03:39:41
2	04:27:55
3	03:18:49
4	03:05:40
5	02:39:48
11	03:13:03
13	02:32:39
14	02:12:56
15	02:57:23
22	01:36:39
23	00:38:43
24	01:37:46
25	01:31:19
26	02:23:09
27	23:22:36

Agenzie Riunite	
Delivery Rounds	Hour Of the Day
1	02:28:30
2	02:20:57
4	02:28:28
5	22:40:33
12	03:26:13
13	23:41:41
14	02:55:19
15	03:33:32
16	02:36:19
17	03:09:47
19	02:55:28
20	23:50:53
21	02:45:57

Table 50: hour at which it is needed to start recharging the vans

The departure time is not the same for all tours, this change from today's case is not very important for this cost-saving part of the study: all vans can be conveniently loaded before entering the F1 price range.

This result shows that it is possible to start loading vans even a few hours in advance in order not to risk being tight on time.

Costs

In this short paragraph I report the costs of the energy needed to power the vehicles. As shown in the previous paragraph for both ADP and Agenzie Riunite, energy is bought in the cheapest price range, at a price of 0.491 [€/kWh].

	€ per day
Agenzie Riunite	182.71
ADP	185.14

The cost of electricity per day is indicative, but cannot be compared with the cost today for two reasons:

1) The current cost of the ride is composed of a fixed part and a part directly proportional to the amount of kilometers travelled by the vehicle; the cost is agreed with a separate company and for privacy reasons is not shown
2) In addition to the daily cost, there is also the cost of the charging stations, which represent not inconsiderable capital.

Below is a calculation of the annual energy cost and the cost of the charging stations [19].

	€/year	€ charging stations
Agenzie Riunite	64862.7	8567
ADP	65724.5	9885

Table 51: cost of the electric scenario in a year

Note: the price of electricity is very volatile [24] and it is a variable that cannot be assumed to be constant in the long run; however, the difficulty in assuming a plausible trend in the near future makes it impossible to assume a real value for this calculation. The purpose of the above values is to provide an order of magnitude of the costs that a company such as ADP or Agenzie Riunite would have to face to make the transition from a fleet of diesel vehicles to a fleet of full-electric vans.

BESS Scenario

Assuming that an accumulator is installed, the part of the reasoning concerning the timing of recharging is eliminated: one can conveniently recharge the batteries during the course of the day, instead buying the required energy at night.

1) First, I calculate the total energy that is required by vehicle fleet:

$$E_{Tot}\,[kWh] = \sum E_i$$

	Tot Energy Daily [kWh]
Agenzie Riunite	372.12
ADP	377.07

2) The daily energy demand is the first parameter to be considered in order to correctly size the storage tank: if it is true that energy is purchased at night, it must be maintained until it is used.
To optimize costs, it is therefore essential to have a sufficiently large battery, but at the same time it does not make sense to invest in a system with an excessively large capacity.

The cost of the battery can be divided into two main elements:

- Capex, a component that depends on the size of the battery.
Many studies, including one conducted by the Annual Technology Baseline (ATB) [23], claim that the cost of batteries is set to fall, today the cost is between 200 and 300 €/kWh.

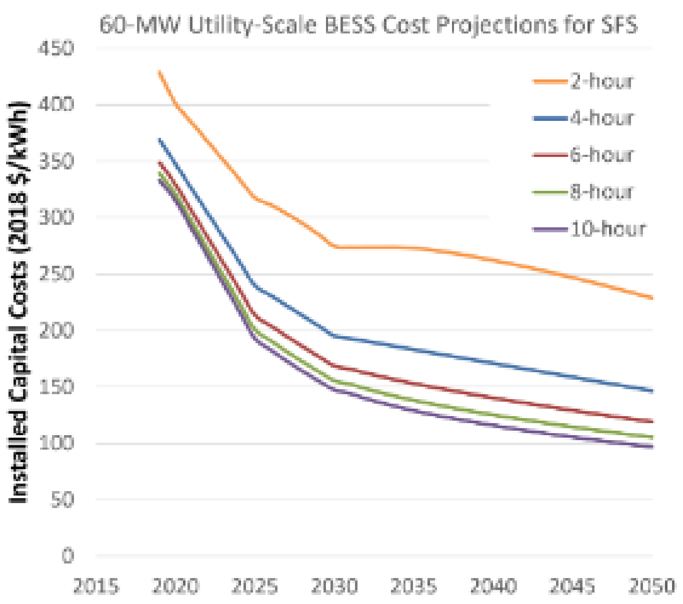


Figure 44: trend of the battery cost through years

Also consulting the data provided during the university course 'Energy and Emissions' [27] and the project [28] for this project I assumed a cost of **200 €/kWh**.

- Operation & Management: cost of operation and maintenance. This component is not negligible and for the sake of brevity is often referred to as a small percentage of the battery installation cost. [23] indicates **2.5% of the Capex** as a good approximation.

3) To calculate the total cost due to the battery, I also consider two coefficients due to the losses during the periods when the battery is charged and discharged.
[28] This coefficient η basically increases the energy required to meet the daily demand.

$$Cost_{BESS}[€] = \frac{(E_{Tot} * Cost_{energy}) * (1 + 0.025)}{\eta} \left[\frac{€}{kWh}\right] * [kWh]$$

	CostBess [€]
Agenzie Riunite	84761.1
ADP	85887.2

4) Adding up all the components gives the total cost including the cost of energy, the cost of the battery and the cost of the charging stations.
As with the previous points, it is not the costs as such that are significant but the order of magnitude and the percentages of the components in relation to the total.

	TOT [€]
Agenzie Riunite	158190.8
ADP	161496.7

%	CostBess [€]	Energy Cost 1 year [€]	Cost Charging Stations [€]
Agenzie Riunite	54%	41%	5%
ADP	53%	41%	6%

Just as with electric vehicles, the most expensive component remains the battery, which accounts for over 50% of the total cost.

Emissions – Electric Scenario

The most significant comparison that can demonstrate the real advantages of the electric solution over the conventional one is certainly the analysis of emissions. As much as one of the main boasts of those selling electric vehicles is the reduction of local emissions to 0, this cannot be said of the CO2 emissions for power generation.

The National Energy Efficiency Agency (ENEA) writes in its document Quarterly Analysis 2/2022 [29] "*Contrary to the trend of recent years, emissions from the ETS sectors jumped in the quarter (+15%), those of electricity generation in particular, for which a trend increase in emissions of over 25% is estimated, the most pronounced trend change in the last two decades. With the revival of coal in thermoelectric power generation, the carbon intensity of electricity produced - measured in grams of CO2/kWh - increased by 18% from a year earlier and was 45% higher than the mid-2020 minimum*'.

After an accurate search, I found data on European emissions for electricity production in recent years. The following graph, taken from the website of the European Emission Agency [30], shows that the trend of CO2 emissions resulting from electricity production has been sharply decreasing, however, after 2020, where the all-time low was reached, the trend was reversed.

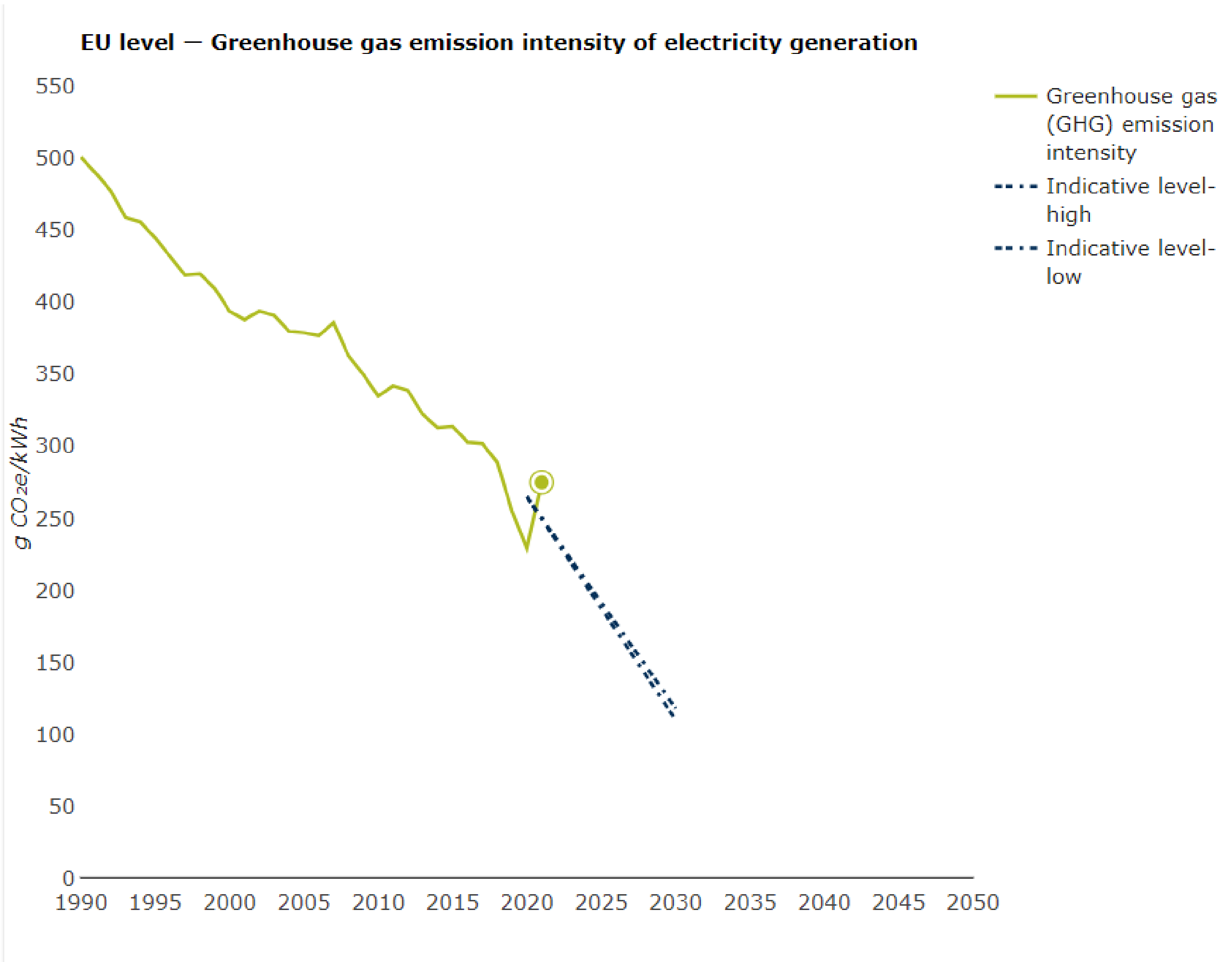


Figure 45: trend and previsions of CO2 emissions in Europe

Since the data in the graph stops at 2021, following ENEA's indications [29], I decided to increase the CO2 figure in [g/kWh] by 18% with respect to 2021 and use this figure as a reference for the elaboration.

Therefore, using the value of 275 [g/kWh] taken from [30] leads to the value of **324.5 [g/kWh].**

At the same time, the graph highlights what are the trends for the future, following studies, analyses and forecasts on the development of technology in favor of energy production with fewer emissions. These projections will be important for the final considerations of the project, in particular for the 'Future Scenarios' section.

After these necessary introductions, I report the steps I followed to calculate the emissions resulting from the production of electricity bought from the national grid.

1) The data required are:
    - the energy consumed by electric vehicles to complete deliveries;
    - the emissions from vehicles with diesel engines;
    - the amount of CO2 produced per kWh of energy.
    - the correction coefficient due to losses in the case with accumulator
2) For the calculation of the CO2 emitted **I have separated the case without accumulator from the case with accumulator**, as in the latter there are also losses due to the battery. Both scenarios are then compared with the initial case, showing significant results.

$$CO2[g] = E_i * c_{CO2}\ [kWh] * \left[\frac{g}{kWh}\right]$$

   Where $c_{CO2}i$ represents the quantity of CO2 emitted per [kWh] relatively to the i Round.

3) The results of the accounts for the two companies are shown below, analyzing the case without accumulator (EV - No BESS) and the case with accumulator (EV - BESS).

ADP – Emission Comparison

		CO2 Emitted [kg]				
Round	**Used Energy [kWh]**	**ICE**	**EV - No BESS**	**Comparison - No BESS**	**EV - BESS**	**Comparison - BESS**
1	17.03	10.5	5.5	47%	6.3	40%
2	8.42	5.7	2.7	52%	3.1	45%
3	17.98	9.8	5.8	40%	6.6	32%
4	18.49	10.0	6.0	40%	6.8	32%
5	21.05	12.9	6.8	47%	7.7	40%
11	18.91	12.7	6.1	52%	7.0	45%
13	21.40	14.4	6.9	52%	7.9	45%
14	29.44	16.0	9.6	40%	10.8	32%
15	19.83	12.2	6.4	47%	7.3	40%
22	30.46	16.5	9.9	40%	11.2	32%
23	38.21	20.7	12.4	40%	14.1	32%
24	25.42	15.6	8.3	47%	9.4	40%
25	30.51	16.6	9.9	40%	11.2	32%
26	30.21	18.6	9.8	47%	11.1	40%
27	49.70	27.0	16.1	40%	18.3	32%

Figure 46: ADP's emission comparison

Agenzie Riunite – Emission Comparison

		CO2 Emitted [kg]				
Round	Used Energy [kWh]	ICE	EV - No BESS	Comparison - No BESS	EV - BESS	Comparison - BESS
1	29.35	13.7	9.5	30%	10.8	21%
2	20.87	14.2	6.8	52%	7.7	46%
4	29.35	18.0	9.5	47%	10.8	40%
5	56.50	34.7	18.3	47%	20.8	40%
12	22.44	15.3	7.3	52%	8.3	46%
13	46.62	24.9	15.1	39%	17.2	31%
14	15.31	10.3	5.0	52%	5.6	45%
15	15.60	10.0	5.1	50%	5.7	43%
16	18.38	13.0	6.0	54%	6.8	48%
17	21.05	11.2	6.8	39%	7.7	31%
19	24.99	13.4	8.1	39%	9.2	31%
20	45.13	24.5	14.6	40%	16.6	32%
21	26.53	17.1	8.6	50%	9.8	43%

Figure 47: Agenzie Riunite's emission comparison

- Energy Used: energy required to complete the Round
- ICE: [kg] of CO2 emitted to complete the round with diesel-powered vehicle.
- EV - No BESS: [kg] of CO2 emitted to produce the energy required to power the electric van associated with the Round in the non-accumulator scenario.
- Comparison - No BESS: shows the percentage reduction in CO2 emissions between the base case and the electric scenario without accumulator.

$$Comparison_{\%} = \frac{CO2_{Diesel}}{CO2_{NoBESS}}$$

- Electric - BESS: [kg] of CO2 emitted to produce the energy required to power the electric van associated with the Round in the scenario with accumulator.
- Comparison - BESS: shows the percentage reduction in CO2 emissions between the base case and the electric scenario without accumulator:

$$Comparison_{\%} = \frac{CO2_{Diesel}}{CO2_{BESS}}$$

Note: the factor to focus on is not the numerical values, but the orders of magnitude and the comparison between the two scenarios.

For both companies, a constant behavior can be seen, buying energy from the grid drastically decreases daily emissions, without of course eliminating them completely.

On average, the reduction in daily emissions is 45%, however, it is important to note that the use of a more efficient or more technologically advanced diesel van can make the advantage of the electric solution less obvious; an example of this is the vehicle assigned to Round1 of Agenzie Riunite.

Conclusions

The strength of this thesis work lies in the fact that it addressed two main issues with the same objective: modernizing the newspaper distribution sector. The two analyses are intertwined in some aspects, but differ markedly in one factor in particular: timing. While it is true that the optimization of Delivery Rounds is feasible in the immediate future, this cannot be said of the transition to electric, whose greatest limitation lies in cost, especially for a small or medium-sized company.

In the introduction I posed a few questions:

In the face of an ever-increasing crisis in the newsstand and print media sector, is it possible to reduce operating costs without disrupting working methods?

Are the solutions proposed by a possible mathematical model practically applicable?

The answer to this question is positive, by organizing the newsstands in a better way the results show a significant cost reduction. The most obvious case is ADP, reducing the number of Rounds by three leads to considerable daily savings.

The strength of this result lies in the method: from an operational point of view, the working method of the company is not disrupted. Furthermore, the proposed model is based on points called Centroids. The way these points have been defined, if in the future the number of kiosks were to decrease further or if other parameters (such as delivery times, loading volume or vehicles) were to change, it is immediate to redefine the composition of the rounds in an optimal way while keeping them balanced.

I also emphasize how this method is suitable not only for companies similar to the two considered in this paper, but also for companies operating in different sectors where the aim is the spatial and temporal optimization of the route for the delivery of goods.

What organizational solutions should be followed to achieve a concrete improvement?

The initial aim of the project was to find a method to optimize delivery rounds and reduce operating costs; the solutions to this problem lie in organizing the rounds better, but also in some respects that were not obvious at the beginning. One example is the over-reliance on the demands of the newsagents on delivery times. As was pointed out in both companies, giving too much importance to the delivery time considerably lengthens the distance the van travels, obviously affecting costs and consumption. A solution that would increase the effectiveness of the solutions proposed in this paper even more would be to obtain shop keys or a skip for all newsagents, a direction towards which ADP especially has stated it is aiming in the near future.

Is a transition to electric vehicles feasible in this case?

The transition is certainly feasible, looking also at other studies and cases around the world the distribution sector and in particular the distribution of printed paper has many points in its favor. The main factors, as also demonstrated in this paper, are:

- Short distances travelled
- Large time intervals during the day to allow charging of electric vans
- Possibility of installing charging points in the forecourts of companies so as not to be dependent on public stations

Is the transition economically viable? If so, which solutions are best to follow?

In the project, I have reported the current costs of the two companies but reduced them considerably to keep sensitive data private; however, despite this factor, the values reported between the original case and the electric scenario are comparable, especially in the case without an accumulator.

	TOT [€] ICE (Fictitious)	TOT [€] BESS	TOT [€] - No BESS
Agenzie Riunite	52549.6	158190.8	64862.7
ADP	54440.8	161496.7	65724.5

Figure 48: total cost of electric scenario in 1 year

As mentioned in the introduction, the print media sector is going through a crisis due to several factors, which makes it very difficult to predict its development in the near future. I therefore find that a transition to electric is possible for companies such as ADP and Agenzie Riunite, but that it makes more sense (as of today) to invest in a solution without an accumulator.

Installing a storage system, according to the studies mentioned, will be cheaper in the near future as technology evolves and prices fall. Two elements that could help small and medium-sized companies to make the transition to electric can be government incentives and the increase in emission taxation expected in the coming decades; the main advantage of the electric scenario being the reduction of local emissions.

Possible future scenarios

Optimization

The continuous evolution of the number of newsstands supplied by the two companies implies that the turns could be re-analyzed and studied. The method proposed in this paper could be re-proposed, for example, using the volume of baskets as a yardstick: an optimization focused primarily on the relative distance between newsstands would then not be carried out, but a solution aimed at balancing the volume occupied in the vans as far as possible.

Assuming a merger of the two companies, how would the scenario develop? The Rounds would have to be reorganized by assuming a single point of departure and arrival, thus requiring a larger warehouse and more organization.

For the purposes of this reasoning, based on the number of baskets and the location of each kiosk, I calculated an *Optimum point*, which would be the ideal location for this hypothetical warehouse:

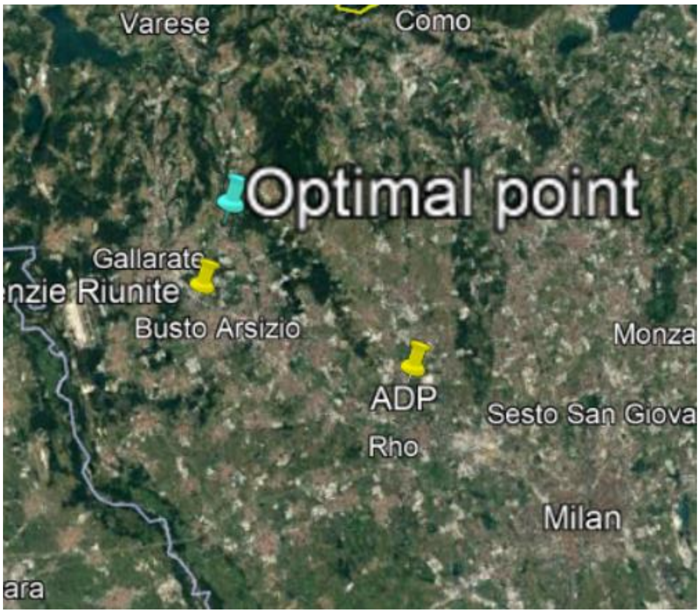


Figure 49: optimal point

The Optimal point is located about 6 kilometers from Agenzie Riunite as the crow flies and about 17 kilometers from ADP

Electrification

In this case, future developments are manifold. Certainly, the most interesting would be the installation of photovoltaic panels to be independent of the national grid, which would eliminate the high variation in energy costs and reduce the total cost. The same reasoning applies here as for batteries: numerous studies show that this technology will be increasingly valid in the near future; however, it is almost obligatory to accompany the installation of photovoltaic panels with storage systems in order to exploit their full potential.

[30] estimates that by 2030 the lowering of prices and the development of technology will make the use of photovoltaic panels coupled with accumulators a technology strongly desired and adopted by many companies.

Agenzie Riunite already has photovoltaic panels dedicated to producing energy for the company, expanding the area covered by the panels would certainly lead to major advantages in the field of electric vans.

References

[1] https://www.wired.it/attualita/media/2020/01/29/edicole-crisi-notte-delle-edicole/

[2] Italia Oggi 11/08/2022

[3] Arunya Boonkleaw, Nanthi Suthikarnnarunai, PhD., Rawinkhan Srinon, PhD. Strategic Planning and Vehicle Routing Algorithm for Newspaper Delivery Problem: Case study of Morning Newspaper, Bangkok, Thailand

[4] Ferreira, J. C., & Steiner, M. T. A. (2022, out./dez.). A new approach to the bi-objective green vehicle routing problem: optimization in newspaper distribution. Exacta. 20(4), 996-1023.

[5] A multi-stage approach for optimizing the three-echelon joint newspaper distribution network of two major publishers in S˜ao Paulo, Brazil Claudio B. Cunha,*, Cauˆe S. Guazzelli, Hugo T.Y. Yoshizaki, Rhandal F. Masteguim, Daniel Colacioppo, Maurício Ajzenberg

[6] Electric Truck Economic Feasibility Analysis, Ram Vijayagopal * and Aymeric Rousseau

[7] Too much or not enough? Planning electric vehicle charging infrastructure: A review of modeling options; M.O. Metais a,b,∗, O. Jouini a, Y. Perez a, J. Berrada b, E. Suomalainen b

[8] https://www.vivienergia.it/casa/vivipedia/guida-energia/fasce-orarie-energia-elettrica

[9] https://www.leaseplan.com/it-it/news-auto/sostenibilita/colonnine-elettriche-italia/#:~:text=Secondo%20i%20dati%20dell'OAFO,potenza%20superiore%20a%2022%20kW.

[10] https://luce-gas.it/guida/contatore/luce/fasce-orarie

[11] Wang Ying Wei, Wang Chuan Ren. Locating passenger vehicle refueling stations.

Transp Res E 2010;46(5):791–801.

[12] He Fang, Yin Yafeng, Zhou Jing. Deploying public charging stations for electric

vehicles on urban road networks. Transp Res C 2015.

[13] https://www.citizensinformation.ie/en/money_and_tax/tax/motor_carbon_other_taxes/carbon_tax.html#:~:text=It%20was%20announced%20that%20Carbon,increase%20from%201%20May%202023.

[14] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_freight_transport_by_journey_characteristics#Road_freight_transport_performance_by_type_of_operation_.28in_tonne-kilometres.29

[15] https://www.ford.it/furgoni-pick-up/e-transit?searchid=ppc:Search_IT(ita)%7C%5BAO%5D_Retail_SD_Commercial-Vehicles_Transit:E-Transit_CPPI_EUR%7CShp-T2%7CExact~Pure:E-Transit-Awareness:+Branded-Exact:ford%20e%20transit:e:c:g:GOOGLE&gclid=Cj0KCQjwuaiXBhCCARIsAKZLt3nMxmkUOgXHUXbdCWuN-i6UmQGraKaEJGwZULoucPDLC5xJySa-N90aAt7nEALw_wcB&gclsrc=aw.ds#

[16] FT_ford_E_transit Technical Schedule

[17] 2022 FORD E-TRANSIT (U.S.)TECHNICAL SPECIFICATIONS

[18] https://www.bec.energy/rete-di-ricarica/?utm_term=mappa%20colonnine%20ricarica%20auto%20elettriche&utm_campaign=20220307+-+Search_Colonnine_TRACTION&utm_source=google&utm_medium=cpc&hsa_acc=6954661191&hsa_cam=16494093249&hsa_grp=137021919071&hsa_ad=586393370585&hsa_src=g&hsa_tgt=kwd-433615404155&hsa_kw=mappa%20colonnine%20ricarica%20auto%20elettriche&hsa_mt=p&hsa_net=adw

ords&hsa_ver=3&gclid=Cj0KCQiAgribBhDkARIsAASA5bu1ZQuIWz77DFyZPkLYzCMrP6aoKO6IejyblruqsRo8el yvW3A9914aAlpiEALw_wcB

[19] Charging Station: https://www.stazioni-di-ricarica.it/prodotto/e-line-wall-box-11-kw/

[20] Charging station 2x: https://www.e-station.store/prodotto/wallbox-modo-3/e-line/securi-charger-2-x-11-kw/

[21] https://www.vivienergia.it/casa/vivipedia/guida-energia/fasce-orarie-energia-elettrica

[22] https://luce-gas.it/guida/contatore/luce/fasce-orarie

[23] https://atb.nrel.gov/electricity/2022/utility-scale_battery_storage

[24] https://www.newsauto.it/notizie/costo-energia-elettrica-pun-oggi-previsioni-aumento-prezzi-2022-rincari-cause-2022-365125/

[25] Cost Projections for Utility-Scale Battery Storage: 2021 Update Wesley Cole, A. Will Frazier, and Chad Augustin; National Renewable Energy Laboratory

[26] Break-Even Points of Battery Energy Storage Systems for Peak Shaving Applications; June 2017; Claudia Rahmann, V. Vittal, Felipe Valencia

[27] EE_04_Batteries_2021, Energy and Emissions Prof Guandalini

[28] Electric and hydrogen HD vehicles for short-range applications, 2022

[29] Analisi trimestrale 2/2022 ENEA

[30] https://www.tgreen.it/il-mercato-del-fotovoltaico-andamento-e-previsioni-future

[31] www.gps-longitudine-latitudine.it

[32] CT-JUMPER-2016-05 technical schedule

[33] Movano varianti per telaio cabinato e di allestimento Catalogo

[34] scheda tecnica Iveco daily https://www.iveco.com/Italy/Documents/Configurator/Brochure/Dailyvan_IT.pdf

[35] https://professional.renault.it/veicoli-commerciali/master/dimensioni-scheda-tecnica.html

[36] https://www.camionsupermarket.it/blog/renault-master-150-cv

[37] https://www.mercedes-benz.ch/vans/it/sprinter/cab-chassis-with-a-platform/technical-data

[38] https://giadilconsulting.com/blog/mercedes-sprinter/

[39] https://www.ultimatespecs.com/it/auto-caratteristiche-tecniche/Volkswagen/111616/Volkswagen-Crafter-2018-L4H3-3500-20-TDI-140HP-4MOTION.html

[40] https://www.slideshare.net/autoblog/scheda-tecnica-ford-transit-2014

[41] https://terraup.it/auto/ford/transit-fwd

[42] https://www.sedoni.it/prodotto/iveco-daily-35c12-telonato/

[43] Technical schedule Fiat Ducato

Acknowledgements

I thank Professor Roberto Maja for his valuable advice and supervision without which I would not have been able to complete this thesis.

I thank Marcello Belotti, Stefano Ferrario and all the workers at ADP and Agenzie Riunite for the opportunity they gave me and for the helpfulness they have always shown towards me.

I thank the Politecnico di Milano, for the stimuli, the knowledge, the possibilities offered, the impossible exams, the university environment and the values.

I thank my fellow students, from those I met in the first year to those I met in the fifth; a special mention goes to Manuel Lorenzo and Federico, without whom university life would not have been the same.

I thank my former colleagues; I shared an unforgettable year and a half with you and it is also thanks to you that I have completed this course.

I thank my friends, Alessandro, I Festaioli, Elisa, Francesco, Jane, Jugy and all the others, over these years the outings the laughter and the experiences I have had with you have been vital; a special thanks goes to Martina, the friendship we have cultivated over these years has been fundamental.

I thank my parents and my brother for their constant support and for always believing in me, I owe you everything.

I thank my family: my grandparents for taking me in during the first years of this journey; my aunt Silvia, for taking me to the station every day; my aunts, uncles and cousins for their continuous support during these years.

Finally, I thank Bea, you gave me the strength to face this path and the difficulties of life, giving me unique emotions.