E.T.S. de Ingeniería Industrial, Informática y de Telecomunicación

Using Agent-Based Simulation and Optimization Models to Design the Automated Parcel Lockers Network in Pamplona (Spain)

Doble Máster Universitario en Ingeniería Industrial y Dirección de Empresas

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Abstract

Urban Logistics (UL) is growing in importance with the rise of e-commerce worldwide and home deliveries of small but frequent orders from consumers. Alternative delivery methods have been in the scope of researchers and delivery companies for years. The introduction of Self Collection Delivery Systems (SCDS) innovates on Last Mile Delivery (LMD) operations in urban areas and bring new advantages to the table. Automated Parcel Lockers (APL) are the evolution of prior developments in SCDS. Thus, APLs are a hot topic among researchers and delivery companies. APL networks are a scalable, customizable, electronic, and cloud-based solution that allow customers unattended parcel collection with no time restrictions and total convenience.

This Master Thesis reviews the available literature on different aspects related to APL implementation and conducts a market research on population's perception and usability forecast of APL in Pamplona. Moreover, Agent-Based Modelling is used to model future demand based on a number of socio-economic parameters, i.e., population as well as the rates of online users, e-commerce growth, e-shoppers, APL usage, and others. Likewise, the APL location optimization model is dynamically executed within the simulation framework to minimize the operational and service costs to meet the expected demand. Promising results are obtained, encouraging the use of simulation and optimization tools to leverage the use of APLs as a last-mile distribution scheme.

Key words

- E-commerce
- Automated Parcel Locker
- Urban Logistics
- Last Mile Distribution
- Agent-Based Modelling

Publications Arising from this Thesis

Serrano-Hernandez, A., Martinez-Abad, S., Ballano, A., Faulin, J., Rabe, M., and Chicaiza-Vaca, J. 2021. A Hybrid Modeling Approach for Automated Parcel Lockers as a Last-Mile Delivery Scheme: a Case Study in Pamplona (Spain). Submitted for presentation and publication in the 2021 Winter Simulation Conference.
URL: http://meetings2.informs.org/wordpress/wsc2021/

Martinez-Abad, S. 2021. Using Agent-Based Simulation and Optimization Models to Design the Automated Parcel Lockers Network in Pamplona (Spain). Submitted for presentation in the 2021 SI-Trans Workshop for Young Researchers.
URL: https://www.uoc.edu/portal/en/agenda/2021/agenda_255.html

Contents

List of Figures

List of Tables

Glossary

ABM	Agent-Based Modelling
ABS	Agent-Based Simulation
APL	Automated Parcel Locker
CFLP	Capacitated Facility Location Problem
CL	City Logistics
CLD	Causal Loop Diagram
DES	Discrete-Event Simulation
FLP	Facility Location Problem
KPI	Key Performance Indicator
LMD	Last Mile Distribution
LML	Last Mile Logistics
MCFLP	Multiperiod Capacitated Facility Location Problem
MCS	Monte Carlo Simulation
OR	Operational Research
SD	System Dynamics
SDSM	System Dynamics Simulation Model
SFD	Stock and Flow Diagram
SO	Simulation-Optimization
UL	Urban Logistics

1. General Introduction

1.1. E-commerce growth

E-commerce is the process of buying goods or services using the internet (Turban et al. 2006; Laudon & Traver 2007). Purchases are concluded in a virtual environment and the main benefits perceived from the perspective of the customer (Polska & Gemius 2014; Chiu et al. 2014) can be focused on the following points:

- 24/7 availability and right to return.
- No need to travel to the shop and home delivery.
- Offer comparison, larger assortments, and attractive prices.

In 2016, global sales of e-commerce reached nearly US$1,8 trillion and are expected to reach US$6,5 trillion in 2022 (Orendorf 2021). Europe has seen a 17% increase in retail sales during 2020.

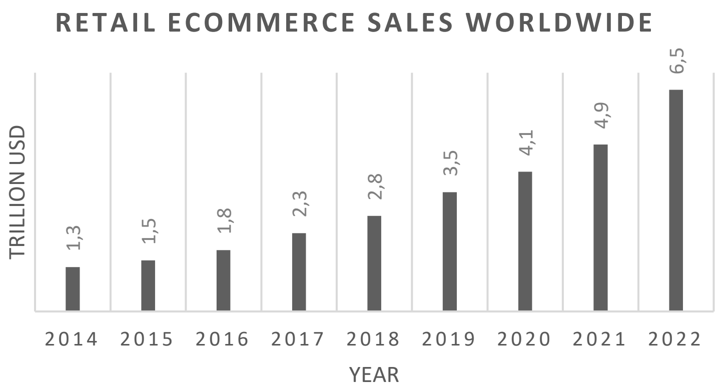

Figure 1. Retail ecommerce sales worldwide

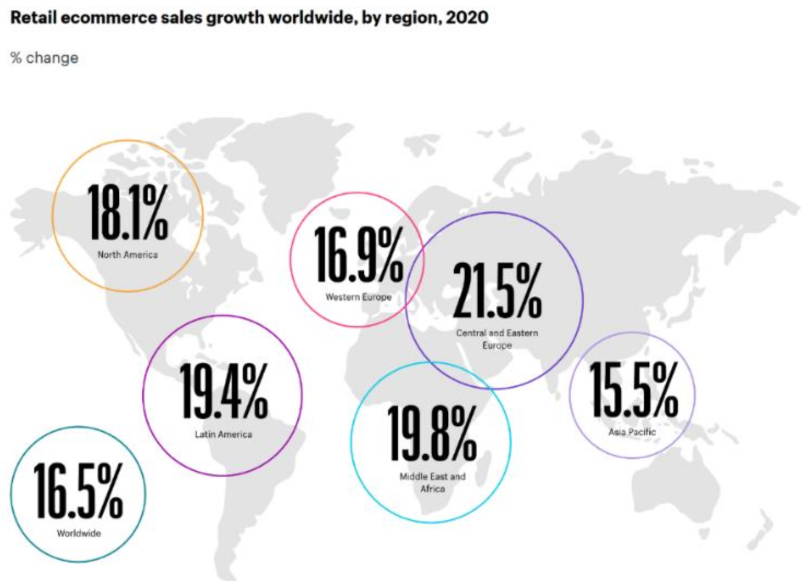

Figure 2. Retail ecommerce sales growth worldwide in 2020. Source: Cramer (2020)

This rapid growth of e-commerce has led to a sharp increase in the delivery of parcels. Competition in the e-commerce sector is very fierce and purchasing conditions like price, delivery fees, delivery method and customer reviews can be crucial. One key factor to lead in the sector is logistics: the process of transporting goods to customs consists of many stages and improvements must be oriented towards efficiency improvement and cost reduction, as Last Mile Delivery (LMD) often involves one package per door, the failed home delivery problem, reverse logistics management and LMD accounts for approximately 70% of total cost of transport operators (Brown and Guiffrida 2014).

The retail e-commerce customer usually orders small quantities of goods – often single items – with higher frequency. This customer is usually not available at the delivery point during the courier company or post office working hours. In addition to the prior failed home delivery problem, a second problem arises due to the characteristics of e-commerce buyers: the freight transportation machinery inadequacy due to the proliferation of small packages and a decrease in space optimization and volume occupation.

As a response, operators have started to offer alternative options to regular home deliveries.

1.2. Urban Logistics

Urban Logistics (UL) or City Logistics (CL) is defined as "the means over which freight distribution can take place in urban areas as well as the strategies that can improve its overall efficiency while mitigating congestion and environmental externalities" (Rodrigue 2016).
Last Mile Delivery (LMD) or Las Mile Logistics (LML) is defined as the last segment of a delivery process which "involves a series of activities and processes that are necessary for the delivery process from the last transit point to the final drop point of the delivery chain" (Lindner 2011).

The rise of e-commerce in recent years has accelerated the growth in consumer freight volume worldwide, UL and the LMD associated to it. The importance of UL and LMD is highlighted since societal and environmental problems associated are the accumulation of pollutants in cities, 25% of the total emissions of CO_2, and the fact that almost 70% of traffic accidents take place in urban areas, not an advantage when the intensification of traffic jams is expected to increase by 50% by 2050 (European Commission 2011)

Many alternatives have been developed as a good practice response in current urban freight transport systems to rationalize last mile delivery leading to the popular Automated Parcel Locker alternative (Allen et al. 2007):

- Reception boxes: fixed to the outside wall of the customer's home. Can be accessed using a key or code and an automatic notification can be sent to the recipient.
- Delivery boxes: owned by the delivery company and temporarily fixed to the customer's property. Once the packages are collected, the transport company can pick the box curing delivery travels.
- Collection points: other businesses that offer to store and parcel out customer's packages. Selected locations have long opening ours and the customers are informed when their package is available.
- Automatic Parcel Lockers (APL): fixed (or mobile) boxes with different compartments and variable opening codes. Usually owned and used by the same company. Customer makes the final leg of the journey once they receive a notification, but the locations are designed so that customers must deviate as short as possible.

	Attended delivery	Reception box	Controlled access	Collection point	APL
Last mile	Delivery company	Delivery company	Delivery company	Customer	Customer
Customer present	Yes	No	No	No	No
Type of product	Any	Packages/Groceries	Packages/Groceries	Packages	Packages/Groceries
Failed delivery	High	Virtually none	Virtually none	Virtually none	Virtually none
Delivery window	Fixed	Operating hours	Operating hours	CP opening	Operating hours
Collection time	Fixed	24h	24h	CP opening	24h
Retrieval time	None	Short	Short	Variable	Variable
Drop-off time	Long	Short	Short	Shorter	Shorter
Initial investment	Low	High/Medium	Medium	Medium/Low	Medium
Delivery cost	High	Low	Low	Lower	Lower
Disadvantages	Failed deliveries Poor use of vehicle capacity	Amount of boxes Customer collection	Safety concerns Suitable location	Customer displacement	Customer displacement
Vehicle reduction	Reference	Some reduction	Some reduction	High reduction	High reduction

Table 1. A comparison of last mile delivery systems. Source: Allen et al. (2007).

1.3. Automated Parcel Locker

Benefits associated to the adoption of self-collection delivery systems, to which Automated Parcel Lockers belong, over traditional home deliveries can be divided into three main groups (Deutsch and Golany 2018):

- From the operators' perspective: failed deliveries closely related to home deliveries can be avoided improving order fulfilment and minimizing failed home deliveries.
- From the environmental and societal perspective: consolidated shipments reduce the number of kilometres, greenhouse gases emissions and reduces road congestion, improving urban quality of life (Chen et al. 2017; Van Duin et al. 2016).
- From the consumer's perspective: inefficiencies associated to the time spent waiting for deliveries no longer are necessary (Agatz et al. 2011). Overall, service perception improves.

In addition, APLs are a scalable solution, customizable, electronic, and cloud-based solution. Can be unattended and instead of requiring 2 hours timeslot agreements with the receiver, enable to virtually receive (and send) packages 24 hours a day 7 days a week allowing consumers to choose the pickup time at their convenience. From the environmental point of view, collected data estimated an emission reduction potential of 27% and a model shift of 12% from car to more environmentally friendly transport modes (Hofer et al. 2020).

The SWOT analysis of APL is the following (Table 2):

Strengths	**Weaknesses**
- 24/7 customer access to parcel - Customer notified after delivery - Freight transport trip mileage reduction - Energy consumption, emissions, and noise reduction - Low delivery cost	- Private action, no information provided to public authorities - Customers made responsible for final leg of the process
Opportunities	**Treats**
- Efficiency improvement for logistic providers - Transferable to other cities	- Ecommerce growth can cause higher freight mileage due to higher number of APL

Table 2. SWOT analysis of parcel lockers. Source: Torrentellé et al. (2012)

Given all the advantages, some logistics providers have already implemented APL as an optional solution for LML. Unfortunately, the trend for companies is to make the system access exclusive to single service providers and not usable by the rest of companies (Hofer et al. 2020). Therefore, the efficiency improvement is limited to some population segments.

1.4. Modelling and Simulation Methodologies

1.4.1. System Dynamics Simulation

System Dynamics is a traditional technique for social systems modelling (Macal 2010). A SD model is defined through a set of difference equations that are periodically solved in time. The roots of SD methodology are in dynamic systems and control theory and feedback effects between system components is highlighted as strong determinant of system behaviour: a small number of state variables that define the state of the system completely depend on the previous state of the system, for which the rate change of every state variable is specified.

System Dynamics models are defined as a triple: a set of variables at time t, a set of rate variables at time t dependent on previous time periods, and the temporal simulation engine that steps the model through time. Model specification includes auxiliary equations and secondary variables defined for convenience. Solving process is equivalent to solving a set of ordinary differential equations with step size Δt (Macal 2010).

1.4.2. Discrete-Event Simulation

DES models are a top-down modelling approach process oriented, focusing on modelling the system in detail instead of the entities, with one thread of control (centralised). Entities are passive and intelligence or decision process is modelled as part of the system, flowing through the system without a model since macro behaviour is modelled. Finally, inputs and distributions are based on measured objective data (Siebers et al. 2010).

Siebers et al. (2010) suggests that the community uses DES software due to the experience with toolkits, but new kinds of problems cannot be correctly addressed without ABS. ABS remains the expertise of few skilled experts. Although the topic of ABS in covered in the following subsection, an introduction to the methodology is included in the following lines for the shake of comparison:

ABS models are a bottom-up modelling approach individual oriented, focusing on modelling the entities and interactions, with one thread of control per agent (decentralised). Entities are active, with initiative and intelligence included in every individual entity, without flows since micro modelling emerges from the micro decisions of the individual agents. Finally, inputs are based on theories and subjective data (Siebers et al. 2010).

1.4.3. Agent-Based Modelling

Agent-based modelling and simulation is a different approach to complex systems with interacting autonomous agents whose behaviours can be described using simple rules. There is no universal agent definition, but common characteristics according to Macal (2010) for agent definition are:

- Self-contained, modular and uniquely identifiable individual, with boundaries.
- Autonomous and self-directed, independent in a range of situations of interest.
- Its state varies on time.
- Social and with dynamic interactions with other agents influencing it behaviour.
- Adaptive, gol-directed and other heterogeneous characteristics across the model.

Patterns and behaviours are not explicitly programmed in the model and arise through interaction with other agents and the environment, agents influence each other, learn from experience, and adapt behaviours. ABM can be applied in small models with essential details and for bigger models with great details (Macal and North 2010).

Agent-Based models are defined as a triple: a set of agents and their states at time t, a set of mechanisms that operates on the agents at time t dependent on previous time periods, and the agent interaction protocol that determines the interaction through time (Macal 2010).

1.4.4. Agent-Based Modelling for Urban Logistics Initiatives

The literature review of specific applications of ABM has shown that only a few of them focus on UL issues (Maggi and Vallino 2016). For example, Tamagawa et al. (2010) analysed the interaction between shippers, forwarders, administrators, and residents by using multi-agent models with reinforcement learning for the evaluation of logistics measures in the city. They pointed out that win-win situations for stakeholders are possible when restrictions on truck flow and common delivery systems are implemented. Similarly, Suksri and Raicu (2012) developed a framework for modelling the dynamic behaviour of different participants in urban freight distribution to enable the evaluation of different strategic measures.

2. Literature Review

2.1. APL Perception, Parameter Tunning and APL Design

Iwan et al. (2016) research the APL acceptance by Polish citizens, addressing its strengths regarding usability and location, finding that main driver for customer's acceptance is location. Similarly, Moroz and Polkowski (2016) analyse the link between APL and the environment for the Y generation. The main outcome, convenience for reception is more important than environmental considerations, but some customers would pay higher prices for cleaner delivery methods. Collins (2015) finds that shorter distances to the APL can lead to a modal shift from car to cleaner transportation and delivery methods. The reduced number of trips could lead to environmental benefits and a reduction in vehicle driven kilometres. Keeling et al. (2020) study the potential of APL in different transport facilities in Portland. The proactive development a public and private partnership with logistic companies is suggested, as different advantages are observed in the various facilities available. Wen and Li (2016) studies the vehicle route optimization problem for Urban Distribution in Mingguangcun, Beijing when APL are present. When APL are present emissions are diminished by 97%, traffic congestion is avoided, and the time window constraints are reduced.

Population acceptability, growth forecasting and ecommerce and APL integration in urban areas have already been contemplated in different geographies. Bjartmar Hylta and Söderberg (2017) investigate the APL market and forecast empirically in London (UK) and found that security concerns, integrability, customer support, and trialability are the biggest obstacles for the APL technology diffusion. Vakulenko et al. (2018) aim to obtain knowledge about customer's perspective of value creation using APL solution following a focus group through interviews and the application of grounded theory. Wang et al. (2018) followed a different approach and used an attitude measuring model with the purpose of assessing APL acceptance by consumers, finding that potential users are attracted by compatibility and trialability but refuse complexity. De Marco et al. (2020) and Mitrea et al. (2020) use an online survey to assess the willingness of the population in Turin (IT) to accept APL technology, based on the main drivers described in the literature.

Two major streams for APL configurations were first introduced by Dell'Amico et al. (2011): monolithic smart locker bank and modular smart locker bank. These design concepts were further developed by Faugère and Montreuil (2017) extending the concept into four design schemes: fixed-configuration, modular tower based, modular locker based and Physical Internet handling container. On a more recent study, Faugère and Montreuil (2020) propose a design method for smart locker banks in an omnichannel supply chain environment, comparing two conceptual designs: fixed configuration locker bank and modular tower-based locker train. Their approach embraces a multistakeholder perspective and deals with uncertainty through a set of probabilistic scenarios, maximizing expected profit.

2.2. APL Macro-location

Rabe et al. (2020a; 2020b; 2021) study the use of APL in de city of Dortmund combining Simulation and Optimization models to represent different scenarios and enabling better support to APL macro localization optimization as tool in UL. They also suggest that dynamic planning methods have not been implemented in APL before.

The contributions made to already existing literature concerning APL are:

- Applying SDSM in the UL field, enriching APL simulation as a LMD alternative.
- Combining SDSM and FLP to have a better representation of real-life APL dynamics.
- Ex-ante behavioural analysis in a real case scenario concerning dynamic variables and their evolution leading to future scenarios and their effect on the APL network.
- Implementation of stochasticity and reliability analysis in the APL network design.

In the proposed model they follow an Integrated Simulation-Optimization Approach (SO), where three different steps are involved:

1. System Dynamics Simulation Model (SDSM) used to find interdependencies and KPIs for the problem.
2. Optimization with the objective of solving the Multiperiod Capacitated Facility Location Problem (MCFLP)
3. Monte Carlo Simulation (MCS) which uses simulation as a tool to estimate cost and reliability of different plausible solutions.

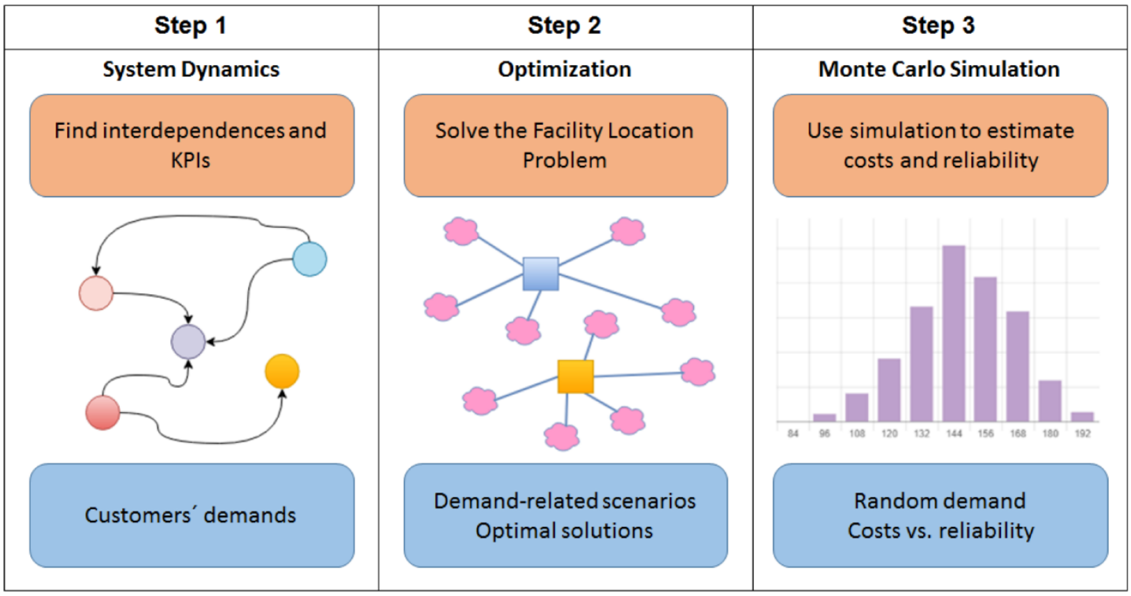

Figure 3. Schema of a Simulation Optimization Approach. Source: Rabe et al. (2021)

2.2.1. System Dynamics Simulation Model

SDSM generates the dynamic behaviour of models, emphasizing time functions and explaining the effects of decisions in complex dynamic systems undergoing constant iteration, continuous questioning, testing, and refinement.

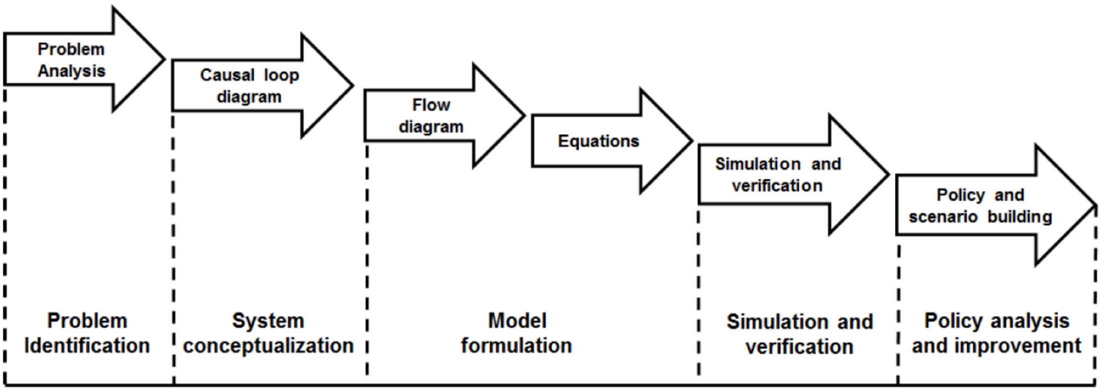

Figure 4. Schema of a SDSM. Source: Rabe et al. (2021)

The first step is identifying the problem. The objective is designing an APL network fulfilling all the requirements of customers and the environment of the city. Identifying the issue, relevant stakeholders, known information and setting variables and a suitable time horizon for the model.

Then, a Causal Loop Diagram (CLD) can be used for system conceptualization. This will help understanding the behaviour and interdependencies of all the components of the APL network from a qualitative point of view. CLD are used to link stocks, flows, information sources and identifying primary feedback loops.

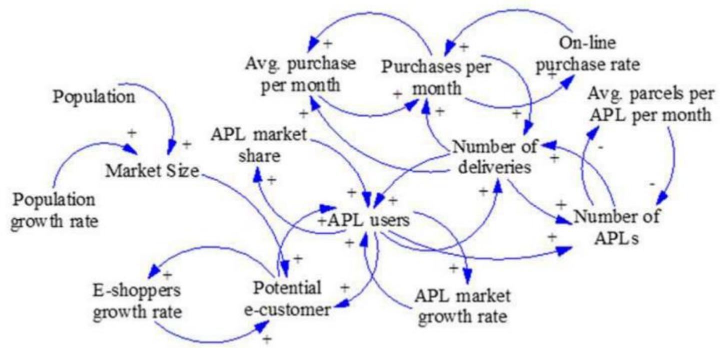

Figure 5. Proposed CLD for APL network design. Source: Rabe et al. (2021)

The next step is model formulation that can be done using a Stock and Flow Diagram (SFD) that quantifies the previous CLD. Now, some components are defined as stocks (squared), flows (straight lines) and auxiliary variables (curved lines).

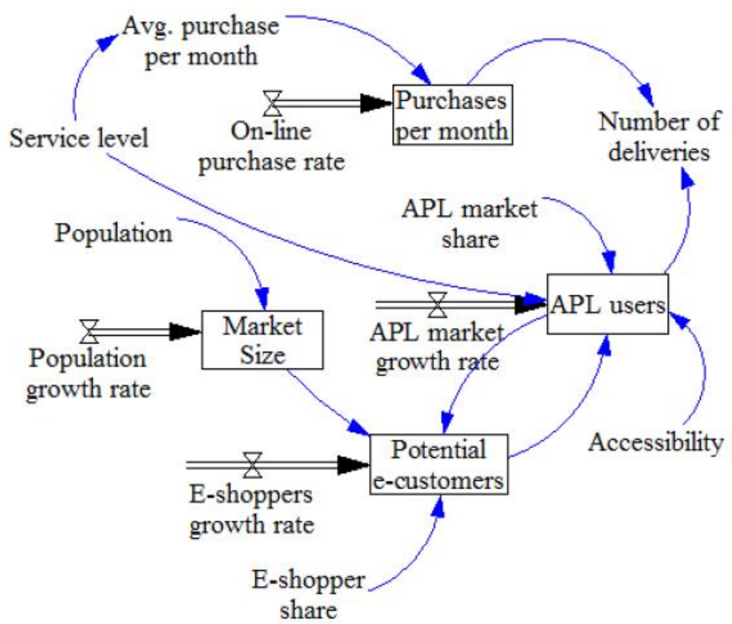

Figure 6. Proposed SFD for APL network design. Source: Rabe et al. (2021)

Now that the model has been defined, simulation can be done. Since components are defined, we can use known data as a first iteration. The dynamics previously defined will change the outcome in every new iteration and generate a different scenario in every period.

2.2.2. *Multiperiod Capacitated Facility Location Problem*

The FLP is a critical strategic business decision. An optimization challenge with the objective of determining the optimal location for the right number of facilities that serve a range of demand points. The FLP consists of potential locations and several demand points that need to be served. The objective is to find the subset of facilities that minimize the total cost of operation. In a classic FLP, customers will be assigned to the nearest open facility using an active connection.

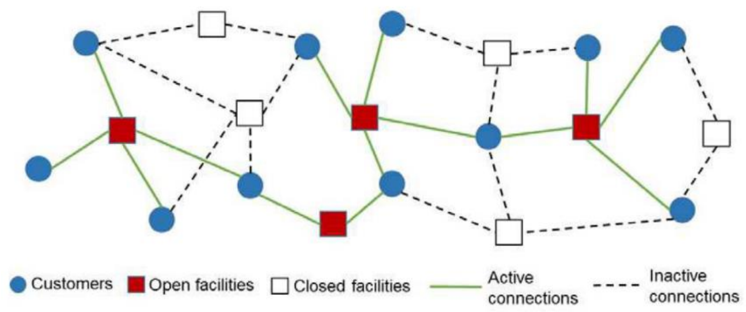

Figure 7. Illustrative example of FLP. Source: Rabe et al. (2021)

Capacitated FLP consider that facilities have a maximum and known limit to the demand they can meet and once this demand is met, customers will remain unserved. Said demand can be deterministic or stochastic. When a CFLP is multi-period, decisions made in each period will affect future periods over the initially set time horizon.

The problem is then defined as follows:

$$Minimize \sum_{i\in I}\sum_{j\in J}\sum_{k\in K} c_{ij}d_{jk}x_{ijk} + \sum_{i\in I}\sum_{k\in K} f_{ik}(\gamma_{ik-1}) + h_{ik}(\gamma_{ik}) \qquad (1.1)$$

Subject to:

$$\sum_{i\in I} x_{ijk} = 1, \qquad \forall j \in J, \forall k \in K \qquad (1.2)$$

$$\gamma_{ik} \leq \gamma_{ik-1}, \qquad \forall i \in I, \forall k > 0 \in K \qquad (1.3)$$

$$\sum_{i\in I} \gamma_{ik} = \rho_k, \qquad \forall i \in I, \forall k > 0 \in K \qquad (1.4)$$

$$\sum_{j\in J} d_{ij}x_{jk} \leq a_i\gamma_{ik}, \qquad \forall i \in I, \forall k \in K \qquad (1.5)$$

$$x_{ijk} \in \{0,1\} \qquad i \in I, j \in J, k \in K \qquad (1.6)$$

$$\gamma_{ik} \in \mathbb{Z}^{+}, \qquad \forall\, i \in I \;\; \forall\, k \in K \qquad (1.7)$$

$$\sum_{j \in I} d_{jk} \geq m \sum_{i \in I} a_i \gamma_{ik}, \qquad \forall\, k \in K \qquad (1.8)$$

"The expression (1.1) indicates the objective function that minimizes the total costs: The first term indicates the service costs of APLs, while the second represents the fixed costs of opening new APLs in the time horizon. Constraints (1.2) ensure that for each period k ∈ K and each district j ∈ I exactly one APL is assigned. Restrictions (1.3) ensure that once an APL is opened, it remains open until the end of the time horizon. Constraints (1.4) ensure that for each APL in district i ∈ I and period k < K, the demand served by that APL does not exceed its capacity. Constraints (1.5) guarantee a minimum utilization percentage of the total installed capacity of APLs for each k ∈ K period. Finally, constraints (1.6) and (1.7) specify the ranges of the decision variables.

Decisions taken in a particular period affect future periods over a time horizon K. In particular, since demand is expected to grow during the next periods, we will assume that whenever an APL is installed inside a period k ∈ K, it has to remain installed until the end of the time horizon, i.e., for all k' ∈ K: k' > k. Similarly, third-party logistics providers state that a minimum percentage m ∈ (0, 1) of the total installed capacity has to be utilized. Therefore, Constraints (1.8) guarantee, for each period k ∈ K, this minimum utilization percentage." (Rabe et al, 2021).

2.2.3. Monte Carlo Simulation

The term Monte Carlo Simulation includes simulations that are "a scheme employing random numbers, which is used for solving certain stochastic or deterministic problems where the passage of time plays no role" (Law and Kelton, 2010). The use of stochastic distribution in the model or random number generation gives to the method characteristics not present in continuous simulation, obtaining a set of results. With the introduction of stochasticity, uncertainty, risk, and reliability for each solution can be assessed.

Each scenario is tested (n times) and the different outcomes will fail (b_{ks} times) or succeed due to stochasticity. Then reliability of its associated solution can be measured as follows:

$$R_{ks} = \left(1 - \frac{b_{ks}}{n}\right) * 100\% \qquad for\ all\ k \in K\ and\ s \in S \qquad (2)$$

2.2.4. Integrated Simulation-Optimization Approach

The Integrated Simulation-Optimization approach offers a feasible solution for scenarios with uncertainty. In sequential combinations, simulation or optimization must be completed before the other is executed. Hybrid models like this can change between optimization and simulation during the execution and the model result is improved by refining parameters or extending them (which generates different scenarios).

The five main steps in the iterative process and verification are:

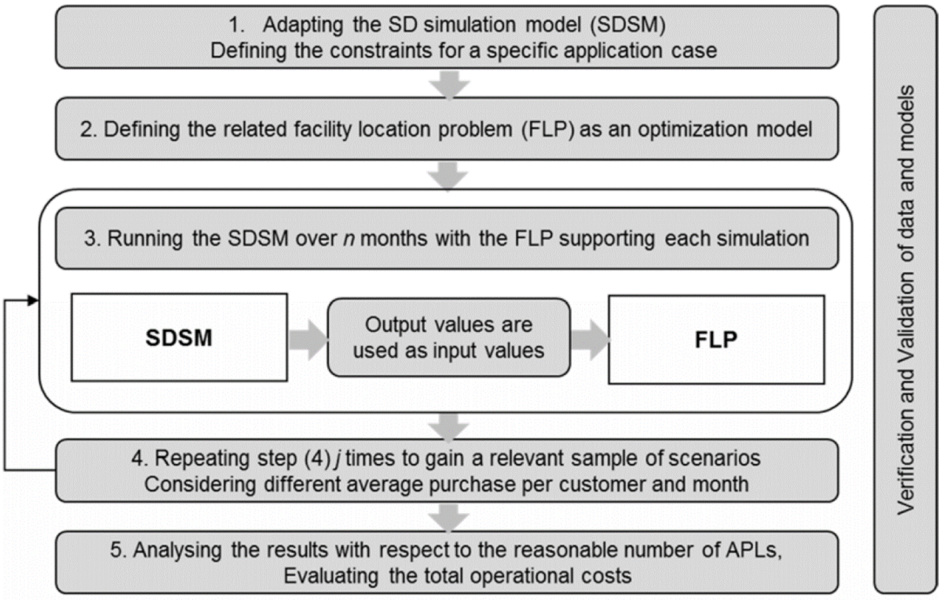

Figure 8. Procedure model for SDSM and FLP combination. Source: Rabe et al. (2021)

2.3. APL Micro-location

Deutsch and Golany (2018) study the optimal location and size of fixed APL and propose the first quantitative approach to the solution. In this model, deterministic customer's choices are assumed, and the objective of the algorithm is optimization and operator's profit maximisation. Lin et al. (2020) study the fixed APL network design. A random utility model is implemented for customer choice prediction, probabilistic interpretations can be a representative solution (Gul et al. 2014) when individual choice behaviours are unknown (Ljubić and Moreno 2018).Schwerdfeger and Boysen (2020) analyse the dynamic location model of mobile APL. As an assumption for model development. APL's location can change any moment so that locations are optimized. The objective is mobile APL number minimization while a sufficient service is available for customers.

3. Methodology

This Master thesis introduces the concept of mobile automated parcel lockers into the APL network design at a macro-planning level as an evolution of previous researches previously reviewed.

Hybrid modeling approaches reflect the complexity of real systems and combine different modeling approaches to solve complex system problems (Martinez-Moyano and Macal 2016). By combining different modeling approaches, a hybrid model could provide a more comprehensive with a holistic view of the system and a very powerful approach to understand the complexity of systems like UL. In our case, we combine an Agent-Based modelling approach with an adapted FLP for APL systems.

The analysis is based on the city of Pamplona (Spain) as a real-world case study. Firstly, an Agent-Based Model (ABM) is designed to determine the three-year performance (divided into weeks) to estimate the future demand based on a number of socio-economic parameters. Then, these results are integrated into a facility location model, which provides the optimal number and location of APLs. An overview of the simulation-optimization framework is shown in Figure 9, which will be discussed in the following subsections.

3.1. Simulation Model

The simulation model was implemented in Anylogic 8.7.3 (AnyLogic 2021) using an agent-based modelling approach over node and time sets $\mathscr{I} = \{1, 2, 3, ..., I\}$ and $\mathscr{T} = \{0, 1, 2, ..., T\}$, respectively.

Additionally, each node represents the set of city districts $i \in \mathscr{I}$ and the set of customers $j \in \mathscr{I}$. The simulation starts with given initial values at t=0 related to the population, eShoppers, APL users, and parcel demands. The simulation is built using the districts as the basic agents. Therefore, the previous magnitudes are referred to each district $i \in \mathscr{I}$.

Afterwards, this data is updated on a weekly basis for population, eShoppers, APL users, and parcel demands following the procedure described in Figure 9:

$$population_{it} = population_{it-1}\alpha_{it}\varepsilon \qquad \forall\, i \in \mathscr{I}, \forall\, t \in \mathscr{T}: t > 0 \qquad (3.1)$$

$$eShoppers_{it} = eShoppers_{it-1} + \beta_{it}\,(population_{it-1} - eShoppers_{it-1})\varepsilon \qquad \forall\, i \in \mathscr{I}, \forall\, t \in \mathscr{T}: t > 0 \qquad (3.2)$$

$$APLusers_{it} = APLusers_{it-1}\gamma_{it}\varphi_{it}\varepsilon \qquad \forall\, i \in \mathscr{I}, \forall\, t \in \mathscr{T}: t > 0 \qquad (3.3)$$

$$parcelDemand_{it} = APLusers_{it}\rho\rho\mu_{it}\delta_{it}\varepsilon \qquad \forall\, i \in \mathscr{I}, \forall\, t \in \mathscr{T}: t > 0 \qquad (3.4)$$

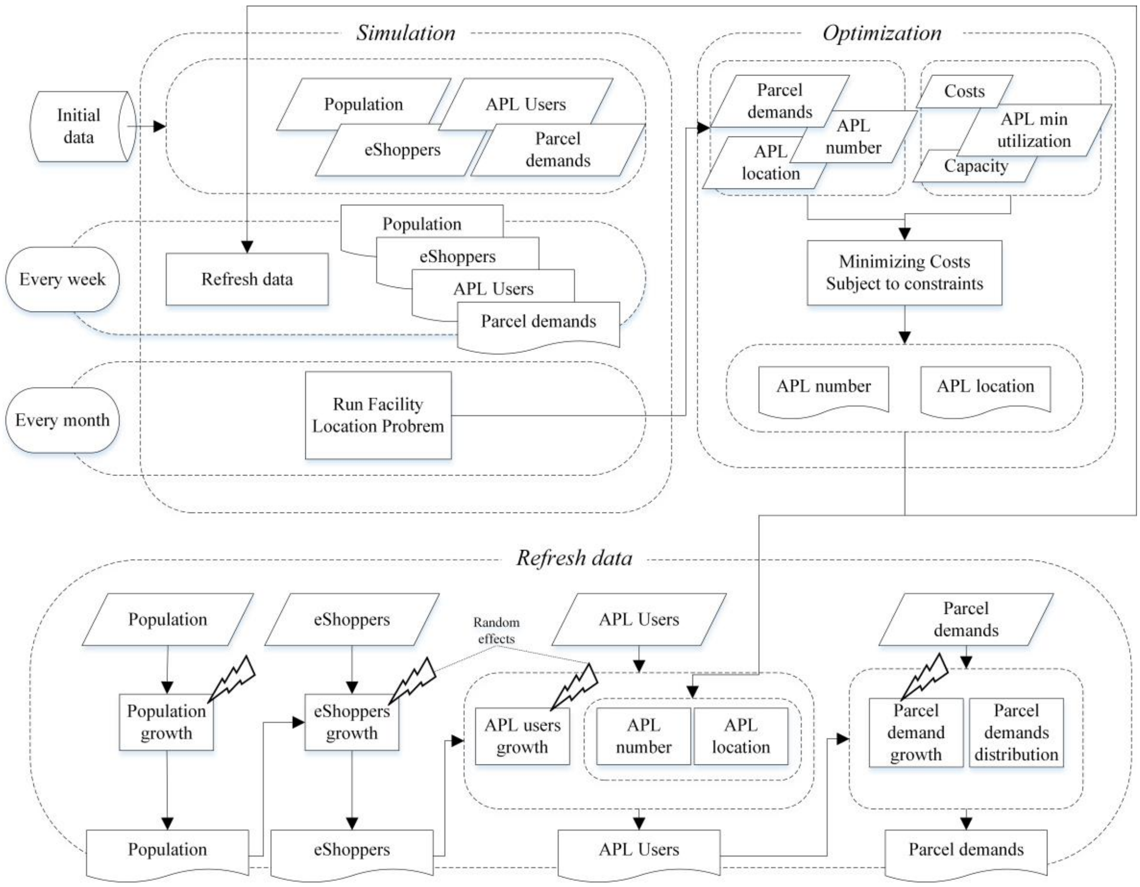

Figure 9. Simulation-Optimization Framework

Where α_{it} is a random variable for historical population growth in the city, whereas β_{it}, γ_{it}, and δ_{it} are the growth factors for eShoppers, APL users, and purchases per user, respectively from t−1 to t, such that:

$$\beta_{it} = \beta_{it} - 1\varepsilon \quad \forall\ i \in \mathscr{I},\ \forall\ t \in \mathscr{T}: t > 0 \quad (4.1)$$

$$\gamma_{it} = \gamma_{it} - 1\varepsilon \quad \forall\ i \in \mathscr{I},\ \forall\ t \in \mathscr{T}: t > 0 \quad (4.2)$$

$$\delta_{it} = \delta_{it} - 1\varepsilon \quad \forall\ i \in \mathscr{I},\ \forall\ t \in \mathscr{T}: t > 0 \quad (4.3)$$

The β_{it} variables need to be adjusted at t=0 by dividing the real eShoppers yearly growth rate over the eShoppers share initial value. Moreover, ε represents the random effects shown at the bottom of Figure 9 as they are realizations from uniform distributions such that $E{\sim}U(a.b)$.

Additionally, φ_{it} stands for the effect of APL availability (the number and location of APLs in district i at time t). This effect is formulated in our simulation model as follows:

$$\varphi_{it} = 1 + \omega \frac{y_i}{\sum_{i \in I} y_i} \quad \forall\ i \in \mathscr{I},\ \forall\ t \in \mathscr{T}: t > 0 \quad (5)$$

Being ω the sensitivity of increasing the number of APL users and $\mathrm{y_i}$ the number of APLs available in district i ∈ $\mathcal{I}$. Finally, the purchases per APL user (ppu_{it}) are obtained by combining the average purchases per year and APL user (pp_y) with the demand distribution (dd_t) on a yearly basis:

$$ppu_{it} = pp_y\, dd_t \qquad (6)$$

Finally, every month, the FLP solver procedure is launched considering the simulated data at that point and feed-backing the simulation model by determining the optimal number and location of APLs. This process is further detailed in Section 3.2 and Section 3.3.

3.2. Facility Location Model for Mobile APL

An FLP is integrated within the simulation framework and solved using IBM®ILOG CPLEX 12.6.2 API for the Java Environment solver. This optimization model is defined over the same set of nodes (i, j) ∈ $\mathcal{I}$. representing districts and customers, respectively. This FLP seeks the optimal location of APLs and assignment of customers to districts hosting APLs in such a way total costs are minimized subject to a number of constraints. In this respect, Table 3 shows the model variables whereas Table 4 shows the model parameters.

Variable	**Description**
x_{ij}	1 if customer j ∈ I is assigned to APL located at district i ∈ $\mathcal{I}$
y_i	Number of APLs located at district i ∈ $\mathcal{I}$
yIn_i	Number of new APLs set up at district i ∈ $\mathcal{I}$
$yOut_i$	Number of APLs retired at district i ∈ $\mathcal{I}$
$h1_i$	Auxiliary variable
$h2_i$	Auxiliary variable

Table 3. Model variables

Parameter	**Description**
c_{ij}	Cost of assigning customer j ∈ $\mathcal{I}$ to an APL located at i ∈ $\mathcal{I}$
d_j	Demand of customer j ∈ $\mathcal{I}$
sc_i	Cost of setting up am APL at district i ∈ $\mathcal{I}$
dc_i	Cost of decommissioning an APL at district i ∈ $\mathcal{I}$
uc_i	Cost of keeping working an APL at district i ∈ $\mathcal{I}$
m	Minimum percentage of an APL capacity utilization
a_i	APL capacity at district i ∈ $\mathcal{I}$
y_{it-1}	Number of previously existing APL at district i ∈ $\mathcal{I}$

Table 4. Model parameters

The FLP is defined as follows:

$$Minimize \sum_{\substack{i \in I \\ j \in I}} c_{ij} d_{ij} x_{ij} + \sum_{i \in I} sc_i(yIn_i) + \sum_{i \in I} dc_i(yOut_i) + \sum_{i \in I} uc_i(y_i) \quad (7.1)$$

Subject to:

$$yIn_i = y_i - y_{it-1} + h_{1i,} \qquad \forall \text{ i} \in \mathscr{I} \quad (7.2)$$

$$yOut_i = y_{it-1} - y_i + h_{2i} \qquad \forall \text{ i} \in \mathscr{I} \quad (7.3)$$

$$\sum_{i \in I} xij = 1, \qquad \forall j \in \mathscr{I} \quad (7.4)$$

$$Mx_{ij} \geq y_i \forall i = j, \qquad \text{(i, j)} \in \mathscr{I} \quad (7.5)$$

$$\sum_{j \in I} dj \geq m \sum_{i \in I} a_i y_i \quad (7.6)$$

$$x_{ij} \in 0{,}1, \qquad \forall \text{ (i, j)} \in \mathscr{I} \quad (7.7)$$

$$y_{i,} yln_{i,} yOut_{i,} h1_{i,} h2_i \in \mathbb{Z}^+, \quad \forall \text{ i} \in \mathscr{I} \quad (7.8)$$

The objective function (7.1) defines the total costs that comprise the items described in the following lines, beginning with the service costs of assigning costumers to districts where an APL is available. These service costs depend on the distance and demand. The second term represents the costs of setting up the APL and the third one the costs of decommissioning an existing APL. Fourthly, the cost of maintaining an APL from one time period decision to the following is included.

Constraints (7.2) and (7.3) define the new APL to set up and the APL to retire, respectively. The auxiliary variables h1 and h2 are used for each i $\in \mathscr{I}$ in order to fulfil the equalities. Constraints (7.4) force each customer j $\in \mathscr{I}$ to be assigned to a district i $\in \mathscr{I}$ where an APL is available. Similarly, constraints (7.5) force each customer j $\in \mathscr{I}$ to be assigned to its own district if there is an APL located. M stands for a sufficiently large number. Equation (7.6) ensures a minimum APL utilization for a given demand. Finally, expressions (7.7) and (7.8) define the variable ranges.

3.3. Facility Location Model for Fixed APL

Variable and Parameters introduced in Table 3 and Table 4 from Section 3.2 are also applicable to this second model where APLs are considered fixed to its district.

The FLP is defined as follows, where restrictions are defined as in the previous model:

$$Min\ totalCost\ = \sum_{\substack{i \in I \\ j \in I}} c_{ij} d_{ij} x_{ij} + \sum_{i \in I} sc_i(yln_i) + \sum_{i \in I} uc_i(y_i) \quad (8.1)$$

Subject to:

$$yln_i = y_i - y_{it-1} + h_{1i} \qquad \forall\ i \in \mathscr{I} \quad (8.2)$$

$$\sum_{i \in I} xij = 1 \qquad \forall\ j \in \mathscr{I} \quad (8.3)$$

$$Mx_{ij} \geq y_i \forall i = j \qquad \forall\ (i, j) \in \mathscr{I} \quad (8.4)$$

$$\sum_{j \in I} dj \geq m \sum_{i \in I} a_i y_i \qquad (8.5)$$

$$x_{ij} \in 0{,}1 \qquad \forall\ (i, j) \in \mathscr{I} \quad (8.6)$$

$$y_{i,} yln_{i,} h1_{i,} \in \mathbb{Z}^{+} \qquad \forall\ i \in \mathscr{I} \quad (8.7)$$

The objective function (8.1) defines the total costs that comprise the items described in the following lines, beginning with the service costs of assigning costumers to districts where an APL is available. These service costs depend on the distance and demand. The second term represents the costs of setting up the APL and the third cost corresponds to maintaining an APL from one time period decision to the following.

Constraints (8.2) define the new APL to set up. The auxiliary variable h1 is used for each i $\in \mathscr{I}$ in order to fulfil the equalities. Constraints (8.3) force each customer j $\in \mathscr{I}$ to be assigned to a district i $\in \mathscr{I}$ where an APL is available. Similarly, constraints (8.4) force each customer i $\in \mathscr{I}$ to be assigned to its own district if there is an APL located. M stands for a sufficiently large number. Equation (8.5) ensures a minimum APL utilization for a given demand. Finally, expressions (8.6) and (8.7) define the variable ranges.

4. Computational experiments

4.1. Parameter settings

The model is tested in the city of Pamplona, in Northern Spain, for a time horizon of 3 years divided in weeks (i.e., T = 157). The Pamplona metropolitan area accounts for 203,944 inhabitants (Instituto de Estadística de Navarra 2020) spreading over 13 districts (i.e., I = 13). In this sense, Table 5 shows the districts and their current population.

District	Population
Azpilagaña	7,374
Buztintxuri	8,771
Casco Viejo	11,187
Chantrea	19,450
Ensanche	25,994
Ermitagaña	16,798
Echayacoiz	5,255
Iturrama	22,976
Mendillorri	10,966
Milagrosa	17,552
Rochapea	25,739
San Jorge	11,994
San Juan	19,888
Total	203,944

Table 5. Population per district in Pamplona

Month	*dd*
January	0.0686
February	0.0653
March	0.0705
April	0.0740
May	0.0791
June	0.0805
July	0.0800
August	0.0763
September	0.0784
October	0.0869
November	0.1171
December	0.1232
Total	1

Table 6. Monthly demand distribution

A time series analysis using historical data for the last 24 years (Foro-Ciudad 2021) in the city of Pamplona shows that population growth rate α_{it} follows a Weibull distribution with $\lambda = 1.24252$, and $\varkappa = 0.01646$. From the national survey conducted in IAB Spain (2021), 93.2 % of the Spanish population has internet access and 67.5 % of those people buy online, giving an e-shopper share of 63 %. The average purchase in Spain is 3.5 parcels per month or 42 parcels per year.

Some international second sources offer information used for weekly demand distribution assessment: the value of internet retail sales monthly (Coppola 2021) is adjusted taking the daily trends in sales volume per month (Brad Ward 2021) and integrated into the simulation model. These monthly data are shown in Table 6.

These monthly values are distributed on a weekly basis during the time horizon. Based on data available in related literature (Rabe et al. 2021), the yearly e-shopper growth rate is set to 10 % and the APL user growth rate is assumed to be the same for simplicity reasons. The APL user share is initially set to 2.2 % of the total population and recomputed in every period in accordance with the system environment. A summary of the initial values for the simulation is available in Table 7.

Finally, yearly growth rates are translated into weekly using $week = \sqrt[52]{1 + year} - 1$

Parameter	Definition	Initial value
$population_{io}$	Current inhabitants per district	See Table 5
$eShoppers_{io}$	Current eShoppers	$0.63 * population_{io}$
$APLusers_{io}$	Current APL users	$0.22 * eShoppers_{io}$
pp_y	Average e-purchases per year	42
α_{i0}	Yearly population growth rate	$A \sim W\ (\lambda = 1.24, \kappa = 0.01)$
β_{i0}	Yearly eShoppers growth rate (adjusted)	0.158
y_{i0}	Yearly APL users growth rate	0.1
o_{i0}	Yearly parcel demand growth rate	0.2
dd	Demand distribution	See table 6
ω	Sensitivity of increasing APL user	0.01
ε	Random effects	E~U (0.8,1.2)

Table 7. Initial values for the simulation (t=0)

With respect to the parameters in the FLP, the set-up costs of an APL are fixed to s_{ci} = 3300 €, decommissioning costs per APL are d_{ci} = 150 €, and the maintenance costs are u_{ci} = 300 €. The costs of assigning a customer to an APL in a different district (c_{ij}) are computed considering the distance among any pair of node from its centroid. Likewise, customer parcel demands (d_j) are given from the simulation model.

No public data are available regarding e-commerce in Pamplona and initial data are gathered primary data from direct observation and using different national and international secondary resources. According to these primary data (observations), the mean size of APLs already active in Pamplona is 72 cubicles, which can be used for the delivery of a new parcel from Monday to Friday, adding up to a total capacity of a_i = 360 parcels per week. In addition, minimum capacity utilization can be fixed to m = 30 % after analysis of the gathered real data.

4.2. Scenario definition

To test the proposed methodology, we defined a set of scenarios based on key parameter levels. 18 scenarios are defined, where 9 correspond to the Mobile APL model in which existing APL can be closed from one month to another, and 9 other simulations are run using the Fixed APL model, in which once an APL is opened in the network it remains open until the end of the simulation. The 9 scenarios defined for each model are the same: a combination of three different initial APL user growth rates (γ_{i0}) that will affect the overall performance of the system and is difficult to estimate from existing literature, and the sensitivity (ω) with utmost interest as feedback to the simulation model. The sensitivity (ω) represents the "call effect" caused by the growth of APL Networks that improve usability considerations (integration in the LMD scheme, population education and convenience of new APL closer to the user) originating from the output of the optimization model.

In scenarios (1, 2, 3), (4, 5, 6) and (7, 8, 9), the initial APL user growth rate γ_{i0} is set to 5%, 10% and 25%, respectively, as can be extracted from the previous paragraph, it means that the initial value of the parameter APL users growth is set to 5%, 10% or 25%. In scenarios (1, 4, 7), (2, 5, 8) and (3, 6, 9) the sensitivity ω APL effect is 0%, 1% and 3%, respectively. This means that the feedback from the APL Network growth affects the model in 0% (no effect), 1% and 3%. These scenarios are summarized in Table 8 for easier understanding.

This scenario definition allows model sensibility analysis and comparison with different initial conditions and different evolution parameters, in addition to the uncertainty included with the random effects $E \sim U(0.8, 1.2)$.

		Mobile APL			Fixed APL		
		ω			ω		
		0.00	0.01	0.03	0.00	0.01	0.03
γ_{i0}	0.05	$S1_m$	$S2_m$	$S3_m$	$S1_f$	$S2_f$	$S3_f$
	0.10	$S4_m$	$S5_m$	$S6_m$	$S4_f$	$S5_f$	$S6_f$
	0.25	$S7_m$	$S8_m$	$S9_m$	$S7_f$	$S8_f$	$S9_f$

Table 8. Simulation-optimization considered scenarios

4.3. Results

4.3.1. Mobile APL

The results are based on 100 runs for any scenario and are given in the key magnitudes described in the methodology. Population and eShoppers do not depend on the scenarios, because they are not affected by the parameters included there. Figure 10 shows 100 runs for projected population and Figure 11 for eShoppers.

Mean values over the 100 runs are also available in Table 9 at the beginning of the simulation (t = 0), year 1 (t = 53), year 2 (t = 105) and the end of year 2 (t = 156). Our simulation projects an increase of population of around 9,000 inhabitants (~ 4 %) and 18,000 eShoppers (~ 13 %).

	Population		eShoppers	
	Mean	sd	Mean	sd
$t = 0$	203,944.00	0.00	128,623.96	4.56
$t = 53$	207,045.95	93.52	135,465.70	1,042.50
$t = 105$	210,211.47	139.98	141,155.86	2,468.93
$t = T$	213,118.80	163.76	145,462.41	3,637.91

Table 9. Population and eShopper values for given moments based on 100 simulations (mobile APL)

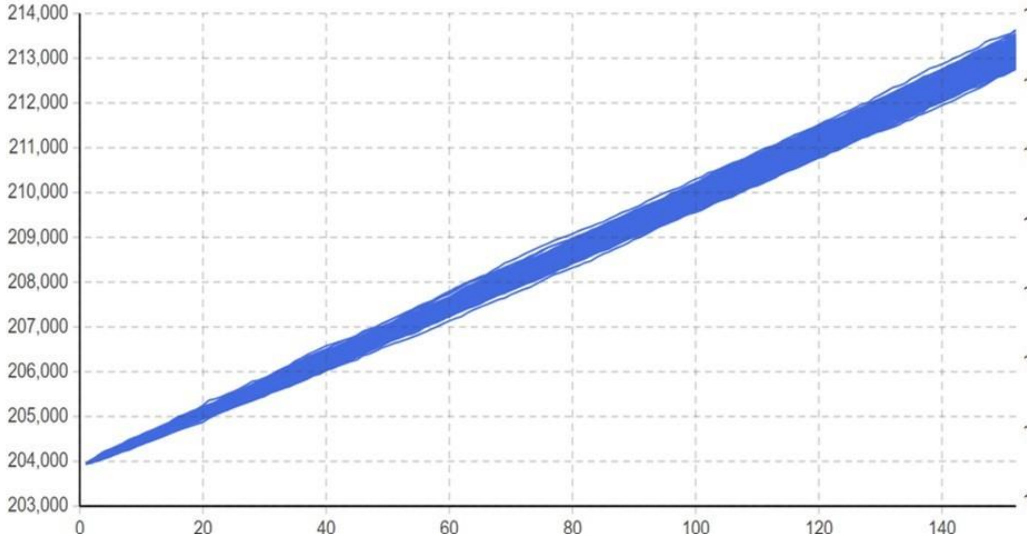

Figure 10. Population evolution for 100 simulations (mobile APL)

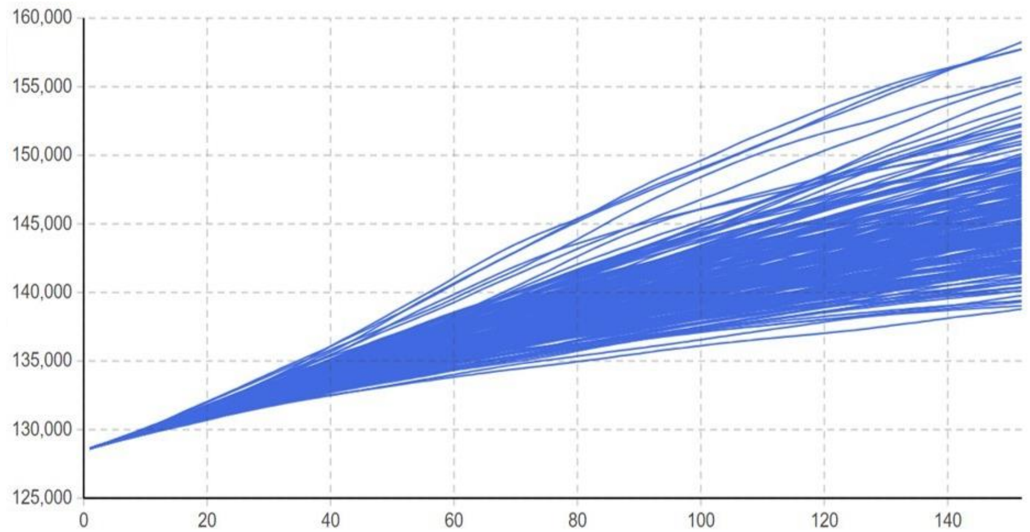

Figure 11. eShopper evolution for 100 simulations (mobile APL)

Focusing on the scenarios described in Section 4.2, Figure 12 shows the expected evolution on APL users and Figure 13 the expected parcel demands in scenarios $S4_m$ (blue) and $S5_m$ (red). Scenario $S4_m$ accounts for a 10 % average APL users growth (γ = 0.10) and ω = 0.00, that is, there is no effect from APL availability on increasing the APL users growth rate, whereas S5 considers ω to be set at 0.01. Similarly, we can see the expected evolution in the same scenarios for the number of APLs in the city for any time (Figure 14). These approximately match the expected demands shown in the Figure 13.

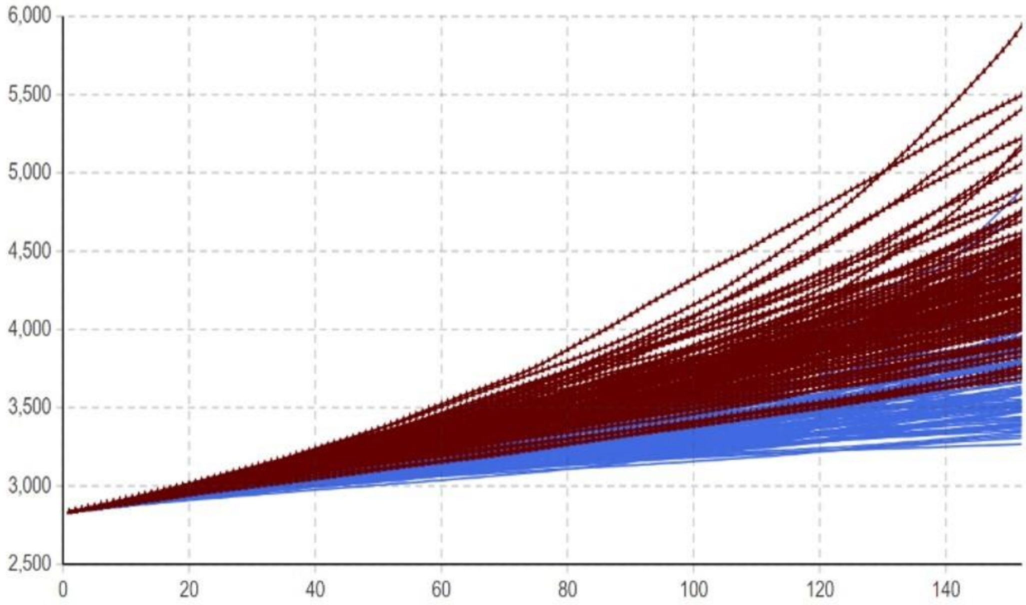

Figure 12. APL users evolution in $S4_m$ (blue) and $S5_m$ (red) for 100 simulations each

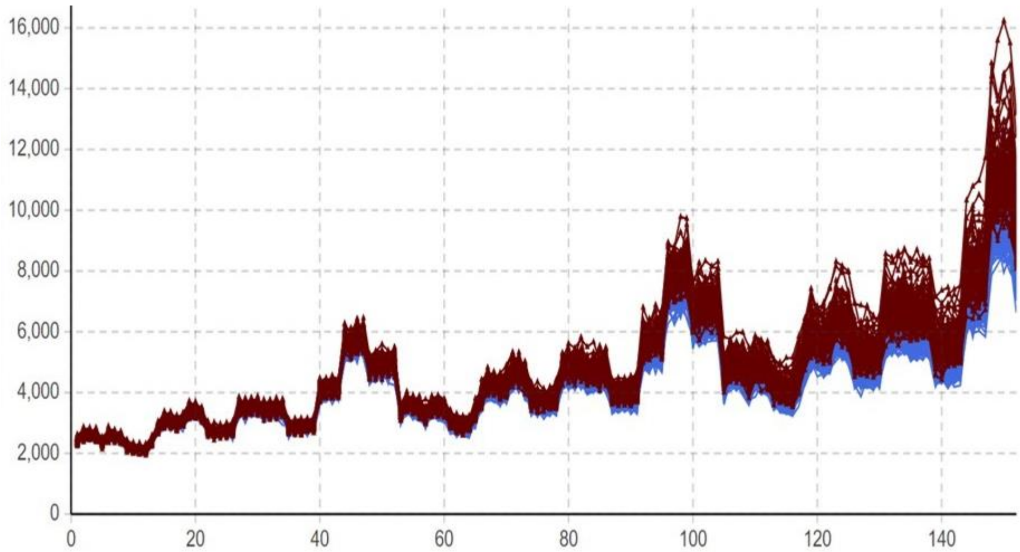

Figure 13. Parcel demand evolution in $S4_m$ (blue) and $S5_m$ (red) for 100 simulations each

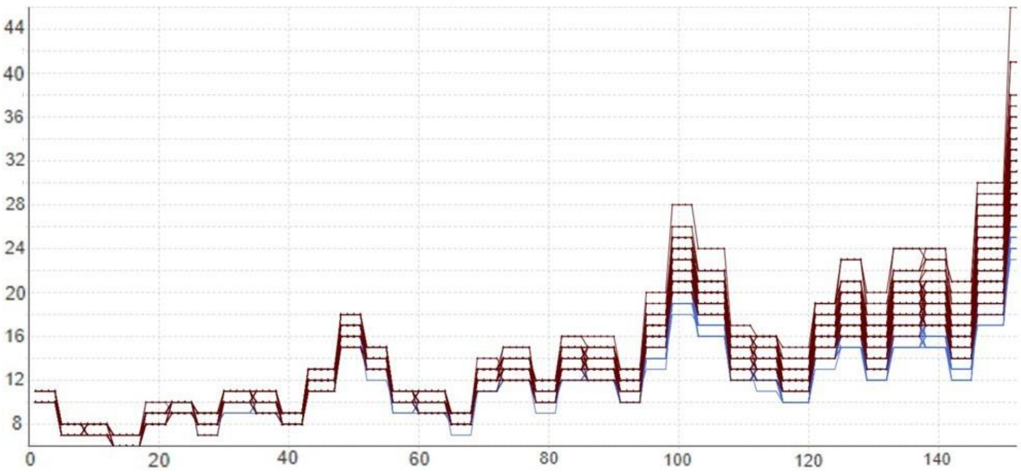

Figure 14. Number of APLs evolution in $S4_m$ (blue) and $S5_m$ (red) for 100 simulations each

In all cases, we can see the effect of the optimization feedback on the number of APL users, parcel demands, and number of APLs. The actual numbers including all the scenarios considered are shown in Table 10. There, we can see how scenarios ω = 0 clearly boost the number of APL users that increases the parcel demand, the number of APLs in the system, and their total costs. For example, $S9_m$ (that stands for a rapid growth in APL users and a huge effect of having an APL nearby) is more than twice the values obtained in $S8_m$ and $S7_m$ in which ω is reduced to 0.01 and 0, respectively. Therefore, a ω = 0.03 value seems to be unreliable.

More interesting are the comparisons between scenarios with ω = 0 and ω = 0.01 (without, and with, APL effects, respectively). In this sense, in a slow APL growth ($S1_m$ and $S4_m$) the ω effect is 15 % increase of APL users, 14 % increase in parcel demands and number of APLs (from average 24 to 27, a 12% increase), and 8 % increase in costs at the end of the simulation.

In the case of moderate APL growth ($S4_m$ and $S5_m$), the increase is similar, but in rapid APL growth ($S7_m$ and $S8_m$) it falls to around 11 %: the greater the APL growth rate, the lower the APL (ω) effect.

	APL users		Parcel demand		Number of APL		Total cost	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd
$S1_m$	3,272.09	172.49	7,186.89	429.46	23.85	1.43	657,993.26	16,526.37
$S2_m$	3,810.17	235.36	8,411.82	638.78	27.81	2.02	719,537.78	25,343.42
$S3_m$	7,660.02	2,422.42	16,974.89	5,373.24	54.79	16.80	1,032,920.00	196,625.69
$S4_m$	3,747.24	329.08	8,194.55	810.25	27.16	2.51	708,084.39	27,324.62
$S5_m$	4,347.51	386.85	9,499.57	888.88	31.71	3.05	775,766.00	32,739.59
$S6_m$	8,356.39	2,574.75	18,399.59	5,637.25	58.51	16.38	1,111,699.28	194,046.28
$S7_m$	5,703.36	1,475.21	12,533.51	3,429.23	40.61	9.92	892,937.53	95,438.61
$S8_m$	6,357.13	1,791.49	13,921.99	3,932.89	45.14	11.81	950,118.11	107,879.39
$S9_m$	12,393.40	5,455.88	27,288.83	11,995.51	87.03	35.97	1,420,313.75	308,629.55

Table 10. APL users, parcel demand, number of APL, and total costs means and standard deviations at t = T for the scenarios based on 100 simulations (mobile APL)

4.3.2. Fixed APL

Population and eShoppers are similar to the results displayed in Table 9, Figure 10 and Figure 11 since these parameters are not affected, as mentioned in Subsection 4.3.1 Mobile APL. Population and eShopper simulation projection are the same.

Focusing on the scenarios described in Section 4.2, Figure 15 shows the expected evolution on APL users and Figure 16 the expected parcel demands in scenarios $S4_f$ (blue) and $S5_f$ (red). Scenario $S4_f$ accounts for a 10 % average APL users growth (γ = 0.10) and ω = 0.00, that is, there is no effect from APL availability on increasing the APL users growth rate, whereas $S5_f$ considers ω to be set at 0.01. Similarly, we can see the expected evolution in the same scenarios for the number of APLs in the city for any time (Figure 17). These approximately match the expected demands shown in the Figure 16.

In all cases, we can see the effect of the optimization feedback on the number of APL users, parcel demands, and number of APLs. The numerical results from all the scenarios considered are shown in Table 10, a similar comparison as in the previous Subsection 4.3.1 is conducted and the yield conclusions are identical to the ones introduced in said Subsection: scenarios ω = 0 clearly boost the number of APL users that increases the parcel demand, the number of APLs in the system, and their total costs. For example, $S9_f$ (that stands for a rapid growth in APL users and a huge effect of having an APL nearby) is more than twice the values obtained in $S8_f$ and $S7_f$ in which ω is reduced to 0.01 and 0, respectively. Therefore, a ω = 0.03 seems to be unreliable.

More interesting are the comparisons between scenarios with ω = 0 and ω = 0.01 (without, and with, APL effects, respectively). In this sense, in a slow APL growth ($S1_f$ and $S4_f$) the ω effect is 15 % increase of APL users, 14 % increase in parcel demands and number of APLs (from average 24 to 27, a 12% increase), and 8 % increase in costs at the end of the simulation.

In the case of moderate APL growth ($S4_f$ and $S5_f$), the increase is similar, but in rapid APL growth ($S7_f$ and $S8_f$) it falls to around 11 %: the greater the APL growth rate, the lower the APL (ω) effect.

In this particular case, in Figure 17 can be seen that the number of APL is always growing, and no APL is decommissioned, differing from the outcome seen in Figure 14.

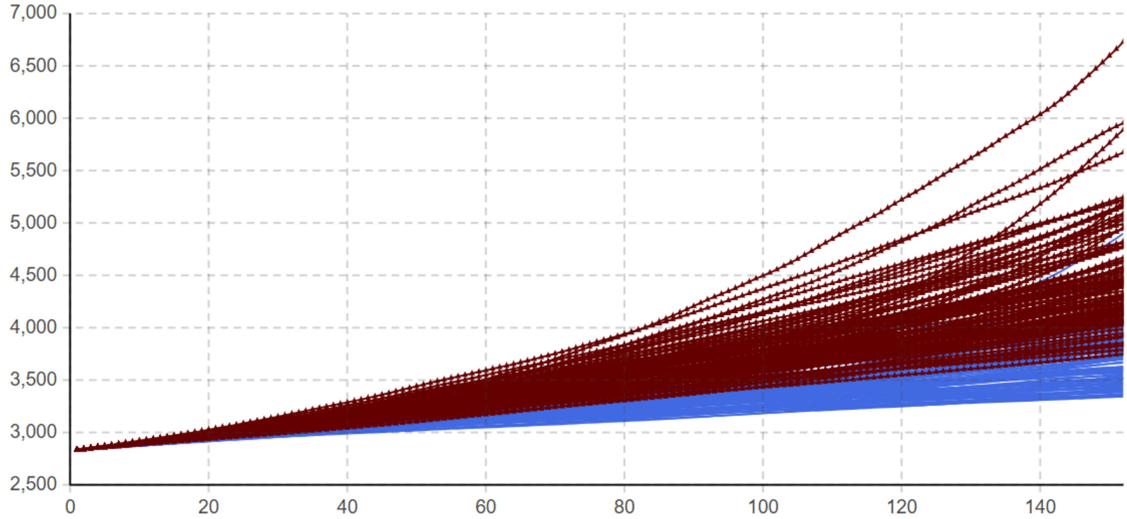

Figure 15. APL users evolution in $S4_f$ *(blue) and* $S5_f$ *(red) for 100 simulations each*

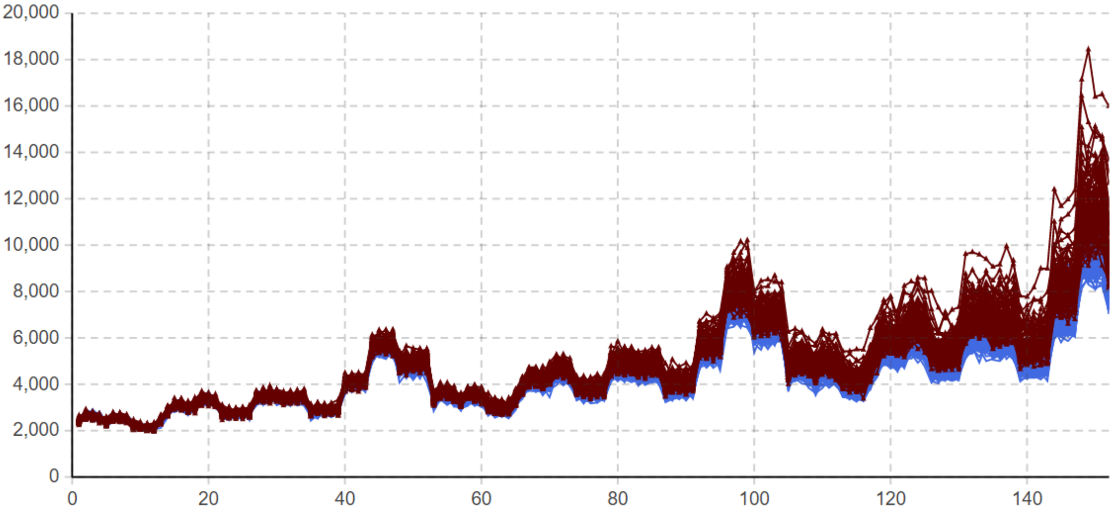

Figure 16. Parcel demand evolution in $S4_f$ *(blue) and* $S5_f$ *(red) for 100 simulations each*

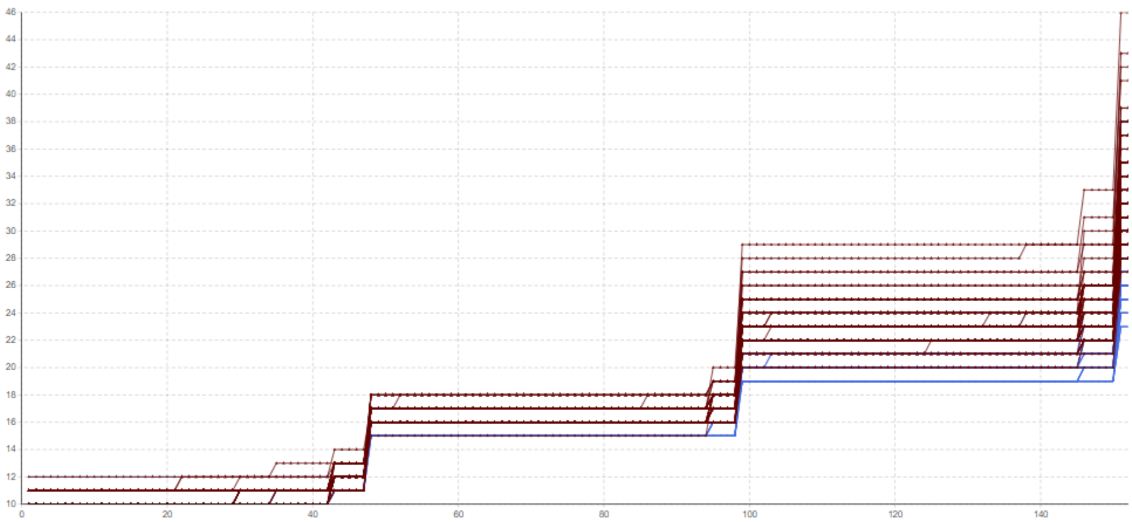

Figure 17. Number of APLs evolution in $S4_f$ *(blue) and* $S5_f$ *(red) for 100 simulations each*

	APL users		Parcel demand		Number of APL		Total cost	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd
$S1_f$	3,266.98	156.63	7,167.81	408.58	23.96	1.41	587,091.04	13,481.02
$S2_f$	3,824.05	617.17	8,380.08	1,372.48	28.13	4.69	644,973.11	25,279.90
$S3_f$	7,784.78	2,899.66	17,029.95	6,354.87	55.69	20.97	975,192.89	242,530.15
$S4_f$	3,745.25	319.91	8,199.39	727.14	27.39	2.38	635,363.40	25,286.18
$S5_f$	4,406.95	907.77	9,775.12	2013.10	32.29	6.25	703,881.88	40,772.53
$S6_f$	8,809.80	3,540,78	19,142.82	7,697.99	62.41	24.20	1,074,064.27	278,1859.27
$S7_f$	5,723.44	1,731.60	12,644.45	4,235.88	40.90	11.31	803,694.72	101,948.96
$S8_f$	7,223.95	3,782.29	15,596.14	7,580.56	51.71	25.98	920,522.42	192,031.77
$S9_f$	13,070.78	7,964.12	28,406.55	16,121.84	90.22	47.55	1,340,630.65	379,063.20

Table 11. APL users, parcel demand, number of APL, and total costs means and standard deviations at t = T for the scenarios based on 100 simulations (fixed APL)

4.3.3. Mobile APL vs Fixed APL

Looking at Table 9 and Table 12, the mean values in the last period considered (week 152) for the considered parameters (APL users, parcel demand, number of APL and total cost) fall within similar ranges for both Mobile and Fixed APL if the standard deviation is considered. For further analysis, total, opening, maintenance and closing cost could be analysed, but results are not comparable since the fixed model is not a particular case of the general mobile model: the fixed model should represent the particular case of setting the value of decommissioning cost to a high value ($d_{ci} \rightarrow \infty$) so that no APL is closed from one period to another even if utilization falls under the minimum required value (m).

Previous Simulation-Optimization methodologies (Rabe et al. 2020a, 2020b and 2021) can apply this minimum utilization level constraint since System-Dynamic simulation is used in the model resolution. The use of Agent-Based methodology in this master thesis is not compatible with this restriction, since parameters are updated weekly but APL decisions are done monthly. There is a conflict with constraint (7.6) that sets a minimum utilization level (m) for an APL to remain open from one month to the next. As a result of this new condition, the model optimizes APL availability rather than total cost. Total cost of the APL network is not minimized, because in some cases having an open APL could be more cost effective than closing it. As done in the fixed model, this restriction should apply for opening a new APL in the network but should not be a requirement for minimal utilization in future iterations if the total cost of the change is going to increase overall cost.

5. Parameter tuning for APL Network Design in Pamplona

The absence of public available data for model simulation encountered modelling the APL network for the city of Pamplona highlights the necessity of high-quality inputs for accurate and actionable model outcomes.

For future research, a conclusive cross-sectional market research is designed based on secondary data sources, databases, observation, panels, and surveys (Martinez-Abad 2021). Some market findings are applied in this model already, while others remain to be implemented in future iterations due to time constraints.

A summary of the process and its outcomes is included in the following subsections:

5.1. Current APL availability in Pamplona

Two APL networks are active in Pamplona, owned and managed by Amazon and Correos.

Amazon's network consists of 10 APL, called Amazon Hub Lockers, distributed all throughout Pamplona. Their APL provide collection services only for Amazon customers and can be used for deliveries and returns, no lines need to be waited, no additional fees are charged. Customers can enjoy an unattended service compelling with all COVID-19 measures thanks to the 6-digit code and the QR code sent as a notification once the package has been delivered to the APL. Customers can select any APL in the city according to personal preferences and benefit from a free two-day shipping, having 3 calendar days to pick their packages with extended pick-up time windows (and even 24/7 availability) from the APL before it is automatically returned for a refund. (Amazon.es 2021)

Six of said lockers are in service stations, two inside shopping malls, one in Pamplona bus station and one inside a local business. Locations are convenient for pedestrians, strategic gas stations and in leisure centres customers frequently attend to.

Logistic company	Ubication	Address	Postal code	Opening days	Opening hours
Amazon	Local business	C/ Teobaldos, 4	31002	Mon - Fri	9 – 14, 15 – 19
Amazon	Bus station	C/ Yanguas y Miranda, 2	31003	Mon - Sun	10h – 23h
Amazon	Service station	C/ María Viscarret, 39	31007	Mon - Sun	24h
Amazon	Service station	Pol. Landaben, C/ A, SN	31012	Mon - Sun	24h
Amazon	Service station	C/ Antica, SN	31013	Mon - Sun	24h
Amazon	Service station	Avd. Guipuzcoa, 1	31014	Mon - Sun	24h
Amazon	Service station	Pol. Talluntxe, C/ N, 32	31110	Mon - Sun	24h
Amazon	Shopping mall	Leclerc Pamplona	31191	Mon - Sat	10h – 23h
Amazon	Shopping mall	CC Itaroa	31620	Mon- Sun	10h – 23h
Amazon	Service station	Ctra. N135, 4.6 IZ	31620	Mon- Sun	6h – 22h

Table 12. Amazon Lockers location in Pamplona. Source: Amazon.es (2021)

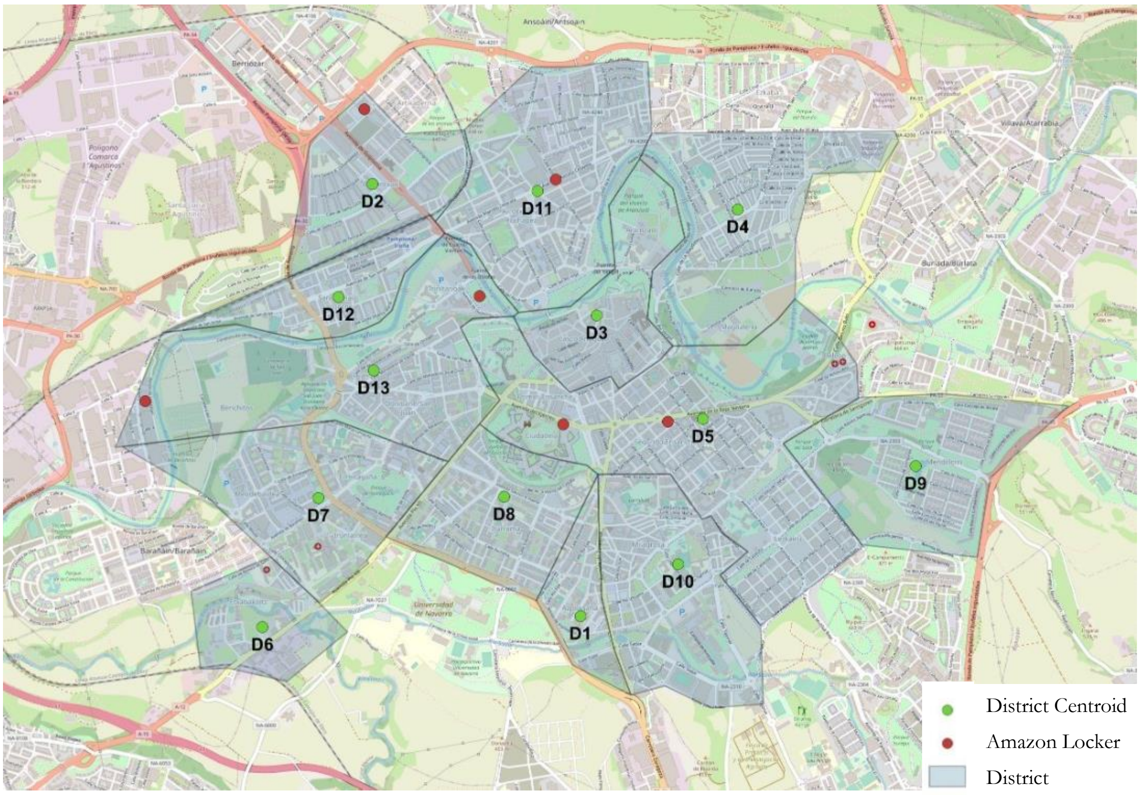

Figure 18. Amazon Lockers located in the neighborhoods of Pamplona.

Most items sold by Amazon and other service users are eligible for APL delivery if package weight is lower than 4,5 kg, dimensions smaller than 40x30x35 cm and total value is lower than 5000€.

Other delivery methods are still available at Amazon for customers: Counters (local businesses used as reception points, packages less than 15 kg and 90x60x60 cm and 2 weeks span for pick up), UPS Access Point and Post Offices, or traditional home delivery.

Moreover, the Correos equivalence to Amazon Hub Lockers is called CityPaq. 17 CityPaq stations are located in Pamplona. It can be used for both pick-up and delivery by any distribution company as long as they had previously reached an agreement with Correos (Spanish Postal Service). When the package is delivered to the APL, a deadline of 5 days is given after the notification for an unattended reception during the accessible hours (24/7 if the APL is in the street or the local business opening hours) and 15 extra days for reception at the post office in case the deadline is not met by the recipient. (CityPaq 2021)

Eight lockers are located inside supermarkets distributed throughout the city, three in service stations, two inside local businesses, two inside post offices, one inside a medical centre and one inside the bus station.

Logistic company	Ubication	Address	Postal code	Opening days	Opening hours
CityPaq	Post office	C/ Pablo Sarasate 9	31002	Mon - Fri	8:30h – 20:30h
CityPaq	Bus station	C/ Yanguas y Miranda, 2	31003	Mon - Sun	6h – 23h
CityPaq	Supermarket	C/ Olite 39	31004	Mon - Fri	9h – 21:30h
CityPaq	Supermarket	C/ Rio Ega, 6-8	31005	Mon - Fri	9h – 21:30h
CityPaq	Post office	Avd. Sancho el Fuerte, 69	31007	Mon - Sun	24h
CityPaq	Supermarket	Avd. Sancho el Fuerte, 67	31007	Mon - Fri	9h – 21:30h
CityPaq	Medical centre	Avd. Pio XII, SN	31008	Rsetricted	Restricted
CityPaq	Supermarket	C/ Monasterio de Oliva, 9	31011	Mon - Fri	9h – 21:30h
CityPaq	Supermarket	Avd. Guipuzcoa, 40	31012	Mon - Fri	9h – 21:30h
CityPaq	Supermarket	Paseo la Habana, 2-4-6	31013	Mon - Fri	9h – 21:30h
CityPaq	Supermarket	C/ Tomás de Burgui, 2	31013	Mon - Fri	9h – 21:30h
CityPaq	Service station	Carretera Artica, SN	31013	Mon - Sun	24h
CityPaq	Service station	Paseo Talluntxe, 32	31110	Mon - Sun	24h
CityPaq	Service station	Ciu. Transp 1, Avd. del Este	31119	Mon - Sun	24h
CityPaq	Local business	Camino de Galar 15	31190	Mon - Fri	9h – 21:30h
CityPaq	Local business	C/ Berroa, 19	31192	Mon - Fri	9h – 21:30h
CityPaq	Supermarket	C/ Bardenas Reales, 60-66	31621	Mon - Fri	9h – 21:30h

Table 13. CityPaq Lockers location in Pamplona. Source: CityPaq, (2021)

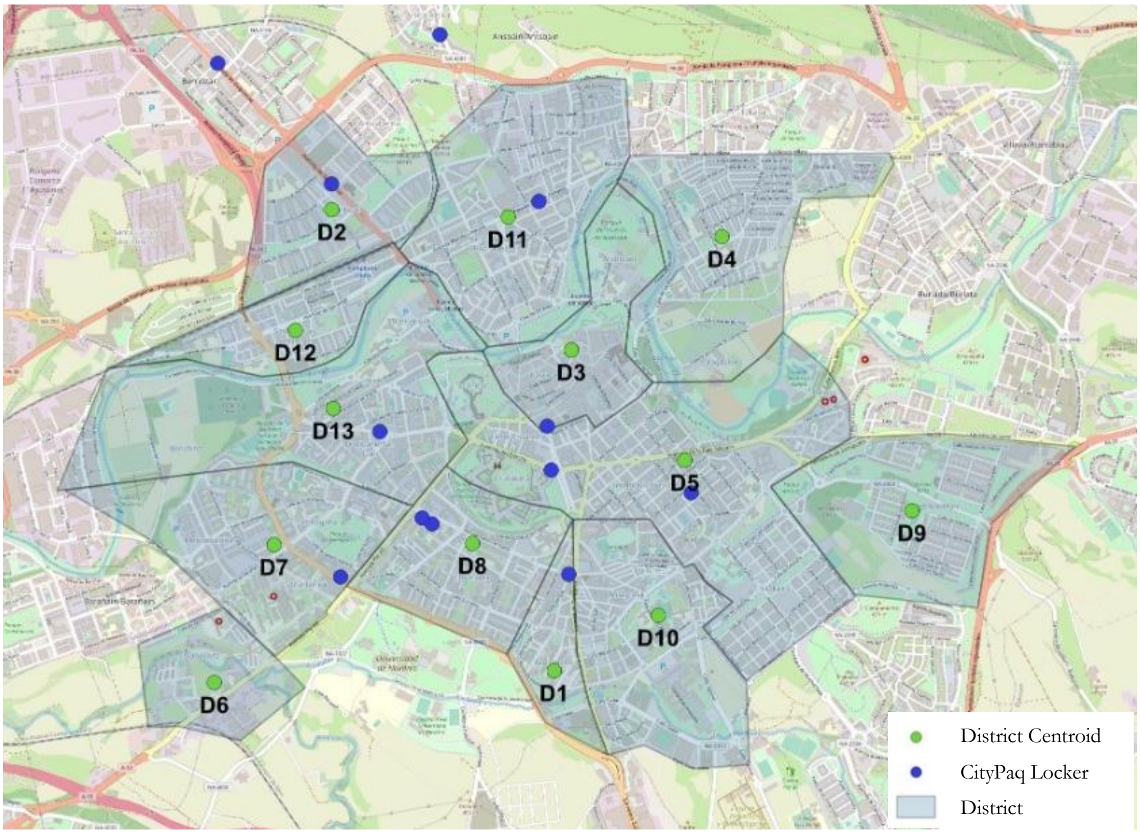

Figure 19. CityPaq Lockers located in the neighborhoods of Pamplona

These locations were selected following an experience-based strategy relying on private sourced data not available for other companies.

5.2. Secondary sources

As already mentioned in 4.1 Data settings, available resources can be used for model's parameter computation. This secondary data is already implemented in the model.

Firstly, Pamplona census for 2020 provides the number of habitants in Pamplona per neighbourhood (Instituto de Estadística de Navarra 2020).

Secondly, total census from 1996 to 2020 (Foro-ciudad 2021) is used for yearly population growth computation. If exponential smoothing is applied, the mean yearly population growth is 0.9 %. Mean values are not accurate enough for population growth description, as heterogeneity on a yearly based is lost. After statistical analysis using Minitab software, data shows that population growth rate αit follows a Weibull distribution with $\lambda = 1.24252$, and $\varkappa = 0.01646$.

Lastly, no better information on weekly demand distribution other than Coppola (2021) and Ward (2021) are available (see Table 6).

5.3. Primary sources

5.3.1. Quantitative observation

For average APL capacity, average parcel deliveries per APL, and minimum utilization levels required, 72 hours worth of information from one available Amazon APL has been collected (Avd. Guipuzcoa 1) and 48 hours from other two (Pol. Landaben and Yanguas y Miranda 2). These values are available before simulations and have been already considered for the simulation. Raw recorded data is included in Annex A.

Covid-19 restrictions were active at the time, which affected observations in two main ways:

- Standing inside businessess or malls was forbidden, meaning not all the locations were sujected to be analyzed.
- Mobility is restricted between 23 pm and 6 am. This implies that no information is lost associated to unseen deliveries or retrievals from customers, because observatins are carried out from 6.15h to 22.45h.

The three APL selected are located in different environments. The bus station in Yanguas y Miranda (Location 2) is located downtown and is accessile for pedestrians and nearby, Av. Guipuzcoa (Location 1) is a popular Service Station close to the city center; and Pol. Ladaben (Location 3) is a gas station in the industrial park from Pamplona.

Figure 20. APL in Avd. Guipuzcoa 1 (Location 1) , Pol. Landaben (Location 2) and C/ Yanguas y Miranda 2 (Location 3)

Other information (e.g., client age gap, client transportation method, company delivery frequency…) has been recorded despite having no direct implications in the model.

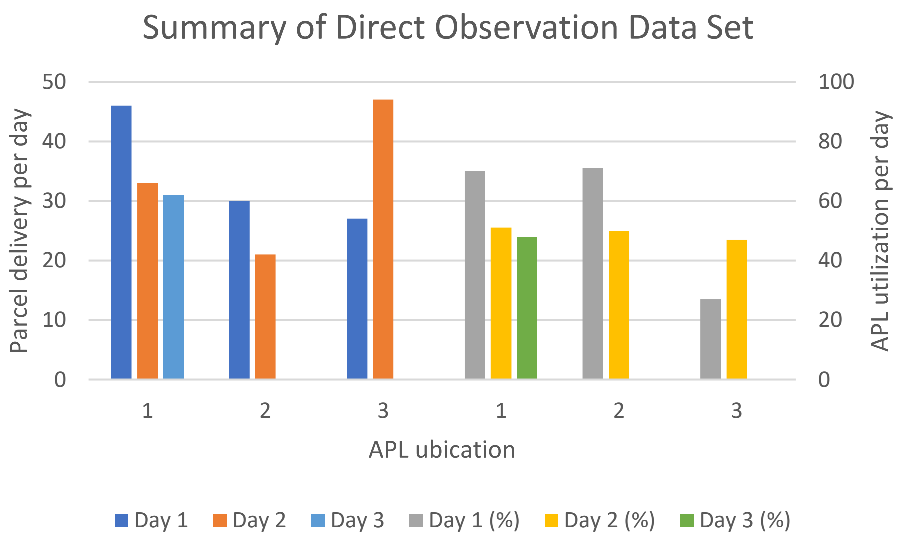

Figure 21. Direct observation data summary

The number of parcels delivered by the logistic company to every APL and the utilization level considering the number of parcels delivered by the logistic company and the total size of the particular APL. Parcel retrieval by users is not actionable data since retrieved parcels can be delivered two days before the retrieval day. The mean utilization is 50 % and the mean size of APL is 72 trays.

5.3.2. Survey

Once the necessary parameters left to define after the secondary research are clearly understood, the survey design can start. This is a long process and results have not been used in the model due to the already mentioned time constraints.

The 6 steps followed in the survey process are:

1. Identification of needs
2. Initial panel
3. Survey draft
4. Pilot test
5. Survey launch
6. Data analysis

The objective of the survey is gathering enough information related to current population, ecommerce and APL use in Pamplona and being able to implement future iterations of the macro location models introduced in this thesis, or different macro and micro location models applied to the city of Pamplona.

An initial panel is used to set a point of reference on potential survey recipients the topic's general knowledge of potential survey recipients. This process shoots down unconscious biases caused by the researcher's expertise in the matter. Once the panel is completed, the survey can be drafted and shared in a pilot test with the panel participants for feedback and possible modifications or rephrasing. An initial analysis of the 6 questionnaire answers is conducted to check if the questions and answers are useful for the parameter tuning. After some modifications including the test suggestions, the survey is launched and remains open until 203 participants submit their answers.

The survey consists of 6 different sections with a maximum of 12 questions. Different questions are shown depending on their previous answers. The survey questionnaire can be found in Annex B.1 and some graph used for data analysis are included in Annex B.2. The 8 sections in which the survey is divided are the following:

- Section 1: An initial introduction explains the survey objective and states the main advantages of the APL alternative compared to home deliveries and 1 question ensures that the participant lives in Pamplona. If not, the survey ends at this point.
- Section 2: 5 questions for participant profiling. Neighbourhood, sex, level of studies, work situation and age. This will allow for further classification and analysis.
- Section 3: This section aims to discover whether the participant already buys online or if expects to start buying in the following months (if not, survey ends here), the number of orders per month, the yearly increase of the number of orders, the level of knowledge on APL and their willingness to use it if available. If the participant rejects using the APL network regardless of conditions, the survey ends here.
- Section 4: When the participants accept the use of APL networks regardless of the conditions, 1 last question in this section aims to gather information related to the frequency of APL use.
- Section 5: When the participants accept the use of APL networks depending on the conditions, 1 question differentiate between cost conditions, distance to the APL conditions, and participants whose level of APL use depends on cost and distance.
- Section 6: Only for price concerned participants. 3 last questions define cost requirements and frequency of use depending on conditions satisfaction.
- Section 7: Only for distance concerned participants. 3 last questions define distance requirements and frequency of use depending on conditions satisfaction.
- Section 8: Only for price and distance concerned participants. 3 last questions define cost and distance requirements and frequency of use depending on conditions satisfaction.

The distribution channel selected is WhatsApp, and researcher's contacts living in Pamplona are kindly asked to share the Google form link with their contacts for reaching a broader sample. The sampling method associated to this distribution tool is known as snowball sampling, which falls under the category of non-probability sampling. It means that sample selection relies on personal judgement and the researcher can decide which elements to include. The results may yield good estimates of population characteristics, but do not allow for objective evaluation of precision, and estimates obtained are not statistically projectable to the whole population. Although other distribution methodologies could drive to probability sampling, due to the available resources, this method is preferred, and results will be considered extensible to all the inhabitants in Pamplona.

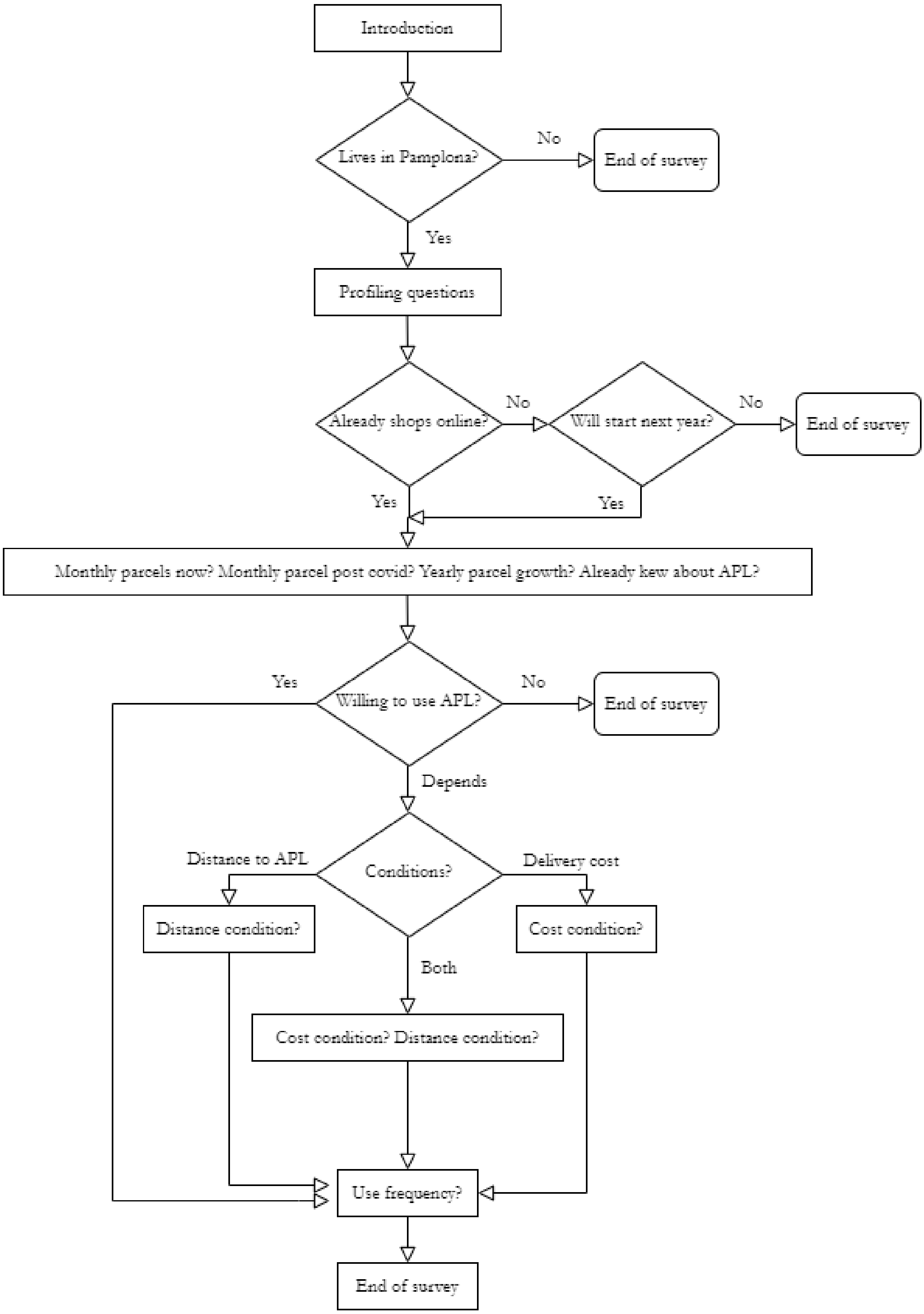

Figure 22. Survey scheme

After the response data set analysis, three different scenarios are defined depending on the distance from the APL user to the assigned APL. 5 minutes (Scenario 1), 10 minutes (Scenario 2) and 15 minutes (Scenario 3) of displacement are considered in the survey for APL user growth rate assessment.

Parameter	Definition	Initial value	Unit
Population	Inhabitants in Pamplona	203.944	People
Population growth rate	Mean yearly growth	0,9	%
E-shopper share	Percentage of population buying on-line	89,5	%
E-shopper growth rate	Yearly expected growth of population buying on-line	6,8	%
APL user share	Percentage of e-shoppers using APL	19,4	%
APL growth rate	Yearly expected growth of e-shoppers using APL	See table 15	%
Average on-line purchases	Monthly orders per e-shopper	2	Parcel
On-line purchases growth rate	Yearly expected growth of parcel number per e-shopper	19,3	%
Aver. parcel number per APL	Number of parcels delivered in every APL per week	360	Parcel
Minimum utilization level	Percentage of minimum occupation per APL required	50	%
Average **capacity per APL**	Trays or daily capacity if utilization is 100%	72	Parcel

Table 14. Initial parameters after survey analysis. Source: Martinez-Abad (2021)

APL growth rate	Scenario definition	Initial value	Unit
Scenario 1	APL closer than 5 minutes walking	94,6	%
Scenario 2	APL closer than 10 minutes walking	53,5	%
Scenario 3	APL closer than 15 minutes walking	43,8	%

Table 15. Scenarios for APL growth rate depending on distance to APL. Surce: Martinez-Abad (2021)

6. Conclusions

This work proposes the use of a hybrid model by combining simulation and optimization to deal with automated parcel locker (APL) systems in the city of Pamplona (Spain). In this context, several scenarios were tested for a range of growth levels of APL users and the sensitivity of eShoppers to become APL users once there is an APL nearby.

A list of conclusions can be drawn after the analysis of the results.

1. Costs and suggested number of lockers: Firstly, our results anticipate an increase in all role- playing magnitudes for the upcoming years in the city of Pamplona. In particular, population would raise up to the (212,500 - 213,500) interval, whereas eShoppers would do up to the (138,000 - 158,000) range. These figures will represent an average increase of about 4 % and 13 %, respectively in relation to their current values. Similarly, APL users and parcel demands will continue increasing according to our experiments. Likewise, depending on the considered scenario of APL growth and sensitivity, APL users are expected to increase up to 12,393, i,e., around 10 % of eShoppers, the current value being of 2.2 %. In the case of the city of Dortmund application, the number of APLs increases after 36 months from 99 at lowest demand to 165 at maximum demand, at a total cost of approximately 750,000 € for a medium demand configuration. In the city of Pamplona application with mobile APL, we expect the number of APLs to increase from 23 to 87 over the same planning horizon at high demand, at an approximately costs from 660,000 € to 1,420,000 €. In the city of Pamplona application with fixed APL, we expect the number of APLs to increase from 24 to 90 over the same planning horizon at high demand, at an approximately costs from 590,000 € to 1,340,000 €. The results in these two applications in terms of number of APLs and costs have a non-obvious economy of scale relative to the number of eShoppers.
2. Mobile APLs: Secondly, our model explores the use of mobile APLs. As can be seen in Figure 4, mobile APLs are able to be adapted to demand fluctuations more efficiently, but fixed APL model delivers a more cost-effective solution. For model comparison, constraint (7.6) should be deleted for cost optimization instead of optimal demand adaptation.

3. APL user sensitivity: Thirdly, the sensitivity to increase the number of APL users is revealed as a catalyst for increasing both values: APL users and demands. Definitely, these effects have to be taken into account in order to promote APLs among customers for both mobile and fixed models.
4. Enhancement of simulation-optimization methodology: Finally, this paper encourages the use of the hybrid methodology of simulation and optimization to deal with complex real-world problems. In effect, complex systems require a combination of methodologies that are able to conveniently cope with a problem.

Nevertheless, our results are based on a number of assumptions and limitations. Firstly, data quality can be improved to obtain a better estimate of the parameters in our models. This in particular applies to those related to the growth of eShoppers and APL users, as these are highly volatile values and depend on many uncontrollable factors (survey results can be applied for better population adaptation). Secondly, our model updates the data on a weekly basis from annual magnitudes. This implies that the increases are homogeneously distributed over the weeks, which is not always the case. Similarly, the FLP is started each month with the data available at that time. This implies that APL companies can change their APL-related decisions every month, and this time can be longer or shorter.

After completing this work, several research opportunities remain open. This is the case of a deeper analysis about the APL availability impact on increasing the APL users. Thus, a planned future research will collect data about these aspects. Additionally, this approach is particularly important in the case of mobile APLs. As discussed in this research, they can be adapted to anticipated peaks in demand. Nevertheless, they will lead to other problems that can also be mastered from an operations research perspective, e.g., optimization of the APL size, time windows design for products pickup, and so on.

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Annexes

A. Quantitative Observation Data Set

B. Survey Data Set

B.1 Survey Questionnaire

B.2 Survey graphs

Annex A

Direct observation data set

Ubicación	1	Avenida Guipuzcoa 1 - Amazon
	2	Pol. Landaben - Amazon
	3	Yanguas y Miranda 2 - Amazon
Día	Día 1, 2 o 3 de muestreo	
Hora	Hora de la acción	
Recoge	1	Recoge un cliente
	2	Entrega el repartidor
Número	Cantidad de paquetes en el día	
Cantidad	Cantidad de paquetes sacados del compartimento	
Tamaño	Hay 5 tamaños de compartimento en la taquilla	
Sexo	1	Hombre
	2	Mujer
Edad	1	Menor 18
	2	Ente 16 y 29
	3	Entre 30 y 39
	4	Entre 40 y 49
	5	Entre 50 y 59
	6	Mayor de 60
Coche	1	En coche
	2	Andando

* "-" means no data available or not relevant

Annex A

Direct observation data set

Ubicación	Día	Hora	Recoge	Número	Cantidad	Tamaño	Sexo	Edad	Coche
1	1	8:10	1	1	1	3	2	5	1
1	1	9:42	1	2	1	1	1	3	1
1	1	12:42	1	3	1	2	1	2	1
1	1	12:45	1	4	1	2	1	3	1
1	1	12:50	1	5	2	1	1	2	2
1	1	12:55	1	6	1	3	1	5	1
1	1	13:34	1	7	1	2	2	3	1
1	1	13:36	1	8	1	1	2	4	1
1	1	13:37	1	9	1	2	2	2	2
1	1	13:39	1	10	2	3	1	3	1
1	1	13:45	1	11	1	1	2	3	1
1	1	13:53	1	12	1	4	1	5	1
1	1	14:03	1	13	1	2	1	2	1
1	1	14:15	1	14	1	2	1	4	1
1	1	14:35	1	15	1	2	1	5	1
1	1	14:36	1	16	1	3	1	2	1
1	1	15:11	1	17	1	5	1	4	1
1	1	15:18	1	18	1	2	2	5	1
1	1	15:32	1	19	1	2	2	3	2
1	1	15:38	1	20	1	2	1	4	1
1	1	15:41	1	21	1	4	1	4	1
1	1	15:45	1	22	1	3	2	2	1
1	1	15:52	1	23	1	1	1	2	2
1	1	16:20	1	24	3	2	1	3	1
1	1	16:28	1	25	1	3	2	3	1
1	1	17:48	1	26	1	2	1	3	1
1	1	18:10	1	27	1	1	1	3	2
1	1	18:30	1	28	1	2	2	4	1
1	1	18:35	1	29	1	2	1	1	1
1	1	18:36	1	30	1	4	1	5	1
1	1	18:52	1	31	1	3	2	3	1
1	1	19:04	1	32	1	3	1	3	1
1	1	19:33	1	33	1	2	1	2	1
1	1	20:23	1	34	2	1	2	2	1
1	1	21:04	1	35	1	1	2	3	1
1	1	21:05	1	36	2	1	1	3	1
1	1	21:48	1	37	1	4	1	5	1
1	2	9:21	1	1	1	3	1	4	1
1	2	9:28	1	2	1	3	2	4	1
1	2	10:20	1	3	2	3	1	3	1
1	2	11:45	1	4	1	3	1	4	2
1	2	12:09	1	5	1	3	1	4	1
1	2	13:20	1	6	1	4	1	5	1
1	2	13:36	1	7	1	1	1	3	1
1	2	14:05	1	8	1	3	1	4	1
1	2	14:06	1	9	2	1	2	4	2
1	2	14:08	1	10	1	2	1	3	1
1	2	14:14	1	11	1	3	1	4	1
1	2	14:41	1	12	1	3	1	3	1

Annex A

Direct observation data set

1	2	15:05	1	13	1	3	2	3	1
1	2	15:20	1	14	1	3	1	4	1
1	2	15:34	1	15	1	1	1	3	2
1	2	15:36	1	16	1	1	1	4	2
1	2	15:54	1	17	2	3	1	4	1
1	2	17:01	1	18	1	1	2	4	2
1	2	17:09	1	19	1	3	2	3	2
1	2	17:24	1	20	2	4	1	4	1
1	2	17:30	1	21	2	4	1	4	1
1	2	17:55	1	22	1	2	1	5	1
1	2	18:00	1	23	2	3	2	4	1
1	2	18:03	1	24	1	3	1	2	1
1	2	18:05	1	25	2	3	1	3	1
1	2	18:20	1	26	1	2	1	4	2
1	2	18:37	1	27	1	1	1	4	2
1	2	18:55	1	28	2	4	1	3	1
1	2	19:10	1	29	1	2	2	2	1
1	2	19:21	1	30	1	2	1	4	1
1	2	19:40	1	31	1	3	1	4	1
1	2	20:50	1	32	1	3	1	3	1
1	2	21:00	1	33	1	2	1	3	1
1	2	21:20	1	34	1	2	1	4	1
1	2	21:24	1	35	1	3	2	4	1
1	2	21:50	1	36	1	3	1	2	1
1	2	21:57	1	37	1	2	1	4	1
1	3	9:40	1	38	1	2	1	3	2
1	1	12:00	2	1	1	2	-	-	-
1	1	12:00	2	2	1	3	-	-	-
1	1	12:00	2	3	1	3	-	-	-
1	1	12:00	2	4	1	5	-	-	-
1	1	12:00	2	5	1	1	-	-	-
1	1	12:00	2	6	1	3	-	-	-
1	1	12:00	2	7	1	1	-	-	-
1	1	12:00	2	8	1	2	-	-	-
1	1	12:00	2	9	1	3	-	-	-
1	1	12:00	2	10	1	3	-	-	-
1	1	12:00	2	11	1	2	-	-	-
1	1	12:00	2	12	1	1	-	-	-
1	1	12:00	2	13	1	2	-	-	-
1	1	12:00	2	14	1	4	-	-	-
1	1	12:00	2	15	1	2	-	-	-
1	1	12:00	2	16	1	2	-	-	-
1	1	12:00	2	17	1	2	-	-	-
1	1	12:00	2	18	1	2	-	-	-
1	1	12:00	2	19	1	3	-	-	-
1	1	12:00	2	20	1	3	-	-	-
1	1	12:00	2	21	1	2	-	-	-
1	1	12:00	2	22	1	1	-	-	-
1	1	12:00	2	23	1	2	-	-	-
1	1	12:00	2	24	1	3	-	-	-

Annex A

Direct observation data set

1	1	12:00	2	25	1	2	-	-	-
1	1	12:00	2	26	1	4	-	-	-
1	1	12:00	2	27	1	1	-	-	-
1	1	12:00	2	28	1	2	-	-	-
1	1	12:00	2	29	1	3	-	-	-
1	1	12:00	2	30	1	2	-	-	-
1	1	12:00	2	31	1	2	-	-	-
1	1	12:00	2	32	1	3	-	-	-
1	1	12:00	2	33	1	3	-	-	-
1	1	12:00	2	34	1	1	-	-	-
1	1	12:00	2	35	1	1	-	-	-
1	1	12:00	2	36	1	1	-	-	-
1	1	12:00	2	37	1	1	-	-	-
1	1	12:00	2	38	1	1	-	-	-
1	1	12:00	2	39	1	3	-	-	-
1	1	12:00	2	40	1	1	-	-	-
1	1	12:00	2	41	1	1	-	-	-
1	1	12:00	2	42	1	3	-	-	-
1	1	12:00	2	43	1	1	-	-	-
1	1	12:00	2	44	1	3	-	-	-
1	1	12:00	2	45	1	3	-	-	-
1	1	12:00	2	46	1	1	-	-	-
1	2	11:47	2	1	1	3	-	-	-
1	2	11:47	2	2	1	4	-	-	-
1	2	11:47	2	3	1	4	-	-	-
1	2	11:47	2	4	1	4	-	-	-
1	2	11:47	2	5	1	2	-	-	-
1	2	11:47	2	6	1	2	-	-	-
1	2	11:47	2	7	1	4	-	-	-
1	2	11:47	2	8	1	3	-	-	-
1	2	11:47	2	9	1	3	-	-	-
1	2	11:47	2	10	1	2	-	-	-
1	2	11:47	2	11	1	3	-	-	-
1	2	11:47	2	12	1	3	-	-	-
1	2	11:47	2	13	1	2	-	-	-
1	2	11:47	2	14	1	2	-	-	-
1	2	11:47	2	15	1	4	-	-	-
1	2	11:47	2	16	1	1	-	-	-
1	2	11:47	2	17	1	4	-	-	-
1	2	11:47	2	18	1	1	-	-	-
1	2	11:47	2	19	1	3	-	-	-
1	2	11:47	2	20	1	2	-	-	-
1	2	11:47	2	21	1	3	-	-	-
1	2	11:47	2	22	1	2	-	-	-
1	2	11:47	2	23	1	3	-	-	-
1	2	11:47	2	24	1	4	-	-	-
1	2	11:47	2	25	1	1	-	-	-
1	2	11:47	2	26	1	3	-	-	-
1	2	11:47	2	27	1	2	-	-	-
1	2	11:47	2	28	1	4	-	-	-

Annex A

Direct observation data set

1	2	11:47	2	29	1	3	-	-	-
1	2	11:47	2	30	1	1	-	-	-
1	2	11:47	2	31	1	2	-	-	-
1	2	11:47	2	32	1	2	-	-	-
1	2	11:47	2	33	1	1	-	-	-
1	3	11:42	2	1	1	5	-	-	-
1	3	11:42	2	2	1	2	-	-	-
1	3	11:42	2	3	1	2	-	-	-
1	3	11:42	2	4	1	2	-	-	-
1	3	11:42	2	5	1	4	-	-	-
1	3	11:42	2	6	1	2	-	-	-
1	3	11:42	2	7	1	2	-	-	-
1	3	11:42	2	8	1	2	-	-	-
1	3	11:42	2	9	1	3	-	-	-
1	3	11:42	2	10	1	3	-	-	-
1	3	11:42	2	11	1	2	-	-	-
1	3	11:42	2	12	1	2	-	-	-
1	3	11:42	2	13	1	3	-	-	-
1	3	11:42	2	14	1	4	-	-	-
1	3	11:42	2	15	1	3	-	-	-
1	3	11:42	2	16	1	1	-	-	-
1	3	11:42	2	17	1	2	-	-	-
1	3	11:42	2	18	1	1	-	-	-
1	3	11:42	2	19	1	1	-	-	-
1	3	11:42	2	20	1	2	-	-	-
1	3	11:42	2	21	1	1	-	-	-
1	3	11:42	2	22	1	2	-	-	-
1	3	11:42	2	23	1	1	-	-	-
1	3	11:42	2	24	1	3	-	-	-
1	3	11:42	2	25	1	1	-	-	-
1	3	11:42	2	26	1	1	-	-	-
1	3	11:42	2	27	1	1	-	-	-
1	3	11:42	2	28	1	3	-	-	-
1	3	11:42	2	29	1	1	-	-	-
1	3	11:42	2	30	1	1	-	-	-
1	3	11:42	2	31	1	2	-	-	-
2	1	12:56	1	1	1	4	1	3	1
2	1	13:27	1	2	1	3	2	3	1
2	1	13:37	1	3	1	3	1	5	1
2	1	13:44	1	4	1	3	1	3	1
2	1	14:13	1	5	2	2	1	4	1
2	1	14:22	1	6	1	3	1	2	1
2	1	15:10	1	7	2	5	2	4	1
2	1	15:50	1	8	1	2	2	3	1
2	1	16:20	1	9	1	2	1	5	1
2	1	18:38	1	10	1	4	2	3	1
2	1	18:41	1	11	1	2	1	4	1
2	1	18:55	1	12	2	1	1	3	1
2	1	19:00	1	13	1	2	1	3	1
2	1	19:23	1	14	1	1	1	5	1

Annex A

Direct observation data set

2	1	19:26	1	15	1	3	1	3	1
2	1	19:36	1	16	1	1	1	5	1
2	1	20:17	1	17	1	1	2	3	1
2	1	22:18	1	18	2	2	1	2	1
2	1	22:25	1	19	2	3	1	2	1
2	2	10:47	1	1	1	3	2	3	1
2	2	12:57	1	2	1	4	1	3	1
2	2	13:40	1	3	1	2	1	3	1
2	2	13:55	1	4	1	3	1	4	1
2	2	14:08	1	5	1	3	1	2	1
2	2	14:12	1	6	1	3	1	4	1
2	2	14:26	1	7	1	3	1	3	1
2	2	14:40	1	8	1	4	1	3	1
2	2	14:46	1	9	1	3	1	3	1
2	2	14:56	1	10	1	1	2	3	1
2	2	15:27	1	11	1	1	1	3	1
2	2	15:39	1	12	1	1	1	3	1
2	2	15:48	1	13	1	4	1	3	1
2	2	16:35	1	14	2	3	2	2	1
2	2	17:10	1	15	1	3	1	5	1
2	2	17:18	1	16	2	3	1	4	1
2	2	18:18	1	17	2	4	2	2	1
2	2	18:50	1	18	1	1	1	3	1
2	2	19:00	1	19	1	2	1	2	1
2	1	12:15	2	1	1	4	-	-	-
2	1	12:15	2	2	1	5	-	-	-
2	1	12:15	2	3	1	3	-	-	-
2	1	12:15	2	4	1	3	-	-	-
2	1	12:15	2	5	1	3	-	-	-
2	1	12:15	2	6	1	2	-	-	-
2	1	12:15	2	7	1	2	-	-	-
2	1	12:15	2	8	1	4	-	-	-
2	1	12:15	2	9	1	5	-	-	-
2	1	12:15	2	10	1	2	-	-	-
2	1	12:15	2	11	1	4	-	-	-
2	1	12:15	2	12	1	3	-	-	-
2	1	12:15	2	13	1	2	-	-	-
2	1	12:15	2	14	1	3	-	-	-
2	1	12:15	2	15	1	1	-	-	-
2	1	12:15	2	16	1	2	-	-	-
2	1	12:15	2	17	1	1	-	-	-
2	1	12:15	2	18	1	2	-	-	-
2	1	12:15	2	19	1	1	-	-	-
2	1	12:15	2	20	1	2	-	-	-
2	1	12:15	2	21	1	2	-	-	-
2	1	12:15	2	22	1	1	-	-	-
2	1	12:15	2	23	1	2	-	-	-
2	1	12:15	2	24	1	1	-	-	-
2	1	12:15	2	25	2	3	-	-	-
2	1	12:15	2	26	1	2	-	-	-

Annex A

Direct observation data set

2	1	12:15	2	27	1	3	-	-	-
2	1	12:15	2	28	1	1	-	-	-
2	1	12:15	2	29	1	3	-	-	-
2	1	12:15	2	30	1	3	-	-	-
2	2	12:08	2	1	1	1	-	-	-
2	2	12:08	2	2	1	3	-	-	-
2	2	12:08	2	3	1	3	-	-	-
2	2	12:08	2	4	1	2	-	-	-
2	2	12:08	2	5	1	4	-	-	-
2	2	12:08	2	6	1	1	-	-	-
2	2	12:08	2	7	1	1	-	-	-
2	2	12:08	2	8	1	1	-	-	-
2	2	12:08	2	9	1	2	-	-	-
2	2	12:08	2	10	1	2	-	-	-
2	2	12:08	2	11	1	3	-	-	-
2	2	12:08	2	12	1	3	-	-	-
2	2	12:08	2	13	1	1	-	-	-
2	2	12:08	2	14	1	3	-	-	-
2	2	12:08	2	15	1	5	-	-	-
2	2	12:08	2	16	1	5	-	-	-
2	2	12:08	2	17	1	4	-	-	-
2	2	12:08	2	18	1	4	-	-	-
2	2	12:08	2	19	1	3	-	-	-
2	2	12:08	2	20	1	1	-	-	-
2	2	12:08	2	21	1	2	-	-	-
3	1	9:42	1	1	1	2	2	2	-
3	1	11:00	1	2	1	4	1	4	-
3	1	11:33	1	3	3	3	2	4	-
3	1	11:55	1	4	1	4	1	3	-
3	1	12:16	1	5	1	2	2	2	-
3	1	12:19	1	6	1	3	2	3	-
3	1	12:31	1	7	1	1	1	3	-
3	1	12:34	1	8	1	3	1	2	-
3	1	12:38	1	9	1	3	2	2	-
3	1	12:43	1	10	1	3	1	2	-
3	1	12:55	1	11	2	3	1	4	-
3	1	12:58	1	12	1	2	1	2	-
3	1	13:06	1	13	1	3	1	2	-
3	1	13:13	1	14	1	3	1	3	-
3	1	13:37	1	15	1	3	1	4	-
3	1	13:40	1	16	1	2	1	4	-
3	1	14:10	1	17	1	2	2	4	-
3	1	14:15	1	18	1	3	1	2	-
3	1	14:20	1	19	1	3	2	2	-
3	1	14:38	1	20	1	2	2	2	-
3	1	14:51	1	21	1	2	1	3	-
3	1	15:14	1	22	1	1	1	2	-
3	1	15:25	1	23	1	3	2	2	-
3	1	15:40	1	24	2	2	2	2	-
3	1	15:41	1	25	1	4	2	2	-

Annex A

Direct observation data set

3	1	15:50	1	26	1	1	1	4	-
3	1	16:03	1	27	2	2	1	4	-
3	1	16:13	1	28	1	1	1	1	-
3	1	16:25	1	29	1	3	2	3	-
3	1	16:36	1	30	1	1	1	4	-
3	1	17:50	1	31	1	2	1	2	-
3	1	17:56	1	32	1	2	1	5	-
3	1	18:35	1	33	1	3	1	2	-
3	1	18:39	1	34	1	3	1	2	-
3	1	18:41	1	35	1	4	2	4	-
3	1	19:06	1	36	1	3	1	4	-
3	1	19:27	1	37	3	3	2	4	-
3	1	19:33	1	38	1	1	1	4	-
3	1	19:55	1	39	1	3	1	4	-
3	1	20:05	1	40	1	1	1	4	-
3	1	20:10	1	41	1	1	1	4	-
3	1	22:30	1	42	1	3	1	5	-
3	1	11:35	2	1	1	4	-	-	-
3	1	11:35	2	2	1	3	-	-	-
3	1	11:35	2	3	1	3	-	-	-
3	1	11:35	2	4	1	3	-	-	-
3	1	11:35	2	5	1	3	-	-	-
3	1	11:35	2	6	1	3	-	-	-
3	1	11:35	2	7	1	4	-	-	-
3	1	11:35	2	8	1	2	-	-	-
3	1	11:35	2	9	1	2	-	-	-
3	1	11:35	2	10	1	3	-	-	-
3	1	11:35	2	11	1	2	-	-	-
3	1	11:35	2	12	1	2	-	-	-
3	1	11:35	2	13	1	3	-	-	-
3	1	11:35	2	14	1	1	-	-	-
3	1	11:35	2	15	1	2	-	-	-
3	1	11:35	2	16	1	3	-	-	-
3	1	11:35	2	17	1	4	-	-	-
3	1	11:35	2	18	1	3	-	-	-
3	1	11:35	2	19	1	2	-	-	-
3	1	11:35	2	20	1	2	-	-	-
3	1	11:35	2	21	1	3	-	-	-
3	1	11:35	2	22	1	1	-	-	-
3	1	11:35	2	23	1	2	-	-	-
3	1	11:35	2	24	1	2	-	-	-
3	1	11:35	2	25	1	1	-	-	-
3	1	11:35	2	26	1	2	-	-	-
3	1	11:35	2	27	1	1	-	-	-
3	2	8:53	1	1	1	1	1	4	-
3	2	11:20	1	2	1	2	1	2	-
3	2	11:47	1	3	1	4	1	4	-
3	2	11:49	1	4	1	3	1	4	-
3	2	12:32	1	5	1	3	1	3	-
3	2	12:34	1	6	1	3	1	3	-

Annex A

Direct observation data set

3	2	12:38	1	7	1	2	1	3	-
3	2	12:51	1	8	2	2	1	4	-
3	2	12:56	1	9	2	2	1	4	-
3	2	13:08	1	10	1	2	2	4	-
3	2	13:10	1	11	1	2	1	1	-
3	2	13:24	1	12	1	2	2	3	-
3	2	13:33	1	13	1	1	2	2	-
3	2	13:45	1	14	2	1	1	4	-
3	2	15:45	1	15	3	3	2	3	-
3	2	16:00	1	16	3	2	2	3	-
3	2	16:08	1	17	4	3	2	3	-
3	2	16:19	1	18	1	4	2	3	-
3	2	16:27	1	19	2	4	2	3	-
3	2	16:46	1	20	2	5	2	3	-
3	2	16:54	1	21	1	2	2	4	-
3	2	16:56	1	22	1	2	2	4	-
3	2	17:00	1	23	1	3	2	4	-
3	2	17:28	1	24	1	1	1	2	-
3	2	17:39	1	25	1	2	1	1	-
3	2	17:40	1	26	3	3	1	4	-
3	2	17:43	1	27	2	1	1	4	-
3	2	17:48	1	28	1	1	1	4	-
3	2	18:02	1	29	1	3	1	2	-
3	2	19:31	1	30	1	2	2	4	-
3	2	19:38	1	31	3	2	2	4	-
3	2	19:52	1	32	1	1	2	3	-
3	2	19:25	1	33	1	1	1	3	-
3	2	20:54	1	34	1	2	2	5	-
3	2	21:05	1	35	2	2	1	3	-
3	2	21:28	1	36	2	3	1	4	-
3	2	21:34	1	37	2	2	1	4	-
3	2	21:42	1	38	2	5	1	4	-
3	2	21:55	1	39	1	2	1	2	-
3	2	11:35	2	1	1	3	-	-	-
3	2	11:35	2	2	1	5	-	-	-
3	2	11:35	2	3	1	4	-	-	-
3	2	11:35	2	4	1	3	-	-	-
3	2	11:35	2	5	1	4	-	-	-
3	2	11:35	2	6	1	3	-	-	-
3	2	11:35	2	7	1	4	-	-	-
3	2	11:35	2	8	1	2	-	-	-
3	2	11:35	2	9	1	2	-	-	-
3	2	11:35	2	10	1	5	-	-	-
3	2	11:35	2	11	1	2	-	-	-
3	2	11:35	2	12	1	2	-	-	-
3	2	11:35	2	13	2	3	-	-	-
3	2	11:35	2	14	2	3	-	-	-
3	2	11:35	2	15	1	3	-	-	-
3	2	11:35	2	16	1	1	-	-	-
3	2	11:35	2	17	1	2	-	-	-

3	2	11:35	2	18	1	4	-	-	-
3	2	11:35	2	19	1	1	-	-	-
3	2	11:35	2	20	1	3	-	-	-
3	2	11:35	2	21	1	3	-	-	-
3	2	11:35	2	22	1	3	-	-	-
3	2	11:35	2	23	1	3	-	-	-
3	2	11:35	2	24	1	2	-	-	-
3	2	11:35	2	25	1	2	-	-	-
3	2	11:35	2	26	1	2	-	-	-
3	2	11:35	2	27	1	2	-	-	-
3	2	11:35	2	28	1	2	-	-	-
3	2	11:35	2	29	1	3	-	-	-
3	2	11:35	2	30	1	2	-	-	-
3	2	11:35	2	31	1	3	-	-	-
3	2	11:35	2	32	1	3	-	-	-
3	2	11:35	2	33	1	1	-	-	-
3	2	11:35	2	34	1	3	-	-	-
3	2	11:35	2	35	1	3	-	-	-
3	2	11:35	2	36	1	1	-	-	-
3	2	11:35	2	37	1	3	-	-	-
3	2	11:35	2	38	1	1	-	-	-
3	2	11:35	2	39	1	3	-	-	-
3	2	11:35	2	40	1	2	-	-	-
3	2	11:35	2	41	1	3	-	-	-
3	2	11:35	2	42	1	1	-	-	-
3	2	11:35	2	43	1	2	-	-	-
3	2	11:35	2	44	1	1	-	-	-
3	2	11:35	2	45	1	2	-	-	-
3	2	11:35	2	46	1	2	-	-	-
3	2	11:35	2	47	1	1	-	-	-

Trabajo Fin de Máster - Taquillas inteligentes en Pamplona

Buenos días,

Soy estudiante del Máster en Dirección de Empresas en la Universidad Pública de Navarra y el objetivo de este trabajo de fin de Máster es conocer la aceptación y uso de las taquillas inteligentes en Pamplona.

Las taquillas inteligentes son taquillas metálicas ubicadas en diferentes puntos de la ciudad para la distribución de paquetería. Sus principales ventajas frente a los envíos a domicilio tradicionales son:

- Los paquetes pueden ser recogidos por el cliente durante las 24 horas del día. Para abrir la taquilla solo se necesita el código que el repartidor envía al teléfono móvil del cliente tras depositar el paquete. Por tanto, utilizar esta alternativa evita esperar a la compañía de repartos en el domicilio.

- Los repartos son más ecológicos. Un mayor número de paquetes se depositan en el mismo punto, por lo que se recorren menos kilómetros conduciendo. Disminuye la congestión de vehículos y la cantidad de emisiones en el interior de la ciudad.

Muchas gracias por su participación, ¡solo le llevará 4 minutos! (máximo 12 preguntas)

*Obligatorio

Puede que haya visto alguna vez una de estas taquillas inteligentes:

1. ¿Reside en Pamplona? *

Marca solo un óvalo.

- Si
- No

Perfil del encuestado

2. Seleccione su barrio: *

Marca solo un óvalo.

- Azpilagaña
- Buztintxuri
- Casco viejo
- Chantrea
- Echavacoiz
- Ensanche
- Ermitagaña
- Iturrama
- Lezkairu
- Mendebaldea
- Mendillorri
- Milagrosa
- Ripagaina
- Rochapea
- San Jorge
- San Juan
- Otro municipio de la Cuenca de Pamplona

3. Sexo: *

Marca solo un óvalo.

- Hombre
- Mujer
- No binario
- Prefiero no definirme

4. Máximo nivel educativo alcanzado: *

Marca solo un óvalo.

- Educación primaria o inferior
- Educación secundaria (ESO, Bachillerato o FP)
- Educación universitaria

5. Situación laboral: *

Marca solo un óvalo.

- Trabajo a tiempo completo
- Trabajo a tiempo parcial
- En desempleo (buscando trabajo)
- No trabajo

6. Edad: *

Marca solo un óvalo.

- Menor de 18 años
- Entre 18 y 29 años
- Entre 30 y 39 años
- Entre 40 y 49 años
- Entre 50 y 59 años
- Más de 60 años

7. 1. ¿Realiza pedidos online en la actualidad? *

Marca solo un óvalo.

- Si
- No

8. 2. ¿Cree que a lo largo del próximo año realizará su primer pedido online? *

Marca solo un óvalo.

- Ya compro online en la actualidad
- Si
- No

9. 3. ¿Cuántos pedidos al mes realiza de media? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Ninguna
- Entre 1 y 2 pedidos al mes
- Entre 2 y 3 pedidos al mes
- Entre 3 y 4 pedidos al mes
- Entre 4 y 5 pedidos al mes
- Más de 5 pedidos al mes

10. 4. ¿Cuántos pedidos espera realizar de media al mes una vez termine la pandemia? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Ninguna
- Entre 1 y 2 pedidos al mes
- Entre 2 y 3 pedidos al mes
- Entre 3 y 4 pedidos al mes
- Entre 4 y 5 pedidos al mes
- Más de 5 pedidos al mes

11. 5. ¿Aumenta la cantidad media de pedidos online que realiza cada año? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Todavía no hago pedidos online
- La cantidad de pedidos se mantiene constante cada año
- Aumenta de media menos de 1 paquete al mes comparado con el año anterior
- Aumenta de media entre 1 y 2 paquetes al mes comparado con el año anterior
- Aumenta de media más de 2 paquetes al mes comparado con el año anterior

12. 6. ¿Conocía la existencia de taquillas inteligentes y cómo utilizarlas? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- No conocía su existencia ni la forma de utilizarlas. No las he utilizado nunca
- Sí conocía su existencia pero no la forma de utilizarlas. No las he utilizado nunca
- Sí conocía su existencia y la forma de utilizarlas. No las he utilizado nunca
- Sí conocía su existencia y la forma de utilizarlas. Las he utilizado

13. 7. ¿Piensa utilizar las taquillas inteligentes (o seguir utilizándolas si las ha utilizado anteriormente) como método de recepción de sus pedidos? (Tamaño del paquete similar a una caja de zapatos) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Sí, en cualquier caso *Salta a la pregunta 14*
- Depende de las condiciones *Salta a la pregunta 15*
- No, en ningún caso

Última sección

14. 8. ¿Con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online

Penúltima sección

15. 8. ¿Qué condiciones afectarían a su decisión de utilizar las taquillas inteligentes? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Coste del envío *Salta a la pregunta 16*
- Distancia a recorrer hasta la taquilla *Salta a la pregunta 19*
- Coste de envío y distancia a recorrer hasta la taquilla *Salta a la pregunta 22*

Última sección

16. 9. ¿Cuánto debería costar el envío para que hiciese uso de la taquilla inteligente? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Pagaría más que por el envío a domicilio
- Mismo coste que el envío a domicilio
- Un 75% del coste del envío a domicilio
- Un 50% del coste del envío a domicilio
- Un 25% del coste del envío a domicilio
- Debería ser gratuito

17. 10. Si se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online

18. 11. Si NO se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online
- Nunca

Última sección

19. 9. ¿Cómo recogería su paquete de la taquilla inteligente? (Paquete del tamaño de una caja de zapatos) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Solo lo utilizaría si se sitúa en lugares que frecuento o de camino a ellos
- Andando hasta 5 minutos de ida y 5 de vuelta
- Andando hasta 10 minutos de ida y 10 de vuelta
- Andando hasta 15 minutos de ida y 15 de vuelta
- Andando hasta más de 15 minutos de ida y 15 de vuelta
- En coche si excede los 15 minutos andando
- En coche en cualquier caso

20. 10. Si se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online

21. 11. Si NO se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online
- Nunca

Última sección

22. 9. ¿Cuánto debería costar el envío para que hiciese uso de la taquilla inteligente? Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Pagaría más que por un envío a domicilio
- Lo mismo que el envío a domicilio
- Un 75% del coste del envío a domicilio
- Un 50% del coste del envío a domicilio
- Un 25% del coste del envío a domicilio
- Debería ser gratuito

23. 10. ¿Cómo recogería su paquete de la taquilla inteligente? (Paquete del tamaño de una caja de zapatos) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Solo lo utilizaría si se sitúa en lugares que frecuento o de camino a ellos
- Andando hasta 5 minutos de ida y 5 de vuelta
- Andando hasta 10 minutos de ida y 10 de vuelta
- Andando hasta 15 minutos de ida y 15 de vuelta
- Andando hasta más de 15 minutos de ida y 15 de vuelta
- En coche en cualquier caso
- En coche si excede los 15 minutos andando

24. 11. Si se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online

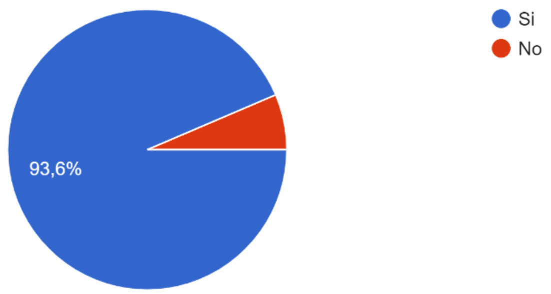
25. 12. Si NO se cumplen sus condiciones para utilizar las taquillas inteligentes, ¿con qué frecuencia las utilizaría? (En situaciones de no pandemia) Elija la opción que más se ajuste. *

Marca solo un óvalo.

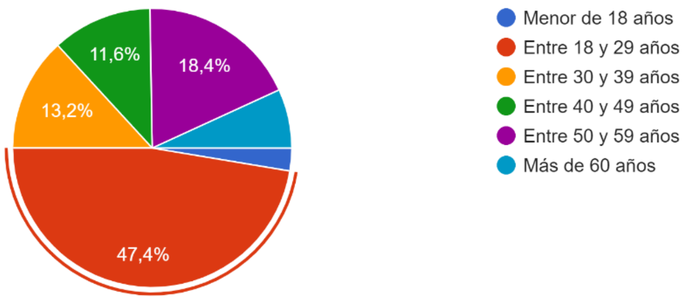
- Con el 100% de mis pedidos online
- Con el 75% de mis pedidos online
- Con el 50% de mis pedidos online
- Con el 25% de mis pedidos online
- Nunca

Annex B.2 - Survey graphs

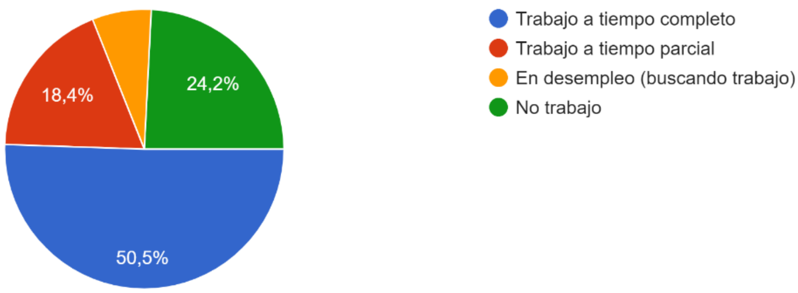
¿Reside en Pamplona?
203 respuestas



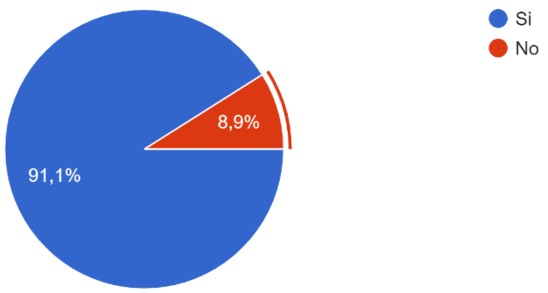
Edad:
190 respuestas



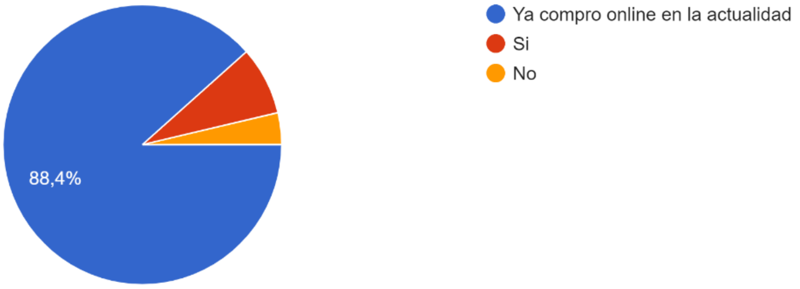
Situación laboral:
190 respuestas



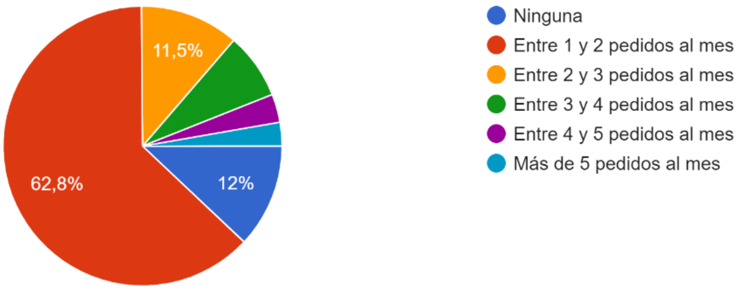
1. ¿Realiza pedidos online en la actualidad?
190 respuestas



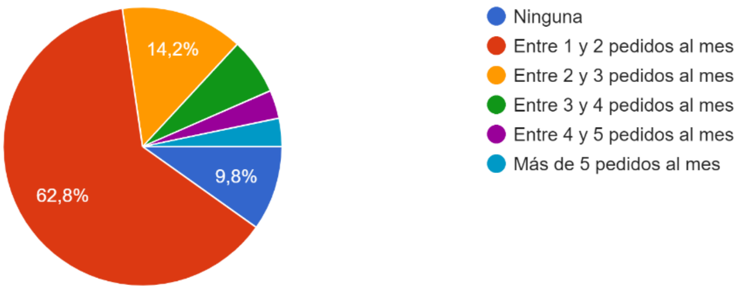
2. ¿Cree que a lo largo del próximo año realizará su primer pedido online?
190 respuestas



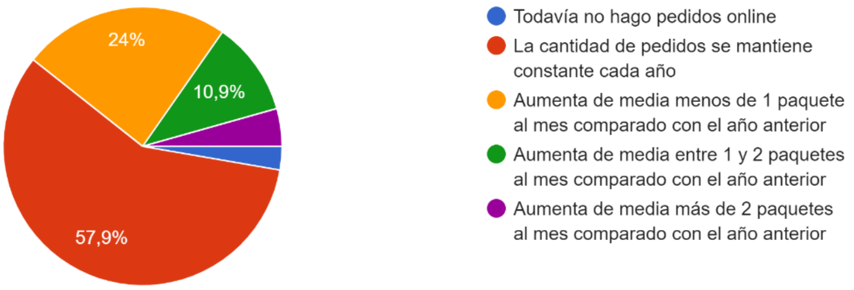
3. ¿Cuántos pedidos al mes realiza de media? Elija la opción que más se ajuste.
183 respuestas



4. ¿Cuántos pedidos espera realizar de media al mes una vez termine la pandemia? Elija la opción que más se ajuste.
183 respuestas



5. ¿Aumenta la cantidad media de pedidos online que realiza cada año? Elija la opción que más se ajuste.
183 respuestas



7. ¿Piensa utilizar las taquillas inteligentes (o seguir utilizándolas si las ha utilizado anteriormente) como método de recepción de sus pedidos? (Tamaño...a de zapatos) Elija la opción que más se ajuste.

183 respuestas