SOON CHUN HYANG UNIVERSITY

Last mile delivery by drones: an estimation of viable market potential and access to citizens across European cities

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contents

Problem

- European cities having to face bigger lastmile challenges

  - General denser urban situationsand
  - Stricter limits on the use of large trucks in comparison to the United States.

- E-commerce, facilitated by the social media marketing,has grown rapidly over the past years.

- In 2016, the online retailer Amazon was reported to serve 310 million customers worldwide

- In Europe, the number of online shoppers

Estimated by Amazon	Estimated by Brohan
300 ~ 340 million	450 million

- As the majority of goods purchased online are delivered directly to customers,last mile delivery has become fundamental to this industry

As the last mile becomes a necessity, costs rise for online retailers

Solution

- ICT (Information and Communication Technologies)
- ITS (Intelligent Transport Systems)
- Industry4.0
- newtransport vehicles

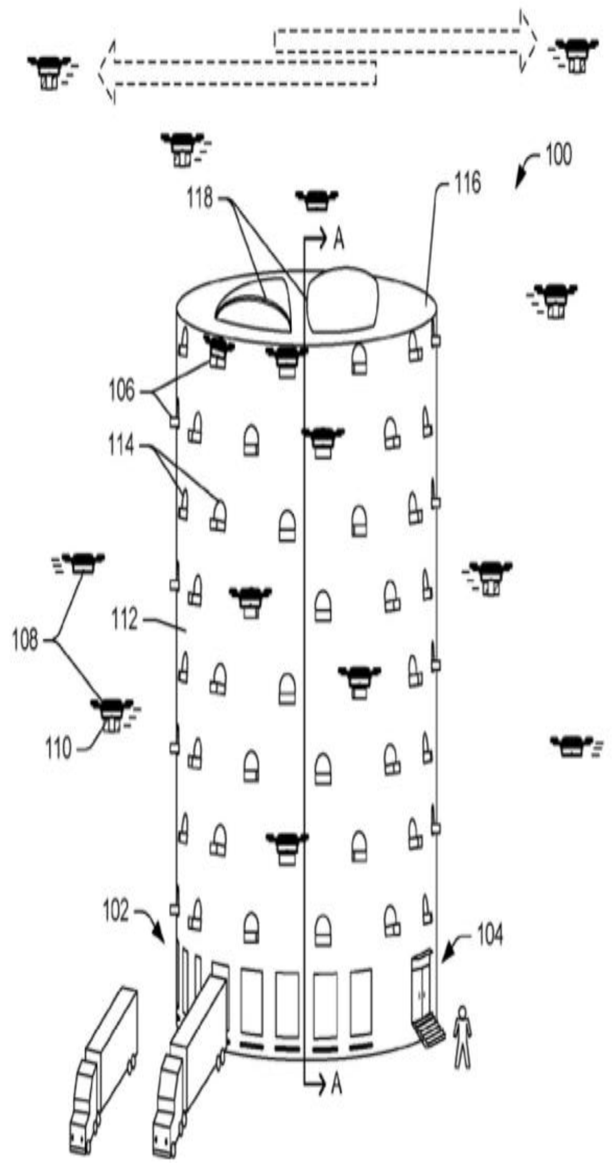
Using Drone

- Reduce driver and truck costs
- Remove congestion costs
- Real-time location and schedule assurance

Drone-beehives

- Relocate or build new distribution centres closer to customers

→ Amazon : "drone-beehives"
  - Confirm industry interest



Research Aim

1. Provide a reality check to the viability of the drone delivery concept

2. Estimate how many EU customers could potentially benefit of this service under and range of different

Literature on Drone

- Hassanalian & Abdelkefi : Provide a taxonomy of drones and propose and discuss solutions for different design challenges, including the importance of swarm flight.

- Rao : Present recommendations on societal challenges from the implementation of drones, on safety, security, privacy, ownership, liability, and regulation.

- De Miguel Molina & Seggara Oña : Provide an overview of the drone industry in Europe, including data of manufacturers, revenues and forecast.

Last-mile delivery with drones

McKinsey : Recognized as a primary option for last-mile delivery
Amazon : A plan to use drones to deliver directly to your doorstep in 30 minutes

In England, with the first customer delivery by drone becoming a reality.

Many start-up companies : Skycart, Matternet and FlyTrex are also planning to offer drone delivery services.

Challenges of using drones

Lohn

- Provide a technical overview of the impact of delivery drone operations
- Explores the areas of energy consumption, infrastructure requirements, aerial congestion, privacy, and noise

The KiM Netherlands Institute for Transport Policy Analysis

- Parcel delivery by drone as one of the key applications and market opportunities for passenger and cargo transportation

Transportation planning perspective

- Murray & Chu : Scenarios for optimal routing and scheduling of drones and deliveries.
- Ha : Implement the goal of minimizing the cost of waste time
- Tavana : Truck Scheduling Problem.
- Poikonen : Vehicle route problem considering drones
- Yurek & Ozmutlu : Focusing on minimizing the combined delivery completion time.
- Dorling : Deriving an Energy Consumption Model for Multi-Rotor Drones.
- Stolaroff : Potential to reduce greenhouse gas emissions and energy use.

Research on reducing CO2 emissions

- Goodchild & Toy : Estimating carbon dioxide emissions and vehicle miles for two delivery models

- Figliozzi : Consider scenarios for average last-mile delivery distances, with an eye toward reducing carbon dioxide emissions

Result

- Concluded that it is significantly more efficient than LCV-based delivery services in terms of energy consumption and pollutant emissions

European Commission

STRIA : Adopted as part of the "Europe on the move" package in 2017

- Highlighting transport research and innovation (R&I) areas and priorities
- Drone : Key enablers of electric air transport

SESAR Joint Undertaking

- Provide an overview of country laws
- Follow the evolution of the European drone market to identify safety issues and sector opportunities

Adopt common EU rules on technical requirements for drones

- Drive investment and innovation
- Provides a framework to facilitate drone business development and operations

FAA

- Rulemaking for small unmanned aircraft operations under 25 kg since 2016

Nakamura & Kajikawa

- Evaluate the effectiveness of Japan's small drone safety regulations in effect since 2015

- Concluded that there is significant room for improvement in terms of contributing to safety and driving innovation

Purpose

1) Understand the number of people within range of potential drone hive deliveries across the EU

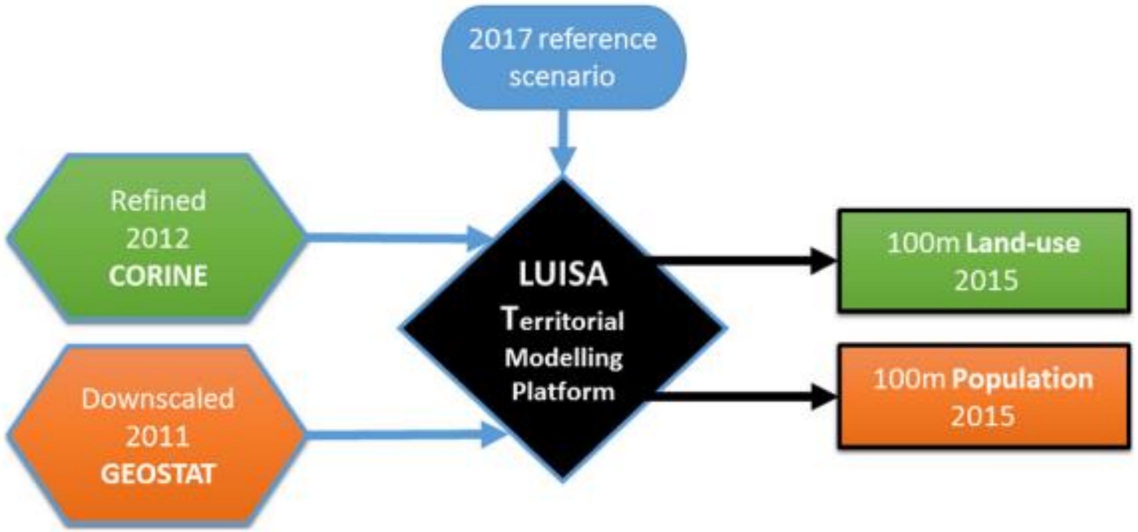
2) Present a modeling framework developed to calculate the cost and revenue of delivering a parcel to each individual.

3-1. Input Data

Population and land use data divided into 100m resolution grids for the entire EU28

LUISA Territorial Modelling Platform
- Assess the impact of European trends and policies on land use and population distribution over time and space

3-1. Input Data



The 2017 baseline scenario

- Use as a basemap to represent land use in 2012

The reference population used by the LUISA platform

- Geostat 2011 downscaled to 1 ha resolution
- Version of the 1km population dataset
- Correlate local population with urban structure classes identified through land use maps.
- Create grid-level projections of land use and population at five-year intervals from 2015 to 2050.

3-2. Modelling assumptions

- Drones used for deliveries need "open space" to land
- Use a population density threshold of 115 people/ha to estimate the availability of open landing space
- Drones can fly over residential neighborhoods and cities, so there are no legal restrictions.
- Deliveries are made directly from the drone hive to the customer, so multiple deliveries are not expected.
- Can fly up to 24 kilometers (12 kilometers each way).

Regarding the drone-beehives specification

- Only pixels with land use classes corresponding to commercial/industrial and abandoned commercial/industrial sites are suitable to house potential drone hives.

- Building permits are granted for drone hive construction regardless of surrounding land use or zoning.

- One hectare of pixels is enough to accommodate a drone hive.

- Each drone hive can accommodate a sufficient number of drones.

- have the ability to dispatch drones quickly enough to meet delivery demand.

- The authors estimate that a drone hive requires up to about 100 drones and can launch up to two drones per minute

Modeling approach

- Two Step & Run multiple times sequentially

- In the first step, create a map for the entire EU28, For each pixel of industrial land use, link the potential economic revenue generated by delivering a fixed-price good to everyone within a certain distance.

- The second step identifies the pixels with the highest economic return, Assign drone hives to these locations and Remove the "served" population from the map used as input for the next step, step 1.

4. Description of the model

4.1. Step 1 – Estimation of maximum return

- Calculate the Euclidean distance to a populated cell within a specified buffer distance.
- Calculate the potential economic return of delivering to each person.

$$Return = \sum_{i=1}^{n} Pop_{cell_i} * \left(ItemPriceMargin - FixCost - \left(MaxDeliveryCost * \frac{DistanceToCell_i}{BufferDistance} \right) \right)$$

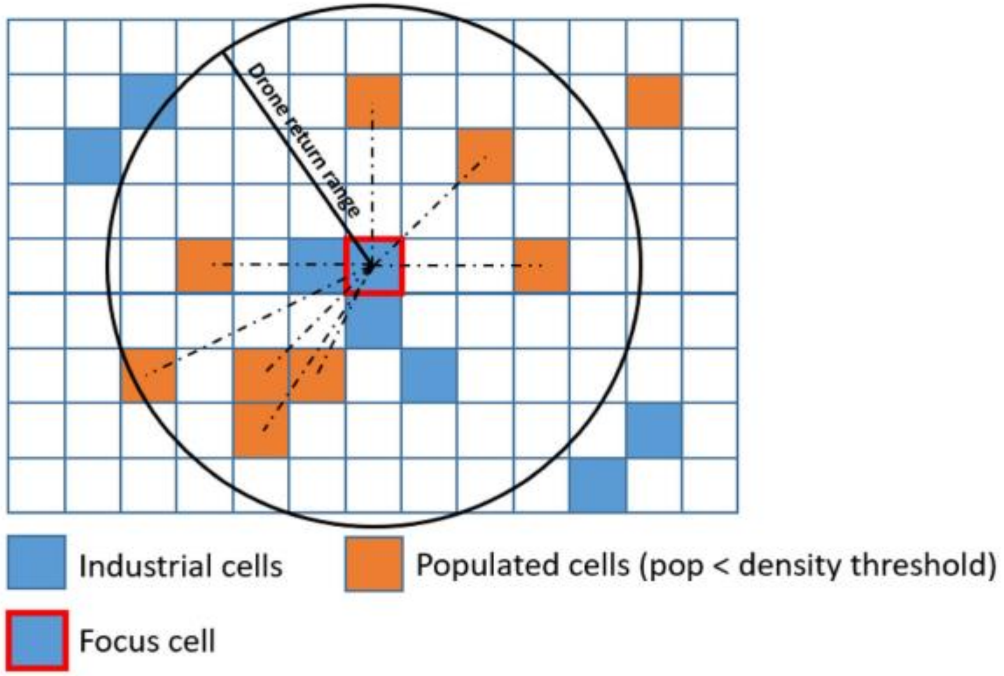
- n : the number of populated cells within a circles of a radius equal to BufferDistance around the target industrial cell.
- i : the number of people living in a specific populated cell i.
- ItemPriceMargin : Realized profit on items to be shipped, 20% of the selling price
- FixCost : Fixed cost for shipping a single parcel, assumed to be equal to 1 euro
- MaxDeliveryCost : the maximum cost of a delivery if the drone travels the maximum distance. It is assumed to be equal to 1 euro.
- BufferDistance : the maximum flying delivery distance of the drone.
- $DistanceToCell_i$: the Euclidian distance separating the populated cell i of interest from the target industrial cell.

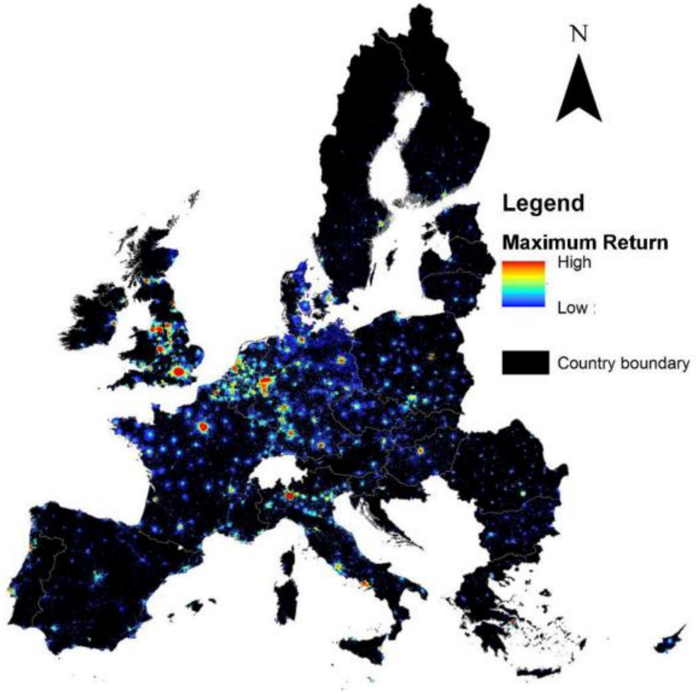
4.1. Step 1 – Estimation of maximum return

- Estimating FixCost and MaxDeliveryCost to be €1 each is a conservative "reasonable guess".

- Expect the cost of making each drone hive self-sustainable to be higher than the average cost of the entire industry ($0.88/shipping)

- Description of illustration





4.2 Step 2 - identification of optimal hive allocation and update of the population input map

- The allocation of hives follows a “selfish” approach.

Through the following steps:

1. Identification of the point of highest return in each Functional Urban Area (FUA). It is assumed that hives with the highest economic return “settle” first and remove the population within their delivery radius from the accessible pool of customers for other potential hives. In case the buffer overlaps (small FUA), only the hive with the highest return (within that specific FUA) is kept and used for a second round of optimization.

2. Creation of a circular buffer of radius equal to the drone delivery distance and removal of populated pixels within the buffer. Steps 1 and 2 are then run successively for multiple iterations until no new hive exceeding a specific economic viability threshold is identified.

Why assign a drong bee-hives

1. In 2009 over 60% of the EU population lived in FUA.

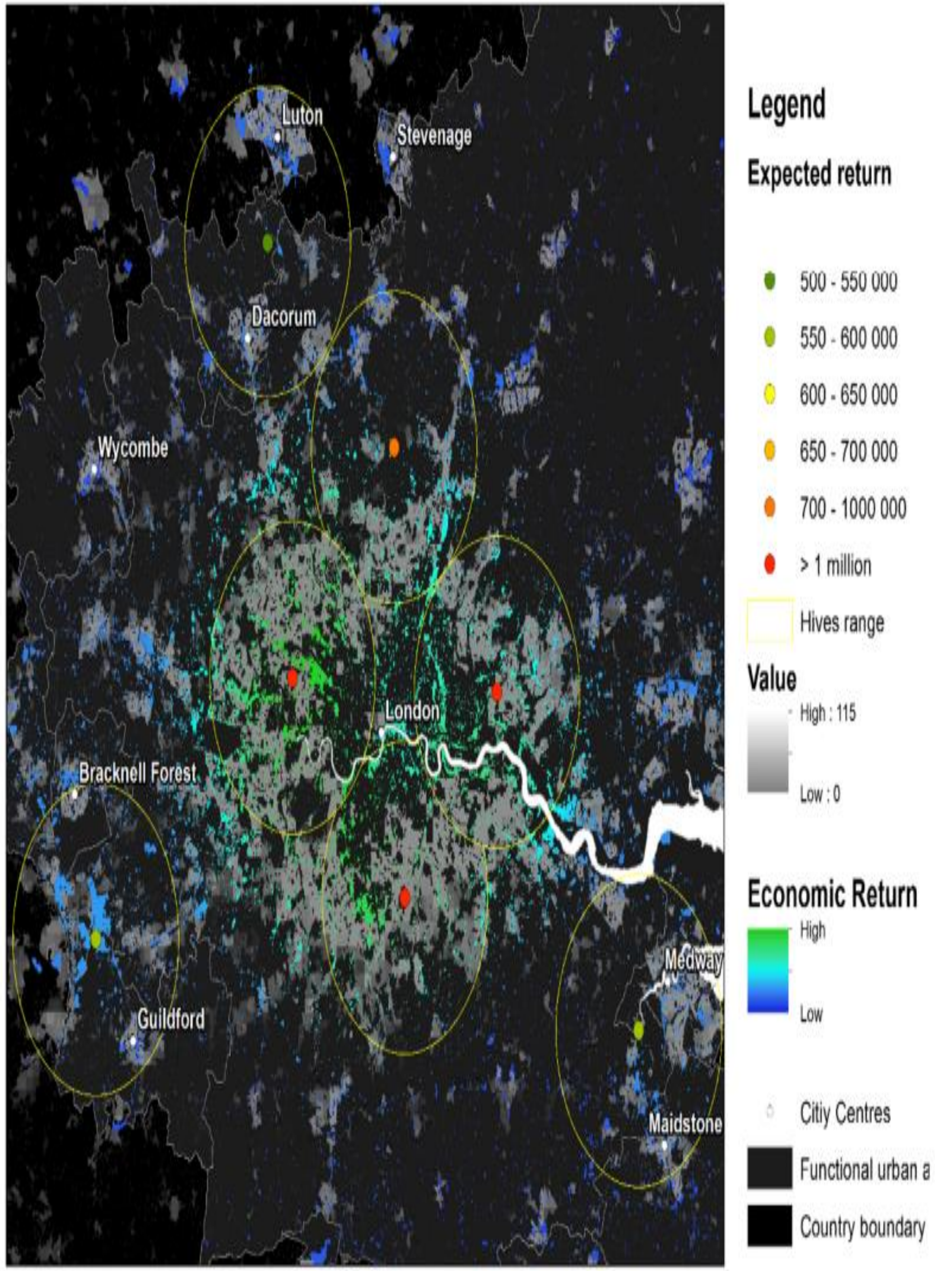
2. Due to the limited range of drones their area of delivery was likely inferior to that of FUAs.

4.3 Financial return calculation

Hypotheses to derive a realistic financial return

- Online buyers are evenly distributed across all EU28 countries.
- 10% of online shoppers use drone air delivery once a year.

- Modeling and financial benefit estimates for the drone hive
- A drone flight distance of 12 km and a population threshold of 115/ha are used.
- Yellow Circle : Drone range around each burrow
- Bulk hives with truncated coverage are assigned to bulk hives where some of the potential customers within their service area already have a high economic interest.



4.4 Scenario investigation

- Scenario 1: 12 km flight distance and 115/ha population landing threshold. This represents the most realistic scenarios under the current technical limitations.

- Scenario 2: 12 km flight distance and 130/ha population landing threshold. This represents a possible scenario achievable through an improvement of the drone landing capacity (improvement of the software to land in smaller gardens).

- Scenario 3: 12 km flight distance and no landing threshold. This scenario, currently unrealistic, correspond to the best that could be achieved by investing in software (no improvement in the drone flight distance). With this scenario, parcels can bedelivered to anyone regardless of the necessity to land in a specific place.

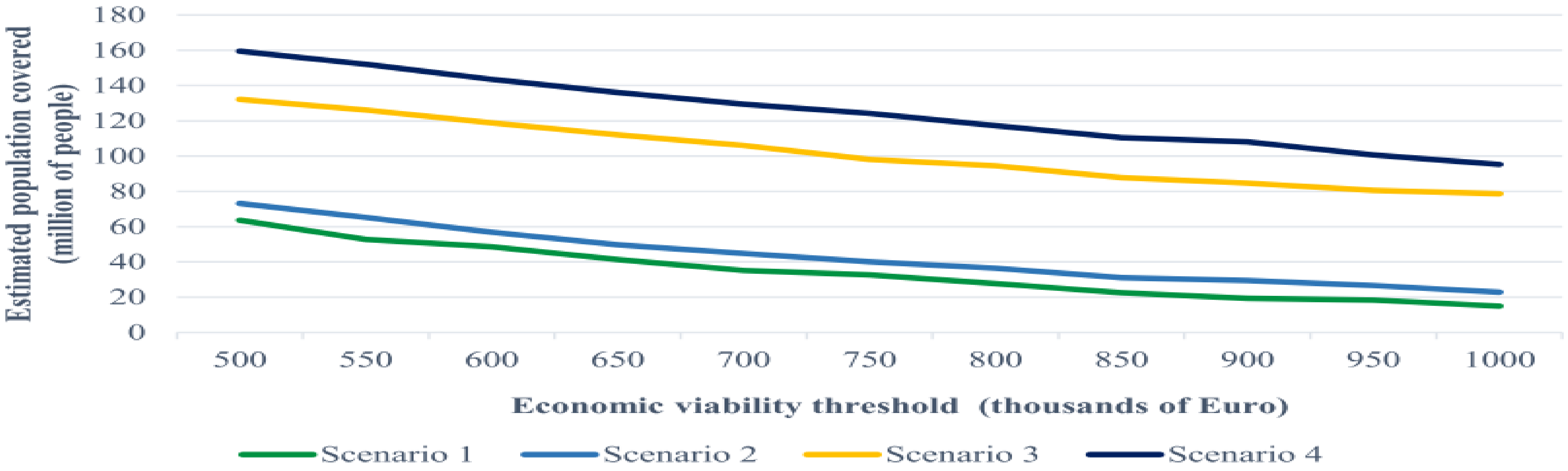
- Scenario 4: 24 km flight distance and 115/ha population landing threshold. This scenario, also currently unrealistic, corresponds to an investment in hardware allowing the doubling of the current flight range of drones without any software improvement.

5. Results

- For each scenario, the relationship between the numbers of people potentially within reach of drones is investigated, related to their economic viability threshold at the EU28 scale.

- The four scenarios follow a similar pattern.

- A low economic availability threshold allows you to serve a larger portion of the population.



Hive Cost

$$Warehouse\_cost + \left(\frac{Pop\_in\_range \times Scaling\_Factor}{Working\_Days \times Working\_Hours} \right)$$

$$\times Backup\_fleet \times Drone\_cost$$

warehouse_cost : The cost of the warehouse estimated here at 5 million euro.

Pop_in_range : total population reachable by drone departing from the hive.

Scaling_Factor : 0.06 (assuming 10% of online buyers make use of the done service).

Working_days : number of days deliveries can occur = 365 days.

Working_Hours : number of hours per day when drone delivery can occur = 12 h.

Backup_fleet : percentage of extra drones that should be purchased to cover potential losses = 150%.

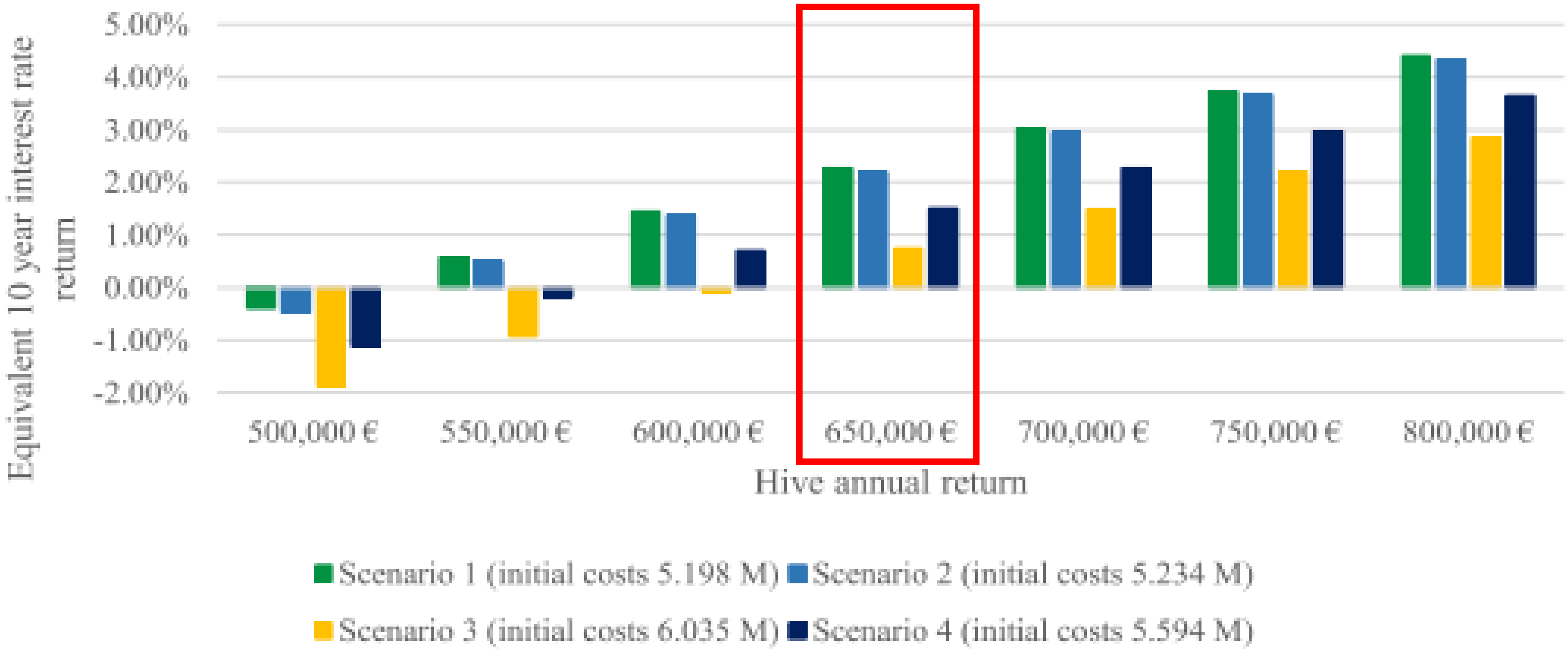
Drone_Cost : 9000 euros

- Based on the above equation, the estimated required drone fleet size for Paris Drone-beehive should be large enough to cover the 24% of customers who need home deliveries between 18:00 and 20:00 (converting from 21 to 109 drone trips per hour).

5. Results

- The correspondence between the 10-year return on investment and the annual economic return of the drone-beehive for each scenario.

- Minimum annual revenue threshold of €650,000 to generate a positive return across all four scenarios.



5. Results

- Identify serviceable population and total economic revenue for member states in the EU28 using an economic viability threshold of €650,000

- Compared to the results in Scenario 1, the match rate is higher in the UK, Germany, Italy, and France.

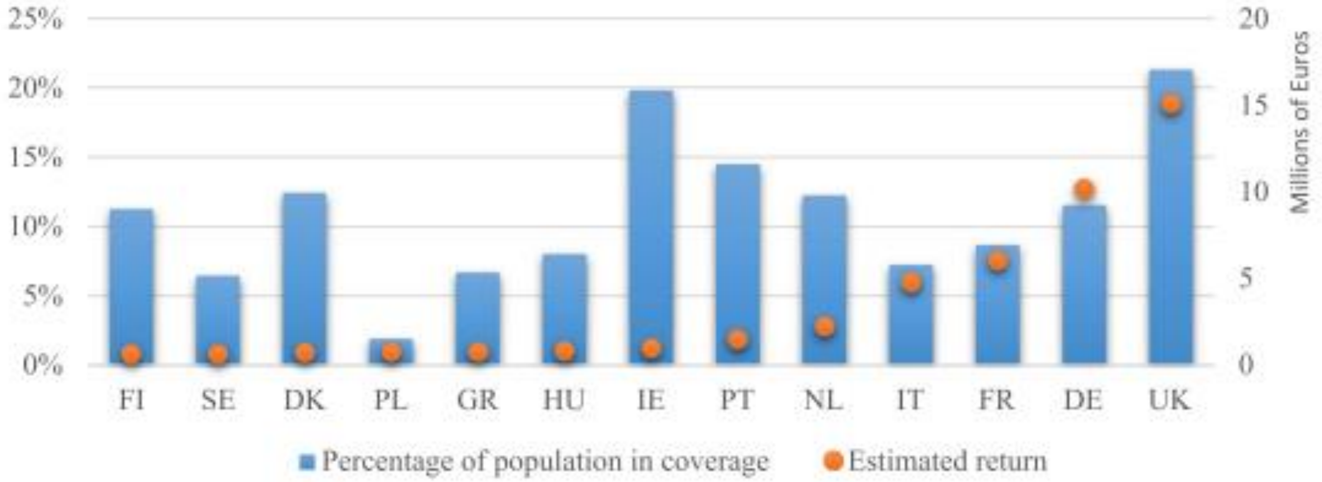
- With Scenario 1, an estimated 40 million EU citizens will benefit from drone deliveries from 50 drone-beehives.

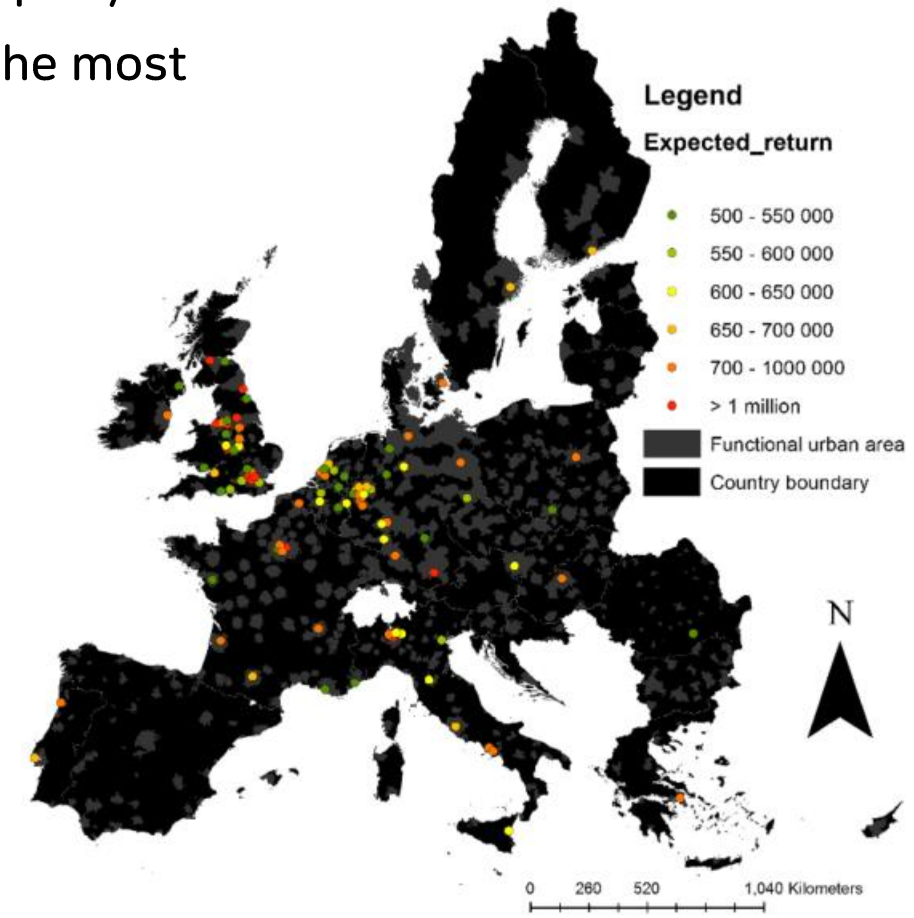
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Population covered	41.4 million	49.8 million	112.0 million	136.1 million
Total Economic return (euro)	45.6 million	53.8 million	123.9 million	150.2 million
Number of drone-bee hives	50	56	96	117

Country	Warehouse number	Hives number (Scenario 1 conditions)
UK	10	14
Germany	9	12
Italy	7	5
Spain	6	0
France	5	7
Poland	4	1
Slovakia	1	0
Denmark	0	1
Finland	0	1
Hungary	0	1
Greece	0	1
Ireland	0	1
Netherlands	0	3
Portugal	0	2
Sweden	0	1

Scenario 1.

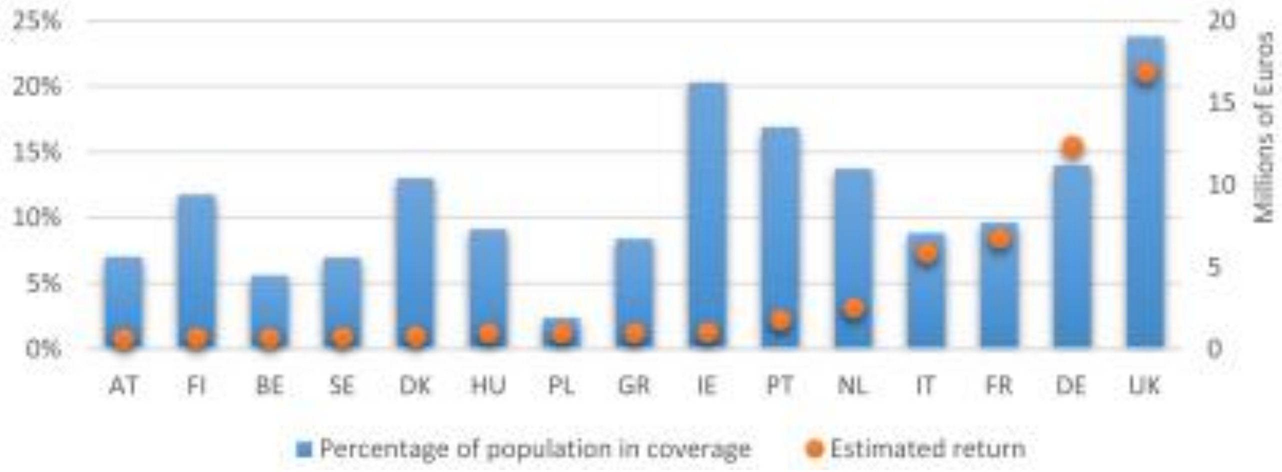
- Suitable for 13 EU countries only
- UK, Germany, France and Italy generate more than €5 million per year
- In terms of population coverage, the UK and Ireland benefit the most

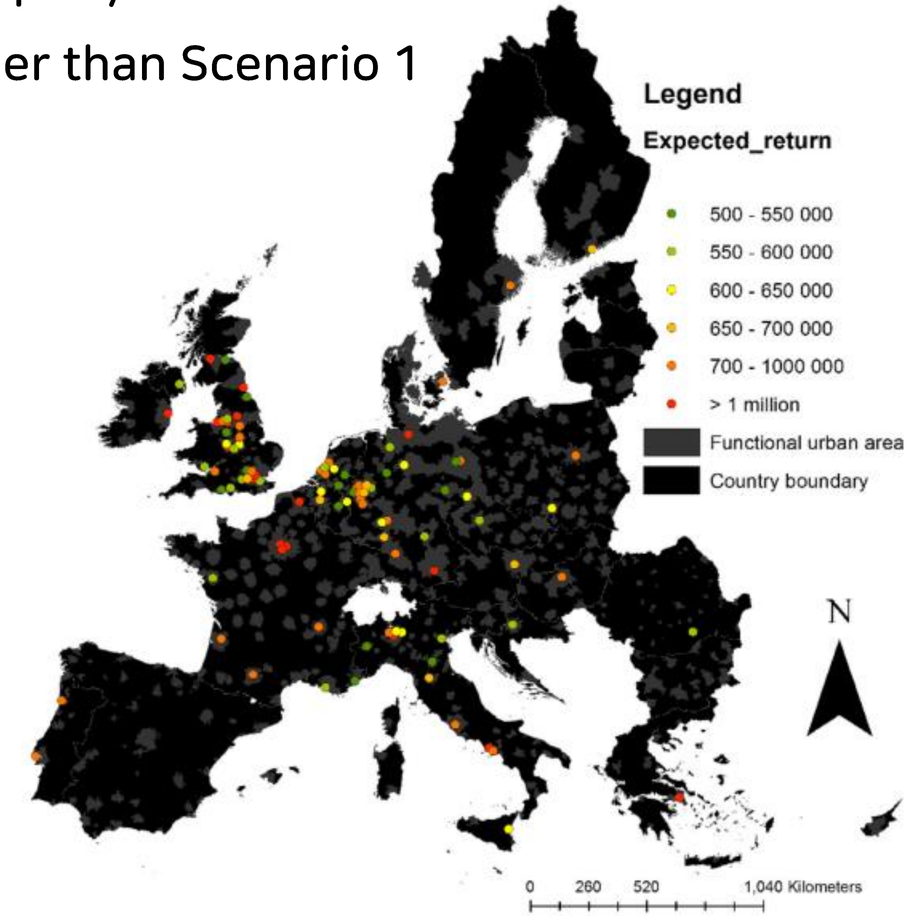




Scenario 2.

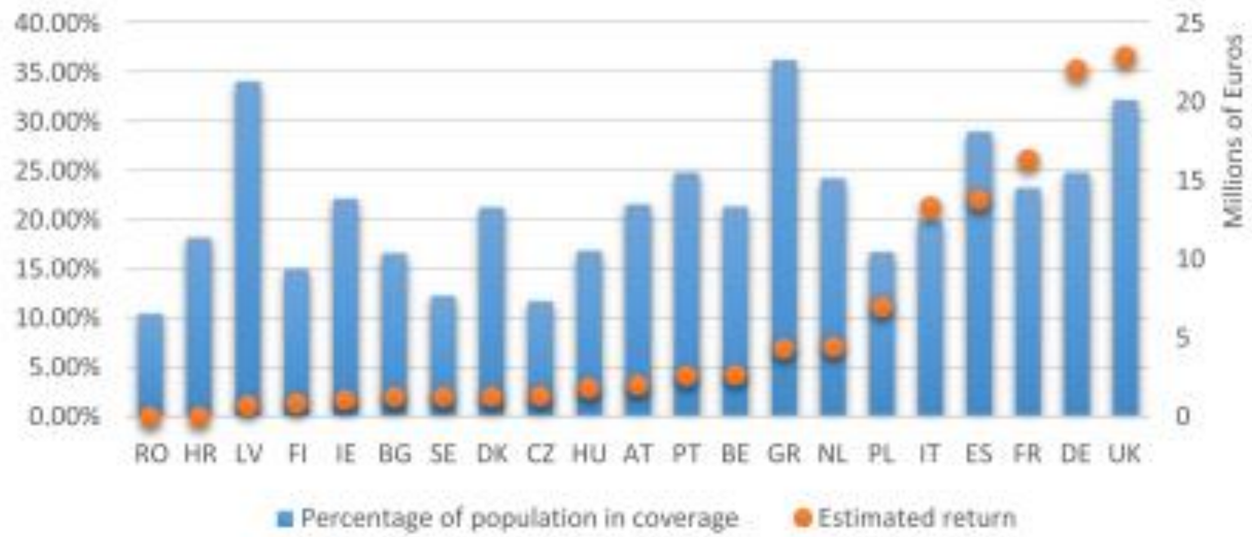
- Suitable for 15 EU countries only
- UK, Germany, France and Italy generate more than €5 million per year
- In terms of population coverage, Expected to be slightly higher than Scenario 1

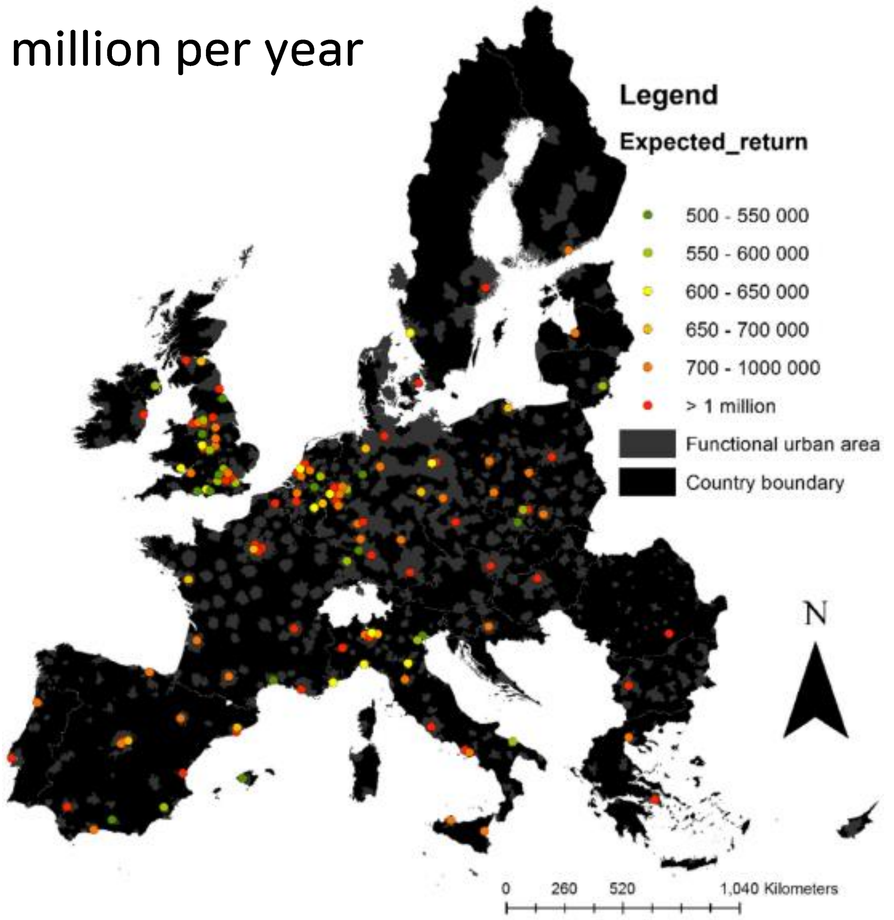




Scenario 3.

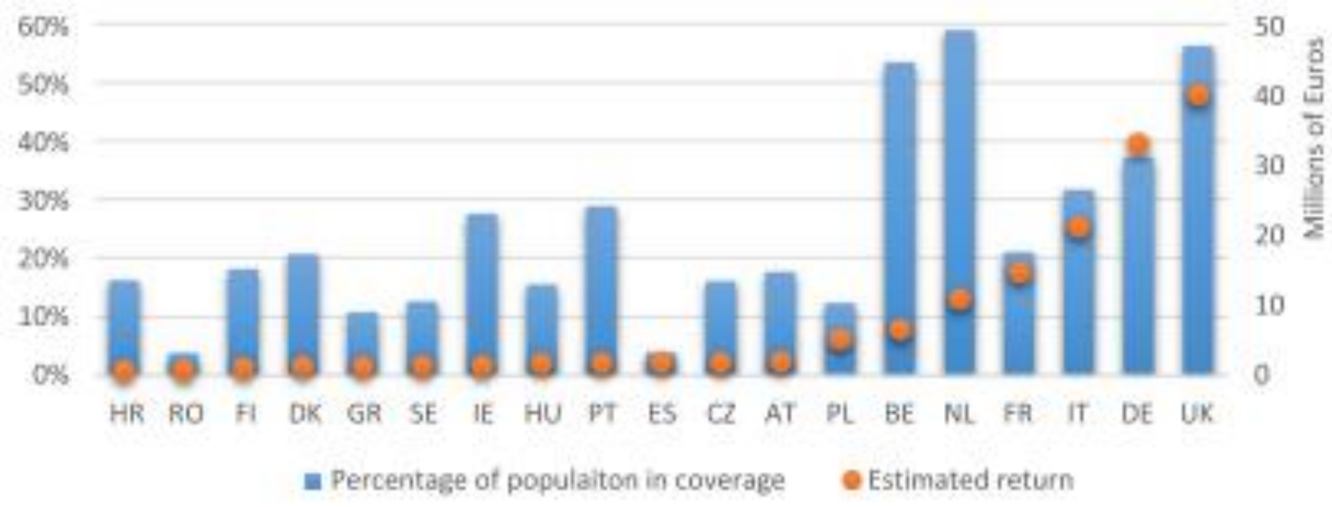
- Suitable for 21 EU countries only
- The removal of landing restrictions is expected to enable drone deliveries in Romania, Hungary, Spain, Latvia, Bulgaria, and the Czech Republic.
- UK, Germany, France, Spain and Italy generate more than €10 million per year
- In terms of population coverage, UK expected to exceed 30

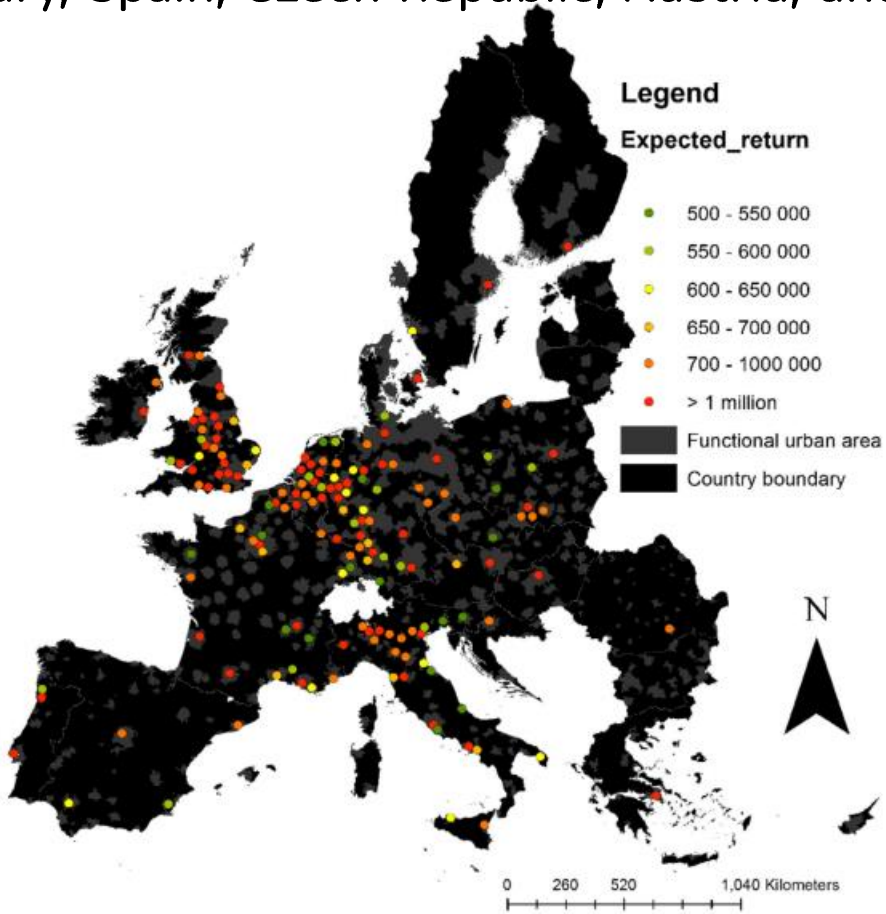




Scenario 4.

- Suitable for 20 EU countries only
- Drone delivery is expected to be feasible in Romania, Hungary, Spain, Czech Republic, Austria, and Belgium
- Expected revenue of nearly €40 million in the UK
- Expected revenue of nearly €30 million in Germany



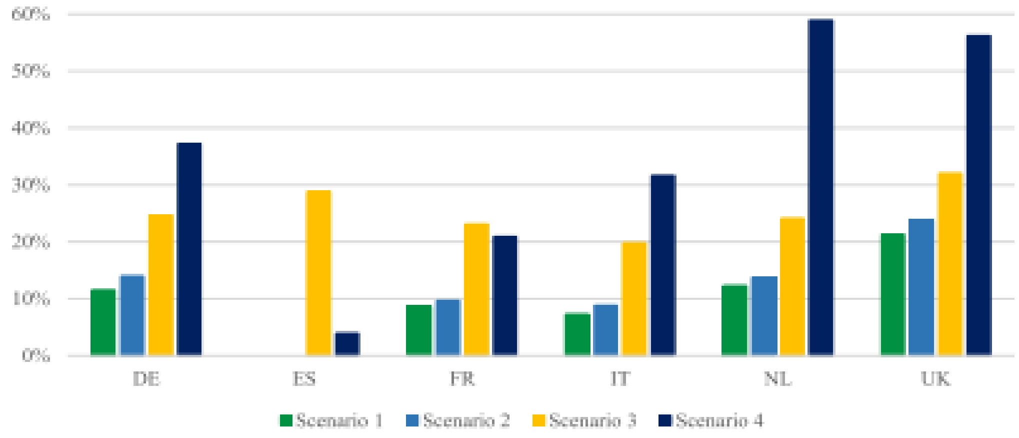


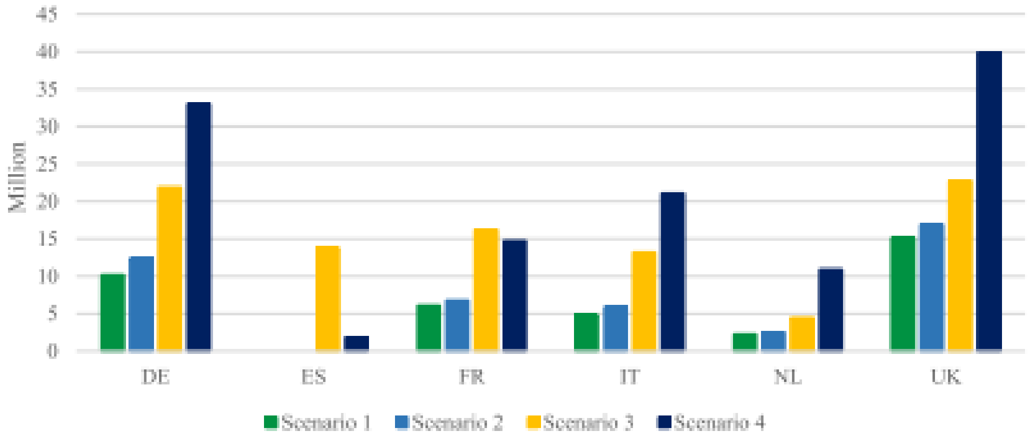
6. Discussion and conclusions

- Summarize demographics and projected revenue in Germany, Spain, France, Italy, the Netherlands, and the UK.

- In the UK, Germany, France, and Italy, drone hubs are consistently the most economically feasible to operate in these scenarios.

- The presence of the online retailer's existing warehouses in four countries(UK, Germany, France and Italy) further supports the idea that drone hubs can operate profitably here.





6. Discussion and conclusions

- Scenario 1 is expected to reach approximately 40 million people, spread unevenly across 13 European countries.

- The countries that would benefit the most from this service are the United Kingdom and Ireland.

- In Scenarios 3 and 4, investments in hardware are targeted at higher economic returns and larger populations.

- These investments are expected to result in uneven changes in services across Europe.

- Given the enormous technical challenges, a development consistent with Scenario 4 is more likely if the legal obstacles to drone deliveries are resolved.

- DT를 이용할때 드론의 시작 지점을 구하는 데 활용

Thank you