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A mobile platform for collaborative urban freight transportation

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Abstract

In recent years, online shopping is increasing the flows that transit into the urban areas. An increase in demand corresponds to an increase in operational complexity for logistics operators and environmental issues.
This paper presents the development of a mobile platform integrated with wearable features to foster the collaboration between different actors in urban freight logistics.

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Keywords: City Logistics; urban freight transportation; cooperative platforms; wearable

1. Introduction

With the rise of e-commerce, the volumes of freight that transit into the urban areas increased. According to Cardenas et al. (2016) and FTI Consulting (2011), while the business-to-consumer represents around 30% of the e-commerce turnover, this segment generates 56% of all e-commerce shipments. Moreover, online shopping involves the time sensitive delivery of small-sized items, leading to more traffic, negative externalities (Taniguchi and Kakimoto, 2004) and higher complexity in logistics operations. These issues make the last mile the most expensive, least efficient, and most polluting segment in the entire logistics chain (Gevaers et al., 2014).

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To face them, City Logistics initiatives are focused on exploring emerging business models based on new delivery options (e.g., cargo bikes, drones, lockers, etc.) and on collaborative strategies for achieving reasonable levels of sustainability and efficiency in logistics activities (Perboli and Rosano, 2018).

Within the above scenario, this paper proposes a novel ecosystem, which leverages a mobile app to match the demand with the supply of parcel delivery services in urban areas, reducing the empty trips for logistics providers, while increasing the sustainability of operations.

This paper is organized as follows. Section 2 introduces the UFreight ecosystem describing the working flow, the value proposition offered to its customers, and the mobile platform architecture. Section 3 discusses the results of the experiments performed. Finally, some preliminary conclusions are reported in Section 4.

2. UFreight ecosystem

UFreight has been developed by the ICT for City logistics and Enterprises (ICE) research center of the Politecnico di Torino, Turin, Italy (ICE Lab, 2017).

The first version has been developed for the Android mobile platform.

In the pioneering phase, the design of UFreight has been conducted according to the GUEST, a Lean Business methodology, which can be used to guide a project from the idea to the factual implementation (The GUEST Initiative, 2017).

UFreight is oriented both to the business-to-consumer and business-to-business segments, providing them with a dynamic and optimized transportation service capable of taking into account the sustainability of the service both from the economic, operational and environmental points of view.

Considering the Italian market, which at present represents the target of UFreight, there is only one potential competing platform (Macingo, 2018). An Italian startup develops this platform with the aim of creating a sharing community of users and transportation companies, to match the demand with the supply of transportation services mainly for heavy or bulky goods. In particular, a user can request a transportation service indicating detailed information about the load (e.g., origin, destination, time, type). This request is then published on the platform, notified to the more compatible (in terms of geographic position and available capacity) transportation companies, which provide an estimate for the service, generating a sort of auction bid-offer mechanism. Finally, the user selects its preferred quote and transportation service starts.

Thus, its business model appears to be affected by two critical aspects. First, it is strongly oriented to the final customer, and the transportation courier's value proposition and requirements are mostly disregarded. Second, it offers a highly static service. In fact, the bid-offer mechanism bounds the user and the courier to access on the platform for updates about the service request and to accept it. Thus, "dynamic" interactions (i.e., notifications not linked to the platform) between the two players are missing, extending the time lag between a request and its fulfillment.

In the following subsection, the value proposition of UFreight is presented using a tool included in the GUEST methodology: the Value Proposition Canvas (Osterwalder and Pigneur, 2015).

2.1. Value proposition

Fig. 1 depicts the value proposition offered by UFreight. As said, UFreight is oriented both to the business-to-consumer and business-to-business segments. In particular, the main customer segments are the final users (private individuals or companies) that require transportation and parcel delivery services, and the transportation couriers that provide these services.

Thus, the users obtain as the gain the transportation and the delivery of their parcels to the destinations by paying a freight rate set by the transportation courier. Indeed, these services represent the main source of revenues for the courier.

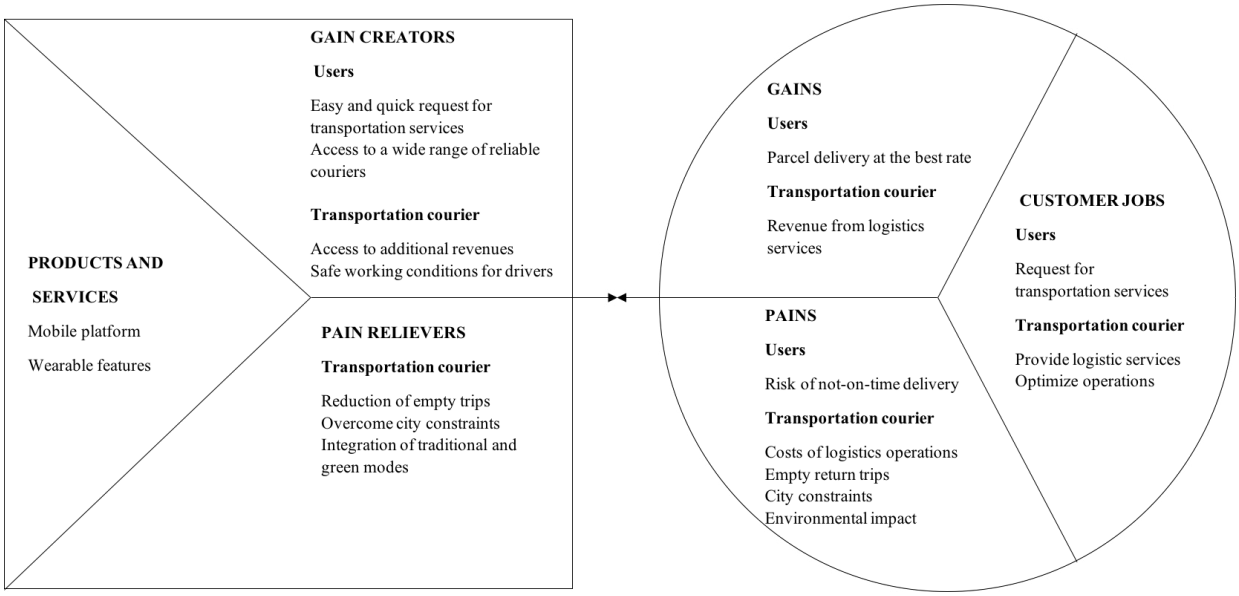

Fig. 1. The value proposition of UFreight.

These transportation services are defined as time-sensitive or time-critical (e.g., same-day, overnight delivery, etc.), they have a guaranteed delivery time, and they must be completed in a strict time window (i.e., two-hour or four-hour time windows during the working day for the same-day deliveries). However, some events like traffic and congestion, unavailability of infrastructures, mechanical failures of vehicles or logistics operators' unreliability could prevent the fulfillment of these constraints with consequent delays in the deliveries, which represent the main pain for the final users.

Similarly, the transportation courier is affected by different pains like the operative and social costs, and the negative externalities (e.g., emissions, noise, traffic, etc.) of logistics activities in cities. According to ALICE (2015), urban freight is responsible for 25% of urban transport-related CO_2 emissions and 30% to 50% of other transport-related pollutants.

Another relevant pain for the courier is the intrinsic cost of the vehicles that travel empty (or with very low capacity occupied) on the return journey to the warehouse.

The above issues combined with city constraints, like the unavailability of loading and unloading areas or limited traffic zones, reduce the efficiency of logistics operations, with consequences on the economic, operative and environmental sustainability for the transportation courier.

The concept of sustainability raised considerable interest among academics and practitioners in the field of logistics and supply chain management so that new City Logistics initiatives and solutions are emerging to make transportation activities more efficient and less polluting, by leveraging new paradigms and technologies.

In this context, UFreight represents a tool that aims to overcome the above-mentioned pains and the issues identified for the competitor's platform. In particular, UFreight proposes the service that is briefly described in the following and integrates it with features to meet the customers' requirements emerged by interviews with potential users and transportation companies.

Fig. 2 depicts the workflow of the UFreight usage. The core of UFreight is represented by a mobile app that, by means of a user-friendly interface, allows the user to request a transportation service by choosing among a list of available transportation couriers displayed on a map, the "best" one with respect to tariffs, delivery time windows and capacity constraints. The service is oriented both to long-haul shipments or last-mile deliveries and mixed paths. In

Fig. 2, these possible alternatives are represented by the dashed lines. In fact, when the transportation request involves both long-haul and last-mile segments, UFreight is able to combine and synchronize different logistics operators, by integrating green couriers (e.g., using cargo bikes) that overcome the complexities of urban areas (e.g., limited traffic zones, etc.) with a low environmental impact. Thus, consistent with the origin and destination locations, and the capacity of the couriers, a new request could be assigned to a traditional courier, to the green one or to both (e.g., the traditional courier manages the long-haul transportation, while cargo bikes are adopted in the city center). This integration is guaranteed by notifications between couriers and the synchronization and exchange of physical and information flows. Moreover, the process is transparent to the user that receive constant updates.

At the same time, UFreight provides the transportation courier with constant updates on requests that are compatible with its routes and capacity. These requests help a transportation company to fill its capacity and to avoid empty return trips, with a valuable impact in a cost-oriented system as the parcel delivery. Finally, the integration of the mobile app with a notification system for wearable devices allows the courier to receive and accept or decline new requests. Wearable technology helps to safeguard driver's performance and has the potential to reduce the risk of roads accidents due to, e.g., the use of smartphones.

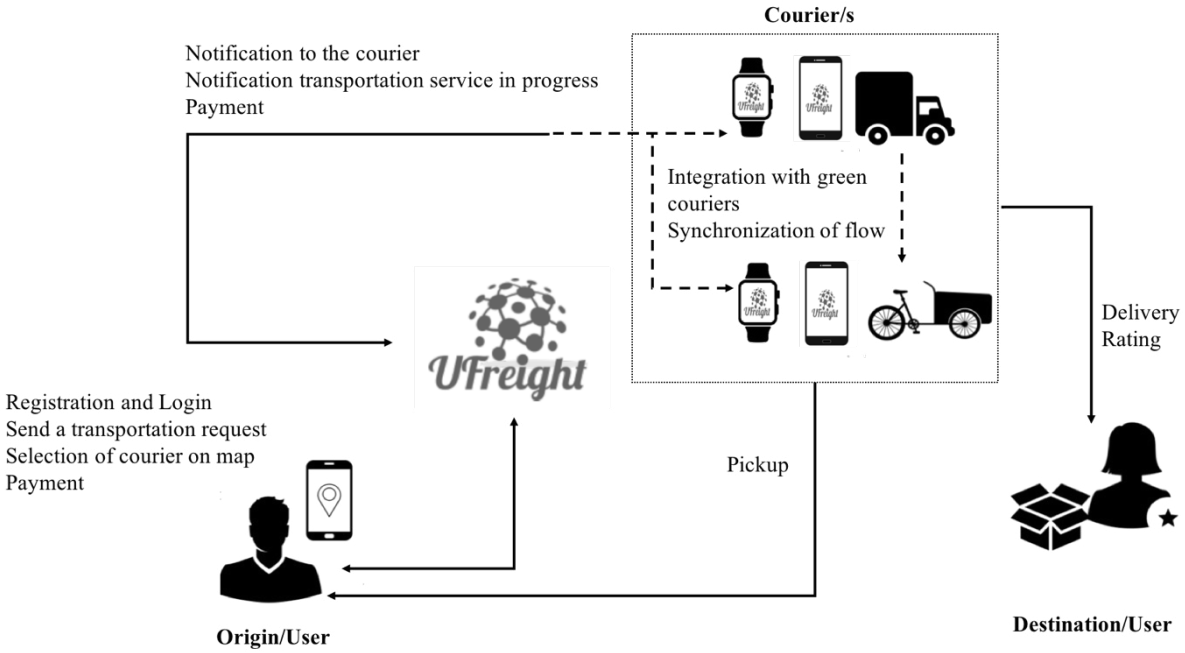

Fig. 2. Workflow of UFreight.

2.2. Architecture

UFreight is composed of a front-end, which is represented by the Android app that communicates and interacts with a webserver, representing the back-end.

For developing the Android app, the Android Studio suite was used. A remotely hosted database was created to store relevant information. Google Maps and PayPal APIs (Google Maps API and PayPal API, 2017) were exploited to integrate functionalities such as courier localization on map and service payments.

In particular, to offer the above-discussed value proposition, UFreight integrates the following main components.

- Geolocation module. Once the transportation courier has informed the system to be available to accept requests for loads through the graphics interface of the app, the geolocation module uses the GPS available on the mobile device to locate the courier on a road (Fig. 3).

  According to the origin-destination points introduced by the user in the request form, UFreight provides a list of available couriers (whose capacity and localization are compatible with the demand) and shows them on the map. When a courier is selected, an association is made between the request and the device, thus guaranteeing the identification of the courier in the system for the entire duration of the delivery.

Fig. 3. List of couriers and representation on the map.

- Wearable notification mechanism. The adaptability to wearable devices is a valuable characteristic of UFreight, which is meant to guarantee safe working conditions for drivers while increasing the visibility of new requests and making their acceptance quick and easy.
  The mobile platform is thus composed of a notification system that, using the APIs made available by Google, creates notifications for wearable devices, by displaying notifications properly on a watch or smartphone (Android developers guide, 2018).
  Moreover, wearable-only actions allow the transportation courier to accept or deny a new request in a simple way and in a short time, thus reducing the risk of accidents due to distractions while driving.
  Other notifications are periodically sent to both parties involved in the transport to guarantee the constant communication, updating, and traceability of the delivery.
  Notice that the system matches a courier to its different devices (both mobile and wearable devices) associated with it.

- Payment system. As UFreight allows the transportation courier to obtain additional revenues from real-time requests, another important component is the payment system. The platform computes, and shows to the user, the service price according to the kilometers to travel and the type of path (urban, long-haul or mixed). Thus, it makes use of the PayPal Android API to accept PayPal and credit card payments.

- Feedback mechanism. When the parcel is delivered, and the database records the status of the transport as "concluded", a notification is sent to the user requiring feedback about the service provided by the selected transportation company. This feedback leverages the rating mechanism provided by Android.
  Gathering feedback is essential to improve platform engagement by better targeting the appropriate audience and the selection of reliable couriers.

3. Experimental plan

So far, UFreight is in a prototype phase. Hence, feedback has not been collected yet from real users. However, a set of simulations have been performed on medium-size instance sets obtained by combining different customer and courier distributions in the city of Turin.

In particular, the experimental campaign is conducted on a set of randomly generated test problems, performing for each operational context described by our framework, ten independent runs and obtaining totally 360 instances, which were independently solved by the optimizer. Moreover, we consider three different-sized operational contexts with, respectively, 500, 250 and 100 potential customers randomly picked from a set of potential customers. This set derives from real data concerning customer distribution and daily volumes of deliveries in Turin (Italy) between 2014 and 2015, provided by the international parcel delivery company that operates in Italy and is involved in the urban electronic logistics (URBeLOG, 2017). The 70% of these customers are offline, while the remaining part is online. Concerning the number of couriers that serve our area, they are 15 traditional couriers (i.e., they use vans) and 5 green couriers (i.e., they use cargo-bikes). Finally, it was considered that a single transportation courier could accept up to 25 new requests for parcel deliveries every day.

3.1. Simulation-optimization framework

To conduct the experiments, the simulation-optimization framework proposed by Perboli et al. (2018) has been adopted for building instances and assess operational settings.

In this section, we provide a brief description of the simulation-optimization framework; for further information, the interested reader could refer to Perboli et al. (2018).

This framework applies a sequential simulation-optimization, where the simulator implements a Monte Carlo method, a module for georeferencing the data using Google Earth APIs and a post-optimization software.

In particular, the simulation-optimization framework is composed of the following building blocks as shown in Fig. 4:

- Data fusion and operational context description. This module combines data from different sources to describe both the problem studied and the operational context.
- Scenario generation and simulation. By means of a high-level scenario generator, this module generates a set of scenarios, which represent particular realizations of all the random variables involved in the problem data (i.e., a working day). The simulations are numerical and based on the Monte Carlo method.
- Optimization. Each scenario generated, is here solved using an optimization algorithm that works as a black box. Moreover, to cope different contexts in urban areas, the simulation-optimization framework is composed by different building elements addressing the following problems: mathematical model generated by the Pyomo modeling tool; VRPTW combined with the load balancing; Stochastic TSP and finally, Dynamic Stochastic VRPTW solved by the optimization algorithm.
- Post- Optimization. This module computes several Key Performance Indicators (KPIs) to evaluate the sustainability of a certain solution in terms of economic, operational and environmental impacts on the system.
- Context modification. This block allows the user to modify some properties of the operational context description and to analyze the new context reiterating through the previous phases.

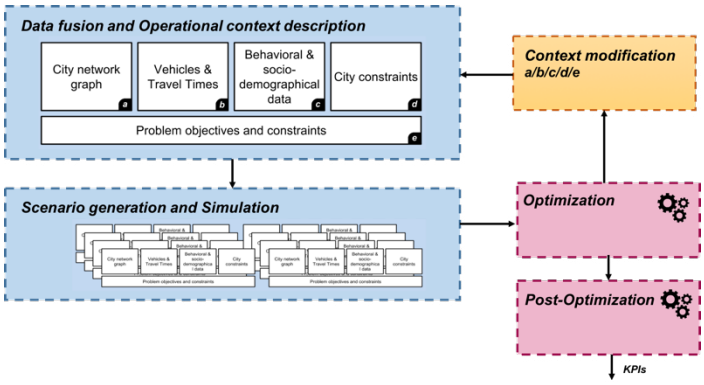

Fig. 4. Simulation-optimization framework (Perboli et al., 2018).

In particular, in our study, the framework receives in input data from different sources, i.e., city map, travel times, customer locations, speed from city sensors as well as parameters like vehicles' capacity, service time, degree of dynamism of the online requests during the daily time-horizon, etc. These data are provided by an international transportation courier operating in the city of Turin. Once an operational context was described by the previous data, the simulation module generates a set of city scenarios using Monte-Carlo sampling.

After, the optimization module scenario is solved using a dedicated optimization algorithm (Dynamic Stochastic VRPTW in our case). Each run in solved by the optimization module and its output is post processed to obtain different KPIs required by the case study into consideration.

3.2. Results

For evaluating the impact of UFreight adoption and the resulting better collaboration between operators and the consolidation of loads, on the parcel delivery system with regard to the environmental, operational and economic sustainability, we identified the KPIs shown in Table 1.

From economic and environmental standpoints, the traditional courier incurs in operative costs related to the fleet management and maintenance, and social costs related to its environmental impact. While, concerning the operational

sustainability, we evaluate the transportation courier's efficiency performance in terms of the number of deliveries per hour.

Thus, to assess the economic, environmental and operational sustainability, we computed the KPIs as percentage variations of operative costs per stops (ΔOpC), social costs of emissions (ΔEmC), number of deliveries per hour (ΔnD/h) respectively, generated by UFreight with the respect to their values in the benchmark scenario, in which UFreight is not adopted and thus, all the parcel deliveries are managed by a transportation courier company without accepting additional loads during its route.

Moreover, as proposed by Perboli and Rosano (2017), the operative costs are computed as the sum of variable costs (e.g., gasoline) and the cost of ownership, which includes fixed monthly costs not related to the distance traveled (e.g., vehicle cost, personnel costs) in which the transportation courier incurs. The operative costs are first computed in term of kilometers traveled and then, translated into a cost per stop, according to the common contract scheme in the industry. This conversion is possible considering an average distance between two stops of the vehicle of about 700 m and a minimum requirement of 80 deliveries per day (Perboli and Rosano, 2017).

With regard to the environmental issue, we quantify the amount of emissions for the delivery process, according to the technical specification ISO/TS 14067:2013 and we express the carbon footprint in an economic term, computing the social costs of emissions applying a carbon tax.

Table 1. Key Performance Indicators.

KPI	Value (%)
ΔOpC	- 25 %
ΔEmC	- 21 %
ΔnD/h	37 %

Preliminary results (Table 1) indicate that the transportation courier could gain economic benefits in terms of reduction of total distribution costs of about 25% by the adoption of UFreight. This saving is generated by the reduction of empty trips, thanks to the collaboration between operators and the consolidation of loads. In fact, the number of deliveries increases by 37%.

A further finding is represented by the reduction of the total delivery time for the final customer. In fact, thanks to the notification system, requests can be quickly managed, thus reducing the time between the request and the parcel pick-up.

Finally, the adoption of UFreight combined with the integration of green vehicles (as cargo bikes) could lead to a reduction in the number of fossil-fueled vehicles on the road and thus, to a reduction of the environmental impact and relative social costs of about 21%.

These benefits could foster the adoption of the proposed ecosystem, making it reach the critical mass.

4. Conclusions

Online shopping is rapidly increasing the freight flows that transit into the urban areas. The consequent increase in traffic and other negative externalities related to the logistics activities in urban centers are thus challenging factors for City Logistics applications, which ask for the development of new solutions to make transportation more sustainable and efficient.

In this direction, the present work proposed a new mobile platform-based ecosystem named UFreight, which was developed by the ICE research center of the Politecnico di Torino (Italy).

As described through the design of the value proposition, UFreigh aims to match the demand with the supply of parcel delivery services in urban areas, reducing the empty trips for logistics providers while increasing the sustainability of operations.

Preliminary results obtained through simulations conducted on medium-size instance sets by combining different customer and courier distributions in the city of Turin (Italy) highlighted the potential of UFreight adoption, which could lead to an improvement in the economic efficiency of the business model of the transportation couriers and to a reduction in the environmental impact of logistics activities and parcel delivery.

Future developments will be devoted to the field testing phase of the ecosystem.

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