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Transportation Research Procedia 14 (2016) 2362 – 2371

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

E-bikes and E-scooters for smart logistics: environmental and economic sustainability in pro-E-bike Italian pilots

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Abstract

The paper presents the final results of the Italian pilots of Pro-E-Bike, a project funded under the Intelligent Energy Europe programme, started on April 2013 and ending on March 2016 (www.pro-e-bike.org). The project promotes clean and energy efficient vehicles, analyses the performance of electric bicycles and electric scooters for the delivering of goods in urban areas and tests the use of these vehicles in seven European countries with thirty-nine companies, both freight transport operators, companies that deliver their own products and services providers, in order to demonstrate that light electric vehicles can replace traditional combustion engine ones contributing on mitigating logistic impacts in urban areas. Pilots enabled the demonstration of measurable effects in terms of reduction of CO_2 emissions and energy savings in urban transport: related data about environmental and social effects resulted by the introduction of e-bikes and e-scooters are shown, with a particular focus on the economic sustainability of these replacements.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: urban logistics; electric vehicles; e-bike; sustainable mobility; goods delivery

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2352-1465
Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.267

1. Introduction

Urban logistics is one of the main issues of big cities: it moves vehicles in rush hours and in roads already congested by private traffic (Lia et al., 2014). Logistics operations do have high impacts onto congestion and urban environmental quality. Concerning their impact to the level of congestion, they represent between 8 and 18% of urban traffic flows (MDS Transmodal Limited, 2012) and they decrease by 30% the road capacity because of pick--up and deliveries operations (Patier, 2002). From the environmental point of view, they are responsible for about 20% of CO_2 mobility emissions in urban areas (Schoemaker et al., 2006).

On the other hand cycle-logistics seems to have great potentialities in reducing these impacts (Schliwa et al., 2015). According to Gruber et al. (2013), 19–48% of the mileage of courier logistics done by combustion engine vehicles could be substituted by electric cargo bikes. Within Cyclelogistics project (cyclelogistics.eu, concluded in 2014), it has been estimated than 51% of all motorized trips in European cities that involve transport of goods could be shifted to bikes or cargo bikes (Schliwa et al., 2015). This shift from traditional motorized vehicles to bikes and cargobikes could be done without increasing overall costs and at the same time reducing social externalities (Conway et al., 2011).

In this framework, the Pro-E-Bike project (www.pro-e-bike.org), funded within the Intelligent Energy Europe programme, investigated the potentialities of electric bicycles and electric scooters (light electric vehicles, LEV), for goods delivering and services provision in urban areas, as an alternative to combustion engine vehicles. The project, started on April 2013 and ending on March 2016, has been focused on the problem of the impacts of good delivery in urban area, studying, testing and monitoring the effectiveness of LEV as an integrated part of the complex delivery chain. Besides this, the project specific objectives are:

- to encourage a modal shift towards less polluting modes in urban logistics;
- to share a practice that demonstrated to be successful, in some European country such as the Netherlands, that is last-mile delivery with e-bikes and e-scooters;
- to engage logistic players, public organizations and administrations, e-cycle distributors and manufactures and commercial activities in a common platform, to foster cooperation and knowledge exchange among actors.

This paper is focused on the analysis of the four Italian pilots, three in Genoa and one in Milan, highlighting the peculiarities of each one and investigating the data collected in the 12 months test. Each pilot represents a specific and well defined case study. The data used for the elaboration of this paper have been collected by pilot companies and, for the Italian pilots, elaborated by Poliedra – Politecnico di Milano.

2. Pro-E-Bike pilots

One of the main topic of Pro-E-Bike has been to test and analyze LEV technology for delivery of goods and services provision in urban areas as an alternative to combustion engine vehicles. Overall, 39 pilot companies tested 74 e-vehicles for a period of 3–12 months. The list of companies involved is shown in Table 1. In general the companies involved deliver small packages and letters, meals and fruits or provide home care or waste collection service. The experience in the use of e-bikes, e-cargobikes and e-scooters was extremely positive for the enhancement of Corporate Social Responsibility, visibility and green image (among customers and clients), cost savings (low energy consumption, low maintenance) and performances (easy access to any location in urban areas, reliability). Some problems were related to the lack of adequate charging stations, the limited autonomy (especially in hilly areas) and some technical malfunctions of engines and batteries.

Concerning the Italian pilots (Figure 1), the first one regards a big express courier, TNT Global Express (TNT), and the test of an e-scooter for delivering letters and small parcels in the city center of Genoa. The second one involves a small e-bike messenger company, Eco Bike Courier (EBC), with the strategic goal of enlarging its business market by introducing e-cargobike in its fleet. In the third case, the focus is on the replacement of a traditional van with an e-cargobike for an ecological print shop (Grafica KC, GKC) which does not have freight delivery in its core-business. The replacement of two traditional vans with e-bikes is the focus of the fourth case study, involving GLS Italy (GLS), a large logistic company, in Milan: the replacement was considered possible because the limiting factors for letters and small parcels delivery is not the load capacity of the vans but the delivery time-window.

Table 1. Overview of the companies involved in the 8 pilots, conducted in 7 EU countries within Pro-E-Bike project.

Partner	Country	Companies	Companies' name	Vehicles	Vehicle type	Testing period (M)
EIHP	Croatia	9	Hrvatske pošte, DHL, City EX, EIHP, Communal inspectors, Tobacco shop, Retirement home service Frane, Social care service, Utility Company for Waste Collection	21	e-bike e-cargotrike e-scooter	6-12
Poliedra	Italy	4	TNT express, GLS Italy, Eco Bike Courier, Grafica KC	7	e-bike e-cargobike e-scooter	6-12
Mobycon	Netherland	5	DHL, Puurland, BSO Struin, Marleen Kookt, Subway	10	e-bike e-cargobike e-scooter	12
IST	Portugal	2	Camisola Amarela, Marujo Restaurant	3	e-bike e-scooter	6-12
Occam	Portugal	3	Camara Municipality of Torres Vedras, SMAS Torres Vedras	4	e-cargobike e-scooter	6
Sinergija	Slovenia	8	Pošta Slovenije, Kratochwill, T-lotus, Biro, 3lan, Smart hose Martjanci, Čista narava, Senpo	6	e-bike	3-9
ITENE	Spain	3	SD Logistica, Eroski, Encicle	3	e-cargotrike	6
ESEA	Sweden	5	5 Home care services (cities of Atvida-Berg, Ydre, Kindra, Motala, Ialeris)	20	e-bike	12
		39		74		

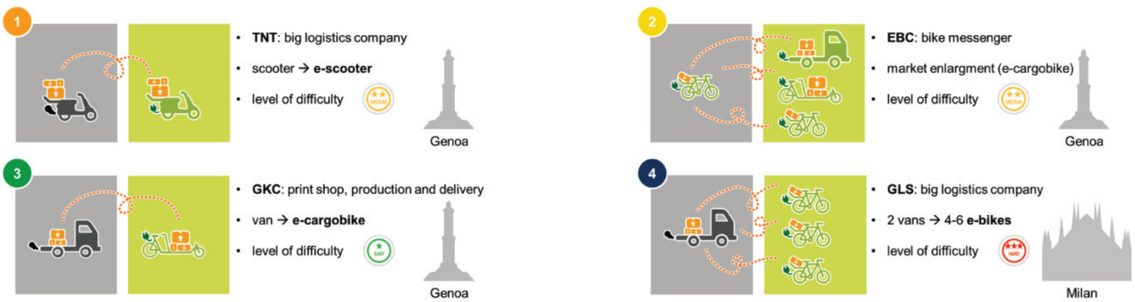

Fig. 1. Overview of the four Italian pilots.

A regard the forth pilot, in addition to the replacement of the vans with e-bikes, GLS needed to change the logistic chain, with the set-up of a temporary warehouse (Figure 2).

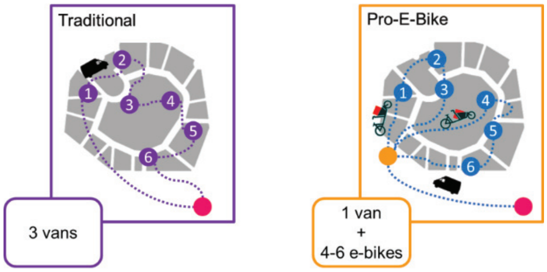

Fig. 2. Traditional model (left) and Pro-E-Bike model (right) for GLS. In Pro-E-Bike management scheme an e-bike warehouse (orange spot) has been set-up.

The vehicles have been accurately chosen in order to fit the needs of the four companies. The main characteristics of vehicles used in the pilots are summarized in Table 2.

Table 2. Main characteristics of e-vehicles used in the pilots.

	1 TNT	2 EBC	3 GKC	4 GLS
Type of E-bike				
Brand	e-tropolis Reload	Stefano Ferrari	Carriola	Winora T2 BH Xenion 700
Market price (€)	€ 5,000-6,000	€ 1,200	€ 1,700	€ 2,000
Number of vehicles of this type	1	1	1	4/6
Consumption (Wh/km)	30-40 Wh/km	10 Wh/km	10 Wh/km	4 Wh/km
Battery range / autonomy (km)	100-130 km	55 km	45 km	75 km
Battery type	Lithium	Lithium	Lithium	Lithium
Battery capacity (Wh)	4,000 Wh	540 Wh	432 Wh	300 Wh
Time for complete recharge (h)	6-8 h	4 h	4 h	3 h
Payload (kg)	175 kg	80 kg	80 kg	25 kg
Capacity (m^3)	0.160 m^3	0.250 m^3	0.250 m^3	0.070 m^3
Turning radius	30°	30°	30°	45°

For TNT the main restriction was the battery range because the warehouse in Genoa is 10 km far away the city center, that is the delivery area, and usually 40 km were covered each day by the traditional scooter. GLS had the same performance constraint but they chose to use e-bikes because they were able to set-up a temporary warehouse very close to the delivery area, the city center of Milan, decreasing widely the travelled kilometers per day.

For EBC and GKC, that for different reasons needed to carry bulky and voluminous boxes, the payload capacity was the most important characteristics: for both of them the choice fell on an e-cargobike with a payload of 80 kg payload and a capacity of 0.250 m^3.

Data were collected during the whole pilot duration. The main results in term of pilots stats are summarized in Table 3.

Table 3. Main results of Italian pilots.

	1 TNT	2 EBC	3 GKC	4 GLS
pilot duration	92 days (6 months)	79 days (9 months)	60 days (12 months)	852 days (10 months)
n° of parcels delivered	10,462 (114/day)	446 (6/day)	161 (3/day)	48,390 (57/day)
kg delivered	4,672 kg	2,347 kg	1,164 kg	28,570 kg
m^3 delivered	4 m^3	42 m^3	32 m^3	114 m^3
km travelled	3,578 km (39 km/day)	1,451 km (18 km/day)	375 km (6 km/day)	20,020 km (24 km/day)
average speed	16 km/h	17 km/h	16 km/h	20 km/h

The e-vehicles used demonstrated their effectiveness also in stress-test days, as reported in Table 4.

Table 4. Performances in stress-test days.

	TNT	EBC	GKC	GLS
date	12|01|15	16|12|14	18|12|14	16|12|14
n° of parcels delivered	**156**	35	31	92
kg delivered	90 kg	**160 kg**	**55 kg**	45 kg
m^3 delivered	0.1 m^3	**3.4 m^3**	**1.5 m^3**	0.2 m^3
km travelled	52 km	34 km	14 km	**55 km**

For TNT pilot, the results (10,000 deliveries and 3,600 km covered) suggest that an e-scooter can replace a traditional scooter without any performance decreases. Furthermore, during the stress test day, the driver was able to deliver more than 150 letters, covering more than 50 km. EBC delivered, with the e-cargobike, more than 400 parcels and bulky boxes for a total weight of 2,000 kg, covering around 1,500 km. The load capacity was tested in the stress-test day, with more than 160 kg and 3.4 m^3 carried (with two round trips). Similar results have been observed for GKC (55 kg and 1.5 m^3 in the stress-test day, with one round trip), even if they delivered less parcels during the pilot duration, using the e-cargobike for a limited number of days; as mentioned before, delivery is a secondary activity, but the pilot showed how an e-cargobike can fit with bulky boxes delivery also for a not--professional e-bike messaging activity. Finally GLS, during 10 months, delivered almost 50,000 letters and small parcels, covering more than 20,000 km with their e-bikes, completely replacing the activities of two traditional vans. During the stress-test day, one of the e-bikes covered 55 km and usually the bike messengers rode more than 40 km/day.

Significant are the savings in terms of CO_2 emissions and costs. In Table 5 an estimation of environmental and economic effects linked to the introduction of e-vehicles is shown.

Table 5. Main environmental and economic effects linked to the pilots.

		unit measure	TNT	EBC	GKC	GLS
vehicles	traditional[1]	-	1 scooter	1 van	1 van	2 vans
	pilot[1]	-	1 e-scooter	1 e-cargobike	1 e-cargobike	4/6 e-bikes
distance[2]	pilot	km	3,578	1,451	375	48,390
consumption	traditional	l/km	0.029	0.110	0.110	0.140
	pilot	kWh/km	0.035	0.01	0.01	0.004
CO_2 emission/unit	traditional[3]	$kgCO_2$/l	2.32[4]	2.66[4]	2.66[4]	2.66[4]
	pilot	$kgCO_2$/kWh	0.621[5]	0.621[5]	0.621[5]	0.621[5]
CO_2 emission/pilot	traditional	kg avoided	238	425	110	18,021
	pilot	kg emitted	78	9	2	120
CO_2 saved	pilot	$kgCO_2$ saved	160	416	107	17,901
	pilot	$kgCO_2$ saved/km	0.045	0.286	0.286	0.370
	pilot	$kgCO_2$ saved/day * bike	1.7	5.3	1.8	21.0

		unit measure	TNT	EBC	GKC	GLS
€/unit	traditional	€/l	1.472[6]	1.387[6]	1.387[6]	1.387[6]
	pilot	€/kWh	0.159[7]	0.159[7]	0.159[7]	0.159[7]
€/pilot	traditional	€ avoided	150	221	57	9,396
	pilot	€ spent	20	2	1	31
Costs saved	pilot	€ saved	131	219	57	9,366
	pilot	€ saved/km	0.036	0.151	0.151	0.194
	pilot	€ saved/day * bike	1.4	2.8	0.9	11.0

[1] Data and results are referred to traditional vehicles used by pilot companies (*traditional*) and e-vehicles used during the pilot (*pilot*).
[2] distances travelled by e-vehicles during the pilot
[3] TNT: gasoline | EBC: diesel | GKC: diesel | GLS: diesel
[4] Values reported by US Environmental Protection Agency (2009)
[5] Values reported by (Itten et al. (2012)).
[6] Values reported by dgerm.sviluppoeconomico.gov.it
[7] Values reported by www.autorita.energia.it

The effects depend on the different vehicles replaced, the e-vehicles used and the pilot duration. Considering CO_2 emissions, the replacement of traditional vehicles with LEV had tangible effects. In fact for each km the use of LEV implies a quantity of CO_2 saved between 45 to 370 g/km. This corresponded, overall, to 18,584 kg of CO_2 avoided emissions during the pilots: this means that each e-vehicle allowed to save between 1.7 and 21.0 kgCO_2 per day. At the same time the companies saved energy costs between 0.036 and 0.194 €/km with savings between 57 and 9,366 € during the pilots: therefore the energy cost saving, for each e-vehicles used during the pilot, varies from 0.9 to 11.0 €/day.

Al the companies, except TNT, decided to keep on using the e-vehicles tested during the pilots. In particular, the performances of e-bikes and of the logistics platform convinced GLS to expand the initiative, creating a full electric vehicles logistic platform, as described in Section 3. In Table 6 general consideration about Italian pilots are summarized.

Table 6. General consideration of Italian pilots.

Company	Benefits	Weaknesses	Continued use of electric vehicles
TNT	e-scooter can replace a traditional scooter without any performance decreases even though some malfunctions affected the trial. The e-scooter performances were really good, in line with company expectation. The e-scooter is perfect for promoting and giving visibility to the company.	The level of success of the pilot was affected by the poor level of assistance in case of malfunction.	The e-scooter is no more in use.
EBC	The e-cargobike is perfect for promoting and giving visibility to the company. The goal of market enlargement has been completely achieved.	No weakness.	The e-cargobike is still in use. The company bought also an e-van for addressing the requests from outside the city of Genoa.
GKC	The traditional van has been almost completely replaced with e-cargobike. The e-cargobike is perfect for promoting and giving visibility and fits completely with the mission of the company of being an ecological print shop.	During rainy days, the fully loaded e-cargobike in downhill can be difficult to be driven.	The e-cargobike is still in use.
GLS	Considering fuel/electricity costs, maintenance cost, insurance and salary for drivers, the results have showed that the average cost for each delivery makes by bike is lower than for those made by the van. E-bikes have been faster, more effective and less polluting. Furthermore they have contributed to a good return on image for the company. The 4-6 e-bikes completely replaced two traditional vans.	Possible weak point is related to the need of adding a new node in the logistic chain (the e-bikes warehouse) with some additional logistic issues to be taken into account.	The e-bikes are still in use. The effectiveness of the tested solution is proved by the second phase, i.e. the start-up of a platform completely dedicated to electric vehicles (12 e-vans and 6 e-bikes, Section 3).

3. Developments: an e-logistics platform in Milan

After the end of Pro-E-Bike pilot, GLS decided to keep on using e-vehicles for goods delivering in Milan, creating a new logistics platform completely dedicated to e-vans and e-bikes. This for some main reasons:

1. Energy costs of e-vehicles are dramatically lower than those of traditional ones;
2. Milan has a congestion charge area (AreaC) in the city center;
3. GLS needed a new logistic platform because of market enlargement.
4. GLS considered the e-logistics platform as a marketing investment and wanted to develop new business opportunities.

GLS identified an area easy to reach from the east and south motorways, close to AreaC and with space for 16 e-vans and 14 e-bikes. GLS started in April 2015 with 12 e-vans and 6 e-bikes for covering the activities of 15 combustion engine vans. The main condition to be achieved was to keep the costs of e-logistics platform at least the same than those with a traditional one. In the following part each hypothesis 1–4 will be briefly explained and substantiated.

1. Energy costs of e-vehicles are dramatically lower than those of traditional ones

The energy costs for the traditional fleet and for the electric one are shown in Table 7. It is possible to observe that, as explained in section 2, the cost for the energy is greatly lower in the electric fleet option.

Table 7. Energy costs for the two alternatives.

item	unit measure	traditional fleet	e-fleet
# van	#	15	-
# e-van	#	-	12
# e-bike	#	-	6
km van/day	km/day	70	-
km e-van/day	km/day	-	70
km e-bike/day	km/day	-	35
cost per km	€/km	0.1942	-
cost per km	€/km	-	0.0318
cost per km	€/km	-	0.0006
total van	€/yr	50,972	-
total e-van	€/yr	-	6,678
total e-bike	€/yr	-	33
1. energy cost	**€/yr**	**50,972**	**6,711**

2. Milan has a congestion charge area (AreaC) in the city center

AreaC is a congestion charge area introduced in Milan in the city centre. AreaC encompasses about 8 km^2 and the area is accessible through 43 gates, monitored by video cameras. The cost for each daily access is 5 € for private vehicles and 3 € for commercial ones. Electric vehicles are exempt (Table 8).

Table 8. Congestion charge costs for the two alternatives.

item	unit measure	traditional fleet	e-fleet
cost congestion charge	€/day	3	-
2. congestion charge	**€/yr**	**11,250**	**–**

3. GLS needed a new logistic platform because of market enlargement

Because of market enlargement and acquisition of new clients, it was necessary to create a new logistic platform, with new vehicles.

Concerning the vehicles, 15 ICE vans were necessary for the service area in the Traditional fleet approach, corresponding to 12 e-vans and 6 e-bikes in the Electric fleet one. Concerning the location, in the Traditional fleet alternative, it was possible to have it in a suburban area; in the Electric fleet alternative the location needs to be closer to the city center with an higher renting costs.

The costs of the two options are summarized in Table 9; the annual quota for the vehicles purchase is calculate considering a life-time of 6 years.

Table 9. Vehicles purchase and platform renting costs for the two alternatives.

item	unit measure	traditional fleet	e-fleet
cost per van	€	15,500	–
cost per e-van	€	–	25,500
cost per e-bike	€	–	2,000
total cost	€	232,500	–
total cost	€	–	306,000
total cost	€	–	12,000
cost per year	€/yr	38,750	–
cost per year	€/yr	–	51,000
cost per year	€/yr	–	2,000
3. annual depreciation	**€/yr**	**38,750**	**53,000**
4. platform renting	**€/yr**	**40,000**	**55,000**

4. GLS considered the e-logistics platform as a marketing investment and wanted to develop new business opportunities

The use of an higher number of vehicles (15 vs 18) entails higher salary costs, as shown in Table 10; GLS considered this as a marketing investment, able to taking care about take care of environment and increase at the same time the number of employees.

Table 10. Salary costs for the two alternatives.

item	unit measure	traditional fleet	e-fleet
# van	#	15	–
# e-van	#	–	12
# e-bike	#	–	6
cost per day van	€/day	125	–
cost per day van	€/day	–	125
cost per day e-bike	€/day	–	80
salary cost van	€/yr	468,750	–
salary cost e-van	€/yr	–	375,000
salary cost e-bike	€/yr	–	120,000
5. salaries	**€/yr**	**468,750**	**495,000**

In Table 11 all costs described above are summarized: colors used in previous tables are reported in Table 11.

Table 11. Costs for the two alternatives.

item	unit measure	traditional fleet	e-fleet
1. energy cost	€/yr	50,972	6,711
2. congestion charge	€/yr	11,250	-
3. annual depreciation	€/yr	38,750	53,000
4. platform renting	€/yr	40,000	55,000
5. salaries	€/yr	468,750	495,000
6. fines	€/yr	1,000	750
total	**€/yr**	**610,722**	**610,461**

Annually the two alternatives present almost the same costs, making the Electric fleet approach economically sustainable, with several positive effects, environmentally (for the society) and marketing (for the company). In Table 12, CO_2 emissions for the two alternatives are shown: 71.5 tCO_2/year are saved thanks to the creation of the e-logistics platform (furthermore, considering an emission factor of 0.843 $mgNO_X$/km, the total amount of NO_X saved is 15 kg/yr).

Table 12. CO_2 emissions for the two alternatives.

item	unit measure	traditional fleet	e-fleet
# van	#	15	–
# e-van	#	–	12
# e-bike	#	–	6
km van/year	km/yr	17,500	–
km e-van/year	km/yr	–	17,500
km e-bike/year	km/yr	–	8,750
consumption	l/km	0.140	-
consumption	kWh/km	-	0.200
consumption	kWh/km	-	0.004
CO_2 emission/unit	$kgCO_2$/l	2.660	-
CO_2 emission/unit	$kgCO_2$/kWh	-	0.621
CO_2 emission/unit	$kgCO_2$/kWh	-	0.621
CO_2 emission	$kgCO_2$/yr	97,760	–
CO_2 emission	$kgCO_2$/yr	–	26,082
CO_2 emission	$kgCO_2$/yr	–	130
total CO_2 emission	**$kgCO_2$/yr**	**97,760**	**26,212**

4. Conclusions

Pilots enabled the demonstration of measurable effects in terms of reduction of CO_2 emissions and energy savings in urban logistics: related data about environmental and social effects resulted by the introduction of e-bikes and e-scooters have been collected and analyzed, with a particular focus on the economic sustainability of these replacements. A particular emphasis has been paid to GLS experience in Milan, describing one of the first example of fully electric vehicles logistics platform in Europe.

Some remarkable points can be quoted about how to success in introducing e-scooter and e-bikes for facing the doubts of companies. Contractors of big companies are afraid to use e-scooters because of doubts about battery duration but travelled km during the working day are often far lower that the battery autonomy, and the scooter can be recharge during the night (avoiding the need of fast recharge systems). Logistics companies have very strict operational standard to be achieved but tested e-scooters demonstrate their technology reliability. Another problem is related to the cost of e-scooter purchase that often should be covered by the subcontractor: in this case, companies can offer incentives, such as free recharge for e-scooter. Big companies are afraid to introduce e-bikes in their logistics chain because e-bikes are perceived as no efficient: during the pilots, they demonstrated their effectiveness for delivering letters and small parcels (e-bikes) and bulky boxes (e-cargobikes). In this sense the experience of GLS proves that they can be a reliable alternative to traditional vans. Another doubt concerns load capacity but pilots demonstrated that an accurate choice of bike type (normal framework bikes, cargobikes or cargotrikes) can assure an adequate load capacity without any performance loss, especially if the company choices a pedal assisted bike. Finally, the introduction of e-bike makes the logistic chain more complex (and expensive) because of the introduction of warehouses for e-bikes: the Public Administration can play a crucial role giving disused public spaces to logistic companies for e-logistics.

With on-field activities, Pro-E-Bike demonstrated the environmental and social effectiveness and the economic profitability of e-bikes and e-scooters for urban logistics in substituting traditional combustion engine vehicles.

Acknowledgements

The Pro-E-Bike consortium includes 10 partners, coming from 7 European countries: EIHR (HR, coordinator), ITENE (ES), Poliedra and Lombardo Cicli (IT), Mobycon (NL), IST and Occam (PT), ESEA (S), Sinergija (SLO) and the European Cyclist Federation: Poliedra is indebted with all partners for the results achieved during the Italian pilots and presented in this paper. Essential has been the enthusiastic contribution of all pilot companies involved in the project, with their precise data collection, important suggestions and proactive problem-solving attitude. For this reason we want to thank Paola Chiadò and Elisa Emertzidis (TNT), Ivan Azzaro and Giulia Notari (EBC), Giacomo Chiarella (GKC), Fabio Fiore (GLS) and Franco Fabriziani (YouLog). Moreover, we thank the later people also for the precious information about their experience with the GLS-YouLog e-logistic platform in Milan.

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