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Factor influencing Logistics Service Providers Efficiency' in Urban Distribution Systems

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Abstract

The increased urbanization and the awareness of freight transportation impacts have stressed the importance of City Logistics (CL) as a comprehensive approach aimed at mitigating the negative effects of distribution activities without penalizing social, cultural, and economic issues. In this context, a crucial role is played by logistics service providers (LSPs) . This paper proposes an empirical analysis on the operational factors determining the level of efficiency of a LSP.
This study represents an attempt to develop a panel of operational variables supporting the efficiency of the urban distribution system of LSPs. The potential benefits are both economic and environmental.

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1. Introduction

Urban population growth and rapid urbanization have generated an increasing freight transportation demand within cities. These phenomena cause environmental and mobility problems linked to air pollution and traffic congestion (Browne et al., 2012; Benjelloun & Crainic, 2008). In recent years, researches and institutional authorities have focused their efforts on City Logistics issues (CL). CL vision suggests a more integrated logistics system, where shippers, carriers, and movements are coordinated, and the freight of different customers and carriers is consolidated into the same "green" vehicles.

To reduce environmental impact of urban freight distribution, City logistics studies aim at identifying alternative and collaborative network designs, such as the introduction of City Distribution Centers and hub-satellite systems,

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developing new environmental-friendly vehicles (*e.g*. hybrid vehicles) and optimizing vehicle routing in terms of travel times, CO_2 emissions and travelled kilometers.

Within CL, Logistics Service Providers (LSPs) play a key role. Their activity mainly consists in undertaking freight distribution to customers (Ehmke & Mattfeld, 2012). Furthermore, they are expected to offer high quality and reasonably priced delivery services in urban areas, which present several peculiarities like traffic congestion and restricted traffic areas (Benjelloun & Crainic, 2008). These aspects affect CLPSs performance as they add route limitations and sources of uncertainty. Recently, CLPSs studies deal with such issues and they aim at minimizing distribution costs and environmental impacts via more efficient and reliable pickup and delivery tours (Demir et al., 2014; Ehmke et al., 2012).

Furthermore, the proliferation of the Internet usage and online shopping have also contributed to transform freight distribution in urban areas, especially the development of e-commerce in the B2C market. Changes of the downstream supply chain concern several aspects: distribution chain, shipment size, shipment type, number of loads per tour, delivery location, number of delivery stops, delivery failures, delivery frequency, delivery time windows, number of vehicles required and vehicle size (Rotem-Mindali & Weltevreden, 2013; Xing et al., 2011). Today, most of the deliveries are single orders with small-sized packages (Hesse, 2002). According to Lim and Shiode (2011), the increasing demand of small-sized frequent shipments related to online shopping represents a significant challenge to the CLPSs. In urban areas, LSPs offer deliveries of goods to several customers' homes or offices in one trip. This new way of carrying out distribution leads to an increase in delivery locations and number of delivery stops. Each vehicle serves up to 200 customers per day, which means that each vehicle has to reach around 200 locations in one day.

In this context, the number of stops during a tour approximately corresponds to the number of processed parcels. Hence, LSPs aim at maximizing the number of stops per vehicle to improve their productivity. Understanding which factors influence the number of stops per tour would improve the productivity of LSPs.

The research challenge of this paper is to give a first insight of this issue, based on an empirical analysis of real LSP data. In particular, the paper aims at identifying a set of operational variables that are likely to influence the productivity of LSPs. The productivity of a LSP is measured as the number of stops made by a driver to pick up or deliver parcels. Several indicators of LSP service are selected and their relationships with the number of stops are investigated through the analysis of data collected from an Italian company.

The paper is structured as follows. First, a literature review of relevant CL studies is proposed. Then, the methodology is described and the empirical analysis is presented. Finally, the results are discussed, and implications and conclusions are drawn.

2. Literature Review

In the literature, several researches have recently studied and described urban freight distribution. Most of the studies propose general distribution models compliant with the City Logistics vision. These papers suggest alternative network designs, investigating the advantages in terms of costs and greenhouse gases emissions. They include the implementation of City Distribution Centers (McKinnon et al., 2012; Benjelloun and Crainic, 2008), networks of satellite platforms close to the city center (Crainic et al., 2009; Perboli et al., 2011), modal shifts and Intelligent Transportation Systems, ITS (Giannopoulos, 2009). All these papers are based on cooperative freight transportation systems and carriers are seen as a service.

Other papers deal with the planning of City Logistics Service Providers' (LSP) activities with two main purposes. The first one is to support City Logistics service providers in performing a reliable and efficient service, while reducing costs. This is the main task of vehicle routing problems. In particular, the reliability of the service is related to the number of timely deliveries. Thus, several new models consider congestion and travel time variations in urban areas, in order to avoid congested links and to respect delivery time windows. (Jiang & Mahmassani, 2013; Ehmke et Al., 2012; and Crainic, 2010). The second purpose focuses on the environmental sustainability of urban freight deliveries. LSPs play an important role to provide green services and products. Recently, new strategies and collaborations focus on the reduction of the impact of urban goods distribution on the environment. In particular, several studies investigate new solutions that allow to minimize the amount of CO_2 emitted (Kara et al., 2007; Jabali et al., 2012; Figliozzi, 2011; Rossi et al., 2013).

The above-mentioned literature highlights the common trends of considering LSPs as passive actors of the system, i.e., they apply the distribution models proposed by other stakeholders (public authorities, owners of the supply chain and manufacturers). On the contrary, LSPs are organizations, which adapt the delivery system rules to their business model in order to maximize their profit. Such issue leads to the research question of this paper: how the productivity of a LSP is linked to its operational delivery service. In fact, papers generally focus on the cost reduction as almost unique way to increase CLPSs' profit, disregarding the revenue component.

Moreover, very few papers discuss an efficiency analysis of LSPs. Examples of performance measurement look at the benchmark of different companies analyzing their activity. Min and Joo (2006) develop a set of financial benchmarks to identify best practices, implementing a Data Envelopment Analysis (DEA) for measuring the operational efficiency of various profit or non-profit organizations. The operational efficiency is assessed through input/output ratios. The input parameters selected by the authors are: account receivables, salaries and wages of employees, operating expenses other than salaries and wages, and property and equipment. On the output side, they measure the overall performance only considering the operating income. Thus, the authors take into account general parameters, which are not strictly related to the daily activities. Wanke (2013) implements three-stage DEA models and Stochastic Frontier Analysis (SFA) to investigate the efficiency of the largest trucking companies in Brazil. The considered inputs are the number of branches, the employees, the fleet size, and the fuel consumption. The outputs are total cargo transported (expressed by tons per year) and distance travelled (measured by the kilometers per year). This paper also proposes an analysis of LSP performance on a year basis. Another example is provided by Chandraprakaikul and Suebpongsakorn (2012), which benchmarks the performance of 55 logistics companies applying DEA and Malmquist Productivity Index (MPI). The inputs include the net value of lands, the buildings and the equipment, the shareholder fund, the operating cost, the cost of sales and/or cost of service, and the current liabilities. Profits and revenues are considered as outputs. Anderson et al. (2005) investigate how new policy measures affect operational activities of freight transport companies. The authors consider as important indicators of operational activity the total number of rounds, the total time taken per round, the delivery time as % of the total time taken, stationary time as % of the total time taken, the total distance travelled per round, the total vehicle operating cost per round, and the total emissions of pollutants. According to the authors, these indicators describe the operational, financial and environmental sustainability of vehicle rounds. Thus, they give an idea of the main aspects about a freight distribution round, but do not discuss their relation with the productivity.

In conclusion, at the best of our knowledge, there is a lack of papers discussing the operational factors that influence the productivity of a vehicle tour. For such a reason, in this paper an empirical analysis is carried out on the operational factors determining the level of efficiency of a LSP.

3. Metodology

The research is conducted through the following steps. First, based on the literature analysis we identify a set of operational variables that are likely to influence the number of stops for a vehicle delivering goods in urban areas. Then an exploratory data analysis is completed and finally, after assuming that the number of stops is the response variable, a linear regression analysis is performed to understand the relationships between the management of the pickup and delivery service, and the productivity of the LSP.

4. Empirical Analysis

This paper studies different performance indicators affecting the productivity of a LSP committed to freight transport, handling storage and delivery of documents, parcels and items throughout the world. In particular we study the productivity defined by the company as the number of stops made by a driver that collects and deliveries items each day. The LSP logistics operations run as follows. Customers place order and a van fleet leaves the local warehouse in the afternoon to pick up the customers' items at their location and return them to the trip-originating local storage. Here all items are loaded into a truck and addressed to a consolidation centre wherein items are sorted by destination, re-loaded into a truck and shipped to the assigned local final warehouse. There, items are received early in the morning re-sorted and re-loaded into van to reach the end customer location. In this model the number of stops that a driver performs appears to be crucial for the business of the company. To describe operations, several variables have been considered. There are a lot of metrics that can describe the activities of a LSP. Krauth et al. (2005) propose a list of 130 elements classified by the perspectives of different stakeholders. Among those, relevance is assumed by the kilometers per day, the labor utilization, the number of deliveries and the delivery performance. Lin et al. (2010) suggest to take into account the vehicles' capacity and Gunasekaran et al. (2001) highlight the importance of the number of faultless deliveries. The company under study monitors a lot of elements related to its business, and several of these, that are supposed to influence the level of productivity have been included into the model. In particular:

- DELIVERY HOUR: it represents the hour of the first delivery, so the time from which the driver is operative. In order to use this data in our analysis, we have calculated these values as the minutes elapsed from the 6 in the morning. In particular, we expect that if the driver leaves the depot too late, he has less time to complete pickup and delivery activities, since the operating window is shorter, as well as the effective hours available to deliver services.
- STEM TIME: it indicates the difference expressed in minutes between the hour of the first delivery and the exit of the driver from the warehouse. It is expected that a high stem time, negatively influences the productivity of drivers because the driver spends more time to carry out the first delivery and consequently there is smaller operating window, resulting in a lower number of stops.
- TIME WORK: it is the work time defined in minutes of the driver calculated as the difference between the backing depot and the exit time. The higher the TIME WORK, the higher the opportunity to increase the number of stops, obviously keeping fixed the upper limits that are the 8 hours of a normal workday.
- MASS: it is the mass (kg) of parcels, packages, documents loaded on the vehicle and intuitively, it is expected that the higher this value, the lower the productivity of the driver because the number parcels that can be effectively loaded is lower. In fact, usually parcels having huge mass are very bulky.
- MASS SATURATION: it shows the relation between the MASS and the load capacity of the vehicle. This variable is recorded because it is useful for the company to understand if the vehicles are saturated or not; the productivity is negatively affected by this variable.
- VOLUME: it indicates the volume (m3) of parcels that are loaded on a vehicle and obviously the lower the VOLUME, the lower the productivity because the number of parcels that can be loaded decreases.
- KM TOT: it represents the number of kilometres performed by the driver during the day. It is calculated by the system following the stop sequence made up during the day. The higher the kilometres, the higher the number of stops because the driver will have more opportunities to meet more customers.
- KM EFFICIENCY: it is the relation between KM TOT and KM optimum, which are the optimal kilometres computed by a software of the company based on the stops sequence of the driver. This indicator is important because it allows to understand how the drivers perform their job. If KM EFFICIENCY is > 1, the driver makes more kilometres and in turn productivity should increase.
- STOP FAILED DELIVERIES: this variable expresses the number of failed stops for the delivery activity. Obviously, the higher its value, the lower the productivity.
- TOTAL SERVICES: they are the daily number of pickups and deliveries performed by the driver. As well as, in this case it is expected easy that the higher the number of services assigned to a driver, the higher his productivity.
- SERVICE LEVEL: it is calculated as the relation between the number of successful deliveries and the assigned ones; hence the closer this value to one, the higher the productivity of the driver because he has completed all the assigned deliveries.
- STOP DELIVERIES/STOP PICK UP: it shows the relation between the number of stops done for deliveries and pickups. High values of this variable state for less stops for pickup activities and since these ones are more time-consuming, we expect that the number of stops should increase.
- DEPOT AREA: this is the operative area (m2) of the depot. Hence, the bigger the depot, the higher the area around it and consequently, the higher the opportunity for drivers to do more stops because probably there are more potential customers (B2B or B2C).
- PARCELS/M2: it is the number of parcels managed by the depot divided by the depot area. So the higher the number of parcels managed in the depot, the higher the number of stops because the area around the depot is probably more productive and more exploitable.

4.1. Data Analysis

Data have been collected for 1 week (namely week 15 of 2013) for all the Italian warehouses of the company under analysis. The period under study appears to be suitable for the analysis, because it is not influenced by special events such as bank holiday, or adverse weather conditions.

Table 1 summarizes the independent variables that are supposed to have an influence on the level of productivity for the company under study. The columns report respectively the mean, the standard deviation, the quartiles and both minimum and maximum value.

Table 1 Summary of the dataset

VARIABLE	MEAN	ST DEV	Q1	Q2	Q3	Q4	MIN	MAX
DELIVERY HOUR (min)	598,55	75,09	556,00	589,00	628,00	1.230,00	421,00	1.230,00
STEM TIME (min)	21,13	16,55	9,00	16,00	29,00	89,00	0,00	89,00
TW (min)	502,32	74,02	456,00	501,00	549,00	985,00	128,00	985,00
MASS (Kg)	589,29	366,84	373,16	516,04	702,67	9.268,73	0,35	9.268,73
MASS SATURATION	0,50	0,35	0,30	0,42	0,60	9,27	0,00	9,27
VOLUME (m3)	5,58	94,63	2,52	3,49	4,83	9.508,59	0,01	9.508,59
KM TOT	138,77	81,51	79,81	121,41	175,60	932,09	4,82	932,09
KM EFFICIENCY	1,62	0,44	1,31	1,53	1,84	4,89	0,00	4,89
STOP FAILED DELIVERIES	1,80	1,90	0,00	1,00	3,00	18,00	0,00	18,00
TOT SERVICES	78,34	24,83	63,00	78,00	93,00	275,00	3,00	275,00
SERVICE LEVEL	0,97	0,03	0,96	0,98	1,00	1,00	0,62	1,00
STOP DELIVERIES/STOP PICK UP	5,36	5,55	2,56	3,80	6,00	67,00	0,06	67,00
DEPOT AREA (m2)	4.134	3.095	1.725	3.264	5.191	11.937	640	11.937
PARCELS/M2	1,17	0,39	0,85	1,11	1,40	3,27	0,34	3,27

To explore the relationship of the productivity performance, the analysis focuses on understanding which ones of the indicators listed above are relevant factors of the number of stops of the drivers. This goal is reached through a regression analysis that aims at testing if the independent variables considered are significant factors and whether they have positive or negative impact on the response variable (Tuckey, 1977). First, the normality test on the response variable has been performed, and then all the independent factors have been normalized, so that to get a better comprehension of the results after the analysis. In order to have predictors linearly independent from one and others the multicollinearity check has been performed (Tabanick and Fidell, 2001).

In order to evaluate the level of multicollinearity among independent variables, it can be used the Variance Inflation Factor (VIF), calculated as follows:

$$\mathrm{VIF}_i = \frac{1}{1 - R_i^2} \tag{1}$$

Where

$R_i^2 =$ multiple coefficient of determination in a regression of its predictor on all others.

Some researchers use a VIF of 5 and others use a VIF of 10 as a critical threshold, which corresponds, respectively, a R_i^2 values of 0.80 and 0.90.

Table 2 Multicollinearity

Predictor	VIF
DELIVERY HOUR(min)	1.004
STEM TIME(min)	1.442
TW(min)	1.067
MASS(Kg)	**14.447**
MASS SATURATION	**13.158**
VOLUME (m3)	2.768
KM_TOT	1.567
KM EFFICIENCY	1..242
STOP FAILED DELIVERIES	**6.746**
TOT SERVICES	1.657
SERVICE LEVEL	**6.700**
STOP DELIVERIES/STOP PICKUP	1.2.03
DEPOT AREA(M2)	1.283
PARCELS/M2	1.129

Table 2 shows that multicollineary exists in the model because several variables presents very high values for the VIF. Therefore multicollinearity is avoided by removing those variables with VIF higher than 5 from the model. Although MASS SATURATION shows a VIF greater than 5, it has been included in the final model because such value is actually due to the dependence on the MASS variable. Once MASS is removed from the model, the VIF of MASS SATURATION becomes acceptable.

Table 3 Results of the regression analysis

Predictor	Coef	T-Value	P-value	Significance	VIF
Constant	0.104		0.000		
DELIVERY HOUR(min)	0.002	0.39	0.694		1.002
STEM TIME(min)	0.038	3.65	**0.000**	***	1.432
TW(min)	-0.412	-77.29	**0.000**	***	1.060
MASS SATURATION	- 0.162	-15.38	**0.000**	***	2.465
VOLUME (m3)	0.171	0.46	0.645		2.557
KM_TOT	0.055	8.30	**0.000**	***	1.540
KM EFFICIENCY	0.011	1.85	0.065		1.231
TOT SERVICES	0.887	143.81	**0.000**	***	1.233
STOP DELIVERIES/STOP PICKUP	-0.031	-3.38	**0.001**	**	1.176
DEPOT AREA(M^2)	0.017	3.12	**0.002**	**	1.248
PARCELS/M^2	0.002	0.40	0.689		1.129

Significance Notation 0;"***" – 0.001;" **" – 0.05: "*"
R^2 : 84.3%
R^2 –adj: 84.3%

Table 3 shows the results of the regression analysis performed with Minitab software tools. The columns reports the estimate of the regression coefficient, the p-value, and the values of VIF. The level of significance is associated with the p-value. The smaller the p-value, the lower the probability that rejecting the null hypothesis is wrong. In the regression analysis the null hypothesis states that the coefficient equals zero (Montgomery and Runger, 1999). If the p-value is lower that a critical value - α - , which usually equals 5%, the null hypothesis is rejected and therefore there is an effect of the independent factor on the independent variable. The outputs of the regression shows that the STEM TIME, the TIME WORK, the MASS saturation, the total number of kilometres, the total number of services completed, the ratio among the stops for to deliver a parcel and the stops for the picking, and the total area of the warehouse are significant factors of the level of productivity of the LSP.

5. Discussion of Results

The results of the regression analysis originate some considerations on the relationships between the productivity of a LSP and both operational and non-operational variables even if two of them have not confirmed the expected behavior. In particular the STEM TIME presents a positive influence on the productivity. This is probably due to the fact that a driver knows that he has to make a long run to perform the first delivery, and he will organize his activities in order to complete deliveries and pickups faster, so his productivity could in turn increase. Relating to the ratio between the stops for deliveries and the stops to pick up the model shows a negative relationship with the number of stops and this could be explained because the system of payment of drivers is based on the successful deliveries that they perform. Therefore a driver is likely to spend much time of its workday to successfully delivery a parcel and trying to avoid failures, especially for B2C services, and this negatively affects productivity. The negative impact of TIME WORK shows that if the driver has a less time to complete is activities he will likely to rush more so that the productivity will be enhanced. Similarly, huge MASS SATURATION on the vehicle reduces the potential number of stops, because the number of parcels that the driver could effectively load is lower. This is especially true in the case of B2B deliveries where the volume and the weight of each single parcel are usually high. For this reason the company should always pay attention to the vehicle loading strategy in order to enhance its productivity. Then referring to KM TOT, outcomes have confirmed that the driver is productive if he makes more km and this is due to the fact that there is a higher opportunity to meet more customers. Coherently, both the total services completed by a driver and the area of the warehouse positively influence the productivity

Seven out of eleven variables show a significant impact on the number of stops. This result shows the level of complexity of the system under analysis. This complexity has been also highlighted by Tamagawa et al., (2010) that consider challenging the modeling of urban freight transport. However, in this environment two main managerial levers can be identified for the improvement of the system. The first one is associated with the design of the network and encompasses the STEM TIME, the TIME WORK, the kilometers covered by a driver, the number of services that are completed, and the trade-off between the number of pick up and the number of deliveries. In particular a more efficient location of the warehouses, an extension of the area covered by each driver and a more efficient route structure can significantly improve the level of productivity. The second lever refers to the vehicle loading strategy and to the dimension of the warehouse. In fact vehicles should not be excessively loaded, especially with big parcels, so that the business can be performed more efficiently.

6. Implications

This model highlights some theoretical and practical implications associated with the design of a distribution system of a LSP. In fact especially in recent years, the strong competition has led higher demand for efficiency in particular in terms of customer service and cost reduction (Hoff et al., 2010). Efficient distributions systems are becoming more and more important considering that transportation costs can account for up to 20% of the total cost of a product. In this context, strategic fleet decisions involve considerable capital investment, and vehicles are generally long-lived assets and there is an intrinsic uncertainty about demand they will serve over their lifetime, and about the condition they will operate. These conditions make the risk associated with these decisions very high. Thus, it is more and more important to design in a proper way the vehicle fleet in order to properly exploit these kind of investments. From a theoretical point of view, this study represents a first attempt to develop a comprehensive panel, that includes many operational aspects, to manage more efficiently the distribution system of LSPs, measuring the main elements that affect its productivity. This is a crucial aspect that leads to another important practical feature related to the structure of the urban environment and to its design. In urban areas, logistics companies should develop proper strategies able to fit with the environment in terms of number of customers, and kilometers. The benefits associated with the enhancement of the productivity are not only economics, but environmental too. Nowadays, the level of pollution and more in general climate change, have become significant drivers towards more efficient transportation. An improved level of productivity for a LSP, in terms of number of stops for pick up and delivery activities reflects on a decreased number of vehicles for a LSP's fleet. In fact an optimized routing, together with a proper location of the warehouse and a better loading strategy, can significantly increase the number of stops for a single van. Thus, a lower number of van properly loaded that cover more efficiently a specific urban area leads to a lower level of CO2 emissions in the atmosphere. Therefore the CL system that operates in the scheduling of logistics operations in urban areas and seeks for fast, accurate and reliable pick- up and delivery tasks (Ehmke et al., 2012), appears to be an important element in achieving better quality of life in urban areas in terms of air quality and traffic congestion. But unfortunately, city transportation systems are characterized by a high level of complexity with often lack of knowledge and it is difficult to identify precise elements that can enhance them. In fact there are many drivers that participate to the running process of these systems and for this reason policy makers are not always able to implement efficient actions. Therefore, there is a strong need for easy tools to support standards, procedures, solutions and good practices (Witkowski & Kiba-Janiak, 2012). In this context the proposed model has identified several areas of action wherein it is possible to operate in order to improve the productivity of a LSP's vehicle fleet with positive effects on the environment and in terms of savings.

7. Conclusion

In this paper an analysis of the productivity of a LSP, here measured as the number of stops made by a driver to collect or to delivery parcels, has been carried out. In particular the objective was the identification of the main aspects- having significant influence of the productivity, that is one of the main aspect of the CL issue. As a matter of fact CL has been recently risen up as a crucial element for the improvement of the quality of life in terms of traffic congestion and air pollution but also a potential source of significant savings for LSP operating in urban areas. To this end a real case study of a logistics company, operating in the Italian territory, has been analyzed. Several variables have been selected and a regression analysis has been carried out in order to highlight the main leverages that impact the productivity. Results show that many of the variables taken into account significantly influence the level of productivity meaning that the issue under study is very complex to be analyzed. However two different levers have been identified for the enhancement of the efficiency of a distribution system. In particular the structure of the routing system and the strategy of loading play a crucial role on the level of productivity, and in turn they can improve both the economics and the environmental efficiency of the system. Future research will be addressed to analyses focused on specific business environments, and other geographical areas. In this way it will be possible to figure out the main aspects associated to each market under study, and to perform comparison between the Italian context and other countries.

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