Modeling e-Logistics For Urban B2C In Europe

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Abstract

Major cities need to carry out good delivery operations that coexist with the rest of urban functions. The efficiency in city organisation depends directly on the proper management of logistic networks. In this context, Urban Logistics is born to improve the efficiency in public facilities dealing with the organisation of supply networks, especially in urban freight transport networks.

This paper quantitatively models supply chains in the vehicle routing problem with time windows, especially in the delivery of e-commerce companies. Orders are placed through internet, but deliveries are made at the customer's home. The model takes special account of the effect produced on logistics variables (distances, times, costs, shipments, stops, etc.), by the way in which orders are received, and includes the delivery in time windows in urban areas.

Planners should design parking space and loading/unloading procedures so that the deliveries are made efficiently and with little traffic perturbation, and the industry should start getting ready to understand the high cost of this quality of service: the "picking" process has a high cost that cannot be assumed in high volumes and everyday the good (the street is contemplated as a scarce social good) and bad (double parking, bus lane blocking, etc. causing additional traffic congestion) use of the streets will likely cost more money. An application to Barcelona, Spain, for the food distribution sector (supermarkets) shows that, for the previously stated reasons, the current industry procedures are only feasible for very low demand share (less than 10%).

1. INTRODUCTION

Nowadays, most cities have been conceived as business units and therefore, local governments are ruled by efficient business principles. The parts that urbanism has to manage are not physical, but economical. In this way, a modern city must provide services and operations in a specific way that depends directly on who is the service operator. The efficiency implies an integral analysis that should provide a global systematic optimization of city services.

In order to achieve this goal, an attitude that encompasses planning and urban management is required to consider thoroughly city services and operations. This new concept that tends to optimize systematically city services would be known as Urban Logistics.

Urban Logistics has evident antecedents in scientific research. Larson and Odoni (1981) analyses urban operations and Daganzo (1984) studies Logistics by continuous approximations. However, Urban Logistics overtakes these partial views and try to raise again whole services and city operations, adapting techniques that have been succeed in private environments and many transport systems: the reengineering of the urban services.

In this context, the synergy derived from the optimization of limited resources in metropolitan areas and the acceptance of the similar performance of these operations and services (just-in-time production and deliveries, time-window deliveries, daily services, etc.) justify jointly the consideration of operations and services traditionally differentiated.

The productivity required by the transport companies entails illegal parking operations that extremely affect the fluidity of traffic flow and road safety. In this way, an inefficient urban distribution transfers the inefficiencies to the society in terms of environmental damages and product price increases.

In the current decade, commercial shops have generated approximately the 75 % of the total amount of load-unload operations while housing has produced the 15% and service sector the rest 10%. Apart of that, e-commerce is presented as a source of demand for road or street space, characterized by practices such as just-in-time, zero stock, personalized delivery with limited windows of time, etc., which results in an increased need for transport and pick-up-and-delivery (Robusté, 2005). The special characteristics of the order (volume, picking, manipulation, etc.) and of the service (hours open, personal delivery, etc.) make this sales channel a true challenge of logistics for the e-companies. In this scenario, the decisions regarding logistics have important financial and economic repercussions not only on the supply chain, but also in the entire business environment and often determine the success or failure of the business.

2. MODEL

The model uses the method of continuous approximations (Daganzo, 1999) and follows the steps of a classic process which determines, among other things, the main indicators of the system's demand (volume and quantity of orders, distribution in time and space, etc.) and supply (number and type of vehicles, rate of service, etc.), to finally make an analysis based on queuing theory. This method presents the density of points to visit as the main demand descriptor, hence it is necessary to know the attraction of online demands and the surface area represented by each of the zones within the defined area of study. The area of study is divided into n delivery zones (subscript i), which are determined according to the functional, geographical and economic characteristics, etc.

2.1 Determining the demand density

Starting from the demand forecast of online orders for the area of study (N), we determine the geographical distribution according to a model (gravitational, etc.), which explicitly relates the representative variables of the attraction of orders for the area (population, number of households, etc.) with a given function of generalized cost. This function may be obtained indirectly by linking the socio-economic indexes (household income, level of education, family size etc.) of the area with other significant variables for households such as level of computer equipment and access to Internet, use of information and communication technologies, etc. Once the number of daily orders attracted (N_i) and the area (A_i) of each zone i, is known, one may obtain the daily density (δ_i).

2.2 Effects of the supply chain on the real calculation density

The supply chain and the logistics costs depend, among other things, on the internal structure of the company, the inventory policy, the type of product, and level of service offered. For example, the type of reception affects the density in each zone, therefore, directly affecting the transportation costs. The main characteristics of each type of reception are as follows:

- ✓ *Personal delivery.* Delivery to the client's door within the agreed-upon time frame (T_r). The density (δ_{ir}) depends on the demand during the period *r* (N_{ir}) and the total area of the zone, since orders that are especially close to each other in space may be distant in time.
- ✓ *"Mailbox" (individual).* Since the order need not be received in person, the company has all the delivery time (T) in which to make the delivery. Compared to the previous reception mode, this achieves a large increase in density (δ_i), a reduction in reception time (almost 50%) and of the distance between clients, which yields a higher rate of service.
- ✓ *Shared drop-off point.* Similar to the preceding case with the added advantage, for distribution, of grouping together θ_i clients in a drop-off point and visiting only $N_{i'} = N_i / \theta_i$ delivery points.
- ✓ *Customer pick-up.* The only process to analyze here is how the orders are prepared with respect to the time requirements of the clients (queuing theory).

2.3 Effect of time windows on local distance

The delivery distance (l_i) is directly proportional to the number of orders N_i (evenly distributed) and inversely proportional to the square root of the density of clients δ_i: $l_i = K N_i \delta_i^{-1/2}$ (see Daganzo 1984, Daganzo 1999 or Robusté 2005). If the reception is "personal" and we introduce *m* windows of time, for each zone *i* there corresponds a window of time *r*, a demand (N_{ir}) and a density (δ_{ir}) which depend on $\varphi_{ir} = N_{ir} / N_i$. The local distance traveled in the zone *i* can be determined by the following formula:

$$\ell_i = K \sum_{r=1}^{m} N_{ir} \; \delta_{ir}^{-1/2} = K N_i \; \delta_i^{-1/2} \sum_{r=1}^{m} \varphi_{ir}^{1/2}$$

$$\sum_{r=1}^{m} \varphi_{ir} = 1$$

Daganzo's work (1987a and b) is pioneer in modelling distribution problems with time windows. He divides the day in time periods (how the company clusters the deliveries) and time windows (the customer preferences for his particular delivery), and models the system with few variables. The methodology is assuming a continuous approximation of the (smooth) demand function over the territory. By using geometric probability it is possible to work with average distances and costs that reproduce the real problem with good accuracy.

2.4 Effect of windows of time on shipments and long distances *(inefficiencies)*

Long distance is a function of the number of shipments and the distance from the distribution center and the area to be served. In a distribution system with a single origin and many destinations, but without windows of time, the shipments needed to fill the demand are a function of the number of customers to visit, the number of deliveries per customer (in this case, 1 delivery), the shipment volume (v) and the maximum capacity of the vehicles (V_{max}). When a vehicle does not have sufficient time (σ_{ir}) to distribute all its deliveries without interruption U_{max} (V_{max} / v), due to the limited window of time permitted (T_r), the number of shipments is no longer a function only of the demand and the maximum capacity (N_i / U_{max}), but now depends also on the vehicles' rate of service (determiner of the number of vehicles that must operate during this period). In this case, we appear to be facing an "inefficiency" of the system caused by the inclusion of windows of time. Fig. 1 shows how the number of shipments increases from 8 to 11 (*b1*) and to 9 (*b2*) with the addition of windows of time. Here the inefficiency invariably translates into the infra-utilization U_{max} of the vehicles, but if a third window of time is added, the inefficiency could translate into either this under- usage (semi-full vehicles) or, in vehicle "dead time" (the wait until the beginning of the next window of time to continue delivery).

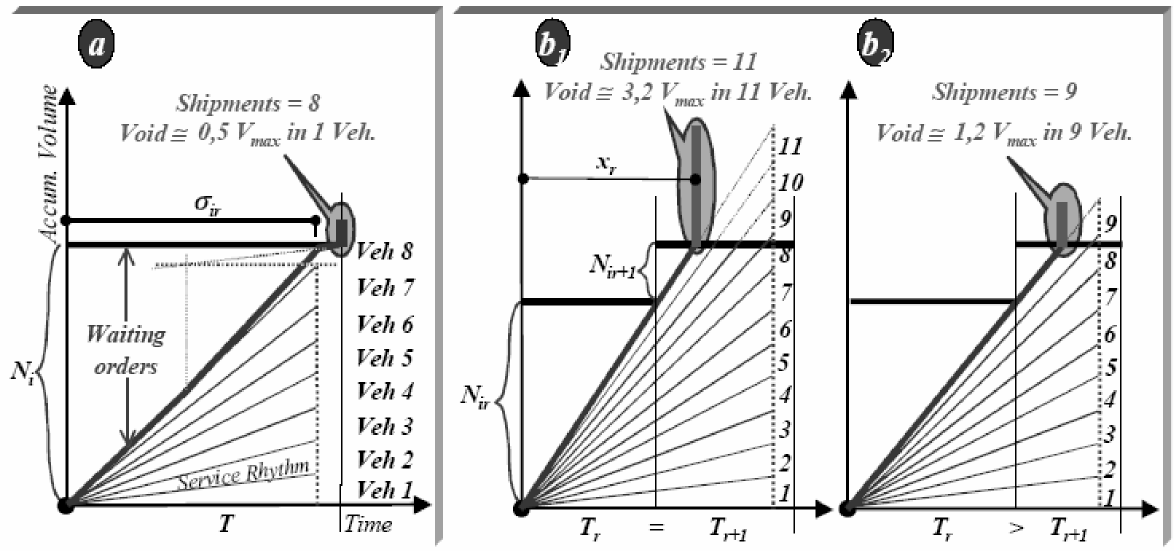

Figure 1. *Impact of windows of time on the number of shipments*

If, in a system with *m* windows of time, all of equal duration $\boldsymbol{T_r}$, and under identical delivery conditions (vehicle speed, time spent at customer reception, etc.) and $\boldsymbol{T_r} < \sigma_{ir} \leq 2\, \boldsymbol{T_r}$, we analyze pairs of consecutive windows of time, we may see that there is “inefficiency”only if the curve of the graph of the hourly distribution is negative (Fig. 2).

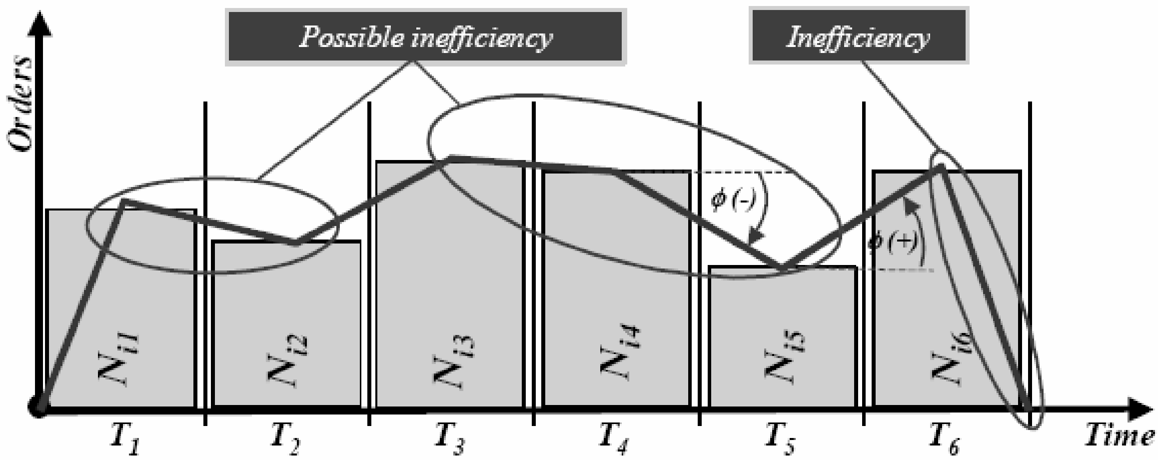

Figure 2. Possible situations in which inefficiencies may arise for constant T_r

If these conditions of delivery and/or windows of time are not met, it is not possible to make a general statement regarding inefficiency and each case must be analyzed as per Table 1 (Galván, 2002). Table 1 shows the possible patterns between two consecutive windows of time and allows us to define a methodology for calculating the number of shipments, taking (H_i) as the threshold of a maximum acceptable wait period. The “decision threshold” is a good tool with which to objectively evaluate the shipment strategy (vehicles that are full or not) to apply in each case. If there are “inefficiencies” in the distribution system, the number of shipments needed per day for the area of service i may be calculated according to the following formula (Galván, 2002). Given the number of deliveries, it is easy to obtain the daily travel distance (Li), which is equal to this multiplied by twice the distance (ρ_i) between the delivery service area and the distribution center ($L_i = 2\, E_i\, \rho_i$):

$$E_i \cong N_i \left[\left(\frac{1}{U_{max}} \right) \sum_{r=1}^{m-m'} \varphi_{ir} + \sum_{r'=1}^{m'} \left(\frac{\varphi_{ir'}}{C_{ir'}} - X_{ir'+1} \right) \right]$$

Where,

r : Subset of windows of time fulfilling cases *1a/b*, *2a/b*, *3a/b* or *4a*,
r' : Subset of windows of time fulfilling cases *1c*, *2c* or *3c*,

m' : Number of windows of time for which there exists some situation of "inefficiency",
X_{ir}'+1 : If the analysis of the following pair of windows of time (*r'+1* and *r'+2*) reveals that, if no inefficiency exists ***X_{ir}'+1*** = **φ_{ir}'+1** / ***Umax***, but if it exists, ***X_{ir}'+1*** = (**φ_{ir}'+1** / ***C'$_{ir}$'+1***) ***-X_{ir}'+2***.

Table 1. *Methodology for calculating the number of shipments per each window of time*

CHOICE OF METHODOLOGY FOR CALCULATING THE NUMBER OF SHIPMENTS					
***Duration* T_r *y* T_{r+1}**	***Demand* N_{ir} *y* N_{ir+1}**	***Relationship between* T_{r+1}, x_r *and* H_i (*)**	***Reltionship between* x_r, T_r *and* σ_{ir}**	***Case***	***Number of shipments per each window of time***
$T_r \le T_{r+1}$	$N_{ir} > N_{ir+1}$	$T_{r+1} - x_r \le H_i$	----	*1a*	According to **Daganzo (1999)**
		$T_{r+1} - x_r > H_i$	$T_r + x_r \ge \sigma_{ir}$	*1b*	
			$T_r + x_r < \sigma_{ir}$	*1c*	According to **proposed methodology**
	$N_{ir} \le N_{ir+1}$	$T_{r+1} - x_r \le H_i$	----	*2a*	According to **Daganzo (1999)**
		$T_{r+1} - x_r > H_i$	$T_r + x_r \ge \sigma_{ir}$	*2b*	
			$T_r + x_r < \sigma_{ir}$	*2c*	According to **proposed methodology**
$T_r > T_{r+1}$	$N_{ir} > N_{ir+1}$	$T_{r+1} - x_r \le H_i$	----	*3a*	According to **Daganzo (1999)**
		$T_{r+1} - x_r > H_i$	$T_r + x_r \ge \sigma_{ir}$	*3b*	
			$T_r + x_r < \sigma_{ir}$	*3c*	According to **proposed methodology**
	$N_{ir} \le N_{ir+1}$	*Noinefficiency exists in* T_{r+1}		*4a*	According to **Daganzo (1999)**

(*)x_r is the distance to the intersection of the demand and supply, from the beginning of ***T_{r+1}*** (Fig. 2)

3. RESULTS

The application of this model has been carried out in food distribution sector in Barcelona. A set of different scenarios has been generated depending on the percentage of transfer from traditional commerce to e-commerce and the number of companies that take part in the food distribution. The range of transfer from traditional business to e-tailers varies linearly from 1% (Scenario 1A) to 10% (Scenario 10A) of a total amount of 1,995 M.EUR/year. Apart from that, the number of competitors in Barcelona food distribution has been modelled from a single company (Scenario 1B) to 10 competitors (Scenario 10B). Hence, there is a total amount of 100 scenarios (the product of 10 scenarios of type A to 10 scenarios of type B).

The inefficiencies associated to the food distribution are dependent to the maximum capacity of the vehicles. Those vehicles that operate with a low capacity guarantee a high distribution performance in whole scenarios. On the other hand, vehicles that are able to serve 10 orders incur a significant lost of efficiency. These effects are especially highlighted when there are an important number of food distribution competitors and low percentage of transfer from traditional commerce to e-commerce. The results are depicted in figure 3.

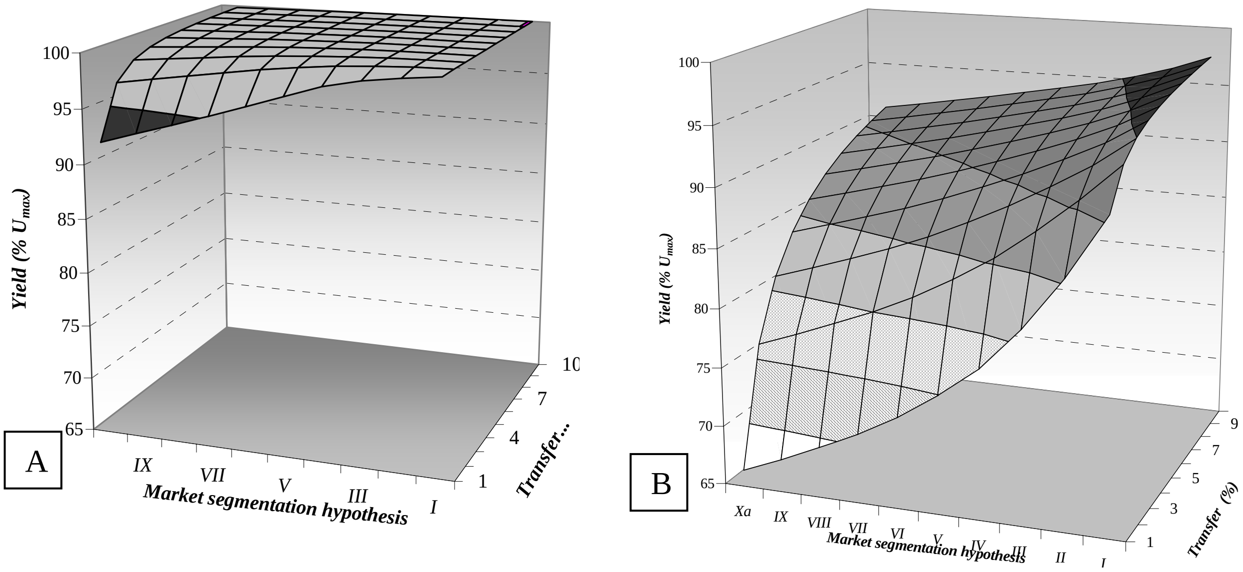

Figure 3. *Comparative yields of maximum capacity for* (A) U_{max} = 6 orders *and* (B) Umax = 10 orders

More specific studies have been conducted in several districts of the city depending on the average household income and the availability of load/unload parking places. A transfer of 1% from traditional commerce to online (916 op/day) generates an increase of 0,6% on the daily operations in 2000 (146.800 op/day) considering the whole area of Barcelona. For example, in the Sarriá-Sant Gervasi neighbourhood of Barcelona which has an average household income of 4,400 EUR/month, an average street width of approximately 6.5 m and 4,470 operations from 10:00am to 12:00noon, the delivery of each 1% of transfer (from traditional sales channel to online) represents an increase of 1.1% of the operations and an additional demand for parking spaces/h of 0.7% (with respect to the year 2000). The problems of distribution during the last hours of the day could be caused by restrictions of access (blocked by delivery trucks) for the private vehicles in certain areas of the city.

4. INITIATIVES OF LOCAL GOVERNMENT

During 1997, an extensive data survey was carried out about freight L-U operations in Barcelona, reflecting odd pattern behaviours. The scope was to correct the use of L-U zones in intersections ("*xamfrans*" defined by Ilfefons Cerdà in the last quarter of s .XIX) and in lanes of specific streets. Derived from the results of this project, Barcelona's Council has implemented an *Action planning* in L-U zones in order to organize these operations. The enforcement initiatives derived from this planning will be:

Intersections: Regulations allow L-U operations between 8:00 AM – 2:00 PM., and a maximum period of 30 minutes. The local police has collaborated with the development of enforce tasks. The control is based on a cardboard clock that users have to locate in the frontal part of the vehicle. However, a new system is being defined based on optical lector devices that will inform when the maximum 30 minutes have passed.

Lanes. In Balmes street, a trial stretch of 250 meters long was considered in order to install a specific traffic devices consisting in variable message signs (VMS). It allows the development of L-U operations from 10:00 AM to 3:00 PM that last less than 30 minutes. During night (10:00 PM to 7:00 AM) and week-ends, this lane is used only for car parking places. The success of its applications results in the transfer of this initiative to other streets in Barcelona (Muntaner and Travessera de Gràcia streets).

Access control zones. Another measure devoted to the L-U operation improvement is implemented taking advantage of the existence of 5 zones with vehicle access control devices. These zones are reserved to pedestrian flows. Apart from that, the resident cars (8,000 tags on the whole) and delivery fleet are the unique vehicles that are allowed to pass through 50 access points. The whole system is controlled by video-cameras. This system is conceived to adjust the access demand, creating short time windows with pre-assigned permission.

Information to operators. Another project that is being conducted by the Barcelona's Council consists of developing the contents of "*Moure's per Barcelona*" web page (<www.bcn.es/infotransit/>). This element allows us to consult the public transport network, the location of traffic jams, free parking places, etc. This service is to be adapted to delivery companies by means of a new telematic tool (*Descàrrega privilegiada-Privileged unloading*) that let consult in real-time the nearest unloading places to a specific address.

Other projects. Apart from the projects detailed above, Barcelona's Council aims to improve the U-L operations by other ways. The most interesting initiatives are: carrying out L-U operations in payment parking places, implementing a tool to calculate routes in real-time or permitting night parking places in specific areas.

5. CONCLUSIONS

For the benefit of the companies, it is important to locate the store as closely as possible to the areas served and to reduce the extended time spent in reloading and order reception, in order to improve the low yield of the vehicles. This is a critical variable in determining the minimal fleet size needed and one of the main aspects to bear in mind at the moment of choosing how the fleet is to be managed (own company or outsourcing). In order to reduce delivery time, they should consider the possibility of switching from direct personal reception to some other type of strategy such as an individual or shared drop-off point, which would offer the additional advantage of being potentially located always on the ground floor. It will be necessary to take proactive measures in those areas with high levels of freight movement, deficient road space and high household incomes, as these areas could suffer serious impacts from the activity during the period of 10:00am to 12:00 noon. The large amount of resources required and the high associated costs, even for low demands, make the home delivery system an alternative with poor feasibility, which worsens considerably in the case of offering the high number of windows of time needed to gain market share. Local authorities should anticipate the impact that the location of e-commerce in time and space may have on the existing model of urban freight distribution. The impact of the peak periods in e-commerce is quite different, since the first peak period (10:00am to 12:00 noon) coincides in time with the maximum activity of commercial delivery, while the second peak period (8:00 pm to 10:00 pm) is superimposed on a time of little or no activity.

Solving this costly distribution system will require e-consortiums and alliances at a new scale, which will involve, among others, product suppliers and specialists in warehousing and distribution. It is possible that the future model will have little in common with the existing model of home delivery, but will entail the creation of a new concept of shared drop-off points, among other things, providing storage for articles shipped by the logistic operator of a commercial distributor.

REFERENCES

DAGANZO, C.F. (1984). The length of tours in zones of different shapes. Transportation Research B, 18B:2, 135-145.

DAGANZO, C.F. (1999). Logistics systems analysis. Third edition. Springer-Verlag.

GALVÁN, D. (2002). Modeling e-logistics for urban B2C. PhD Thesis. Advisor: Dr. Francesc Robusté. Civil Engineering School, Technical University of Catalonia at Barcelona, Spain (in Spanish).

ROBUSTÉ, F. (2005). Transportation Logistics. Editions UPC, Barcelona (in Spanish).

ROBUSTÉ, F. (1999). Logistics of Urban Freight Distribution. Proceedings of the 1st International Congress on Urban Traffic, April 14-16, Madrid (in Spanish).

ROBUSTÉ, F., J.M. CAMPOS and D. GALVÁN, D. (2000). Urban logistics is born. Proceedings of the 4th Spanish Congress on Transportation Engineering, Valencia, vol. 2, 683-691 (in Spanish).

Larson, R.C. y Odoni, A.R. (1981). "*Urban Operations Research*". Prentice-Hall. ISBN 0-13-939447-8.