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A New Process Model for Urban Transport of Food in the UK

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Abstract

Urbanisation is increasing at a rapid pace and one of the consequences of this trend is that more people live in cities, more people demand more products, and above all, more food needs to be transported to and distributed within the cities. With the advancement of new technologies and widespread use of mobile devices in the population, more and more people prefer to shop online, not just books, electronics, or fashion products, but food products as well, in particular the groceries. In this work, we focus on this growing challenge of food distribution in the cities, from the viewpoint of this emerging channel: home deliveries of online food purchases. Especially in the UK which is the second biggest online grocery market over the world, retailers are offering online shopping to their customers and then fulfil the home delivery using their own fleet. This poses challenges to retailers in terms of increased costs from providing a non-core service of distribution and logistics to end-consumers and the life in the cities in general in terms of increased carbon emissions and traffic. We design models that propose appropriate incentives to retailers to collaborate for the distribution of home deliveries. For this purpose, we initially investigate the current market structure and operations. Then, we test our logistics sharing models with empirical data from a retailer based in London to show the relevance of collaboration. Our results suggest that it is theoretically possible to collaborate and reduce economic, environmental, and social costs arising from the uncoordinated case; however, implementation of these ideas still pose a great challenge due to the extremely competitive nature of the food retail market.

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Keywords: Home Deliveries; Co-opetition Model; Reduction Cost; Shared Logistics

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1. Introduction

Logistics is a key factor for the competitiveness of the EU economy, as well as a key sector for the EU's economic integration. A considerable amount of research has been carried out to optimise the organisational and operational practices of logistics. Moreover, transport is the fastest growing sector with road transport subsector being the largest contributor to global warming, through the emissions of CO2. The negative consequences are more intense, especially in urban areas. In Europe, around 75% of the population lives in urban areas and it is foreseen to increase up to 80% by 2020 (EEA, 2010). Moreover, food products are among the most frequently delivered items to retail shops in city centres. They also require special distribution conditions owing to their perishable nature and quality requirements (Gebresenbet et al. 2011). In this work, we investigate the transport of food in urban areas, and especially in the area of London to identify possibilities for:

i)   CO2 and emission factors such as CO, NOx and Hydro Carbons reduction,
ii) better and efficient fuel consumption,
iii) reduction on the operational cost for the transportation of food products, and
iv) mitigation the traffic nuisance.

The improvements would be arising from different logistics sharing practices; such as transport pooling and collaboration among retailers and 3PLs.

The market in the grocery retail sector in the UK is very competitive with major retailers such as Tesco, ASDA, Ocado, Sainsbury's. According to the IGD (2015), the total grocery market size in the UK was £174.5 billion in 2014 and estimated to be approximately £177.5 billion in 2015 and more than £200 billion in 2019. There is a continuous growth in the grocery market; however, the rate of growth is declining, leading to higher levels of competition among retailers. It is obvious that all retailers want to raise their customer base and their market share, without compromising their profitability (Murfitt, 2014). In fact, all retailers within this industry are confronted with extreme rivalry, resulting from aggressive price competition, due to the fact that customers have the opportunity to make comparisons among retailers about prices and quality of products (Barker, 2014), service level provided and convenience of the service. These comparisons are now feasible to do online as well, due to the significant technological growth (e.g. Internet, mobile apps) which provides the opportunity to (almost) anyone to search the market more easily than 10 years ago. The direct result of the latter is that the retail sector of groceries has a heavily competitive market, not only concerning the items' prices but also the service provision.

Many predictions have highlighted that the e-market would dominate the retail sector in the next few years, while the online shops would harm the traditional retailer shops (Doherty and Ellis-Chadwick, 2010). E-commerce introduces a new channel for fulfilling customer's needs more efficiently in order to gain market share and sustain growth of the business (Huang et al. 2013). Many people, especially the time pressured customers, seek a convenient shopping experience such as the online shops (McKinnon and Tallam, 2003) both for food and non-food purchases. Therefore, retailers across the world and also in the UK have started offering online shopping service to their end-consumers about fifteen years ago (Tedeschi, 2002).

We study the UK as our major case, due to the fact that it is the biggest online grocery market in the world in terms of size after the Chinese online grocery market (IGD, 2016). Although the share of the online UK grocery market is small with 4.3% of the total market for the year 2014 and estimated to be 5% in 2015 and 8.3% in 2019 (IGD, 2014), it still amounts to a significant size; £7.5 billion in 2014 (Mintel, 2015) and estimated to reach £16.9 billion in 2019 (IGD, 2014). Moreover, the online UK grocery retail market has seen a yearly growth of around 17%, while the total grocery market has an annual growth of less than 5% in the last 10 years (IGD, 2015). Note that, the online grocery market is completely competitive, where the four significant retailers (Tesco, Sainsbury's, ASDA and Ocado) possess around the 85% of the online grocery market for the past three years (IGD, 2015). Therefore, each retailer strives to obtain a significant share of this developing 'new market'.

Nowadays, it is common for online retailers to provide the following options to the consumers: home delivery with a delivery charge or click and collect services; i.e. collection from a predefined collection point such as the retail store. In the case of home delivery, the consumer selects a day and a time slot in order to have his grocery order delivered to his house, while in the second alternative, the retailer transports the consumer's order to a predefined collection point and the customer has to collect his order within a selected time interval on a selected day. In this work, we focus only on home deliveries of groceries and the transport challenges associated with it.

The existing logistics business model in the UK grocery market is a competitive game, without any cooperative strategies or collaboration in logistics aspects among the retailers. The retailers act as rational players having to make private decisions, usually competitive, in order to maximize their utility functions. In our problem, this means that each retailer has its own fleet of trucks under its brand and uses their own distribution centres, in order to satisfy its customers' online orders for groceries. Thus, each retailer solves a 'local' optimisation problem about its own routing problem concerning only its own orders, without considering the global aspects of the decision problem. Obviously, the routing problem is constrained by the retailer's pre-determined time slots for the home deliveries. A common approach by the retailers until now is that they try to alleviate the problem through pricing strategies such as extremely reduced price for off-peak hour deliveries and to consider the location of new distribution centres.

Customers are free to decide from which retailer to buy their groceries, according to their preferences. Therefore, on some days some customers are likely to be visited by more than one retailer or some neighbourhoods will be visited by many retailers at the same time, due to the fact that different customers who live nearby will not order from the same retailer. From a holistic perspective, it is very likely to have overlapping areas during the daily routing of vehicles to serve the customers. These overlapping routings increase the total transportation cost, and decrease the capacity utilization of vehicles while negatively affecting the society through traffic congestion, accident fatalities, noise pollution, etc. and the environment through carbon and NOx emissions. It would be helpful, if we could propose and use a model that eliminates these overlapping routings, increase vehicle utilisation whilst adhering to customer service levels.

The importance of reducing overall costs instead of just tackling individual costs is underlined by both private firms and academic researchers (Cachon and Terwiesch, 2006). A common proposed way of improving performance and competitiveness in supply chains is by integrating the activities of the nodes, in order to eliminate duplicated efforts in the same activities (Forslund, 2015). The logistics and distribution process of home delivery services face inefficiencies depending on the order pattern and geographical distribution of end consumers. Home deliveries are subject to highly volatile demand with peaks in the mornings and the evenings during the day and at the weekends. Since retailers own and operate their delivery fleet; the utilisation of assets is highly variable over time. Note that, the cost per a home delivery on average is estimated to be more than £21 (Ocado, 2015), an extremely high amount when the minimum order value imposed by retailers on consumers for their order to be eligible for home delivery is £40. Hence, there is room for collaboration to minimise not only delivery costs, but also the negative impact on the environment (CO_2) and the society (traffic and noise).

It would be ideal if we could find ways of coordinating the home deliveries without restrictive and unrealistic assumptions, in order to align the individual incentives of the retailers. Moreover, if the retailers succeed in coordinating their home deliveries, opportunities for mutual benefits may arise and the gains will be significant not only in terms of economic aspects, but also for environmental and social aspects by reducing carbon emissions and traffic nuisance, respectively. Obviously, opportunities for mutual benefits cannot be found, unless the retailers share honestly their internal business information, which is proving highly impractical. To proceed in sharing this information in a free market, players would have to be provided with appropriate incentives, and choose to reveal their information because it is in their self-interest. The contribution of this work is twofold: i) First, to present the existing situation in the UK online grocery market about order fulfillment, in particular home deliveries of groceries purchased online. ii) To investigate opportunities for voluntary participation of the retailers in a collaborative logistics model.

2. Methodology

It is well known that the distribution capability has a crucial role in supply chain; especially, in the grocery market, where the retailers have to work in an uncertain environment where they have to cope with fast changing market demands and to ensure that the right products are in the right place at the right time in order to meet the final demand (Eng, 2016). Recently, many retailers including the ones in the grocery market have decided to begin collaborations in logistics activities through 3PL or 4PL providers, in order to strengthen their distribution capability and to obtain more flexibility to follow the customers' preferences and the new trends of the market structure, while improving the services that they provide. A (potential) collaboration in logistics activities has a direct effect to reduce the total transportation cost and the inventory levels without harming the customer service levels. Shared

logistics process models involve collaboration in transportation: By pooling demand from multiple retailers, the volatility of demand could be reduced and the utilisation of fleet could be improved. The idea of shared logistics is that the retailers have to work as a coalition where all retailers act as a single decision maker to satisfy the demand for home deliveries. This means that the retailers possess a joint fleet of trucks and make a shared route into the areas where they provide home deliveries. However, even though the retailers collaborate in the logistics activities, it does not mean that the competition is over; as it continues on the other aspects of business such as product quality, and prices. Note that, it is not always feasible to achieve perfect cooperation through a coalition, as any collaboration should also comply with the anti-trust legislation imposed by the EU or national governments.

The idea is to have a centralised logistics business model with a single decision maker and all retailers participate voluntarily in this model, because it is in their self-interest. If we propose a model in which the total costs for home deliveries are reduced, it would be feasible to reduce the individual costs for all retailers. The centralised model is the ideal scenario, but in a free and competitive market such as the UK grocery market, it is not easy to apply a centralised model, where the individual players have competitive objectives, different preferences and endowments in terms of internal business information. Moreover, retailers do not have to consider only the cost reduction as the unique criterion for participation in a shared logistics model; but, they consider factors such as brand name, service levels, expectations about future profits, etc. which are very difficult to be modelled. Our main objective is to develop a new model about collaborative transportation, in order to reduce the operational costs and to decrease the negative impacts on the environment. In this framework, it would be more than useful if we could propose ways to raise the existing fill rate of trucks and reduce the total distance of the fleet for the deliveries, by eliminating overlapping routings. In fact, one vehicle can load at several retailers and can deliver to several customers in one round trip. The proposed model should help improve the performance of grocery supply chains by harmonisation and cooperative adaptation of commonly agreed business processes as well as standards that can help avoid duplication of costs associated with transport and improve the service in terms of reliability, cost, as well as environmental and social performance.

We propose a shared logistics model, in order for retailers to coordinate home deliveries of groceries to their customers (last mile logistics) or alter their strategies about home deliveries to maximise their profits whilst minimising operational costs and negative impacts on the environment and the society. We propose a co-opetition model, where some or all of the retailers could collaborate with their competitors in logistics and compete on the sales floor, in order to raise their profits. Under the proposed model the retailers have the opportunity to focus on the core business procedures (supplies, marketing, sales, etc.) and continue to compete with the other retailers in terms of prices, products, discounts, etc. Since the retailers have internal business information we can develop a Bayesian game (Gibbons, 1992) as follows: $< N, C^1, ..., C^N, T^1, ..., T^N, h^1, ..., h^N, P >$, where:

- N, a nonempty set which enumerates the retailers (players) of the UK online grocery market; i.e. $N = \{1, 2, ..., n\}$,
- C^i the set of choices available to the retailer $i, i \in N$, we denote with C the Cartesian product of all C^i's; i.e. $C = \prod_{i \in N} C^i = C^1 \times ... \times C^N$,
- T^i the set of internal business information of retailer $i, i \in N$, we denote with T the Cartesian product of all T^i's, i.e. $T = \prod_{i \in N} T^i = T^1 \times ... \times T^N$,
- h^i the utility function of retailer $i, i \in N$, depends both on the retailers' private information and choices; i.e. $h^i: C \times T \to \mathbb{R}$,
- P a probability distribution on T.

In the Game Theory literature, in order to model private information, a finite set of types T^i is considered for every player $i, i \in N$. Each element in the set T^i corresponds to an aspect of private information held by the ith-player. At each run of the game only one element of T^i is selected; let this be $t^i \in T^i$, which is known only to the player i who is subsequently called a player of 'type t^i'.

A basic assumption in our model is that each retailer is free to make his decisions and acts in order to maximise his utility function. Note that, each retailer is the only one who knows their internal business information, and no one can prevent them from disclosing incorrect information, since they may expect advantage from such a behavior. Moreover, each retailer has to make private decisions. Therefore, appropriate incentives should be provided to motivate all retailers to participate in the proposed shared logistics model and provide their internal business information. This means that no rational retailer would expect more gains from being the only player to disclose incorrect private information or not to participate in the shared logistics model or to do both, when the others are

planning to provide their internal business information and to participate in the proposed model. In other words, universal honesty and participation in the shared logistics model is an equilibrium strategy for all retailers. The challenge is to develop a model that will define in a clear way the retailer's utility functions if they participate in the game. Adverse selection and moral hazard incentives (Myerson, 1991) can be included in the proposed model in order to make it in the retailers' self-interest to participate honestly in a collaborative network for home deliveries. The retailers could analyze the situation (game) in advance and find that the optimal strategy for them is to participate in the shared logistics model.

As already mentioned, the ideal scenario is that all retailers collaborate in the last mile logistics; however, this appears impractical due to severe competition and additional constraints relevant to the home deliveries problem. Otherwise, we can have some coalitions among the retailers. In the proposed model, the total benefits; i.e. the sum of the retailers' profits, customers' utilities, and the environment's and the society's gains will be significant. Retailers will reduce their logistics costs (with effect reducing prices and raising profitability) and will provide better services to the customers, reducing the traffic nuisance, CO2 emissions and making cities friendlier to live.

The proposed model is as follows: The transportation of food will be done through shared hubs, which will be located across the whole city. The hubs could be warehouses or some of the existing superstores to avoid building new hubs and investing in new facilities and can be used by some or all of the retailers. The proposed idea is to divide the area of London into smaller areas in order to reduce the total distance of the fleet for the transportation of groceries. In terms of the location of the hubs, we do not propose to have a uniform distribution in the study area according the size of the area, but we have to consider several factors; such as population density and frequency of orders in specific areas. The main responsibilities of a shared hub are:

i) To receive the orders that have to be delivered the next day from the retailers during off-peak hours (e.g. the previous night). The hub will not be a storage space for the retailers.
ii) To prepare the route for the daily deliveries to customers' houses in its service area, combining the time windows requirements and the customers' locations by solving vehicle routing problem to minimise the total logistics cost whilst adhering to the customers' restrictions and satisfying a predetermined service level for on time deliveries.
iii) To deliver orders to customers' houses keeping them under the required conditions; i.e. temperature restrictions for chilled and frozen products until the customer receives them. Home deliveries could be done by white label trucks, which are unbranded trucks that are shared among retailers.

The basic idea is to have these hubs in the cross-docking to achieve an efficient routing according the customers' preferences about the time of deliveries. The owner of the hub(s) can be either a specific retailer or a consortium of retailers or a different non-retailer, such as a 3PL or a 4PL company. In the proposed model, it is feasible to reduce the total transport distance to be covered by the retailer's fleet of trucks and increase the fleet utilisation. The consequences are:

i) Reduction of the total delivery cost, allowing the retailers to review their pricing policies for home deliveries.
ii) Reduction of the road congestion in the city and of the total emissions of CO2, NO_X, Hydro Carbons, achieving better living conditions for the residents of London. Note that, many forecasts estimate a significant increase in vehicle numbers in the next years for most countries. Therefore, traffic congestion is an existing problem for all cities and not only for the area of London.
iii) Provision of better services to their customers, in terms of time windows, on time deliveries, etc.

3. Proposed Model Results

We have exclusive data from a retailer (denoted with R) offering online grocery purchase and home delivery service in the UK. The data includes (see Appendix):

i) Total number of deliveries,
ii) Indexed numbers by postcode,
iii) The spoke serving postcode,
iv) Percentage of orders delivered by hour by day,
v) Percentage of orders checked out by hour by day,
vi) Average number of deliveries for postcode,
vii) Average order weight for postcode, and

viii) Average order volume for postcode.

Due to reasons of confidentiality, the data was aggregated over a year and anonymised. The data set received from the retailer R is from 1st June 2014 to 31st May 2015 and concerning 346,745 orders for home deliveries on a specific area of the northwest London. From the analysis of the data, we have the distribution of aggregate consumer demand over time (specific time slots in a day in the left panel and specific days in a week in the right panel) Figure 1a, where the vertical axis reflects the percent of the customers that decided to buy home delivery service from the retailer R, according to specific time periods in a day and the specific day of the week. We observe that there are two peaks for the time periods within the day (mornings and on the evenings) and Friday is the day with the highest percentage of orders (17.4%). We will assume that this demand distribution is generalizable to all customers buying grocery online. We present in Figure 1b the distribution of orders across the days of the week where Friday, Monday and Saturday are the peak days for consumers to have groceries delivered.
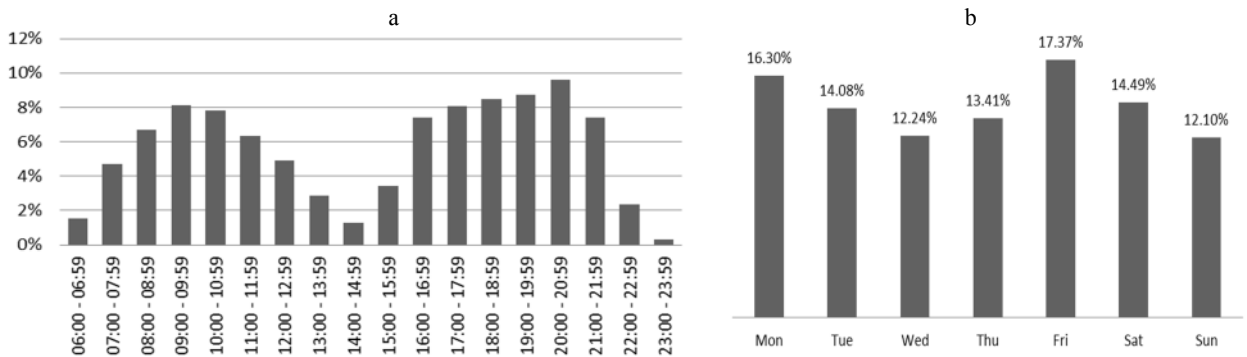

Figure 1: Demand distribution for home deliveries from retailer R

Moreover, we use public data from Ocado, which is an online retailer in the UK grocery with a online grocery market share of 13% in 2012-2014 (Mintel, 2015). We use Ocado's published data in its annual financial reports (Ocado, 2015 and 2016) to:
  i)   generate customers' demand (data) in an accurate way based on the population,
  ii) analyse the existing situation in grocery home delivery market,
  iii) investigate the opportunities for collaborations among the retailers, and
  iv) evaluate the performance of our proposed model for shared logistics for grocery home deliveries.

Based on: i) the market shares, Table 1 (Mintel, 2015), ii) the population data (Office of National Statistics, UK) and iii) the data from Ocado annual financial reports (Ocado, 2015 and 2016), we generate the demand for each postcode district within London. Table 2 presents a summary of the cumulative results about the average annual orders per capita and household in UK.

Table 1: Market Shares in 2014 in the UK Online Grocery Market (Mintel, 2015)

Morrisons	Waitrose	Other	Ocado	Asda	Sainsbury's	Tesco
0.9%	5.0%	10.7%	13.4%	13.4%	17.5%	39.1%

Table 2: Annual orders per capita and household in UK

Retailer	Morrisons	Waitrose	Other	Ocado	Asda	Sainsbury's	Tesco
Order / capita	0.0435	0.0585	0.1402	0.1567	0.1756	0.2293	0.5123
Order / household	0.1070	0.1439	0.3449	0.3857	0.4320	0.5641	1.2604

After the generation of the data for each retailer, we examine pre-defined scenarios for potential collaborations among different retailers. The ideal scenario is that retailers work as a single coalition, where the distribution decision is centrally optimised. Via the scenarios, we evaluate the performance of collaboration strategies on home deliveries.

As an example in Table 3, we present the estimations of the average demand per day for each retailer for SW16

postcode district (Figure 2) with a population of 83K residents and 32K households. Based on the demand profile presented in Figure 1, we estimate the demand across days of the week and across a day.

Figure 2: SW16 postcode district

Table 3 Estimates of home deliveries demand in SW16 postcode district across the days of the week

Retailer	2014	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Morrisons	3444	561	485	422	462	598	499	417
Waitrose	4632	755	652	567	621	805	671	561
Other	11101	1810	1564	1359	1488	1928	1609	1343
Ocado	12413	2024	1748	1520	1664	2157	1798	1502
Asda	13903	2267	1958	1702	1864	2415	2015	1682
Sainsbury's	18157	2961	2557	2223	2434	3154	2631	2197
Tesco	40567	6614	5713	4967	5439	7047	5878	4909
Total	104216	16992	14677	12760	13972	18104	15101	12611

Table 4 presents the aggregate demand for Saturday; we select Saturday due to the fact that this day is closer to the average demand per day.

Table 4 Estimates of home deliveries demand in SW16 postcode district on a Saturday

Time slot	Demand	Time slot	Demand	Time slot	Demand
6:00-6:59	228	12:00-12:59	740	18:00-18:59	1278
7:00-7:59	708	13:00-13:59	434	19:00-19:59	1317
8:00-8:59	1011	14:00-14:59	192	20:00-20:59	1451
9:00-9:59	1225	15:00-15:59	517	21:00-21:59	1120
10:00-10:59	1184	16:00-16:59	1117	22:00-22:59	354
11:00-11:59	958	17:00-17:59	1219	23:00-23:59	48

Based on these assumptions, we generate the demand for the whole area of London, and we develop an optimization model that defines the most suitable locations for shared hubs in order to minimize the total logistic costs of home deliveries. Moreover, we add a constraint for the locations of the existing individual operating hubs and superstores in order for them to be used as a shared logistics hub as well. Until now, in the area of London there

are 14 hubs, which are exclusive for fulfilling the online grocery market (Figure 3). The four colours denote that the hubs are operated by four different firms (Ocado in black, Tesco in red, Sainsbury's in orange and Morrisons in green).

Figure 3 Exclusive hubs for online grocery market in the area of London

4. Conclusions

If all retailers collaborate on the last mile logistics for home deliveries; we are able to reduce the total transport distance which is required by retailer's fleets of trucks and the operational costs about the distribution centres in order to satisfy the demand. The direct consequences are:

i)   to reduce the total transportation cost, allowing the retailers to change their pricing strategies about grocery home deliveries,

ii) to reduce the road congestion in the city, with the reduction of total CO_2 emissions, achieving lower traffic conditions for the residents, and

iii) to provide better services to their customers, in terms of time windows, on time deliveries, etc.

The evaluation of our proposed is based on specific economic, environmental and social sustainable KPIs; such as: Cost per order, Cost of basket size, On time delivery, Total distance, Truck loading factor, Drops per route, CO_2 emissions and Traffic nuisance.

Potential extensions of our work include investigating the scenarios in which there is more than one coalition among the retailers to satisfy the home deliveries measuring the gains under these situations, where the competition will be more rivalry. A further extension could be to study the case where the retailers could use the network of the shared hubs to supply their retail shops and how a CPFR system could improve their operations.

Acknowledgements

Appendix

In the UK, postcodes consist of two main parts (separated by a space): an outward code that is between two and four characters long where one or two-letter postcode area code for a local town or area of London and one or two digits signifying a district in that region. The outward code is used to sort one town from another. The inward code,

which is an arbitrary code of one number and two letters, is used to sort small areas and addresses within the local town. Therefore, the postcode shows a specific area in the map, for example Cranfield University postcode is MK43 0AL, the outward code is MK43 and inward code is 0AL. It can be interpreted as:

- **MK** means the area of Milton Keynes (Figure 4).
- **43** means a specific district in the area of Milton Keynes (Figure 4).
- **0AL** defines the specific point in the map.

Figure 4 Postcode map of the area of Milton Keynes with the corresponding districts

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