KPIs for performance measurement of e-fulfillment systems in multi-channel retailing
An exploratory study

Gregory Bressolles
Department of Marketing, KEDGE Business School,
Bordeaux, France, and
Gerald Lang
Department of Management, KEDGE Business School, Paris, France

Abstract
Purpose – The purpose of this paper is to expand existing research on fulfillment systems for multi-channel retailers by combining analysis of customer expectation (CE) with economic performance (EP) aspects.

Design/methodology/approach – This exploratory study is based on a literature review of supply chain management and marketing combined with the results of an online questionnaire submitted to French and Chinese multi-channel retailers from two sectors.

Findings – The results enable the authors to identify 13 important key performance indicators (KPIs) used by multi-channel retailers for measuring e-fulfillment system performance and also to determine under which of the EP or CE criteria these KPIs might be linked.

Research limitations/implications – Although the sample size is limited, this research is intended to be exploratory, based on the practices of supply chain and marketing managers. Moreover, the results do not address interdependencies among the different KPIs.

Practical implications – E-fulfillment is a major challenge for multi-channel retailers; it is cost intensive and critical for customer satisfaction. The identified set of KPIs enables retailers to choose those relevant to their particular infrastructure.

Originality/value – A limited number of scholarly works have explored the operational implications of online retailing in terms of e-fulfillment in a multi-channel context. In order to manage such supply chains efficiently and effectively, traditional measures of supply chain performance need to be adapted. This study expands existing knowledge by developing measurement systems and metrics for the evaluation of supply chain performance in this context.

Keywords Economic performance, Key performance indicators, Customer expectation, E-fulfilment, Multi-channel retail

Paper type Research paper

1. Introduction

A majority of traditional store-based retailers are becoming multi-channel retailers by opening an additional online channel. At the same time, formerly pure online retailers (e.g. Amazon, Zalando, etc.) are opening stores or physical pick-up points to allow their customers physical interaction (Euromonitor International, 2016; Fornari *et al.*, 2016; McKeough, 2016; Walsh, 2016).

Multi-channel retailing has received primary attention principally in the field of marketing by focusing on customer behavior (Belvaux and Labbé-Pinlon, 2009; Venkatesan *et al.*, 2007) and on the relations and conflicts between channels (Falk *et al.*, 2007; Filser and Paché, 2008; Poirel and Bonet Fernandez, 2008). The operational implications of online retailing in terms of e-fulfillment, defined as fulfilling orders placed over the internet (Agatz, 2009; Tarn *et al.*, 2003), seem to be treated as only a minor issue among others in e-commerce (Bask *et al.*, 2012). Specific analysis of the operational implications of multi-channel retailing remains scarce (Agatz *et al.*, 2008), but recently it

seems to be receiving growing attention and requires more in-depth consideration (Durand and Jeanpert-Henry, 2016; Hübner, Wollenburg and Holzapfel, 2016).

In multi-channel retailing, customers expect at least the same level of service, counsel and information with every channel. This channel hopping, which is a legitimate desire from a customer's point of view, may nevertheless prove to be very difficult to implement for the retailer (Vanheems, 2009). The challenge for retailers is to satisfy this customer expectation (CE) and maximize the economic performances (EP) of every channel. Agatz et al. (2008) indicated that there is a lack of studies regarding the best practices companies can follow in order to meet CE and EP at the same time. Since then, some research on the performance of the retail supply chain has been conducted (Anand and Grover, 2015; Bouzaabia et al., 2013; Forslund, 2015), but Anand and Grover (2015) indicated that there have been very limited studies that have focused on specific approaches in the retail industry. Multi-channel distribution has become a strategic necessity for retailers, and there is, to our best knowledge, no analysis on the performance measurement of e-fulfillment systems of multi-channel retailers.

The purpose of this paper is to expand the existing research on fulfillment systems to the specific configuration of multi-channel retailers (Agatz et al., 2008) by combining existing analysis of customer satisfaction and physical distribution service quality (Xing and Grant, 2006; Xing et al., 2010) with EP aspects (Gunasekaran et al., 2001). The widely used criteria of customer service as performance indicator for supply chains (Gunasekaran et al., 2004; Mitra and Bagchi, 2008; Mitra et al., 2010; Sambasivan et al., 2009) are therefore refined and completed with EP criteria.

There have been limited scholarly works exploring the operational implications of online retailing in terms of e-fulfillment in a multi-channel context. In order to manage such supply chains efficiently and effectively, traditional measures of supply chain performance need to be adapted. This study expands existing knowledge by gaining insights to measurement systems and metrics for the evaluation of supply chain performance (Anand and Grover, 2015) in a multi-channel retailing context, focusing on the business-to-customer setting. Although some business-to-business (BtoB) settings could show similar characteristics (e.g. office supplies and medical supplies), general BtoB e-commerce could generate different results.

Based on a review of supply chain management and marketing literature, this paper identifies 30 key performance indicators (KPIs) that measure the EP and CE of e-fulfillment systems in multi-channel retailing. In order to determine the most relevant KPIs (defined as those KPIs most important and most widely used by multi-channel retailers), a questionnaire was completed by 16 supply chain or marketing managers of French and Chinese multi-channel retail companies.

This paper is organized into four parts. First, the literature review is presented. Then, the methodology based on a questionnaire completed by 16 supply chain and marketing managers of French and Chinese multi-channel retail companies is detailed. The results then present the 13 most relevant KPIs (in terms of importance and use by multi-channel retailers) according to the EP or CE criteria for measuring e-fulfillment system performance for these retailers. The conclusion presents the managerial implications, limitations and research avenues.

2. Literature review and conceptual framework

In this section, we first define e-fulfillment and e-fulfillment systems, then we focus on the concepts of multi- and omni-channel retailing. We then recall the criteria of EP and CE before setting the framework of performance measurement in the retail supply chain. To conclude this part, we present the results of a literature review that identified 30 KPIs to measure the performance of e-fulfillment systems in multi-channel retailing.

2.1 E-fulfillment and e-fulfillment systems
In order to offer an online channel to its customers, a retailer has to be able to manage its operations in a very different way from its physical store activity because the online channel has to serve individual customers with a large variety of small orders (Tarn *et al.*, 2003). E-fulfillment, defined as fulfilling orders placed over the internet (Agatz, 2009; Tarn *et al.*, 2003), includes the processes of warehousing, picking and order preparation, distribution and delivery and returns (Straube and Lueck, 2000).

Four e-fulfillment systems that can deliver products to customers, organizing the process from order intake to delivery, have been identified in the literature (Table I). Several authors suggest typologies of e-fulfillment schemes that focus on the locus of order preparation: in central distribution center(s) or in the existing stores of the retailer (de Koster, 2002; Durand and Gonzalez-Féliu, 2012; Hübner, Kuhn and Wollenburg, 2016). The customer can opt for delivery at home or pick up the products from a pick-up point or from one of the retailer's stores (Agatz, 2009; Boyer *et al.*, 2003; Hübner, Kuhn and Wollenburg, 2016). In addition to these four main fulfillment systems, hybrid systems may exist that use different elements (de Koster, 2002) and lead to different levels of complexity, costs and product availability, therefore providing different levels of satisfying CE and EP.

E-fulfillment is often considered to be one of the most expensive, critical and challenging operations of internet retailers (Agatz, 2009; de Koster, 2002; Lee and Whang, 2001; Ricker and Kalakota, 1999). From an operational point of view, e-fulfillment systems have to be time and cost efficient. Logistics and stock management are becoming core competencies (Benghozi, 2001). From a strategic marketing point of view, the e-fulfillment system has to be able to meet CE (Bouzaabia *et al.*, 2013).

All types of fulfillment systems need to be time and cost efficient. What is particular noteworthy in e-fulfillment is that these systems prepare high numbers of orders with very low quantities, whereas traditional fulfillment of orders aims mainly at store replenishment. Order preparation and delivery costs are very sensitive in e-fulfillment, because this is a cost parameter of the profitability possible from each customer. As the delivery speed becomes more and more a competitive advantage for online retailers, fulfillment time is much more sensitive than traditional fulfillment.

Supply chain performance includes tangible and intangible factors (Chang *et al.*, 2013). The overall performance of a multi-channel retailer is therefore influenced by a number of operational challenges (product availability, stock keeping, order taking and fulfillment, delivery to the customers, reverse logistics, etc.) and CE parameters (delivery timing, availability, returns, etc.) that have to be managed in parallel by the retailer. This may lead to a trade-off for the retailer between operational costs and customer service (Agatz *et al.*, 2008; Jeanpert and Paché, 2016).

		Delivery to the customer	
		Home delivery	Pick up in the store
Order preparation	In central distribution center(s)	Products are picked, prepared, packed and expedited from a central warehouse or distribution center(s) (de Koster, 2002)	Orders are prepared at central warehouse (s) (picked, prepared, packed and expedited), are delivered and are kept ready for pickup in the store (Agatz, 2009; Lee and Whang, 2001)
	In store	Products are picked, prepared, packed and expedited from one of the retailer's existing stores (de Koster, 2002; Yrjölä, 2001)	Products are picked, prepared, packed and kept ready for pickup in the store (Agatz, 2009; Durand and Gonzalez-Féliu, 2012)

Table I.
The four
e-fulfillment systems

2.2 Multi- and omni-channel retailing

The academic literature increasingly adopts a distinction between multi-channel and omni-channel retailing. Any retailer operating more than one channel to make a product or service available for consumption acts as a multi-channel retailer. Depending on the level of interconnection and integration of the channels (Picot-Coupey *et al.*, 2016), multi- and omni-channel strategies can be differentiated from a logistical point of view, although the two terms continue to be used indifferently (Hübner, Wollenburg and Holzapfel, 2016).

In a multi-channel logistics approach, retailers operate multiple channels but with isolated units and stand-alone systems for operations and logistics (Hübner *et al.*, 2015). Processes are not integrated from a customer point of view and there are no operational or logistics interfaces between the in-store and the direct-to-customer deliveries (Hübner, Wollenburg and Holzapfel, 2016).

In an omni-channel logistics approach, neither the customer nor the retailer can differentiate between channels anymore (Beck and Rygl, 2015; Verhoef *et al.*, 2015). One common logistics interface with the customer enables distance orders to be processed through the stores as well as orders placed in the store for home delivery (Hübner, Holzapfel and Kuhn, 2016). Information exchange, joint operations, logistics and inventories across all channels enable a mutual fulfillment process (Hübner, Wollenburg and Holzapfel, 2016). According to Rafay *et al.* (2016), omni-channel operations seek to provide a seamless consumer experience across all available shopping channels. Brynjolfsson *et al.* (2013) underline that it requires retailers to align their physical (store-based) and virtual (online and mobile) channels through the coordination of order management, fulfillment and logistics processes.

Because the surveyed companies in this paper all implemented multi-channel logistics, the results may be applicable only to this widespread "multi-channel" logistics concept.

2.3 The criteria of economic performance and customer expectation in multi-channel e-fulfillment systems

Past research has identified five EP and four CE criteria in multi-channel e-fulfillment systems (Lang and Bressolles, 2013). The EP criteria take into account the process steps included in the fulfillment system (warehousing, picking and packing, distribution and delivery and returns) as defined by Straube and Lueck (2000) and the infrastructure and investment aspects of fulfillment systems (Agatz *et al.*, 2008; de Koster, 2002).

The five EP criteria are stock and inventory efficiency, indicating the performance of the warehousing process; picking and order preparation efficiency, indicating the performance of the picking and order preparation process; delivery cost efficiency, indicating the performance of the distribution and delivery process; return handling efficiency, indicating the performance of the return process; and fulfillment infrastructure costs, indicating all the investments, rents or outsourcing costs for the fulfillment infrastructure.

The four CE criteria developed by Xing and Grant (2006) and Xing *et al.* (2010) are retained to assess CE of the e-fulfillment system in a multi-channel retail context – timeliness: speed of delivery, choice of delivery date, delivery within specified time slot and so on; availability: confirmation of availability, substitute or alternative offer, order tracking and tracing system, waiting time in case of out-of-stock situations and so on; condition: order accuracy, completeness, damage in transit and so on; and return: ease of return and return channels options, promptness of collection and of replacement and so on.

2.4 Measuring performance in retail supply chain

To measure retail supply chain performance, financial and non-financial performance should be considered (Anand and Grover, 2015). Ayers and Odegaard (2018) suggest the use of service, operational and financial metrics, which have to be selected according to the

strategic objectives of the retailer. Multiple metrics are needed, although some research uses single metrics to express retail supply chain performance (e.g. Appelqvist *et al.*, 2016).

Previous research has identified different activities of the performance measurement process between suppliers and retailers in retail supply chains (Forslund and Jonsson, 2007): selecting performance variables, defining metrics, setting targets, measuring and analyzing/acting.

We adapt these activities to the specific case of multi-channel retailers and their relation with the end customers through e-fulfillment systems. In this paper, we focus on the activities selecting performance variables and defining metrics. Selecting performance variables linked to customer value can be difficult (Forslund, 2015) and qualitative performance measures can be used (Abushaikha *et al.*, 2018). On-time delivery, service level, complete orders, efficient handling of returns and out-of stock have been identified as typical metrics. The defined metrics have to be validated and sufficiently specified.

This paper contributes to this field of research by identifying and defining performance variables as KPIs.

2.5 KPIs for performance measurement of e-fulfillment systems

Based on a literature review of performance metrics and KPIs used in supply chain management, e-logistics and retailing, 30 KPIs have been identified that measure the performance of e-fulfillment systems in multi-channel retailing. In order to identify these KPIs, we searched academic databases (EBSCO and Emerald), Google Scholar and professional consultancy reports (to understand the reality of companies' practices, because research about e-fulfillment systems is very recent and quite scarce) for several keywords: KPI, performance measurement, performance management, customer satisfaction and customer service combined with the search terms supply chain, fulfillment and/or logistics. We focused on those articles that mentioned KPIs in the text, and we retained as KPIs for our study only those that were mentioned in at least two different references.

Whereas strategic KPIs have the tendency to aggregate related numbers and measures to provide high-level information about business performance, operational KPIs are more widely used to monitor the activity on a day-to-day level within a division or department (Griebeler, 2012). The retained KPIs are mostly operational KPIs for monitoring the activity. These retained KPIs are mostly connected to logistics order fulfillment systems and apply to the multi-channel environment characterized by shop replenishment as well as direct-to-customer delivery. Some KPIs, especially those linked to direct-to-customer delivery, are more specifically linked to e-commerce, because customer delivery is a specific characteristic of e-commerce.

Table II lists the 30 KPIs identified (see Table AI for a detailed definition and references for each KPI).

3. Methodology

In order to identify the most relevant KPIs of the e-fulfillment systems' performance (in terms of importance and use by multi-channel retailers), an online questionnaire was sent to 100 supply chain or marketing managers of French and Chinese multi-channel retail companies (58 in France and 42 in China). The focus on these two countries was chosen for two reasons. First, these two countries host major multi-channel retailers, and second, France historically has a strong retail sector with store and mail-order retail, whereas China's retail sector is rather an emerging one. For example, within the top 20 retailers of the world, there are 4 French companies acting in different sales channels (Deloitte, 2017). China is one of the biggest retail markets facing similar development than western countries. Growing competition leads store-based retailers to strengthen their online channels. At the same time, pure internet retailers open physical stores to increase service offerings to their customers (Euromonitor International, 2016).

KPI	Name	KPI	Name
1	Total investment of the warehouse	16	Percentage of shipments arriving in good condition
2	Inventory cycle time	17	Average delivery re-planning time
3	Inventory carrying costs	18	Cost of returns
4	Safety stock volume	19	Enquiry-to-response time
5	Rate of obsolete inventory	20	Average fulfillment cycle time
6	Order to delivery time	21	Percentage of on-time deliveries
7	Percentage of error in goods picking	22	Order fill rate
8	Revenue per order	23	Stock-out rate
9	Pick rate per employee	24	Shrinkage
10	Units shipped per employee	25	Order entry accuracy
11	Order entry time	26	Warranty claims
12	Average delivery time	27	Number of damage claims
13	Ratio of transportation cost to value of product	28	Invoice accuracy
14	Shipping accuracy	29	Notification-to-refund time
15	Cost per shipment	30	Average return rate

The respondents were identified and approached through a database of alumni of a major French supply chain management master program. We sent the list of the 30 KPIs with their definition to the respondents and asked them to indicate the KPIs they used in their company in order to evaluate the performance of their e-fulfillment system (KPI use variable: yes/no). We also asked them to give a mark (out of 10) of the 30 KPIs in order to evaluate the general importance of the KPI (KPI grade variable). Furthermore, we asked them to specify if they used the KPI under one specific of five EP or the four CE criteria (yes/no question).

We had a total of 19 answers (response rate: 19 percent) from four sectors. In order to reduce the heterogeneity in the data, we decided to focus on the two main sectors for which we had the highest level of responses: grocery and fast-moving consumer goods (FMCG) and electronics, books and CDs (we deleted two responses from the clothing sector and one response from the flowers sector in order to have a homogeneous sample). These two sectors were retained because they represent a historical e-commerce sector for electronics, books and CDs on the one hand and online orders are a rapid-growth category for grocery and FMCG on the other hand.

After deleting three answers, we created a sample composed of 16 companies, 8 from China and 8 from France, which is quite good considering that the number of the multi-channel companies is not that high in each sector and for each country. We are working within the context of an exploratory research, and it is quite difficult to get feedback from real supply chain or marketing managers of multi-channel companies. Ten companies were from the grocery and FMCG sector and six from the electronics, books and CDs sector. Ten respondents were from the supply chain department of the company and six from the marketing department. For confidentiality reasons, we are not allowed to indicate the names of the multi-channel retailers, nor the names of the respondents.

The objective of this research is exploratory but the research method is not. We are not looking to confirm a model. We use an inductive approach to review and elaborate a framework to measure the performance of e-fulfillment systems in multi-channel retailing, so we chose a questionnaire to collect data (instead of interviews).

Less than half (44 percent) of the 16 surveyed companies use only one e-fulfillment system to prepare online orders. About two-thirds of the 16 companies (62.5 percent) pick and pack products from a central warehouse or distribution center and deliver them to customers' homes. More than half (56.2 percent) of the 16 companies use dedicated warehouses for the physical store and for online sales. More than three-quarters (81.2 percent) of the 16 surveyed companies keep different inventories for the different

fulfillment channels. Only half of them (56.2 percent) use the inventory of one channel to cover demand in case of a stock-out in another channel. About one-third of them (37.5 percent) accept returns only through the same channel that the product was sent. Only half of the 16 companies allow customers to return the products bought online to the physical store. Table III presents the e-fulfillment system characteristics of the 16 surveyed companies.

4. Results
Based on the feedback of the 16 companies that completed the questionnaire, the following methodology was used in order to select the most relevant KPIs among the 30 KPIs identified.

First, the mean and the standard deviations of each KPI grade (out of 10) were calculated. Then the mean of the KPI was compared to the mean of the means of the 30 KPIs (6.43), and the standard deviation of the KPI was compared to the mean of the standard deviation of the 30 KPIs (1.90). In order to select a KPI at this stage, its grade mean needs to be superior to the mean of all the grade means, and its grade standard deviation needs to be inferior to the mean of all the grade standard deviations. By doing that, the retained KPIs are important (have a high grade mean) and homogeneous (are weakly dispersed around the mean).

Then, in order to retain the KPIs that are widely used by the 16 surveyed companies (KPI use variable), only the KPIs that are declared to be used by more than 75 percent of the surveyed companies (third quartile of the sample) are retained.

Finally, only the KPIs that are mentioned by at least 50 percent of the 16 respondents (median of the sample) to be used under the same criteria among the five EP or the four CE criteria of the e-fulfillment systems' performance are retained.

At the end of the process, only 13 KPIs out of 30 (43 percent) are retained to evaluate EP and CE of multi-channel e-fulfillment systems by the 16 surveyed companies.

Concerning the EP aspect, two KPIs (1 and 22) measure the fulfillment infrastructure cost criteria. Five KPIs (2, 4, 5, 6 and 23) evaluate the stock and inventory efficiency criteria. Three KPIs (14, 21 and 28) evaluate the picking and order efficiency criteria. One KPI (15) evaluates the delivery cost efficiency criteria. Concerning CE, one KPI (16) measures the condition criteria, and one KPI (27) measures the return criteria. We note that no KPI was mentioned by the respondents under the timeliness and availability criteria from the CE aspect. Moreover, no KPI is mentioned by the respondents under the return handling efficiency criteria from the EP aspect. This could be due to the fact that this criterion is very close to the return criteria on the CE side and therefore can be applied internally in an identical manner for both. Table IV presents the 13 best graded and most used KPIs by the 16 multi-channel retailers by criteria.

The respondents were asked to specify if they use a KPI under one specific of five EP or four CE criteria, so we obtain different percentages for each KPI, reported in Table IV. These percentages indicate how many of the 16 surveyed companies identify the specific

E-fulfillment system characteristics of the surveyed companies	% of the total surveyed companies (16)
Use only one e-fulfillment system to prepare the online orders	44.0
Pick and pack the products from a central warehouse (or distribution center) and deliver to the customer's home	62.5
Use separate warehouses for the physical store and for online sales	56.2
Keep different inventories for the different fulfillment channels	81.2
Use the inventory of one channel to cover the demand in case of stock-out in another channel	56.2
Returns only through the same channel that the product was sent	37.5
Allows customers to return the products bought online to the physical store	50.0

Table III.
The e-fulfillment system characteristics of the 16 surveyed companies

KPI	Name	Grade mean	Grade SD	Use	Criteria
1	Total investment of the warehouse	6.55	1.69	78.60	Fulfillment infrastructure cost (100.0%)
22	Order fill rate	8.46	1.66	92.90	Fulfillment infrastructure cost (75.0%)
2	Inventory cycle time	6.75	1.54	92.90	Stock and inventory efficiency (100.0%)
4	Safety stock volume	5.92	1.51	85.70	Stock and inventory efficiency (81.3%)
5	Rate of obsolete inventory	6.73	1.35	85.70	Stock and inventory efficiency (81.3%)
6	Order to delivery time	7.15	1.77	85.70	Stock and inventory efficiency (81.3%)
23	Stock-out rate	8.42	1.56	85.70	Stock and inventory efficiency (68.8%)
14	Shipping accuracy	8.15	1.34	92.90	Picking and order efficiency (50.0%)
21	Percentage of on-time deliveries	7.90	1.66	78.60	Picking and order efficiency (62.5%)
28	Invoice accuracy	8.08	1.78	85.70	Picking and order efficiency (87.5%)
15	Cost per shipment	6.43	1.90	100.00	Delivery cost efficiency (68.8%)
16	Percentage of shipment arrived in good condition	7.15	1.77	92.90	Condition (68.8%)
27	Number of damage claims	6.82	1.78	78.60	Return (68.8%)

Table IV.
The 13 best graded and most used KPIs by the 16 multi-channel retailers by criteria

KPI with one of the criteria. Only 2 of the 13 best graded and most used KPIs have been named unanimously by the respondents for the same criteria: KPI 1 – total investment of the warehouse in the criteria fulfillment infrastructure cost (EP): 100 percent and KPI 2 – inventory cycle time in the criteria stock and inventory efficiency (EP): 100 percent. The other KPIs have been identified with more than one criterion: KPI 28 – invoice accuracy, for example, has been specified by 14 companies (87.5 percent) to be used under the picking and order efficiency criteria (EP), but two companies use this KPI under different criteria, indicating that there may be an overlap between the criteria. This overlap becomes very clear for KPI 14 – shipping accuracy, which has been identified by only eight companies (50 percent) and used under the criteria picking and order efficiency (EP). Three companies (19 percent) use this KPI under the delivery cost efficiency criteria (EP), and three other companies (19 percent) use it under the timeliness criteria (CE). Therefore, in total, 69 percent use this KPI as an EP indicator, and 19 percent use it as a CE indicator. This clearly indicates that different KPIs are used under different criteria, because there are many possible overlaps in the attribution of the KPIs.

In order to test the possible influence of country (France/China) or sector (grocery and FMCG and electronics, books and CDs) in the evaluation of the KPIs (KPI grade), one-way analysis of variance (ANOVA) has been conducted. Table V summarizes the results of the Levene and ANOVA tests only for the significant differences in the KPI grades for the effect of country. The result of the Levene test shows that all the 13 KPIs successfully pass the variance homogeneity test at a threshold of 5 percent (except for KPI 6 – order lead time: 0.009 and KPI 15 – cost per shipment: 0.008). The results of the ANOVA test reveal an effect of country on the KPI grade for only 4 of the 13 KPIs identified for the 16 surveyed companies: KPI 2 – inventory cycle time, KPI 5 – rate of obsolete inventory, KPI 16 – percentage of shipment arrived in good condition and KPI 23 – stock-out rate.

	KPI	Levene's test		ANOVA	
Number	Name	Statistics	Sig.	F	Sig.
2	Inventory cycle time	0.980	0.761	11.575	0.007***
5	Rate of obsolete inventory	1.640	0.232	5.610	0.042**
16	Percentage of shipment arrived in good condition	0.623	0.447	5.535	0.038**
23	Stock-out rate	2.913	0.119	15.600	0.003***

Table V.
ANOVA results for the effect of country

Notes: **,***Significant at the 5 and 1 percent levels, respectively

We observe that four KPIs receive significantly different mean grades from Chinese and French multi-channel retailers (Figure 1). KPI 2 – inventory cycle time, KPI 5 – rate of obsolete inventory, KPI 16 – percentage of shipment arrived in good condition and KPI 23 – stock-out rate all receive a significantly higher mean grade from French multi-channel retailers than from the Chinese ones based on the 16 surveyed companies.

Three of the KPIs (2, 5 and 23) refer to the criteria stock and inventory efficiency, and KPI 16 refers to the criteria condition. These observed differences in the KPI grade means suggest that, based on the 16 surveyed companies, multi-channel retailers in France, where we can assume a higher retail sector maturity than in China, pay more attention to the stock and inventory efficiency than in China.

Table VI summarizes the results of the Levene and ANOVA tests only for the significant differences in the KPI grades for the effect of the sector. The result of the Levene test shows that all the 13 KPIs successfully pass the variance homogeneity test at a threshold of 5 percent (except for KPI 14 – shipping accuracy: 0.026). The results of the ANOVA test reveal an effect of the sector on the KPI grade for only 2 of the 13 KPIs identified: KPI 5 – rate of obsolete inventory and KPI 23 – stock-out rate. In both cases, the mean of the two KPIs is higher for the grocery and FMCG sector than for the electronics, books and CDs sector for the 16 surveyed companies.

As shown in Figure 2, the mean of the KPI Grade for KPI 5 – rate of obsolete inventory and for KPI 23 – stock-out rate is higher for the grocery and FMCG sector than for the electronics, books and CDs sector.
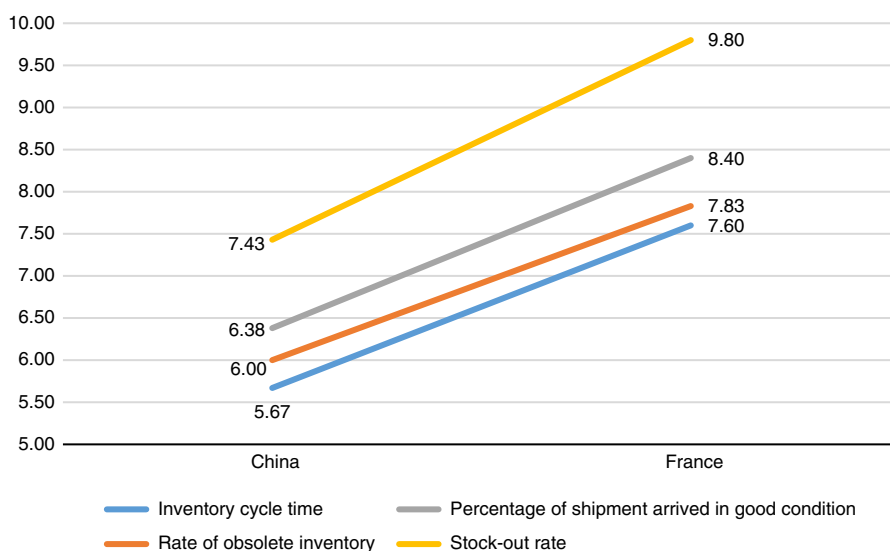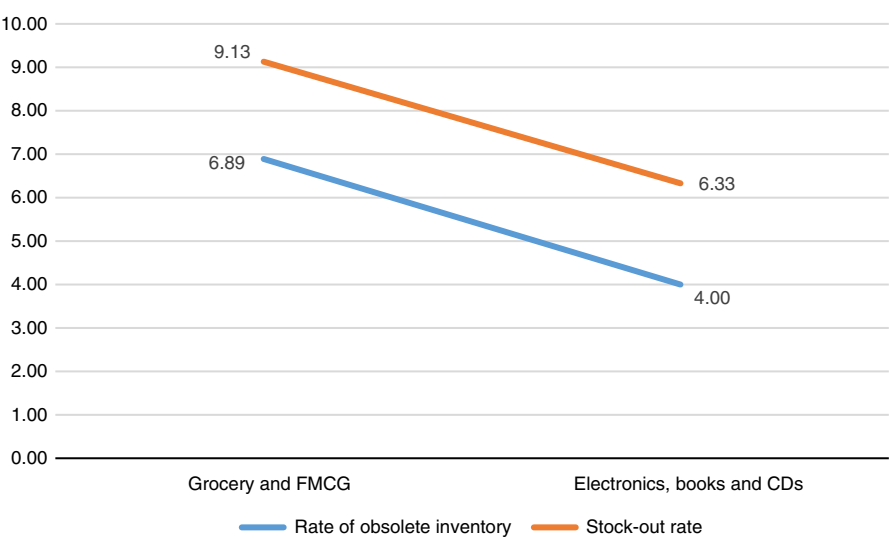

Figure 1.
Means of KPI grade according to country

Number	KPI Name	Levene's test		ANOVA	
		Statistics	Sig.	F	Sig.
5	Rate of obsolete inventory	1.145	0.371	6.760	0.032**
23	Stock-out rate	1.368	0.308	16.039	0.003***
Notes: **,***Significant at the 5 and 1 percent levels, respectively					

Table VI.
ANOVA results for the effect of sector

Figure 2.
Means of KPI grade
according to sector

In the same manner as before, we observe that two KPIs receive significant different mean grades from grocery and FMCG and electronic, books and CDs multi-channel retailers (Figure 2). KPI 5 – rate of obsolete inventory and KPI 23 – stock-out rate received a significantly higher mean grade from multi-channel retailers in the grocery and FMCG sector than those in the electronics, books and CDs sector. Both KPIs refer to the criteria stock and inventory efficiency. These observed differences in the KPI grade means suggest that multi-channel retailers in the electronics, books and CDs sector pay less attention to the stock and inventory efficiency than the ones in the grocery and FMCG sector, where inventory efficiency may be more important to the EP of the activity, based on the 16 surveyed companies. This may be explained by the fact that grocery products especially have to be managed considering the perishability of these types of goods. At the same time, grocery and FMCG products are characterized by a high turnover rate, therefore the stock-out rate is more crucial and more important to manage for these types of products.

Among the 16 surveyed companies, only four KPIs (2, 5, 16 and 23) show significant differences for the mean grade regarding the country, and only two KPIs (5 and 23) show significant differences for the mean grade regarding the sector. Moreover, only two of these KPIs (5 and 23) show significant differences for the mean grade regarding the country and the sector at the same time.

All the other KPIs grades do not show significant differences for the mean grade regarding the country or the sector.

5. Conclusion

5.1 Contributions

Our exploratory results contribute to expand the existing research about performance measurement in the supply chain. Research has been conducted about performance measurement in the supply chain (Gunasekaran *et al.*, 2004; Morgan, 2004; Papakiriakopoulos and Pramatari, 2010) and, to a minor extent, about performance management in the retail supply chain (Anand and Grover, 2015; Bouzaabia *et al.*, 2013; Forslund, 2015). But, there is, to our best knowledge, no research about the performance measurement of the e-fulfillment systems of multi-channel retailers, which is the main contribution of our paper.

Based on a literature review in supply chain management and in marketing, this paper has identified 30 KPIs that measure the performance of the e-fulfillment systems in multi-channel retailing. In order to identify the most relevant KPIs in terms of importance and use by multi-channel retailers, an online questionnaire was completed by 16 supply chain or marketing managers of French and Chinese multi-channel companies from two sectors (grocery and FMCG and electronics, books and CDs). The results of this exploratory study enable us to identify 13 KPIs that are important and used by these multi-channel retail companies and also to determine under which of the five EP or four CE criteria these KPIs might be linked. Only few of the identified KPIs show significant differences for the mean grade regarding the country and/or the sector.

These exploratory results contribute to expand the existing research on fulfillment systems for multi-channel retailers (Agatz *et al.*, 2008) by identifying KPIs that combine existing analysis of physical distribution service quality and customer satisfaction (Xing and Grant, 2006; Xing *et al.*, 2010) with EP appraisal (Gunasekaran *et al.*, 2001). The widely used criterion of customer service as a performance indicator for supply chains (Mitra and Bagchi, 2008; Mitra *et al.*, 2010) is therefore refined and completed with the addition of EP criteria.

This paper contributes to gaining insights in measurement systems and metrics for the evaluation of supply chain performance (Anand and Grover, 2015) in the context of multi-channel retailers in providing a greater understanding of KPIs in the 16 companies investigated. The 13 KPIs identified are mostly connected to logistics order fulfillment systems (Mitra and Bagchi, 2008; Mitra *et al.*, 2010) and apply to the multi-channel environment. Some of them, especially those linked to direct-to-customer delivery, are more specifically linked to e-commerce, because customer delivery is a specific characteristic of e-commerce (Gunasekaran *et al.*, 2004; Sambasivan *et al.*, 2009). A traditional store-based retailer has to add specific KPIs to take into account the particularities of multi-channel retailing.

5.2 Managerial implications

From a managerial point of view, these exploratory results prove useful for multi-channel retailers in various ways. They provide KPIs to help in evaluating the performance of e-fulfillment systems and therefore identify potential areas of improvement for specific criteria (EP or CE criteria). When setting up or improving the organization of e-fulfillment systems, the information about how different e-fulfillment systems perform regarding the KPIs of EP or CE is extremely helpful.

These KPIs can steer the fulfillment operations and activities, and therefore they support management in piloting the trade-off between EP and CE. The identified KPIs are rather more operational than strategic. They allow monitoring the activity on a day-to-day level (Griebeler, 2012).

6. Limitations and research avenues

Our results have some limitations. First, the sample size is limited. The research was intended to be an exploratory one based on the practice of supply chain and marketing managers in multi-channel retailing. Even if the response rate of 16 companies out of 100 is satisfying regarding similar research approaches, our exploratory results cannot be generalized to other companies, sectors or countries. Moreover, data were collected from retailers in two specific countries: France and China. Although this was made with the intention to cover a large scope of different retail markets, our results may be biased by local markets and differences in CE.

A further limitation may be the fact that these exploratory results do not address interdependencies among the different KPIs, because one KPI may give indication on more than one criterion. Each of the identified KPIs relevant for EP and CE has multiple implications for other KPIs, so these indicators may be interdependent. Three of the five EP

and four CE criteria, previously identified, have not been attributed by the respondents as being used with one of the retained 13 KPIs (return handling efficiency (EP), timeliness (CE) or availability (CE)). The reason for this may be the fact that interdependencies exist between the different criteria. For example, the criterion return handling efficiency (EP) is closely linked to the criterion return (CE), which may have been indicated by the respondents indifferently. In the same vein, the criterion timeliness (CE) may be linked to the criterion delivery cost efficiency (EP), and the criterion availability (CE) may be linked to the criterion stock and inventory efficiency (EP).

Finally, our research does not take into consideration the impact of the different types of e-fulfillment systems a multi-channel retailer may operate. The importance of the different KPIs depends on whether a retailer is fulfilling online orders in a dedicated distribution center, in its physical stores or in both. It further matters whether orders are prepared for home delivery or for customer pick-up in the stores or pick-up points. Most of the surveyed companies combine several fulfillment systems with centralized and decentralized order preparation. The importance given to a specific KPI may be influenced by the fulfillment system(s) used by the companies. This aspect opens promising research avenues.

We focus in this paper on the two first activities – selecting performance variables and defining metrics – from the performance measurement process developed by Forslund and Jonsson (2007). Future research should expand this approach to the remaining activities of setting targets, measuring and analyzing/acting for this process.

Further research should also replicate this study including multi-channel retailers in different countries and sectors with different product types in order to explore the influence of the country, sector and product type on the performance of the e-fulfillment system. Further research could also conduct some in-depth interviews with experts in multi-channel retailing in order to confirm our exploratory results. Furthermore, it might be interesting to question more respondents from each company in order to have a better validity and relevance of the results. Moreover, the evaluation of KPIs should take into consideration the specific fulfillment system used by multi-channel retailers. This would enable refining the results and to be better able to apply the KPIs to specific company settings, therefore validating our exploratory results.

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Appendix

Number	Name	KPI Definition	References
1	Total investment of the warehouse	Investment, rental cost and/or outsourcing cost	Ploos van Amstel and D'Hert (1996), Rouwenhorst *et al.* (2000)
2	Inventory cycle time	Average time of items in inventory	Chae (2009), Chan and Qi (2003)
3	Inventory carrying costs	Total costs that contain material handling costs, inventory capital cost, storage space cost, risk cost	Chan and Qi (2003), Morgan (2004)
4	Safety stock volume	Inventory held to meet uncertain demand because of mismatch between forecasted and actual consumption or demand	Daskin *et al.* (2002), Soni and Kodali (2010)
5	Rate of obsolete inventory	Products in stock without usage or sales capability because of reaching the end of their product life	Chae (2009), Soni and Kodali (2010)
6	Order to delivery time	Time between order receiving and goods delivery	Morgan (2004), Soni and Kodali (2010)
7	Percentage of error in goods picking	Number of goods picked with errors compared to total number of goods picked	Chiu (1995), Gunawan *et al.* (2008)
8	Revenue per order	Revenue per order	Griffin (2008), Gunawan *et al.* (2008)
9	Pick rate per employee	Employee number compared to total number of picked items	Griffis *et al.* (2004), Morgan (2004)
10	Units shipped per employee	Employee number compared to total number of shipped units	Fawcett and Cooper (1998), Morgan (2004)
11	Order entry time	Time between an order received and when it is entered into a paper or electronic system	Aronovich *et al.* (2010), Lapide (2000)
12	Average delivery time	Transit time from when a shipment leaves the order preparation facility until it arrives at its destination (end customer)	Aronovich *et al.* (2010), Gunasekaran *et al.* (2001)
13	Ratio of transportation cost to value of product	Total transportation costs divided by the total value of product shipped	Aronovich *et al.* (2010); Lee and Whang (2001)
14	Shipping accuracy	Number of units shipped without error divided by the total number of units shipped	Morgan (2004), Soni and Kodali (2010)
15	Cost per shipment	Total cost divided by the total number of shipments	Baumol and Vinod (1970), Soni and Kodali (2010)
16	Percentage of shipments arriving in good condition	Percentage of shipments arriving in good condition without damage during a defined period of time	Aronovich *et al.* (2010), Forslund (2007)
17	Average delivery re-planning time	Total re-planning time divided by times of return for a period	Krauth *et al.* (2005)
18	Cost of returns	General cost of returns	Bernon *et al.* (2016), Morgan (2004)
19	Enquiry-to-response time	Time between customer enquiry and retailer response	Gunawan *et al.* (2008), Ploos van Amstel and D'Hert (1996)
20	Average fulfilment cycle time	Total time between the customer order and the customer receipt of the product divided by total number of orders	Lin *et al.* (2006), Sürie and Wagner (2008)

(*continued*)

Number	Name	KPI Definition	References
21	Percentage of on-time deliveries	Percentage of orders delivered by the requested delivery date	Morgan (2004), Papakiriakopoulos and Pramatari (2010)
22	Order fill rate	Percentage of items ordered filled from stock compared to total items ordered	Chae (2009), Chan and Qi (2003)
23	Stock-out rate	Rate of stock-out and the duration of stock-out compared to the total number of units in stock	Beamon (1999), Chan and Qi (2003)
24	Shrinkage	Average inventory divided by average daily cost of goods sold (COGS)	Bauer (2004), Thomas *et al.* (1998)
25	Order entry accuracy	Percentage of orders entered completely and correctly into the records compared to total number of orders entered	Aronovich *et al.* (2010), Lapide (2000)
26	Warranty claims	Request for reimbursement of material costs, labor costs and external service costs that are incurred while repairing damage	Morgan (2004), Murthy *et al.* (2004)
27	Number of damage claims	Number of damage claims over a specific period of time	Morgan (2004), Ploos van Amstel and D'Hert (1996)
28	Invoice accuracy	Percentage of correct invoices (reflecting products, quantities and price) issued compared to total invoices issued	Morgan (2004), Ploos van Amstel and D'Hert (1996)
29	Notification-to-refund time	Time between customer notification and getting refund	Gunawan (2010), Gunawan *et al.* (2008)
30	Average return rate	Number of product returns out of the total number of processed orders	Fawcett and Cooper (1998), Ofek *et al.* (2011)

Table AI.

Corresponding author
Gregory Bressolles can be contacted at: gregory.bressolles@kedgebs.com