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Designing and Assessing a Sustainable Networked Delivery (SND) System: Hybrid Business-to-Consumer Book Delivery Case Study

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We attempted to design and assess an example of a sustainable networked delivery (SND) system: a hybrid business-to-consumer book delivery system. This system is intended to reduce costs, achieve significant reductions in energy consumption, and reduce environmental emissions of critical local pollutants and greenhouse gases. The energy consumption and concomitant emissions of this delivery system compared with existing alternative delivery systems were estimated. We found that regarding energy consumption, an emerging hybrid delivery system which is a sustainable networked delivery system (SND) would consume 47 and 7 times less than the traditional networked delivery system (TND) and e-commerce networked delivery system (END). Regarding concomitant emissions, in the case of CO_2, the SND system produced 32 and 7 times fewer emissions than the TND and END systems. Also the SND system offer meaningful economic benefit such as the costs of delivery and packaging, to the online retailer, grocery, and consumer. Our research results show that the SND system has a lot of possibilities to save local transportation energy consumption and delivery costs, and reduce environmental emissions in delivery system.

Introduction

Over the past decade, business-to-consumer (B2C) and consumer-to-consumer (C2C) e-commerce (electronic commerce) systems have become one of the most important and obvious commercial applications of information and communication technology (ICT), allowing consumers to buy and exchange goods and services quickly and conveniently (*1*−*3*). The popularity of these technologies is enhanced because they also enable consumers to compare products and prices easily, and choose preferred delivery options, making shopping more enjoyable, less expensive, and less time-consuming. For many reasons, then, e-commerce will be the fastest growing segment of the U.S. retail marketplace for the foreseeable future (*4*), especially as Internet use in the U.S. continues to grow, concomitantly expanding the potential market size for e-commerce. According to the U.S. Census Bureau of the Department of Commerce, total e-commerce sales for 2007 were estimated at $136.4 billion, an increase of 19.0% from 2006. The total retail sales in 2007 increased 4.0% from 2006. E-commerce sales in 2007 accounted for 3.4% of total sales. E-commerce sales in 2006 accounted for 2.9% of total sales (*5*). Moreover, Americans in particular are enthusiastic about e-commerce options: in 2004, 27% of U.S. Internet users made online purchases, compared with 20% in Japan, 18% in the UK, and 16% in South Korea (*6*). Books and music CDs are the most purchased products on the Internet by volume shipped (*6*). Such e-commerce systems also benefit sellers, who can more easily expand and compete in worldwide markets. Moreover, expenses are reduced; e-commerce sales require minimal physical infrastructure such as well-stocked stores, and reduced need to carry location-specific large inventory. Specialized e-commerce sites and auction services also make specialized and hard-to-obtain items more available, benefiting both potential buyers and sellers seeking as broad a market as possible.

Although comprehensive data are not yet available, it also appears to be the case that e-commerce systems taken as a whole are more environmentally and energetically efficient (*7*). Thus, in terms of energy and environmental aspects, Romm (*8*) provided evidence for the reduction of energy intensity due to the growth of e-commerce. Gay et al. (*9*) showed 40−50% reduction in life cycle energy and pollutant expenditures of e-commerce compared with the conventional business strategy by a case study of personal computers. Sivaraman and colleagues (*10*) conducted comparative life cycle assessment (LCA) of two competing digital video disk (DVD) rental networks, the e-commerce and traditional business option, and found that the traditional business option consumed more primary energy than the e-commerce option. In the transportation stage, the energy consumption of the traditional business option was, in fact, 6 times higher than the e-commerce business option. Matthews and colleagues (*11*) compared the delivery and logistic systems of traditional and e-commerce retailing, finding that the e-commerce system consumed less energy and produced fewer environmental impacts than the traditional system. However, studies also showed possible increased environmental impacts by taking into account rebound effect on transport and indirect effects such as increased consumer buying power (*12*−*14*). In terms of cost and environmental effects, Brynjolfsson and Smith (*15*) found that, from February 1998 to May 1999, prices of books on the Internet were 9−16% lower than prices in conventional stores; moreover, the Internet retailer prices differed by an average of 33%. Matthews et al. (*16*) assessed the economic and environmental impact of e-commerce for book retailing and found that the logistics cost and environmental impact of e-commerce were lower if considering unsold book returns in the conventional retail model. Matthews and Hendrickson (*17*) studied the economic and environmental implications of e-commerce from the perspective of inventory management, finding that e-commerce generated large economic and environmental benefits because of reductions in warehousing expenses. Dinlersoz and Li studied the shipping strategies of e-commerce and found that online book retailers often offer lower product prices, lower shipping fees together, and higher quality shipping together (*18*). However, lower price does not always mean higher consumer fulfillment satisfaction.

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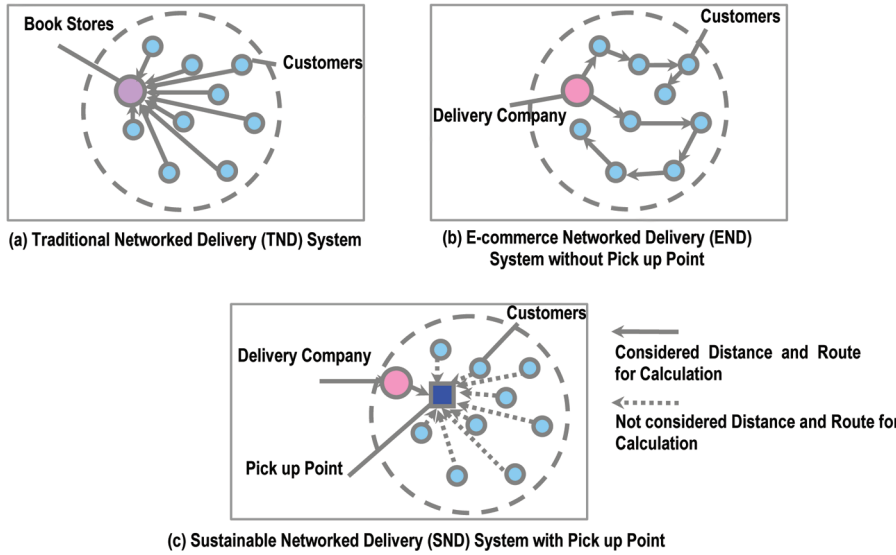

FIGURE 1. Three types of book delivery systems: traditional networked delivery (TND), e-commerce networked delivery (END), and sustainable networked delivery (SND).

According to Cao et al., competing on price may not be a good strategy for e-commerce in the long-term (*19*). Moreover, when shipping costs are included, e-commerce does not always provide lower prices than conventional retailers (*20*).

These studies suggest that environmental benefits depend heavily on the design and operation of the particular systems involved in each case. Indeed, Fichter (*21*) argued that the technology used in e-commerce itself does not determine sustainability, but rather its design, use, and regulation do. Thus, we evaluated these studies to determine which specific domains within these delivery and logistic systems are particularly important in determining overall impacts. As a result, we found the local delivery subsystem is a key: moving the purchased item from consumers to local bookstores or delivery companies generated about 45% of the total cost and environmental impact in both delivery systems. Accordingly, we focused our efforts on the design of a sustainable local networked delivery (SND) system (*22*) and, for simplicity's sake, on book sales (we anticipate that CD sales would have similar network characteristics, but did not research the flow of products associated with auction sites). In particular, given book sales system's resource consumption and emissions profile, noise generation, and contribution to congestion, we focused on the impacts of different delivery patterns on the transportation networks.

Methods and Approach

Research Approach. *Goal and Functional Units.* The goals of this study are to (a) design a sustainable networked delivery (SND) system; (b) compare transportation cost, energy consumption, and concomitant emissions in the three delivery systems (traditional networked delivery (TND) systems, e-commerce networked delivery (END) systems, and SND systems; see Figure 1); (c) estimate the energy savings and CO_2 reduction potential for each option. Furthermore, estimation of the energy consumption and CO_2 generation from book delivery systems (TND and END systems) in the Metropolitan areas (30 largest Metro areas and other Metro areas from U.S. Census Bureau data) in the U.S. is a major goal of this research. For this study, the functional unit is the purchase and delivery of 100 books to 100 customers. This number is based on the determining sample size and techniques of Israel and Cochran (*23, 24*).

Research Boundary and Assumptions. The geographic area chosen for this study was the 85281 zip code within Tempe-Arizona. As a part of the Phoenix Metropolitan area, the findings and results from this area could be extended to any Metropolitan area in the U.S. Two big grocery stores, two bookstores, and one delivery facility were located inside the study area and were selected as part of the TND, END, and SND, respectively.

The study is performed considering the following assumptions:

(a) All 100 consumers use only the grocery stores and bookstores within the area of study;
(b) In the SND system, the energy consumption and emissions resulting from the customer's travel to the grocery store (the pickup point for the SND model) are considered to be the result of the primary purpose of the trip, the purchase of groceries, and are therefore not counted as part of the book delivery process;
(c) For the TND system, all 100 consumers purchase their books in the same day;
(d) For all the cases, the average round trips of consumer's driving to bookstore and delivery trucks are considered;
(e) For the TND system, all trips to bookstores are made by automobiles, not by alternative modes;
(f) For all the cases, the environmental burdens associated with the use phase of the facilities are not considered;
(g) For the END system, two trucks deliver the 100 books in one day of work as part of their delivery route. The route and number of trucks are selected based on interviews with delivery companies and experts;
(h) For the END system we assume that every book is delivered successfully in the first attempt;
(i) For the END system, the delivery of books from the delivery facility to the residential buildings is only considered;
(j) For the SND system, the delivery of books from the delivery facility to the pickup point is only considered;
(k) For the TND system, the transportation of the books to the bookstore is not considered;
(l) In all delivery systems, book returns are not considered;
(m) Life cycle burdens of manufacture, maintenance, and end-of-life of trucks and cars are not considered; life cycle burdens of construction, maintenance, and end-of-life of facilities are not considered.

Book Delivery Systems. The study compares three different "last mile" book delivery systems, the two currently in use—the TND with consumer's trip to bookstore and the

TABLE 1. Book Online Retails and Total Book Retail Sales Data (in Millions of U.S. Dollars)[a]

year	book online sales	total book retail sales	% of book online sales
2005	$3,946	$25,629	15.40%
2004	$3,584	$24,876	14.41%
2003	$3,193	$24,584	12.99%
2002	$2,812	$23,728	11.85%
2001	$2,344	$23,037	10.17%
2000	$2,207	$23,269	9.48%
1999	$1,150	$23,989	4.79%
1998	$653	$26,541	2.46%

[a] Data source: U.S. Census Bureau. The 2007 Statistical Abstract; 2007.

END system with delivery to the consumer's house—and the proposed SND system. As below, each of these is described in more detail.

Traditional Networked Delivery (TND) System. TND systems sell products from a retail store to consumers that physically travel to the store, browse the selection, and choose the product, and then travel home by means of car, bus, bicycle, or walking. Although as Table 1 shows e-commerce options have been growing market share rapidly, this is still the preferred option for most people in part because for some customers the bookstore is not just a place to purchase books but also for social activity or enjoyment. Indeed, many bookstores have sought to differentiate themselves from online options by adding coffee shops, comfortable chairs, and other accessories that make them a "destination" rather than just a store. To the extent they succeed, they enhance their social value, a factor we did not attempt to quantify in this study.

E-Commerce Networked Delivery (END) System. END system is widely applied nowadays. As stated above, about 15% of books sold in the U.S. in 2005 were ordered online and delivered directly to consumers. The process of the END system is generally as follows. First, consumers browse the different online stores (e.g., Amazon.com) via the Internet. After selection of the book, a delivery option is selected by the customer. Then the purchase is made and the desired delivery location is indicated. The sellers then send the delivery information to their contracted delivery company, such as FedEx, UPS, USPS, or DHL. The delivery company arranges the pickup and delivery process based on information they get from the seller. Finally, the delivery company physically performs the delivery to the consumer. If the product cannot be delivered properly at the first time, delivery companies usually attempt delivery one or two more times, keep the product at the local facilities for pickup, or return the product to the sellers (because this is difficult to quantify, we make the conservative assumption that delivery occurs first time). Note that each delivery point adds only an incremental amount to the existing route structure, rather than a complete trip, as might occur when one picks up a book from a bookstore.

Sustainable Networked Delivery (SND) System with Pickup Point. While a number of more complicated schemes are possible, we have elected to model the simplest SND, a combination of e-commerce and centralized pickup point (PP), with the PP being a location that the consumer will already be visiting regularly. Currently South Korea and Japan have a very similar system for book delivery, which is drop-off and pickup services at convenience stores (*25, 26*). In our model for the U.S., for example, grocery stores as PPs were used, since most people have to shop for food frequently in any event. This is similar to the model already used in many apartment complexes and some communities: a mailman delivers letters or residential packages to a mailbox in a centralized location and then residents pick up the mail or packages.

Nielsen's consumer packaged goods research shows the annual number of shopping trips (e.g., grocery, supercenters, convenience stores, and warehouse, etc.) per household was 164 in 2007 (*27*). This means a household made shopping trips 3.2 times per week. Consumers do not create additional trips to pick up orders (i.e., by an incentive to do the right thing and avoid unnecessary trips, grocery store charges nothing for pickup with another purchase, but charges $X without purchase).

Also, according to UPS, FedEx, and U.S. Postal Service (USPS) data (*28*), about 63% of total package volume was delivered by using ground shipping, in distinction from just 13% of overnight air shipping, in 2005. Therefore, SND system could be an attractive system to END system users.

In addition to possible economic and environmental efficiency (e.g., energy saving and delivering cost), the SND model could have several additional benefits. First, it enables efficient collection and recycling of the packing material associated with e-commerce books (recycled materials; grocery stores already bulk-package cardboard on site due to heavy volumes received), identified in other studies as a major environmental consideration with the pure e-commerce model (*15*−*17*). Research undertaken by the Solid Waste Association of North America (SWANA) shows the collection of solid waste and recyclables typically represents 50% of MSW management system costs (*29*). Clearly, improvements in collection efficiency can have a big impact on total waste management costs. Additionally, it avoids the problems of multiple attempted deliveries, in that customers can be sure the book will be there when they want it.

Analysis. The framework of the research in this paper is presented in the Supporting Information. First, the network is defined by identifying relevant nodes: bookstores, delivery company locations, and PPs. Experiential driving information such as distance and time from consumers' houses to PPs, book stores, and delivery company locations is then gained for each delivery system. The geographic distribution data are also validated by the experiential driving information of 5 delivery persons of the delivery company. Second, links between nodes are quantified (this can be done either on the ground, or through GIS or mapping software). Once the networks are defined, energy consumption and emission generation can be calculated for each system. Finally, each network can be ranked according to the impact calculations. In our case, we obtained a random distribution of customers across the geographic region by randomly selecting located 100 houses within the "blocks" of the grocery networks in zip code 85281 in the Tempe area.

Driving distances and times for all nodes, including the delivery facilities, book stores, and PPs, were obtained from Google Maps (http://maps.google.com), which is a leading online provider of driving direction and time services. In calculating the routes, we assumed that consumers would go to the nearest bookstore or pickup point. We interviewed delivery companies to establish that given our routing model and the characteristics of the selected zip code area, they would use two delivery trucks. A standard vehicle routing algorithm (*30*), combined with interviews with delivery company drivers, was used to establish the specific vehicle delivery mapping.

Using the information gained about driving distance, the geographic distribution data of final demand followed by normal distribution with mean 4.42 km and standard deviation 2.27 for consumer's houses to bookstores, and with mean 2.91 km and standard deviation 1.19 for consumer's houses to pickup point. The environmental impacts of each delivery system were quantitatively calculated using EPA

TABLE 2. Energy Consumption and Environmental Emissions from Each Delivery System to Deliver 100 Books[a]

	TND	END	SND
distance (km)	883 (66)	98 (7)	13 (1)
time (min)	920 (46)	194 (10)	20 (1)
fuel consumption (L)	87 (47)	13 (7)	2 (1)
energy (MJ)	2,963 (42)	512 (7)	71 (1)
hydrocarbon (HC), (g)	747 (56)	98 (7)	13 (1)
carbon monoxide (CO), (g)	6,807 (52)	952 (7)	131 (1)
nitrogen oxides (NO_x), (g)	521 (52)	74 (7)	10 (1)
particulate matter (PM_{10}), (g)	2.9 (53)	0.4 (7)	0.1 (1)
particulate matter ($PM_{2.5}$), (g)	2.7 (54)	0.4 (7)	0.1 (1)
carbon dioxide (CO_2), (kg)	203 (32)	31 (7)	6 (1)

[a] In parentheses is the ratio between systems when SND system is one. Fuel energy density: automotive gasoline = 34.2 MJ/L, automotive diesel oil = 38.6 MJ/L.

average emission factors and fuel-consumption factors for passenger cars and light-duty trucks (*31*) (see Supporting Information). The final analysis was based on a general model for assessing the environmental performances for delivery systems. Thus, although our results apply to book delivery systems, our methodology could easily be extended to other products, such as electronics, footwear, or music CDs.

An economic analysis to verify the feasibility of the proposed SND system was also conducted. We first looked at the costs of the respective supply chains, beginning with the observation that many aspects of the systems are the same (e.g., printing the book), and that the cost differences between the two systems thus depend on the differences in delivery and packaging. Assuming a reasonable dimension and weight of books, we can then calculate and compare the different costs arising from the delivery and packaging components of the END and SND systems. Finally, the price-cutting potential for delivering a book in the proposed SND system shows the feasibility of the SND system from an economic aspect.

Results

Energy Consumptions and Environmental Emissions. Energy consumption and air emissions, including hydrocarbon (HC), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), and carbon dioxide (CO_2), from each delivery system are compared. Table 2 shows that the SND system, because it involves much less dedicated driving, is more environmentally friendly than the TND and END systems. Regarding energy consumption, about 2,963, 512, and 71 MJ are consumed in the TND, END, and SND systems, respectively; the SND option would consume 47 and 7 times less than the TND and END systems. Concomitantly, the TND system results in much higher amounts of emissions in all categories than the END and SND systems; in the case of CO and CO_2, releasing 6807 g of CO and 203 kg of CO_2, compared to the END system, which released 952 g of CO and 31 kg ofCO_2, or the SND system, which released 131 g of CO and 6 kg of CO_2. Overall, implementation of a SND last mile delivery system offers the potential for significant reductions compared to current alternatives (this conclusion appears relatively robust given that we focused on transportation networks, and the SND system appears capable of significantly increasing the packaging recycling rate associated with END systems).

Economic Analysis. From the perspective of the consumer, one of the major advantages of the END system compared with the TND system is lower cost (*6*). Here, the SND system would appear to offer additional economic and operating efficiencies as well. Unlike the case with either the TND and END systems, the SND system creates shared costs in the infrastructure required for the last mile administration and delivery: stores can benefit perhaps significantly by the additional customer loyalty and traffic generated by operating a pickup service. Indeed, this is the reason many supermarkets now offer banking, pharmacy, and other nonfood services, and "loyalty cards" that routinely attract substantial price discounts.

To illustrate the costs of delivery and packaging, assume that the average weight of a book is 0.68 kg (1.5 lbs). The total delivery process contains two parts: bulk packaging delivery and local delivery. Bulk packaging weighs about 3.3% of the weight of books (*32*). Average cost for air carrier in 2002 is $3/ton-km ($4.8/ton-mile) (*33, 34*). Assume that the average mileage per freight shipment for printed products within the U.S. by domestic establishment is 510 km (816 miles) for both 2001 and 2006 (*33, 34*). Therefore, the highest cost for long-distance book shipment is a relatively trivial part of the charge paid by the consumer, costing only around $1.79 (based on 2002 data).

The packaging associated with a single book package is about 5.3% by weight, which means the total weight of a package for local delivery is 0.72 kg on average. The average cost of local ground shipping with guaranteed day, definite one to five days (within the same zip code) from major domestic carriers are $8.12 from UPS, $6.88 from FedEx, $2.47 from USPS, and $6.54 from DHL (The average dimension of a book package is about 28 × 23 × 5 cm (11 × 9 × 2 inch). Rates are cheapest option provided by the delivery companies (*28*).

The proposed SND system thus reduces, if not eliminates, the element of the logistics system that accounts for by far the predominant proportion of costs, which means it can therefore reduce shipping costs by as much as $8.12 for each delivered book. This reduction is dramatic compared with the upstream freight shipping cost, which remains the same for all systems, and is sufficient to offer meaningful economic benefits to the online retailer, the PP, and the customer, an important incentive if one is attempting to change existing patterns of behavior.

Additional economic value (and probably environmental value) would result if migration to the SND system also reduced overall levels of packaging, as bulk packaging replaces individual packaging at least for some shipments. In terms of individual books, this effect pales against the elimination of the local delivery cost, but it might still be significant over the system as a whole. To illustrate, assume an average price for bulk packaging (heavy-duty bulk container, 36 × 36 × 24 in., holds max. wt. 72.6 kg) of 100 books at $26.20 (*32*), giving a unit packaging cost for each book of $0.26. The average price for single book packaging (kraft easy-fold mailers, 20 × 16 × 4 in., holds max wt. 8.2 kg) is about $2.25 (*32*). Therefore, reduction in packaging cost in a SND system could be up to $1.99 per book compared to that in END system.

Although it is possible that a high-volume SND system could partially substitute bulk packaging for individual book packaging at some additional cost savings, we did not quantify this factor further given the high degree of uncertainty any assumptions regarding degree of substitution would necessary entail. For similar reasons, we did not attempt to quantify the costs and benefits associated with increased rates of packaging recycling from a PP as opposed to individual homes, as data on such patterns are lacking, although the efficiency of being able to recycle in bulk from a PP as opposed to individual book packaging is apparent. Finally, environmentalists have argued that lower prices for books and other articles as a result of e-commerce are undesirable because they create a "rebound effect" as money saved is spent on additional consumption with concomitant increases in environmental impact. We do not address this argument, but do note that

TABLE 3. Households and Calculated Delivered Book Quantity in the 30 Largest Metro Areas and Other Metro Areas Based on Total Book Sales Data in the U.S in 2005

area	households	delivered book quantity in TND system	delivered book quantity in END system
ZIP Code 85281	20,173	442,315	80,516
Phoenix metro areas	850,190	18,641,343	3,393,341
30 largest metro areas	51,339,133	1,125,666,473	204,908,554
other metro areas	31,582,413	692,478,844	126,054,068
U.S total	105,480,101	2,312,766,234	421,000,000

from a sustainability viewpoint it is not trivial, since higher prices may provide an environmental benefit by reducing consumption, but impose a social cost since such consumption is apparently viewed as desirable by the individuals involved. Thus, unless one simply assumes that environmental values are preferable to others, this phenomenon involves a conflict between the social and environmental values inherent in the sustainability formulation, and it lies beyond the scope of this paper to resolve it.

Discussion

Greenhouse gas emissions generated by the transportation sector represent a significant contribution to global anthropogenic emissions. CO_2 emissions from the transportation sector in the U.S., at 1958.6 million metric tons (mmt), accounted for 33% of total U.S. energy-related CO_2 emissions in 2005 (*35*). Over the next 50 years, rising numbers and use of vehicles could increase greenhouse gas emissions from the U.S. transportation sources 80% above current levels (*36*). In order to evaluate the potential impacts on greenhouse gas emissions of implementing a SND system, we expand our consideration of the system to the level of 30 largest metro areas and other metro areas in the U.S. as well as the Phoenix metropolitan area, within which our Tempe study area is embedded. According to the U.S. Census Bureau, a household is classified within strata as residing in the top 30 metropolitan areas nationwide, any other metropolitan area, or a nonmetropolitan area. About 79% of households live in the 30 largest metropolitan areas and other metro areas in the U.S. (*5*).

We begin by assuming that the number and location of groceries (PPs), bookstores, delivery companies, and customers are similar in terms of geographic and distance distribution as in our original data sample. The 30 largest metro areas and other metro areas book purchase patterns by using total household (population) numbers and total book delivery data in the U.S., according to the USPS Household Diary study, were estimated in 2005 as 421 million books delivered to 105,480,101 total U.S. households through the END system (*37, 38*). This amount is 15.4% of total book sales in the U.S. The other 84.6% of books were sold through the TND system. Overall, in the 30 largest metro areas and other metro areas, about 331 million books were delivered to households by END system, while about 1.8 billion books were sold by TND system; on a household basis, this equates to about 4.0 books sold per household through the END system, and about 21.9 books through the TND system per year (see Table 3).

With these results, the energy consumption and CO_2 emission from each delivery system in the 30 largest metro areas and other metro areas were calculated.

Table 4 shows the total energy consumption and CO_2 emission from the TND and END systems. About 1,575 million L of fuel were consumed by TND, and 44 million L were consumed by END in the 30 largest metro areas and other metro areas; this equates to 3.7 and 0.1 million metric tons of CO_2 emissions, respectively. Emissions from TND system are 37 times higher than those from END system.

TABLE 4. Energy Consumption and CO_2 Emission from Each System in the 30 Largest Metro Areas and Other Metro Areas in 2005

item	book delivery in TND system	book delivery in END system
distance (million km)	16,058	323
fuel consumption (million L)	1,575	44
energy (million MJ)	53,872	1,694
carbon dioxide (CO_2) (MMT)	3.7	0.1

On the basis of this result, the SND system's effect could be roughly estimated. If the SND system is running, when 10% of consumers from TND system use SND system about 155 million L of fuel consumption and 0.36 million metric tons of CO_2 could be reduced. When 30% of consumers from TND system use SND system, about 463 million L of fuel consumption and 1.07 million metric tons of CO_2 could be reduced in the 30 largest metro areas and other metro areas for book delivery system.

Also, if 10% of consumers from END system use SND system, about 3 million L of fuel consumption and 8,124 t of CO_2 could be reduced. When 30% of consumers from END system use SND system, about 11 million L of fuel consumption and 24,371 t of CO_2 could be reduced in the 30 largest metro areas and other metro areas. If the consumers who are using SND system are increased, fuel consumption and environmental emissions from local delivery system could be significantly reduced.

Undoubtedly, some assumptions have been applied in this research. It is necessary to discuss the validity of those assumptions. First, to make it possible to quantitatively identify each system's economic and environmental characteristics, consumers' shopping trips are considered to be dedicated. However, consumers will combine their trips for shopping for various goods together. This will reduce the marginal costs as well as environmental impacts as presented herein. Second, our research focuses only on local delivery because the upstream processes for END and SND are the same. It will be interesting to explore the differences between TND and the other two systems in terms of upstream logistic processes. Third, because individual consumers have different time windows and different preferences to buy books, single-book packaging is more plausible than bulk packaging. However, bulk packaging is still a potential advantage of SND compared with TND and END. Fourth, we assumed all trips to bookstores are made by automobiles, but not alternative modes such as walking or public transportation. According to the 2001 national household travel survey data, in the proportion of trips by mode, personal vehicle travel accounts for 87% of the total (*39*). Moreover, trips made by personal vehicles are responsible for most of the energy consumption and air emissions. Therefore, although this assumption overestimates the total environmental impacts, the collective magnitude of energy consumed and air emissions generated in the book retail market can be presented by our results. In further study, alternative trip modes should be considered to make the results close to the reality. Finally, in our research, the staff and storage space required in PPs are not studied. When we calculate the required storage space in the grocery, based on the annual total volume for 80,516 books in ZIP code 85281,

about 39.7 cubic feet per day (1.1 m^3/day) space is enough in two groceries. In terms of revenue of grocery space, according to the grocery stores and supermarket industry data, average annual sales per square foot of selling space is about $500 (*40*). Based on 19.85 cubic feet per day space data for a grocery, we assume that the grocery needs about 20 cubic feet of space per day. Therefore the lost revenue from storing e-commerce deliveries is just $27.40 per day. This amount is not a significant value in a grocery. The calculations are shown in the Supporting Information. All in all, assumptions help to make this study possible. However, future studies will model the reality in more detail based on this primary research.

In this paper, we have proposed an alternative to current e-commerce and retail local delivery system that appears, based on an initial and bounded analysis, to offer potentially substantial environmental, social, and economic benefits when compared to existing networks. It would require different commercial arrangements and changes in consumer behavior, but, especially given that cost reductions exist and could be shared across the system, these might be feasible. As mentioned before, a very similar system is running in South Korea and Japan. The reason an SND system or similar has not been applied in other places is complicated. The main reason may be that the economic incentive provided by the SND system is not high enough to make retailers add it to their service portfolio. In theory, SND system is easier to implement in area with higher population density. In areas with low population density, SND system may not have any advantage at all. Consumers with different social and cultural backgrounds may also have different perspectives toward SND system.

We recognize, however, that this is just a beginning. If SND systems are to be understood and implemented, and their full benefits realized, further research on network structure and performance over time will be necessary, especially as implementation occurs. As any human system, we would anticipate that unpredicted new opportunities, benefits, and costs would emerge as people and institutions adjusted. Indeed, it is for this reason that we regard the proposed SND, as we regard the theory of SND in general, as a continual work in progress.

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Supporting Information Available

Details about the analysis and calculations. This material is available free of charge via the Internet at http://pubs.acs.org.

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