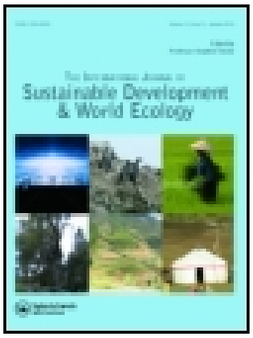

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Impacts of home shopping on vehicle operations and greenhouse gas emissions: multi-year regional study

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ABSTRACT
As a shopping behavior trend, home shopping has become more popular. This shopping method seems to decrease shopping trips, yet more delivery trucks are required to be on the roads. In addition, even more personal trips may occur because saving time on shopping might allow more time for alternate activities. A study investigated the effects of home shopping on vehicle operations and greenhouse gas emissions. The purpose of that study was to identify the home-shopping impacts on transportation system, its net effects on traffic volume of the transportation network, its effects associated with environmental sustainability and then to provide some projections for future condition. Simulation results showed that home shopping will put additional burden on Newark transportation network, as identified through four measures of effectiveness (MOEs) which were travel time, delay, average speed and greenhouse gas (GHG) emissions.

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Home shopping; emissions; environmental impacts; mobility; vehicular effects

1. Introduction and background

Home shopping allows consumers to shop for goods and services in their own home, in contrast with traditional shopping, which requires a visit to stores and shopping malls. Shopping from home has been available as a shopping option for more than one hundred years (Cherry 2008). The growth of car ownership and expansion of road network after World War II made store shopping easy and put a hold on home-shopping spread (Cvetek 2001). Nowadays home shopping is revived and is expected to increase rapidly in the near future (Margolis 1996). Catalog shopping is a good old-fashioned example of ordering and purchasing goods from home. Internet Shopping or Online Shopping as a new shopping method contributed to rapid growth of home shopping in recent decade.

With the dawning of the new millennium, information and communication technology (ICT) has created new fundamental challenges to transportation planners and policymakers (Fichter 2002). The Internet makes it much easier to conduct activities such as working, banking, shopping and socializing without visiting to activity places. As the popularity of home shopping via the Internet rises, it could fundamentally change the travel behavior and the spatial configuration of shops (Farag et al. 2003; Williams & Tagami 2003). Online shopping can eliminate personal trips. This occurs when online shopping replaces a shopping trip and no other trip is undertaken. At the same time another trip has to be taken since the purchased good has to be delivered.

To understand the current home-shopping expansion and to make predictions for the future, it is important to know the advantages and disadvantages of home shopping and the value people place on them, as well as to understand the different home-shopping technologies and the benefits and the limits they impose on consumers. Some of the advantages that home shopping provides include convenience (Schaupp & Bélanger 2005), no need for vendors and no pressure to buy (Limayem et al. 2000), infinite shelf space available and instant delivery of some products (Cvetek 2001). On the other hand, home shopping includes some disadvantages as well, such as enjoyment of retail shopping lost, privacy and security issues (Schaupp & Bélanger 2005), product category risk (Bhatnagar et al. 2000) and delivery problems (Cvetek 2001).

There are four categories of shopping that are known as home shopping. A brief description of each one could provide a better perspective on the issue of home shopping.

(1) Catalog shopping is the first official form of home shopping that was introduced more than 100 years ago (Cherry 2008). The spread of the Internet changed the economics of catalogs. However, the burst of the dot-com bubble showed that for most companies online sale from the website formed another channel,

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not a replacement. As a record, the highest percentage of total retail sales that catalog shopping ever reached was 10% (Cvetek 2001).

(2) Television shopping originated from a successful regional radio show in the late seventies, and grew from US$19 million in sales in 1985 to US$2 billion in 1988 (Grant et al. 1991). A trend that appeared with the increasing penetration of cable TV was a channel dedicated to advertising and/or selling products with providing the option to buy immediately through the telephone or the Internet.

(3) Selling by the phone, also known as Telemarketing, refers both to suppliers offering goods or services (usually financial products like various insurance policies, selling subscription to newspapers, etc.), and a consumer placing various kinds of orders by phone. However, unwanted calls at inconvenient time are not popular with consumers and are generally perceived as the invasion of privacy (Miller 2004).

(4) Internet shopping. Until 1991, commercialization on the Internet was strictly prohibited by the National Science Foundation (Kelly 2005). Despite the fact that the Internet became popular worldwide around 1994, it took about 5 years to implement security protocols. By the end of 2000, many European and American business companies started offering their services through the World Wide Web (Kalyanam & McIntyre 2002). Since then people began to associate electronic commerce or a word 'ecommerce' with the means of purchasing various goods through the Internet using secure electronic payment protocols. Online retailers, such as Amazon.com or eBay, are called e-tailers and online retail is sometimes known as e-tail (Kalyanam & McIntyre 2002). In many cases, convenience of use is one of the key determinants and is relatively more important for the consumer making purchasing decisions. However, concerns about security of payment, speed of delivery, privacy policy and after-sales service are listed as potentially negative aspects of the ecommerce.

Home shopping imposes some mobility problems and costs on society in general. Heavy-duty diesel trucks have long been recognized as one of the most important source of environmental pollution (Kirchstetter et al. 1999; Sawyer et al. 2000; Lloyd & Cackette 2001). The increase in the number of delivery trucks contributes significantly to emissions of fine particulate matter (PM2.5). The increase in the number of delivery trucks implies the need for more parking spaces both at package distribution centers and on street networks. Residential and downtown streets were not designed to accommodate frequent truck stops, parking, loading, and unloading. In addition to interfering with through traffic and causing delay, there is already an increase in the number of illegally parked trucks, conflicts, and compromised safety. Some of the long-term impacts likely to develop are an increase in infrastructure maintenance costs (due to increases in truck volume), changes in land-use patterns such as the disappearance of large shopping malls with vast parking spaces, changes in labor markets (less demand for sales personnel, more demand for truck drivers), etc.

It is not likely that the Internet will create additional consumption; rather it will take from the traditional store shopping and already existing home-shopping technologies. On the other hand, many orders from home made by phone, through catalogs, even the purchases in regular stores are being placed based on information obtained on Internet (Cvetek 2001).

Internet shopping has increased nearly six-fold since 2000 (Kim & Eastin 2011). An Internet audience measurement service, Nielsen/Net Rating, performed an online survey, and in February 2008 reported that 92% of US Internet population (48.2% of US population) shopped on Internet. This figure was almost 81.2% of US Internet population in 2001 (Nielsen Company 2008). The first official US government estimates of retail e-commerce sales were produced for the fourth quarter of 1999. E-commerce sales were 0.64% of total retail sales for that quarter. According to the latest report provided by the US Census Bureau, in the second quarter of 2015, the estimate of US retail e-commerce sales was $83.9 billion, which still only accounts for just over 7% of total retail sales but this share is likely to rise in certain sectors (DeNale et al. 2015).

2. Literature review

In recent years, there has been a rapid growth of interest in the likely consequences of ICT on travel patterns and transportation system, particularly the energy use and the environment impact related to ICT, such as the impacts on passenger travel behavior (Li 2011; Zhou et al. 2011; Li et al. 2011a, 2011b) or emissions from freight transportation (Gould & Golob 1997; Abukhader & Jönson 2003; Yi & Thomas 2007; Agatz et al. 2008; Rotem-Mindali & Weltevreden 2013). Sivaraman et al. (2007) investigate the important differences between ecommerce and traditional rental options based on primary energy consumption, pollutant emissions and traditional life-cycle assessment metrics. Their findings show that the e-commerce emitted 40.5% less CO_2 than the traditional option.

At the same time, there is an intense debate going on in terms of its potential benefits and a growing focuses on what is termed the 'rebound effect' (Masanet & Matthews 2010). Erdmann defines the rebound effect as being 'effects which occur when the efficiency gains stimulate new demand that counterbalances or even outweighs positive environmental gains' (Erdmann et al. 2004). Sui and Rejeski (2002) believe that it is necessary to recognize the potential for positive environmental impacts related to the three Ds: namely dematerialization, decarburization and demobilization. Nevertheless, they suggest that due to the rebound effect, many of the likely benefits could not be fully achieved. They conclude that 'the law of entropy points to the inevitability of environmental degradation no matter how sophisticated our technologies are'. The use of ICT to improve the competitiveness of business will necessarily lead to economic and environmental problems considerably because it leads to increased consumption of goods and services as well as greater energy consumption for air delivery logistics. In order to find out how physical travel is substituted by online shopping, the Royal Automobile Charity (RAC) foundation found that 80% of online purchases still had to undertake a physical trip (RAC Foundation 2006). Moreover, telecommuting does reduce peak traffic levels and energy consumption from reduced passenger trips in the case of single-purpose shopping trips made by car. Nevertheless, accounting for the growing multipurpose use of passenger cars, ecommerce will not necessarily decrease traffic volume. Instead of driving to the physical stores, people may travel to several destinations (viewing a movie at a cinema, meeting friends in a cafe or restaurant, etc. Without detailed multi-year regional study, the system-wide impacts on mobility, energy, and the environment are still unclear (Siikavirta et al. 2002; Rotem-Mindali & Weltevreden 2013).

Researchers have found that the relationship between Internet shopping and the environment impact from freight transportation is complex. Several past studies have examined the freight aspect from so-called 'last mile' perspective (Lee & Whang 2001; Cullinane et al. 2008; Weber et al. 2010; Zanni & Bristow 2010). Cairns (2005) investigates the increasing interest in the growth of home deliveries of shopping and corresponding concern about delivery traffic and suggests that home shopping for groceries could reduce vehicle distance travelled (VDT) or vehicle miles traveled (VMT) by 70% or more. Mayers et al. (2015) conduct comparative analysis on the carbon footprints of the lifecycle of console games distributed by conventional physical Blu-ray discs (BDs) and online downloaded over broadband Internet. Contrary to the finding of Weber et al. (2010) that downloaded music will result in lower carbon emissions than distribution by disc, they found that distribution of games by BDs results in approximately 50–90% lower emissions than by Internet download. Hesse (2002) argues that early assessments of the promising potential of electronic retailing (e-tailing) to make the freight transport, logistics distribution system more efficient were perhaps too optimistic.

Mokhtarian (2002) examines the impact of telecommunications on VMT and vice versa. She points out that growth in telecommunications is likely to be faster than travel demand, though the latter continues to increase. Mokhtarian (2004) further provides a conceptual framework to explore the potential advantages of e-shopping over conventional store shopping and analyze the shopping-related changes in transportation. Wygonik and Goodchild (2012) present a case study to evaluate the efficacy of shared-use vehicles and compare the logistical details and greenhouse gas emissions due to personal versus shared-use vehicles.

Although there have been extensive previous investigations carried out to estimate the impact of ICT on total VMT, the fact remains that little studies of research have been performed for the mobility and environmental effects of online versus conventional shopping specifically. A study that was conducted at the University of Delaware in 2001, investigated the effects of home shopping on the transportation system of Newark, Delaware (Cvetek 2001). Recently, another study was performed on the same subject to verify the projections provided by the 2001 study. This paper provides the results achieved through that comparative study.

3. Methodology

The methodology of identifying the vehicular effects of home shopping has been the same in both of the studies. The first step was data collection which was performed through a survey questionnaire to identify the shopping behavior of the study area. This was a very important step because the behavioral characteristics of every region depend on the demographic characteristics of that region. There is no identical set of behavioral characteristics that could be a good fit for all societies. In the second step, the survey results were summarized by product category, in order to obtain an estimation of total home shopping in the area in terms of number of purchased items per customer per year per product category. This measure was used in order to calculate total home shopping in the area regarding the population of home shoppers. The information provided by delivery companies about the number of working days per year and the average package delivery per truck completed the knowledge to calculate the number of

trucks for delivery purposes. The third step was simulation and analysis. The first study used CORSIM for simulation purpose and the second study used Synchro as simulation software. The required data for simulation were obtained through a field inspection and the local agencies such as Newark Traffic Police Department and Wilmington Area Planning Council (WILMAPCO) which is a federally funded Metropolitan Planning Organization (MPO) working with Delaware Department of Transportation (DelDOT) and Maryland Department of Transportation (MDOT).

The simulation for each of the studies was performed for two conditions. The normal condition which included the delivery trucks in traffic volume for the network, and the no home-shopping condition which excluded the delivery trucks from traffic volume for the network. Therefore, the difference between the results revealed the net effects of home shopping on MOEs of the transportation network.

4. The survey

The transportation network of interest for this study is Newark in Delaware. The survey questionnaires were also distributed in downtown area. Part of the main campus of the University of Delaware is within the study area. Figure 1 shows the survey area geographically.

In order to figure out the impact of home shopping on the transportation network, it is important to know the shopping habit and the travel behavior of the people in the area. Despite many limitations, survey is still a reliable tool to collect information for research purposes (Gillham 2008). In the 2001 study, a survey questionnaire was designed to obtain the required information. A new survey was prepared and was distributed in the same study area. The survey questionnaires were distributed in the middle of September through early October. In order to identify net changes, the new questionnaire was designed similar to the previous one in terms of the content.

The aim of the questionnaire, which contained 14 questions (Figure 2), was to find:

(1) When, how, and with who people usually go shopping?
(2) Do they buy from home?
(3) What are their reasons for and against home shopping?
(4) Which items do they purchase from home and how frequently?
(5) Items they may never buy from home.
(6) Some demographic information about the respondents.

The survey questionnaire was personally distributed mostly among the University of Delaware students and employees and other residents of Newark, of the age 18 and over. The residents of downtown Newark area were the target group of this study. Around 60% of the respondents were students who mostly live on the University of Delaware campus. The remaining 40% were the university staff or people having business around the campus. Newark is basically a college city and 65% of the population is students. Therefore, the high percentage of students among respondents represents the population combination of the city. Based on the population,

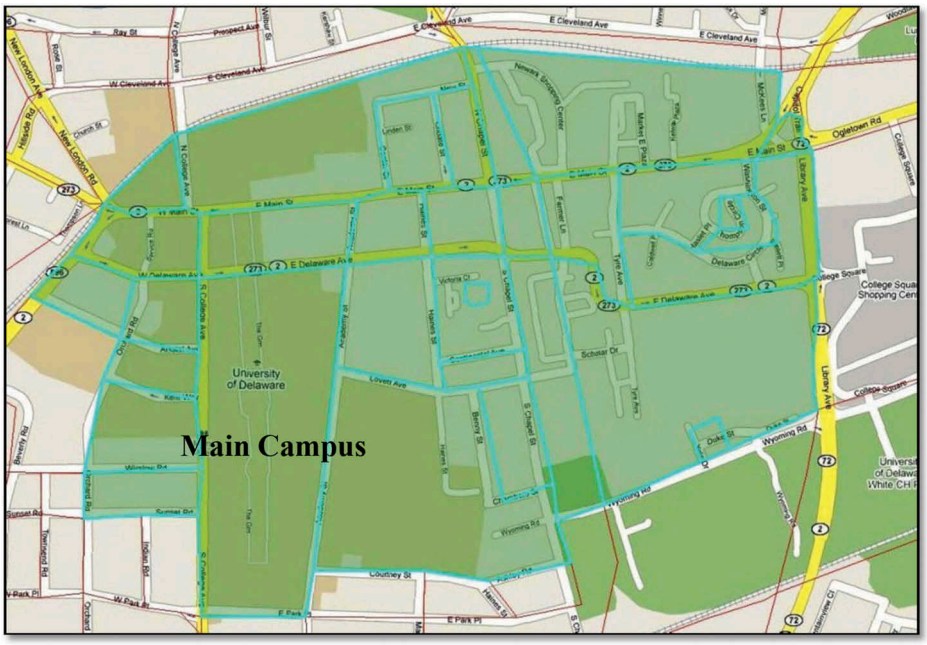
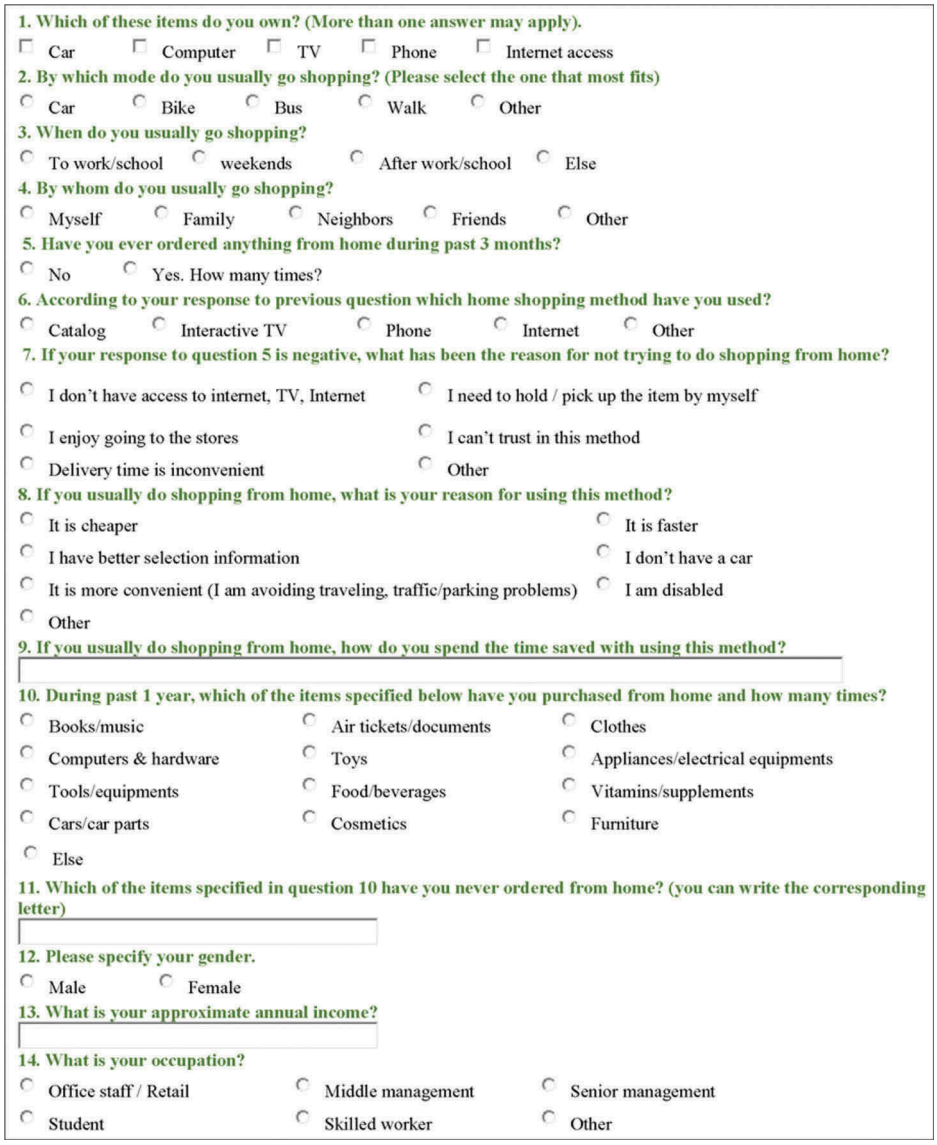


Figure 1. Survey area.



1. Which of these items do you own? (More than one answer may apply).
☐ Car ☐ Computer ☐ TV ☐ Phone ☐ Internet access
2. By which mode do you usually go shopping? (Please select the one that most fits)
○ Car ○ Bike ○ Bus ○ Walk ○ Other
3. When do you usually go shopping?
○ To work/school ○ weekends ○ After work/school ○ Else
4. By whom do you usually go shopping?
○ Myself ○ Family ○ Neighbors ○ Friends ○ Other
5. Have you ever ordered anything from home during past 3 months?
○ No ○ Yes. How many times?
6. According to your response to previous question which home shopping method have you used?
○ Catalog ○ Interactive TV ○ Phone ○ Internet ○ Other
7. If your response to question 5 is negative, what has been the reason for not trying to do shopping from home?
○ I don't have access to internet, TV, Internet ○ I need to hold / pick up the item by myself
○ I enjoy going to the stores ○ I can't trust in this method
○ Delivery time is inconvenient ○ Other
8. If you usually do shopping from home, what is your reason for using this method?
○ It is cheaper ○ It is faster
○ I have better selection information ○ I don't have a car
○ It is more convenient (I am avoiding traveling, traffic/parking problems) ○ I am disabled
○ Other
9. If you usually do shopping from home, how do you spend the time saved with using this method?
10. During past 1 year, which of the items specified below have you purchased from home and how many times?
○ Books/music ○ Air tickets/documents ○ Clothes
○ Computers & hardware ○ Toys ○ Appliances/electrical equipments
○ Tools/equipments ○ Food/beverages ○ Vitamins/supplements
○ Cars/car parts ○ Cosmetics ○ Furniture
○ Else
11. Which of the items specified in question 10 have you never ordered from home? (you can write the corresponding letter)
12. Please specify your gender.
○ Male ○ Female
13. What is your approximate annual income?
14. What is your occupation?
○ Office staff / Retail ○ Middle management ○ Senior management
○ Student ○ Skilled worker ○ Other

Figure 2. Survey questionnaire for home shopping.

confidence level of 90%, and confidence interval of 10%, the calculated sample size was 65. The survey was distributed during the fall semester. Participation in the survey was voluntary and anonymous. In 2001 study, 100 survey questionnaires were distributed whereas 70 responses were returned. In the new study, out of 140 distributed surveys, 103 responses were obtained.

5. The study network

Downtown Newark area which is presented in Figure 3 was the study network. The selected network consists of six signalized intersections and two intersections controlled with stop signs. The selected street network included Main Street, Delaware Avenue, South College Avenue, Academy Street, Haines Street, and South Chapel Street. All signalized intersections were controlled by the pre-timed signals. The only two unsignalized intersections within the network were those where Haines Street intersects with Delaware Avenue and Main Street. Main Street and Delaware Avenue are the only one way streets in the network. Main Street carries the traffic toward west, and experiences a lot of pedestrian traffic, several traffic lights, several bus stops and on-street parking on both sides. Delaware Avenue carries the traffic toward east and faces less congestion because there is no side parking and no stores on the street. Both Main Street and Delaware Avenue are part of the State Routes 2 and 273 (SR 2 and SR 273) and probably the busiest arterials in the downtown Newark.

6. Overview of the 2001 study

Through the mentioned methodology, researchers at the University of Delaware determined the number of delivery trucks added to traffic volume due to home shopping. For the sensitivity analysis purpose, they also assumed different growth rates for the percentage of home shoppers and for the amount

Figure 3. Downtown Newark network.

of goods purchased per person per year in order to make a number of scenarios to project the condition in 2005 and 2010. In fact, each of the scenarios was developed for two different time periods in the years 2005 and 2010. Scenario number one (Scenario I) assumed that the percentage of home shoppers stayed the same as in the base scenario, while average number of purchases per customer increased 60%. The second scenario (Scenario II) assumed that the percentage of home shoppers increased 30% while the average number of purchases per year stayed the same. The third scenario assumed a 50% increase in the number of buyers and a 30% increase in the average number of purchased products per year per customer. With the procedure described, each scenario was summarized in the form of the number of required delivery trucks per day.

The 2001 study evaluated traffic impacts of delivery trucks through four MOEs which were travel time (sec/vehicle), delay (sec/vehicle), average speed (mph) and vehicle emission. It was concluded that travel time, delay, greenhouse gases, and other typical air pollutants increase in the values following the increase in the number of the trucks for different scenarios, while average speed decreases. However, these changes were not uniformly distributed among different streets in the network. The one which showed to be the least affected by changes in truck percentages was surprisingly Main Street, the busiest street in the network. One of the explanations could be that the synchronized traffic signals that are operating along this arterial are providing an efficient movement of traffic even when the volumes and the heavy vehicle percentages significantly increase. This might be confirmed with a longer travel time and delay as experienced on the side streets, South College Avenue northbound (NB), South Chapel Street, Haines Street, and especially Academy Street (NB).

7. Comparative results

The evaluation process was divided into several stages. Some of them referred to the methodology and the provisioning of input data for simulation and others referred to the results obtained through simulation.

7.1. Home-shopping projections

In the 2001 study, three home-shopping projections were made in terms of the percentage of buyers and the average number of items purchased per year per customer based on the survey results. Those projections resulted in different numbers of purchase per person per product category. Another survey was performed to evaluate those projections. Table 1 presents comparative results of previous study with the current condition. It will also be noted, by comparing the values, that the home-shopping growth in the area has been lower than the previous projections.

The last column of (Table 1) shows the growth rate since 2001. Variation of the growth rate for different product categories is remarkable, which means the home-shopping behavior of the survey respondent group has been very different from the survey respondents in 2001. The last number in the column shows that the total home shopping has experienced 14.8% growth in Newark Delaware. The 2001 study considered three scenarios for home-shopping growth rate (for sensitivity analysis), which were 30%, 60% and

Table 1. Comparative results of number of purchased items per person per year for each product category.

Product category	Number of purchased items per product per person per year					Change since 2001
	Scenario Base 2001	Scenario I (2005 and 2010)	Scenario II (2005 and 2010)	Scenario III (2005 and 2010)	Recent Survey	
Books/CD/DVD	1.8	2.9	2.4	3.6	2.2	20.4%
Air tickets/documents	1.0	1.6	1.3	2.0	0.8	−21.4%
Clothes	1.3	2.1	1.7	2.6	1.2	−12.5%
Computers and hardware	0.5	0.8	0.7	1.0	0.6	10.2%
Appliances/electrical equipment	0.6	1.0	0.8	1.2	0.4	−28.4%
Tools/equipment	0.8	1.3	1.1	1.6	0.2	−72.0%
Toys	0.2	0.3	0.3	0.4	0.2	17.4%
Food/beverage	0.1	0.2	0.1	0.2	1.3	1194.8%
Vitamins/ supplements	0.1	0.2	0.1	0.2	0.2	71.8%
Cars/car parts	0.1	0.1	0.1	0.1	0.3	363.5%
Furniture	0.0	0.0	0.0	0.0	0.2	N/A
Cosmetics	0.1	0.1	0.1	0.1	0.1	41.5%
Total	6.7	10.7	8.7	13.0	7.7	14.8%

95%. The actual growth rate shows that those projections have been very optimistic.

7.2. Number of required delivery trucks

The calculated number of delivery trucks in the 2001 study for Scenario Base 2001 was 16. This figure was 1.3% of the total traffic volume at that year. That study assumed this ratio stays the same in the future projections. In the current study, it was proved that the delivery trucks are still 1.3% of the traffic volume although there is a small difference between the projected number of trucks for scenario Base 2005 and Base 2010. Table 2 shows the number of delivery trucks for different condition. The required number of trucks is very close to scenarios Base 2005 and Base 2010. This is mainly because home-shopping growth rate has been very low in the region.

7.3. Network MOEs

Table 3 represents the simulation results of the scenario Base 2008 in comparison with the projections provided in the 2001 study for the three main MOEs which are travel time and delay.

Main Street and Delaware Avenue play an important role in downtown Newark. These two one way streets are almost the only choices for the drivers who want to cross the downtown from east to west and vice versa. The simulation results show that the traffic MOEs of Main Street are worse than what was projected in the previous study. As shown in Table 3, the worst-case scenario which was supposed to be Scenario Base 2010 projected 118.5 seconds travel time whereas in the 2008 condition this figure was 138.1 seconds. This is almost 17% more than the worst projection. This phenomenon is basically because of the increase in Delay.

For Delaware Avenue, the 2008 travel time and delay is very close to Scenario III 2005. The 2001 study projected 95% increase in home shopping for Scenario III whereas it proved to be almost 15% increase for 2008 situation. Therefore, it could not be concluded that Scenario III is the dominant case. Overall, for both Main Street and Delaware Avenue, we see remarkable worsening trends of delay and travel time compared to 2001 condition. This is mainly because of the growing traffic volume. For South College Avenue (NB), travel time is the same as Scenario III 2010 but Delay has increased. Besides, the ratio of delay to travel time is 86%. For South College Avenue Southbound (SB), travel time and delay have decreased to less than 50% of 2001 condition. The only explanation could be the discrepancy between input data for the 2008 study and the 2001 study. The only similarity is that in both set of results, the ratio of delay to travel time is approximately 50%.

For Academy Street, we see a considerable reduction in travel time and delay in both directions. Surprisingly, these two measures are even less than 2001 condition. One possible explanation is that the simulation settings in the 2008 study have been different from those of the previous study. Apart from this odd trend, analyzing the values of the two MOEs in the both directions of the Academy Street shows that the ratio of delay to travel time for the northbound has decreased whereas for the southbound an increase in the mentioned ratio is observed. This means that for northbound the traffic is flowing and drivers see less congestion, but for southbound it is vice versa.

Table 2. Projections for required number of delivery trucks.

Scenario	Required number of delivery trucks
Scenario Base 2005	17
Scenario I 2005	29
Scenario II 2005	26
Scenario III 2005	32
Scenario Base 2010	17
Scenario I 2010	30
Scenario II 2010	27
Scenario III 2010	34
Scenario Base 2008	18

Table 3. Comparative simulation results of scenario base 2008 with the projections provided in the 2001 study.

MOE	Scenario	Main St.	Delaware Ave.	South College Ave. NB	South College Ave. SB	Academy St. NB	Academy St. SB	South Chapel St. NB	South Chapel St. SB
Travel time (sec/vehicle)	Base 2001	101.0	129.8	128.7	93.8	141.3	62.2	84.7	86.2
	Base 2005	109.5	133.8	131.2	93.3	140.9	64.1	84.2	89.1
	Base 2010	118.5	155.3	143.2	94.9	198.7	71.6	103.3	94.9
	Scenario I 2005	110.9	142.9	132.8	91.8	164.0	70.1	88.2	89.9
	Scenario II 2005	112.6	142.1	130.7	89.9	189.0	88.2	87.1	90.9
	Scenario III 2005	112.7	228.9	142.4	100.3	191.1	73.7	85.2	89.7
	Scenario I 2010	118.2	191.8	148.3	93.8	199.4	76.6	97.7	96.5
	Scenario II 2010	114.1	159.3	145.9	93.4	187.0	69.6	92.9	92.8
	Scenario III 2010	113.0	264.9	161.1	105.9	245.0	75.6	104.9	96.0
	Base 2008	138.1	223.5	160.5	42.2	124.0	48.7	140.4	175.3
Delay time (sec/vehicle)	Base 2001	35.2	47.9	79.9	45.0	104.2	24.9	36.4	37.9
	Base 2005	43.9	51.9	82.4	45.0	103.7	24.8	36.0	40.1
	Base 2010	52.6	73.4	94.3	46.2	161.5	34.5	55.0	46.5
	Scenario I 2005	45.2	61.0	84.1	43.1	126.9	32.9	39.3	41.6
	Scenario II 2005	46.9	60.2	82.0	40.9	151.7	51.5	38.3	42.5
	Scenario III 2005	47.0	146.2	93.5	51.4	154.0	36.6	36.9	41.4
	Scenario I 2010	52.5	109.0	99.6	44.9	162.2	39.5	49.5	48.0
	Scenario II 2010	48.4	77.4	97.0	44.6	149.9	32.5	44.6	44.4
	Scenario III 2010	47.2	183	112.3	57.0	207.8	38.4	56.6	47.6
	Base 2008	80.1	144	138.5	20.5	75.8	27.6	94.0	136.6

For South Chapel Street, the condition is completely different. A considerable increase is observed in travel time and delay for both directions. In addition, for both directions the ratio of delay to travel time has increased, which means this street is facing more congestion than what was expected. Another reason is the traffic distribution pattern in the network. For the drivers Chapel Street is possibly the best choice to cross downtown Newark from north to south. Otherwise, drivers have to go to Main Street and pass through Academy Street or South College Avenue which implies facing congestion on those two streets. For crossing the downtown in the reverse direction, Delaware Avenue and Chapel Street is the shortest path with least traffic lights comparing to other alternatives such as Library Avenue or New London Road.

As a result, one can find that none of the projections provided in the 2001 study, was the dominant case through the evaluation that was done. In many cases, travel time and delay for the streets were considerably more than even the worst-case projection. Especially, for the Main Street, Delaware Avenue and South Chapel Street this phenomenon was more obvious.

Greenhouse gases and other typical air pollutants are presented in Table 4 and simulation results of the new projections for 2013 and 2018 are presented in Figure 4. The trend for greenhouse gases and other typical air pollutants is also similar to travel time and delay, which is a continuous ascending trend. In some cases such as South College Avenue, even this figure increases to double or triple its initial value in 2008.

8. Summary and conclusions

This paper presented the results of two consecutive studies since 2001. In these two studies, a method was developed to identify the home-shopping impact on the selected transportation network. The method included performing survey questionnaire and gathering information on consumers shopping preferences, quantities of purchased goods and simulation of delivery truck volumes. The main idea was to identify survey responses on home-shopping preferences and express them in number of delivery trucks required for their distribution. The motivation to study this issue came from the recognition that recent growth of home shopping, induced mainly by Internet and communication technologies, has started to change travel patterns and to put additional demand on congested transportation facilities. Therefore, an efficient transportation system is a vital factor for efficient distribution of purchased goods. Several studies as mentioned in section four of this paper have investigated different sides of this problem.

The 2001 study projected the home-shopping effects on the transportation network of Newark, Delaware. That study used the information gathered through survey questionnaire to determine truck demand for delivery of goods purchased from home. The survey responses on type and frequency of purchased goods were expressed in daily volumes and divided by average truck carrying capacity to calculate the exact number of delivery trucks. The second step in the study involved building the Newark roadway network where impact of home-shopping delivery trucks was studied through CORSIM simulation. The simulation included a base scenario where the 2001 condition were simulated, and three other scenarios describing projected home-shopping growth. Simulation results showed what kind of impact home shopping would have on Newark transportation network in 2005 and 2010 if those scenarios realize. Simulation results showed that home shopping will put additional burden on Newark

Table 4. Simulation results of greenhouse gases and other typical air pollutants.

Scenario	Pollutant (Kg/hr)	Main St.	Del. Ave.	South College Ave. NB	South College Ave. SB	Academy St. NB	Academy St. SB	South Chapel St. NB	South Chapel St. SB
Base 2001	CO	3.4835	3.4835	1.1612	1.5020	1.6002	1.3403	2.3512	2.0566
	VOC	0.3601	0.3601	0.1200	0.1553	0.1654	0.1386	0.2431	0.2126
	NOx	0.2795	0.2795	0.0932	0.1205	0.1284	0.1075	0.1887	0.1650
	PM_{10}	0.0014	0.0014	0.0005	0.0006	0.0007	0.0006	0.0010	0.0009
	$PM_{2.5}$	0.0013	0.0013	0.0004	0.0006	0.0006	0.0005	0.0009	0.0008
	CO_2*	151.0805	151.0805	50.3602	65.1425	69.4018	58.1272	101.9731	89.1951
	CH_4*	0.0130	0.0130	0.0043	0.0056	0.0060	0.0050	0.0088	0.0077
	N_2O*	0.013431	0.013431	0.004477	0.005791	0.00617	0.005168	0.009065	0.007929
Base 2008	CO	5.4300	5.6100	1.4300	1.1000	0.4000	0.2000	1.0200	1.2500
	VOC	0.5613	0.5800	0.1478	0.1137	0.0414	0.0207	0.1054	0.1292
	NOx	0.4357	0.4501	0.1147	0.0883	0.0321	0.0160	0.0818	0.1003
	PM_{10}	0.0022	0.0023	0.0006	0.0005	0.0002	0.0001	0.0004	0.0005
	$PM_{2.5}$	0.0021	0.0021	0.0005	0.0004	0.0002	0.0001	0.0004	0.0005
	CO_2*	235.4987	243.3053	62.0190	47.7069	17.3480	8.6740	44.2373	54.2124
	CH_4*	0.0203	0.0209	0.0053	0.0041	0.0015	0.0007	0.0038	0.0047
	N_2O*	0.020936	0.02163	0.005513	0.004241	0.001542	0.000771	0.003933	0.004819
Base 2010	CO	3.9919	3.9688	1.2421	1.6464	2.1664	1.4038	2.2184	2.0913
	VOC	0.4127	0.4103	0.1284	0.1702	0.2240	0.1451	0.2293	0.2162
	NOx	0.3203	0.3184	0.0997	0.1321	0.1738	0.1126	0.1780	0.1678
	PM_{10}	0.0017	0.0016	0.0005	0.0007	0.0009	0.0006	0.0009	0.0009
	$PM_{2.5}$	0.0015	0.0015	0.0005	0.0006	0.0008	0.0005	0.0008	0.0008
	CO_2*	173.1287	172.1265	53.8678	71.4062	93.9555	60.8832	96.2105	90.6984
	CH_4*	0.0149	0.0148	0.0046	0.0061	0.0081	0.0052	0.0083	0.0078
	N_2O*	0.015391	0.015302	0.004789	0.006348	0.008353	0.005413	0.008553	0.008063

*Greenhouse gases.

transportation network, as identified through four MOEs which were travel time, delay, Average Speed, greenhouse gases and other typical air pollutants.

The first objective of the new study was to evaluate the projections provided in the 2001 study. For this purpose, similar to the 2001 study, a survey questionnaire was prepared to identify the shopping habits of the residents in the study area and provide a rough estimation of the home-shopping amount within a year in the study area. The new survey was tried to follow the same theme as the previous survey. Furthermore, the results were used to make a Synchro model to evaluate the projections which were provided in the previous study.

The following is the summary of conclusions regarding the survey findings and simulation outputs.

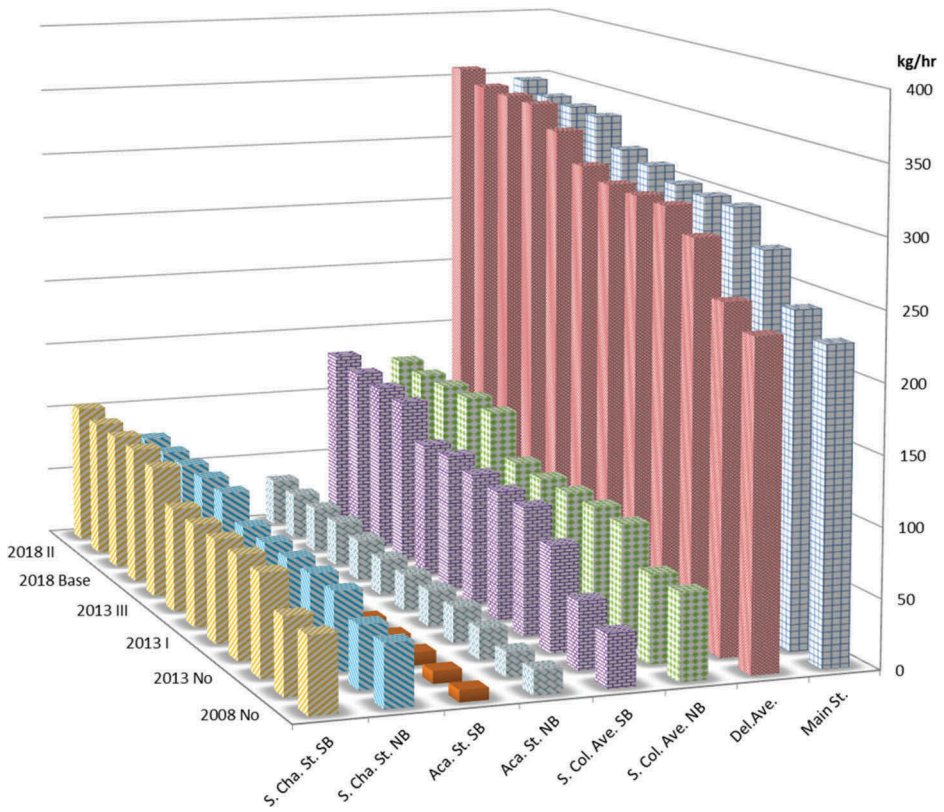


Figure 4. Simulation results of greenhouse gases and other typical air pollutants from road-based transportation.

(1) A 14.8% growth since 2001 had occurred in the average number of purchased goods through home shopping per product category per person per year has experienced.
(2) The calculated number of trucks needed for delivery purposes is very close to scenarios Base 2005 and Base 2010 in the previous study.
(3) None of the scenarios provided in the previous study in the 2001 study, were proved to be the dominant case for current condition.
(4) Although the growth in home shopping has been significantly less than what was projected in the scenarios I, II and III, the MOEs for 2008 condition were even worse than the worst-case scenario projected for 2010.

Finally, two recommendations are provided for further study.

(5) Study of the values that people place on the time spent in traffic versus value of the store shopping experience are considered essential for studying the problem and for making reliable projections of home-shopping impact on transportation network.
(6) Another suggestion for future studies is to include the economic trends effects on home shopping in the projections.

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