THE ROLE OF INTELLIGENT TRANSPORTATION SYSTEMS IN REDUCING THE IMPACT OF TRAFFIC POLLUTION ON THE ENVIRONMENT AND HEALTH

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Abstract
This paper assesses the importance of the environment related issues that are the product of traffic related pollution and suggests the use of intelligent transportation systems to provide real time information about air pollution. The study indicates strong public support for information systems on air pollution provided via GPS and the internet. Installation of Traffic Information Boards on roads (having high level of air pollution) was the second most popular issue that was supported by most individuals. However, their willingness to pay for air pollution information was shown to be quite low. Another important finding that was observed during the survey analysis was that respondents from cities with higher levels of air pollution such as Peshawar (Pakistan) and Toronto (Canada) responded more positively towards steps that can be taken to avoid air pollution as compared to relatively clean cities like Calgary (Canada) and Manchester (U.K.).

1. Introduction

Road transportation is widely recognised as a significant source of air pollution world wide. The problem of air pollution has drastically aggravated in the last few decades, especially the increase in vehicle traffic emissions of sulphur dioxide, carbon dioxide, carbon monoxide, nitrogen oxides, volatile organic carbons, particulate matter and other pollutants. Air pollution caused by these substances is the result of the combustion of sulphur-containing fossil fuels such as coal for domestic, vehicular and industrial purposes. The quality of the air is closely related to morbidity and mortality from respiratory and cardiovascular diseases.

The aim of this paper is to evaluate the role of Intelligent Transportation Systems (ITS) in providing real time information about air pollution to the public as well as evaluating public response through a questionnaire survey, for introducing such systems in our road transportation systems. The implication of this study will be the long-term environmental sustainability of our towns and cities. A wide range of technologies are available by the term ITS that have been tested and are successfully in use to address various traffic related issues. Second, this study will discuss how intelligent transportation systems could identify the location and intensity of air pollution and inform the public through various sources of communication, thus allowing those who are sensitive to air pollution as well as those who are cautious about their health and want to avoid the long term exposure effects of air pollution to avoid polluted roads. Third, the paper discusses how ITS in the longer term can persuade people to change their attitudes and lifestyles in order to achieve sustainability of our city transportation networks.

2. Pollution from road transportation

The widespread use of road transportation is recognized as a major contributor to the number of ailments to our environment in which air pollution is a major issue. Road transportation emissions are now the single largest source of urban air pollutants that constitute the following gases, chemicals and particulate matter.

2.1 *Particulate matter (PM)*

Airborne particulate matter refers to particles or droplets of various sizes, their physical characteristics and chemical compositions present in the air. Evidence has suggested that there is a link between PM2.5 and various respiratory and cardiac ailments. Most of the research on particulate matter is focused on the effects of PM2.5 and its cardiopulmonary impacts (Goldberg et al., 2001; Janssen et al., 2002; Magari et al., 2002). Based on known health effects, the World Health Organization (2005) has recommended an upper limit of PM2.5 as 10 μg/m3 annual mean and 25 μg/m3 24-hour mean**.** Similarly the range of PM10 is **20** μg/m3 annual mean, 50 μg/m3 24-hour mean. (PM 2.5: Particulate matter ≤2.5 micrometer; PM10: Particulate matter ≤10 micrometer)

2.2 *Carbon monoxide (CO)*

High concentrations of CO generally occur in areas with heavy traffic intensity and congestion. The toxic effects of carbon monoxide become evident in organs and tissues with high oxygen consumption such as the brain, the heart, exercising skeletal muscle and the developing fetus. Based on known health effects, the World Health Organization (2000) has recommend maximum exposure level of 100 mg/m3 (90 ppm) for 15 minutes, 60 mg/m3 (50 ppm) for 30 minutes, 30 mg/m3 (25 ppm) for 1 hour and 10 mg/m3 (10 ppm) for 8 hours.

2.3 *Volatile organic compounds (VOCs)*

There are more than 300 different kinds of VOCs that can be detected by chromatography. In urban regions, these aromatic VOCs are mainly released from traffic vehicles. Currently, traffic is a predominant source of ambient VOCs in many urban areas in industrialized countries. Among the various VOCs, benzene has been widely recognized as a human carcinogen and the others also possess high toxicity, especially to the central nervous system in humans. Therefore, this group of VOCs has received much attention in exposure assessment studies.

2.4 *Nitrogen dioxide (NO)*

Nitrogen dioxide, one of the main traffic-related air pollutants and precursors forming photochemical smog (together with VOCs) and ground-level ozone, is currently under intensive investigations. Short-term exposures to this irritant gas may cause airway and lung function injury. Long-term exposures may reduce immunity and lead to respiratory infections. Based on known health effects, the World

Health Organization (2005) has recommended an upper limit of 40 μg/m3 annual mean and 200 μg/m3 1-hour mean as the allowable limit.

2.5 *Ozone (O_3)*

Ozone is formed in the atmosphere by photochemical reactions in the presence of sunlight and precursor pollutants, such as the oxides of nitrogen (NOx) and volatile organic compounds (VOCs). Ozone is a strong oxidizing agent and health affects are the same as that of carbon monoxide. The World Health Organization (2005) has recommended an upper limit of 100 $\mu g/m^3$ 8-hour mean as the allowable limit.

2.6 *Polycyclic aromatic hydrocarbons (PAHs)*

PAHs are a group of environmental contaminants that are formed during the incomplete combustion of fossil fuels, or other organic substances like tobacco or food. There are more than 100 different PAHs. Complete details can be found in World Health Organization (2000).

3. The role of ITS

ITS strategies that can address the problem of air pollution on roads depend upon the specific area, ITS technology and local conditions. Various ITS technologies adopted are targeted to mitigate specific traffic related problems such as congestion, road calming, parking, speed control, vehicle stopping, smoother movement of traffic flow, shortest route and reduction of number of vehicles on roads that result in control of emissions on roads (Bell, 2006). In speed control traffic signals, signal control systems are optimized to minimize the traffic congestion and avoid unnecessary display of red signals on priority lanes, thus the intersection will operate at optimal efficiency, reducing congestion and emissions of roads (Bell, 2006).

ITS technologies can be adopted to divert single occupancy vehicles (SOV) drivers to ridesharing, biking, use of public transportation and other alternatives to decrease the number of vehicles on roads so that emissions can be reduced to some extent (Burbank, 1995). ITS can also be employed to make transit "smarter" and more efficient; expanding and improving ridesharing programs;

beefing up speed limit enforcement, especially for high-emitting trucks and buses; adopting traffic flow improvements that give preference to buses and other high-occupancy vehicles; and providing better information on transit, ridesharing, and bicycle/ pedestrian access to potential users. (Burbank, 1995). Remote sensing, ITS devices include roadside devices which can detect vehicles with higher emissions on roads. These vehicles may be penalized and referred to routine maintenance. It has been suggested by various studies that about 10 % of vehicles are responsible for 50 % of road emissions. So it is wise to detect such vehicles on roads for corrective measures with available ITS technologies (Burbank, 1995).

4. Previous work

The use of Variable Message Signs (VMS) to display real time air pollution on roads has not been previously studied before; however some previous work of similar nature that encompasses forecasting of air pollution for the control of traffic has been done. The "Environmental Forecasting for the Effective Control of Traffic (EFFECT) project was demonstrated in the cities of Leicester and Maid stone in the U.K, Gothenburg in Sweden and Volos in Greece. In this experiment, traffic queues that caused excessive pollution were relocated to an upstream junction that was close to a park where sufficient open space for the dispersion was available. The environmental performance was evaluated by direct measurement and by modeling. The predicted emissions and measured concentrations were compared between sites. The results showed that there was a greater measured decrease of carbon monoxide, of up to 5 grams/sec, at the closed site compared with the increase, of up to 1 gram/sec, at the open site, demonstrating the significant value of tactical control of queue location.

5. Survey Methodology

As data collection through questionnaire is one of the efficient ways to collect fixed-response questions about various features of a study, it can be administered to large numbers of participants simultaneously and they can be quantified and analyzed quickly especially with the use of computers. Therefore a questionnaire, with the guidance of Assistant Professor Dr. Alexandre de Barros was prepared, who identified the critical issues regarding the role of ITS in minimizing air pollution.

5.1 *Data Collection*

Data was collected through a questionnaire that asked participants about the key issues regarding the role of ITS in minimizing air pollution.

5.2 Participants

The criterion for the participation in the study was that the individual must be 18 years of age or older and hold a driver's licence. The questionnaire was sent to 130 drivers by email and 95 participants responded. 26 participants at the University of Calgary were also interviewed in person with the questionnaire completed on the spot.

The survey was conducted at the University of Calgary, Toronto (Canada), Manchester (U.K.) and Peshawar (Pakistan). The participants received emails with a cover letter from the author which stated the purpose of the survey and requested that the participants answer the questionnaire attached.

Respondents from Calgary consisted of 27 females (36%) with an age distribution as follows: under 20 years (14.8%), 20—29 (40.7%), 30—39 (7.4%) and 40—50 (37.0%). Thus, over half of the sample was comprised of drivers aged 29 years or younger. 48 males (64%) from Calgary participated with an age distribution as follows: under 20 years (20.8%), 20—29 (37.5%), 30—39 (27%), 40—50 (8.5%) and 50 and above (6.25%). Similarly, over half of the participants were drivers aged 29 years or younger and two third of the participants were males.

Respondents from Toronto consisted of 14 male participants with an age distribution as follows: 20—29 (35.7%), 30—39 (28.5%) and 40—50 (35.7%). Thus, over half of the sample was comprised of drivers aged 29 years or younger.

Participants from Manchester consisted of 11 males and 1 female. The age distribution of males is as follows: 20—29 (41.6%) and 30—39 (58.4%).

Respondents from Peshawar consisted of 8 females (40%) with an age distribution as follows: under 20 years (25%), 20—29 (50%) and 30—39 (25%). Thus, three quarter of the sample comprised of drivers aged 29 years or younger. Males from Calgary consisted of 12 (60%) with an age distribution as follows: under 20 years (33.3%), 20—29 (41.6%), 30—39 (15%) and 40—50 (10%). Similarly over two third of the sample comprised of drivers aged 29 years or younger.

6. Findings and results

This survey examined six ITS specific questions.

6.1 *Attitudes towards installation of Traffic Information Boards (Question 1):*

In question 1, the participants were asked whether "Installation of Traffic Information Boards" were useful. The responses from four different cities were different but over all approval of the question was over 64% (Calgary 53%, Toronto 86%, Manchester 58% and Peshawar 90%). (Participants that definitely and probably agreed are shown Figure 1). However those who disapproved (≤26%) outnumbered the neutral (≤10%) in response. (Figure 1)

6.2 *Attitudes towards rerouting of trip in the presence of higher air pollution on a road (Question 2):*

In response to question 2, the participants were asked "Will you reroute your trip on available alternative route if *Traffic Information Board* displays higher level of air pollution".

The responses from different cities were different. Respondents from Peshawar (60%) favored to reroute their trip in the presence of high level of air pollution. From Toronto (36%) favored to reroute their trip in the presence of high level of air pollution. From Manchester no one was willing to reroute their trip.

Participants from Calgary and Manchester who definitely and probably disagreed (Calgary 44%, Manchester 0%), out numbered participants who definitely and probably agreed (Calgary 31%, Manchester 0%). However participants from Toronto and Peshawar that definitely and probably agreed (Toronto 36%, Peshawar 60%) outnumbered participants who definitely and probably disagreed (Toronto 29%, Peshawar 0%). The neutral were (≤29%). Though 64% participants agreed to installation of pollution information boards but only 32% (half of them) expressed to reroute their trip.

32% looks a small number but previous studies suggest that above 10% of rerouting of on alternate routes in fact causes an increase in total travel time. So 32% is quite high percentage for rerouting. (Figure 2).

6.3 *Attitudes towards availability of air pollution information on GPS (Question 3):*

In question 3, the participants were asked “Would you like the information to be available on onboard vehicular GPS display and internet”. Participants from the four cities (Calgary 60%, Toronto 93%, Manchester 83% and Peshawar 80%) all responded in favour of air pollution information on GPS and internet. (Figure 3)

6.4 *Attitudes towards availability of pollution information on payment (Question 4):*

In question 4, the participants were asked “Will you be willing to pay, if the information regarding pollution hazard on roads is available on payment only”. Participants from the four cities (Calgary 12%, Toronto 0%, Manchester 17% and Peshawar 30%) strongly opposed the idea of paying for air pollution information. (Figure 4)

6.5 *Attitudes towards selecting a route with lower air pollution at the cost of fuel and time (Question 5):*

In question 5, the participants were asked “If the alternate route is longer than the one with pollution hazard; will you be willing to sacrifice some time and fuel to avoid pollution”. Respondents from different cities (that definitely and probably agreed; mean: 27%) were less than the respondents (that definitely and probably disagreed; mean: 36%).

This question is similar to the question of rerouting but in this case they will have to pay extra and spend some mere time as this route will be longer than the one with higher level of air pollution. Still 28% vehicles rerouting is a very high percentage in the context of previous studies as discussed earlier. (Figure 5)

6.6 *Perception towards “pollution information through ITS in minimizing air pollution”*

In response to question 7, the participants from Peshawar and Manchester (Peshawar 70% and Manchester 67%) were more optimistic (Participants the definitely and probably agreed) than Toronto and Calgary (Toronto 43% and Calgary 28%). (Figure 6)

7. Conclusions

This study provides useful insights for transportation professionals and policy makers. The overall levels of support indicate fairly strong public support for some ITS options, particularly provisions of Traffic Information Boards on roads with high level of air pollution.

Pollution information on GPS devices and on the internet were supported by a majority of respondents from different cities. The second most popular issue that was supported by most the individuals was the installation of "Traffic Information Boards" along the roadside. This option was supported by 64% of respondents..

The option that was not supported well was their willingness to pay for air pollution information (only 14% supported). The level of support was equal between males and females.

Males and females reacted differently to a number of, though not all of the options surveyed. When there was a difference in responses by sex, males were more supportive of various options in the survey except question 1.

Males have higher support for information availability on GPS devices and for rerouting due to air pollution. These reflect their sensitiveness and more exposure to air pollution on roads. Some issues were equally supported by males and females such as willingness to pay for pollution information, importance of ITS in minimizing air pollution and avoiding road with higher pollution.

Another important finding, during this survey/study, was that respondents from cities with higher level of air pollution such as Peshawar (Pakistan) and Toronto (Canada) responded more positively towards steps that can be taken to avoid air pollution as compared to clean cities such as Calgary (Canada) and Manchester (U.K.). This finding suggests that policy makers should pursue the preemptive measures to avoid air pollution on roads instead of waiting for worse air pollution scenarios. (Like Peshawar or Toronto).

8. **Directions for future research**

The results of the research suggest several questions to be explored in future studies. The author suggest additional research on how people sensitive to air pollution react to this idea of ITS. In addition, author suggest that pilot scale installation of Traffic Information Boards before the entry of a road (with higher level of air pollution) and thereby examining the behavior of the road users and using simulation model (for rerouting) to see the impact of such rerouting on other roads.

Figure 1

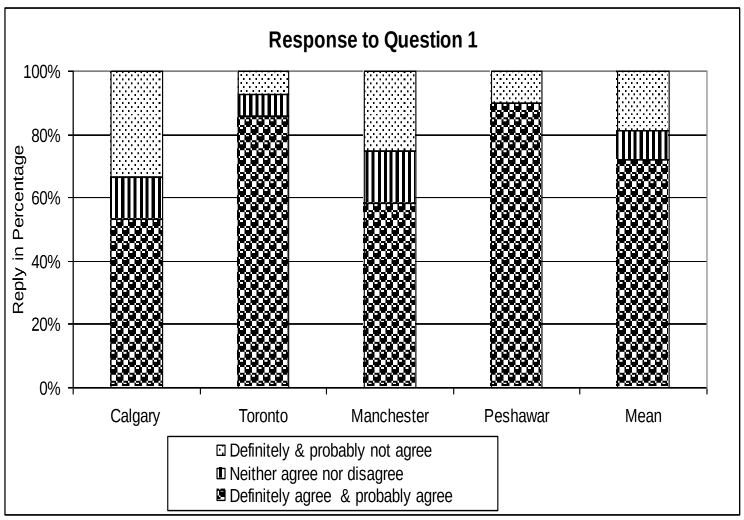

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Figure 2

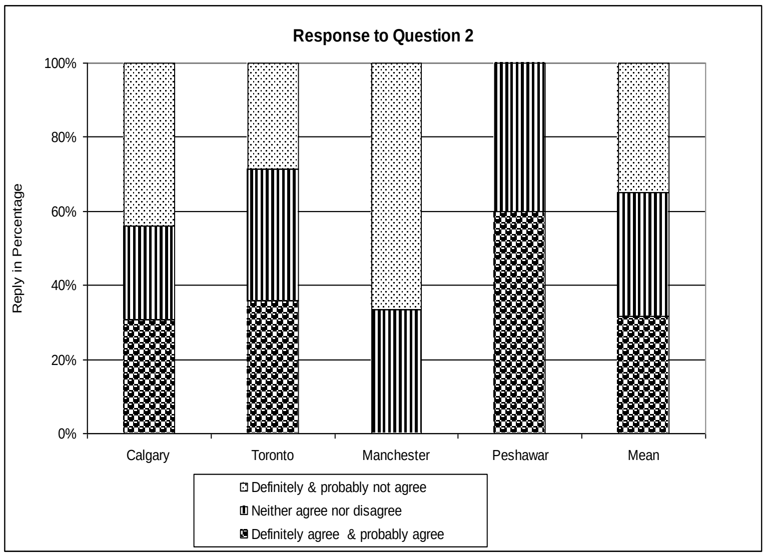

Figure 3

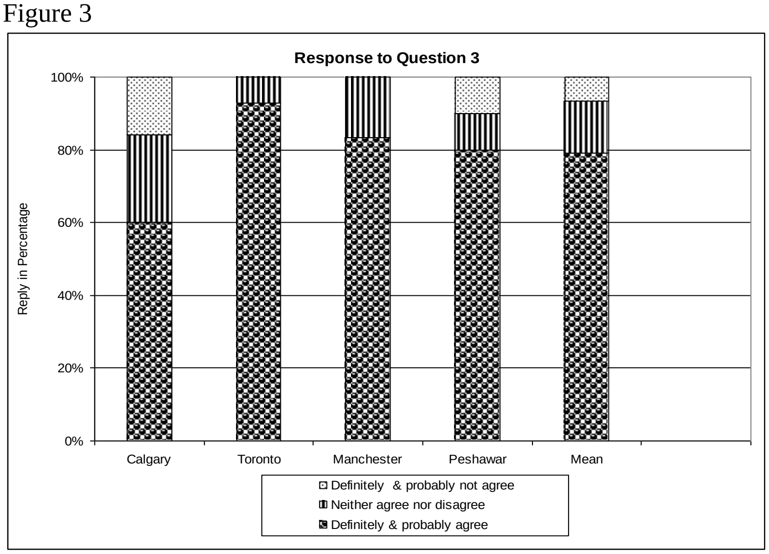

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Figure 4

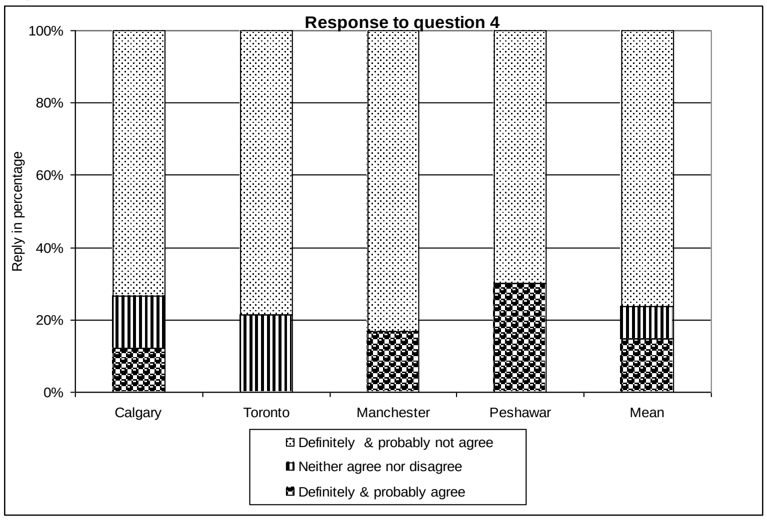


Figure 5

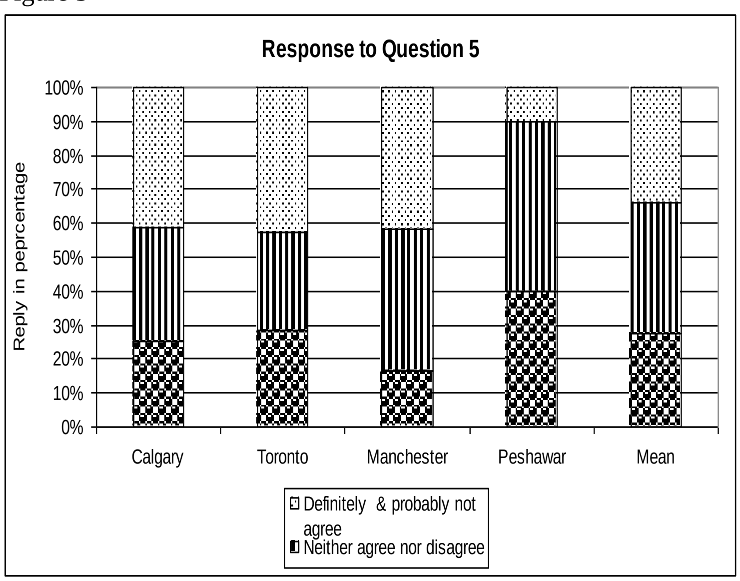


Figure 6

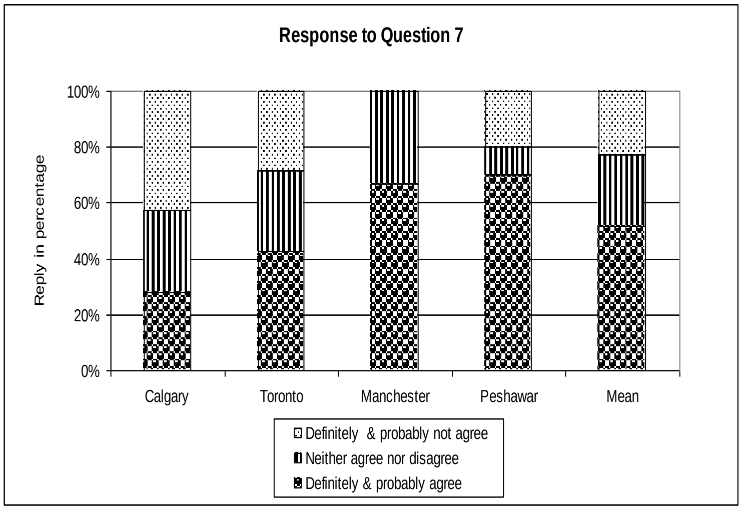
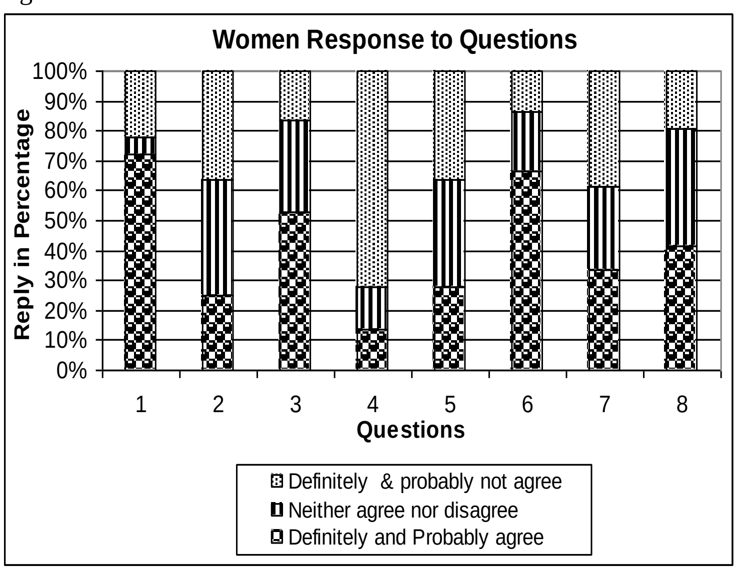


Figure 7



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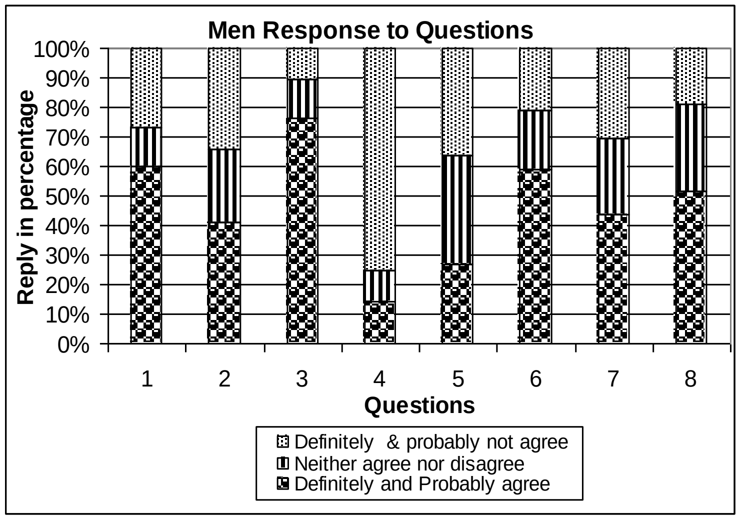

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