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Air Quality Based Informational Intervention Framework To Promote Healthy And Active School Travel

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Abstract

This paper presents a comprehensive framework that guides in setting up an effective intervention design to promote active school travel keeping in view the air quality. As lack of physical activities are observed in school going children all over the world so various programs have been launched to encourage active commuting among school going kids using different intervention strategies. So far no effort was found in which the pollutant exposure aspect is taken into account. The primary objective of this study is to develop a computational model that helps in detecting walking/cycling school routes at an individual level that enhance physical activity alongside lesser exposure to air pollutants. The computations involved in this process is dependent on a variety of data sets such as individual's school travel dairy, street level pollutant concentration data, public and active transport network data. The output generated gives exposure and physical activity involved in the current and suggested school routes. It is taken into consideration that the changes identified are healthy (having low exposure to pollutants) and encourage active school travel. These changes can be considered as alternatives/suggestions to develop the customized information package that can be used as a behavioural intervention tool.

Keywords: Active school travel; air pollutant exposure; informational intervention framework; computational algorithm

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1. Introduction

The technological advancement in automobile and infrastructure sector encourages more and longer distance travel but at the same time the way people travel to perform their daily tasks effect environment a lot. As a result the transport sector is responsible for around 25 % of the total CO_2 emissions generated, which is 2nd highest in Europe [1]. Further increase in car use has a bad effect on human health in the form of sedentary behavior [2]. As a consequence physical inactivity is now identified as fourth leading risk factor for global mortality. Lack of physical activity has also been observed in the 11 to 12 years old children in Europe. Only 17.5 percent of Belgian adolescents met the recommended WHO physical activity levels for health [3]. The low rate of physical activity is linked with various health threats among children such as cardiovascular problems and bone health issues, metabolic syndrome, high blood pressure and obesity [4] . Statistics computed from OVG data gathered from Flanders region in Belgium shows that 6-12 and 13-17 years old children are spending around 3% and 7% of their daily time in walking and running respectively. However, this percentage is more than double i.e. 15% in individuals older than 45 years [5]. So there is a potential to boost the physical activity level of the children in Flanders.

Active school travel (AST: e.g. walking and cycling to/from school) has a great potential to contribute significantly to physical activity (PA) and health. Westman et al found that children who commute actively to school are in a more positive mood as compared to car and public transport users [6] . Despite significant personal benefits, AST has decreased considerably during the last few decades in many countries [7]. It is evident from the literature that human behaviour can be changed or managed by implementing variety of physical and technical interventions. Steg and Vlek defined informational strategies as an approach to change perceptions, motivations, knowledge and norms, without disturbing the external context in which decisions are made [8]. Information campaigns, use of social support and role models to influence the behavior of individuals can be categorized within this type of intervention approach. Sometimes informational strategies are used to complement the structural strategies (such as congestion charging, fare reduction, increased parking pricing, low emission zones etc.) for producing optimal results [9] .

In the past, various direct and indirect efforts have been made to encourage active commuting among school going kids using different intervention strategies. "Beat the street", "Ride2School Program", "School Travel Plan" (STP) "Safe Route to School" (SRTS), "Walking School Bus" and "Click Obesity Study" has been implemented as programs targeted to promote physical activity in UK, Australia, New Zealand, USA and China [10]. It is evident from the literature that interventions designed and implemented so far are based on strategies to educate, motivate, encourage and incentivize by providing general information about benefits in a general perspective and providing some training to have practical experience of biking and walking [10] . There is no such effort found in which information is provided considering the context of an individual. For example, strategies are not based on examining their details of travel behavior, so that focus should be on improving a specific part of their travel behavior. Such as providing guidance about safer and healthy routes to school by giving quantitative information about exposure on each route. However, a simulation study was carried out in which availability of the least polluted alternative walking routes was detected. It was found that 40 to 60 percent healthy route alternatives are available [11] . Based on this study it can be concluded that there is a significant potential available in terms of least exposed routes and it should be exploited. So there is room to promote active commuting to school by giving individual specific contextual guidance based on air quality.

Informational based interventions regarding individual mobility aspects are limited in the literature despite their advantages. Schultz mentioned that these interventions can influence change in the travel behaviour of individuals which are relatively easier and have high benefits [12]. For example; use of bicycle/walk for short trips, use of least exposed routes etc. Based on literature findings a distinct mechanism is proposed to identify possible potential in school commuting by walk or cycling at the individual level by considering various constraints such as route length, family engagement, bike lanes availability etc. This proposed mechanism presented in later sections is used in the development process of an informational intervention where individuals are provided information regarding their school travel behaviour in the following aspects.

- Exposure to air pollutants based on recording their school routes
- Exposure to air pollutants based on suggested walking/cycling school routes
- The extent to contribute in physical activity (based on suggested walking/cycling routes).

So the overall effectiveness of the intervention is primarily dependent on the developed model mentioned in the proposed mechanism. The primary objective of this study is to develop a comprehensive methodological framework that helps set up effective information based behavioural intervention to influence changes in the travel mode and route to school by providing customized information about the exposure and physical activity involved per trip. The remaining part of the paper proceeds as follows. In Section 2, we give a brief overview of the data requirement and their acquisition methods. In section 3, we illustrate the computational model to detect the potential improvement in current school travel behaviour. Section 4 provides the details regarding the structuring of a behavioural intervention in a comprehensive way. Section 5 provides the conclusion and next steps of the research.

2. Data requirement and their acquisition methods

The proposed model relies primarily on the algorithm which detects active school travel alternatives with least exposed routes. So this computational algorithm requires different type of datasets. On one hand it requires data from the children and their parents (or individuals that escorts children to school) regarding home to school routes, and on the other hand, it requires detailed pollutant concentrations at the street level where they are travelling. Additionally, it also requires other third party datasets such as information about the availability of public transport routes (their frequency, access and egress walking time) and bicycle/footpaths etc. Therefore, acquisition and handling of such a variety of dataset require the careful development of database and protocols under which these datasets are integrated to each other. Paragraphs below provides detail of acquisition of these datasets.

Individual school dairy information will be collected via smartphone application R2S that has been developed by Transportation Research Institute (IMOB) at Hasselt University. The main idea of using this application is to provide a user friendly digital platform where individuals can easily record their school route as shown in figure 1. The individual is asked about the origin (home) and destination (school) with mode used to perform that trip. Based on this input, most suitable route is automatically displayed on the GUI of google maps. Individuals can also adjust the route if required. This application was developed for the Route2school project. This project was launched to help schools and municipalities to analyze road safety on school routes thoroughly and to collect information about the travel behavior. Parents and teachers can report the mobility bottlenecks they encounter on their way to and from school by describing the problem, upload a photo and propose a solution. Experts analyze the problem and, together with the municipality, the police and the schools, look for a suitable solution. 575 schools of 51 municipalities and cities took part in this project but the information regarding exposure on school routes are not provided yet. So with the consent of the participants, we can use their home to school routes details recorded in the Route2school platform to meet the objectives as mentioned earlier.

In order to estimate exposure of an individual while performing school trip, high resolution pollutant concentration data/maps are required. We want to calculate exposure of an individual school trip and give him suggestions about routes where he/she will be exposed less. So for this purpose, we need refined pollutant concentration data from which each street pollutant concentration can be known. The higher the resolution of pollutant concentration, the more accurate will be the individual exposure at suggested routes. In this regard average annual NO_2 concentrations at a spatial resolution of 100 m^2 are obtained in the form of Heat maps from Flemish Institute of Technological Research (VITO). The map as shown in figure 2 is based on the interpolation of the results of the measurement stations in Flanders and the surrounding regions, supplemented by a high resolution modeling. RIO-IFDM-OSPM model is used in the estimation of NO_2 concentrations for the development of heat maps. Initially the land use regression model RIO is coupled with a bi-Gaussian dispersion model IFDM that is developed on the basis of meteorological data and the emission of air pollutants. Further to accommodate the effect of street canyons on air quality, OSPM model is integrated with RIO-IFDM model. The great advantage of the RIO-IFDM-OSPM combination is that air quality can be estimated with a high spatial resolution at street level. Based on the validation results of the model it can be concluded that the RIO-IFDM-OSPM combination is currently the best possible (calculation) tool for modeling the air quality down to street level [13]. So we have a fine quality NO2 pollutant concentrations for the estimation of individual school route exposure.

Public transport timetable and route information along with other relevant details can be obtained from General transit feed specification. This information can easily be integrated with the road network data to identify a public transport routes between an origin and destination together with other details such as waiting time, travel time and access/egress distance to check if it is appropriate to replace a car trip. Bicycling and walking route information is also essential for our study, and therefore, it is acquired from available route planner platforms such as Graph Hopper Directions API in which routes are optimized with the help of Google open street maps. Infrastructure details linked with each route such as gradient, number of intersections, availability of segregated path etc. can also be found using this API.

Activity travel routine of the parent/escorting individual also affects the school travel behaviour of children. Further household details also play a significant role in this regard. Such type of details is taken in the form of responses received from the questionnaire.

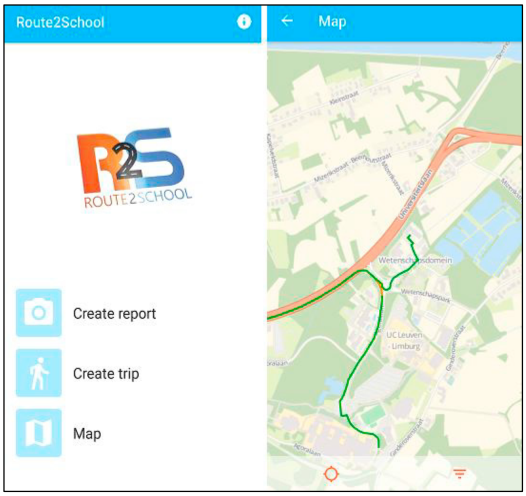

Fig. 1 : Route2School app User Interface

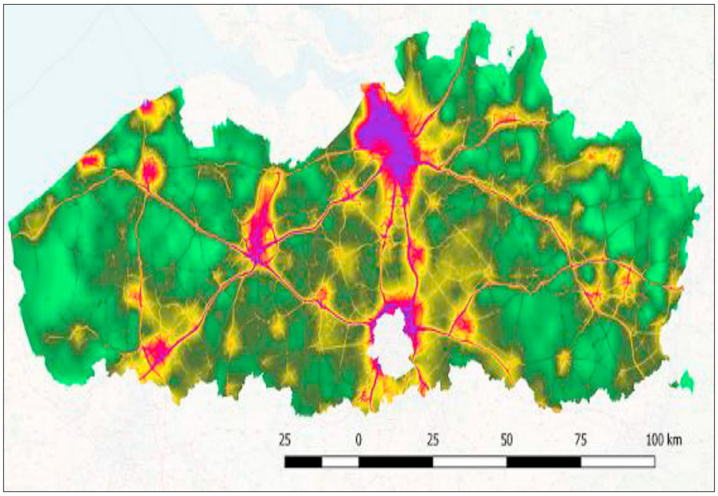

Fig. 2 : Heat map showing avg. annual NO_2 concentrations of Flanders

3. Computational Model Development

The model to detect the healthy and active school route alternatives relies on the data driven computational algorithm. This algorithm is developed keeping in view the contextual information and situational factors gathered from the literature and online data sources for school commuting. One cross sectional study conducted in Flanders concluded that maximum distance of 3 km from home to school should be considered for encouraging active school travel [14]. So in this regard the developed algorithm identifies such aspect of an individual school travel behavior that can be relatively easy to change. Therefore in algorithm development, the primitive step is the identification of threshold limits and constraints involved in the current and suggested route with travel mode [15]. These are described in the section below.

3.1. Rules- Travel mode and route

Rules were defined on the basis of the norms identified in the literature and some decent considerations about the situational factors [16,17]. Active mobility is often expressed by a walk, bike and public transport. For each of these travel modes with associated routes, we defined the rules as follows:

i. *Walk*:

- Trip is not part of a complex activity-travel tour, where parent/escorting individual is using a personal vehicle to travel for other activities within the same tour.
- Current and suggested route is maximum up to 1.5 km
- End time of activity at the origin or start time of the activity at the destination is flexible
- Weather conditions are reasonable (no heavy showers/ not very cold (i.e. less than 0 ^{o}C))
- Children (less than 3 years old) are not accompanying
- Footpaths are available all along the route
- Crossings in the footpath are limited to 3

ii. *Bicycle*:

- Trip is not part of a complex activity-travel tour, where parent/escorting individual is using a personal vehicle to travel for other activities within the same tour.
- Current and suggested route is maximum up to 3 km
- End time of activity at the origin or start time of the activity at the destination is flexible
- Weather conditions are reasonable (no heavy showers/ not very cold (i.e. less than 0 ^{o}C))
- Children (less than 3 years old) are not accompanying
- Segregated bike lanes are available all along the route
- Crossings in the bike route are limited to 3
- Route gradient is not more than 10%

iii. *Public Transport (Bus/Train/Tram):*

- Trip is not part of a complex activity-travel tour, where parent/escorting individual is using a personal vehicle to travel for other activities within the same tour.
- Current route is greater than 3 km
- Availability of public transport between the home and school.
- End time of activity at the origin and start time of the activity at the destination is flexible.
- Travel time difference between the used mode and public transport is no more than 30 minutes
- Access/Egress walk in total is maximum up to 1 km
- Waiting time is no longer than 10 minutes
- Number of transfer is limited to 1 only.
- Weather conditions are reasonable (no heavy showers/ not very cold (i.e. less than 0^{o}C)).
- Crossings in the walking path are limited to 3

3.2. Integration- Data and Rules

Based on the developed rules the integration of various datasets is done that can help in finding out potential changes in the activity-travel schedules of school going children. For this purpose, a script is written for the algorithm and the resulting output gives us the healthy and active school travel potential. It is taken into consideration that the changes identified are healthy (having low exposure to pollutants) and encourage active school travel. These changes can be considered as alternatives/suggestions to develop the customized information package that will be used as a Behavioral Intervention Tool. The overall model framework together with behavioural intervention design is shown in Figure 3.

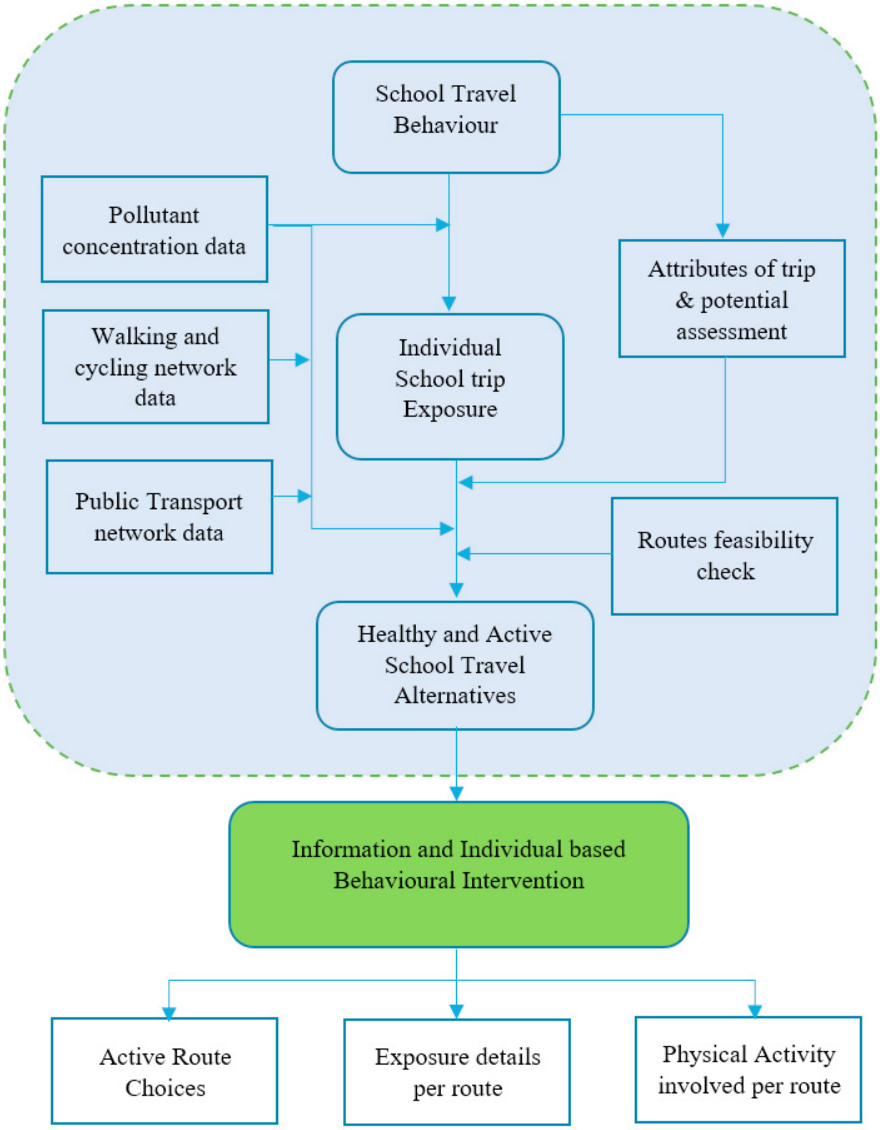

Fig. 3: Framework to assess Active school travel potential with Behavioural Intervention Design

The critical component in the integration phase is how data flows between different model components to get the desired output. It starts with the interaction of recorded home to school trajectories with average hourly pollutant concentration maps to get the exposure. Individual school trajectories are collected using smartphone application in the form of x,y pairs. Pollutant concentration maps contain values in micrograms per meter cube in 10 x 10 square meter zones. Unique pollutant concentration value is assigned to each x,y pairs by matching it to zones. Exposure of a trip is calculated by taking summation of the time one spends in different pollutant concentration ranges. The next step is to find the alternative cycling and walking routes if the distance from home to school is less than 3 km. These routes are determined as trajectories having x,y pairs using Graphhopper Direction API and screened based on the rules mentioned in section 3.1. The selected routes are analyzed concerning health indicators such as exposure and physical activity level and compared with the current route to optimize the route where maximum health benefits are achieved. If the distance from home to school is more than 3 km and current commuting is via car or bus then some dropping points are selected within a radius of 1.5 km. From this point child can walk to school. The procedure to optimize the route is the same as mentioned above. Integration phase ends up with multiple routes with mode alternatives at an individual level based on the current school commuting behaviour. The information therefore, can be compiled further to develop behavioural intervention tool.

4. Behavioural Intervention Design

Often hard and strategic interventions (such as road pricing, regulating car use) are required to guide individual actions as it is very challenging to change human behaviour such as travelling habits. It is evident for the literature that informational strategies when coupled with hard interventions give more desirable and optimal change in behaviour. In order to provide information various methods are discussed in detail and examined keeping in view their effectiveness [9]. The design of our information-based intervention is following the four methods suggested in the literature (i.e. Feedback, Justification, Cognitive dissonance, and Commitments) [18]. The customized information package will be prepared for every individual that is considered as a primary tool for information based behavioural intervention. The overall effectiveness of the informational based behavioral intervention considerably depends on how information is organized and presented. So the information regarding each aspect will be presented based on the following three fundamental elements

- Brief information to increase the awareness of participant regarding a particular aspect, which is easy to understand and digest.
- Feedback regarding a quantitative measure of their behavior on each aspect and description of its effect
- Some recommended suggestions on how to change travel behavior to decrease the effects along with its quantification. These suggestions are designed considering the ease in change for a particular participant based on certain rules as mentioned in section 3

The hypothetical scenarios of the current and suggested school route with exposure and physical activity indicator is depicted in fig. 4 and 5. Current school travel behaviour is represented by showing the regular school route with exposure on google street level map that is assumed to be performed by car. Exposure is expressed at the top in percentage of time one spent in different pollutant concentration levels while performing trip as represented by colour bandings. General information regarding exposure is provided at the start to increase the understanding of the problem. Suggested school route that can be performed either by foot or bike having the least exposure values are shown in fig. 5 with a physical activity indicator.

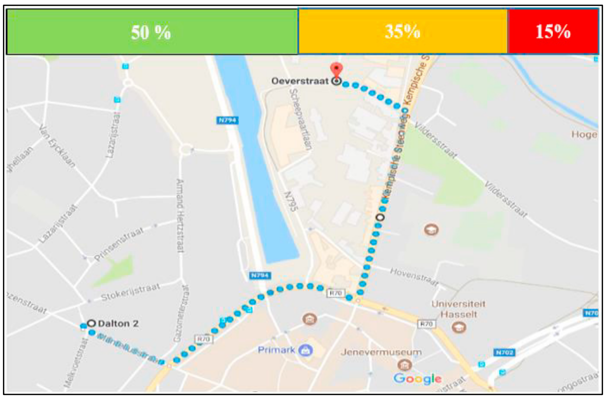

Fig. 4: Current School Route Details

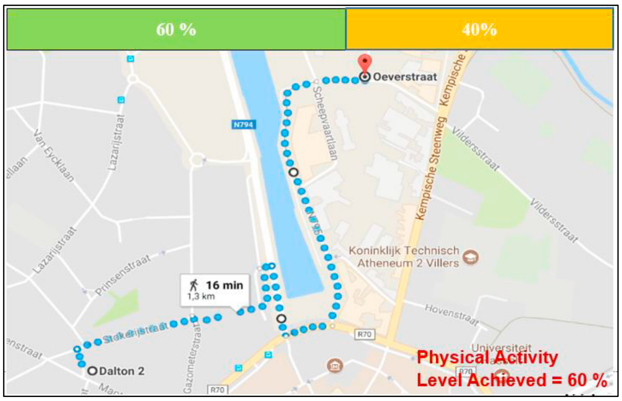

Fig. 5: Suggested School Route Details

5. Conclusion

In this paper, an attempt is made to develop a comprehensive framework for setting up an effective air quality based informational intervention that encourage healthy and active school travel behaviour. Information required to feed in the Customized Information Package, considered as a primary tool of intervention, is dependent on the developed algorithm. The developed algorithm can detect individual oriented active school travel potential keeping in view the health indicators such as pollutant exposure and physical activity level. This type of customize approach used in designing information intervention proves to be very efficacious where information presented to the subject clearly shows the health benefits associated with the suggested as compared to current school routes. Such type of interventions provides substantial help to change children and escorting individuals lifestyle that is more healthy for them and also for the environment. Further, the impact of air pollutants on children will be reduced when they have awareness about the selection of the healthiest routes with less air pollutant concentrations.

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