AN INTEGRATED ANALYSIS OF HEALTH EFFECTS AND RISKS OF TRANSPORT SYSTEMS

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Abstract: The main purpose of the HEARTS (Health Effects and Risk of Transport Systems) project was to develop and test an integrated impact assessment methodology to assess changes in exposure patterns and the related health effects due to different urban transport policies. Risks under consideration include: air pollution, noise and accidents. In order to develop an integrated approach a thorough review of different models relating to transport was undertaken, including in particular, models of road traffic, air pollution, noise, accidents, time-activity, exposure and health effects. Based on this review, existing models were selected for incorporation and use in HEARTS, and new (mainly micro-environmental) models developed where necessary. These models operate by assigning exposures to individuals or populations according to the proportion of their time spent in different micro-environments, each of which can be characterised by distributions of risk concentrations. The various models were linked through a Geographical Information System to provide an integrated assessment toolbox. In order to help develop the HEARTS methodology, field-test and validate the various tools, and demonstrate how the HEARTS approach might be used for policy assessment, three case studies were carried out in the cities of Leicester, Lille and Florence.

Key words: health effects, pollution, noise, accidents, exposure, GIS.

1. INTRODUCTION

Transport is an essential component of modern life, and brings with it the potential to improve and erode public health. Road traffic is a major cause of adverse health effects – ranking with smoking and diet as one of the most important health determinants in Europe. Traffic-related air pollution, noise, accidents and social impacts combine to generate a wide range of negative health consequences, including increased mortality, cardio-respiratory and stress-related diseases, cancer and physical injury. These affect not only transport users, but the population at large, with particular impact on the vulnerable groups such as children and the elderly, cyclists and pedestrians.

The main purpose of the HEARTS (Health Effects and Risk of Transport Systems) project was to develop and test an integrated impact assessment methodology to assess changes in exposure patterns and related health effects due to different urban transport policies. Risks under consideration include: air pollution, noise and accidents. Psychosocial effects, lack of physical activity and other risks associated with transport scenarios also play a role, but they were not considered primarily because of the need for further basic research to confirm these effects and the causative mechanisms involved. In order to inform the study, a thorough review of different models relating to transport was first undertaken. In particular models concerning traffic, air pollution, noise, accidents, time-activity, exposure, and health effects were reviewed. Based on this review, relevant models and methodologies were selected and brought together, and new models were developed where necessary. The various methods and models were then linked via a Geographical Information System (GIS). In order to help develop the models, field-test the methods and demonstrate use of the HEARTS approach, three case studies were carried out: in Leicester, Lille and Florence.

The HEARTS project aimed at achieving a better characterization of the health implications of road traffic and urban transport in Europe by developing and demonstrating an integrated approach to, and methodology for, risk assessment. Application of this approach would then help to reduce adverse consequences of transport on health in Europe by:

- more accurately specifying the health effects of urban transport;
- improving the ability to carry out integrated risk assessment to assess and compare different urban transport schemes and policies;
- deepening understanding of the geographic and social distribution of the different health risks of transport within urban areas, and developing related land-use policies specific to local conditions and to population groups across the European Union;
- better characterizing the subgroups most at risk for multiple health effects and better targeting public health and transport-related policy interventions to mitigate these risks;
- facilitating dialogue between different sectors of urban administration, policy makers and stakeholders, and explicit trade-offs in urban transport and land-use planning decisions.

These goals were pursued through:

1) discussing and reviewing risk assessment methods, dose response relationships and exposures/effects evidence and measures of risk assessment outcomes;
2) identifying relevant transport-related health end-points to be considered in integrated health impact analysis;
3) reviewing existing models and software tools regarding traffic;
4) integrated modelling of exposures to, and risks of, air pollution, noise and accidents;
5) identifying spatial/temporal scales suitable to integrate risk analysis;
6) defining case studies in terms of policy scenarios and data requirements;
7) planned surveys and monitoring campaigns in the city case studies.

2. MATERIALS AND METHODOLOGY

2.1. Reviews

The work undertaken in HEARTS, in particular the modelling, was strongly informed by the completion of state-of-the-art reviews of key areas of research, including air pollution, noise pollution, traffic and pedestrian movements, and accidents. These reviews were completed early in the project but, reflecting the dynamic nature of this field of research, developments continued to occur throughout the lifetime of the project, so reviews were updated as necessary.

2.2. Traffic and emissions

Information on road traffic and their associated emissions underpin the HEARTS methodology. They were essential as a basis both for assessing risks, and for identifying potential needs for intervention. Reliable data and models on road traffic and emissions were thus a prerequisite for integrated risk assessment, using the HEARTS approach. In order to help identify and select appropriate methods and models, clear criteria were initially developed.

More particularly, the following specific methodological criteria were defined for the traffic models selected:

- Full spatial coverage of the area of impact
- Capability to model different travel modes
- Ability to handle detailed information on trips and network
- Adequate micro-representation of cold trips (i.e. the fraction of cold vehicles in each link)
- Provision of information on the speed variability along each link of the modelled network

Similarly the following specific methodological criteria were identified for emission models:

- capability to predict emissions in terms of appropriate sensitivity to the parameters
- capability to provide results related to different spatial and temporal scales;
- capability to consider all the vehicle categories comprising the European fleet
- adequate micro-scale representation of cold start effects
- realistic modelling of the effects of speed variability along the modelled network.

The use of the Transport Energy and Environment (TEE) 2005 version, which was developed in the framework of HEARTS Project, was finally adopted. This version is a significant upgrade of a previous 2004 version, produced for the ISHTAR Project and focuses on the modelling of parking processes that have a major role in the quantification of cold start emissions, among the major contributions to total emissions in urban centres. The TEE2005 software was applied and validated in the Florence case study. Traffic input mainly came from EMME2 model calculations.

2.3. Air pollution

A large number of dispersion models have been developed for modelling emissions from a range of source types (i.e. point, line, area) and these loosely fall into two groups of models: intermediate and advanced models. Intermediate dispersion models are those models that are capable of providing estimates over both space and time, whilst having relatively simple parameterization and capabilities. Advanced models can accommodate relatively large numbers of sources and provide concentrations at high spatial and temporal (i.e. hourly) resolution, for a number of grid or point receptors. They can use detailed information on traffic emissions and meteorology, varying by time of day and week. A distinguishing feature of advanced models is that they incorporate the effects that boundary layer conditions have on dispersion.

The HEARTS approach was designed to accept data on air pollution from external models, where these are available. Generally, use of data from external models such as these is to be preferred, since this offers the scope to use sophisticated and locally calibrated air pollution models. However, such models may not always be available and / or accessible; therefore, an internal module was developed to model air pollution within GIS.

2.4. Noise

Most traffic noise models presently available use semi-empirical methods, based on a combination of well established theories on noise propagation with a large amount of experimental data from different origins (emission data bases). This approach has the disadvantage that is based on data extrapolations which can lead to large uncertainties.

The existing noise models may need improvements and harmonisation in accuracy. In urban areas, noise source models need to be improved to include additional factors, such as noise due to traffic congestion and to traffic lights (idling engine noise), which can greatly affect the accuracy of the overall prediction model. However this can hardly enhance the accuracy of the overall prediction model. It was therefore necessary to also have a better and more detailed description of urban traffic as a noise source by taking into account the kinematic behaviour (acceleration, deceleration and idling) of vehicles in the urban driving cycle and the effects of traffic signals.

To overcome some of these remaining modelling problems, a new approach was tested within the Florence case study, which remedies the standard computational methods with a statistical model. This enables the results of the traditional calculation methods, applied to the main streets network, to be adjusted to take account both of the traffic flowing along the secondary streets and specific local noise attenuation factors.

2.4. Accidents

Accident risk modeling: A critical analysis of existing accident risk models concluded that "the accident risk formulae estimated from samples of road elements such as links or junctions are not really suitable for estimating the individual risk of involvement in an injury accident for any kind of road user". This is mainly because the forms of the relationship between the individual risk measured as the accident rate per kilometre for a car occupant and the three traffic variables (volume, concentration and speed) obtained from them are not realistic.

Against this background, specific research was carried out in HEARTS to develop a risk indicator that was:

- suitable for pedestrian and car occupants;
- linked to speed and concentration of the flow of vehicles, by lane;
- applicable both to road links and junctions;

- based on the principle of exposure to risk consistent with the concept used in environmental epidemiology like for exposure to pollutants.

Based on this, a measure of "concentration" for a pedestrian was defined, giving the proportion of space not available for a free and safe crossing (Routledge, Repetto-Wright, 1974). This is defined as the space occupied by a virtual flow of vehicles with a length equal to the distance run by the vehicle during the time spent by the pedestrian crossing the street. This same approach has also been extended to take into account multiple flows on a link and at junctions (with and without traffic lights). The same kind of indicator has also been adapted as a measure of risk for car occupants. At junctions, the "concentration" is based on crossing and merging flows, regulated or not by traffic lights, in the same combination (Lassarre et al., 2004).

Pedestrian behaviour modeling: Several attempts of modelling pedestrians crossing behaviour have previously progressed as far as to produce interesting results. However, an overall approach on pedestrians crossing decisions (i.e. where pedestrians are more likely to cross) and the relative determinants has not yet been presented. In particular:

- Most studies analyse crossing decisions at a particular location, while the behaviour of pedestrians along an entire trip has not been explored in detail.
- Most studies focus on particular determinants (road, traffic and individual parameters) and neglect or consider only partially other important parameters.
- Crossing at uncontrolled locations (mid-block crossing, jaywalking etc.), which is a commonly adopted behaviour, is not considered in most studies.
- Most studies are not designated to link the observed crossing behaviour to pedestrian risk exposure.

In the framework of HEARTS, therefore, analysis was undertaken to investigate pedestrian crossing behaviour in a more holistic and integrated way: i.e. along an entire trip. For that purpose, existing methods were exploited and adapted (Baltes, Chu, 2002; Chu et al., 2003), and new models were developed. In particular, a hierarchical methodology was developed and tested, based on the following steps:

1. Estimation of the total number of crossings along a trip, in relation to origin and destination parameters.
2. Estimation of crossing probabilities at different locations along each road segment (link), in relation to roadway, traffic, trip and individual parameters.
3. Estimation of crossing probabilities along each trip, in relation to the distance from origin and destination.
4. Calculation of the weighted final crossing probabilities for each location along the trip.

On the basis of the above, a complex model for the estimation of the type, number and location of crossings along a trip was developed. The resulting algorithm allows for the calculation of probabilities for different pedestrian crossing choices along a trip through a limited yet adequate number of variables. Validation of the model in the case study cities gave promising results.

2.5. Exposure

Micro-environmental models operate by assigning exposures to individuals or populations according to the proportion of their time spent in different micro-environments (e.g. residence, workplace, outdoors, in traffic), each of which can be characterised by distributions of pollution concentrations derived from representative (mostly outdoor) monitoring studies, monitoring sites, or dispersion models (Hänninen et al. 2004, 2005). The advantages of this approach are that it can readily be applied to large populations, on the basis of aggregate time-activity data and estimates can be validated against population exposure survey data. The main disadvantage of microenvironmental modelling, perhaps, is that it gives no individual- or location-specific information on exposures.

On the other hand, dynamic geographical models are designed to provide detailed, individual or near-individual assessments of exposure, over both time and space. They thus require detailed space time-activity data as well as information on time-varying patterns of pollution. Typically they operate by following individuals as they move through the changing pollution field, and thereby accumulate exposure profiles. Their advantage is that they provide far more finely resolved information on exposures which reflects individual behaviour patterns. Their disadvantage is that they place high demands on data and processing resources, and are difficult to validate and extend to large representative populations.

Based on the review of exposure models, it was concluded that both types of exposure models could be used within HEARTS. Dynamic geographical models were used for detailed assessments of transport-related exposures to air pollution and noise at the local scale, while population exposure models using a probabilistic simulation framework (i.e. micro-environmental models) were used for broader-scale population-level exposure assessment or studies of long-term impacts.

2.6. Health effects

The selection of health end-points and related indicators due to air pollution, noise and road traffic-accidents was a fundamental step in developing an integrated risk assessment for traffic-related health effects. This selection was based, by and large, on the availability and strength of evidence on the health effects of exposures associated to transport. Building on the established methodology developed in risk assessment, several methods for more comprehensive health impact assessment, developed in recent years, (WHO-ECEH, 2000; Martuzzi et al, 2003) were exploited.

3. RESULTS

3.1. The GIS based exposure modelling: the STEMS model

This section reports on the development of model integration with particular focus on the STEMS (Space Time Exposure Modelling System) models and providing an overview of the system architecture and data stream. The assessment system was built on, and greatly extends, a GIS-based methodology – the Space-Time Exposure Modelling System (STEMS) - previously developed as part of an EPSRC-funded project (Gulliver and Briggs 2005). In its original form, STEMS was concerned only with air pollution, and used externally provided data on time activity patterns and air pollutant concentrations to simulate exposure profiles for sample individuals. Within HEARTS, this simple base model has been greatly extended and enhanced by incorporating internal models of:

1. air pollution concentrations;
2. traffic-related noise;
3. traffic accident risks (to both vehicle-users and pedestrians);
4. trip selection and time-activity;
5. pedestrian crossing behaviour.

The system has also been greatly refined through the development of a graphical user interface, which provides menus and drop-down windows to enable the models to be run interactively.

The overall system structure is shown in Figure 1. The main principle on which STEMS-2 works is that any individual's risk experience depends on what Hagerstrand (1970) called their time-line – i.e. the sequence of activities they undertake and the places in which they perform them, as a continuous series or narrative. STEMS-2 uses information on individual time-lines (or imputes time-lines when necessary) to model the exposures of the individual to air pollution, noise and accident risks from road traffic. Both the temporal and spatial resolution of the modelling can be altered, according to the availability of data or user need; the default is a 1 hour increment and 100 metre spatial resolution. The important feature of this approach is that exposures are modelled as continuous processes, operating in time and space, not as a set of discrete events. This means that people's entire exposure experience is considered, allowing interactions between behaviour and exposure to be taken into account, and cumulative effects of different exposures to different hazards, in different micro-environments at different times of the day (or life) to be assessed. STEMS-2 thus provides a means of integrated risk assessment.

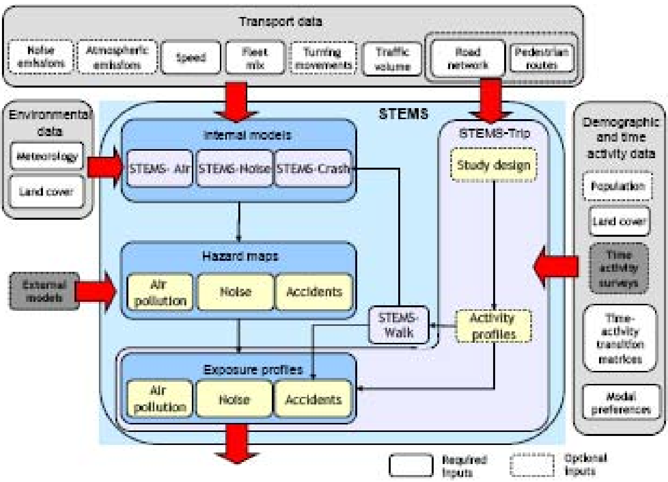

Figure 1. The STEM (Space Time Exposure Modelling) system architecture

As indicated above (and as shown in Figure 1), STEMS-2 comprises five main modules or components. The underlying framework that links the system is STEMS-Trip. This models time activity patterns and trip behaviour on the basis either of detailed, individual-level time-activity data (where these exist) or by imputation on the basis of aggregate statistics on time activity patterns. This module also provides the graphical user interface to design any individual study or assessment, and constructs exposure profiles by dynamically intersecting the time-line of each individual with the underlying and changing hazard surfaces. These hazard surfaces can be provided as ready-made inputs, derived from external models, or can be generated using the internal models: STEMS-Air provides an internal model of ambient air pollution concentrations for every grid cell in the study area; STEMS-Noise models ambient noise levels on the same basis; STEMS-Crash models risks of vehicle accidents, and by extension risks of accidents to pedestrians. STEMS-Walk provides an additional module that simulates pedestrian crossing behaviour (and thus accident risks) along the selected routes.

STEMS-2 is thus designed to be run either using data derived externally (e.g. from purpose-designed surveys or external models) or using the internal models. The minimum input requirements comprise detailed, geographical information on the road network and land cover, and time-varying data on traffic characteristics (volume and flow profile by road link and hour of the day), along with statistical information on time activity (hourly transition matrices and model preferences). Other data requirements (e.g. fleet mix, vehicle speed, air pollutant and noise emissions, and details of time-activity, pedestrian behaviour and road characteristics) can be provided if available, but will otherwise be automatically imputed within the system.

3.2. Case studies

Three case studies were developed during the project. The cities chosen for the case studies were Lille (France), Leicester (United Kingdom), and Florence (Italy). Each case study differed in its focus. In addition to the HEARTS partner agencies, local institutes and organizations were involved in order to support the completion of the case studies. The purpose of the case studies was threefold:

- To help inform the design and development of methods and models
- To test and validate the models under real-world conditions
- To demonstrate the use of the HEARTS approach to evaluate potential health consequences of locally relevant transport issues

In each case, cities focused on specific aspects and issues, depending on their data situation and on local policy concerns as shown in Tables 1 and 2.

Table 1. Models tested within the HEARTS Case-studies

Case Study	GIS development	Air Pollution	Time Activity	Pedestrian Crossing	Traffic Modelling	Noise	Emission/ Dispersion	Accidents
Leicester	•	•	•		•	•		
Lille	•	•	•	•	•			•
Florence	•	•			•	•	•	

Table 2. Data, tools, parameters and scenarios modeled in the HEARTS Case-studies

City	**Data and / or Tools**	**Scale and/or Parameters**	**Scenarios Modelled**
Leicester	Children's time activity patterns and personal exposures to air pollution in different transport micro-environments. Validation and testing of air pollution and noise models against monitored data.	A small-area (ca. 20km2) around Narborough Road in Leicester. Key parameters: exposure to air pollution (particulates) in different transport micro-environments; time-activity patterns and route choice of children; noise monitoring and modelling measures.	Policy scenario for a "no-drive-to-school" initiative

City	Data and / or Tools	Scale and/or Parameters	Scenarios Modelled
Lille	Data on mobility, networks, traffic, air pollution, accidents. Special simulation tools developed. Urban transportation specially designed to decrease the car use. A methodology to measure the exposure to accident risk for pedestrian has been set up with observation techniques such as follow up, interview, and GIS coding techniques	Study area was limited to Villeneuve d'Ascq, located on the west of Lille Métropole. Two types of risk due to transportation: - Accident, - Air pollution, Two groups in the population : - Children (5-10 years), - Employed (18-60 years).	Two scenarios of transportation policy for 2015: a business as usual one and a pro-active one based on a set of actions recommended into the "Plan de Déplacements Urbains"
Florence	Integrated modelling system by loose-coupling the various models within GIS. Carrying out an exposure measure campaign of PM2.5 and elemental analysis of PM2.5 samples	The whole area of Florence municipality (Comune di Firenze) The entire population of Florence Municipality	Application to the existing and planned transport scenarios by the Florence Municipality at 2010.

In Leicester, the study focused on collecting detailed data on time activity patterns of children, and personal exposures to air pollution both in-vehicle and whilst walking, to inform and validate the modelling. A purpose-designed survey of time activity patterns was undertaken in 10 schools in the area, and repeated personal monitoring carried out on two routes. Detailed monitoring and modelling of noise was also undertaken. Data on traffic flows were obtained using a vehicle allocation model (TRIPS), and this was used, together with the STEMS model developed during HEARTS, to simulate exposures under a "safe routes to school" initiative scenario. Model testing and validation was also undertaken using the data collected in the study area. Some results concerning air pollution exposures are presented in Figure 2.

In Lille, much of the focus was on accident modelling. Target subgroups investigated include: children, 5-10 year old and employed, 18-60 year old. In Lille, a new methodology was tested to measure the exposure to accident risk for pedestrian with observation techniques such as follow up, interview, and GIS coding techniques for the route and crossings of the walking trip for children, teenagers and adults. A do-nothing scenario and an transportation action-plan scenario were compared, concerning year 2015. Some results concerning pedestrian accident risk are presented in Figure 3.

In Florence traffic emissions, noise measurements and exposure modelling were performed. In particular, an exposure measure campaign of PM2.5 and elemental analysis of PM2.5 samples were carried out to run exposure statistical model. Two scenarios were tested comparing 2003 to 2010 situation regarding traffic and emission modelling. Some results concerning noise exposure are presented in Figure 4.

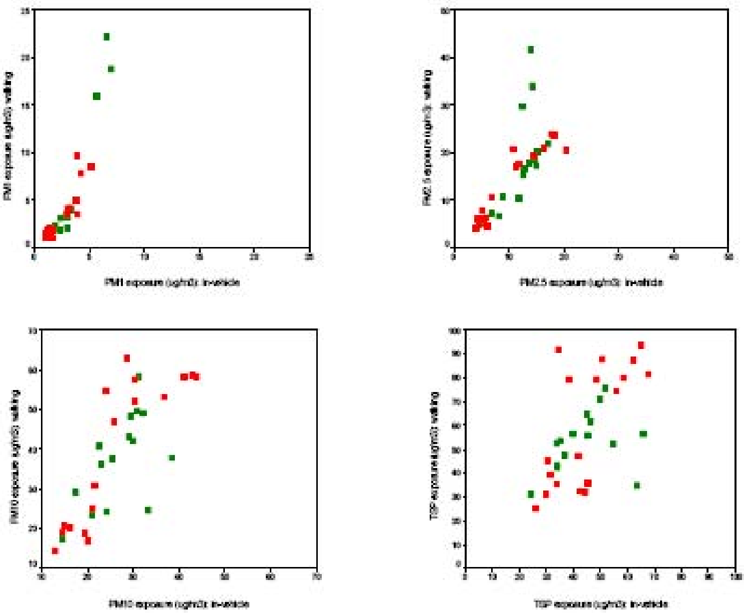

Figure 2. Relationships between air pollution exposures for the two scenarios (in-vehicle and while walking) on two routes in Leicester

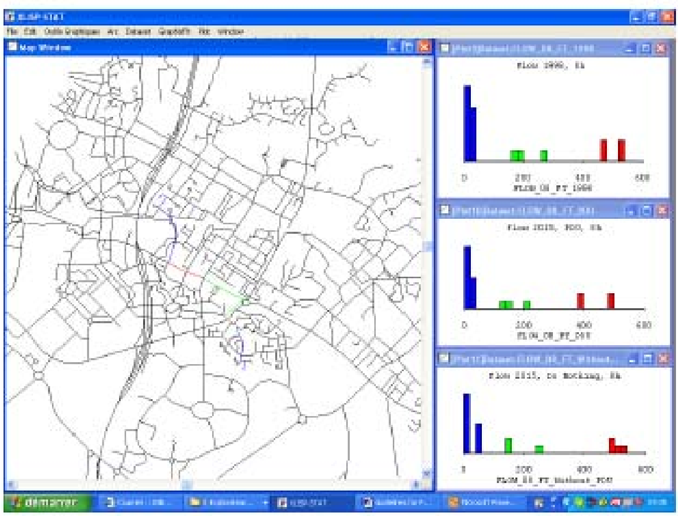

Figure 3. Traffic flows encountered along a pedestrian path at 8 a.m. in Lille for the three scenarios

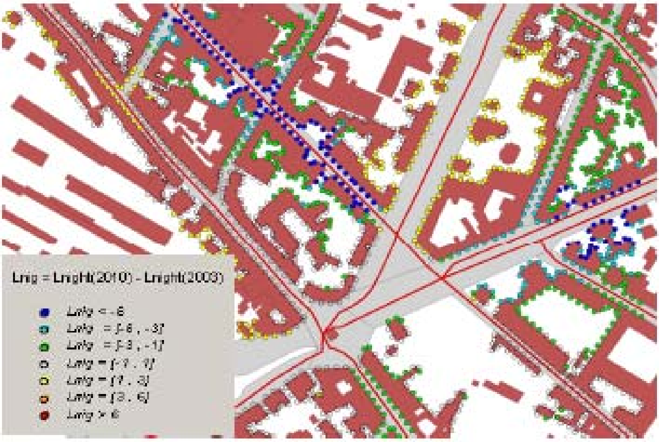

Figure 4. Comparison of noise exposure (Lnight level differences in receptors) between the 2003 and 2010 scenarios in Florence

4. DISCUSSION

The overall objective of HEARTS project was to develop and apply an integrated methodology for health risk assessment in order to evaluate the multiple health impacts of road traffic, as a basis for informing policy and improving public health protection. Its motivation was the need for more integrated methods for health risk assessment which consider the full range of exposures and health effects and can be applied early in the policy or planning process. These tools should also make explicit the trades-off of certain policy options. One of the achievements of HEARTS was the development of a loosely-coupled modelling system, enabling an integrated assessment of the exposure to air pollution, noise and traffic accidents and associated health risks in relation to road traffic. The question during the process has been whether in addition to this, it is useful and possible to calculate an overall estimate of the combined exposures and total health loss.

The initial objectives of the projects were achieved. The Consortium identified and characterised a complex set of steps and selection of models that, when integrated together, will constitute a decision support tool to test different urban policy scenarios. The relevant health outcomes and specific exposures that determine the most significant impacts were identified through an extensive review of the large body of evidence on the effects of ambient air-pollution, noise and road accidents. To accommodate for each complex structure of information, the STEMS software was developed to include new models for air pollution, noise and accidents risks and was also greatly enhanced by the development of a time activity model and graphical user interface.

As part of this process, a range of new models have been developed, and others adopted and adapted. The TEE emissions model was extensively improved to take account the fact that STEMS needed some modifications and the insertion of a new algorithm for the risk of accidents. Two additional issues were explored: the first one refers to the analysis of pedestrian crossings characteristics in relation to the infrastructure; the second one deals with speed variations along the links and near the junction areas. The results of the investigations described above are expected to allow for the degree of exposure to be calculated for different traffic conditions and pedestrians behaviours in an accurate and realistic way.

The HEARTS approach represents a step forward in the development of an integrated approach to assess the health-effects of urban transport policy. The feasibility of an integrated approach was demonstrated but some issues remain open:

- Validation: different models can be validated to different degrees. Means of carrying out "fair" comparisons should be further identified.
- Data access/integration: methodological reflection and development of models and tools for implementation are the main objective of projects like HEARTS. However, experience shows that difficulties in obtaining data, assessing its completeness and quality, ensuring consistency between different sources, preventing questions of property and rights, cleaning, formatting, transferring and so on, absorb a large proportion of the efforts.
- Training for implementation: systems for integrated analysis are complex entities and cannot be used "off the shelf". The applications require a good level of knowledge, normally to be found in established teams. It is not clear how a satisfactory balance between level of complexity and necessary know-how (and/or investment in capacity building) can be pursued.
- Construction of an automated decision-support system: while in principle such a system is conceivable, it is uncertain whether algorithms and software to accomplish this are realistic feasible, and above all the utility of such a system is dubious.
- Applicability to other transport modes, railways, aircraft; Inclusion of further health implications of transport policies in urban areas, notably physical activity through cycling and walking and psychosocial effects; Extension of the modelling to include a regional scale: by design, HEARTS did not cover all possible areas of interest in transport and health. One of the biggest challenges for the future is to identify what additional areas of research and implementation would be most profitable and useful to support policy making.

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Περίληψη: Ο βασικός στόχος του ερευνητικού έργου "HEARTS (Health Effects and Risk of Transport Systems) - Κίνδυνοι και επιπτώσεις στην υγεία των συγκοινωνιακών συστημάτων" ήταν η ανάπτυξη και ο έλεγχος ολοκληρωμένης μεθοδολογίας για την εκτίμηση της έκθεσης στον κίνδυνο και των σχετικών επιπτώσεων στην υγεία από διαφορετικές πολιτικές αστικών μεταφορών. Οι παράμετροι επικινδυνότητας που εξετάστηκαν αφορούσαν στην ατμοσφαιρική ρύπανση, στο θόρυβο και στα οδικά ατυχήματα. Προκειμένου να αναπτυχθεί μια ολοκληρωμένη προσέγγιση, πραγματοποιήθηκε διεξοδική ανασκόπηση και αξιολόγηση των υφιστάμενων προτύπων που σχετίζονται με τη λειτουργία και τις επιπτώσεις των αστικών συγκοινωνιακών συστημάτων, συμπεριλαμβανομένων κυκλοφοριακών προτύπων, προτύπων ατμοσφαιρικής ρύπανσης, θορύβου και οδικών ατυχημάτων, αλλά και προτύπων χρόνου-δραστηριότητας, έκθεσης στον κίνδυνο και επιπτώσεων στην υγεία του πληθυσμού. Με βάση τα παραπάνω, επιλέχθηκαν κατάλληλα υφιστάμενα πρότυπα για προσαρμογή, ενσωμάτωση και χρήση, ενώ αναπτύχθηκαν νέα πρότυπα, κυρίως μικροσκοπικού περιβάλλοντος (micro-environmental), όπου αυτό ήταν απαραίτητο. Η εφαρμογή αυτών των προτύπων βασίζεται σε μια διαδικασία κατανομής της έκθεσης στον κίνδυνο σε άτομα ή πληθυσμούς με βάση την κατανομή του χρόνου που περνούν σε διαφορετικά μικροσκοπικά περιβάλλοντα, καθένα από τα οποία μπορεί να χαρακτηριστεί από διαφορετικές πυκνότητες (concentrations) επικινδυνότητας. Τα διάφορα πρότυπα συνδέθηκαν μεταξύ τους σε ένα περιβάλλον Γεωγραφικού Συστήματος Πληροφοριών (GIS) για τη δημιουργία ενός εργαλείου ολοκληρωμένης εκτίμησης επιπτώσεων. Παράλληλα, προκειμένου να υποστηριχθεί η ανάπτυξη της μεθοδολογίας, να ελεγχθούν και να επικυρωθούν τα διάφορα πρότυπα και να παρουσιαστεί ο τρόπος με τον οποίο η προσέγγιση του ερευνητικού έργου μπορεί να χρησιμοποιηθεί για την αποτίμηση πολιτικών μεταφορών, πραγματοποιήθηκαν τρεις πιλοτικές εφαρμογές (case studies) στις πόλεις του Leicester (Αγγλία), της Lille (Γαλλία) και της Φλωρεντίας (Ιταλία).

Λέξεις κλειδιά: επιπτώσεις στην υγεία, ατμοσφαιρική ρύπανση, θόρυβος, οδικά ατυχήματα, έκθεση στον κίνδυνο, Γεωγραφικά Συστήματα Πληροφοριών.