Socio-economic impact of IMPROVE LIFE project

March 2018

IMPROVE LIFE13 ENV/ES/000263

Coordinated by

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

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CONTENT

The direct impact of improving subway air quality on socio-economic development is a concrete, measurable benefit for stakeholders and the public, and is central to the IMPROVE LIFE project. In this report we focus on the most obvious socio-economic impacts of the project although in addition, as with any such activity designed to improve urban lifestyle, there are broader social impacts on employment, health and environmental protection. Such wider impacts, are characterised by benefits that are not so easily measured as most social changes are driven by many factors other than air quality measures and policies, including investment strategies.

HEALTH

The main social impact of air quality is how it affects the health of subway passengers, many of whom commute on a regular basis so that their inhalation of particulate matter while underground forms a significant and measurable part of their daily exposure to air pollutants. Good air quality improves the public health by reducing the population's exposure to air pollutants, thus health problems caused by air pollution will be reduced and consequently the admission to hospitals. Direct costs related to respiratory and/or cardiovascular problems (medicine, physician, medical tests and hospitalization) and indirect costs (loss of wages due to illness) will be reduced as lifestyle improves. Although in the limited lifetime of the IMPROVE LIFE project it is difficult to evaluate precisely the benefits concerning health there is no doubt that a reduction of ambient PM in subways will improve commuter health. As the World Health Organisation has written: "The lower the levels of air pollution, the better the cardiovascular and respiratory health of the population will be, both long- and short-term" (http://www.who.int/mediacentre/factsheets/fs313/en/).

POLICY EFFECTIVENESS

Better cost-effective air quality regulation for subway systems will seek both to save money while at the same time improve the quality of respirable air. The project has generated the largest open access scientific database on air quality in subway platforms and trains, and used this to focus on what changes can and should be done to improve matters. The IMPROVE LIFE project has also provided knowledge and advice to subway air quality managers, enabling and encouraging them to recognise the problem and consider cost-effective air quality measures for decreasing air pollutant concentrations. We have emphasised that although at present there is no official regulation on air quality in such environment, such regulatory control is likely to be applied in the future.

The benefits of this project on policy effectiveness include:

- Enhanced visibility of mitigation measures (existing and new) for air pollution through the numerous communication activities carried out by IMPROVE LIFE partners.

- Strong and positive collaboration between IDAEA-CSIC and TMB for the development of efficient mitigation measures in the Barcelona subway system (transferable to any other subway system worldwide).

- Motivation of other national and international subway systems to adapt and strengthen their current air quality policies. The main recommendations of IMPROVE LIFE to the subway systems were to adjust the ventilation protocols for each subway station, to install platform screen door systems to all lines, and to avoid the use of brake materials containing high concentrations of toxic metals such as Sb.

AIR POLLUTION MANAGEMENT

The meticulous source apportionment study carried out over 500 chemical analyses of $PM_{2.5}$ and their source materials (such as brakes) breathed on the subway platforms, at 10 different stations on 7 different lines, within the Barcelona subway system was crucial to calculate the contribution of each air pollutant source characteristic of the subway system. This helped to categorise the major problems and the effectiveness of best practice measures that could be used for air pollution abatement (such as the flow and direction of ventilation in trains and tunnels, the use of dust suppressants on ballast, and the location of air purifiers on platforms) were assessed. The collaboration between the two IMPROVE LIFE partners provided an added value to the project outcomes and lead to recommendations to subway air quality managers elsewhere in Europe regarding the adjustment of best practices used.

Further benefits of this project include:

- Pilot testing to assess the effectiveness of air purifiers from two different companies, in various locations along different subway platforms. Budget: 11.325 €

- Analysis of bioaerosol concentrations on different subway environments. Collaboration with University of Laval (Canada) and Centro de Estudios Avanzados de Blanes (CEAB-CSIC).

- The continuation of the project actions by IMPROVE LIFE beneficiaries through national projects. The coordinator of IMPROVE currently runs a national project funded by the Ministry of Economy and Competiveness named BUSAIR and related to IMPROVE activities. The actions that will be continued include the impact of brake wear emission sources and ventilation protocols on air quality inside public buses. Thus the knowledge gained during the IMPROVE LIFE programme is already being used and applied to other urban public transport scenarios.

REPLICATION, TRANSFERABILITY, COOPERATION

Since the beginning of the project significant replication efforts have been made, as the aim of the project is to present pollution mitigation measurements applicable to all subway systems worldwide. Thus a strict protocol was established for all measurements, with monitoring campaigns being carried out a minimum of twice, and at different times of the year, and with monitoring equipment being located in the same location at all times, to minimise the influence of other parameters in the analysis.

Using IMPROVE methodology and dissemination, any subway operator worldwide now has full access to clear guidelines as to how to characterise the spatial and temporal variability of particulate matter, and determine the sources and their impact on the air quality of the station platform.

Various meetings with stakeholders to present and discuss IMPROVE LIFE results have been carried out, including: Metro Bilbao, Metro Valencia, Metro Sevilla, Metro Madrid, Renfe (Spanish National Railway Network), Barcelona City Hall, Adif (owner of Spanish rail infrastructure), Transport for London, Munich Subway, Vienna Subway (U-Bahn), and the International Association of Public Transport (UITP, Rotterdam). In all meetings the IMPROVE technical guide for improving air quality in the subways systems was presented as a keynote reference publication to which all future mitigation actions should be referred, especially with respect to the innovative colour-coded diagram for subway air quality improvement presented in the guide.

The cooperation of all TMB technical personal was key for the development of the project. In relation to this, annual meetings with TMB workers to discuss IMPROVE LIFE progress, especially in relation to subway worker's exposure (TMB Safety Committee) were held in TMB main offices since the beginning of the project.

EMPLOYMENT

Air quality measures can affect local employment as the companies and industries that should comply with any new measures will attract and retain skilled staff. Possible job gain might arise from the need of additional staff to implement new measures. New business and employment opportunities in the area of improving air quality in the subway system during the project and after its finalisation include:

- the market of nanopolymers. This benefited from IMPROVE LIFE project as the efficiency of nanopolymers to mitigate dust resuspension while adding and manipulating ballast has been tested during several night-time tunnel activities in Barcelona subway system.

- the manufacture and installation of platform screen door systems in subway platforms. The project has shown this measure as one of the most practical in order to reduce air pollutant concentrations on the platforms.

- mechanical/electrician workers to plan and control (flow direction and intensity) the best ventilation protocol for both tunnel and platforms.

- IMPROVE LIFE created full time new jobs of 3 specialized scientists and 1 administrator, all of them women, working in CSIC for this project.

PUBLIC AWARENESS

The implementation of the public awareness activities also has an important indirect socio-economic impact on different target groups and stakeholders. The importance of all the project actions and their effect on understanding subway air quality have been communicated in diverse ways (leaflets, presentations to institutions, interviews in tv and radio, mass media releases etc.). Local people were approached by means of public questionnaires to evaluate public perception on the Subway Air Quality issue. This included a survey available in the website of the IMPROVE LIFE (uploaded in English and Spanish), and two annual questionnaires for subway passengers that were carried out during September 2015 and 2017 in the frame of the activities that TMB carries out annually. The results from both types of questionnaires are shown in the Deliverable 11 (Action C2): "Questionnaires for the general public".

The dissemination actions of the project were particularly successful, especially as measured by website hits and media interest, and all results have been publicized through different means of communication:

- IMPROVE LIFE website,
- IMPROVE LIFE videos: 2 informative videos in 3 languages -English, Spanish and Catalan- of 10 (in the web page) and 20 (to be shared with other subway systems) minutes,
- IMPROVE LIFE pamphlet,
- IMPROVE LIFE notice boards,
- IMPROVE LIFE in the media: 58 media and press releases (including 39 in digital press, 10 in newspapers and 9 in radio and TV interviews). See Deliverable 15 (Action D3): Articles in general and trade press.

IMPROVE LIFE has also coordinated international events to promote its results, including the SETAC 2015 (http://barcelona.setac.eu/home/?contentid=767&pr_id=766) and RICTA 2017 (http://www.ricta2017.org/) conferences, as well as the "Air Quality Platform Meeting" hold in Barcelona on 26-27th of September 2017 (http://improve-life.eu/event/life-platform-meeting-on-air-quality-in-barcelona/), to which other LIFE projects were invited. See description on Deliverable 5 (Action E3): Minutes of the Experts Workshop.

Finally, the long list of peer-reviewed scientific papers generated by the IMPROVE LIFE project work has most recently culminated in a short commentary article published by the prestigious international journal Environmental Pollution (Moreno and de Miguel, 2018. *Improving air quality in subway systems: An overview*). This article is written in a non-technical style deliberately aimed at a wide audience and is freely available online to the general public.

COST-BENEFIT ANALYSIS

The primary objective of any air quality improvement campaign within a subway system must be to reduce the number and concentration of inhalable particles breathed by passengers on platforms and trains. Unlike above ground in the city, where particulate pollutants are joined by volatile organic compounds and toxic gases related to hydrocarbon combustion, in the subway system the main problem are the ferruginous and carbonaceous particles generated by train movement. The exact costs resulting from applying the recommendations presented by IMPROVE LIFE will depend on the detail of each subway system. The following Table summarises the abatement measures involved in the project proposals for better subway air, and offers a qualitative approach to the relative costs and benefits involved.

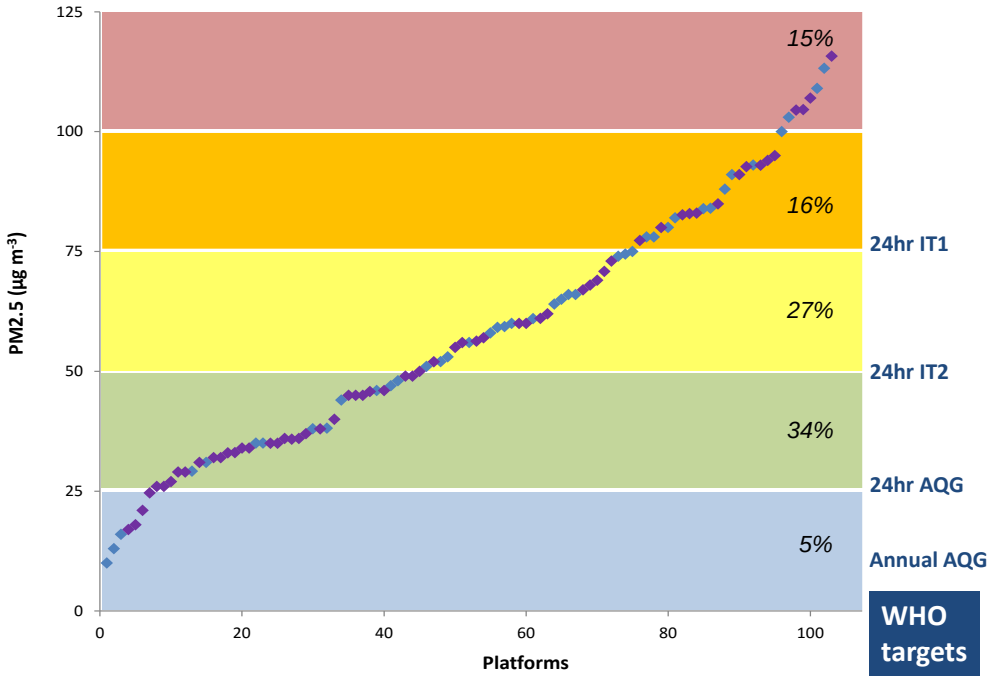
Cost/benefit analysis of the IMPROVED LIFE proposed abatement measures to improve subway air concentrations.

ABATEMENT MEASURES			BENEFIT	COST
SOURCE REDUCTION	**Indoor source:** Selected train components, avoiding known toxic compounds. *Specific recommendations:*		- Lower passenger exposure to air pollution, associated with a reduced emission of toxic heavy metals.	- Differential cost of alternative materials and supplies.
	-Brakes with the lowest % in Sb and Cu. -Graphite pantographs. -Brushless motors.			
	Outdoor source: Selected location of new metro stations' ventilation grills, avoiding high traffic areas.		- Lower passenger exposure to air pollution, associated with a reduced entrance of outdoor pollutants.	
SOURCE MANAGEMENT	**Ventilation settings**	Forced ventilation at tunnels and platforms. *Specific recommendations:*	- Lower passenger exposure to air pollution, associated with reduced PM concentrations.	- Installation. - Maintenance. - Energy costs for equipment operation.
		-Impulsion of outdoor air at platforms during metro hours.		
		-Strong ventilation at platforms (> 25 Hz).		
		-Ventilation at tunnels always connected during metro operating hours.		
		Air conditioning systems inside trains.		
	Air purifiers in platforms and trains		- Lower passenger exposure to air pollution, associated with reduced PM concentrations (dependent on the distance to the passenger and flow rate).	- Acquisition. - Installation. - Maintenance. - Energy costs for equipment operation.
	Maintenance works. *Specific recommendations:* - Timing of nocturnal maintenance works. They should be conducted as early in the night as possible. - Use of dust suppressant when laying ballast.		- Increased passenger exposure to coarse particles averted. - Lowering early daytime platform $PM_{2.5}$ concentrations by at least 10%.	- Cost of dust suppressant product (unless only water is used).
	Platform Screen Doors (PSD)		- Reduced exposure to tunnel-generated pollutants.	- Maintenance. - Energy costs for doors operation.
			- Passenger security.	

FINAL REMARKS

The broad range of published $PM_{2.5}$ concentrations recorded on subway platforms from the Barcelona metro and other subway systems around the world are plotted on the figure below (see reference list in IMPROVE LIFE Technical Guide: Improving air quality in the subway environment). Of the > 100 data points, more than two-thirds lie below 75 µg m^{-3}, which coincides with the 24hr mean Interim Target Level 1 proposed by the World Health Organisation (WHO).

In the context of subway air quality IMPROVE LIFE propose a targeted, colour-coded scheme based on WHO methodology and designed to encourage transport authorities to aim for progressive PM reductions on platforms. The method defines a series of thresholds that cascade down through bands of decreasing PM concentrations towards the WHO Annual Mean Air Quality Guideline of $PM_{2.5}$ levels of just 10 µg m^{-3}, which is the lowest annual mean levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase (>95% confidence).



Published mean $PM_{2.5}$ concentrations up to 125 µg m^{-3} measured on platforms of subway systems around the world are plotted against a ***colour-coded background aimed at encouraging the targeting of progressive improvements in air quality****. An initial Air Quality Audit will first ascertain where a given subway platform lies on this curve. For comparison, Level Yellow (75-50 µg m^{-3}) spans the concentrations lying between the WHO recommended 24-hour Mean Interim Targets 1 and 2 (24hrIT1 = 75 µg m^{-3}; 24hrIT2 = 50 µg m^{-3} respectively). Level Green includes the WHO 24-hour Mean Interim Target 3 (24hrIT3 = 37.5 µg m^{-3}) and arrives at the 24-hour Mean Air Quality Guideline (24hrAQG = 25 µg m^{-3}), a level which also includes the WHO Interim target 2 for annual mean concentrations of $PM_{2.5}$ (AnIT2). Level Blue includes the WHO Annual Mean Interim Target 3 (AnIT3 = 15 µg m^{-3}) and the WHO Annual Mean Air Quality Guideline (AnAQG = 10 µg m^{-3}). Percentages indicate the proportion of platforms (from a total of 114) within each PM range (60% of the platforms- coloured in purple- belong to the Barcelona subway system).*

Although the WHO 2006 targets were developed with an initial focus on outdoor air, a recent report by this organisation makes it clear that they "relate to all environments" (WHO, 2017) and they are thus considered as equally appropriate for subways.

We are confident that application of the air quality measures recommended in this project, using our colour-coded scheme presented in IMPROVE as a guideline with which to mark and compare progress, will successfully reduce underground pollution levels and improve city commuter health. Such improvements will involve financial outlay and political commitment, and will have to be judged in some cases against possible environmental costs such as increased CO_2 emissions resulting from increased energy use. However, in many cases (particularly in the older subway systems) modernising, for example, the ventilation system will likely involve installing new machines that both improve air quality and are energetically more efficient. Similarly, the effects of installing platform screen doors, which not only improves passenger safety but also air quality, provide another example of how the results of an air quality audit underground can lead to synergistic improvements for the underground commuter.

Finally, as outdoor city air is improved by the phasing-out of diesel and petrol cars in favour of hybrid and all-electric vehicles, so the issue of subway air quality is likely to assume a higher priority in public awareness. The numbers of people who use the subway worldwide is huge and growing. Already all the "top ten" busiest subways in the world (Beijing, Shanghai, Tokyo, Seoul, Guangzhou, Moscow, New York, Hong Kong, Mexico City and Paris) each carry well over 1 billion people annually. In China alone more than ten new metro systems are currently under construction, with another forty or so at the planning stage. In comparison the Barcelona Metro operated by TMB carries "only" around 416 million people per year and is the eighth busiest subway in Western Europe. Despite its relatively small size, however, it has proved itself to be a pioneer in air quality by enabling the IMPROVE LIFE project to generate the largest publicly accessible physicochemical database on subway air quality currently available. The challenges and opportunities revealed by this database are directly applicable not only to the Barcelona Metro but to all subway systems worldwide.

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