



Urban Air Quality Guidance Based on Measures Categorization in Road Transport

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Abstract

Air pollution is a cause for serious concerns in urban areas in Republic of North Macedonia. Intensive development of road transport increases the main air pollutants' concentrations - particulate matter and nitrogen dioxide, whose monitored values are continuously exceeding the limit. The main disadvantage of the national plans and annual reports is the absence of comprehensive and categorized list of reduction/mitigation measures for road transport impacts on air quality. Analyzing the current air pollution problem and road transport contribution this paper provides the needed and detailed categorization of short-to-long term reduction/mitigation measures consisting of five subcategories. Based on measure categorization, a guiding frame for urban air quality is designed, intended for further support and assistance for local authorities in the process of air pollution control. Designed with integrated activities, the air quality guidance enables them to select suitable measures to manage road transport pollution and to evaluate their effects estimating the changes in air pollution levels. Hence, the guidance can be used for thorough planning of air quality issues caused by road transport and for policy making. Contributing for urban air quality improvement the guidance is a first step towards the implementation of air pollution management in urban areas.

Keywords: Urban Air Quality; Air Pollution; Road Transport; Measures.

1. Introduction

Air pollution is a global threat leading to harmful impacts on health, ecosystems and life quality. Biggest air pollution impact on health and economy results from exposure to increased levels of toxic pollutants leading to rising occurrence of diseases and premature death [1]. Air quality is a major concern particularly in urban areas where traffic is very intensive. There, road traffic is recognized as the biggest single contributor to two of the most harmful and widespread air pollutants – nitrogen oxides (NO_x) and particulate matter (PM) [2].

Republic of North Macedonia is not an exemption. Air quality remains poor in most of the towns in the country. Ambient concentrations of one of the most damaging air pollutants, fine particulate matter, are often several times above permitted levels. The situation is most serious in the biggest urban centers in R.N. Macedonia: Skopje, Tetovo, Bitola [3]. Several sources and reasons for these problems with air quality have been identified, but they may differ not only in one urban area, but also between several urban areas. Apart of the industry, energy production, households heating with wood and agricultural activities, road transport is also a significant source of air pollution in urban areas [4].

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The contribution of road transport to air pollution comes from the high traffic intensity and also from older vehicle fleet and inappropriate maintenance of the vehicles. In R. N. Macedonia, air quality is followed through monitoring of air pollutants concentrations, which gives precise information for the range of the problem. Hence, available monitoring data provide definition of the pollutants trends in ambient air, as well as contribution of every pollution source [3]. This is useful for deciding which measures for air pollution reduction are most needed in which sector and where they would have the biggest effect. Air pollution problem has raised political, media and public interest in air quality issues and also has increased the public support for action. This has led to growing demand for measures to improve air quality.

Although air pollution problem is recognized and the need for actions is nationally acknowledged, in the “fight” with this problem, usually local and national authorities are without scientific support. The measures introduced locally so far are based on the experience on other cities, without plan or consideration for their appropriateness for our conditions. Apart of that, their effect isn’t monitored, so their contribution for improvement of air pollution is unknown. The national plans and annual reports, prepared by the Ministry of transport and environment, are very solid with valid facts referring to the analysis of air pollution and contribution from different sources. But, the part where measures or concrete activities should be thoroughly analyzed and proposed, they failed. For every pollution source, including road transport, the measures are only modestly listed, without further analysis or recommendation. Hence, the position in which authorities or urban planners are currently could be understandable: from one side, there is a public pressure for measures to be undertaken. From the other, there is an absence of national policy, strategy or even guidance based on which they will have a clear direction how to begin and what to do.

Hence, this ineffective type of approach in national plans and reports presenting only simple outlining of modest number of measures in a form not useful for decision makers and also their insufficient or nonexistent elaboration was an impulsion for designing the categorized scheme of measures in road transport.

The necessity for valid analysis of air pollution coming from transport is clearly established, although the range of available measures is altering. Different measures for reduction/mitigation can contribute for different pollution declination under different conditions. In some cases pollution reduction is unlikely to be achieved without previous determination of main phases or underlying conditions. Additional difficulty is clarification of the measures prior to their implementation, e.g., whether the measures are “proven”, what is the level of difficulty for their implementation or whether the measures are still in the phase of pilot-testing.

While the measures that have reduction/mitigation impact of road transport pollution are known, the challenging task was to make a categorization based on time duration for their implementation. Hence, the presented categorized scheme of measures first is divided in two main categories: short/medium time measures and long-time measures. Both categories contain five subcategories: measures for traffic control, inspection/maintenance programs, demand management and development of transport policies. The necessity for such categorization of measures arise from the complexity of the road transport impacts on air quality and many aspects in which those impacts could be reduced or mitigated. In addition, categorization scheme of measures is supported with given example of best practices, as well as explanation of the range and effects of several measures widely implemented in practice.

Considering that implementation of selected reduction/mitigation measure/s doesn’t solve the air pollution problem by itself, the analysis was further extended. In practice, the categorization list will assist and facilitate the local authorities’ legal obligation to provide air quality improvements. They would now be able to select a measure that best fits to their local and economic constraints, or to the available human and technical resources. However, apart of this possibility, local authorities would need a frame of activities for assessment of the effect of selected and implemented measure. Hence, the guidance for urban air quality was designed by integrating several activities for analysis; in this format, air quality guidance could be considered as a first step toward the process of air pollution management and control in urban areas.

Presented guiding framework consists of four steps: selection of measure, emission estimation, estimation of changes in transport emissions and estimation of air pollution changes. The function and potential of each of the steps is elaborated. Starting with the selection of measures, the guidance in the final step allows clarification of the impacts of the selected measures in road transport upon air quality. Hence, the local authorities will have validated results that would support their decision referring measure selection and implementation.

Faced with such complex task and real need for air pollution control in our urban areas, the structure of this paper starts with the analysis of pollutants’ concentrations trends. Thus, only the concentrations of particulate matter and nitrogen oxides as main air pollutants are considered (Sec. 2.2 – 2.3). The aim of this analysis was to stress out the extent of air pollution problem in urban areas in R. N. Macedonia and factors that contribute road transport to be one of the main pollution sources. Then, a categorization of reduction and mitigation measures in road transport for protection of urban air quality is presented (Sec. 2.5). Defined categorization serves as a base for composing the air quality guidance in four steps (Sec. 2.6). In the discussion section, factors and limitations for measure selection are

elaborated, together with the examples of best practices and effects of measures (Sec. 3.1. - 3.3). This section ends with parts dedicated to: importance of regular monitoring and reporting of the measure effect, which could serve as a confirmation for properly conducted measure selection (Sec. 3.4) and application possibilities of proposed air quality guidance (Sec. 3.5) for broader range of users for policy making and design of strategies for pollution control.

2. Research Methodology and Analysis

2.1. Characteristics of the National Vehicle Fleet

Considering the transport sector, the biggest impact on air pollution have road transport emissions [3]. Road transport emissions are highest in urban areas, where dense road network and high vehicle frequency is typical. Road transport contributes for the emissions of nitrogen oxides, particulate matter, carbon monoxide, benzene, heavy metals and other pollutants.

One of the key reasons for air pollution problem from road transport, which is common for most of the urban areas in R. N. Macedonia, is old and inappropriately maintained vehicle fleet. At national level, approximately half of the passenger cars and buses are old and are placed in the category of high polluting vehicles [3]. Traffic jams and poorly developed public transport or complete lack of service for public transport additionally deteriorate the current state.

Based on the vehicle register data from the national statistical burro, the total number of registered motor vehicles in R.N. Macedonia in 2019 was 472.700 (Figure 1). Passenger cars dominate with 90.12%, followed by high duty vehicles (8.88%).

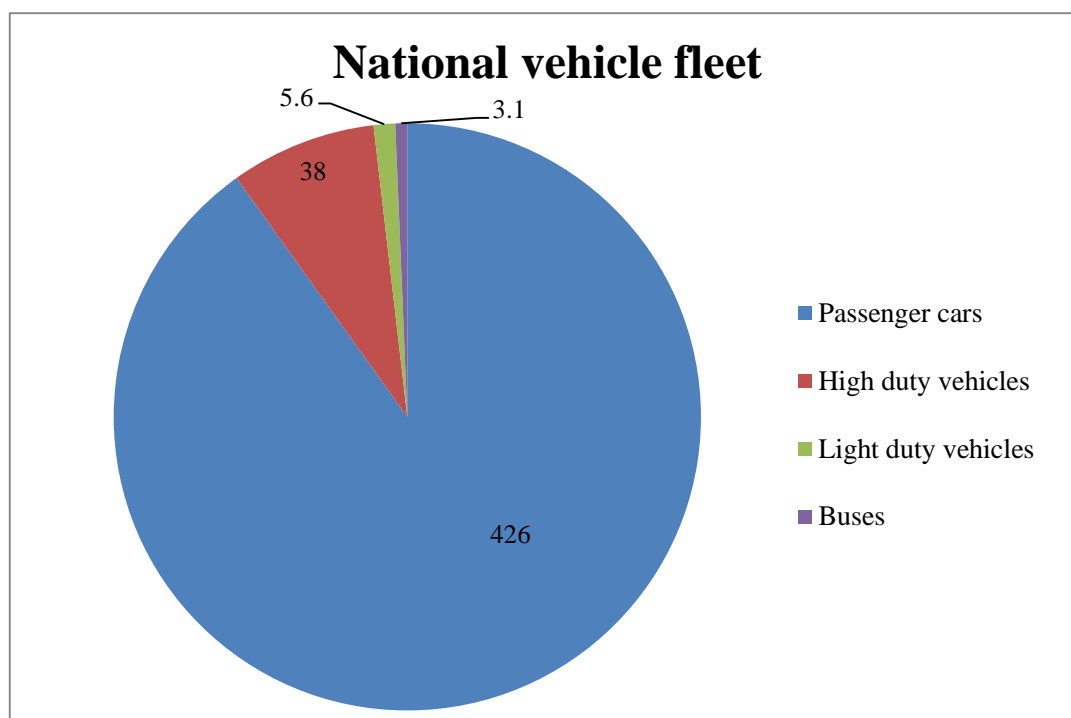


Figure 1. Composition of the national vehicle fleet in 2019 (in thousands) [5]

Categorization of national vehicle fleet by age is given at Figure 2. The average age of the passenger cars is 19.3 years, of buses 18.1 years and of high duty vehicles is 16.4 years. The high average age of vehicles in the national fleet is a clear indicator that their system for exhaust emission treatment has questionable installment and proper functioning, which places them in the category of high polluting vehicles. Considering air quality impact, the current condition of the national fleet is unsustainable and unacceptable and measures must be undertaken for its renewal in order to mitigate its impact.

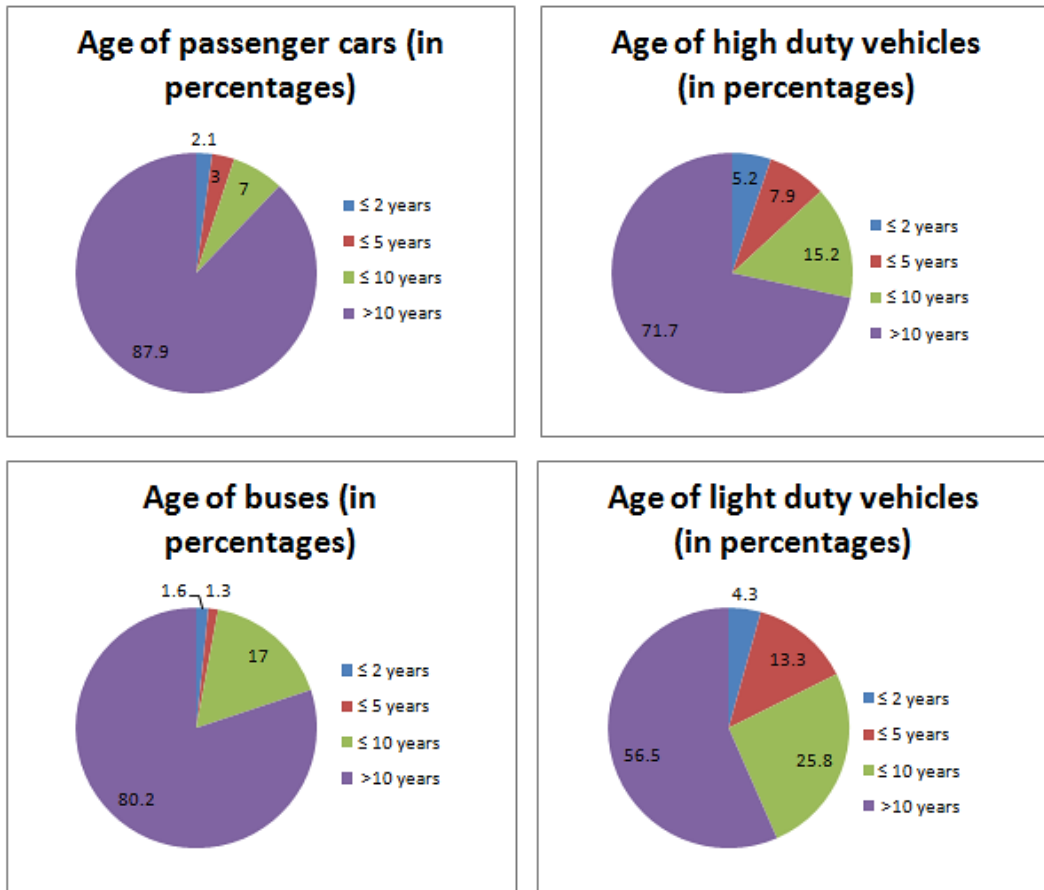


Figure 2. Age of the registered passenger cars, heavy duty vehicles, light duty vehicles and buses, 2019 [5]

As a positive example of measure at national level, regarding the fleet age was the regulation introduced in 2014, with which the import of used vehicles under Euro 1 and Euro 2 had been banned. Hence, since January 1, 2015, the import of vehicles at least above Euro 3 has been permitted.

2.2. Particulate Matter (PM₁₀ and PM_{2.5}) Emission Trends

The main sources of particulate matter emissions in R. N. Macedonia are energy industries, residential heating and industrial processes [6]. In 1990, national total PM₁₀ emissions amounted to 48 kt. Since then, the emissions are continuously decreasing, reaching a level of 14,27 kt in 2018 or a decrease of 70% compared to 1990 (Figure 3). The main reason for the decrease are declining emissions from industrial processes (ferroalloys production), but also decreased use of solid fuels since 2013.

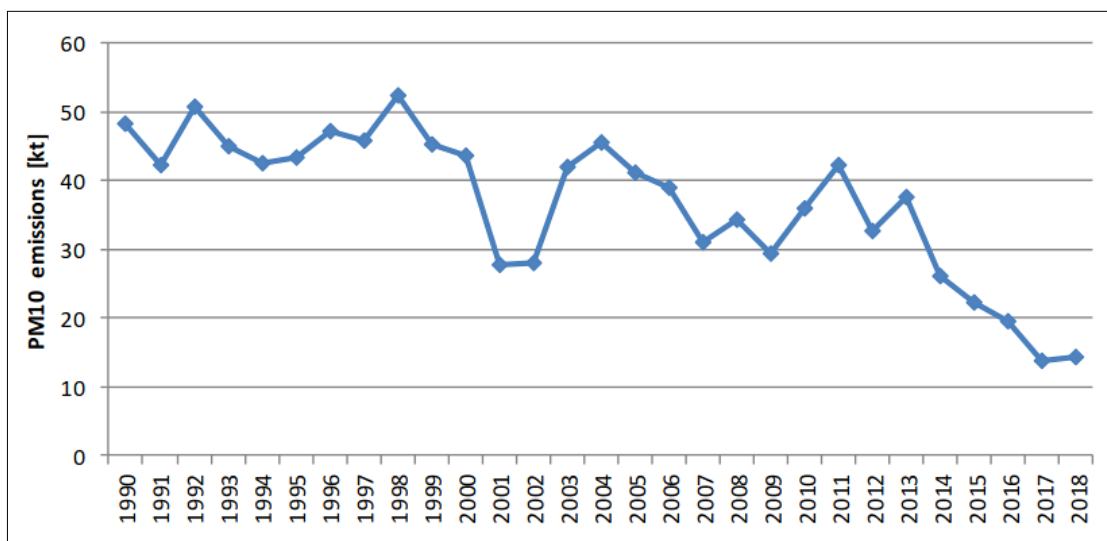


Figure 3. National total PM₁₀ emissions 1990-2018

The yearly trends of national emission of PM₁₀ and PM_{2.5} are similar, because emission sources are mainly the same. The main emission sources for PM₁₀ in 2018 are residential heating, with a share of 42% in the total PM₁₀ emissions, followed by energy industries with 24% and industrial processes and product use (mainly ferroalloys production) with 7% [6]. Agriculture sector contributes for 17% to the total PM₁₀ emissions. As a result, a conclusion can be drawn that while in the past the major source for PM₁₀ was the industry sector, in the latest years that is the fuel combustion in residential sector and administrative capacities.

Similar to PM₁₀, the main emission source for PM_{2.5} in 2018 was residential heating with a share of 68% in the total PM_{2.5} emissions. Energy industries share is 11% and the contribution of the industrial processes and product use (mainly ferroalloys production) is very low - only 5% [6]. Compared to PM₁₀, the contribution of residential heating is higher while the contribution from energy industries is lower.

Regarding the emissions from the transport, it should be noted that its share in the total emissions of particulate matter with 2017 calculations remained very low and is around 2% for PM₁₀, up to 3.5% for PM_{2.5} [4]. The share of transport in particulate emissions is expected to increase with the application of national emission factors for calculating braking emissions and friction emissions on car tires, but transport is not expected to become a key source of emissions of these pollutants [4]. This sector despite having a low share in the total emissions at national level has a significant impact on locally measured concentrations.

However, the fact remains that the dominant use of wood for heating households as well as the non-application of the best available emission reduction techniques in large thermal power plants contribute to these sources being the most dominant in particle emissions nationally [4].

Regardless of the decreasing trend of particulate matter emission, pollution caused by suspended particles is at high level and is spread all over urban areas in the country. The average annual values of PM₁₀ exceed the annual limit value (40 µg/m³) in all urban monitoring stations (except for the monitoring station located in the village Lazaropole), in every year since 2005 (Figure 4). The highest annual average values of PM₁₀ exceeding 120 µg/m³ are measured in Tetovo and Skopje (Lisice). The concentrations level stays stable in the whole period between 2005 and 2015. It is estimated that the average value of PM₁₀ at urban locations is approximately 80 µg/m³ [3].

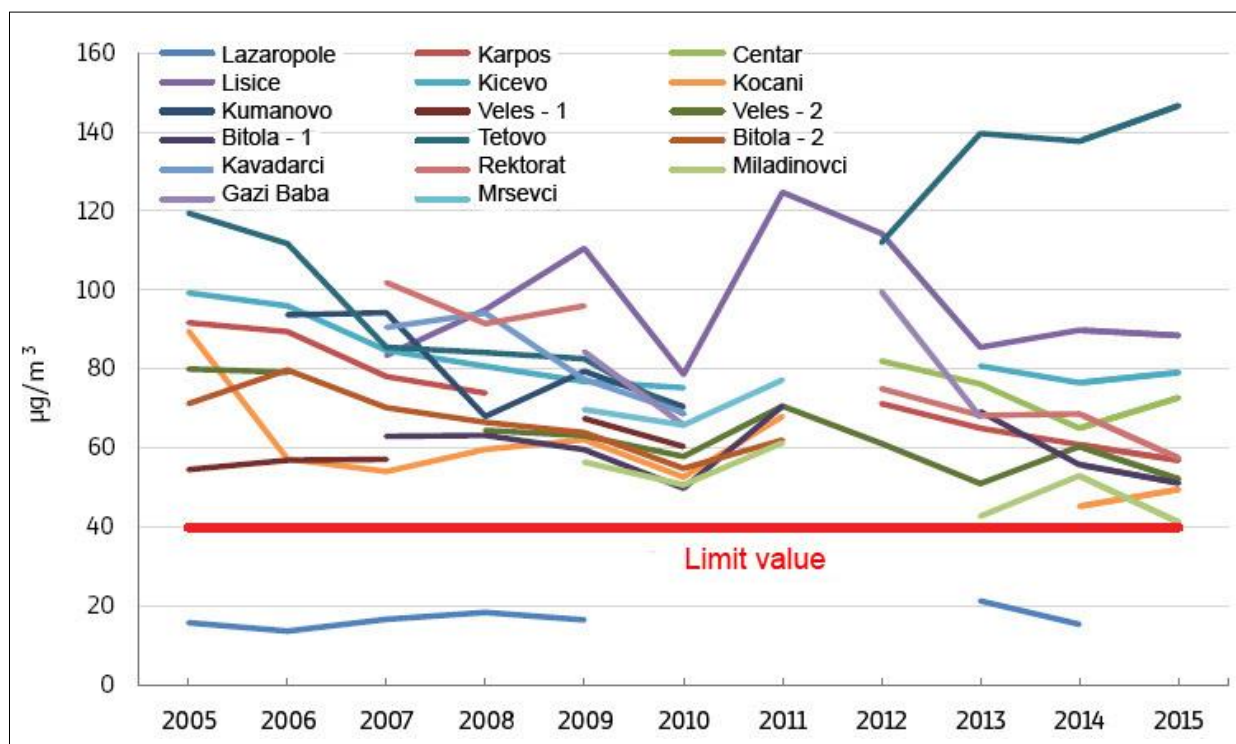


Figure 4. Average annual values of PM₁₀ for the period 2005-2015 [3]

The variations of the yearly emissions are mainly caused by the oscillations in industrial production or mild winters, when the need for households heating was decreased. Concentrations of PM₁₀ in urban areas have shown equal seasonal variations; concentrations are higher in the period December-January (Figure 5).

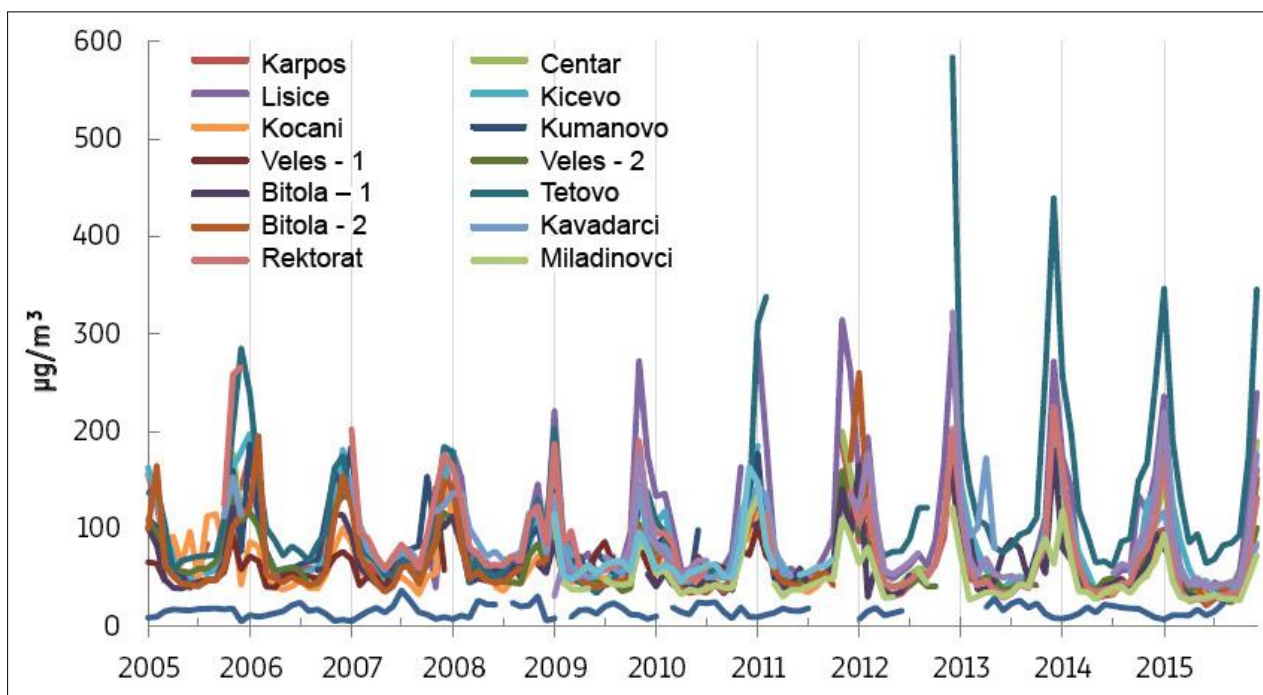


Figure 5. Average monthly values of PM₁₀ for the period 2005-2015 [3]

High PM₁₀ concentrations during the winter are connected with the higher direct emission (households heating, especially on wood), but also with the meteorological conditions which limit dispersion of the emission and alleviate the chemical reactions, creating secondary particles, for example, from the vehicle exhaust emissions [3]. During the winter months, smog appearance is typical in the towns settled in the valleys. To summarize: the concentrations of particulate matter are at the high level in every urban area in the country, with an average level of 80 µg/m³ exceeding by twice the annual limit value of 40 µg/m³.

2.3. Nitrogen Dioxide (NO₂) Emission Trends

The main sources of NO₂ emission are the high temperature heating processes (heating, energy production and fuel combustion in vehicle engines). The emissions are mainly in the form of NO, which is quickly transformed to NO₂ in the atmosphere. The total national NO_x emissions have reached around 45 kt in 1990. Since then an emission decrease of 59% has been observed. In 2018 emissions amounted around 18 kt (Figure 6). The causes for the emission drop are essentially to be found in the notable decrease of the emissions resulting of the energy sector (public electricity and heat production) and manufacturing industries.

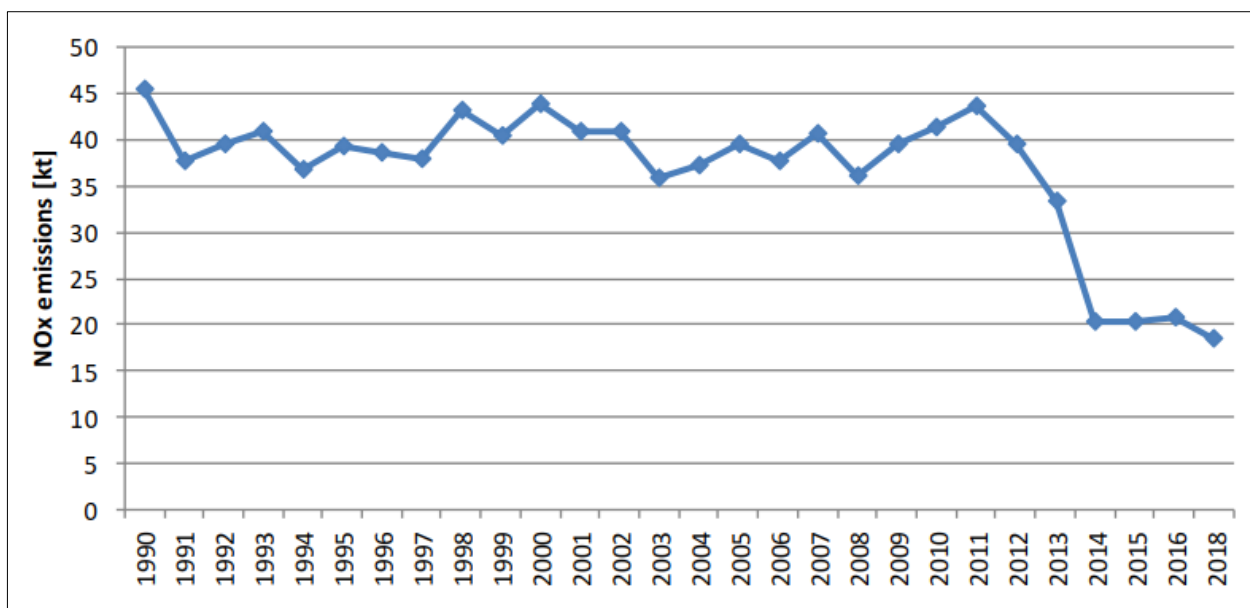


Figure 6. National total NO_x emissions 1990-2018 [6]

The target value for NO_x according to the Gothenburg Protocol for the year 2010 is 39 kt. Republic of North Macedonia which is party to the UNECE Gothenburg protocol since 2014 regularly meets that target value and starting from this year the emissions trend is stable. The country is also in compliance with the Protocol in controlling the nitrogen oxides or their trans-boundary fluxes, meaning that NO_x emissions in 2018 are less than the NO_x emissions reported for 1987 [6].

The leading sources of NO_x emissions in 2018 are transport and energy sector. Namely, energy industries, manufacturing industries and construction contributed with 21%, 28% and 24% respectively, of the national total NO_x emissions [6]. As a result of the vehicle number growth during the reporting period and the lower consumption of coal as well as oil, the primary source of emissions in 2018 is found to be transport, as opposed to 1990, when the energy sector and heat production were the largest source of emissions [6].

Transport shares in the total NO_x emissions are 30% [4]. The share of the transport in the total emissions of nitrogen oxides is lower in recent years (2014-2017) due to the application of calculation methodology at a higher second level (Tier 2), according to the EMEP / EEA guidelines. According to the data from the national emission inventory, nitrogen oxides emissions originating from transport in the past years have stayed at the same level. However, the appraisal of the trends of NO₂ concentrations is a challenge, because of the significant degree of insecurity and small coverage with monitoring data [3].

Monitoring of NO₂ concentrations is under serious impact of irregular maintenance and aging of the instruments; as a result, the time series are often without the continuity. In the first several years the yearly limit values of NO₂ were exceeded at all monitoring stations in Skopje and at the monitoring station in Kicevo (Figure 7). The highest concentrations of NO₂ are measured in the center of Skopje, near the frequent roads [3].

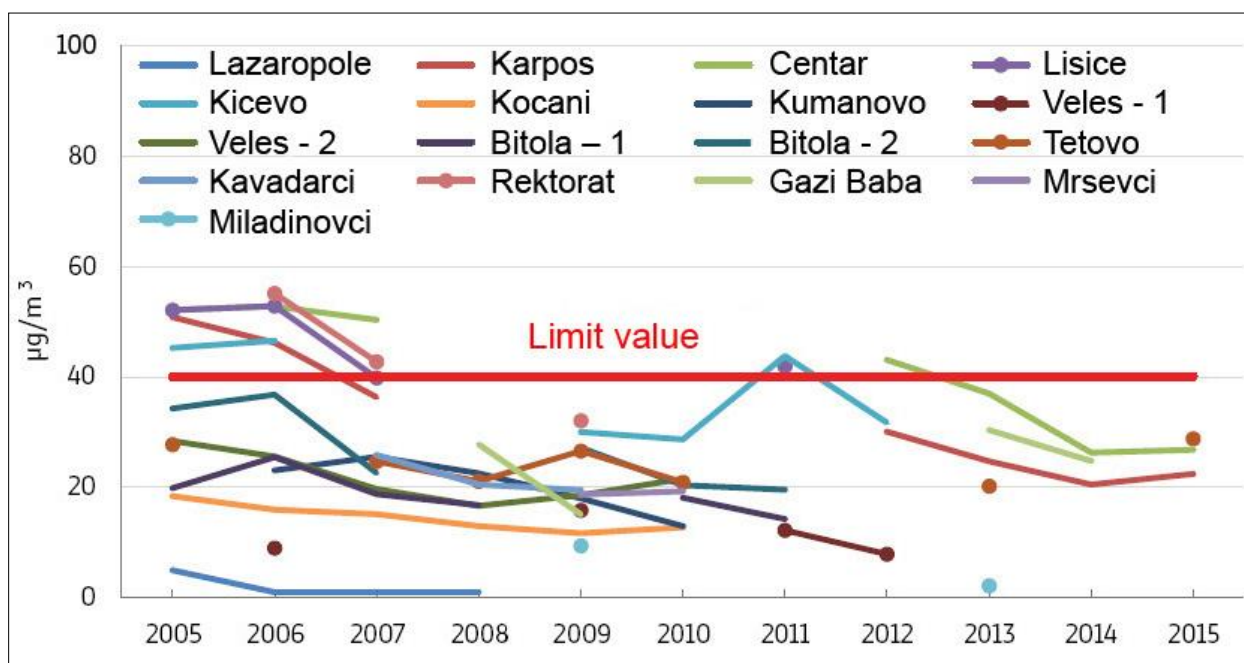


Figure 7. Average annual values of NO₂ concentrations [3]

In the last years, the limit value is not exceeded. Having in mind that monitoring results for NO₂ concentrations contain significant insecurity, it cannot be confirmed whether the limit values of NO₂ won't be exceeded in the future [3]. Hence, the instruments for NO₂ measurements should be regularly maintained in order to obtain credible data referring the concentration level. According to the measurements of air quality, there is a clear and equal seasonal variation of NO₂ concentrations, which may be linked with the meteorological conditions, i.e., unfavorable conditions for air mixing in winter time [3]. To summarize: yearly limit value of NO₂ is exceeded at the stations which follow traffic pollution; still, there is a future possibility for exceeding the NO₂ limit values. Road transport has the biggest influence on NO₂ concentrations, especially in the urban areas and near the frequent roads and crossroads.

2.4. The Current State: Planned and Undertaken Measures

According to the national legislation, measures for air quality improvement should be conducted when the pollutants' concentration limit values for health protection are exceeded [3]. As a reminder of the previous analysis, limit values for particulate matter are exceeded at the territory of the whole country.

For effective implementation of the measures defined in the National plan for ambient air protection (brought in 2012), several measures were conducted during 2013-2014 in energy sector, transport and production processes as key sectors for air pollution. At the same time, activities had been started for conducting the short-term and long-term measures, listed in this plan [7]. However, the list of the measures in this plan defined for road transport is very modest, considering that the attention has been given only at the:

- Legislation frame for support of the alternative fuels and other emission control technologies;
- Emission inventorying and
- Support for the public transport (without considering other sustainable modes).

In other national reports, such as Annual report for the quality in the environment for 2018, referring the road transport, measures that are listed for pollutants reduction include renewal of the national vehicle fleet, usage of clean fuels with low sulfur content (in accordance to the demands listed in the Book of rules for clean fuels quality), promotion of alternative transport, speed limitation (for decrease of fuel consumption) and introduction of low emission zones [8].

At the same time, the majority of the measures are conducted only in the capital city (the city of Skopje) because of the highest traffic (and population) intensity. For example: during the winter period a special traffic regime for high duty vehicles is introduced, using the ring-road to avoid the entrance in the city; for decreasing the road transport PM_{10} emissions, calcium magnesium acetate was put (although not continuously) on the surface of the major city streets, in order to reduce the dust concentrations from the road re-suspension; since 2013 the city of Skopje undertakes promotional campaigns and subsidies for improvement of the cycling, public transport and introduction of electric vehicles. Cycling network is continuously extended, and less-polluting buses (on compressed gas) are introduced in the public transport. Zonal parking is also in function. Other towns in R. N. Macedonia are lacking behind in comparison with these measures.

However, the gradual renewal of national vehicle fleet and orientation to the low emission vehicles is still not visible in the national emission assessment [3]. There are many factors which influence the renewal rate, such as economic situation in the country, legislation and regulations, transport subsidies, taxation of the new vehicles/different types of vehicles. Based on all this, the consumers decide when and what type of car to buy. The cheapest are imported used cars which are older and during their purchase, environmental impacts usually aren't deciding factor.

Similarly, in other national annual reports, measures are listed without going into detailed analysis or categorization [9]. For example, the following measures as effective measures for air pollution control in urban areas are just mentioned: public transport improvement in bigger areas, promotion of the usage of low emission vehicles, promotion of cycling, creation of the pedestrian zones and low emission zones, decreasing the impact of the road dust by improving the streets cleanness, especially in the dry periods. Further on, it is mentioned that a national regulation for emission control is needed, introducing the measures for vehicle fleet renewal and fuel quality control.

Hence, this type of approach for definition of measures and short or nonexistent elaboration of measures in annual reports was an impulsion for creating a categorized scheme of short-to-long time measures in road transport, containing five sub-categories. For in-depth analysis of the road transport impact on air pollution and definition of the measures, it is necessary that measures for traffic control, inspection/maintenance programs, demand management and development of transport policies should be also included. All these measures are aiming to the reduction and mitigation of air pollution contribution from road transport.

2.5. Guidance Approach: Proposal and Categorization of Measures in Road Transport

Development and implementation of reduction and mitigation measures for prevention of air quality decline is a necessity in order to provide an environmentally acceptable transport system [10]. It must be clear that measures in road transport should not be solely undertaken; it should be continuously worked at measures appropriate for other sources of pollution [1]. Hence, there cannot be any kind of separation in overall policy decision considering environment and transport sector.

Categorization of the reduction and mitigation measures in road transport is presented at Figure 8. The measures are categorized in two main groups: short/ medium- term measures and long-term measures. Then a sub-categorization in five groups was performed:

- Traffic control measures
- Inspection/maintenance program
- Transport policies

- Emission control technologies
- Demand management.

An essential component in the development and implementation process of these measures is cooperation between central and local governments, business sector, various agencies and non-governmental organizations, relevant stakeholders, but also with the citizens as well. For maintaining efficacious transport system without compromising environment or economy, it is recommended that all previously mentioned parties work closely and transparently and keep informed with any change in policy and decision making [2].

Creating policy changes in the transport and fuels sector is a precondition for achieving long-term optimality or effectiveness of measures undertaken for reduction of air pollution coming from transport [1]. Transport emission reduction and mitigation measures could be directed to the entire transport system or individual vehicle, affecting both at once [1]. For example, change in fuel price can immediately influence on the individual vehicle rate of usage and, over time, can effect on vehicle fleet structure.

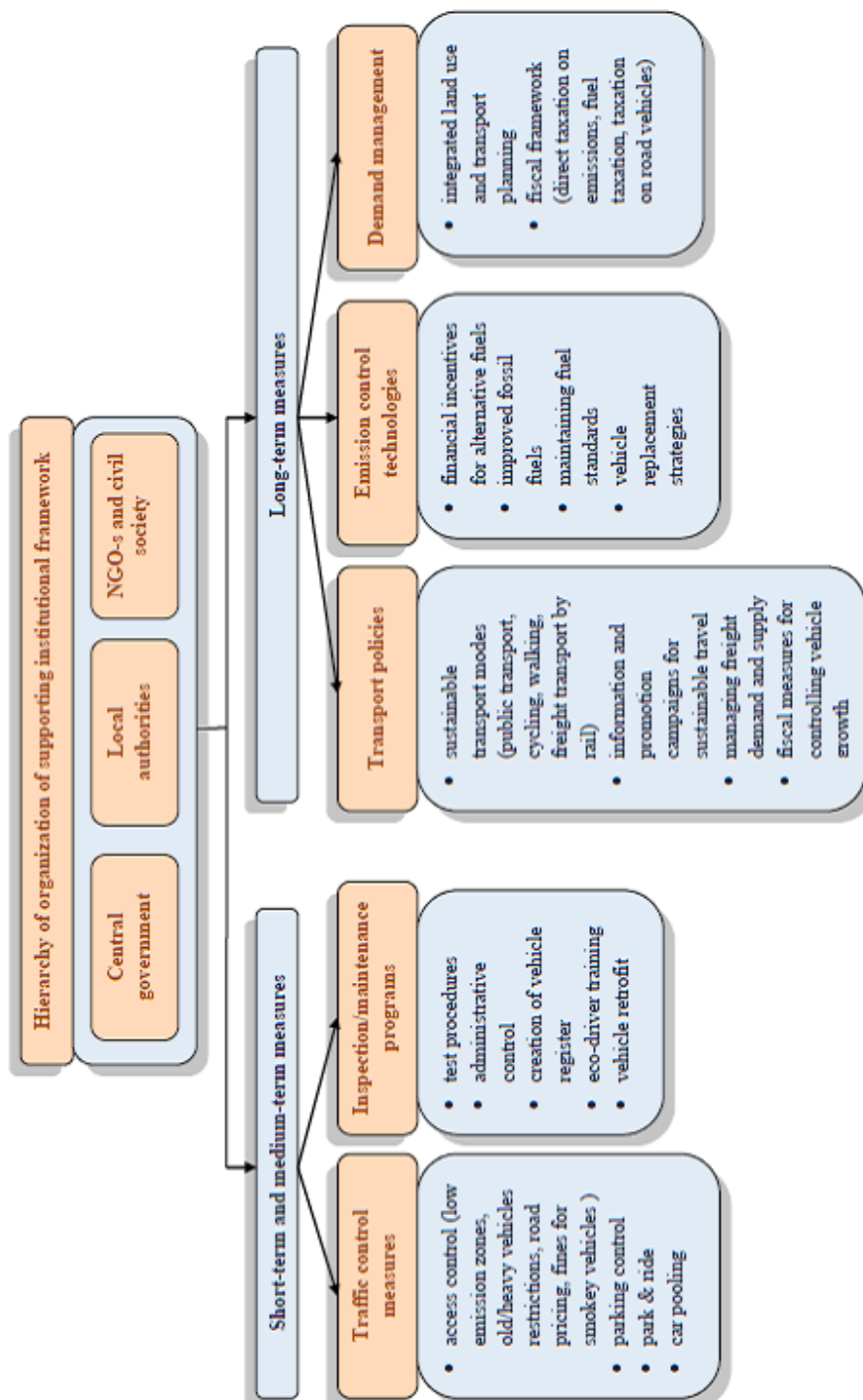


Figure 8. Scheme of the categorized measures in road transport for air pollution reduction and mitigation

There are many different opportunities for transport emission reduction, but for many of them, especially for the long-term measures, large investments for improvement of the transport network and infrastructure at local level would be needed [9]. The “most aggressive and bold” measures for reduction/mitigation of transport emissions should be implemented in urban areas with continuous air quality deterioration for which transport is a main pollution source.

2.6. Guidance for Air Quality Planning: Step by Step

Integration of several activities, as it is done in this guidance, has always been a challenge for air quality management [11]. At the same time, this integration is needed for selection and evaluation of measures for reduction of air pollution negative impacts. Air pollution control and management process is a complex task involving different institutional jurisdiction and obligations, shortages in human and technical resources, data unavailability and uncertainty, high public expectations, impossibility for delivering quick results [12]. This is highlighted to clarify that even though the guidance framework is not at the same level as air quality management system, a difficulties and obstacles when performing the step’s activities should be expected.

The current policies in our urban areas referring control of air pollution have been reduced only to urban monitoring systems and occasional introduction of measures without previous analysis. Hence, this guidance is useful for the authorities to support their efforts while undertaking measures to improve air quality. Correctly used, it can clarify the impacts of selected measures in road transport upon air quality.

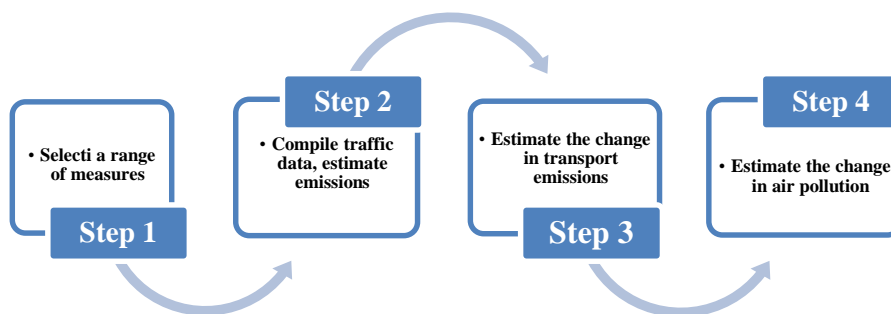


Figure 9. Guidance plan for air quality

The guiding criteria for the design were flexibility (meaning that the number of steps could be increased without mutual interference, for example, step for public information) and non-complicated usage that could provide solution that is both reliable and adequate.

Step 1: Select a range of measures

The range of measures should comprise not only the measures with the greatest and immediate impact, but also measures that are financially affordable and adaptable for the city/region considering behaviour of individuals [2]. It must be acknowledged that implementation of such selected measures comes with obstacles, considering the extent of the air pollution problem and advancement in severe conditions.

Step 2: Compile traffic data, estimate emissions

For the compilation of traffic data, first a selection of road links considering the following characteristics: representative road types, locations, traffic flow, classification by vehicle type and speed data should be performed. After that calculation of emissions can be conducted, based on previously compiled traffic data and other needed input data such as emission factors. The data should be regularly updated, available and in format that is easily manageable [12]. The results of the estimation process will specify the contribution that road transport, categorized by vehicle type has on the total air pollution.

Step 3: Estimate the change in transport emissions

Implementation of measures selected in Step 1 results with a changes in traffic flow characteristics (speed, density, volume), as well as changes in vehicle fleet structure and age. Therefore, new emission estimation should be conducted, considering changed input data. The result once again will provide the contribution that road transport, categorized by vehicle type has on the total air pollution.

Step 4: Estimate the change in air pollution

In this step dispersion modelling is performed in order to estimate the air pollution impact. The quality of the modelling process mainly depends of the quality of collected input data [13]. This kind of air quality modelling is complicated and it is recommended that performer has experience and expertise in dispersion modelling. Also, a good decision is that transport and air quality experts closely cooperate during this task. Modelling can help understand in

advance the effect of measure implementation [2]. Data analysis will provide several outputs: exceeding of the maximum allowed concentration level, number and frequency of exceeding and the highest level of pollutant concentrations [13]. The proposed guidance has operational framework relevant for the policy design, although the constraints imposed by human, technical and financial resources should be under serious consideration [14].

3. Discussion

3.1. Selecting Measures in Road Transport

Selected measures in road transport are causing different level of change which is best defined from intensity rate of application or their range. Understandably, measures that include low intensity actions or narrow range actions will not have major impact on transport emissions. However, if the analysis is from cumulative point of view, probably there is a right direction in the long term, which is difficult to determine and measure [2].

Hence, if only financially appropriate or inexpensive measures that at the same time are easy for implementation are considered, then the final result would be transport measures that are ineffective [2]. For triggering a measurable change usually large changes are needed, considering the significant background level of air pollution in urban areas.

Also, an opportunity exists for selection and implementation of measures at smaller intensity rate. Such measures could be defined as supporting measures, which could provide a complementary package approach. Very often the constructive cooperation between transport and air quality expert teams will result in a thorough analysis and change of ideas and information, needed for the selection of appropriate measures.

However, measures that are compulsory will certainly have higher positive impact in comparison to those measures that as only precondition they have are changes in the behaviour achieved educationally or through the encouragement [15].

3.2. Range of Measures

Local authorities and also organisations/agencies with legal responsibilities have wide range of available transport measures for dealing with air pollution problem. It is recommended to combine the selection of transport measures by mode with the goals noted below [2]:

REDUCE

Reduction of the number of travels could be achieved with effective urban planning, minimizing the need to drive or improving the attractiveness of alternatives to travel. Here, an attention also should be given to measures for reduction of total vehicle kilometres travelled in the areas where air quality is highly deteriorated.

SHIFT

Shifting of the journeys as many as possible should be directed toward non-motorised modes (walking or cycling) or toward sustainable transport modes (e.g. bus, light rail).

IMPROVE

Improvement of the emissions resulting from road transport journeys through:

- *Operational improvements*, e.g. priority lanes or driver training will influence on the way of usage of individual vehicle
- *Technical improvements*, comprising the vehicle retrofitting or replacement with low-emission vehicle.

3.3. The Effect of the Measures and Examples of Best Practices

Many measures can produce co-benefits, including improvements to the economy, congestion, noise, safety, urban realm, streetscape and individuals' physical activity [2].

Next, effects of several measures are elaborated.

Traffic management and measures for access control (e.g. vehicle restricted areas, low emission zones and parking management) are very effective in the reduction or removal of the vehicles as a source of air quality deterioration. In a combination with sustainable urban planning, their effect on urban life quality and economy is higher [16]. Their main lack is financial issue being expensive for implementation; apart of this, they are politically unpopular for being restrictive. Hence, a careful consultation and involvement is recommended for effective implementation. Sustainable solutions, availability of the resources and optimal measure design should be the basic considerations in the process of traffic management [17].

For the *introduction of low emission vehicles* subventions, labelling schemes, grants and other incentives could be used. For realization of the goals of this measure several obstacles must be overcome: lack of incentives, availability

of proper infrastructure, low awareness and misinformation of the consumers etc [18]. If the replacement of fossil fuel vehicles with low emission vehicle has wider range, the result could be significant emission reduction and improvement of air quality. However, the real effectiveness of this measure doesn't correspond with theoretical expectation, mostly because of the low prevalence and expensiveness of the clean vehicle technologies [16]. Additional disadvantage is their inability to contribute for wider benefits like congestion reduction or higher physical activity. The effect on air quality improvement also depends of their optimal design for making the wanted transition to clean mobility [19].

Demand management measures and measures to encourage shift to sustainable transport modes (walking, cycling, public transport) can be very cost effective and can contribute for numerous gains: congestion reduction, air quality improvement, reduction of carbon emissions, noise reduction [16]. A good approach is to manage both travel supply and demand management at the same time and to provide a balance between them [20]. Effects of some measures in this category, e.g. land use planning, regarding air quality could be felt over the long-term. Usually, it is very difficult to change travel behaviour and travel practices; as a help an additional approaches such as personalised travel planning and information could be used. For the demand management a route choice could be considered, together with the choice of trip destination. Also, support of information systems should be used for optimization of travel demand management in time and space [20].

Pricing mechanisms influencing both the vehicle purchase and vehicle usage can provide cost effective benefits. Introduction of this measure at national level should be carefully planned to avoid unintended social inequality [16]. At regional or local level design of the pricing mechanisms should prevent displacement of pollutant emissions occurring when drivers are using alternative urban routes in order to avoid road fees. Pricing contributes for reduction of travel demand using passenger cars [21], and hence can contribute for shift to more sustainable travel modes, such as walking, cycling and public transport.

Each one of the measures presented in the categorized scheme (Figure 8) has potential for emission reduction, but the effect on air quality improvement is greatest when several measures are integrated in one package [16]. For example, as a support of low emission zone where high polluting vehicles are banned, several complementary measures could be introduced: walking, cycling and public transport improvements; traffic management and pricing mechanisms (for example, for discouragement of zone peripheral parking); subventions for vehicle retrofitting or purchase of clean vehicle. With appropriate design, integrated package of measures not only contributes for emission reduction, but also for other benefits such as climate change mitigation, noise reduction, congestion alleviation and economic development [16].

Examples of best practices

Different studies provide numerous examples of best practices already implemented in the cities and regions worldwide. The main measures with proven effect are [22]:

- Low emission zones;
- Long term strategies to promote and support bicycling;
- Urban and spatial planning, e.g., public space redistribution;
- Parking management;
- Public transport promotion;
- Tax schemes for discouragement of diesel vehicles;
- Congestion fee.

3.4. Monitoring and Reporting Outcomes

Implementation of measures by themselves isn't enough when reporting the improvements of air quality. It is necessary the implementation process to be continuously tracked and impacts of the measures to be estimated when possibility and feasibility as preconditions are enabled. Monitoring the air quality is a necessary step for control of air pollution levels and may support the proper and timely decision referring selection and implementation of the measures [23].

Reporting on the regular basis should be performed by local authorities to the relevant ministry regarding activities undertaken for air quality management. The ministry should review progress reports and should use their results or conclusions as a ground for conduction of the national progress reports towards national air quality standards and the EC limit values.

It's important to provide resource equipment and developed skills at both the public and private institutions which

can serve not just for support of the reduction/mitigation measures of transport emissions, but also for evaluation of measure effectiveness [24]. Cost-effectiveness and affordability of resources is highly appreciated considering the economic shortcomings in developing cities.

3.5. Urban Air Quality Guidance: Application Possibilities

The urban air quality guidance with its integrated activities provides knowledge and insights of the potential effects that measures have on air quality improvement and the quantity of avoided damage. Hence, this guidance frame is an opportunity local authorities to start evaluate the effects of undertaken improvements in air quality planning. The ultimate goal of the guidance is to support future implementation of air quality planning and management system.

Proposed air quality guidance can also be used by a broader range of users, including transport and urban planners and every institution engaged in the policy making process and air pollution management. In the core of every decision are valid information, and in that context and considering also the current situation in the country, the proposed guidance is a big advance towards the improvement of the process for air pollution control.

Properly used, the guidance can contribute for control of road transport as a source of air pollution, providing the impact assessment of undertaken and planned measures on air quality. Hence, it could facilitate the accomplishment of the authorities' legal obligation to provide clean air. The higher contribution of the guidance would be policy making for urban air protection, as well as design of local/national pollution control strategies, both optimal and cost-efficient.

4. Conclusion

Air pollution in R. N. Macedonia is very serious problem in urban areas and a growing concern. Road transport is one of the main air pollution sources. Analyzing the pollution trends from road transport, it could be confirmed that this sector has significant contribution, especially in nitrogen dioxides emission. For PM_{10} and $PM_{2.5}$ the contribution from road transport is not very high, but including other sources, pollution with particulate matter is a very serious problem for the whole country.

Polluted air has a serious pressure on urban life quality and researching and investing in appropriate reduction/mitigation measures is a necessary starting point. National reports and plans don't provide comprehensive analysis referring measures appropriate for every pollution source, including road transport. To overcome this gap and to provide a clearly defined direction for decision makers to start dealing with air pollution problem the paper provides a categorized scheme of measures for reduction/mitigation of road transport emissions. Presented scheme of short-to-long term measures is detailed and comprises five subcategories including: traffic control, inspection/maintenance program, transport policies, emission control technologies and demand management. Proposed emission reduction and mitigation measures could be directed to the entire transport system or individual vehicle, affecting both at once. It should be also considered that higher potential and better results in decreasing air pollution are accomplished when several measures are integrated in one package.

The analysis was further extended considering that measure selection and implementation whether individually or in a combined form isn't enough for problem solving. The complexity of air pollution problem and absence of whatsoever activity for air quality management and control imposed the necessity for designing the urban air quality guidance. The organizational structure of the guidance is based on categorization of measures and consists of four steps: selection of measures aimed for protection of air pollution adverse effects, assessment of transport emissions, assessment of the changes in transport emissions, assessment of the changes in air pollution.

The designed and proposed guidance allows selection of the suitable measure for air pollution reduction/mitigation and evaluation of its effects. This guidance is an integrated approach for improving air quality in urban areas and has a potential to influence on the air pollution level of toxic emissions. Hence, the guidance provides additional support and assistance to the local policy and decision makers for more careful consideration and planning of air quality issues coming from road transport in urban areas.

5. Declarations

5.1. Data Availability Statement

The main data sources used for the analysis of air quality problem and road transport contribution were national plans and annual reports for air quality, prepared by the Macedonian Environmental Information Centre at the Ministry of Environment and Physical Planning and by the State Statistics Office of the R.N.M.

5.2. Funding

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5.3. Conflicts of Interest

The authors declare no conflict of interest.

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