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Quantitative evaluation of air pollution in transport strategic environmental assessment: a case study based on uncertainty analysis and graphic information system technology*

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Abstract: Although the impact of road transport on urban air quality has achieved a high profile in China, still greater attention is required as it has not yet been considered fully even in relation to the road network linking cities and urban areas. Strategic environmental assessment (SEA) is a systematic and comprehensive process for evaluating the environmental impacts of a policy, plan or program in publicly accountable decision-making. Air pollution has been recognized as a significant issue in most transport SEA practices. The Strategic Environmental Assessment of the Hubei Road Network Plan (2002–2020) (HRNP) was introduced as one of the World Bank's pilot SEA projects. An effective framework was developed to investigate the functional relationship between the road network and its potential air pollutant emissions. In this study, two indicators were identified: emission intensity/inventory of pollutants and the spatial distribution of the most polluted areas. Because strategic actions are inherently nebulous and data quality is often disappointing, three alternative scenarios were employed to address uncertainties and data/scale issues. Calculations were made using emission models and results were analyzed with the help of statistical tools and the geographic information system (GIS). The results from the project implementation and the feedback from the World Bank have both shown that the proposed framework is effective in the transport SEA process.

Key words: Air pollution, Transport strategic environmental assessment (SEA), Quantitative evaluation, Uncertainty
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1 Background

China is experiencing rapid urbanization, industrial development and infrastructure construction. In the transport sectors, the importance of infrastructure to societal development triggers more and more road construction projects and underpins transport development plans, policies and programs (PPPs). Most provinces and many cities in China have prepared transport development strategies (e.g., road network plans) to guide specific future projects. These proposed activities will contribute to more serious potential pollution problems if few environmental considerations are taken into account. Also, road transport is widely recognized as one of the most significant anthropogenic sources of air pollution. This is not only because of the magnitude of its emissions, but also because automobile exhaust pollutants are emitted in close proximity to people, thus increasing exposure levels (Ahrens, 2003; Lim, 2005; Jonsson and Johansson, 2006; Rutherford and Leonard, 2008; Smit *et al.*, 2008).

To achieve coordinated development of the economy, society and the environment, strategic environmental assessment (SEA) has been introduced into China to make economic growth more environmentally friendly (Chen, 2005). SEA can be defined as the formalized, systematic and comprehensive process of evaluating the environmental impacts of a

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policy, plan or program and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision-making (Therivel *et al.*, 1992; Therivel, 2004). SEA has been widely accepted as being an effective tool for evaluating the impact of development PPPs at the early stages of the overall planning process (Tonk and Verheem, 2000; Bina, 2001; Fischer, 2003). In 2002, China promulgated legal requirements for SEA with the adoption of the Environmental Impact Assessment Law of the People's Republic of China (the EIA Law). Implemented in China in 2003, the EIA Law required plans that have potential significant environmental effects to undergo environmental impact assessment. Although SEA has a legal foundation in China, the EIA Law does not cover the whole range of strategic PPPs.

When it comes to large scale and long-term plans and policies, in China, both data availability and data quality are disappointing, so 'data-hungry techniques' would be relied on for most SEAs. As for a road network plan, most transport SEA practices consider air pollution as a significant issue and the screening of air quality as an important indicator (Bai *et al.*, 2004; OECD, 2004; Donnelly *et al.*, 2007). However, the relationship between potential transport emissions and the resulting concentrations is by no means simple (Costabile and Allegrini, 2008). It is critical but difficult for decision-makers and SEA practitioners to evaluate or forecast the impacts of automobile exhaust pollutants on air quality (Fischer, 2002). To make a transport SEA more effective, researchers urgently need to develop more flexible approaches for linking transport emissions and air quality (Fischer, 2004). With the help of scenario analysis for addressing the problems of missing data and uncertainties, this paper introduces a quantitative evaluation of air pollution as part of a pilot study in China—the Strategic Environmental Assessment of the Hubei Road Network Plan (2002–2020) (HRNP), supported by the World Bank.

2 Overview of the strategic environmental assessment for the Hubei Road Network Plan (2002–2020)

Located in central China, Hubei has an area of 185 900 km^2 (similar in size to Syria or about twice the size of South Korea) and has a central location in the transportation system (Fig. 1). It is at the crossroad of the north-south axis of the Beijing-Guangzhou link and the east-west axis of the Shanghai-Chengdu link. To improve economic and transport development, the HRNP 2002–2020 was completed in 2004 and approved by the provincial government at the end of that year. As a typical road network plan, it consists of "6-longitudinal, 5-latitudinal and 1-loop" roads (abbreviated as the "651" road network), and some branches as connecting roads. The total length of the "651" road

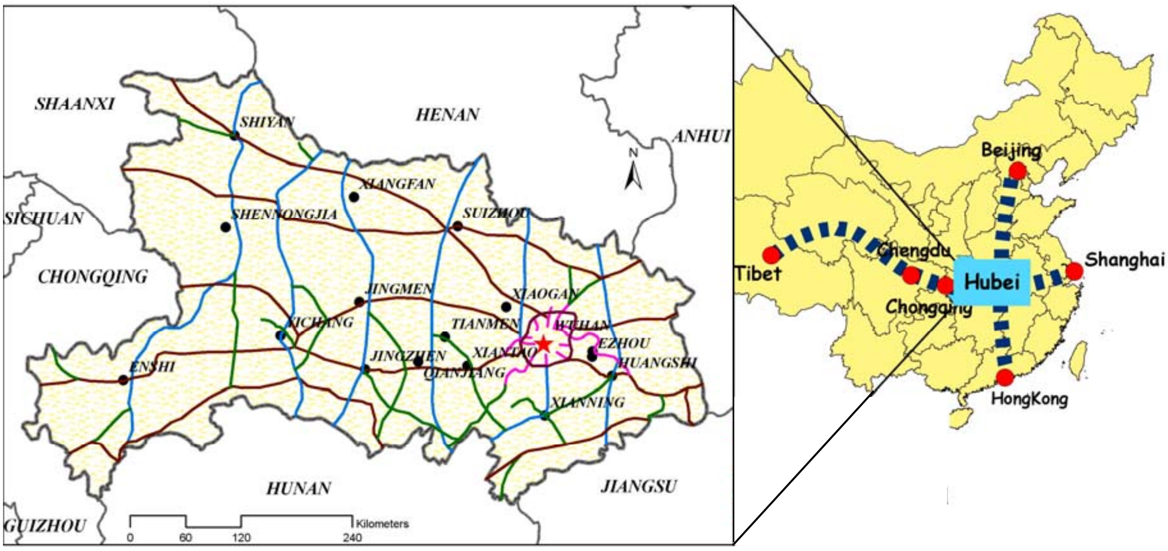

Fig. 1 Location of Hubei Province and the Hubei Road Network Plan (HRNP)

network will be up to 7350 km, including 5000 km of expressways and 2350 km of classes I and II highways.

Core procedural elements in a typical SEA process in China include the following stages: screening, scoping, impact assessment/forecasting, monitoring and public participation (Partidario, 2000; Fischer, 2006; Fahy and Cinneide, 2008). The screening stage is used to determine if an SEA is needed and, if so, what type of SEA should be carried out. At the scoping stage, the likely extent (geographic, temporal and thematic) and the level of detail required in the assessment are determined, baseline information is collected, and environmental problems are identified. The assessment/forecasting stage is key for the SEA process and should be sufficiently robust and transparent to convince stakeholders and the public that the results are as reliable as possible. Developing strategic alternatives and predicting/evaluating the effects, and proposing reasonable measures to avoid and minimize adverse impacts are also performed at this stage.

According to the EIA Law in China, for integrated plans “one land, three-area plan” (short form of “land-use planning, construction and development plans for regional, river basin and sea areas plans”; special plan includes: industry, agriculture, stockbreeding, forestry, energy, water management, transport, city construction, tourism and development of natural resources plan), an SEA should be conducted during the planning and preparation phase. For special plans with more detailed standards and requirements (e.g., sector plans), an SEA should be conducted after a draft plan has been prepared and completed but prior to submission of the plan for review and approval. After the transport plan for HRNP was completed and approved, the SEA (Fig. 2) was carried out by ECON Pöyry (Norway) and the SEA Centre of Nankai University (China) with the support of the World Bank. There are some differences between the terms of reference (ToR) for SEA provided by the World Bank and the requirements of the EIA Law and relevant EIA plan guidelines. Thus, this SEA is an example of an ‘international SEA’ and includes some new ideas on how to conduct an SEA in China. Both consultants decided to take air pollutant emissions as one of the key issues based on the results of impact identification, the opinions of stakeholders and the applicability of assessment methods.

3 Evaluation process for air quality

The framework of evaluation for air pollution in this transport SEA is shown in Fig. 3. The key pollutant and its spatial extension are identified first based on an analysis of the plan. Then appropriate methods (e.g., scenario analysis) are used to address uncertainties. Data gathered and produced are processed to meet the emission models. Taking the road users into account, the SEA identifies the instantaneous emission intensity and inventory of the automobile exhaust pollutants on a certain road section and the spatial distribution of the most polluted areas. This focus is necessary for two reasons: (1) an SEA is supposed to evaluate environmental issues from a strategic viewpoint and (2) more detailed data and technologies are often unavailable. In this study, the emission intensity was calculated based on a statistical tool and the spatial distribution of pollution was determined using the Geographic Information System (GIS). Finally, some mitigation measures were also proposed.

3.1 Identifying the objectives

Empirical evidence has shown that there are two types of air pollution caused by road transport: (1) air pollutants like dust and asphalt smoke (which are temporary and restorable), produced in the construction phase; and (2) automobile exhaust pollution including key air pollutants produced mainly in the operating phase, which is the key issue of this SEA. Clearly, environmental impacts from transport vary in terms of their spatial extension, ranging from global to local (Fischer, 2006).

Based on the opinions of stakeholders, availability of data and applicability of assessment methods, (1) two years were selected for forecasting, 2010 (short-term) and 2020 (long-term), and (2) the air pollution assessment was divided into two parts, including not only the emission intensity of key air pollutants, but also an inventory of greenhouse gases caused by the HRNP. The key issues of air pollution assessment were then identified (Table 1).

Table 1 Scoping of air assessment

Priorities	Key issues
Air	CO, NO_x emission intensities in the road network
Climate factors	Greenhouse gas emission in the road network

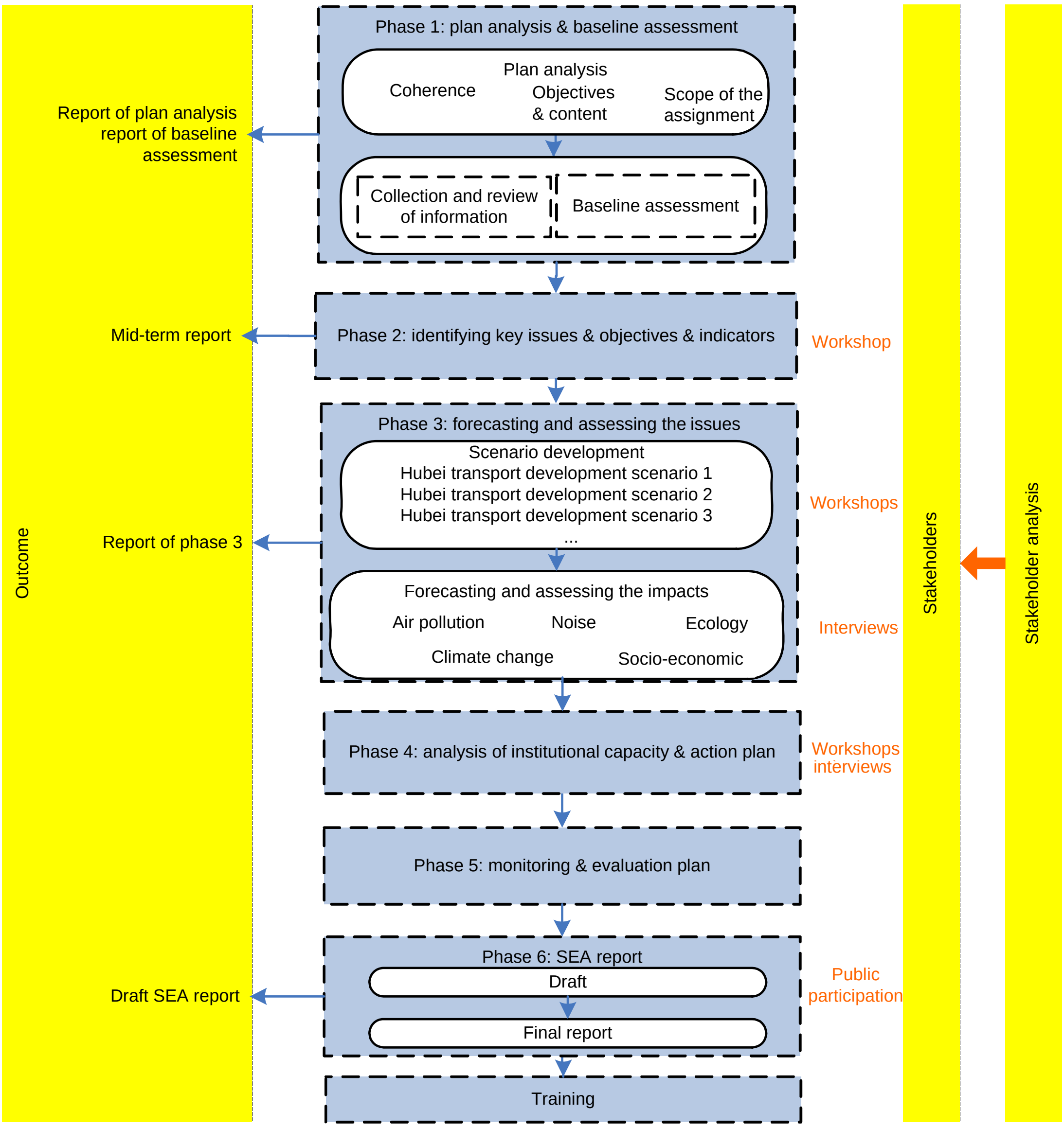

Fig. 2 SEA process for HRNP

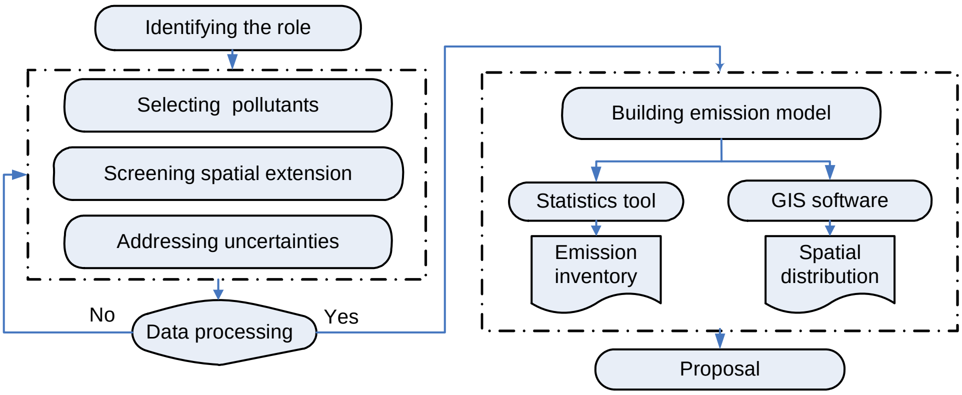

Fig. 3 Framework of evaluation process

3.2 Screening the spatial extension

The spatial extension of impacts for a certain pollutant is determined by its inherent attributes and the environment such as the meteorological status (Mediavilla-Sahagún and ApSimon, 2006; Joao, 2007; Ozden *et al.*, 2008).

As for the greenhouse gases, such as CO_2, CH_4 and N_2O, the global concentration is of interest regardless of the instantaneous meteorological status, so total emission inventories are valuable in providing an estimate of the contribution of transport to air pollution compared with other activities (Faiz, 1993).

The spatial distribution of other air pollutants, especially automobile exhaust pollutants such as CO and NO_x is quite different. Road transport differs from other sources of air pollution in that its emissions are released in very close proximity to human receptors. This reduces the opportunity for the atmosphere to dilute the emissions and render them less likely to damage human health (Jantunen *et al.*, 1998). But as network plans often cover national or regional areas, most major roads would be considered as links between central cities and consequently located away form urban areas. The distribution of human receptors is difficult to identify and necessary meteorological data are often unavailable. Besides, there may be relatively few inhabitants alongside these roads. However, the negative impacts of automobile exhaust pollutants on the road users should be considered. So the issue of spatial extension for a road network plan related to SEAs needs further consideration. It is widely accepted that in most cases, most emissions occur at the time and place of transport use (Colvile *et al.*, 2001) and the pollutants are localized temporarily on the road surface. Based on the assumption that there are many sheltering structures with absolute steady meteorological status (This assumption is reasonable and feasible for: (1) The most effective SEA practice should keep to the maximal probability principle to forecast pollution issues and (2) The so-called shelters are in fact common, maybe more and more widely in the future, in the form of the sound barriers and ecological sight), such as trees and buildings, alongside the roads, the air pollution emission intensity on a certain road surface during road use and the spatial distribution of the most polluted areas were adopted as indicators of pollution in this study.

3.3 Addressing uncertainties

To address the uncertainties in a network plan of such great spatial and temporal scale, three different future scenarios were considered (Bartlett and Brunstad, 2006; Duinker and Grelg, 2007), taking account of the following factors: (a) Changing social and economic trends; (b) Different environmental policies in the next decade related to transport and their effects on transport development; (c) Development and use of technologies related to transport which allow greater eco-efficiency; (d) The traffic demand of the proposed road network; (e) The emission intensity of air pollutants and the amount of greenhouse gas emissions.

Scenario A: Open Hubei—fast development of the economy with few changes in environmental protection from transportation;

Scenario B: Relatively Slow Development—relatively slow economic growth, while environmental protection from transportation remains at the same level as in Scenario A;

Scenario C: Focus on Environmental Protection—great progress in environmental protection and relatively slow economic growth.

The technical approach for building transport development scenarios in this SEA is shown in Fig. 4. Within each scenario we examined the consequences on the environment of different sets of plausible drivers: socio-economic development, urban development, transportation, technologies, energy policy, environmental management and others, all of which were determined after face-to-face consultations with stakeholders.

The SEA aimed to identify and forecast the likely effects on the environment caused by the HRNP in different transport development scenarios, to analyze plausible problems and pollutants and to provide suggestions for decision-making in Hubei regarding socio-economic, transportational, environmental and other aspects.

3.4 Processing data

Based on the identification of important issues, including the key pollutants and the method for addressing uncertainties, data collection should be straightforward. However, difficulties stem from two complications: (1) there are indeed no or few existing data about certain issues, and resource restrictions and

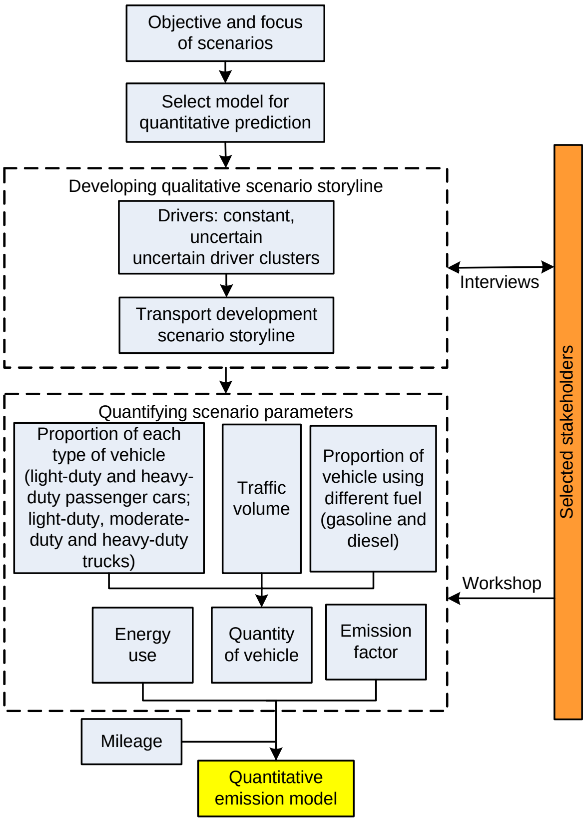

Fig. 4 Technical flowchart for scenario analysis

decision-making deadlines limit the amount of data that can be collected; (2) There are plenty of existing data but they are of low quality. These data are kept by different sectors having preferences for different scales. In this context, data abuse is possible.

In this SEA, traffic volumes in both 2010 and 2020 had been predicted and listed in the HRNP for each road section among the main cities in Hubei. The traffic volume of a particular road corridor in each scenario was adjusted according to the predicted traffic volume. The distribution of vehicle types, including light-duty passenger cars, heavy-duty buses, and light, medium, and heavy-duty trucks, was set under different assumptions for economic and transportation development (Table 2). Pollutant discharge coefficients (Table 3) (data about pollutant discharge coefficients for other vehicle types are not presented. Please contact authors for details through seacenter@nankai.edu.cn and baiht@nankai.edu.cn) and ratios of vehicles for fuel consumption (Table 4) were selected on the basis of social-economic development and transportation, as well as technology innovations and environmental management measures.

3.5 Building an emission model

The emission intensity and inventory are affected by the traffic volume, ratio of vehicle types, pollutant discharge coefficient, ratio of vehicles using different fuels (gasoline or diesel oil), and fuel consumption (Sokhi *et al.*, 2008; Sturm *et al.*, 2003; Solazzo *et al.*, 2009). The calculation of the intensity of a certain air pollutant emission is described below. The total inventory can also be obtained by consideration of the road length and use time.

Air pollutant emissions can be divided in two parts according to the fuel: gasoline-powered motor vehicles and diesel-powered motor vehicles.

$$P = P_\mathrm{g} + P_\mathrm{d}, \qquad (1)$$

where P is the intensity of air pollutant emission on a certain road section (t/km). P_g and P_d refer to the intensity of air pollutant emission from gasoline-powered motor vehicles and diesel-powered motor vehicles, respectively, on a certain road section (t/km). Eq. (1) is applicable to any situation in transport development.

As for P_g and P_d, several parameters, such as the number of motor vehicles, emission factors and fuel consumption, would be employed using Eqs. (2) and (3).

$$P_\mathrm{g} = \sum A_{\mathrm{g}i} \cdot E_{\mathrm{g}i} \cdot L_{\mathrm{g}i} \cdot \rho_\mathrm{g} \times 10^{-11}, \qquad (2)$$

where $A_{\mathrm{g}i}$ is the number of gasoline-powered motor vehicles of type i (vehicle), $E_{\mathrm{g}i}$ is the emission factor of the air pollutant from gasoline-powered motor vehicles of type i (g/kg fuel), $L_{\mathrm{g}i}$ is fuel consumption per 100 km of gasoline-powered motor vehicles of type i (L/100 km vehicle) and ρ_g is the density of gasoline (747 kg/m^3).

$$P_\mathrm{d} = \sum A_{\mathrm{d}i} \cdot E_{\mathrm{d}i} \cdot L_{\mathrm{d}i} \cdot \rho_\mathrm{d} \times 10^{-11}, \qquad (3)$$

where $A_{\mathrm{d}i}$ is the number of diesel-powered motor vehicles of type i (vehicle), $E_{\mathrm{d}i}$ is the emission factor of the air pollutant from diesel-powered motor vehicles of type i (g/kg fuel), $L_{\mathrm{d}i}$ is the fuel consumption per 100 km of diesel-powered motor vehicles of type i (L/100 km vehicle) and ρ_d is the density of diesel oil (840 kg/m^3).

Table 2 Adjusted traffic volumes and distribution of vehicle types

Scenario	Year	GDP growth rate (%)	Distribution of vehicle types (%)				
			Passenger cars		Trucks		
			Light-duty	Heavy-duty	Light-duty	Medium-duty	Heavy-duty
A	2010	14	6.00	34.00	6.00	27.00	27.00
	2020	12	11.25	33.75	5.50	27.50	22.00
B	2010	10	3.00	27.00	8.40	29.40	32.20
	2020	9	5.25	29.75	6.50	29.25	29.25
C	2010	8	2.80	32.20	6.50	26.00	32.50
	2020	7	4.00	36.00	6.00	25.20	28.80

Table 3 Pollutant discharge coefficients for light-duty passenger cars

Scenario	Year	Fuel consumption (L/100 km)		Pollutant discharge coefficients (g/kg)									
				CO		NO_x		CO_2		CH_4		N_2O	
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
A	2010	14.00	12.00	57.93	6.04	4.55	6.62	3172.31	3172.31	0.37	0.12	1.810	0.14
	2020	11.50	10.50	45.92	7.35	4.67	6.88	3172.31	3172.31	0.28	0.08	1.890	0.13
B	2010	15.00	13.00	57.93	6.04	4.55	6.62	3172.31	3172.31	0.37	0.12	1.810	0.14
	2020	12.05	10.50	45.92	7.35	4.67	6.88	3172.31	3172.31	0.28	0.08	1.892	0.13
C	2010	14.00	12.00	45.92	7.35	4.67	6.88	3172.31	3172.31	0.28	0.08	1.892	0.13
	2020	10.50	9.50	38.96	7.54	3.07	5.68	3172.31	3172.31	0.25	0.06	0.453	0.09

Table 4 Ratios of vehicles powered by different fuels

Scenario	Year	Ratio of vehicles powered by different fuels									
		Light-duty cars		Heavy-duty buses		Light-duty trucks		Medium-duty trucks		Heavy-duty trucks	
		Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
A	2010	1.00	0	0.13	0.87	0.97	0.03	0.10	0.90	0	1.00
	2020	0.95	0.05	0.08	0.92	0.90	0.10	0.05	0.95	0	1.00
B	2010	1.00	0	0.13	0.87	0.98	0.02	0.11	0.89	0	1.00
	2020	0.98	0.02	0.10	0.90	0.92	0.08	0.08	0.92	0	1.00
C	2010	0.95	0.05	0.10	0.90	0.90	0.10	0.05	0.95	0	1.00
	2020	0.80	0.20	0	1.00	0.80	0.20	0	1.00	0	1.00

$$T_{\mathrm{GHG}} = \sum_j P_j \cdot l_j , \qquad (4)$$

where T_{GHG} is the total emission inventories for greenhouse gases (t), P_j is the intensity of greenhouse gases emission on a certain road section of j (t/km), and l_j is the length of a certain road section of j (km).

Based on the emission intensity results of each road section, quantitative statistics tools, including Microsoft Office Excel and MatLab, were used to analyze the characteristics of the data clusters (maximum intensity, growth rate, etc.). The spatial distribution of the pollution was given simply by ArcGIS9. The results provide a basis for scientific proposals including mitigation measures.

3.6 Quantitative assessment

3.6.1 Emissions of key air pollutants

The predicted emissions of key pollutants in 2010 and 2020 for each road section under the three scenarios are presented in Figs. 5–8.

For the ‘Open Hubei’ scenario (Scenario A), the CO emission intensities in 2010 in most roads are less than 0.20 t/(km·d), except for nine highway sections concentrated mainly in the regions of the Wuhan City Circle and areas on the Jianghan Plain around Jingzhou and Yichang. Most road sections have NO_x emission intensities of less than 0.1 t/(km·d), with a similar distribution of CO. By 2020, emission intensities of both CO and NO_x are much higher than those in 2010, and the pollution of NO_x is more serious. The geographic distribution of both emissions tends to cover all the sections.

Under the assumption of relatively slow economic development (Scenario B), the CO emission intensities in most road sections are lower than 0.10 t/(km·d). However, it is predicted that the emission intensity will rise significantly from 2010 to 2020,

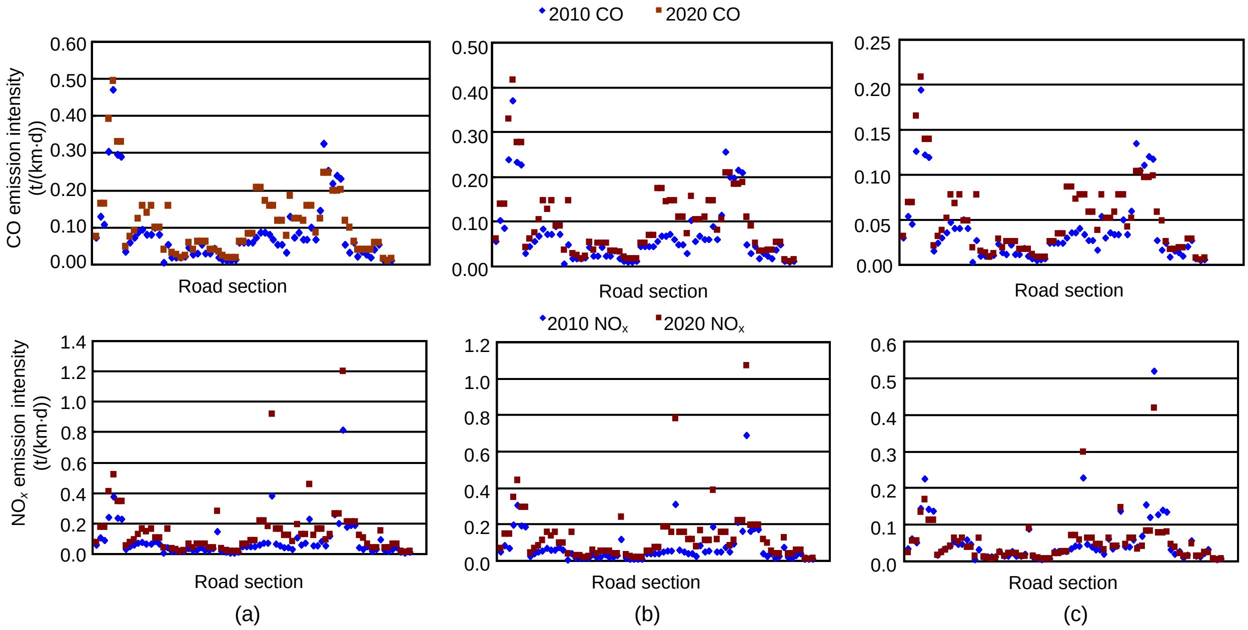

Fig. 5 Results for CO and NO_x emission intensities in different scenarios. (a) Open Hubei (Scenario A); (b) Relative slow development (Scenario B); (c) Focus on environmental protection (Scenario C)

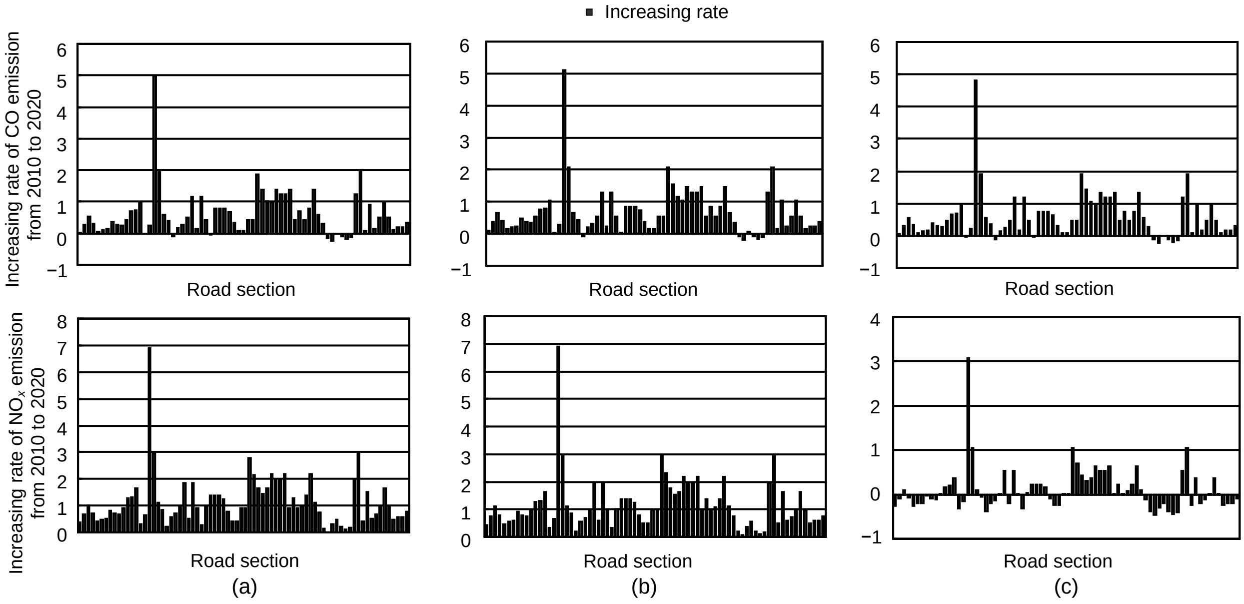

Fig. 6 Increasing rates of CO and NO_x emission intensities in different scenarios. (a) Open Hubei (Scenario A); (b) Relative slow development (Scenario B); (c) Focus on environmental protection (Scenario C)

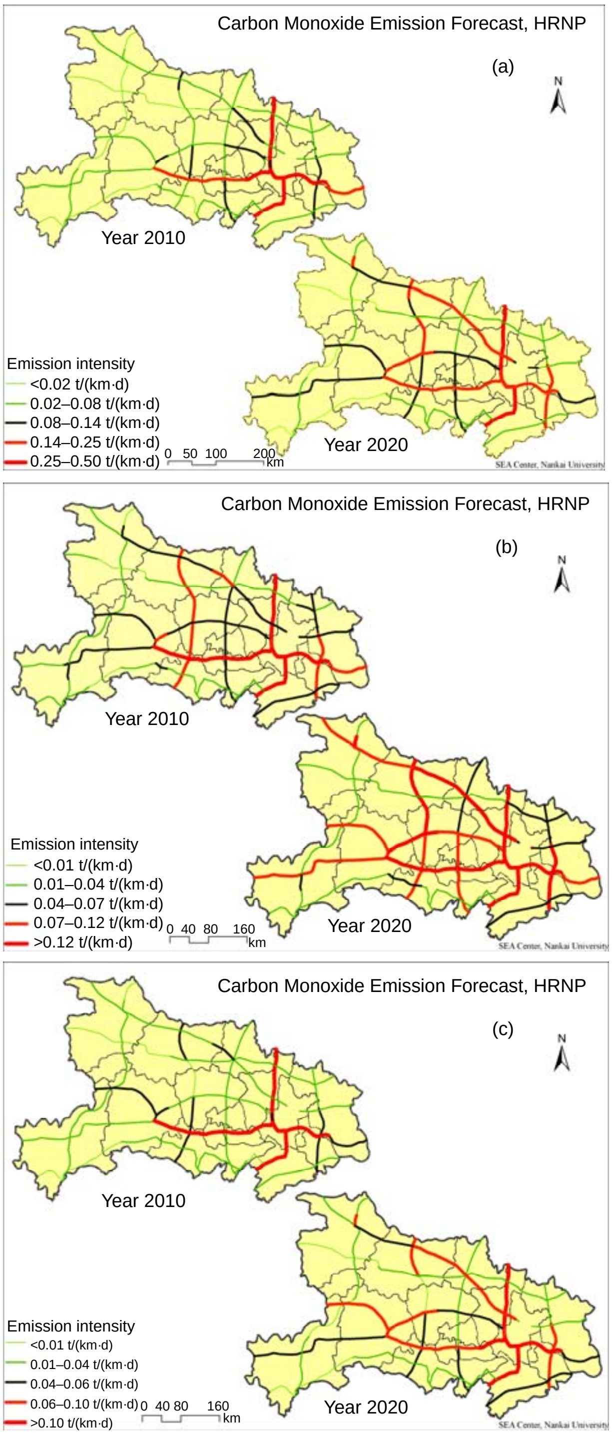

Fig. 7 Geographic distribution of CO emission intensity in different scenarios. (a) Scenario A; (b) Scenario B; (c) Scenario C

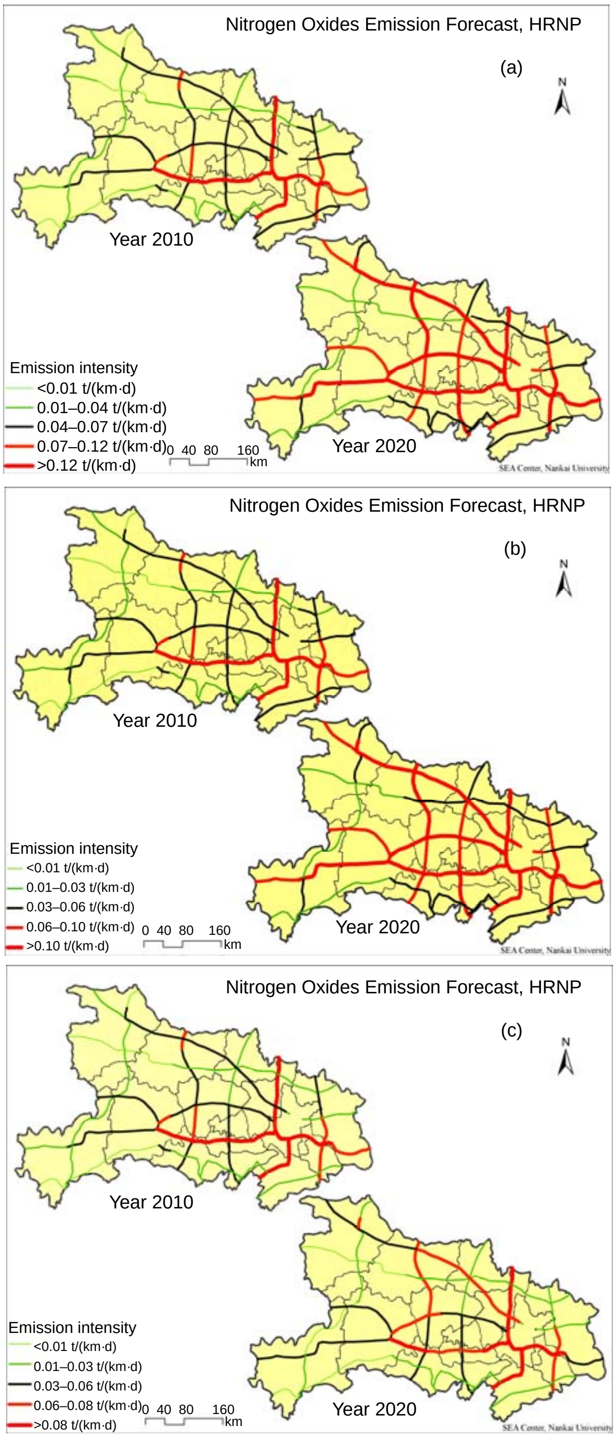

Fig. 8 Geographic distribution of NO$_x$ emission intensity in different scenarios. (a) Scenario A; (b) Scenario B; (c) Scenario C

with 31 road sections with CO emissions exceeding 0.10 t/(km·d). Only a few roads reduce their emission intensity. Meanwhile, the trend for NO$_x$ emission up to 2020 is the same as that for CO and no road would be expected to show a decrease in its emission intensity. In this scenario, the emission intensities increase to a relatively large extent and cover the whole province.

A descending trend for CO emission for some road sections would appear if there were a focus on environmental protection (Scenario C). The emission intensities of NO_x in 2020 would also decrease, except for four roads belonging to the Longitudinal 2 highway. Almost half of the road sections show a decreasing trend in NO_x emissions. The geographic distribution of emissions in Scenario C is also similar to those of Scenarios A and B (Figs. 7 and 8).

3.6.2 Emission inventory for greenhouse gases

According to the model described above, total emission inventories for greenhouse gases, including CO_2, CH_4, and N_2O, caused by HRNP in each scenario in the years 2010 and 2020, were calculated (Table 5).

The greenhouse gas emissions in Scenario A, "Open Hubei", are the highest, while those in Scenario C, "Focus on Environmental Protection", are the lowest. The total emissions of greenhouse gases in Hubei caused by the HRNP show an increasing trend. Clearly, environmental protection measures are effective in reducing greenhouse gas emissions.

3.7 Conclusion

Based on the above calculations: (1) Emissions of CO and NO_x show a similar distribution in Hubei province, but the pollutant emission intensity is different for each pollutant and each road section; (2) Emissions in eastern Hubei are much higher than those in western Hubei, especially in the regions of the Wuhan City Circle and areas on the Jianghan Plain around Jingzhou and Yichang (two sub-central cities in Hubei). This is because these regions are the most developed areas in Hubei, with the highest road density and the biggest transportation demand; (3) The total energy consumption in the three scenarios show upward trends because of the increase in traffic volumes. Scenario A has the highest energy consumption and Scenario C the lowest; (4) Highway sections with high air emissions lie mostly on two key highways. These roads are parts of the national highway network, bearing high transportation pressures throughout the country and therefore have relatively high levels of air pollution. Consequently, detailed environmental protection measures should be proposed under the EIA and implemented effectively in the future, targeting particular highway sections; (5) For emissions of both air pollutants and greenhouse gases, air quality can be improved effectively not only by using high-technology and encouraging energy savings, but also by improving and enforcing environmental protection regulations.

Although the formal legal arrangements for SEA in China have been in place on paper for more than six years, the application of the SEA process has been slow to develop. The EIA Law does not include the whole strategic process. One reason for this is the lack of effective methodologies for the evaluation of the potential environmental impacts. As one of the World Bank's seven pilot projects, the Strategic Environmental Assessment (SEA) of the Hubei Road Network Plan (2002–2020) focused on the technological innovation of evaluation methods. This case, a typical retrospective SEA, paid more attention to assessing the environmental impacts caused by the implementation of the approved plan. In this study, we described the integrated framework needed to address the air quality issues in a transport SEA by taking uncertainties and data/scale issues into account. Pollutant emission intensity was taken as a focus as well as the spatial distribution of the most polluted areas. Following the SEA, we conducted a quantitative assessment using given emission equations and analyzed the data with statistical tools and GIS software. Finally, a checklist of evaluation results and countermeasures was proposed to prevent or alleviate future adverse impacts. From a methodological point of view, this framework has proved to be an effective tool for use in a transport SEA process to assist with the interpretation of road network air pollutant emissions, and the feedback from the World Bank is that the framework is "so interesting and useful". Some countermeasures have been taken on board in the plan

Table 5 Results of greenhouse gas emission inventory in Hubei

Greenhouse gas	Emission quantity (t/d)								
	Open Hubei			Relative slow development			Focus on environmental protection		
	2010	2020	Increasing rate (%)	2010	2020	Increasing rate (%)	2010	2020	Increasing rate (%)
CO_2	73.27	123.03	67.91	59.95	114.35	90.75	50.30	94.95	88.77
CH_4	5.29	7.53	42.34	4.27	6.33	48.24	2.68	4.24	58.21
N_2O	5.62	15.13	169.22	4.25	11.67	174.59	4.32	3.20	−25.93

implementation process and the environmental management capacity of the transport authorities in Hubei has also been strengthened through the institutional recommendations and various action plans.

4 Discussion

For the SEA is becoming a useful policy tool, it must be integrated into the strategic planning and decision-making processes from the start. However, in the case discussed in this paper, the transport plan had already been completed and approved before the SEA was conducted. Therefore, the SEA has to focus on the environmental challenges and opportunities associated with implementing the plan in the future, and on strengthening institutional capacities in the transport authorities in Hubei for managing these environmental risks. This SEA is being implemented in a rather mechanical way to fulfil legal requirements. Measures to mitigate negative impacts are hardly considered. Thus, most countermeasures are not included in the decision-making process when road plans and other investment projects are considered in Hubei. The key issue is how to ensure integration of SEA in the planning and decision-making process as early as possible. This will require a new way of thinking and of preparing policies and plans in China. Institutions will have to cooperate much more closely and share information and data. The long-term goal should be to build constituencies and transparent processes that allow for the voices of those most affected by environmental degradation to be heard and that ensure that the authorities are held accountable for acting on the needs of vulnerable groups.

Lack of data is a key challenge during the evaluation process, especially in China. Because of a lack of previous analysis, the SEA work discussed in this paper had to start almost from scratch when assessing the various effects of the plan. Considerable time and effort was spent on trying to find primary data and other studies of road projects or similar from the transport sector that could be used in the air assessment. Environmental monitoring data exist for some cities in Hubei, but the road network goes mostly through rural areas. Thus, there was no environmental baseline information for these areas for air emission concentrations. Useful data do exist, but these are seldom fully available. Local authorities are monitoring air pollution in cities but it is hard to get access to the results, especially time series data. Even if data exist they are not commonly shared, even within the same institution. Great effort should be made to establish an environment for data creation and exchange to improve the quality of the SEA assessments. This would likely have to start at the top level among central government agencies and gradually spread down to provincial and local levels.

Openness about negative impacts from plans and open discussion of the various effects is difficult during a project, because the plan “owner” always has a vested interest in the plan being realized without having to implement too many mitigation measures. This may be an even greater challenge which needs time and effort to overcome. In China, stakeholders are very cautious about how they and their issues are dealt with in the SEA, and concerned that the effects on their interests or grievances are presented in a fair way. Above all, it is important for most groups that they are not marginalised in the analysis and participation process compared to other groups. In this SEA, the main focus at the final workshop was on the analytical results of the effects of the plan, and several stakeholders had detailed comments on how their issues and areas were presented. Some stakeholders felt that their concerns were not properly presented, and given too little space in the final SEA report. Consequently, the implementation of most of the recommendations and countermeasures proposed by the SEA should not be taken for granted. Even when the recommendations are endorsed, their follow up is not guaranteed as various stakeholder groups try to capture the changes. In particular, proposed institutional changes that require great effort and perhaps also changes in the way various institutions interact should be expected to meet considerable resistance. Therefore, a monitoring scheme is crucial to follow up the recommendations and ensure their implementation. Also, strong external support to the committed agency in charge of the changes would be necessary.

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