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Introduction

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In the global campaign to reduce carbon emissions, China faces two challenges: *promoting urbanization* and *reducing carbon emissions*. Failing to address these challenges appropriately could easily result in stronger emission. According to statistics from the International Energy Agency in 2011, China's carbon dioxide emissions exceeded those of the United States by 2.6 billion tons. Chinese emissions exceeded aggregate emissions of the United Kingdom, Germany, Sweden, Australia, Japan, South Korea, and Brazil by 450 million tons, compared with other Organisation for Economic Co-operation and Development nations. Urban areas are the main battlefield of global carbon emission reduction because 71 % of global greenhouse gases (GHGs) and carbon emissions are emitted from cities. Although a great deal of energy is consumed in cities and there are tremendous GHG emissions there, we cannot conclude that a high urbanization rate inevitably causes strong emissions. Studies of countries with different development levels show that an

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advanced economy with greater urbanization is not essentially related to greater carbon emission. However, in China, urban development and carbon emission are positively correlated at the present stage of urbanization. Therefore, establishment of low-carbon cities will promote transformation of urban development to achieve new-type urbanization, and foster industrial upgrades for green and sustainable development. The establishment of low-carbon cities, urban transformation, and industrial upgrade issues are analyzed and discussed herein, and suggestions are given for reference by relevant paragraphs.

1 Part 1 Current Status

Statistics show that, among 287 cities at the prefectural level and above in China, 259 have set out construction goals related to low-carbon eco-cities. This research illustrates local efforts in the construction of a low-carbon healthy city using two layers: metropolitan areas and model cities (Fig. 1).

1.1 Relevant Plans in Three Major Urban Regions with Focus on Preventing Air Pollution

In 2013, the Ministry of Environmental Protection of the People's Republic of China, and five other ministries and commissions, introduced "Region and Surrounding Areas Air Pollution Prevention Action Plan Implementing Rules." These rules focus on the prevention of air pollution and control of levels of PM2.5 (particulate matter with aerodynamic diameter <2.5 μm), as well as the coordinating mechanism for exploring aspects such as industrial development, energy structure, and traffic mode.

In *Yangtze River Delta Regional Planning* of 2010, city governments of the Yangtze River Delta region issued promotion goals to prevent air pollution from the perspective of regional eco-environmental protection, to adjust energy structure through the projects "Transporting Natural Gas from West to East" and "Power Transmission from West to East," and to implement control of total coal utilization. It is expected that 8 % of sulfur dioxide emissions will be eliminated by 2015.

From the standpoint of *Resource Saving and Environmental Protection Report in the Pearl River Delta Region*, *The Outline of the Plan for the Reform and Development of the Pearl River Delta (2008–2020)* and *Clean Air Action Plan for the Pearl River Delta Region of Guangdong Province* has established goals for building a regional coordinating mechanism in the arenas of circular economy, pollution control, and eco-environment. They also put forward targets to prevent regional air pollution, i.e., building up a basic foundation within 1 year, achieving initial success within 3 years, and improving remarkably within 10 years.

Fig. 1 The whole China low-carbon healthy city evaluation map (N = 287, by SARI, CAS). *Data Source* China City Statistics, 2013, The criteria score, which show as the color of cubic, is computed by the capability and ranking number of economic and social, urban construction, resource consumption, traffic and transportation, environment impact, and healthy and security data index. The area of cubic is the coverage of political region of different cities. Index number equals from 0 to 1, and different weights would show the importance of index and factors. See more in Chap. 7: *Low-carbon Healthy City Assessment Systems*

Meanwhile, some representative foreign metropolitan regions have forwarded specific quantitative targets of carbon emission reduction, with emphasis on combating climate change. They also promoted low-carbon healthy city construction by formulating measures of clean and renewable energy utilization, energy utilization management, energy-saving building renovation, bus-prioritized traffic patterns, and waste recycling. Among these metropolises, Chicago achieved its regional emission reduction by three means, establishing regional coordination units, quantifying carbon dioxide (CO_2) emission reduction, and regional carbon trading. The Tokyo Metropolitan Government formulated *Tokyo Climate Change Strategy* and outlined five major initiatives to mitigate climate change. These are reducing CO_2 emissions from private enterprises, households, urban development, and motorized traffic, and support from the Tokyo Metropolitan Government to support these efforts. The Greater Manchester area mainly reduced CO_2 emissions in five areas: construction, energy distribution and electricity generation, traffic, green space and drainage systems, and sustainable consumption. In comparison, foreign

metropolitan areas pay more attention to the implementation of specific goals of emission reduction, but China's low-carbon construction at metropolitan level focuses on preventing air pollution.

1.2 Various Patterns in Local Cities

After China launched pilot programs for low-carbon healthy cities, many pilot provinces and cities proposed different development ideas. For instance, Tianjin formulated measures with various aspects, including restructuring industry, facilitating emergence of industrial clusters, enhancing energy assessment of investment projects, and practicing industrial energy saving.

Liaoning Province focused on energy conservation for breakthroughs and specified specific goals. Liaoning aimed to gradually explore low-carbon mechanisms from point to area, taking Anshan as its initial experimental unit.

Hangzhou introduced 50 new policies of low-carbon construction, and strongly promoted the six-in-one pattern of low-carbon healthy city development:

(1) Fostering low-carbon industries and developing low-carbon economies
(2) Promoting building energy conservation and constructing low-carbon buildings
(3) Advocating green commuting and introducing low-carbon traffic
(4) Encouraging green consumption and promoting green life
(5) Enhancing ecology construction and creating low-carbon environments
(6) Changing urban management and building a low-carbon society

Wuxi focused on establishing six low-carbon systems: low-carbon legal systems, low-carbon industry systems, low-carbon urban construction systems, low-carbon life and culture systems, and carbon sink absorption and utilization systems. The city also emphasized development of low-carbon agriculture, industry, transportation, construction, consumption, and carbon sinks.

Zhenjiang started with a cloud computing platform of low-carbon urban construction and management, supervising this construction at five levels: urban, region, industry, key enterprise, and project.

Some cities adopted specialized low-carbon technologies. Dezhou implemented a solar city strategy and added low-carbon economic development to its *Comprehensive Development Planning of National Economy*. Xiamen practiced low-carbon construction modes in three major aspects: transportation, construction, and production. Hubei Province established the Wuhan metropolitan area as its experimental unit for a low-carbon economy, where it carried out development models of low-carbon energy, transportation and industries, and promoted a number of low-carbon economic demonstration projects.

Current low-carbon development in foreign cities can be summarized into five low-carbon patterns: grassroots, structural, morphological, supportive, and behavioral. More specifically, their practices cover a wide range of means, including

energy renovation, industrial transformation, promotion of a recycling economy, construction of compact cities, optimization of the urban ecological network, development of green transportation, spread of technology, and encouragement of energy-saving behaviors.

A comprehensive development pattern prevails in most foreign cities. Denmark's cities are a representative example. The country features wide coverage of low-carbon construction modes, including almost all the aforementioned patterns on all levels, such as construction of a complete system of wind power generation, promotion of energy conservation construction, development of green urban transportation, encouragement of waste recycling, and guidance for a low-carbon life.

Furthermore, in response to climate change, most foreign cities have formulated climate change action plans based on their own particular conditions, and established emission reduction targets to reach a national target index. For instance, London promulgated *London Climate Change Action Outlines* with the goal of reducing CO_2 emissions in 2025 by 60 % over that of 1990. Tokyo issued *Tokyo Climate Change Strategy*: *A Basic Policy for the 10-year Plan for a Carbon-Minus Tokyo*, putting forth a 2020 GHG emissions goal of 25 % less than those of 2000. However, at present, few cities in China have claimed quantitative target indices of emission reduction, and most low-carbon construction is at the demonstration level of policies and projects.

2 Part 2 Summary of Main Problems

2.1 Lack of Well-Organized Structure

China's present emission reduction efforts are mainly promoted by the National Development and Reform Commission (NDRC) system, focusing on industrial reduction. This lacks due attention to urban emission reduction, which includes reduction not only from industries but also from areas such as transportation, infrastructure, and citizen livelihoods. China has not constructed a complete emission reduction system that includes regions, city agglomerations, and large, medium, and small cities. Therefore it is impossible to systematically guide local low-carbon construction or establish a complete policy system of low-carbon energy utilization. As a result, national low-carbon construction is fragmented, with each city following its own path, which is not conducive to demonstrating and diffusing successful experiences. Additionally, strategic planning of multi-energy coordination centered on low-carbon energy supply has not been formulated on the regional or even national level. Development planning of clean energy—i.e., natural gas, wind energy, photovoltaic energy, and nuclear power—has been separately distinguished, whereas the development of high-carbon energy still lacks an alternative plan. Further, planning of the structure and system of trans-regional

energy supply is seriously lagging. Hence, low-carbon healthy city construction is restricted by the lack of a low-carbon supply structure and system featuring complementary advantages, supply-and-demand coordination, and efficient utilization. In contrast to industrial emission reduction in policy guidance, patterns and methods, and effect monitoring, urban emission reduction requires comprehensive planning and coordination for low-carbon urban construction strategies and policy systems.

2.2 Lack of Legal Status

In China, there are presently no legal provisions of low-carbon construction planning in either sequence planning of urban and rural development or in land development. This causes the following disadvantages.

(1) ***Lack of Standardization***. Low-carbon construction planning of local cities is not standardized or regulated.
(2) ***Lack of Guidance***. This should have a compulsory role in the comprehensive development of local cities.
(3) ***Lack of Coordination.*** It is difficult for low-carbon planning to be as legally valid as, for instance, specialized planning of road transport, water supply and drainage, and electric power, and so has been reduced to the status of a superfluous ornament.
(4) ***Lack of Feasibility***. After formulation of low-carbon planning, it is uncertain as to who should be responsible for implementing the planning and relevant management. However, many departments have been involved in low-carbon construction, such as local development and reform commissions, planning departments, administrative departments of construction, and environmental protection departments.

2.3 Lack of Evaluation Standards, Stimulation, and Restriction Systems

Construction of low-carbon healthy cities in China still lacks unified evaluation standards and stimulation and restriction systems. Hence, there is no corresponding measurement or assessment mechanism for the implementation of low-carbon urban development. First, owing to the lack of assessment mechanisms, low-carbon construction in many cites has been reduced to mere slogans, without total emission reduction targets or restriction mechanisms. Thus, it is difficult to implement low-carbon construction. Second, the significance of demonstration pilot projects is undermined by the lack of assessment mechanisms for low-carbon construction and required assessment tools to draw lessons from the past. Third, given the lack of

relevant assessment mechanisms, the economic and social benefits of local Low-carbon healthy city development have not been evaluated. Hence, it is difficult to evaluate certain low-carbon demonstration projects with huge investment but little achievement.

2.4 Lack of Consideration of Domestic Market and Local Conditions

The development of low-carbon cities is motivated more by policy than by market. This calls for substantial fiscal investment by governments in early and subsequent stages. However, because of serious differences in local fiscal revenue and between developed and underdeveloped regions, we should consider local conditions and specific city cases in formulating strategic designs for low-carbon urban development. Moreover, current development of low-carbon cities is largely driven by the government rather than market forces, which is not conducive to sustainable development of low-carbon cities. Given that China has undertaken huge emission reduction tasks in the international community, the government has certain aspirations for low-carbon construction and has introduced a series of policies to facilitate energy conservation as well as emission reduction. However, because of the lack of market forces, cities often invest substantial capital but achieve little short-term payoff, which induces short-term behavior and "show-off" projects, which make it difficult to establish a long-term policy.

2.5 Lack of Public Foundation

Currently, low-carbon development focuses on the renovation and reconstruction of infrastructure, and so lacks public foundation. In addition, because of the lack of popular low-carbon concepts, ordinary citizens do not pay attention to low-carbon urban construction, nor do they participate in it. Given this situation, the original goal of comprehensive low-carbon development is unlikely to be achieved. Consequently, the government will achieve half the targets with double the effort. Even if low-carbon construction is realized, citizens will revert to their expensive and wasteful ways of practical use.

2.6 Lack of Technical Innovation and International Influences

In China, low-carbon healthy city development has become a testing ground for advanced technologies and new concepts originating in other countries, because

domestic development lacks the planning, systems, standards, patents, and technical innovations of engineering and equipment. Chinese urbanization has received global attention. The number of cities and size of urban population ranks first globally, which furnishes a strong foundation and extensive space for low-carbon urban construction. However, during Chinese low-carbon healthy city construction, no low-carbon healthy city has attained global influence, no mode or experience is worth learning from both at home and abroad, and no low-carbon technique cluster has served as guidance to global development. In the long run, all these contribute to China's passive status on the international stage of emission reduction.

3 Part 3 Chinese Low-Carbon Healthy City Development

3.1 Beginning with Low-Carbon Planning

Guidance from planning is indispensable for the development of low-carbon cities. Low-carbon planning of high quality lays the foundation for development of low-carbon cities and guides rational progress of various urban systems. Compared with traditional urban planning, new urban planning reflects three core values.

(1) Respect nature, protect the environment, save resources, adhere to the idea of nature first, and give full respect to the basis of nature ecology and its relation to the built environment.
(2) Adhere to multiple elements, diversity, recycling use, and coexistence in harmony; pay attention to the cyclical process of various microsystems; apply the process of nature and human activities to these circulations.
(3) Adhere to the concept of people; improve development quality; regard improvement of all people's wellbeing as the core criterion; formulate planning of low-carbon healthy city development.

Therefore, on the precondition of maintaining the competitive force of cities and promoting sustainable growth of people's living standards, low-carbon planning should comprehensively evaluate and audit the total amount, intensity, and structure of urban carbon emissions, so as to set targets for emission reduction and put its modes and approaches into practice.

3.2 Low-Carbon Industries as Driving Forces

Low-carbon industries are the principal driving forces of low-carbon healthy city development and the major trend of global economic development. To facilitate rapid development of low-carbon industries, we should operate from a strategically advantageous position, formulate comprehensive and rational planning of industrial

development, and create rational resource allocation and favorable conditions in several aspects: industrial restructuring, regional industrial distribution, technical innovation, and infrastructure construction.

We should:

(1) Make clear the development directions of various industries within the low-carbon economic mode.
(2) Hierarchically advance the adjustment of low-carbon industries incrementally.
(3) Focus on development of clean-energy and renewable-energy industries, including energies from wind, water, and solar energy, straw and firewood and marsh gas, as well as gasification, carbonization, and compression molding of forestry and agricultural residue.
(4) Promote the development of low-carbon industries, including ecological agriculture, green forestry, medical, finance and insurance, scientific research, sanitation, physical education, and food manufacturing.
(5) Impose reasonable restrictions on the development of high energy-consumption industries, including cement, iron and steel, architecture, transportation, metals and mining.
(6) Accelerate the restructuring of low-carbon technology dominated industries, reduce carbon emissions at the source, restrict market access of high-carbon industries, intensify technical transformation for emissions reduction of key industries, eliminate energy-consuming old equipment and heavy-polluting project construction, strictly conduct environmental impact assessments, perform energy conservation reviews, and develop admission criteria for energy savings and emission reduction in projects.

The above will establish a direction for low-carbon industries through low carbonization trends in industrial development and change of energy utilization patterns.

3.3 Infrastructure of Low Carbonization

Urban infrastructure consists of urban transportation, energy, water authority, refuse disposal, safety, and disaster prevention systems. Thus, the restructuring and optimizing of infrastructure is the foundation of low-carbon healthy city development. With the concept of low-carbon healthy city construction, the following aspects will become centers of attention: construction of efficient and convenient transportation systems, low power consumption and clean energy systems, secure and recycling water systems, minimization and regeneration of waste treatment systems, harmonious and pleasant ecosystems, and intelligent and efficient information systems.

3.4 Low-Carbon Healthy City Construction

In recent years, we have gradually realized via the experience of low-carbon healthy city construction that the public is the most fundamental force in the development of such cities. Therefore, we should advocate low-carbon life, develop low-carbon cities, and promote the happiness and acceptance of citizens. Meanwhile, we should alter our living habits to help reduce carbon emissions.

3.5 Low-Carbon Assessment

Research on the global low-carbon index is dominated by standards of the United Nations, Europe, United States, Australia, and Japan. The global low-carbon standard system often emphasizes the integration of three dimensions, the sustainability, greenness, and ecology of low-carbon healthy city development. This provides a comprehensive reflection of the low-carbon index of cities. The United Nations and World Bank have established the *Global Urban Index Database*. European and American countries, Australia, and Japan have introduced, based on conditions in each country, various assessment systems, for example, the low-carbon healthy city development index and urban sustainable development index. In China, we should quickly establish a low-carbon assessment system and scientifically select a relevant

Table 1 China low-carbon healthy city evaluation ranking (Top 10, by SARI, CAS)

RANK	City	Province	Criteria	Demographic
1	Hefei	An Hui	0.8369	Science and Technology
2	Guangzhou	Guang Dong	0.8366	Global Trading Center
3	Nanjing	Jiang Su	0.8212	Nature Landscape and China Culture Center
4	Fuzhou	Fu Jian	0.8169	West Sea Culture Center
5	Shanghai	Shanghai	0.8142	World Economical Center
6	Qingdao	Shan Dong	0.8141	Mountain Sea and Culture
7	Dalian	Liao Ning	0.8114	Sea Trading and Financing Center of North China
8	Beijing	Bei Jing	0.8009	China Political and Culture Center
9	Jinan	Shan Dong	0.7963	North China Big City
10	Xiamen	Fu Jian	0.7943	Beautiful South China City

Data Source China City Statistics, 2013, The Criteria Score is computed by the Capability and Ranking Number of Economic and Social, Urban Construction, Resource Consumption, Traffic and Transportation, Environment Impact, and Healthy and Security Data Index. Index number equals from 0 to 1, and different weights would show the importance of index and factors. See more in Chap. 7: *Low-carbon Healthy City Assessment Systems*

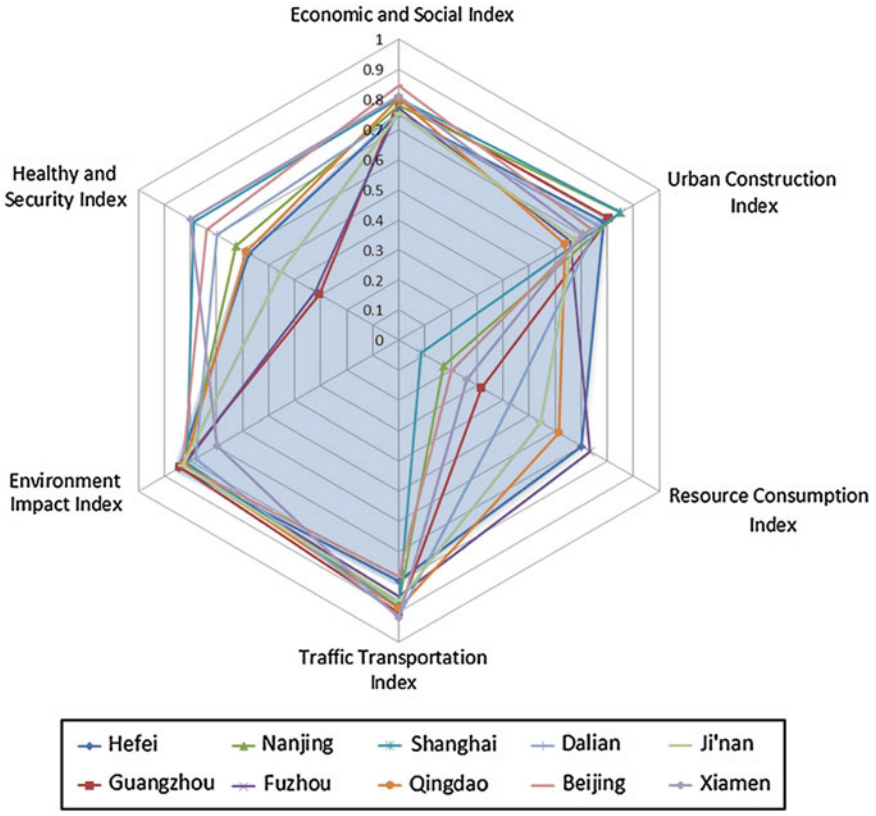

Fig. 2 China low-carbon healthy city evaluation six vision ranking (Top 10, by SARI, CAS). *Data Source* China City Statistics, 2013, The score means the capability and ranking number of economic and social, urban construction, resource consumption, traffic and transportation, environment impact, and healthy and security data index. Index number equals from 0 to 1, and different weights would show the importance of index and factors. See more in Chap. 7: *Low-carbon Healthy City Assessment Systems*

index to evaluate city development during low-carbon healthy city construction. The establishment of these systems can assist local governments in correctly assessing the feasibility and prospects of low-carbon construction projects and, at the same time, provide a standard for the central government to evaluate local low-carbon construction achievements (Table 1 and Fig. 2).

4 Part 4 Countermeasures and Suggestions

In light of practice and problems in the development of domestic low-carbon cities, the present study resulted in the following key aspects for implementation.

4.1 Formulating Standards, Quantifying Achievements, and Providing Comprehensive Guidelines and Coordinating Methods for Local Low-Carbon Construction

First and foremost, at the national level, the government should formulate a set of relevant standards and guidelines to coordinate and guide local cities in their low-carbon construction behavior. Meanwhile, a set of evaluation criteria, featuring universal, scientific, and accessible indices, is needed to evaluate local low-carbon construction achievements within a unified framework. Thus, the current study suggests relevant departments and commissions, as well as scientific research institutions, to devise standards and evaluation criteria for low-carbon construction at the national level, and to regularly update the roadmap of slow-carbon cities. In this way, we will be able to determine the dynamic processes and achievements of local low-carbon construction.

4.2 Legalizing the Planning and Establishing Coordinating Mechanism

We should identify the function and role of low-carbon planning in China's legal planning system, and introduce these in statutory documents to guide the construction and development of cities. Local governments should be required to promptly develop low-carbon planning, set emission reduction goals, and construct action plans. On both central and local levels under the coordination of the NDRC, the government should establish coordinating mechanisms, which consist of planning, construction, land, and environment protection departments and ministries. The government can thereby coordinate low-carbon construction in different fields, and consolidate deployment of low-carbon industries, planning construction, infrastructure, and social life. The present study also suggests that national organizations explore a path toward legalization of low-carbon planning and establish coordinating mechanisms of low-carbon construction involving several departments.

4.3 Establishing Carbon Verification and Exchange Mechanisms at City Level, and Exploring Interurban Transfer Payment Mechanisms

Compared with verification mechanisms of carbon emission on the corporate micro-level and national macro-level, China lacks on the former level an exact

verification mechanism of urban carbon emissions. Therefore, urban low-carbon construction lacks objective supporting data, which makes it difficult to quantify achievement of low-carbon cities. Thus, the current study suggests that China should explore and list local urban carbon emissions, to provide guidelines for city carbon emissions. Furthermore, in the future, local cites should gradually form interurban carbon emission exchange systems based on establishment of carbon emission verification systems, and conduct emission permit trade with cities acting as the government. The establishment of carbon emission trade systems at the urban level will encourage cities to promote emission reduction in various fields. This book suggests that the government should begin to collect taxes on extra carbon emissions directed toward provincial or central finance, which should be exclusively used as subsidies for low-carbon cities to establish exchange mechanisms of interurban tax revenues.

4.4 Innovative Technology and Supporting the Development of Low-Carbon Industries

With the comprehensive progress of domestic low-carbon urban construction, many new technologies and products will be applied to urban construction, creating favorable conditions for low-carbon industrial development and technical renovation. Special focus will be placed on the development of smart energy grid technology centered on, for instance, smart power grids, cleaner high-carbon energies, alternative technologies, and intelligent electricity technology. In demand-side guidance for urban low-carbon projects, the government should encourage technological enterprise to develop innovations for improving the overall level of low-carbon science and technology. Moreover, in future urban low-carbon construction, the government should introduce supportive policies for low-carbon healthy city development, to foster benign interaction between urban and industrial low-carbon construction. At the same time, we should transform low-carbon cities and industries through industrial development and technical innovations. Additionally, with the overall progress of new urbanization construction, numerous low-carbon technologies and systems will be applied to domestic urban construction. Thus, we have every reason and condition to take a leading role in global urban low-carbon construction and strive for international dominance in this respect. Through the development of domestic low-carbon demonstration areas and test cities, we endeavor to set an example for not only domestic cities but also global low-carbon construction. We would like to share our successful experiences with cities worldwide. Meanwhile, based on long-term accumulation of construction practice and experience, we should actively participate in formulation of global low-carbon criteria, so as to break the monopoly of western countries in low-carbon development and global emission reduction (see supporting materials in special investigation report).