优化交通运输发展
助力环境质量提升

西门子股份公司

1. 引言

交通是现代社会和经济发展的命脉，对于中国城镇化的健康发展起着至关重要的作用。然而，交通运输的发展在中国正面临着越来越多的挑战，尤其是对环境所产生的负面影响。这些可能成为社会和经济可持续发展重要障碍的负面影响正在得到越来越多的关注。

本文结合了可持续发展和绿色交通的理念，举例介绍了一些发达国家通过改善交通运输的各个环节以保护环境的经验，探析了目前中国交通运输所面临的环境方面的挑战和主要成因，并提出了如何通过优化交通运输的发展来提升环境质量的建议。文章中借鉴了西门子在交通运输领域的一些全球项目和生产实践经验。

2. 世界范围内交通污染的治理

为提高全球竞争力，世界各国一直都十分重视交通运输领域的发展，这也导致了二十世纪中期欧美一些发达国家的部分城市开始遭遇严重交通拥堵和由此所带来的环境污染问题。在接下来的很长时间内，为解决发展交通运输与改善环境质量之间的矛盾，这些国家先后采取了综合的发展和管控策略，并取得了良好效果。这些策略可以概括为以下几个方面。

轨道交通引导和促进城市、大都市和区域的可持续发展

全球城市的多年发展经验表明，通过大力发展舒适和高效的轨道交通体系可以大幅度降低私人交通工具的使用强度。同时，轨道交通本身也是最环保的交通运输方式。城市轨道交通为连接郊区与市中心提供了便捷和优选的交通方式，有利于市区向外发展形成多中心的城市发展形态，从而有效降低市中心的

交通拥堵和排放以及其它资源的过度消耗。

尽管城市的形态和规模不同，不断地发展和完善轨道交通网络是伦敦、新加坡、慕尼黑、斯德哥尔摩、哥本哈根、苏黎士等城市能够实现交通可持续发展和改善环境质量的重要举措之一。

精细化规划、管理、运营和维护及系统整合

精细化规划是基于现代规划的理论，结合项目实际经验和对解决方案效果的深刻理解而形成的规划方法。例如，伦敦市政府最近发布的“智慧伦敦规划”明确提出，到 2016 年，要建立对于技术解决方案和有关服务对交通和环境的影响量化的理解，并用于指导未来的规划和方案选择。

精细化交通运营与管理是建立在最新科技的发展和先进的管理理念基础上的、以优化为目标的运营和管理模式。精细化的交通管理解决方案不仅能够取得显著的节能减排效果，也会为各种交通大数据的采集、未来交通基础设施建设与维护的精准决策、智慧城市的建设奠定坚实的基础。例如，被世界上很多城市采用的 SCOOT 自适应道路交通控制系统可以将机动车在道路交叉口的延误减少 8-33%[1]。该系统在加拿大多伦多实施后，每年可为通过控制区域（75 个交叉口）的车辆节约 984 千公升燃油，减少超过 11 吨碳氢物和 72 吨一氧化碳排放。

在城市轨道交通控制领域，精细化和自动化的运营和管理不仅能够大幅度提高列车运行效率吸引更多乘客，而且能够帮助节约列车牵引能耗。以北京地铁 8 号和 10 号线为例，这两条线路所安装的 CBTC（基于通信的列车控制系统）每年可以节约能耗 5 百万千瓦小时。城市轨道交通的智能平台通过获取设备的技术数据，不仅能够监控运输设备，降低能耗，还可完成运营过程中的环境监测，如温室效应的趋势、温室气体排放比较、噪音及震动等级等。

精细化交通运营与管理在高速铁路领域也发挥着重要作用。高铁智能驾驶员辅助系统可以确保牵引及制动系统的最低限度使用，减少能量的消耗。除此以外，高速铁路系统中的再生制动器、涡流轨道制动器、摩擦制动器在运营过程中可回收约 30%的能源。降低能耗和能量回收双管齐下，实现节能减排的目

[1] 资料来源：Fehon, Kevin (2004). Adaptive Traffic Signals: Are we missing the boat? ITS District 6 2004 Annual Meeting.

标。

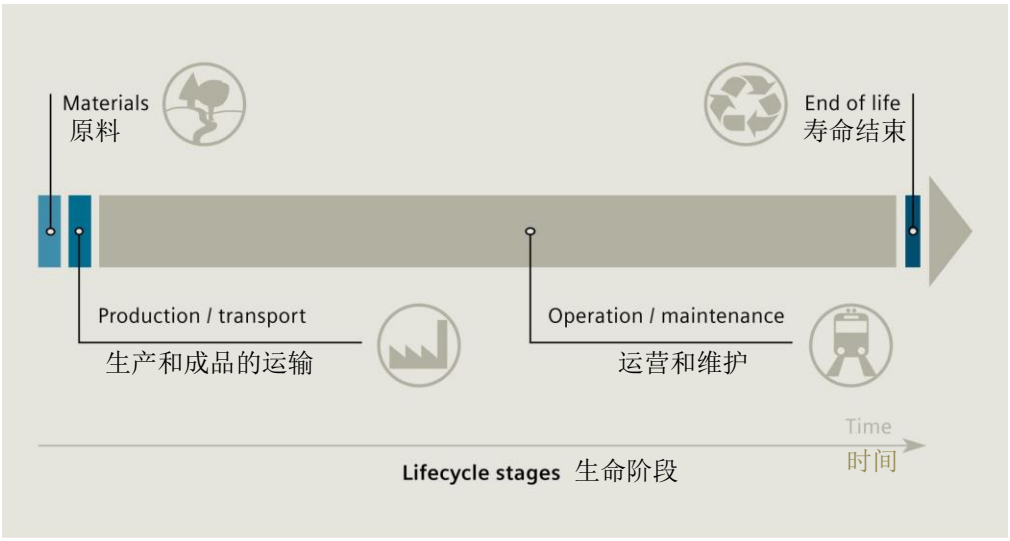
精细化维护体现在设备服务领域，数字化和智能的维修及设备升级服务，均提倡以结合实用性及可持续性为基础。从产品初始时便于维修的优化设计到运营中创新的数字化服务，即设备的远程监测、技术诊断、远期的维修保养等，均为各种交通运输参与者节省了大量的社会及自然资源。

通过系统整合，交通管理系统可以为特定街道和区域制定更直接有效的污染防治策略。例如，“以环境为导向的交通管理系统”可以集成交通与气象数据，实时计算出不同街道和路段的污染状况，然后引导车流远离污染太高的地区。得益于这些措施，德国波茨坦市 NO2 大气浓度降低了 4%。在道路照明普遍使用了 LED 光源之后，德国的一些城市实现了交通管理系统与街道照明系统的整合与联动，从而在保证了行人和车辆交通安全的前提下实现了非交通高峰时间段的街道照明能源消耗的大幅降低。

全生命周期的绿色环保

交通运输设备的制造、运输和回收以及废物处理也会造成环境污染。形成完整的物质循环对于产品发展过程中资源和环境的保护日渐重要。因此，一些企业提出了解决方案和设备的“全生命周期绿色环保”的理念（**错误!未找到引用源。**），并贯穿于商业活动的各个环节。

图 1 设备和产品的全生命周期



例如，西门子产品全生命周期的评估管理体系除了在运输设备的设计阶段就考虑到能量的高效利用外，还坚持使用环境友好型材料和可回收再利用的材料，以保证产品具有极高的可回收比率，一些产品的可回收比率高达 98%。针对成品的运输环节，近 45000 辆货物运输车辆的 CO2 排放问题正在得到优化和解决。在完成了产品的生命周期的同时，也对环境保护做出巨大的贡献。

技术和方案不断创新

通过不断的研发，推出创新的技术方案以达到交通运输领域的节能减排是全世界各个国家和企业都在积极追求的目标。电气化高速公路和快速充电电动公交车是两个典型的案例。

电气化高速公路系统是专为繁忙的货运路线而开发的高能效、低排放解决方案。这个系统由道路高架线缆，以及配备了智能集电器的电动或混合动力的卡车构成。电气化高速路系统的能效约为 80%，大约是柴油卡车的两倍。该系统试点项目已经在德国柏林和美国的洛杉矶港分别展开。

为降低公交车在市区内的排放，瑞典斯德哥尔摩市政府沿着一条城市公交线路建设了一套能够为混合动力公交车快速充电的系统。充电站由具备电力转换器和变压器的电网连接系统，以及具备接触臂的充电塔构成。巴士一抵达充电站，就会通过 WLAN 建立无线连接，以识别巴士身份和询问电池管理系统要求。这些巴士能在 70%线路上仅靠电能行驶——不仅运行安静而且不会产生任何排放。

强化交通需求管理，建设以人为本的绿色交通

交通需求管理是大城市控制机动车使用强度、解决交通供需矛盾的最有效

措施之一，主要分为政策法规手段和经济手段。目前，国外城市主要采取的是经济手段。伦敦、新加坡、奥斯陆、斯德哥尔摩等城市先后实行了交通拥堵收费和市区内相对昂贵的停车收费。伦敦还建立了低减排区。这些措施都取得了显著的减少交通拥堵和提高空气质量的效果。例如，伦敦的交通拥堵收费使得收费区内拥堵减少 20%以上，每年减排 15 万吨 CO2。

这些城市有一个共同特点，就是在强化交通需求管理的同时，都建立了发达的公共交通系统（包括轻轨）、高效的外围交通管理系统、安全的慢行交通设施、便利的外围停车换乘设施。例如伦敦的大部分道路安装了世界最先进的自适应式行人过街系统，保证行人的过街安全同时最大程度减小对车流的影响。这些城市的路面公共交通普遍实现了公交优先，丹麦哥本哈根甚至实现了交通信号控制路口的自行车优先。这些措施充分体现了以人为本和绿色交通的理念。

通过以上国际交通运输发展在环保方面的一些主要经验，可以看出，无论是从规划、运营和管理还是交通设备制造，未来发展的趋势将依靠现代科技和可持续发展的理念，越来越重视细节和以人为本，并通过各种形式的技术创新，最大限度地降低交通对环境的影响。

3. 中国的交通运输的发展和所面临的环境挑战

改革开放三十年来，中国交通运输的发展和基础设施的建设取得了举世瞩目的成就。截止 2014 年末，全国公路总里程已超过 446 万公里[2]。到“十二五”末，全国铁路营业里程达到 12.1 万公里。全国高铁运营里程超过 1.9 万公里，位居世界第一[3]。中国的城市轨道也进入了快速发展期，累计有 25 个城市建成投运城轨线路 114 条，运营里程超过 3516 公里[4]。一些交通基础设施项目的技术水平和质量已达到甚至超过世界先进水平。

交通运输的快速发展为社会和经济的发展做出了巨大的贡献，但同时也对环境造成了不同程度的破坏，尤其是汽车尾气对空气的严重污染。例如，北京市和上海市 PM2.5 排放源分析表明，超过 30%来自机动车的排放[5]。从全国范围看，10-25%的 PM2.5 一次排放源来自机动车，20-25%的二次排放源（例如

[2] 资料来源：中国交通运输部
[3] 资料来源：盛光祖铁总工作报告摘要（2015 总结与 2016 计划）
[4] 资料来源：世界轨道交通发展研究会
[5] 资料来源：北京市环保局网站和上海市政府网站

SO2 和 NOx）来自机动车[6]。机动车排放对环境的污染近年来呈现逐渐加剧的趋势，其主要原因可以归结为以下两个方面。

粗放式的发展模式

首先，城乡规划和土地利用以及交通的发展还没有完全兼顾对环境的保护。很多城市的交通还处于粗放式的发展状态，解决拥堵的举措还是侧重单一的增加道路供给的环节上。但是，道路供给的速度总是赶不上交通需求的增长。实践证明大规模的道路建设在改善交通基础设施的同时，也大幅降低了小汽车使用的时间成本，从而刺激了小汽车的加速发展和使用强度的猛增，使交通拥堵状况变得更加严重。世界城市发展的经验早已证明，寄希望于通过单纯靠增加道路来解决交通问题是无效的。

其次，对现有交通基础设施缺乏优化与整合。中国建成了高效运营的高铁和城际铁路，很多城市也建成了高质量和完善的公共交通系统（例如快速公交，城市轻轨和地铁），但是这些交通系统往往缺乏有效的整合、精细化的协调管理和整体优化。另外，大部分城市现有的交通管理和控制系统没有得到深度优化，数据没有得到深度发掘，没有实现基于交通管理平台的动态监测和决策体系，因此这些系统在交通管理和决策过程中没有发挥出其应有的作用。

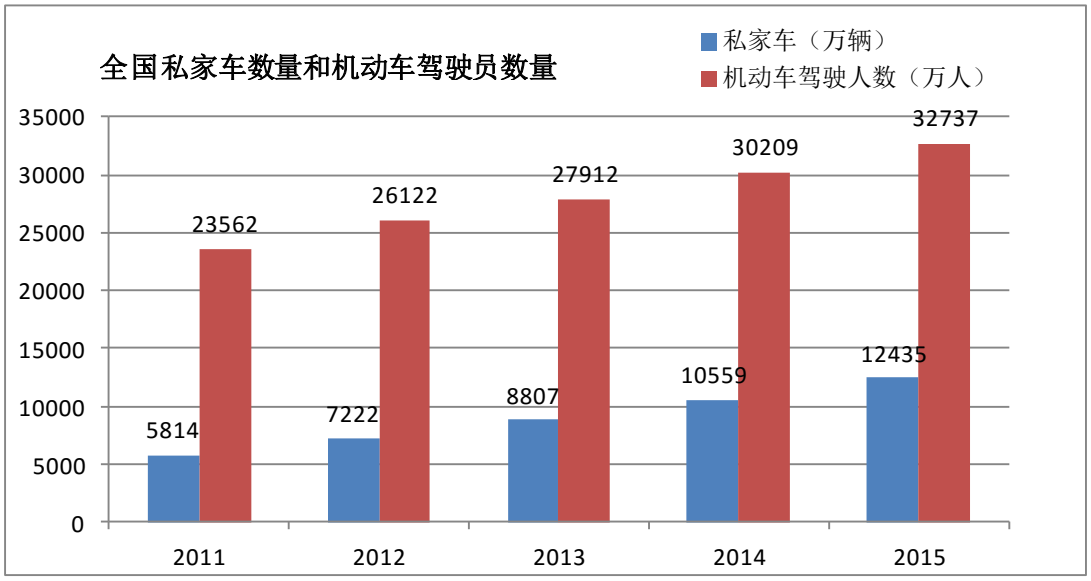
交通规划中缺乏精细化的考量，没有以节能环保为导向，选择解决方案时过分注重前期或初始投资，忽视对每种解决方案在全生命周期内在集约、绿色、智能和低碳方面的贡献的综合分析。规划的前瞻性不够也导致了大量重复建设问题。很多道路规划和设计没有坚持以人为本的理念，实施后导致交通拥堵甚至交通事故。

交通需求管理体制不够完善

截止 2015 年，全国机动车保有量 2.79 亿辆，其中汽车 1.72 亿辆。40 个城市汽车保有量超过 100 万辆，11 个城市超过 200 万辆。如图 2 所示，私家车保有量增长趋势虽有减缓，但每年仍以超过 15%的速度在增加，机动车驾驶人数也以近 10%的速度在增长。

[6] 资料来源：中国国家发改委能源研究所

图 2 全国私家车和机动车驾驶人数量



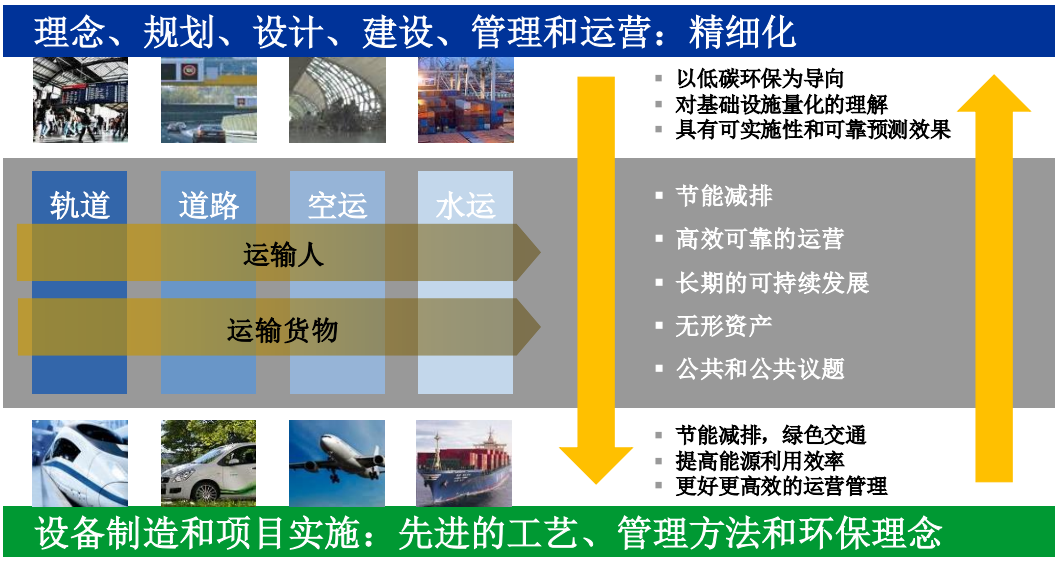
伦敦的汽车保有量大约是 400 辆/千人。以中国汽车保有量最高的城市北京做对比，2015 年北京的汽车保有量是 535 万辆，大约 250 辆/千人。尽管伦敦机动车保有量始终处在一个较高的水平，但因多年来一直处在严格需求管理措施的监管下（例如路税和交通拥堵费），其对环境的影响不太严重。中国城市的问题不是汽车保有量高的问题，而是使用强度过大的问题。目前的交通需求管理往往是一刀切的措施（例如限号和限制车牌发放），没有体现出差异性。

4. 建设具有中国特色的环境友好型交通运输体系

可持续发展体现在对环境、生活质量和竞争力的综合考虑和平衡发展，这已经成为中国的一项基本国策。“十三五”规划更加注重生态文明建设和绿色发展，所有这些都需要绿色低碳交通的支撑。加快建设安全、便捷、高效、绿色、经济的综合交通体系，最大限度减小由于交通运输的发展对环境的影响是完善环境治理体系，提升环境质量的一个不可分割的部分。

中国交通运输发展可以从两个维度进行优化（如图 3 所示），要兼顾精细化的规划、实施、运营与管理、设备制造。对解决方案的环保性进行全生命周期的考量。

图 3 优化交通运输发展的方法



绿色交通运输的发展需要长期的坚持不懈和不断努力。回顾一些交通发展与环保矛盾处理的比较好的国家的发展历程，无不是经过了几十年的艰苦曲折的探索的结果，而且至今仍然在不断完善。中国的情况比这些国家更加复杂，交通运输领域的环保应该注意以下几个方面。

以节能环保为终极目标、通过精细化发展实现交通运输的整体优化

“十三五”期间，在大力发展更加节能型城市轨道、郊区和城际轨道交通基础设施，缓解高速公路的拥堵状况的前提下，改善城市内部的交通管理，以智慧城市的建设作为一个发展契机，实现交通模式系统性的整合和优化。

要从粗放式的发展观念向精细化的理念转变，各类交通运输项目要从量的扩张向质的提升转变，更加注重结构优化，多管齐下，以节能环保为导向，通过各种数字化、电气化、自动化和智能化的解决方案，和大数据、互联网+等技术手段实现交通运输最优化的规划、制造、实施、运营和管理。在这方面，中国的一些中小城市已经走在了前列，例如珠海和常州，都是以绿色环保的理念贯穿于其城市交通运输的发展。

充分借鉴和吸收国外先进理念、实践经验并实现技术创新

充分借鉴和吸收国外交通领域节能减排多年积累的经验，了解交通技术的

未来发展趋势，并结合自己的实际情况进行探索和创新。利用一些创新技术手段，重点解决瓶颈问题和重污染领域，例如货物运输污染。在中国，占机动车总量 22%的货运卡车所带来的排放占了机动车排放总量的 56%。因此，可以考虑对一些货物运输集中的公路进行电气化。

完善交通环保机制、强化需求管理

健全环保与交通发展的协调机制，在做到交通基础设施全面优化的基础上，逐步推行和强化灵活的和具有差异化的交通需求管理措施。建立全面的针对交通运输发展和环境影响的、跟国际接轨的动态监测和评价指标体系。该体系将成为衡量城市交通发展水平的主要标准和指导中国城市交通运输发展方向的重要依据，并成为城市交通运输管理信息和决策平台的关键组成部分。

注重硬件设备的全生命周期的节能环保，不仅要考虑初始投资，更要考虑后期的更新换代和回收成本，例如电动车电池、轨道交通的车辆和配件的生产和回收。随着越来越多的交通运输的电气化，还要重视能源结构的改善和煤电效率的提升。

努力在重点发展地区打造一批具有国际先进水平的绿色交通示范和试点项目，并在不断总结的基础上向全国进行推广。京津冀的交通一体化建设和迫切的地区环保需求，为这类项目提供了很好的切入点和实践平台。

5. 结束语

交通运输的可持续发展是以集约、绿色、智能和低碳为目标，在促进经济和社会发展的同时把对环境的污染程度降到最小。一些发达国家的经验告诉我们，通过精细化的规划、实施、运营管理和维护，可以做到交通运输发展的最优化，达到其与经济、社会、环境之间的协调发展。这也是对创新、协调、绿色、开放、共享的发展理念的具体体现，为建设美丽中国提供有力的支撑， 并引领“一带一路”的建设和发展。

Improving Environment Quality Through Optimisation of Transportation Development

Siemens AG

1. Introduction

Transportation is the lifeblood of modern social and economic development. It plays a crucial role in the healthy development of China's urbanisation. However, the transportation development in China is confronting more and more challenges, especially its negative impacts on the environment. These adverse effects that threaten to become the main obstacle to the sustainable development of society and economy are attracting more and more attention from the public.

This paper combines the concepts of sustainability and green transportation and introduced some developed countries' experiences in improving their transportation systems for environment protection. It explored the current environmental challenges China's transportation sector is facing and their main causes, and made recommendations on how to improve the environment quality through optimisation of transportation development. The paper also draws on the experiences from Siemens' projects and manufacturing practices worldwide.

2. Global experiences in transportation pollution reduction

In order to increase global competitiveness, countries around the world have always attached great importance to the development of the transport sector, and this led to severe traffic jams and pollution in some cities in Europe and North America in mid-20th century. In the subsequent long period of time, these countries adopted comprehensive and integrated counter measures to resolve the conflict between developing transportation and improving environment quality, which had produced good outcome. These measures can be categorised as follows.

Promote sustainable development of cities, metropolis and regions through rail transport

Many years of worldwide city development experiences have demonstrated that well-developed and highly efficient public transport can significantly reduce the intensive use of private transport. Furthermore, rail transport is also the most environmental friendly transport mode. Urban rail transit offers a convenient and usually preferred way of transport for linking city centres and suburban areas. This facilitates cities to expand towards multi-centred urban layout, thereby effectively reduce traffic congestion and emissions as well as excessive consumption of resources in downtown areas.

Despite their differences in layout and size, continuously developing and improving rail based transit network is one of the most important measures adopted by London, Singapore, Munich, Stockholm, Copenhagen, Zurich and some other cities to achieve sustainable development in transport.

Fine planning, management, operation and maintenance, and system integration

Based on modern planning theories, the fine planning methodology combines practical experiences from real projects and deep understanding of the impacts of solutions. For example, the "Smart London Plan" recently published by the City of London clearly stated that by 2016 the government would establish a robust quantitative understanding of the contributions that smart technical solutions and associated services can make towards the management of the city's transport infrastructure. The approach will be applied for future planning exercise and selection of solutions.

Fine transport management and operation is a practice that is based on the latest technological developments and advanced management concepts, and aims for optimisation. Solutions targeting fine management and operations of transportation can not only achieve significant energy conservation and emission reduction but also form a solid foundation for the collection of transport big data, accurate decision making on future transport infrastructure development and maintenance, and smart city initiatives. For example, the SCOOT adaptive traffic control systems that have been installed in many cities around the world can reduce vehicle delays at road junctions by 8-33%[1]. The system installed in Toronto Canada can save

[1] Source：Fehon, Kevin (2004). Adaptive Traffic Signals: Are we missing the boat? ITS District 6 2004 Annual

984,000 litres of fuel every year for the vehicles passing through the controlled area (75 junctions). It can also reduce 11 tons of hydrocarbon and 72 tons of CO emissions.

For urban rail transit control, fine and automated operation and management can not only increase operational efficiency and attract more passengers, but also save traction energy consumption of vehicles. Take Beijing metro line 8 and 10 for example, the installed CBTC (Communication Based Train Control) system can save 5 million kWh of electricity per year. The data collected from the intelligent urban rail transit management platforms could be used not only to supervise the operational conditions of the facilities and reduce their energy consumption, but also to monitor the environment data, such as trend of ambient greenhouse effects, greenhouse gas emission, ambient noise and vibration level, and so on.

Fine management and operation also plays an important role in high speed rail. The intelligent driver assistance system for high speed rail can minimise the use of traction and braking systems to reduce energy consumption. In addition, regenerative brake, eddy current track brake, and friction brake systems in high speed trains can recover 30% of the energy during operation. Energy consumption reduction and energy recovery combined could achieve the goal of energy saving and emission reduction.

To reflect fine maintenance in equipment services, digitalised and automated repairing and upgrading services all emphasise the combination of availability and sustainability for more efficient maintenance. From serviceability in design to innovative data service as basis for future maintenance, such as monitoring, diagnosis, and long-term maintenance, all these can save a large amount of social and natural resources for the stakeholders.

Through system integration and based on a variety of information, traffic management systems can generate even more effective pollution reduction strategies for specific streets and districts. For example, “Environment-oriented traffic management system” can be integrated with meteorological systems and calculate pollutant profiles of individual streets and road sections in real time, then guides traffic away from places where pollution concentrations are high. Benefited

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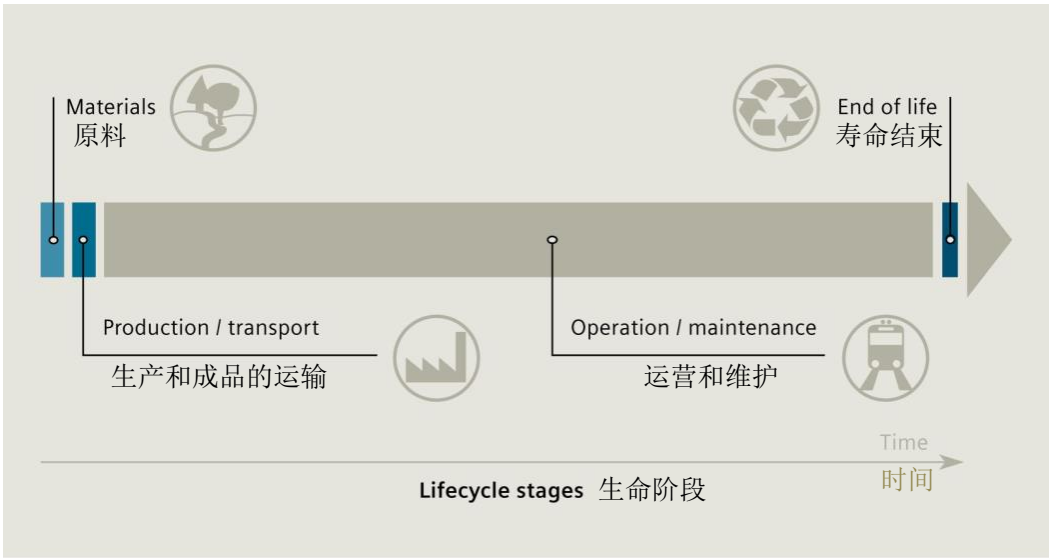
Meeting.

from such systems NO2 concentration in Potsdam (a German city) dropped by about 4%. Following the wide installation of LED for street lighting, some cities in Germany then integrated their traffic management system with street lighting management systems for coordinated actions. These schemes have significantly reduced energy consumption during off-peak hours without sacrificing the safety of both traffic and pedestrians.

Green and environment-friendly whole product lifecycle

Manufacturing, transporting and recycling transportation equipment and products could also pollute environment. Closing material loops is increasingly important for resource conservation and environment protection in product development. Therefore, a number of manufacturers have proposed the "green and environment-friendly whole lifecycle" concept for equipment production (as shown in Figure 1). The concept is realised throughout the business processes.

Figure 1 Whole product lifecycle stages



Under its whole product lifecycle assessment and management framework Siemens endeavours to ensure highly efficient use of energy from the design stage of transport equipment. In addition, Siemens also only uses environment-friendly materials to guarantee the equipment produced has very high recycling rate. Some

equipment's recycling rate can reach as high as 98%. For the logistics of finished products, the company is solving the emissions issue of its nearly 45000 cargo vehicles. Through these measures, the company completes the product lifecycle and makes great contribution to environment protection at the same time.

Continuous technological innovation

To achieve energy conservation and emission reduction for the transportation sector through innovative technical solutions acquired by constant research and development is the goal that worldwide countries and enterprises are pursuing.

The eHighway system is an energy-efficient, low-emission solution that was developed for heavily used truck shuttle routes. The system encompasses overhead cables for roads and electric or hybrid trucks fitted with intelligent current collectors. With the energy-efficiency reaching around 80 percent, the eHighway system is about twice as efficient as a diesel truck, thanks to the higher efficiency of electric drives. Pilot projects have been carried out in Berlin (Germany) and the Port of Los Angeles (USA).

To reduce the emissions from the buses in the urban areas, Stockholm (Sweden) municipal government constructed a fast charging system for hybrid buses along an public transport corridor. The charging station consists of a grid connection with a power converter and a transformer as well as a charging tower with a contact arm. As soon as a bus arrives at a charging station, a wireless connection is established via WLAN so that the bus can be identified and the requirements of the battery management system queried. On average, the buses were able to cover 70 percent of the route solely on electricity — quietly and without producing any emissions.

Reinforcing transport demand management and developing people-oriented green transport

Transport demand management is one the most effective ways for controlling motor vehicle usage intensity and solving the conflict between transport supply and demand, mostly through various policies/regulations and economic measures. Presently, the transport demand management measures adopted by most overseas cities are economic measures. Cities such as London, Singapore, Oslo, and Stockholm implemented congestion charging schemes and high charges for parking in downtown areas. London also implemented low emission zone. These measures have resulted in significant decreases in traffic congestion and increases in air quality. For instance, the traffic congestion within the congestion charging zone was brought down by 20%, and CO_2 emission was reduced by 150 thousand tons.

These cities have a common characteristic, that is, while reinforcing the transport demand management measures they all established advanced public transport systems (including light rail), highly efficient traffic management systems around the charging zones, safe pedestrian facilities, and convenient parking facilities outside the charging zones. For example, World class adaptive pedestrian crossings have been installed on most of London's road, to ensure the safety of pedestrians when they cross the roads and minimize the impeding of traffic flows at the same time. These cities also widely implemented public transport priority. The Danish capital Copenhagen even achieved bicycle priority at signal controlled junctions. Such measures have fully embodied the concept of people oriented and green transport.

The international experiences in transportation development from the environment protection perspective indicate that the future development trend in transportation, be it planning, operations and management or manufacturing of transportation equipment, is to rely on modern technologies and the concept of sustainable development, to pay more attention to details and the people orientation, and to minimise transportation sector's impacts on environment through a wide range of technological innovation.

3. Transportation development in China and environmental challenges

After 30 years of reform and opening up, China have made remarkable achievements in the growth of the transportation industry and development of the transportation infrastructure and attracted much worldwide attention. By the end of 2014, the total length of highways in China exceeded 4.46 million kilometres[2]. By the end of 2015, China's railway in operation reached 121 thousand kilometres, and the length of its high speed railway is over 19 thousand kilometres, the longest in the world[3]. China's urban rail transit also entered a rapid development period. Totally there are 25 cities that constructed 114 lines of urban railway lines, and the operational length is over 3516 kilometres[4]. The technological level and quality of some of the transportation infrastructure projects have reached or even exceeded world's advanced level.

The rapid development of the transportation sector have made great contributions to the social and economical development of China, but also caused varying degrees of damage to the environment, especially the severe pollution from the exhaust of motor vehicles. For example, the emission source analysis for Beijing and Shanghai showed that more than 30% emissions came from motor vehicles[5]. Nationwide, 10-25% of PM2.5 first emission source is from motor vehicles, and 20-25% of the secondary PM2.5 source (e.g. SO2 and NOx) is from motor vehicles[6]. Environment pollution caused by motor vehicle emissions worsens in recent years. The main causes can be summarised in the following two aspects.

Extensive development model

First, China's urban-rural planning, land use and transport development has not fully taken environment protection into consideration. Many cities are still taking an extensive approach towards their transportation infrastructure development. Measures for tackling congestion still rely heavily on building new roads to cope with the increasing traffic. However, the supplies of roads can never match the increases in transport demand. It has been proven that while increasing road capacities could improve the transportation infrastructure in cities, it could also reduce the time cost of using private cars, thus accelerating the growth in car

[2] Source：China Ministry of Transportation.
[3] Source：the executive summary of Sheng Guang Zu CRCWorking Report（2015 summary and 2016 Plan）.
[4] Source：World Rail Transport Development Research Society.
[5] Source：Beijing Environment Protection Bureau and Shanghai Municipal Government's web sites.
[6] Source：China NDRC Energy Research Institute.

ownership and stimulating the intensity car usage, which in turn makes the congestion even worse. The experiences of worldwide city development have demonstrated that solving congestion problem by purely building more roads is mistaken.

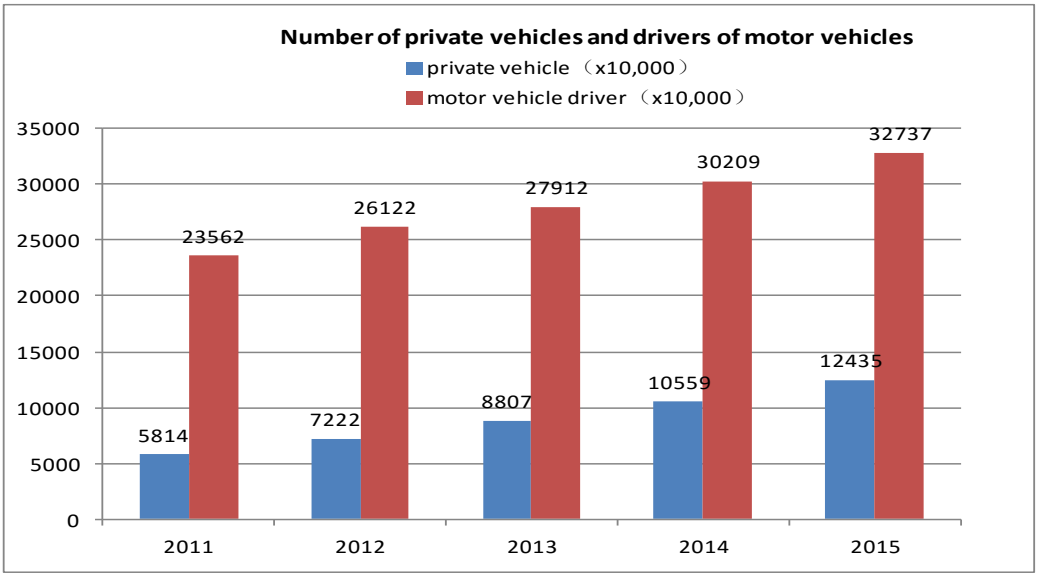
Second, there is a lack of integration of transportation infrastructure. China has constructed high speed and intercity railways with high operation efficiency, and many cities have also built high quality and comprehensive public transport systems (e.g. Bus Rapid Transit, urban light rail and metro). However, in most cases, these systems are not integrated, or fine managed with coordination. Nor are they optimized as a whole. Furthermore, most cities' current traffic management systems requires deeper optimisation, further data exploration, and more dynamic monitoring and decision making framework for them to play their crucial roles as they should in the process of traffic management and decision making.

There is a lack of detailed examination and deliberation during the transport planning stage. Environment protection issues have not become the main focus. The selection of solutions overemphasises initial capital investment without systematically analysing the solutions' contribution to the intensification and the building of green, intelligent and low carbon transportation within their whole product lifecycles. This lack of foresight often leads to repetitive construction. A large number of plans and design for roads did not stick to the concept of people-oriented transport, and this often results in traffic congestion and even accidents.

Inadequate transport demand management scheme

By 2015, the number of motor vehicles in China is 279 million, of which 172 million are automobiles. There are 40 cities where the number of automobile has exceeded 1 million, and 11 cities with over 2 million. As shown in Figure 2, the speed of private vehicle ownership increase is slowing down but the number of vehicles is still increasing by more than 15% every year. The number of motor vehicle drivers also increase by about 10% every year.

Figure 2 Nationwide numbers of private cars and drivers



The automobile ownership in London is about 400 vehicles per thousand. In comparison, there are 5.35 million cars in Beijing, whose automobile ownership is the highest in China, at about 250 vehicles per thousand. Although London's vehicle ownership has always been relatively high, its impact on the environment is insignificant, due to the city's stringent transport demand management measures (e.g. road taxes and congestion charging). Hence, China's congestion problem is not caused by the high car ownership. It is mainly due to the problem of extremely high use intensity. However, the current transport demand management measures adopted in China are mostly "one size fit all" type of measures (e.g. restrictions on travel based on car registration numbers and restrictions on issuing number plate). These measures have not differentiated the diversity of requirements for environment protection (e.g. cars with bigger engine sizes should shoulder more responsibilities).

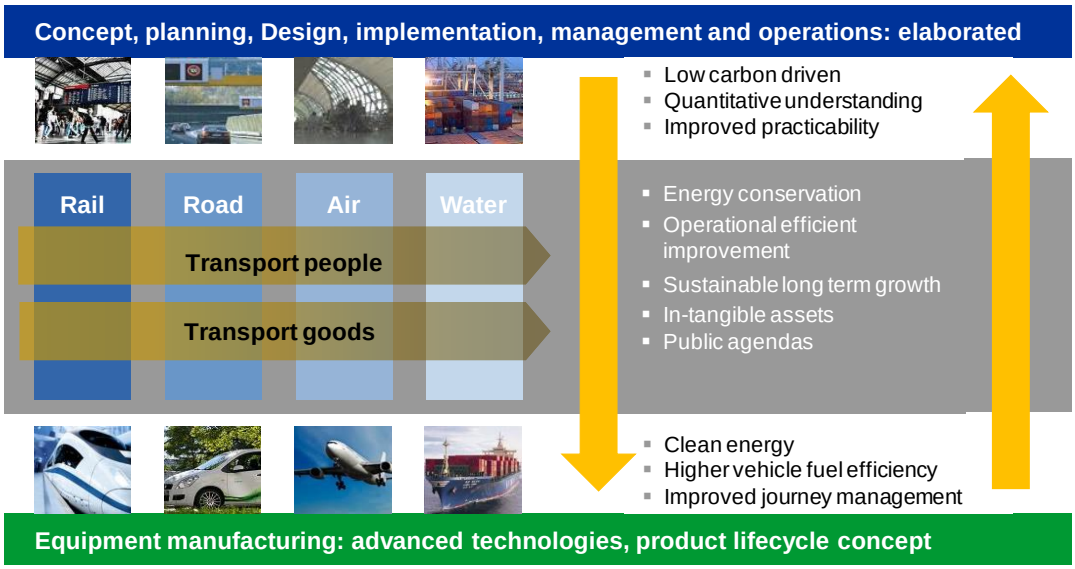
4. Construct an environment friendly transportation system with China characteristics

Sustainable development is reflected through balanced development between the environment, life quality and competiveness. It has become China's basic policy. The 13th Five Year Plan will put more emphasis on developing ecological

civilisation, which requires the strong support of green low carbon transportation. Stepping up the construction of safe, convenient, highly efficient, green, economical and integrated transport system to minimise the effects from the transportation development is an integral part of enhancing environmental management system and comprehensively improving the environment quality.

The development of transportation in China can be optimised in two dimensions, taking into account of fine planning, implementation, operation and management, and manufacturing of equipment (as illustrated in Figure 3). The impacts on environment need to be considered based on the entire product lifecycle.

Figure 3 Method for optimising transportation development



The development of green transportation requires persistence and continuous efforts. The other countries successful experience in handling the relationship between transportation development and environment protection showed that they achieved the results through decades of arduous and tortuous process of exploration, and are still making improvements. Given that the situation in China is much more complicated, the following are the main recommendations on environment protection for the transportation sector.

Overall transportation optimization through refined development with environment protection as the ultimate goal

During the 13th Five Year period, besides continuing with the development of energy-efficient urban rail transit, suburban rail transport and intercity rail transport infrastructure to ease the traffic congestion on motorways, traffic management in urban areas should also be improved by taking the opportunity of the smart city initiative, and systematically integrated and optimised.

The development thinking mode should be shifted from extensive approach towards refined approach. Transportation infrastructure development should be more focused on quality rather than quantity, as well as on structured optimisation. With the multipronged approach and the energy efficiency and environment protection principal, the entire transportation industry should achieve the most optimised planning, manufacturing, implementation, operations and management through digitalisation, electrification, automation and intelligent solutions. In this respect, some small and medium-sized Chinese cities are already in the lead, such as Zhuhai and Changzhou. Both cities are implementing the green transportation and environment protection concepts to guide the cities' transportation infrastructure development.

Fully draw good practices and absorb advanced concepts from model countries, and achieve technological innovation

Over the years the transportation sectors in some countries and cities overseas have accumulated a lot of good practices and experiences in environment protection. China should try to draw on and utilise these experiences, understand the future development trends of transport technologies, taking account of the situation in China explore the opportunities and innovate. The focused should be on utilising some innovative solutions to solve bottle-neck problems and sectors that produce heavy pollution, such as the pollution problem from freight transport operations. In China, trucks account for 22% of the total number of motor vehicles, whereas the emissions from them account for 56% of the total emissions from motor vehicles. Thus, for some highways with heavy flows of trucks electrification may be a good option to consider.

Improve the environment protection mechanism and strengthen transport

demand management

The coordination mechanism between environment protection and transportation development should be strengthened. Having fully optimised the transportation infrastructure as a whole, more flexible and differentiated transport demand management measures should be gradually promoted and reinforced. A dynamic monitoring and evaluation index system for analysing transport development and its environmental impacts should be established. This index system should be in line with international standards to facilitate future bench marking. It will become a standard for Chinese cities' transport development level measurement and guidance for their transportation development. It will also become a crucial part of city transportation management information and decision support platform.

Stakeholders and users must pay much attention to energy efficiency throughout the entire product lifecycle. They should consider not only the initial capital expenditure but also the costs of future upgrade and recycle, such as the manufacturing and recycling of the batteries of e-vehicles, the rolling stocks and components of rail transport. As more and more transportation infrastructure and vehicles are being electrified, more attention should be paid to improve the energy structure and efficiency of coal-fired electricity generation.

Lastly, another focus area should be creating a number of pilot and demonstration projects in some key development regions with the most advanced international standards and the highest quality, the experience from which will be constantly summarised and promoted throughout China. The Jing-Jin-Ji integrated transport development initiative and the region's pressing demand for environment improvement have offered very good entry points and practical platform for these kinds of projects.

5. Summary

Intensive, green, intelligent and low carbon transport is the goal of sustainable transportation development, which should minimise the pollution while contributing to the economic and social development. Some developed countries' experiences have shown us that through refined planning, implementation, operations and management, the development of transportation can be optimised to achieve the coordinated development of economy, society and environment. The

approach presented in this paper also embodies the concept of “innovation, coordination, green, openness and sharing” which supports the construction of beautiful China and will certainly guide the execution of “the Belt the Road” Initiative.