D1.6 IMPACT ASSESSMENT RESULTS

VOLUME 11: NANJING, CHINA

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PROJECT PARTNERS

ABOUT

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SOLUTIONSplus Impact Assessment Results

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EXECUTIVE SUMMARY

PROJECT PARTICIPATION

SOLUTIONSplus stands for Integrating Urban Electric Mobility Solutions in the Context of the Paris Agreement, the Sustainable Development Goals, and the New Urban Agenda. It is a flagship project of the European Union on smart and electric urban transport solutions. SOLUTIIONSplus unites a diverse group of stakeholders, including cities committed to sustainability, leading industry experts, research organizations, operational bodies, and financial partners, to establish a comprehensive platform for fostering electric mobility solutions that serve public and private transportation needs. This initiative is driving the shift towards more sustainable urban transportation systems. At the city level, it supports the experimentation and enhancement of various innovative electric mobility strategies through an extensive toolkit, initiatives for building capacity, and efforts to engage the community. The project receives financial support from the European Union's Horizon 2020 research and innovation program under grant agreement No 875041, highlighting its significance in advancing green urban transport solutions.

Following an invitation from Mr. Zhong ZHANG, Director at Jiangsu International Technical Communication and Collaboration Center (JISTC), Dr. Li WAN from China-Link Invest (CLI) made a trip to Nanjing in September 2019. During this visit, he had a meeting with Prof. Yong QI of Nanjing University of Science & Technology (NJUST), and they subsequently organized a virtual meeting involving three key European stakeholders: Dr. Oliver LAH of the Wuppertal Institute, Dr. Giacomo SOMMA from ERTICO ITS-Europe, and Mr. Ralf WILLENBROCK from T-Systems International. This virtual gathering served as an opportunity for a reciprocal introduction between the experts from Nanjing and the SOLUTIONSplus project.

Situated in the lower reaches of the Yangtze River, Nanjing covers an area of 6,598 square kilometers and is a pivotal part of the vast Yangtze River Delta economic zone. This region is crucial, as the Yangtze River basin, spanning approximately 700,000 square miles, supports almost one-third of China's population of 1.3 billion and accounts for more than 40% of the country's GDP.

As a result of concerted efforts, Nanjing is the only Chinese city covered under the SOLUTIONSplus project. The city's involvement aims to evaluate the impact of the LCMM (Low Carbon Mobility Management), adopting the pioneering standards of ISO/DIS 23795-1 for enhancing transport systems and planning future strategies while deepening commitments to environmental sustainability. Additionally, the LCMM project in Nanjing is recognized as a significant National Key Research initiative, receiving accolades and financial support from two Chinese ministries.

Cities participating in the SOLUTIONSplus project alongside Nanjing are Hanoi, Pasig, Kathmandu, Kigali, Dar es Salaam, Quito, Montevideo, Madrid, and Hamburg. Including Nanjing in the SOLUTIONSplus represents an important collaboration between the EU and China. Cooperation with JISTC and NJUST has been essential in aligning the project with local priorities, and CLI has been engaged in supporting the Nanjing LCMM demonstration under SOLUTIONSplus.

PROJECT DEVELOPMENT

The SOLUTIONSplus project, commencing on January 1, 2020, brings together 45 global partners to promote sustainable urban mobility through innovative electric solutions. Building on the Urban Electric Mobility Initiative was launched in 2014, and working in conjunction with a project overseen by the IEA and UN Environment, SOLUTIONSplus strives for a worldwide transformation in e-mobility and aims to showcase city demonstrations.

Dr. Li WAN, representing the demonstration city of Nanjing, participated in a kick-off workshop in Berlin. Upon his return, and in collaboration with Nanjing's leadership, he formed two crucial teams:

1. LCMM Demo Core Team: This team includes Associate Professor HE Liu from NJUST, Dr. Xianli ZHU, Senior Economist from UNEP, and Mr. Xin XU, Project Manager from T-System China, with Dr. Li WAN from China-Link Invest (CLI) serving as the coordinator. The team operates under the guidance of Professor QI Yong from NJUST and Mr. Ralf WILLENBROCK from T-Systems International.
2. Nanjing Capacity Build Core Team: This team is highlighted by Ms. Qian GONG from JISTC, with coordination by Dr. Li WAN and oversight by Mr. Zhong ZHANG, the Director at JISTC.

Nanjing's demo operations are reviewed monthly among teams and reported in the SOLUTIONSplus Asia-Pacific meeting, headed by Dr. Shritu Shrestha (Wuppertal Institut) and Ms. Kathleen Dematera Contreras (Clean Air Asia).
The Nanjing SOLUTIONSplus activity started during a notable event on April 14, 2020, focusing on "Management of Public Transport to Contain COVID-19: Lessons from Nanjing, Madrid, and Hamburg". The first China-EU quarterly meeting on November 13, 2020officially introduced the Nanjing demonstration to government representatives from China and the EU.

The SOLUTIONSplus Program celebrated the opening of its Nanjing Training Centre in the Jiangning District Park on September 15, 2021. The inauguration, attended remotely by European partners such as UEMI and ERTICO, highlighted the synergy between European and Chinese efforts towards sustainability and e-mobility, drawing participants from both the academic and industrial sectors.

Despite the challenges posed by COVID-19, the ITS World Congress took place in Hamburg in mid-October 2021. Dr. Li WAN represented Nanjing and shared updates on the city's progress within the SOLUTIONSplus demonstration.

In 2022, a service contract was finalized between NJUST and T-System for the LCMM demonstration deployment in Nanjing, alongside a Memorandum of Understanding (MoU) with UNEP for assessing the Nanjing LCMM demonstration.

The launch event for the LCMM demonstration in Nanjing was held on June 14, 2022. Later, on September 15, 2022, during the SOLUTIONSplus General Assembly in Potsdam, Germany, Dr. Li WAN updated the participants the LCMM demonstration from Nanjing's perspective. The platform, which became operational and released its first application in August 2022, by solving obstacles such as the unavailability of Google Maps in China and security concerns regarding GPS tracking, and began testing with ten private vehicles with assigned responsibilities:

- LCMM Demo Deployment: Directed by Prof. Liu HE, this has three phases: LCMM knowledge acquisition, deployment on 15 private cars, and extension to public buses.
- LCMM Localization: Led by Xin XU from T-System China, this includes platform localization, an app launched in August 2022, and operational support.
- LCMM Nanjing Demo Assessment: Guided by Dr. Xianli Zhu from UNEP, the steps involve aligning SOLUTIONSplus criteria with LCMM, supporting data sampling, and finalizing an assessment report. The consortium is encouraged to reflect on expansion strategies and objectives.

Dr. ZHU from UNEP and Prof. HE from NJUST completed a user needs survey, incorporating a questionnaire and online interview aligned with the SOLUTIONSplus assessment framework. This revealed the significance of different impact indicators. All data practices adhere to Chinese laws, EU laws, and UNEP guidelines.

On March 26, 2023, Prof. HE and Mr. XU presented the "SOLUTIONSplus LCMM Nanjing Field Trial Report" v.0.2. Dr. Xianli ZHU and Dr. Subash Dhar from UNEP reviewed it. Initial feedback indicated challenges in drawing conclusions due to the demo's small sample size and limitations in adapting the LCMM App for China, affecting real-time driver interactions and map display. Feedback from demo drivers is also suggested. Consequently, an extended LCMM field test was proposed: using 1000 km for LCMM calibration using daily driver feedback and the remaining 9000 km to employ 3-4 taxis for LCMM field testing.

Based on the insights gained from our previous experience, we structured the second iteration of the LCMM tests into three distinct Stages: calibration, a baseline demonstration with the LCMM disabled, and a comparative demonstration with the LCMM active. This demonstration involved four electric passenger cars with 12000 km data. On November 22, 2023, the Demo results were presented, and the United Nations Environment Programme (UNEP) provided a positive assessment of these results.

Professor He, from NJUST, spearheaded the survey of LCMM drivers, utilizing the questionnaire developed by Dr. Zhu from UNEP. On November 27, 2023, Prof. HE submitted the answers.

ERTICO-ITS invited Nanjing to join the "ERTICO City Moonshot survey." The initiative interviewed 300 global cities about their mobility challenges and trends, aiming to create a centralized knowledge database on smart mobility needs.

Dr. WAN has been asked to review the document titled "D3.8 IDIADA Standardisation and Harmonisation_IDI_rev_1.0.docx" under WP3 for the SOLUTIONSplus project.

PROPOSALS FOR SCALE-UP

On September 13, 2023, Professor He from NJUST presented a comprehensive summary of the LCMM (Low Carbon Mobility Management) scale-up. This initiative from T-System in Germany, transplanted in Nanjing, China, targets reducing urban traffic pollution through eco-driving. The program educates drivers using vehicle data, effectively cutting CO_2 emissions and fuel usage. A Nanjing pilot achieved a 14.09% reduction in emissions. Expansion plans involve collaborations with transport agencies and integrating features into mapping apps. Significant challenges include technical compatibility, partner engagement, privacy issues, and financial viability. Overcoming these through government partnerships, corporate agreements, community involvement, and international collaboration indicates LCMM's potential for wider adoption, advancing China's sustainable transportation and energy objectives.

LCMM NANJING DEMO PARTNERSHIP IN CHINA

To date, NJUST, the Chinese lead for the SOLUTIONSplus project, has completed its designated tasks, yielding the following outcomes:

1. LCMM Implementation: In Nanjing and Beijing, LCMM technology was demonstrated, gathering 15,000 km of data. Post-implementation, carbon emissions in these cities were reduced by approximately 10%-20%.
2. Nanjing New Energy Transportation Training: Over 500 individuals received training in Nanjing on promoting and applying new energy transportation methods.
3. Nanjing New Energy Transportation Development Survey: Multiple surveys were conducted in Nanjing to assess the development of new energy transportation, collecting around 1,600 responses.
4. Nanjing Intelligent Networked Electric Bus Demonstration: An Intelligent Networked Electric Bus Cloud Control Platform, utilizing digital twin technology, was launched in Nanjing's Baixia Hi-Tech Zone and Jiangxinzhou. It covers more than 20 bus lines, enhancing bus punctuality by about 25% and reducing bus energy consumption by approximately 18%.

In summary, NJUST has been instrumental in advancing Green I.T.S., optimizing energy use in transportation, reducing transportation-related carbon emissions, and significantly improving global climate conditions. The achievements have surpassed the objectives set in the SOLUTIONSplus project.

The LCMM demonstration in Nanjing also involved participation from several organizations, including:

- Nanjing E-Charger Electric Vehicle Service Co. Ltd
- Jiangsu Zhicheng Huining Transportation Technology Co. Ltd
- China Design Group
- Nanjing Intelligent Transportation Information Co. Ltd

ACKNOWLEDGMENTS

The Nanjing demonstration, as part of the SOLUTIONSplus initiative, received backing from a diverse array of entities, programs, and organizations. Key supporters encompassed the Jiangsu International Technical Communication and Collaboration Center, Nanjing University of Science & Technology (NJUST), Nanjing Intelligent Transportation Information Co. Ltd, the Urban Electric Mobility Initiative (UEMI), the UN Environment Programme (UNEP), ERTICO ITS-Europe, T-System, the Wuppertal Institute, along with all other consortium members of SOLUTIONSplus.

Coordinator (Signature): Dr. Li WAN   Date: March 8, 2024

TECHNICAL SUMMARY

This is the Impact Assessment Report for the demonstration activity in Nanjing City, Jiangsu Province, China, under the SOLUTIONSplus project. The full name of the SOLUTIONSplus project is Integrating Urban Electric Mobility Solutions in the Context of the Paris Agreement, the Sustainable Development Goals (SDGs), and the New Urban Agenda. SOLUTIONSplus project is funded by the European Union's Horizon 2020 research and innovation program. It aims to enable transformational change towards sustainable urban mobility through innovative and integrated electric mobility solutions. Under the 5-year project (2018-2023), 47 partners and over 100 associated partners work together on transformative change towards sustainable urban mobility through innovative and integrated electric mobility solutions.

SOLUTIONSplus involves ten demonstration cities, also known as living labs; among them, four are in Asia: Hanoi (Vietnam), Kathmandu (Nepal), Pasig (Philipines), and Nanjing (China).

ABOUT THE LCMM TOOL

Nanjing participated in the SOLUTIONSplus city demonstration as an associated partner. The city received capacity-building support and learned from the experiences of other cities under the SOLUTIONSplus project. Still, the in-country activities in China did not receive funding support from SOLUTIONSplus.

The contents of the Nanjing demonstration activities were based on installing the Low Carbon Mobility Management (LCMM) app on the smart phones of private car and public bus drivers and using the app's feedback about each driver's driving performance to motivate eco-driving for saving fossil fuel/electricity and reducing the emissions of GHG and other pollutants. The LCMM was developed by the German Telecom Company (Deutsche Telekom AG) from 2011 to 2014, with funding from the German government. The Nanjing demonstration project obtained access to the LCMM and technical support for its pilot application via the Beijing office of T-Systems International GmbH[1], an IT service company owned by Deutsche Telekom AG T-systems.

The LCMM technology combines mobile communication with smart phones, GPS profiling and cloud-based computing. The core of the system architecture is the Advanced Telematics Platform (ATP)[2]. Based on real-time GPS monitoring of vehicles and using vehicle technical parameters linked to the user profile, LCMM analyzes a driver's driving behavior and provides timely feedback on fuel efficiency, journey summary, and driving behavior categorization on the driver's smart phones. The LCMM platform functions include detailed analysis and display of all driving data, data export, and reporting.

The LCMM has been applied in China, Germany, and other EU countries, mainly through logistic firms, to motivate eco-driving and eco-routing. Previous applications of LCMM generated between 8% and 15% fuel savings.[3,4] Eco-routing and eco-driving

1 https://www.t-systems.com/de/de.
2 https://energypedia.info/wiki/Emission_Data_Monitoring_Technology.
3 https://www.telekom.com/en/company/details/why-logistics-companies-should-rely-on-the-driving-style-app-619688.
4 https://unfccc.int/climate-action/momentum-for-change/activity-database/momentum-for-change-low-carbon-mobility-management-lcmm.

are important approaches for saving transport fuel, reducing GHG emissions and local air pollution, and avoiding traffic congestion and accidents. The ISO recently issued a two-part standard related to intelligent transport systems based on several similar digital tools and solutions.

- ISO/DIS 23795-2 (en)-Intelligent transport systems — Extracting trip data using nomadic and mobile devices for estimating C02 emissions — Part 1: Fuel consumption determination for fleet management.[5]
- ISO 23975 – 1: 2022 (en) - Intelligent transport systems (ITS) — Extracting trip data via the nomadic device for estimating CO2 emissions — Part 2: Information provision for eco-friendly driving behaviours.

About the Nanjing Demonstration

The Nanjing demonstration activities (Nanjing demo) under SOLUTIONSplus consist of two parts: 1) establishing a regional training centre and offering training on sustainable and smart transport, including e-mobility, and 2) demonstration of LCMM use among private car drivers.

The training program started in September 2021, and as of August 2022, the training center had organized seven online and in-person training, with around 100 in-person participants and over 70,000 online participants and viewers.

The Nanjing Demo of LCMM application includes three Stages: Stage 1 involved eight private cars (six in Nanjing and two in Beijing) and a bus (in Nanjing) participating in the Demo. The baseline data collection Stage was from November 2022 to January 2023, and the intervention period was from January to March 2023. Although SOLUTIONSplus focuses on electric vehicles, all the private cars involved in the first Stage of the Demo are fossil-fuel ones. This is because even though e-buses are common in Nanjing, the ownership of electric cars is still low.

Due to the low mileage of several of the demo cars and unusually high fuel consumption (in some cases 1 litre/km based on LCMM platform calculation), the Nanjing demo team discussed in June 2023 and decided to engage more cars for the LCMM demo, which consisted of Stages 2 and 3 of the LCMM Demo on electric taxis in Nanjing.
Stage II involved only one taxi. The objective was to recalibrate the LCMM parameter settings by recording the e-taxi's actual electricity consumption and comparing it with the electricity consumption data estimated with the LCMM app.

During the baseline Stage, the project team helped the drivers install the LCMM app on their mobile phones, and the drivers kept the LCMM on during their driving trips. In this way, the LCMM platform could track the vehicle movement and assess the eco-driving performance of each trip. The real-time feedback function was disabled so the LCMM could collect and evaluate each driver's driving performance without influencing it.

Under the LCMM intervention Stage, the feedback function was enabled so the drivers could see real-time assessment results on their driving performance compared to the optimal indicators, illustrated as green (good), yellow (average) and red (poor) segments of their trip route.

5 https://www.iso.org/obp/ui/#iso:std:76971:en

The LCMM app stimulates eco-driving behaviour based on the assumption that when the drivers see the real-time assessment of their driving performance, they will be motivated to make corrections and improve their driving performance.

The Impact Assessment process and results

Under the SOLUTIONSplus project, several leading institutions developed detailed methodologies to assess the impacts of promoting e-mobility, including a 3-tier indicator system to evaluate the demo activities from financial, environmental, social, and macroeconomic aspects of e-mobility projects and activities (tier 1); tier 2 include more sub-categories for each tier 1 criteria, while tier 3 provides the detailed indicators for each tier 2 parameter. Each demonstration city conducted user needs assessment, using questionnaire surveys and interviews to find out the weight of each indicator.
The project team assessed the data collected for the 8 cars, and the result indicated 8.7% improvement in driving performance (fuel consumption reduction). The bus data was not included in the assessment as LCMM app only captures the driving performance data for a few trips. Moreover, in China, bus drivers are forbidden to watch their phone screens while driving, and there is camera surveillance on buses to ensure that bus drivers comply with the driving rules in Nanjing. As a result, bus drivers can’t check their mobile phones while driving to access the LMCC feedback on their driving behavior.

Recommendations for future scale-up

Due to economic development and income growth, vehicle ownership has been growing quickly in China. As shown in Figure 1 below, in the 11 years from 2011 to 2022, the number of registered vehicles more than tripled in China. Quick increases in vehicle ownership and transport activity creates economic prosperity, convenience and efficiency for passenger and freight transport. They also bring problems such as high fuel consumption, traffic jams, GHG emissions, local air pollution, and noise.

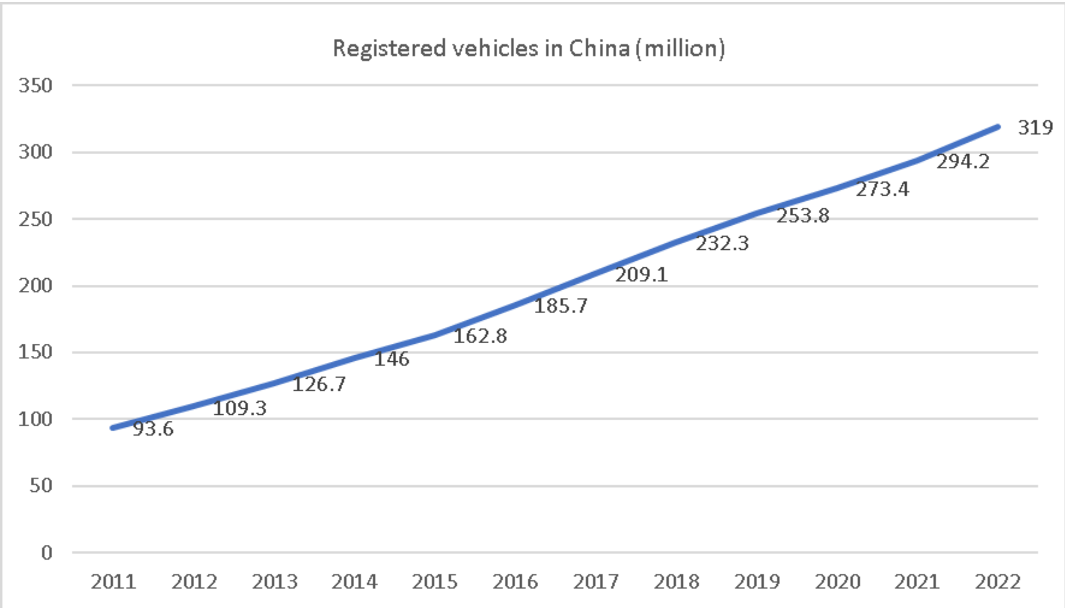

Figure 1. Rapid increases in registered vehicles in China

Eco-driving and intelligent transport can be an essential solution for fuel and cost saving, reduced GHG and pollution emissions, reduced travel time, improved road safety, and improved social well-being without expensive investment. It is essential for Chinese cities, which often have high population density and are home to millions of residents.

The results of the Nanjing Demo indicate that LCMM application is effective in stimulate fuel and electricity saving behaviors in China. They also provide valuable insights for further scaling up the application of LCMM and similar products. For instance, users are highly aware of privacy information and are reluctant to install and keep additional apps running on their mobile phones. The Nanjing demo team has innovative ideas for addressing such concerns and motivating continuous driving performance improvement based on LCMM. One idea is to integrate the LCMM into the popular GPS services in China, as most drivers use GPS services when driving. Another solution is to provide feedback to the drivers in the form of voices instead of visual signals so they do not need to look at their phones regularly. A third option is to promote the application of LCMM among companies with large fleet, use peer competition among the drivers, and provide monthly eco-driving awards.

As indicated in the report, LCMM is based on accurate and real-time GPS data collection on vehicles. The enormous data collected through LCMM also provides valuable inputs that cities can use to monitor and regulate traffic flows, take preventive measures, and quickly respond to traffic jams or road accidents. They can be an integrated part of smart cities and intelligent transport. The results of LCMM can also be used to track everyone’s carbon footprint to drive and encourage environmental and green lifestyles.

CONTENTS

ABBREVIATIONS

ATP	Advanced Telematics Platform
CNY	Chinese Yuan
CO2	Carbon dioxide
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
GPS	Global Positioning System
ISO	International Organization for Standardization
IOT	Internet of Things
ITS	Intelligent transport systems
KPI	Key Performance Indicator
MAAS	Mobility as a Service
NJUST	Nanjing University of Science and Technology
LCMM	Low Carbon Mobility Monitoring (LCMM)
MT	Million tonnes
NOX	Nitrogen oxides
PM	Particulate Matter
SDG	Sustainable Development Goals
USD	US dollar
WLPT	Worldwide Harmonised Light Vehicle Test Procedure

1 BACKGROUND AND CONTEXT

Nanjing is an associated demonstration city under the SOLUTIONSplus project. While the rest of the demo cities and technical partners receive EU Horizon2020 funding under SOLUTIONSplus project, the partners in China, Jiangsu International Science and Technology Promotion Association and Nanjing University of Science and Technology (NUST) do not get direct funding support from SOLUTIONSplus. Instead, their demo activities under the SOLUTIONSplus in Nanjing City and Jiangsu Province are funded by the Chinese Ministry of Science and Technology through a research project.

SOLUTIONSplus focuses on electric urban mobility and the demonstration of most other cities are on electric vehicles and charging infrastructure. In contrast, the Nanjing demo is on digital solutions for eco-driving and eco-routing. LCMM app can be applicable for both electric vehicles and fossil fuel vehicles, and the vehicles involved in the Nanjing demo includes both private gasoline cars and electric taxis.

1.1 GEOGRAPHY AND THE SOCIAL/URBAN CONTEXT

1.1.1 Geographic location of Jiangsu and Nanjing

Jiangsu is in the middle part of China's eastern coast and on the lower reaches of the Yangtze River and the Huaihe River. It borders the Yellow Sea in the east, Shandong Province in the north, Anhui Province in the west, and Zhejiang Province in the South, and Shanghai in the southeast. It is an important part of the Yangtze Delta, and 87% of the province's terrain consists of plains, 11.5% of hills, and only 1.6% of mountain areas. Jiangsu has high density of lakes, rivers, and sea areas, and water surface contributes 17% of the province's area. Jiang is the transition zone of sub-tropical and warm temperate climates. The province's overall climate is warm and humid. With its fertile land, Jiangsu is also known as China's basket of rice and fish.

Jiangsu's total area is 107,200 square km, accounting for only 1.12% of China's total area. Jiangsu Province consists of 13 cities with districts and 95 counties/districts. It had a population of 85.05 million at the end of 2021, about 6% of China's total population.

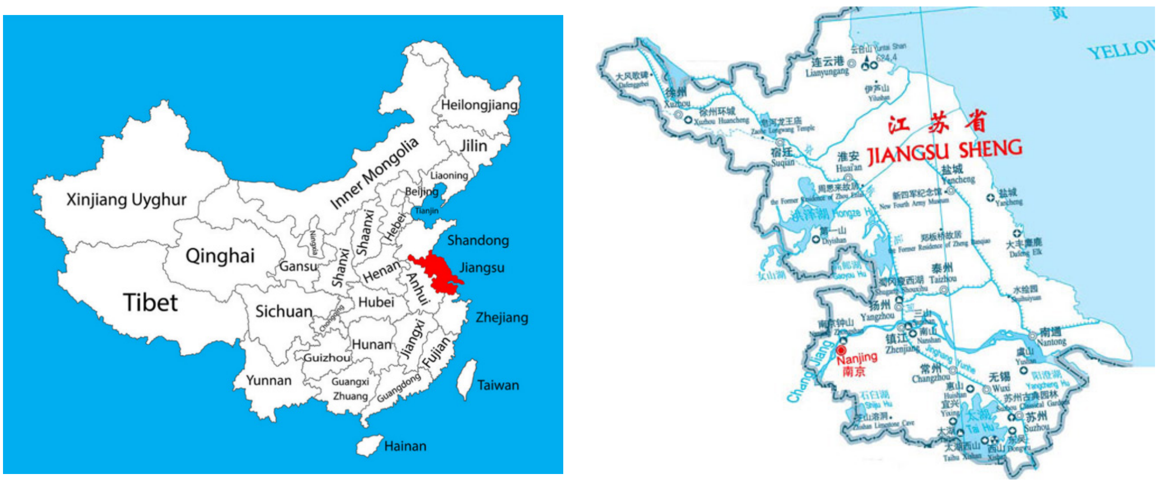

Figure 2. Jiangsu province's location in China

Nanjing is a regional transport hub. It is well connected to the neighboring cities via water ways along the Yangtze River, highways, and railways. China's new national network of express trains shortens travel time in cities. For example, today it is possible to cover the 300-km trip from Nanjing to Shanghai within 1 hour.

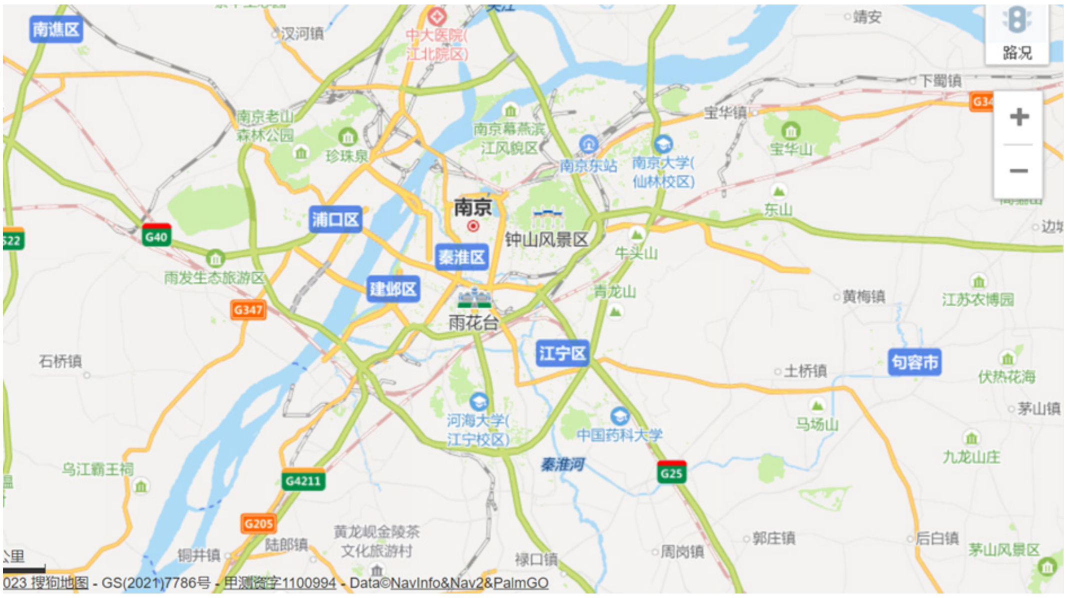

Figure 3. Nanjing's external transport connection

Nanjing consists of 11 districts; from north to south, they are Liuhe, Xixia, Gulou, Xuanwu, Jianye, Qinhuai, Pukou, Yuhuatai, Jiangning, Lishui, and Goachun. Downtown Nanjing mainly has six small districts in the middle, while the five large suburban districts used to be counties. According to the Nanjing Municipal Government[6], Nanjing is home to 9.42 million people.

Nanjing's per capita GDP reached 20,000 USD in 2021; during the 8 years from 2013 to 2021, the city's GDP grew 104%[7]. Data from the Chinese National Statistical Bureau indicated that in 2022, the average per capita disposable income in Nanjing city was 69,039 CNY and reported a 4.4% increase from 2021. The economic prosperity in the city and its neighbouring areas also means rapid increases in private car procession.[8]

Key Facts about Nanjing

Population: 9.32 million (2020)
Area: 6587.02 square kilometres (urban area: 2,543.26 square kilometres)
Location: in the south of Jiangsu Province, east China
Administrative Division: 11 districts (Xuanwu, Qinhuai, Jianye, Gulou, Qixia, Yuhuatai, Jiangning, Pukou, Liuhe, Lishui, Gaochun)
GDP (2019): CNY 1,403.015 billion (USD 203.365 billion)

Nanjing and its neighboring regions in Jiangsu province are densely populated. As the capital of Jiangsu province, Nanjing's population density is 1412 persons per square kilometer, almost double the average of 791 persons in Jiangsu province. Under the rapid urbanization in China, big cities experience population growth.

6 https://www.nanjing.gov.cn/index.html, accessed on 15 Feb 2023.
7 http://js.news.cn/2022-06/17/c_1128751772.htm
8 http://www.xhby.net/js/jj/202201/t20220113_7385287.shtml

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Figure 4 The 11 Districts of Nanjing City

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1.2 Urban transport

Like many other big Chinese cities, Nanjing has invested heavily in recent years to develop its public transport system, consisting of buses, multiple metro lines, taxis and over 5 million electric bikes.

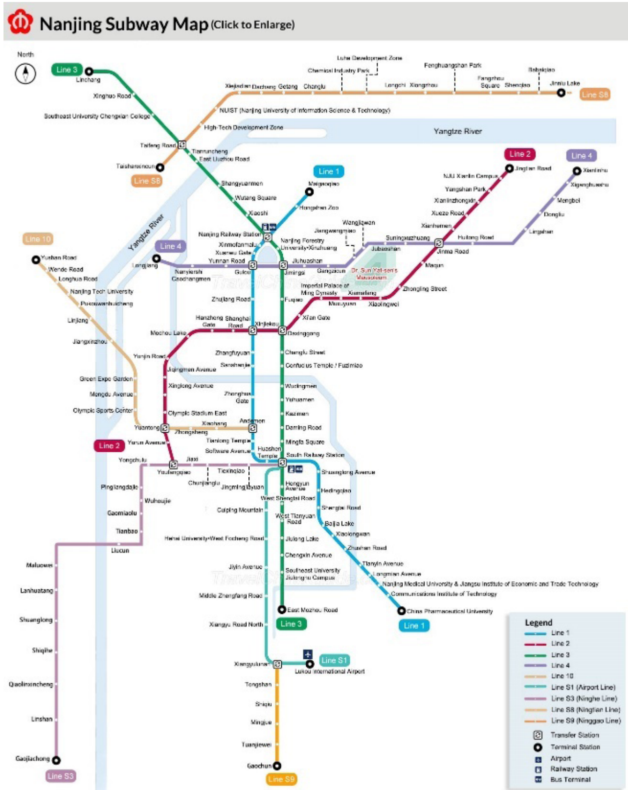

Figure 5. Nanjing's metro map

For many Chinese people, owning a car is a symbol of a well-off or middle-class life. By the end of 2022, there were 85 million people, and 25 million registered motor vehicles in Jiangsu province. Nanjing has over 2 million registered motor vehicles. How to manage the traffic flow and reduce urban traffic jams, energy consumption, and the emissions of GHG and local air pollutants is a priority for the local government.

1.3 IDENTIFICATION OF MAIN PROBLEMS

With limited space to build more roads, promoting eco-driving can be a cost-effective solution for eliminating urban transport problems while meeting people's daily transport needs. With its huge number of vehicles, even a few percentages of improvement in each driver's fuel efficiency means huge fuel savings and GHG emission reduction at the national level. Eco-driving is still in its early stages in China. The development of digital technologies, high penetration of smartphones, and constant internet make it possible to track real-time vehicle position using satellite signals.

Due to its limited oil reserve and high demand for oil products, China relies heavily on crude imports to meet its domestic demand for transport fuel. In 2021, 72% of the country's crude consumption depended on imports, declining for the first time since 2010. However, this declining trend is considered temporary and China's overall dependence on oil imports is expected to remain high in the coming years. The fuel savings from LCMM application can reduce the country's oil consumption, hence generating benefits in the macroeconomic KPIs and general social benefits.

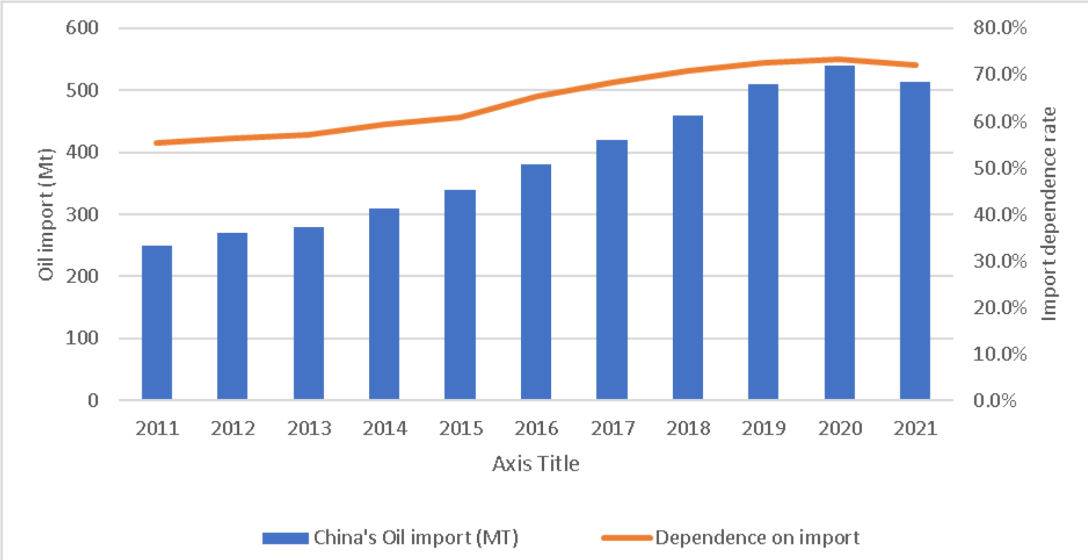

Figure 6. China's high dependence rate on oil import   Data Source [9, 10]

1.4 DESCRIPTION OF DEMONSTRATION PROJECT

The Nanjing demo includes two parts; one is establishing a regional training centre on e-mobility, and the other component is using the LCMM digital tool to stimulate eco-driving and eco-routing among private cars and public buses.

The Regional Centre on E-mobility: the Jiangsu Province establishes a regional training centre for e-mobility and organizes training activities on e-mobility. The regional training center belongs to Work Package 4 of SOLUTIONSplus. The trainings lead to improved knowledge and capacity among the participants to act on e-mobility and directly generate various social, economic, and environmental impacts. The Nanjing demonstration activities under SOLUTIONSplus consist of two parts: 1) establishing a regional training centre and offering training on sustainable and smart transport, including e-mobility, and 2) demonstration of LCMM use among private car drivers. The training program started in September 2021, and as of August 2022, the training centre had organized seven online and in-person training sessions, with around 100 in-person participants and over 70,000 online participants and viewers.

As the Impact Assessment is on the direct social, environmental, and economic impacts, this impact assessment report will focus on the LCMM application part of the Nanjing demo activity.

1.4.1 Applying the LCMM among passenger cars and buses

During the implementation of the Nanjing Demo under SOLUTIONSplus, the Nanjing University of Science and Technology (NJNUST) signed an agreement with the T-Systems Beijing office to help localize the LCMM, help install the LCMM App on smartphones of drivers, and operate the LCMM platform to analyse the data collected through the LCMM App.

9 http://news.cnpc.com.cn/system/2022/02/25/030060019.shtml#:~:text=2021%E5%B9%B4%EF%B-C%8C%E4%B8%AD%E5%9B%BD%E5%8E%9F%E6%B2%B9%E8%BF%9B%E5%8F%A3,72%25%EF%BC%8C%E4%B8%8B%E9%99%8D1.6%25%E3%80%82

10 https://m.huaon.com/detail/769006.html

1.4.2 About the Low Carbon Mobility Management (LCMM) App

LCMM Principle and Implementation

The driver gains information on how to drive more efficiently and the effects this will have on fuel consumption and CO2 emission of his vehicle. Besides considerable CO2 reductions, significant reductions in fuel consumption may lead to noticeable cost reductions, which, connected with environmental costs (CO2 certificates, compensation costs), result in a sustainable improvement of the CO2 footprint, as consumption and emission are closely related.

After starting the application on the device, positioning data is submitted continuously. This, combined with the vehicle's speed and chosen profile, results in a real-time calculated efficiency profile, which can be made available on the device during the drive and in parallel, e.g., on the dispatcher's web browser. Furthermore, after shutting down or stopping the application, the driver can promptly obtain the results regarding the drive and efficiency of the device.

The Nanjing demo is based on applying the LCMM digital tool to stimulate eco-driving among private cars and public buses. The LCMM app was provided by the Beijing office of the German company T-systems and localized to meet the conditions in China.
Reducing traffic congestion and noise, NxO emissions, particulate matter (PM), and CO2 emissions from road transport is a common challenge facing many cities. Instead of restricting road traffic, the LCMM uses digital solutions to improve drivers' driving behaviors to save energy and reduce the negative environmental impacts associated with road transport. The LCMM can track, control, and prevent air pollution from road transport, reduce CO2 emissions and environmental noise pollution, and improve traffic safety[11]. The LCMM system has been applied in multiple European cities and Chinese cities for freight transport. The results indicate the LCMM can reduce fuel consumption by 9% on average.

How the LCMM works

LCMM uses smart phones and satellite-based Internet of Things (IoT) technology to increase the energy efficiency in logistics by making fuel consumption & CO2-emissions visible for strategic reduction decisions on the operational level. LCMM analyzes driving behavior and guides drivers based on daily real-time driving score/ trip summaries/regular reports and Eco-driving training to increase their awareness of efficient and safe driving.

By combining cloud services, mobile phone applications, and vehicle speed detection based on satellite positioning data, the LCMM platform calculates fuel and carbon dioxide emissions that vehicle drivers can access via smart phones. The indicator's color on the smart phone screen – red, yellow or green – makes it easy for the drivers to adjust their speed and increase fuel efficiency. The system processes the data in real-time and provides immediate feedback.

11 https://container-news.com/european-ports-test-it-solution-for-road-freight/

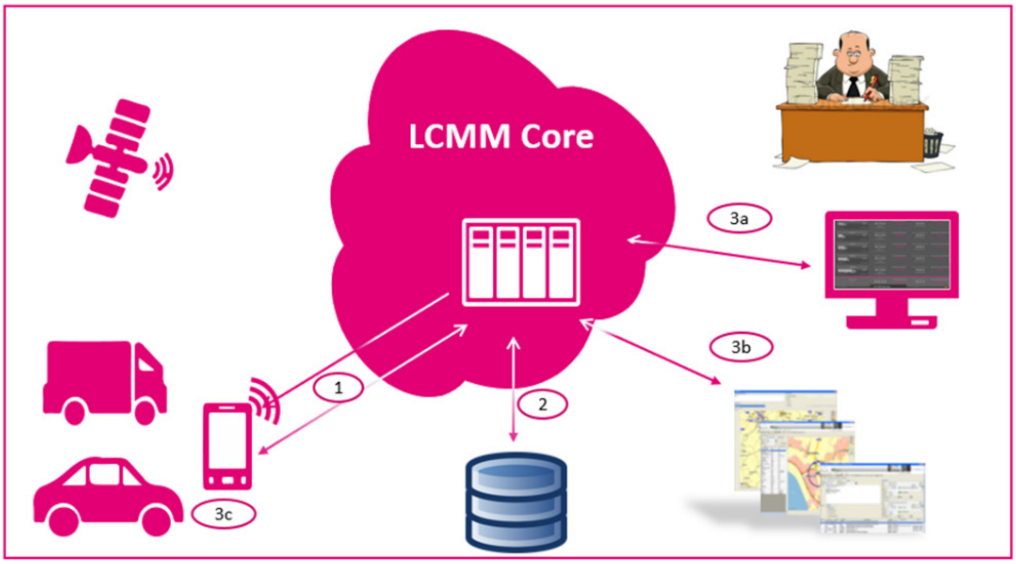

Figure 7. How the LCMM works

1. Mobile terminal device App; 2. Telecom mobile network; 3. LCMM Platform; 4. Visulisation Tool and Dashboard
2. LCMM App collects vehicle data (location, speed, rpm, emission data, vehicle parameters...)
3. LCMM App sends the data to the LCMM backend via Mobile network
4. LCMM backend process and save vehicle data from LCMM App (raw data, trip data, emission data and other calculation result data)
5. LCMM delivers (processed) emissions data to LCMM Web Portal, Download various data (emissions per trip/vehicle etc.) and provides data in APP Dashboard

During the LCMM app installation and registration process, a user provides input about a vehicle's technical parameters, such as maker, model, year, engine size, etc. It usually takes a few minutes to install the LCMM and register a vehicle.

LCMM uses the Global Navigation Satellite System (GNSS) receiver (a smart phone or a mobile device) to track a vehicle's location, and the smart phone or mobile device then uses mobile communication to send the data to a server. Unlike standard GPS navigation software, it has high GPS accuracy (max 4 meters) and high data collection frequency (one data collection per second). Moreover, the LCMM also collects the vehicle's elevation information apart from the location. The server calculates the vehicle's following real-time mechanical energy contributions: aerodynamic, rolling friction, acceleration/braking, slope resistance, and stand-still. The LCMM measures %--deviation relative to Driving Cycles commonly used by Governmental Vehicle Registration offices (WLTP) and sends feedback to drivers to motivate changes in driving behaviors.[12]

All the vehicle's real-time location data is stored on a centralized server. LCMM can also provide briefings for drivers. The vehicle routing information can be collected and presented in maps like Google Earth for visualization and additional analysis to improve efficiency.

12 Kemal Ayyildiz, Federico Cavallaro, Silvio Nocera, Ralf Willenbrock. Reducing fuel consumption and carbon emissions through eco-drive training. Transportation Research Part F 46 (2017) 96–110

Worldwide Harmonised Light Vehicle Test Procedure (WLTP)

The EU developed the WLPT for laboratory tests of new cars and enacted it in 2017, aiming to make WLPT a global test cycle across different world regions so pollutant and CO2 emissions and fuel consumption values would be comparable worldwide. WLPT measures the fuel consumption, CO2, and pollutant emissions from passenger cars. Although the WLTP has a common global 'core', each country or region can apply the test differently depending on their road traffic laws and needs. The EU has its conditions for WLPT lab tests. The WLTP driving cycle is based on real-driving data gathered worldwide. Therefore, it better matches road performance.

The WLTP driving cycle is divided into four parts with different average speeds: low, medium, high, and extra high. Each part contains a variety of driving phases, stops, acceleration and braking phases. Each powertrain configuration is tested with WLTP for the car's lightest (most economical) and heaviest (least economical) version for a certain car type. As the LCMM was originally developed in Germany, it uses a car model's EU WLTP lab test values to evaluate a car's driving performance and give the driver feedback via smartphones or mobile devices. The results are shown in green, yellow, and red so that the driver can change or improve their driving behavior.

1.5 METHODOLOGY AND PROCESS OF IMPACT ASSESSMENT UNDER SOLUTIONSplus

1.5.1 Relevant stakeholders and user needs

Nanjing's participation in the SOLUTIONSplus City Demo work came a bit late after other cities. The Impact Assessment work on the Nanjing Demo started in late 2020 and the actual stakeholder mapping took place in early 2021. The User Needs Assessment and Prioritization took place from May – September 2021. The Nanjing team's original plan for the E-mobility demo was to cover the four themes of "green, efficient, safe, smart" urban transport to build the intelligent networked electric bus, MaaS (Mobility as a Service) travel for last mile, last-mile delivery in four years. The demonstration project aimed to build a cooperation bridge between Europe and Nanjing, China, promote the development of new energy transportation technology and industry, support the application and promotion of new energy transportation in Nanjing, China, and create an efficient, safe and environmentally friendly public transportation travel experience.

Stakeholder mapping

(1) Government units

- Jiangsu International Sci &Tech Communication and Collaboration Center
- Nanjing Transportation Bureau
- Traffic Administration Bureau of Nanjing Public Security Bureau
- Nanjing Municipal Bureau of industry and information technology

(2) Colleges

- Nanjing University of Science & Technology

(3) Company

- Nanjing Yichong Electric Vehicle Service Co., Ltd
- Jiang Su Smart City and Intelligent Transportation Technology Co., Ltd
- China Design Group Co., Ltd

The original plan for the Nanjing demo in 2021

Nanjing is the only Chinese city among the ten global demonstration cities of SOLUTIONSplus (project number: lc-gv-05-2019), the flagship project of the sustainable, intelligent transportation demonstration of 2020 European horizon plan. Nanjing will focus on "green, efficient, safe, smart" themes to build a smart networked electric bus, MAAS travel for last mile, last-mile delivery in four years. This demonstration project will build a cooperation bridge between Europe and Nanjing, China, promote the development of new energy transportation technology and industry, support the application and promotion of new energy transportation in Nanjing, China, and create an efficient, safe, and environmentally friendly public transportation travel experience.

(1) MaaS

The project is expected to provide new energy-sharing vehicles in the parking lot of the XinCheng Building (i.e., the Nanjing Municipal Government Office building) , which is located near the Olympic Stadium East Station of Nanjing Metro Line 2. The parking lot is close to the Olympic Stadium, the municipal government, and the subway station, with a large flow of people and a large demand for the last mile transport services. 25 new energy shared cars are provided by the project partner Nanjing Yichong Electric Vehicle Service Co., Ltd.

Figure 8.The ground parking lot of Xincheng Building

Figure 9. Selection of new-energy sharing cars

At present, users can reserve, rent and pay for their cars through the "Easy Charge Car Rental" app installed on their mobile phones. The management platform has functions such as station management, vehicle management, member management, historical track analysis, etc. At the same time, the project plans to add a traffic carbon emission assessment module (i.e., LCMM) based on vehicle working conditions and driving paths on the system platform, and users will receive the assessment results (indicated from this project) through the "Easy Charge Car Rental" app to improve their driving habits. Project data will be uploaded to Ali-cloud or other servers, and all analysis data will be shared with the EU.

Figure 10 The "Easy Charge Car Rental" app

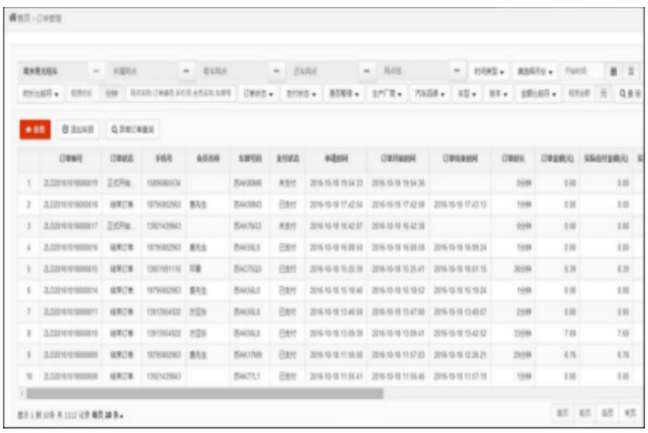

Figure 11 The management platform

(2) last mile delivery

Benefiting from open environment, driven by the development of emerging technologies such as big data, cloud computing and the Internet of Things, China's last mile of smart logistics has become very developed. At present, there are many forms of delivery, such as doorway-booking, unmanned cloud cabinets and community Courier stations. The Courier can receive and deliver orders in real-time through handheld terminals, and the recipient can check the location of goods at any time, be informed of the time of receipt or adjust the delivery time through mobile phones.
Due to real-time changes in delivery requirements and location technology, the planning of the last-mile logistics route relies more on Courier experience than algorithm tools, so the focus and necessity of this demonstration in Nanjing remain unclear. Besides, delivery stations do not allow couriers to install apps privately on handheld terminals unless authorized by headquarters.

The project plans to use E-bike or electric tricycle through the installation of LCMM dynamic path planning module in the mobile phone of couriers to monitor the delivery trajectory and evaluate the transportation carbon emissions. Project data will be uploaded to Ali-cloud or other servers, and all analysis data will be shared with the EU.

(3) Intelligent network with electric buses

The project plans to conduct an operational demonstration with five electric public transport vehicles, either existing or newly purchased. And three places have been chosen for demonstration: Baixia Science and Technology Park, Jiangxinzhou Islan, and the Economic Development Zone. The figure below shows the bus route planning of Baixia Science and Technology Park, including four bus stops and three intersections.

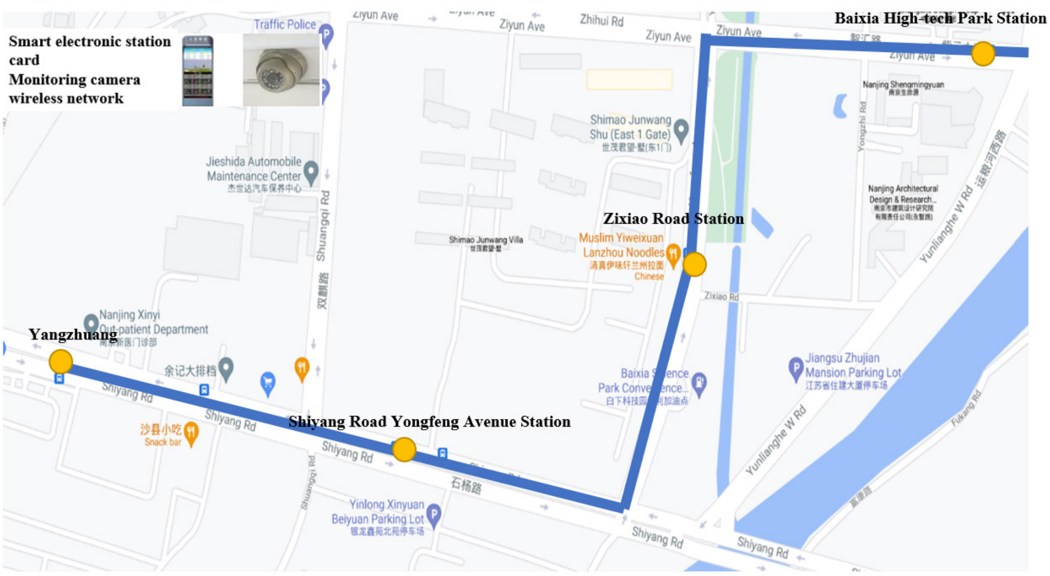

Figure 12 Planning bus route in Baixia Science and Technology Park

The main display scenarios of the project are 1) active traffic safety inside and outside buses, 2) bus priority at intersections, 3) Information screen of bus stop, 4) charge the robot in the parking lot, 5) the construction of digital twin cloud control platform. Project data will be uploaded to AliCloud or other servers, and all analysis data will be shared with the EU.

During the preparatory Stage of the Nanjing SOLUTIONSplus demo, the focus was on e-mobility; therefore, the stakeholder mapping and user needs assessment focused on electric vehicles. After the plan changed to LCMM software application, Nanjing simply followed the same process and schedule as other SOLUTIONSplus demo cities and no new stakeholder needs assessment was carried out. Therefore, the stakeholders' weights on different KPIs were not applied in the LCMM data assessment.
As the LCMM software is a solution for intelligent transport, the impacts of LCMM application are different from the impacts of switching from fossil fuel vehicles to electric vehicles, the latter is the focus of SOLUTIONSplus and the target area of the SOLUTIONSplus' impact assessment approach and methodology.

For the Nanjing LCMM Demonstration, the impact assessment work was also different in the following aspects: 1) the LCMM data collected the vehicle spatial location data every second, and used the enormous data collected to assess a vehicle's eco-driving performance. The processing of the data requires special software. The LCMM software was originally developed in Europe and the technical settings and indicator values are based on the vehicle driving performance data in Europe. Also, the App uses Google Maps to track vehicle positions. However, in China, Google is forbidden, and Google Maps is unavailable. For the Nanjing LCMM demo, it was agreed that T-Systems Beijing Office localized the LCMM by adapting it to the Chinese circumstances and helped process the data collected through the demonstration activities. 2) Another constraint is data security and restrictions on cross-border data transfer. China requires the data collected in the country to be stored domestically, making it impossible for the UNEP-CCC and other SOLUTIONSplus European partners to access the original data collected through LCMM.

LCMM software applications can have many side benefits, like less noise, better road safety, and reduced fossil fuel imports. The LCMM data analysis by the T-systems experts focuses on fuel saving. The results also include travel time saving as eco-driving leads to faster and smoother trips. As LCMM does not involve any fuel switch, the reductions in GHG emissions, air pollutant emissions, and fuel cost savings are equal to the percentage decreases in per kilometer electricity or gasoline consumption reduction.

Steps to adapt the LCMM software and the demo process:

Step 1. Localization of LCMM

T-systems Beijing Office localizes the LCMM and provides help installing the LCMM on smart phones of private car owners' smart phones.

Step 2. Trial and debugging of the LCMM

The localized version of the LCMM was installed on cars of a few project team members to test the data collection process.

Step 3. Baseline data collection period

Step 4. Period of Demo – LCMM stimulates eco-driving

Figure 13 below shows the originally planned schedule of the LCMM demo in Nanjing. However, after Stage 1 of the demo, the technical partners were unsatisfied with the results. To improve the quality of the demo, the NUST mobilized more financial resources to calibrate the LCMM, and recruited electric taxis for additional demo activities.

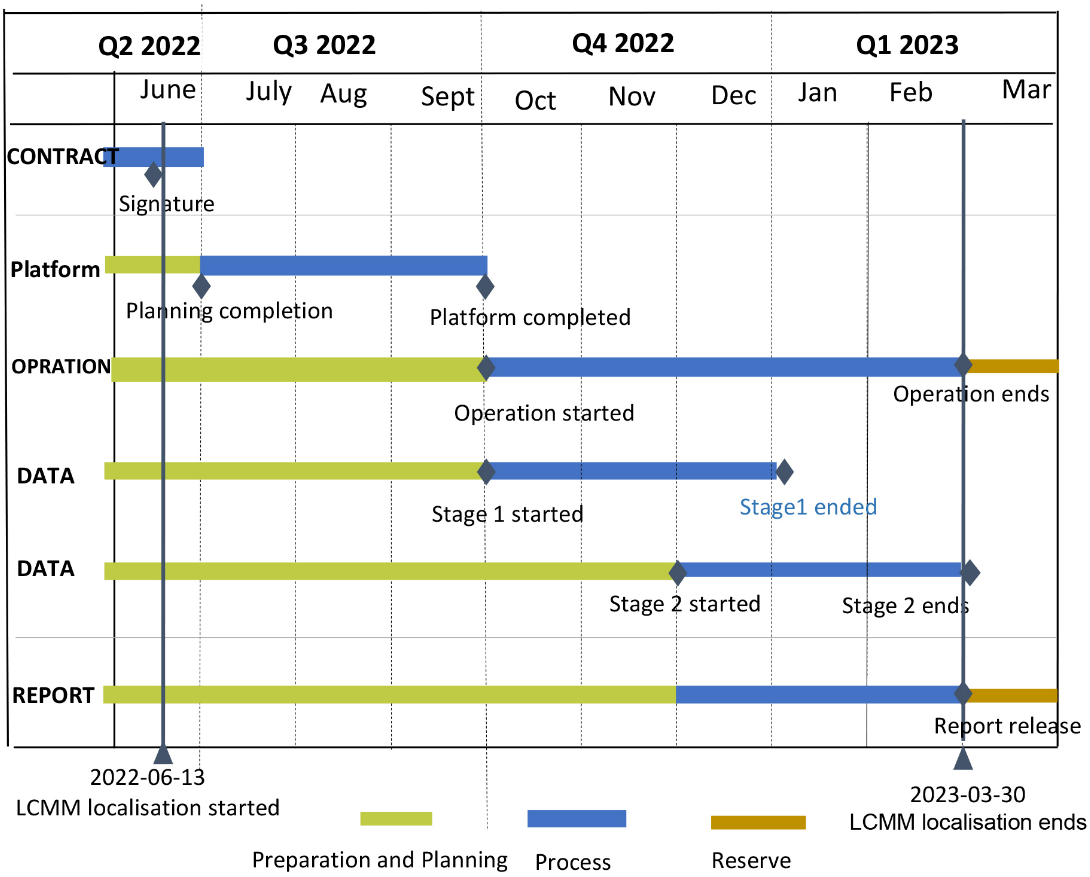

Figure 13 Original plan of the Nanjing LCMM Demo

2 KEY PERFORMANCE INDICATORS (KPIS)

2.1 PRIORITISATION OF KPIs ADDRESSING THE SPECIFIC CITY NEEDS

Based on the KPIs provided by the SOLUTIONSplus, the 15 stakeholders in Nanjing have provided the weights for different KPIs. They gave weights for all three levels of indicators, indicating they consider all the indicators relevant for the impact assessment for the demonstration and expansion projects in Nanjing (see Table 1).

Table 1. User needs assessment for Nanjing Demo

NO	TYPE	AFFILIATION	TITLE	NAME	KPI SCORING	UNA INTERVIEW
1	Government	Jiangsu Provincial Centre on International Science and Technology Exchange and Cooperation	Director	Zhong ZHANG	Y	Y
2			Deputy director of the Science and Technology Exchange Section	Qian GONG	Y	Y
3			Employee	Yurong YIN	Y	Y
4	University	Nanjing University of Science and Technology	Lecturer	Zi YANG	Y	Y
5			Undergraduate student	Xiangui LI	Y	Y
6			Post-graduate student	Jiaxin YUAN	Y	Y
7	Consulting Company on Transport Planning and Designing	Huashe Design Group Company Ltd.	Chief Technology Executive	Zhenqiang DING	Y	Y
8			Engineer	Miaomiao WANG	Y	
9			Project manager	Jiesong SUN	Y	
10	Business on smart transport	Jiangsu Zhicheng Huining Transport Technology Co. Ltd.	Project manager	Wenbo XU	Y	
11			Technology manager	Xiang ZHAO	Y	
12			General manager	Ningbo GAO	Y	Y
13	Enterprise on new energy based transport	Nanjing Easy Charge Eletric Car Service Co., Ltd	Employee	Cheng CHEN	Y	Y
14			Employee	Luwen GU	Y	Y
15			Deputy General Manager	Liang SHEN	Y	Y

When the User Needs Assessment was conducted in 2021, the planned contents of the Nanjing demo were to do the demo on electric shared cars and municipal bus lines. They were similar to the e-mobility demo activities in other SOLUTIONSplus cities, therefore, the impact assessment followed the methodology framework and guidance for e-mobility impact assessment from the SOLUTIONSplus Team. The methodology framework involves three levels of KPIs, which consist of 6 Level-1 KPIs, 20 Level-2 KPIs, and 36 Level-3 KPIs are used (see Figure 14).

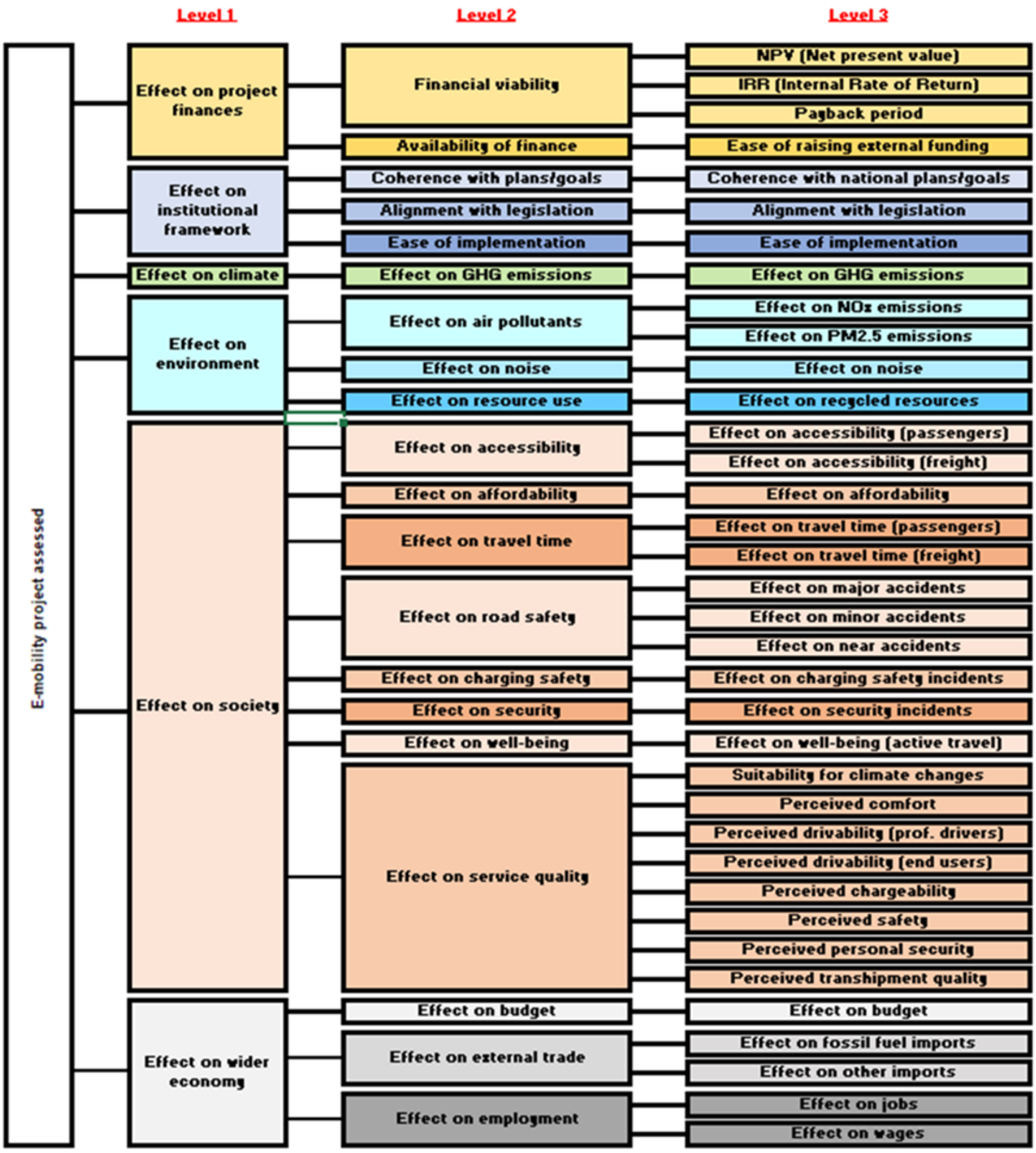

Figure 14: SOLUTIONSplus KPI Framework for E-mobility Demo Evaluation

2.2 PRIORITIZATION OF KPIS ADDRESSING THE SPECIFIC CITY NEEDS

2.2.1 KPI Prioritization

The assessment team conducted the User Needs Survey and Stakeholder Assessment regarding e-mobility in Nanjing during May – September 2021 through three steps:

Step 1: User needs survey + KPI (Key Performance Indicator) selection for the assessment (½ hour)

(list of KPI options available, need to give weight by around 10 stakeholders, and the stakeholders need to come from different types of organizations, like e-transport users, government agencies, research organizations, transport companies etc.)

Step 2: Online survey (questions in English, needs translation into English) of stakeholders (½ hour, mainly standardised questions, selecting one of the answers)

Step 3: Interview (in-depth question, open-ended questions)

During Step 1, stakeholders first gave a weight between 0 and 100 for the Level 1 KPIs, then gave weight to a 0-100 weight score for each of Level 2 KPIs belonging to the same Level 1 KPI. For instance, they gave relative scores for financial viability and availability of finance. Then, for Financial Viability (Level 2 KPI), they scored the relative weights of NPV, IRR, and Payback Period (Level 3 KPIs).

Based on the average relative weights (0-100), the assessment team calculated the average weight of each Level-1 KPI (the sum of all Level-1 KPIs' weights is 100%); similarly, the weight sum of all Level-2 KPIs belonging to the same Level-1 KPI is 100%; and the weights sum of all Level-3 KPIs belonging to the same Level-2 KPI is also 100%.

After the value of each KPI is determined through filed data collection during the demo, such a KPI weight system makes it possible to calculate the weighted total of all KPIs (see Table 2).

Table 2. Results of KPI Prioritization and Weighting by Stakeholders

LEVEL 1	LEVEL 2	LEVEL 3
A. EFFECT ON PROJ-ECT FINANCES 0.202 (20.22)	Financial viability 0.524 (10.60)	NPV (Net present value) 0.344 (3.65)
		IRR (Internal Rate of Return) 0.360 (3.81)
		Payback period 0.296 (3.14)
	Financial viability 0.524 (10.60)	Ease of raising external funding 1.000 (9.63)
B. EFFECT ON INSTI-TUTIONAL FRAMEWORK 0.178 (17.80)	Coherence with plans/goals 0.342 (6.10)	Coherence with national plans/goals 1.000 (6.10)
	Alignment with legislation 0.321 (5.72)	Alignment with legislation 1.000 (5.72)
	Ease of implementation 0.337 (5.99)	Ease of implementation 1.000 (5.99)

LEVEL 1	LEVEL 2	LEVEL 3
C. EFFECT ON CLIMATE 0.148 (14.81)	Effect on GHG emissions 1.000 (14.81)	Effect on GHG emissions 1.000 (14.81)
D. EFFECT ON ENVIRONMENT 0.168 (16.76)	Effect on air pollutants 0.403 (6.75)	Effect on NOx emissions 0.460 (3.10)
		Effect on PM2.5 emissions 0.540 (3.64)
	Effect on noise 0.303 (5.07)	Effect on noise 1.000 (5.07)
	Effect on resource use 0.295 (4.94)	Effect on recycled resources 1.000 (4.94)
E. EFFECT ON SOCIETY 0.145 (14.52	Effect on accessibility 0.153 (2.23)	Effect on accessibility (passengers) 0.616 (1.37)
		Effect on accessibility (freight) 0.384 (0.85)
	Effect on affordability 0.163 (2.37)	Effect on affordability 1.000 (2.37)
	Effect on travel time 0.098 (1.43	Effect on travel time (passengers) 0.597 (0.85)
		Effect on travel time (freight) 0.403 (0.57)
	Effect on road safety 0.107 (1.55)	Effect on major accidents 0.429 (0.67
		Effect on minor accidents 0.295 (0.46)
		Effect on near accidents 0.276 (0.43)
	Effect on charging safety 0.127 (1.85)	Effect on charging safety incidents 1.000 (1.85)
	Effect on security 0.089 (1.29)	Effect on security incidents 1.000 (1.29)
	Effect on well-being 0.119 (1.72)	Effect on well-being (active travel) 1.000 (1.72)
	Effect on service quality 0.143 (2.08)	Suitability for climate changes 0.126 (0.26)
		Perceived comfort 0.140 (0.29)
		Perceived drivability (prof. drivers) 0.113 (0.24)
		Perceived drivability (end users) 0.114 (0.24)
		Perceived chargeability 0.142 (0.30)
		Perceived safety 0.132 (0.27)
		Perceived personal security 0.111 (0.23)
		Perceived transhipment quality 0.122 (0.25)

LEVEL 1	LEVEL 2	LEVEL 3
F. EFFECT ON WIDER ECONOMY 0.159 (15.88)	Effect on budget 0.355 (5.64)	Effect on budget 1.000 (5.64)
	Effect on external trade 0.330 (5.24	Effect on fossil fuel imports 0.574 (3.01)
		Effect on other imports 0.426 (2.23)
	Effect on employment 0.315 (5.00)	Effect on jobs 0.614 (3.07)
		Effect on wages 0.386 (1.93)

Note: in the above table. The weights in the brackets are absolute percentage points. The numbers before bracket () are relative percentage points. In case a Level 2 indicator has only one Level 3 sub-indicator, then the relative weight before the Level 3 indicator should be 1.000. If a Level 2 indicator has three Level 3 sub-indicators, then the sum of the absolute weights of the three sub-indicators should be equal to the absolute weight of the Level 2 indicator. The relative weights (number before the brackets) of all Level 3 sub-indicators of a Level 2 indicator (its number before the brackets).

According to the user needs assessment, the e-mobility stakeholders in Nanjing emphasize the impacts on project finance and compliance with rules and institutions. Yet generally, the weights of different Level 1 indicators are relatively even and in the range of 14% and 20%.

2.2.2 Other needs indicated through the stakeholder survey and interview

During the survey and interview, the stakeholders also indicated it is important that the intelligent transport software could facilitate eco-routing and the big data collected on different vehicles can be used by municipal authorities to improve road planning and retrofitting, traffic light regulation, and take timely measures to reduce traffic congestion.

2.3 KPI ESTIMATION METHODS AND DATA NEEDS

As the Nanjing demo is limited to using LCMM on a dozen private cars using fossil fuel and one e-bus for urban public transport, the impact assessment team discussed which KPIs should be used in the demo assessment. After consulting the SOLUTIONSplus impact assessment experts. it was agreed to limit the impact assessment to a few KPIs whose data collection can be directly based on the LCMM.

2.2.1 KPIs selected for the Nanjing demo

Table 3. KPIs selected for Nanjing demo impact assessment

CATEGORY	KPIS
C. GHG emission reduction	• GHG emission reduction
D. Environmental indicators	• D 1.1. NOx emissions abated • D 1.2 PM emissions abated

CATEGORY	KPIS
E. Social indicator	• Effect on travel time • Effect on affordability (fuel/electricity saving)
F. Effect on wider economy	• Effect on fuel import (fuel saving)

The impact assessment for the LCMM demo in reality mainly focuses on the impacts of fuel saving and GHG emission reductions. As in the baseline and the LCMM intervention scenario, the participating cars keep use the same fuel (either gasoline or electricity), this means the NOx and PM emission factors of the fuel remains the same. The LCMM demo's impacts on NOx emission and PM emission abatement are of the same percentage points as the fuel saving.
As for travel time, the LCMM application led to slight increase in driving speed. For private drivers and taxi passengers, this can lead to less travel time; for each taxi driver, the effect on travel time can vary as the drivers may drive longer distance in case their driving time remains the same.

The use of LCMM app is also expected to contributing to the KPIs of Improvement in road safety (E), Perceived Road Safety, and Perceived Comfort as it reminds drivers of more smooth driving, steering, braking, and acceleration. However, these impacts can be difficult to monitor and conduct quantitative assessment.

2.4 KPI ESTIMATION METHOD AND DATA NEEDS

The LCMM, with its real-time and precise vehicle location function, can monitor the travel time and estimate the fuel consumption of a driving trip based on the vehicle configuration data and system data of WLTP. With info about the fuel use of each trip, the LCMM system calculates the GHG emissions, NOx emissions. and PM emissions based on the vehicle's combustion efficiency.

By comparing the values of these KPIs during the baseline/reference period (when LCMM was installed on the users' smart phones. but the feedback function disabled) and those during the LCMM feedback activated period. the impact assessment team can calculate the reductions in GHG emissions. NOx and PM emissions. fuel saving. fuel cost saving. and travel time saving and assess the impacts of the Nanjing demo in these aspects.

The data sources for the estimation include 1) data on the specific trips collected during the demo period; 2) vehicle configuration data collected during user registration stage; 3) WLTP indicator values embedded in the LCMM system; 4) additional data collected by the impact assessment team. including the average monthly fuel (mainly gasoline and electricity) prices in Nanjing and Beijing. for estimating the fuel cost saving from LCMM demo.

Due to practical difficulties. the Nanjing demo did not proceed as originally planned. In the end. only the eco-driving demo only took place on private cars and an electric bus running on a bus line run by the public bus service provider.

3 EXPECTED IMPACTS OF THE SOLUTIONSPLUS DEMONSTRATION PROJECT

During the user needs assessment, the policy framework assessment targeted at e-mobility. It has been realised that unlike most other city demos under SOLUTIONSplus. The Nanjing demo is on smart/intelligent transport. Hence the policy framework assessment needs to be adjusted accordingly.

One important step in the impact assessment of SOLUTIONSplus city demo is the ex-ante assessment, aiming to establish the detailed plan for the impact assessment and provide inputs for the demonstration project designing.

In Nanjing, Ex – Ante impact assessment was not done as the LCMM app has its own built-in data collection and impact assessment system. The Chinese partners used a large part of the project funding on funding the LCMM app localization and demonstration by the T-Systems Beijing Office.

When deciding the contents of the Nanjing demo, they did consider the GHG mitigation impacts of recent cases of LCMM app use in other places and use them as reference for estimating the expected impacts of LCMM app use under the Nanjing Demo, including the expected reductions in CO2 emissions, NOx, PM2.5, and fuel consumption.
LCMM has been applied in multiple cities for eco-driving among freight delivery fleet. Below is a summary of a few causes of LCMM use and the CO2 mitigation impacts

Example of LCMM application at DHL China

From 2016 to 2018. DHL and T-Systems implemented LCMM on around 300 heavy-duty DHL trucks in DHL's Dongguan and Qingdao branches in China. The solution is based on the analysis of speed profiles from GPS equipped Android Smart Phones and allows the Best Practice evaluation of Driving Behavior and Eco-Drive friendly driving performance by comparing trip data to reference cycles. The algorithm is based on Newtonian Physics and makes psychological behavior measurable. After baseline determination in 2016. the smart phone technology was explained to drivers which had a direct feedback channel in Yellow-Green-Red colors. Impressive improvement could be achieved in fuel and CO2 savings after introducing LCMM in 2016. evaluating the energy consumption in year 2017 and 2018. The fuel and CO2 emissions per ton of pay load were cut down in Dongguan by-13.9% (2017) and -19.4% (2018) and in Qingdao by -9.5% (2017) and -11.5% (2018), both relative to the baseline reference value from2016. Thus, LCMM helped both branches to save a total number of 341 tons of CO2 emissions.

Table 4. Details of the LCMM applications at DHL heavy trucks in 2017 and 2018

ITEM	DATA
Recorded total distances	ca. 8.20 million km. in the city Dongguan/ Qingdao/ Shenzhen. extra-urban. highway
Recorded time	ca. 200.000 working hours
Documented and verified saving	4 –15 % fuel consumption. CO2-Emission (ca. 180L/ Month/12-Ton-High duty truck)

GPS accuracy	< 4 m
Deviation with fixed measuring systems	< 5 %
Installation and registration duration:	Android < 5 Minutes. iOS < 10 Minutes

Source: DHL presentation in 2018 (document obtained from Ralf)

3.1. EXPECTED OUTPUT

The expected outputs of the Nanjing demo is detailed driving performance data collected through the LCMM app. indicating improvement in eco-driving through the real-time feedback of LCMM app.

3.2. PLANNED INPUT

LCMM installation on the drivers' mobile phones; the drivers keep their app on during their driving journeys. The LCMM collect the driver's real-time vehicle location data and sent them to the LCMM platform. The platform assesses the data and gives real-time feedback to the drivers on their mobile phones.

Table 4. Details of the LCMM applications at DHL heavy trucks in 2017 and 2018

LEVEL 1	EVALUATING THE BENEFITS OF ECO-DRIVING	LEVEL 3
Samaras et al. 2016[13]	Assessed the CO2 benefits of eco-driving for various degrees of penetration rates (from 25% up to 100%) and three levels of traffic congestion	The savings can reach 15% in free flow traffic and 10% in normal traffic. In contract, the study found that eco-driving could increase the overall CO2 emissions in congested traffic.
Guo et al. 2013[14]	Evaluated the environmental benefits of time-dependent green routing in the greater Buffalo-Niagara region of the U.S.. using a combination of two simulation models	The emission reduction was 12.76% for trucks (vs. 12.63% for passenger cars) when attempting to minimize CO emissions and 10.22% (vs. 10.37% for passenger cars) when minimizing NOx emissions.

3.3. EXPECTED EFFECTS

The drivers. stimulated by real-time feedback on their eco-driving performance, improves their driving behaviour, leading to travel time saving, fuel/electricity saving, and reductions in GHG and local air pollutant emissions. as well as contribution to oil import reductions.

The LCMM application does not cause any change in the type of fuel used by the vehicle. Generally, the chemical ingredients of gasoline or diesel, and the power sources of local grids, and the vehicle motor's efficiency level remain the same over a few months or even years. It can be generally assume that the fuel saving, reductions in NOx and PM2.5 are of the same percentage as the GHG emission reductions. In other words, if the use of LCMM app leads to 10% reductions in GHG emissions, it impacts on fuel saving, NOx and PM2.5 emission reductions is also 10%.

13 Samaras, Z.; Ntziachristos, L.; Toffolo, S.; Magra, G.; Garcia-Castro, A.; Valdes, C.; Vock, C.; Maier, W. Quantification of the Effect of ITS on CO2 Emissions from Road Transportation. Transp. Res. Procedia 2016, 14, 3139–3148.

14 Guo, L.; Huang, S.; Sadek, A.W. An Evaluation of Environmental Benefits of Time-Dependent Green Routing in the Greater Buffalo–Niagara Region. J. Intell. Transp. Syst. 2013, 17, 18–30.

4 EX-POST ASSESSMENT OF THE SOLUTIONSPLUS DEMONSTRATION PROJECT

4.1 BASELINE SCENARIO

Under the baseline scenario, the LCMM was installed on the drivers' smart phones, and the drivers kept the LCMM app on during their driving journeys. But the LCMM platform's function of providing real-time eco-driving performance feedback on the smart phones was disabled. The baseline scenario was to track and assess the drivers' eco-driving performance without real-time feedback from LCMM.

4.2 PROJECT SCENARIO

Under the LCMM feedback scenario, the LCMM App's function of providing real-time feedback to the drivers' eco-driving performance was displayed on the drivers' smartphones. The feedback was given in the driving route's red, yellow, and green segments. Red means poor eco-driving performance; yellow indicates average, and green indicates good. Such simple and straightforward feedback is expected to enable the drivers to take action to improve their eco-driving performance. Such as regular checks, keeping the tyre air pressure at the recommended range, and avoiding speeding up and slowing down too quickly whenever possible. and trying to maintain a steady driving speed closer to the recommended speed limit on the road.

In Stage 2 of the pilot, additional actions were taken to motivate drivers toward eco-driving. The T-Systems' Beijing Office experts analyzed each of the four drivers' eco-driving performance. They gave them feedback on their driving performance and individual advice on improving it.

4.3 IMPACTS OF THE DEMO

From September 2022 to 2023, two Stages of LCMM demonstration were conducted in Nanjing. Stage 1 also involves two cars from Beijing due to difficulties in recruiting private car owners to participate in the demo in Nanjing.

INDICATOR		STAGE I
Number of vehicles		8
Type of vehicles		7 private cars and 1 Bus
Each vehicle's driving distance		52 to 3700 km
Fuel of vehicles		Gasoline cars and diesel bus
Location of demonstration		Nanjing + Beijing
Baseline	Duration	1 Sept 2022 – 10 Mar 2023
	Total driving distance (km)	5249
	Total driving time (hours)	232
	Total electricity consumption	
	Average GHG emission (kg CO2/km)	0.432

INDICATOR		STAGE I
LCMM feed-back	Duration	11 Jan. – 10 Mar 2023
	Total driving distance (km)	3077
	Total driving time (hours)	84
	Average GHG emission (kg CO2/km)	84
Reduction in average GHG emissions per km		8.84%

During Stage 1, some data was unusually high. Therefore, the Nanjing demo decided to conduction additional LCMM demo and data collection. The tuning Stage was based one single electric taxi and took place during 11 – 16 July 2023 and the total driving distance was 1000 km. The team requested the driver to record his electricity consumption and driving distance data after each trip, so the actual data can be compared with the data collected by the LCMM in its platform. The tuning Stage did not find any significant deviation between the driving performance data collected by the LCMM in its online platform and the actual driving distance and electricity consumption data recorded by the driver.

Table 7. Overview of the Recorded Data from Stage 1 of the Nanjing LCMM Demo

VEHICLE	TOTAL KM	TOTAL TIME	AVG. TIME LOST	TOTAL CO2 (KG)	TOTAL NOX-(G)	ECO INDEX4
NJ01	62	3H 12MIN	35%	65.05	1.36	55.13
NJ02	52	1H 17MIN	39%	33.14	0.69	6.98
NJ03	652	22H 32MIN	47%	518.45	10.80	46.99
NJ05	1253	37H 09MIN	26%	462.02	9.63	5.84
NJ102	82	5H 53MIN	48%	196.03	4.08	15.24
NJ106	202	15H 06MIN	48%	55.27	1.15	4.01
BJ01	2305	127H 39MIN	46%	760.46	15.84	9.57
BJ02	3700	99H 43MIN	48%	1369.89	28.54	9.06
Total	**8,326**					

As burning per litre of gasoline generates around 2.3 kg of CO_2, using the above table, we can deduct the fuel efficiency of the cars as following Table 8.

Table 8.: Calculated speed and fuel efficiency of the cars during Stage 1 Demo

VEHICLE	TOTAL KM	TOTAL TIME	TOTAL CO2 (KG)	SPEED (KM/H)	TOTAL GASOLINE CONSUMPTION (L)	FUEL EFFICIENCY
NJ01	62	3H 12MIN	65.05	19.4	2.3	3.7
NJ02	52	1H 17MIN	33.14	40.0	14.4	27.7
NJ03	652	22H 32MIN	518.45	29.0	225.4	34.6
NJ05	1253	37H 09MIN	462.02	33.7	200.9	16.0
NJ102	82	5H 53MIN	196.03	13.9	85.2	103.9
NJ106	202	15H 06MIN	55.27	13.4	24.0	11.9
BJ01	2305	127H 39MIN	760.46	18.1	330.6	14.3
BJ02	3700	99H 43MIN	1369.89	37.1	595.6	16.1

Some of the participating vehicles, like NJ102 and NJ03, have very high fuel consumption per km of driving and the speed of NJ 102 and NJ 106 are less than 15 km per hour. These are out of the normal range of urban traffic for personal vehicles. The above results made the project team wonder whether the LCMM failed to track certain driving segments or whether the unusual results were due to improper parameter settings in LCMM.

After discussion, the Nanjing team decided to tune the LCMM parameter setting and to expand the LCMM demo.

4.3.1 THE LCMM TUNING STAGE AND REASSESSMENT OF THE STAGE 1 DATA

The tuning Stage involved only one electric taxi. The LCMM was installed on the driver's smartphone to track the driver's driving data. At the same time, the taxi driver was requested to record his actual driving distance and electricity consumption. The driving distance for the tuning Stage is 1000 km.

As there was only one single driver, the T-systems team analyzed the distribution and trending of the driver's driving performance based on the ISO-23795 standard. They compared the data from the LCMM platform and the actual data to assess the LCMM parameter value setting and conducted some fine-tuning to make the LCMM modeling results align with the actual driving distance and electricity consumption data.

After the tuning, the T-system Beijing office team cleaned data of the Stage 1 demonstration and eliminated trip data meeting any of the following three conditions:

- Remove trips with a driving distance of less than 1km.
- Remove trips with CO2 emissions equal to 0.
- Remove trips with CO2 emissions exceeding 1kg per kilometer.

After the data cleaning. The T-Systems Beijing office experts recalculated the LCMM data from Stage 1. The recalculation indicates that the average "Avg.CO2Emission (per km)" for trips before January 11 2023 is approximately 0.3278; the average "Avg. CO2Emission(per km)" for trips after January 11 2023 is approximately 0.2816.[15] The results of the Nanjing test are that under eco driving mode (LCMM feedback), the per km emissions were 14.09% lower than the level under the baseline scenario.

LCMM app directly provide fuel consumption and CO2 emission reduction feedback. The impacts on the KPIs of fuel saving, NOx and PM emission reduction can be estimated as of the same percentage points as the vehicle motor efficiency, fuel contents, and grid emission factors are not affected by the LCMM app use and generally remain stable within the timeframe of a few years.

4.3.2 Stage 2 of the LCMM demo

Following the practice of the tuning Stage, the Nanjing Demo team recruited another four electric taxis for almost of 8000 km of the additional demo. During Stage 2, the team required the drivers, like during the LCMM tuning Stage, to keep a record of their driving distance and electricity consumption data before and after each journey and submit them to the Nanjing Demo project team. In this way, the team can compare the LCMM platform's data and identify gaps in the two data sources. Table 9 below provides an overview of the Stage 2 LCMM demo.

Table 9. Overview of Stage 2 LCMM Demo in Nanjing

INDICATOR		STAGE 2
	Number of vehicles	4
	Type of vehicles	Electric taxi
	Location of demonstration	Nanjing
Baseline	Duration	22 – 31 August 2023
Baseline	Total driving distance (km)	6818
Baseline	Each vehicle's driving distance	1535 – 1922 km
Baseline	Total electricity consumption	1199.35 kWh
Baseline	Average electricity consumption (kWh/km)	0.176
LCMM feedback	Duration	26 September – 8 October 2023
LCMM feedback	Total driving distance (km)	7680.5k
LCMM feedback	Each vehicle's driving distance	
LCMM feedback	Average electricity consumption (kWh/km)	0.164

15 Please note that the recalculation covered more data for the LCMM-feedback scenario, the LCMM continued tracking some drivers' eco-driving performance data until 28 June 2023, while during the original calculation only covered LC-MM-feedback scenario data until 10 March 2023.

Table 10. Impacts of Stage 2 – based on electricity consumption and driving distance data from the drivers

DRIVER	BASELINE ELECTRICITY CONSUMPTION(KWH/KM)	LCMM FEEDBACK SCENARIO ELECTRICITY CONSUMPTION(KWH/KM)	DIFFERENCE	IMPROVEMENT	AVERAGE IMPROVEMENT
NJ202	0.178459938	0.16035503	0.018104908	10.1451%	6.67%
NJ203	0.177939575	0.167017052	0.010922523	6.1383%	
NJ204	0.173941368	0.163265306	0.010676062	6.1377%	
NJ205	0.172523191	0.165142857	0.007380334	4.2779%	
T-statistic	5.207370908				
P value	0.013764685				

4.3.3 Cleaning of the LCMM platform data before the data analysis

Data cleaning is a key step in data pre-processing to guarantee data quality and provide accurate, consistent, and reliable data for analysis. Under the Nanjing demo, the date cleaning including the following contents:

- Remove all repeated data and make sure each data is unique;
- Add default value: in case of data gaps or missing data, the expert team chose to either add a default value, delete incomplete data, or use specific calculations to estimate the missed data.
- Correct irregular data and outliers: using statistical analysis and visual analysis to identify irregular data and outliers. Then the analysts decide whether to correct or delete these values based on the context and relevant LCMM knowledge.
- Convert all data to the proper and consistent format: the same format for all dates and units for all distances.
- Eliminate all trips far shorter than 1 km;
- Check the data for spatial and temporal continuity of the same trip.

After data cleaning, the T-systems expert team analyzed the fuel consumption data estimated from the system and the actual data fuel consumption data shared by the drivers to see the differences.

Table 11. Comparison between the analyzing results of data from the drivers and the LCMM platform

DRIVER	REAL AVERAGE ELECTRICITY CONSUMPTION PER KM	LCMM CALCULATED THE AVERAGE ELECTRICITY CONSUMPTION PER KM	GAP
NJ202	0.16035503	0.1586	-1.09%
NJ203	0.167017052	0.1583	-5.22%
NJ204	0.163265306	0.1532	-6.17%
NJ205	0.165142857	0.1595	-3.42%

The results in Table 11 indicate that the gaps between analysis results based on data from LCMM and the data collected from the drivers are small and within the statistical acceptance range. One possible reason of the small gaps could be date loss occasional due to power mobile signal coverage or data loss during the date cleaning process.

Table 12: Eco-driving indicator change under the baseline and LCMM feedback scenario

	Phase_1_Mean	Phase_2_Mean	Difference
Distance(KM)	130.1871284	139.1564269	8.969298431
Average_Speed(km/h)	23.711066	26.07219313	2.361127125
CombustionEngineTotal_CO2_Emission	5.7355118	1.829464167	-3.906047634
Eco_Index_1	1.203748511	1.146855854	-0.056892657
Eco_Index_4	7.82478	7.410346667	-0.414433333
Braking_Index	-1.583109667	-1.535528623	0.047581044
AccWork(joule)	0.521134222	0.511369333	-0.009764889
AeroWork(joule)	0.18640812	0.18451586	-0.00189226
RollWork(joule)	0.223140327	0.227991792	0.004851465
GradeWork(joule)	0.069317411	0.076123062	0.006805651
ZeroFuelDist(km)	22.31069333	21.1526029	-1.158090438
HashBrakeDist(m)	11086.0462	11941.79227	855.7460708
ComfortIndex	70.82484222	70.33786042	-0.486981806
AccECE	1.098390444	1.178822646	0.080432201
AeroECE	1.175264	1.1161495	-0.0591145
CombustionEngineCO2Emission(kg/km)	0.046107302	0.042260633	-0.003846668
ElectricConsumption(kwh/km)	0.171167575	0.156887301	-0.014280274
TripScore	84.06401778	89.78142402	5.717406243

Table 12 above presents the changes of specific eco-driving indicators in the LCMM system under the baseline (Stage_1_Mean) and the LCMM Feedback Scenario (Stage_2_ Mean) under Stage 2. Both the average driving distance and the average driving speed increased, while the average CO2 emissions (CombustionEngineTotal_CO2_Emission) was 3.75 kg lower, indicating the drivers' driving behavior became more environment-friendly.

Both Eco_Index_1 and Eco_Index_4 dropped under the LCMM Feedback scenario, reflecting driving performance improvement. The Braking_Index and ConfortIndex changes indicated less sudden braking and more smooth driving.

The overall score was 5.67 higher, showing that the project team's eco-driving training to the drivers based on the LCMM analysis results of the baseline stage is effective and led to driving performance improvement.

The table below indicates the overall electricity efficiency improvement among the four taxis participating in the Stage 2 demonstration of LCMM in Nanjing. The data in the table indicate that LCMM effectively leads to more environment-friendly driving.

Table 13: Overall electricity efficiency improvement in Stage 2 LCMM demonstration

DRIVER	AVERAGE ELECTRICITY CONSUMPTION UNDER THE BASELINE (KWH/KM)	AVERAGE ELECTRICITY CONSUMPTION UNDER THE LCMM FEEDBACK SCENARIO (KWH/KM)	CHANGE (%)
nj202	0.1811	0.1548	-14.53%
nj203	0.1787	0.1583	-11.40%
nj204	0.163	0.1533	-5.93%
nj205	0.1697	0.1595	-6.03%
OVERALL	0.1711	0.1563	**-8.66%**

It is worth mentioning that taxi drivers are generally very skilled drivers. Even for them, LCMM effectively reduced their electricity consumption, indicating the high potential of its application to bring about various social, economic, and environmental benefits.

In Nanjing, the electricity is mainly from coal-fired power plant. For each kWh of electricity supply, the average CO2 emission is 960 g. Applying LCMM and promoting eco-driving can be an effective way for greenhouse gas emission reduction.

4.4 ASSESSING THE MULTIPLE BENEFITS OF LCMM USE

In the stakeholder mapping and user needs survey Stage, the UNEP-CCC team, in consultation with the SOLUTIONSplus impact assessment team, had agreed that the Nanjing demo impact assessment should cover the following aspects: fuel saving, GHG emission reduction, reduction of other air pollutants (NOx, PM2.5), effects on road safety, effects on travel time, effects on budget, and effects on international trade.

Due to the fact that Chinese laws forbid the cross-border transfer of data collected in China, the international impact team was unable to access the original data collected through the LCMM app. Moreover, one needs to use special software to analyze the large quantity of vehicle positioning data collected. Although the Nanjing University of Science and Technology had access to the original data, it could not directly analyze the data. As a result, the T-system Beijing office had to do the data analysis using their own tools. The team calculated that the average GHG emission reductions per km for the vehicles covered in Stage 1 is 8.84%, and the average fuel saving among the taxis participating in Stage 2 of the demonstration was 8.66%.

All the vehicles in Stage 1 are gasoline cars, while all the taxis participating in Stage 2 demonstration are electric vehicles. As the fuel quality and the grid emission factors remained the same, the environmental impacts, including GHG emission reductions, NOX emissions, and PM2.5 emissions, are the same level as the fuel saving. The fuel saving also contributed to the same percentage of fuel cost saving, better car driving affordability, and reduced the need for China's fuel import. The LCMM application also contributes to smoother driving, reducing traffic accidents and improving road safety.

Given China's huge and continuously increasing car ownership, expanding the use of LCMM app among the tens of millions of drivers can be significant.

Table 13: Overall electricity efficiency improvement in Stage 2 LCMM demonstration

	STAGE 1	STAGE 2	COMMENTS
Fuel saving (affordability of individual trips and international trade for oil)	8.84%	8.66%	Direct reported by LCMM
CO2 emission reduction	8.84%	8.66%	Direct results of LCMM
NOx emission reduction	8.84%	8.66%	Estimated
PM2.5 emission reduction		8.66%	Estimated

Even though the LCMM app also collected the travel time and speed data for each trip, technically it is possible to calculate the travel speed difference under the baseline and the LCMM feedback scenario, the T-Sytems Beijing office stopped the server hosting and further technical support to the Nanjing Demo in November 2023. The NJUST team received the original data collected for the Nanjing Demo, the NJUST team had no software to analyze the data. The international SOLUTIONSplus team has neither access to the data nor the software to make the additional impact KPI quantification. Therefore, the team is unable to provide a quantitative assessment of the impacts of travel time saving. A user experience survey was conducted on the drivers participating in the Demo, the results, as indicated in the following section, indicated that the majority of them found improvements in two additional KPIs, road safety and perceived comfort by the drivers and passengers.

4.5 Results of the LCMM User Experience Survey

From June to November 2023, the Nanjing project team conducted a user experience survey on the drivers participating in the demonstration. 11 drivers submitted their feedback on their LCMM using experience using a questionnaire consisting of seventeen questions through the social media WeChat. The detailed results of the survey is in Annex 1 of this report. This section provides a summary of the survey results.

The first five questions are about the overall user-friendliness of the LCMM app, including the time it takes to install the app, the app’s feedback, and response speed. Most users’ answers are positive or very positive, indicating that the App is easy to install, responsive, and user-friendly.

Question 6 is “The coverage of LCMM of your driving trips (when it is on)”, among the 11 drivers, six choose the range of 80-100%, 3 select the range of 60-80%, while the other two report 40-60%. This indicates that even if the drivers kept the LCMM running on their mobile phones while driving, the App can only cover around 70-80% of their driving routes.

Question 7 is “How often do you forget or intentionally avoid starting the LCMM? If yes, please explain why”. 8 of the 11 drivers reported that they never forgot to start the LCMM, while the other three indicated that they sometimes forgot.

Question 8 is “Compared to the other GPS software you have used, what are LCMM’s advantages and disadvantages?” Except for one “no opinion” answer, all other drivers indicated that they were glad about the LCMM app’s function of driving performance feedback, and some expressed wishes to have the routing and navigation functions integrated into LCMM.

Question 9 asks, “Do you find the LCMM App’s feedback on your driving performance useful and timely? If no, please explain why.” 9 out of the 11 drivers reported that they found LCMM useful and helped remind them on eco-driving.

Question 10: “When driving, how often do you check the LCMM App’s feedback on your driving performance?” Eight drivers said they checked the LCMM App once every 3 to 10 minutes, while the other three reported that they rarely checked the LCMM App while driving. Drivers need to pay attention to the traffic when driving consistently, and the law forbids drivers to check their phones while driving. Like in many other countries, Chinese laws prohibit phone use among drivers when driving. Many taxi drivers have two phones running while driving, one for GPS navigation and another one for communication with a platform to get new orders or clients. This makes it challenging for them to check their phones frequently for LCMM App feedback.

Question 11: “Have you noted any inconveniences or issues in LCMM app use, e.g. Quick mobile power depletion or other issues?” Three out of the eleven users reported fast mobile phone power depletion as the main shortcoming of LCMM app, while most others encountered no inconveniences or issues.

In response to Question 12: “Do you adjust your driving based on the feedback from LCMM app?”, nine users replied yes, while two replied no, indicating the substantial effects of the LCMM feedback on the drivers’ driving performance.

Question 13: “As a user, what your comment on the LCMM app’s main strengths and weaknesses?” Most users found the LCMM app useful and some hope for further strengthening the LCMM’s feedback function on driving behaviours.

Question 14: “What’s your advice on how to make more people use LCMM or other similar apps for smart transport?” To answer this question, some drivers suggest integrating LCMM with GPS navigation software or wide promotion of LCMM app use. Questions 15 – 19 are about the benefits of using LCMM app, including “shorter driving time”, avoiding traffic accidents, improving driving performance, and fuel saving. To these questions, the majority of the eleven drivers agreed or agreed, indicating their personal experience in the benefits of LCMM app use.

The user experience survey provides valuable input for designing the scale-up project for LCMM wide use.

5 ASSESSMENT OF THE SCALED-UP PROJECT

By the end of 2022, the motor vehicle ownership in Nanjing had reached 3.2 million, including 2.33 million private cars. Assume each of the 3 million drivers in Nanjing can reduce their fuel or electricity consumption by 8.7%, the total annual electricity/fuel consumption in Nanjing will be huge. The cost of such an initiative will be small as LCMM is the digital software, once it is developed and the platform is up and run, the additional cost of servicing more users will be tiny.

5.1 CHALLENGES AND OPPORTUNITIES IDENTIFIED THROUGH THE NANJING DEMO

Applying LCMM at large scale can disseminate the multiple benefits of LCMM, including fuel saving, travel time saving, reductions in local air pollution, fuel cost saving, and more comfort and road safety.

Yet scaling up the application of LCMM faces many challenges. During the Nanjing demo, one barrier was that drivers were reluctant to install and use LCMM: due to privacy concerns against the real-time tracking of LCMM; others worried about quick drainage of battery power to keep the LCMM app on during their driving trips; the requirements to turn on the LCMM app before and after each trip is also considered a hassle. Many people have other GPS software on their phones for navigation; taxi drivers need to keep their taxi-hailing app on all the time to find the next client and keep communication open with their platform; in many cases, it is illegal to watch phones while driving. Tale 14 lists the various challenges the team encountered when trying to recruit drivers for the LCMM Nanjing demo.

Table 13: Overall electricity efficiency improvement in Stage 2 LCMM demonstration

LOCALISATION	DEPLOYMENT	ASSESSMENT	SCALE-UP
• **Map:** the LCMM platform is owned and developed by T-Systems Germany based on Google Maps. Google map is not used in China. Instead Gaode map for instance. is widely used in China	• **Privacy:** individual users have privacy concerns on LCMM app. as it collects the vehicles' real-time positioning. for instance. The user has concerns over private data leakage and thus. is reluctant to join in the demo.	• **Revenue:** during the demo. The LCMM software will be installed for free, and no revenue will be generated. The projected revenue could be estimated through the surveys of pay willingness. the gap still exists between the estimation and scale-up reality.	• **Deployment:** LCMM deployment does not necessarily request end-user awareness. For example. LCMM algorithm can well be embedded in driving route planning in map applications.
• **Security:** data security regulations in China restrict Google Map usage and require all data from China to be saved and processed in China. This can cause some difficulties in LCMM localization and data analysis and sharing.	• **GPS:** every mobile phone. by default. has GPS and map services; some vehicles even have built-in GPS systems and/or real-time fuel-efficiency displays. On the other hand. LCMM app needs extra installation. Both disincentivize LCMM use.	• **Incentives:** the LCMM is based on a new ISO standard that has not yet been implemented at the policy level. so the assessment may include some assumptions beyond demo scope.	• **Policy:** When the ISO standard is widely adopted. China will implement it nationwide through policies. then LCMM eco-routing will have an economic effect by default.

5.2 IDEAS FOR SCALE-UP

5.2.1 Horizontal scale-up

Expand LCMM app to freight transport such as cargo/package delivery companies. Even the government eco-routing incentive has not yet been implemented. However, the economic effect of LCMM eco-routing may become the motivation for payment for LCMM deployment.
May expand LCMM demo to another city in China. Seeking funding and support from municipal/provincial governments that have set goals to develop smart/intelligent transport systems. On the other hand, I would like to get more insight on LCMM deployment.

5.2.2 Vertical scale-up

One option is to prepare for a low CO2 emission incentive with a new business model: find a map company interested in eco-routing so LCMM can be embedded into the map app on the front-end and the LCMM model is integrated into the map data cloud or another layer of CO2 emission control. Lower CO2 emission policy study: to collaborate with policy study partners in China to have a new research on integrating and implementing the LCMM eco-routing on the policy level.

5.3 Discussions

In Nanjing, LCMM was installed on the mobile phones of drivers of 5 combustion-engine cars and an e-bus. The data collection on the cars has stopped, while that on the e-bus continued during the 2nd half of February 2023.

The LCMM demo encountered several challenges. First, the LCMM functions through the drivers' mobile phones. Every time, drivers must open the app on their phones to check the LCMM feedback. Such an approach requires the users to check their phones frequently. This poses a challenge for the long-term use of the LCMM. Second, bus operation companies prohibit drivers from checking their phones while driving. This makes it difficult for bus drivers to promptly access the LCMM App's evaluation results on their eco-driving performance and improve their driving behaviors. Third. LCMM collects real-time location data about the users, which raises privacy concerns among potential users and causes reluctance to install and use LCMM.

Possible solution: Address the above barriers. One option is to embed the LCMM into the GPS device fixed to vehicles so that it can automatically start and operate during driving trips. Thus, it can eliminate the frequent action requirements for users. The demo team also recommends that the LCMM developers enhance LCMM's functions by analyzing driving performance and advising drivers on improving their eco-driving performance. Currently, the feedback is given in the route's red, yellow, and green segments, indicating whether the driving performance deviations from the WPLT optimum driving cycles (red: high. yellow: medium. green: close). To reduce distractions to the drivers, the feedback can be made more specific and provided in sound.

The ISO Standards of Using Nomadic Devices to Estimate CO2 emissions from eco-driving

The International Standard Organization (ISO) is preparing a new ISO standard on using nomadic devices to estimate CO2 emission reduction from eco-driving. The standard ISO/ DIS 23795-2(en)Intelligent transport systems (ITS) — Extracting trip data via nomadic device for estimating CO2 emissions includes two Parts. Part 1: Fuel consumption determination for fleet management was published in May 2022. Part 2: Information provision for eco-friendly driving behaviour is under inquiry and at the halfway point in the development circle as of February 2023.[16]

- The demo content uses LCMM tool for real-time electricity consumption and GHG emission feedback to stimulate eco-driving. The vehicles involved include private cars (e-cars & combustion cars), electric buses, and electric sharing cars.
- During the user needs assessment, the policy framework assessment targeted e-mobility. Unlike most other city demos under SOLUTIONSplus. The Nanjing demo is on smart/intelligent transport. Hence, the policy framework assessment needs to be adjusted accordingly.

16 IISO /DIS 23795-2(en)Intelligent transport systems (ITS) — Extracting trip data via nomadic device for estimating CO2 emissions — Part 2: Information provision for eco-friendly driving behaviour. https://www.iso.org/obp/ui/#iso:std:iso:23795:-2:dis:ed-1:v1:en

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